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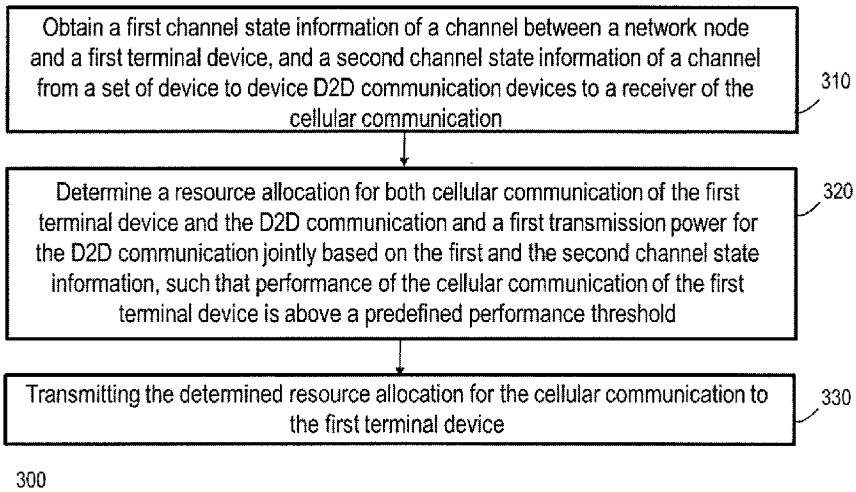


FIG. 3a

**(57) Abstract:** Embodiments of the present disclosure provide methods, apparatuses and computer program for communication. A method implemented at a network node comprises: obtaining a first channel state information of a channel between the network node and a first terminal device in cellular communication with the network node, and a second channel state information of a channel from a set of device to device (D2D) communication devices to a receiver of the cellular communication; determining a resource allocation for both the cellular communication and the D2D communication and a transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and transmitting the determined resource allocation for the cellular communication to the first terminal device. By virtue of the method, performance of the cellular communication can be guaranteed.

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# METHOD AND APPARATUS FOR DEVICE TO DEVICE COMMUNICATION

## TECHNICAL FIELD

**[0001]** The non-limiting and example embodiments of the present disclosure generally relate to a technical field of wireless communications, and specifically to methods, apparatuses and computer programs for device to device (D2D) communication.

## BACKGROUND

**[0002]** This section introduces aspects that may facilitate a better understanding of the disclosure. Accordingly, the statements of this section are to be read in this light and are not to be understood as admissions about what is in the prior art or what is not in the prior art.

**[0003]** As telecommunication operators are struggling to accommodate existing demands from mobile users, new data intensive applications, for example proximity-aware services, are emerging. Though current fourth generation (also referred to as 4G) cellular technology, for example Long Term Evolution–Advanced (LTE-A) developed by the third generation partnership project (3GPP) can provide efficient physical (PHY) layer and media access control (MAC) layer solutions and good performance, it is still lagging behind mobile users' booming data demand. New architectures to revolutionize the traditional communication methods of cellular networks have been considered, and among which D2D communication appears to be a promising solution for next generation.

**[0004]** In a traditional cellular network, all communications must go through a base station (BS) even if both parties involved in the communication are close to each other, and this is suitable for conventional low data rate mobile services, such as voice call and text message, and/or when users are not close enough to conduct direct communication. In contrast, D2D communication is defined as direct communication between terminal devices, that is, data can be transmitted from one terminal device to another terminal device directly without passing through the base station. Mobile users having a requirement for high data rate services, for example video sharing, gaming, proximity aware social networking, may potentially locate in a range short enough for direct communication (i.e., D2D communication), and in such a scenario, D2D communication can be exploited to improve spectral efficiency, throughput, energy efficiency, delay or fairness of a wireless network.

**[0005]** D2D communication may be implemented in a cellular spectrum, that is, a frequency band dedicated for cellular communication, or, it may be implemented in an unlicensed shared spectrum. The former is also referred to as an in-band D2D deployment and the latter is called an out-band D2D deployment. D2D communication is usually considered as a complementary solution to conventional cellular communication, and therefore in both of the above deployments, there is a possibility for the D2D communication and the cellular communication to coexist.

**[0006]** In a wireless communication network where both the D2D communication and the cellular communication coexist, an efficient control for the D2D communication may be required to avoid significant negative impact to the convention cellular communication.

SUMMARY

**[0007]** Recently, D2D communications underlying a cellular infrastructure has been proposed as a means for increasing resource utilization, improving user throughput and extending battery life of user equipment. Such a scenario, however, also brings a challenge for interference management. In order to control D2D communication so as to reduce negative impact (e.g., interference) to non-D2D communication (e.g., conventional cellular communication), methods, apparatuses and computer programs are provided in the present disclosure. It should be appreciated that embodiments of the present disclosure are not limited to the example scenario where the D2D communication is deployed underlying a cellular infrastructure, but could be applied widely to other scenarios where similar problems exists.

**[0008]** Various embodiments of the present disclosure mainly aim at providing methods, apparatuses and computer programs for facilitating coexistence of the D2D communication and the cellular communication in a wireless communication network without introducing significant degradation to the cellular communication. Other features and advantages of embodiments of the present disclosure will also be understood from the following description of specific embodiments when read in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of embodiments of the present disclosure.

**[0009]** In a first aspect of the disclosure, there is provided a method implemented at a network node. The method includes: obtaining a first channel state information of a channel between the network node and a first terminal device in cellular communication with the network node, and a second channel state information of a channel from a set of device to device D2D communication devices to a receiver of the cellular communication between the network node and the first terminal device; determining a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and transmitting the determined resource allocation for the cellular communication to the first terminal device.

**[0010]** In one embodiment, said determining may be performed under at least one of the following conditions: total transmission power for the D2D communication of the set of D2D communication devices is minimized, a physical resource block is allocated to no more than one terminal device in the cellular communication with the network node, and a physical resource block is allocated to no more than one D2D pair for the D2D communication.

**[0011]** In another embodiment, said determining may include: calculating a set of signal to interference and noise power ratios SINR for the cellular communication between the first terminal device and the network node based on at least the first channel state information, the second channel state information, and an adjustable transmission power for the D2D communication; and selecting, from the calculated set of SINR, a minimum SINR above the predefined performance threshold; and determining the first transmission power for the D2D communication as a transmission power corresponding to the selected minimum SINR.

**[0012]** In still another embodiment, said determining may comprise: determining the resource allocation and the first transmission power by solving an optimization problem:

$$\min \sum_{j=1,\ldots n} P_D^j$$

$$s.t. \sum_{j=1,\ldots n} P_D^j h_{DC}^j x_j \leq (P_B h_{BC}) / \gamma_{\min} - N$$

$$x_j = 0,1$$

$$P_D^j \geq 0$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_j$=1 if the $j$th D2D transmitter is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; $n$ is the number of terminal devices in the set of D2D communication devices; $h_{DC}^j$ denotes channel gain from the $j$th D2D transmitter in the set of D2D communication devices to the first terminal device and it is indicated by the second channel state information; $P_B$ denotes transmission power of the network node; $h_{BC}$ denotes channel gain from the network node to the first terminal device and it is indicated by the first channel state information, $\gamma_{\min}$ denoting the predefined performance threshold for the first terminal device and it may be a predefined SINR value in one embodiment, and $N$ denoting the received noise power at the first terminal device.

**[0013]** In one embodiment, the said determining may comprise: determining the resource allocation and the first transmission power by solving an optimization problem:

$$\min \sum_{j=1,\ldots,n} P_D^j$$
$$s.t. \sum_{j=1,\ldots,n} P_D^j h_{DB}^j x_j \le (P_C h_{CB}) / \gamma_{\min} - N$$
$$x_j = 0,1$$
$$P_D^j \ge 0$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_j$=1 if the $j$th D2D transmitter is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; n is the number of terminal devices in the set of D2D communication devices, $h_{\mathrm{DB}}^j$ denoting channel gain from the $j$th D2D transmitter to the network node and it is indicated by the second channel state information; $P_C$ denoting transmission power of the first terminal device, $h_{CB}$ denoting channel gain from the first terminal device to the network node and it is indicated by the first channel state information, $\gamma_{\min}$ denoting the predefined threshold for the first terminal device and it may be a predefined SINR value in one embodiment, and $N$ denoting the received noise power at the network node.

**[0014]** In another embodiment, the determined first transmission power is a maximum transmission power allowed for the D2D communication.

**[0015]** In some embodiments, the method may further include: transmitting the determined resource allocation for the D2D communication and the first transmission power to the set of D2D communication devices.

**[0016]** In an embodiment, the method may further include: obtaining a third channel state information of a channel from a transmitter of the cellular communication between the first terminal device and the network node to a D2D communication device in the set of D2D communication devices, and a fourth channel state information of a channel for the D2D communication of the D2D communication device; determining a signal to interference and noise power ratios SINR for the D2D communication of the D2D communication device based on the determined first transmission power, the third channel state information and the fourth channel state information; and transmitting the determined SINR to the D2D communication device.

**[0017]** In a second aspect of the disclosure, there is provided a method implemented in a terminal device. The method includes receiving a configuration for the D2D communication from a network node, the configuration indicating a transmission power or a signal to noise and interference power ratio SINR, and a resource allocation for the D2D communication; selecting a modulation and coding scheme for the D2D communication based on the received configuration; and conducting the D2D communication according to the resource allocation and the selected modulation and coding scheme.

**[0018]** In one embodiment, said selecting a modulation and coding scheme for the D2D communication based on the received configuration comprises at least one of: selecting, from a predefined set of modulation and coding schemes, a highest modulation and coding scheme supportable by the configuration; and selecting a coding scheme not included in the predefined set of modulation and coding schemes if the indicated transmission power or SINR is below a threshold.

**[0019]** In another embodiment, the method may further include: transmitting a first signal and a second signal to the network node, the first signal indicating channel state information of a channel from a transmitter of cellular communication to the terminal device, and the second signal indicating channel state information of a channel for the D2D communication of the terminal device.

**[0020]** In a third aspect of the disclosure, there is provided a network node. The network node includes: a first obtaining unit, configured to obtain a first channel state information of a channel between the network node and a first terminal device in cellular communication with the network node, and a second channel state information of a channel from a set of device to device D2D communication devices to a receiver of the cellular communication between the network node and the first terminal device; a determining unit, configured to determine a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and a first transmitting unit, configured to transmit the determined resource allocation for the cellular communication to the first terminal device.

**[0021]** In a fourth aspect of the disclosure, there is provided a terminal device. The terminal device includes: a receiving unit, configured to receive a configuration for the D2D communication from a network node, the configuration indicating a transmission power or a signal to noise and interference power ratio SINR, and a resource allocation for the D2D communication; a MCS selecting unit, configured to select a modulation and coding scheme for the D2D communication based on the received configuration; and a D2D communication unit, configured to conduct the D2D communication according to the resource allocation and the selected modulation and coding scheme.

**[0022]** In a fifth aspect of the disclosure, there is provided a network node. The network node includes at least one processor and at least one memory including computer program code; the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to perform a method according the first aspect of the present disclosure.

**[0023]** In a sixth aspect of the disclosure, there is provided a terminal device. The terminal device includes at least one processor and at least one memory including computer program code; the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to perform a method according the second aspect of the present disclosure.

**[0024]** In a seventh aspect of the disclosure, there is provided an apparatus comprising means for performing a method according to the first aspect of the present disclosure.

**[0025]** In an eighth aspect of the disclosure, there is provided an apparatus comprising means for performing a method according to the second aspect of the present disclosure.

**[0026]** In a ninth aspect of the disclosure, there is provided comprising at least one computer readable non-transitory memory medium having program code stored thereon, the program code which, when executed by an apparatus, causes the apparatus to perform a method according to the first aspect of the present disclosure.

**[0027]** In a tenth aspect of the disclosure, there is provided comprising at least one computer readable non-transitory memory medium having program code stored thereon, the program code which, when executed by an apparatus, causes the apparatus to perform a method according to the second aspect of the present disclosure.

**[0028]** According to the various aspects and embodiments as mentioned above, negative impact from the D2D communication to the cellular communication can be reduced.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0029]** The above and other aspects, features, and benefits of various embodiments of the present disclosure will become more fully apparent, by way of example, from the following detailed description with reference to the accompanying drawings, in which like reference numerals or letters are used to designate like or equivalent elements. The drawings are illustrated for facilitating better understanding of the embodiments of the disclosure and not necessarily drawn to scale, in which:

**[0030]** FIG. 1 illustrates an example wireless communication network 100 in which embodiments of the disclosure may be implemented;

**[0031]** FIGs. 2a-2b illustrate schematically interference to/from D2D communication in a cellular uplink scenario and a cellular downlink scenario respectively;

**[0032]** FIGs. 3a-3c illustrate flowcharts of a method implemented at a network node according to an embodiment of the present disclosure;

**[0033]** FIG. 4 illustrates an example of signaling flow according to embodiments of the present disclosure;

**[0034]** FIGs. 5a-5b illustrates a flowchart of a method implemented at a terminal device according to an embodiment of the present disclosure;

**[0035]** FIG. 6 illustrate an example of a mapping relationship between signal to interference and noise power ratio (SINR) and modulation and coding schemes (MCSs);

**[0036]** FIG. 7 illustrates a schematic block diagram of an apparatus implemented as/in a network node according to an embodiment of the present disclosure;

**[0037]** FIG. 8 illustrates a schematic block diagram of an apparatus implemented as/in a terminal device according to an embodiment of the present disclosure; and

**[0038]** FIG. 9 illustrates a simplified block diagram of an apparatus that may be embodied as/in a network node, and an apparatus 1120 that may be embodied as/in a terminal device.

## DETAILED DESCRIPTION

**[0039]** Hereinafter, the principle and spirit of the present disclosure will be described with reference to illustrative embodiments. It should be understood, all these embodiments are given merely for one skilled in the art to better understand and further practice the present disclosure, but not for limiting the scope of the present disclosure. For example, features illustrated or described as part of one embodiment may be used with another embodiment to yield still a further embodiment. In the interest of clarity, not all features of an actual implementation are described in this specification.

**[0040]** References in the specification to "one embodiment," "an embodiment," "an example embodiment," etc. indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

**[0041]** It shall be understood that, although the terms "first" and "second" etc. may be used herein to describe various elements, these elements should not be limited by these terms.

These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed terms.

**[0042]** The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be liming of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

**[0043]** In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

**[0044]** As used herein, the term "wireless communication network" refers to a network following any suitable wireless communication standards, such as Long Term Evolution (LTE), LTE-Advanced (LTE-A), , Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), and so on. Furthermore, the communications between a network node and a terminal device in the wireless communication network may be performed according to any suitable generation communication protocols, including, but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the future fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future.

**[0045]** As used herein, the term "network node" refers to a node in a wireless communication network via which a terminal device accesses the network and/or receives control or services therefrom. The network node may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth.

**[0046]** The term "terminal device" refers to any end device that can access a wireless communication network and receive services therefrom. By way of example and not limitation, a terminal device may be a user equipment (UE), which may be a Subscriber Station (SS), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a mobile phone, a cellular phone, a smart phone, a tablet, a wearable device, a personal digital assistant (PDA), portable computers, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, wearable terminal devices, vehicle-mounted wireless terminal devices and the like.

**[0047]** In the following description, the terms "terminal device", "terminal", "user equipment" and "UE" may be used interchangeably.

**[0048]** FIG. 1 illustrates an example wireless communication network 100 in which embodiments of the disclosure may be implemented. As shown in FIG. 1, the wireless communication network 100 may include one or more network node, for example network node 101, which may be in the form of an eNB. It will be appreciated that the network node 101 could also be in a form of a Node B, BTS (Base Transceiver Station), and/or BSS (Base Station Subsystem), access point (AP) and the like. The network node 101 provides radio connectivity to a plurality of terminal devices for example cellular UEs (also denoted as CUEs in the FIG.1 and hereafter) 102-105 within its coverage. The wireless communication network 100 may also include one or more terminal devices capable of D2D communication, for example, D2D communication devices (also denoted as DUE in the FIG. 1 and referred to as D2D device of DUE hereafter) 106-109. The D2D communication enables direction communication between a D2D pair which includes a D2D transmitter (Tx) and a corresponding D2D receiver (Rx). The D2D communication between DUEs in FIG.1 may be used to increase resource utilization efficiency of the wireless communication network 100, and improve user experience by improving user throughput and extending the battery life of user equipment.

**[0049]** As an example, the wireless communication network 100 may be a 4G LTE network. In this example, downlink (DL) transmissions from the eNB 101 (Tx) to CUEs (Rx), for example CUEs 102 and 103, are multiplexed via a orthogonal frequency division multiple access (OFDMA) framework and an uplink (UL) transmission from a CUE (Tx), for example CUE 104, to the eNB 101 (Rx) uses single carrier frequency division multiple access (SC-FDMA) technique.

**[0050]** In the LTE network, a system bandwidth may be divided into a plurality of resource blocks (RBs), and each downlink/uplink transmission or D2D communication may be assigned one or more RBs. If D2D users occupy resources that are not occupied by the CUEs, they cause no interference to the CUEs and experience no interference from the CUEs. On the other hand, if the D2D users use same resources as the CUEs, they may cause/experience interference to/from the CUEs. Example interference signals 111-114 are illustrated in FIG. 1.

**[0051]** In FIGs. 2a-2b, potential interferences to/from D2D communication devices are illustrated for a DL transmission scenario and an UL transmission scenario respectively for a wireless system 200. As shown in FIG.2a, during a DL period, two types of interferences will be seen, one of which is the interference from a D2D transmitter (e.g., DUE 203 or 206 in FIG.

2a) to a cellular UE ( e.g., CUE 202) which is receiving from the network node (e.g., eNB 201), the other of which is the interference from the network node to a D2D receiver (e.g., DUE 204 or 205). Since the maximum transmission power of an eNB is larger than that of a D2D transmitter, the interference from the D2D transmitter to a CUE may only result in a trivial performance loss in some embodiment, however, if the D2D transmitter is very close to the CUE, the interference may not be negligible. As shown in FIG. 2b, during a UL period, coexistence of a D2D pair and a CUE in a same RB also causes two types of interference. One is interference from a D2D transmitter (e.g, e.g., DUE 203 or 206 in FIG. 2a) to the eNB which is receiving from a CUE (e.g, CUE 202), and the other is interference from the CUE to a DUE (e.g, DUE 204 or 205). All these interferences may degrade the overall system performance. Therefore, interference management plays a key role in harvesting potential benefits from the D2D communications, and the overall system capacity and efficiency may even be degraded if interference is not well controlled.

**[0052]** To reduce interference, various schemes may be used including power control, adaptive scheduling, and cross-layer optimization. In a convention solution where power control and resource allocation are managed separately, an optimized decision can hardly be made at the eNB side. Furthermore, most of the conventional solutions fail to take into account performance of both the CUE and the DUE at the same time.

**[0053]** In order to solve at least part of the above problems, methods, apparatuses and computer programs have been proposed herein. With some embodiments of the disclosure, performance of normal cellar UE communication can be guaranteed by controlling resource allocation and transmission power of DUEs jointly. With some other embodiments, power of D2D devices may be minimized under a condition of ensuring normal cellular communication.

**[0054]** It should be appreciated that embodiments of the disclosure are not limited to the example wireless communication network 100 or 200 shown in FIG. 1 or FIGs. 2a and 2b, but could be more widely used to any application scenario where similar problem exists.

**[0055]** Reference is now made to FIGs. 3a-3c, which show flowcharts of a method 300 in a wireless communication network (e.g., the wireless communication network 100 shown in FIG. 1). In one embodiment, the method 300 may be implemented by a network node, for example the network node 101 as shown in FIG. 1 or the network node 201 shown in FIGs. 2a-2b.

**[0056]** As illustrated in FIG. 3a, the method 300 includes obtaining, at block 310, a first channel state information of a channel between the network node (e.g., eNB 101 in FIG. 1) and a first terminal device (e.g., CUE 105 shown in FIG. 1) in cellular communication with the network node, and a second channel state information of a channel from a set of D2D communication devices (e.g., DUEs 106-109 shown in FIG. 1) to a receiver of the cellular communication between the network node and the first terminal device. It can be appreciated that the receiver of the cellular communication is the first terminal device for downlink communication and the eNB for uplink communication. At block 320, the network node determines a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold. At block 330, the network node transmits the determined resource allocation for the cellular communication to the first terminal device.

**[0057]** With the method 300, normal cellular communication of the first terminal device (e.g., CUE 105 shown in FIG. 1) can be guaranteed by determining resource allocation for both the first terminal device and D2D communication and the transmission power of D2D communication jointly.

**[0058]** It can be appreciated that the first terminal device can be any cellular communication device in a wireless communication network, and method 300 can be applied to determine resource allocation for more than one cellular UE. Assuming that a base station serves N cellular UEs and M UEs in a cell, then a set of cellular UEs can be denoted as $C = \{1, 2, \ldots, N\}$ and a set of D2D communication devices can be denoted as $D = \{1, 2, \ldots, M\}$. In one embodiment, the first terminal device described with reference to FIG. 3a and method 300 can be any CUE in the set C (e.g., the $i$th terminal device in the set C), and the method 300 may be performed to determine resource allocation for all or some UEs in the set C. In another embodiment, the set of D2D communication devices described with reference to method 300 can be the set D or a subset thereof. In some scenarios, the number of DUEs can be larger than that of CUEs, for example, M>>N.

**[0059]** In one embodiment, at block 310, the network node may obtain the first channel state information and the second channel state information by receiving a channel state information report from the first terminal device. For example, in a downlink period, the first terminal device may measure pilot signals (or reference signals (RS)) from the network node and D2D transmitters in the set of D2D communication devices, evaluate channel state information for corresponding channels and report it to the network node via uplink.

**[0060]** In another embodiment, at block 310, the network node may obtain the first channel state information and the second channel state information by measuring, at the network node side during a uplink period, pilot signals (or reference signals (RS)) from the first terminal devices and D2D transmitters in the set of D2D communication devices. It can be appreciated that in some embodiments, the network node may obtain the first channel state information by measuring data transmission from the first terminal device, and/or, obtain the second channel state information by measuring preambles or discovery signals from the D2D communication devices in the set of D2D communication devices. Embodiments are not limited to any specific way for the network node to obtain the first and second channel state information.

**[0061]** Though in some embodiments described below, the first and second channel state information take an example form of channel response which can be denoted as H, it can be appreciated that embodiments are not limited thereto. For example, in some embodiments, the first and/or second channel state information may be any indication capable of indicating channel state of a corresponding channel. For example, the channel state information can be, but not limited to, a path loss, a channel response, or a distance. In some other embodiments, the first and/or second channel state information may be an indication for interference level experienced in a corresponding channel.

**[0062]** In one embodiment, at block 320, the network node may determine the resource allocation and the first transmission power under at least one of the following conditions:

**[0063]** - total transmission power for the D2D communication of the set of D2D communication devices is minimized,

**[0064]** - a physical resource block is allocated to no more than one terminal device in the cellular communication with the network node, and

**[0065]** - a physical resource block is allocated to no more than one D2D pair for the D2D communication.

**[0066]** The first condition is advantageous in keeping the power consumption of the D2D devices at a minimum level, while the other two conditions may facilitate a simplified calculation and thereby reducing computation complexity at the network side.

**[0067]** As shown in FIG. 3b, in one embodiment, at block 320, the network node may determine the transmission power for the D2D communication by the following sub-blocks 3201-3203.

**[0068]** At sub-block 3201, the network node may calculate a set of signal to interference and noise power ratios (SINR) for the cellular communication between the first terminal device and the network node based on at least the first channel state information, the second channel state information, and an adjustable transmission power $P_D$ for the D2D communication. For example, assuming the first terminal device is the $i$th terminal device in a set of the CUEs, DL SINR for the $i$th CUE (i.e., the first terminal device) can be calculated using the following equation (1):

$$\gamma_C^{DL}(i) = \frac{P_B h_{BC}^i}{N + \sum_j P_D^j h_{DC}^j x_{i,j}} \tag{1}$$

wherein $P_B$ denotes transmitting power of the eNB; $P_D^j$ denotes transmitting power of the *j*th D2D transmitter in a set of D2D devices; $h_{BC}^i$ is channel gain (or channel response) between eNB and the *i*th CUE (i.e., the first terminal device) and it can be indicated by the first channel state information obtained by the network node (e.g., the eNB 101 in FIG. 1) at block 310; $h_{DC}^j$ denotes channel gain from the *j*th D2D transmitter to the *i*th CUE; $N$ denotes received noise power at the CUE, which can be assumed as additive white Gaussian Noise (AWGN) in some embodiments; and $x_{i,j}$ indicates whether the *j*th D2D transmitter and the *i*th CUE share same resource block(s), and if same RB(s) is allocated to them, $x_{i,j}$=1, otherwise $x_{i,j}$=0. For each candidate value of $P_D^j$, the network node may obtain a value for the SINR $\gamma_C^{DL}(i)$. In one embodiment, the network node may calculate SINR value $\gamma_C^{DL}(i)$ for each candidate value of $P_D^j$ and each candidate value of $x_{i,j}$. In another embodiment, the network node may determine a value for $x_{i,j}$ first, and then calculate SINR value $\gamma_C^{DL}(i)$ based on each candidate value of $P_D^j$ and the determined $x_{i,j}$.

**[0069]** At sub-block 3202, the network node may selecting, from the set of calculated SINR $\gamma_C^{DL}(i)$, a minimum SINR above the predefined performance threshold. Just for example, in one embodiment, the predefined performance threshold may be a SINR threshold which can guarantee a performance requirement of the ith UE (i.e., the first terminal device). In another embodiment, the predefined performance threshold may be a SINR threshold which can guarantee a minimum cellular communication of the first terminal device.

**[0070]** Alternatively, in some embodiments, the predefined performance threshold may be a threshold with respect to a bit error rate (BER), a block error rate (BLER), a throughput, or a data rate.

**[0071]** At sub-block 3203, the network node may determine the first transmission power for the D2D communication as a transmission power corresponding to the selected minimum SINR.

**[0072]** As another example, in one embodiment, at block 320, the network node may determine the resource allocation and the first transmission power under conditions (constraints) shown in equation (2):

$$\begin{aligned}&\min \sum_j P_D^j \\ &s.t.\ \gamma_C^{DL}(i) \geq \gamma_{\min}^i\ \forall i \in C \\ &\sum_i x_{i,j} \leq 1, x_{i,j} \in \{0,1\}, \forall i \in C \\ &\sum_j x_{i,j} \leq 1, x_{i,j} \in \{0,1\}, \forall j \in D \\ &P_D^j \geq 0\end{aligned} \tag{2}$$

wherein $\gamma_{\min}^i$ denotes the predefined performance threshold for the first terminal device which may be a predefined SINR value in one embodiment.

**[0073]** In one embodiment, at block 320, the network node may perform the determination by solving an optimization problem shown in Equation (2a) below:

$$\begin{aligned}&\min \sum_{j=1,\ldots,n} P_D^j \\ &s.t.\ \sum_{j=1,\ldots,n} P_D^j h_{DC}^j x_j \leq (P_B h_{BC}) / \gamma_{\min} - N \\ &x_j = 0,1 \\ &P_D^j \geq 0\end{aligned} \tag{2a}$$

The Equation (2a) may be obtained based on above Equation (2) and the definition for the $\gamma_C^{DL}(i)$ shown in Equation (1). In Equation (2a), $P_D^j$ denotes a transmitting power for the *j*th D2D communication device in the set of D2D communication devices; in one embodiment, since we only consider the *i*th CUE as the first terminal device, and then for simplicity the index *i* can be omitted; in this case, $x_j$=1 if the *j*th D2D communication device is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; n is the number of terminal devices in the set of D2D communication devices; $h_{\mathrm{DC}}^j$ denotes channel gain from the *j*th D2D transmitter in the set of D2D communication devices to the first terminal device and it is indicated by the second channel state information; $P_B$ denotes transmission power of the network node; $h_{BC}$ denotes channel gain from the network node to the first terminal device and it is indicated by the first channel state information, $\gamma_{\min}$ denoting the predefined performance threshold (for example, an SINR threshold) for the first terminal device, and $N$ denoting the received noise power at the first terminal device.

**[0074]** In this embodiment, the determination performed by the network node at block 320 guarantees a reasonable DL communication performance of the first terminal device.

**[0075]** In order to solve this above problem with low complexity, equation can be summarized as a change-making problem which is one of variation of the knapsack problem. For example, the network node may pre-set a minimum transmitting power of each D2D transmitter (denoted as $P_D^j$), and then let $w_j = P_D^j h_{DC}^j$, and $C = (P_B h_{BC}) / \gamma_{\min} - N$, then the following Equation (2b) for optimization can be obtained:

$$\min \sum_{j=1}^{n} x_j$$
$$s.t. \ \sum_{j=1}^{n} w_j x_j = C$$
$$x_j = 0,1 \qquad (2b)$$

This change-making problem makes changes for a fixed amount of money and minimizes the number of changes. The unit for each change is denoted by $w_j$ and the overall amount of money is $C$. The change-making problem can be easily solved by various methods known to skilled in the art, such as dynamic programming algorithm, greedy method, corresponding specific principle and implementation can be found in corresponding references, and embodiments of the disclosure are not limited to any specific method for solving the formulated Equation (2b), and therefore details will be omitted herein.

**[0076]** After solving the equation, if $x_j$ equals to 1, the DUE will transmit data at this RB using a pre-set minimum power, if $x_j$ equals to 0, the DUE will not transmit data at this RB, so by minimizing the sum of $x_j$, the total transmission power of the DUE $\sum_j P_D^j$ will be minimized.

**[0077]** Alternatively or additionally, in another embodiment, the optimization can be performed for the UL communication of the first terminal device. For the uplink, the SINR at the network node may be calculated using Equation (3), for example:

$$\gamma_{ENB}^{UL}(i) = \frac{P_C^i h_{CB}^i}{N + \sum_{j=1,\ldots,n} P_D^j h_{DB}^j x_{i,j}} \qquad (3)$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_{i,j}=1$ if the jth D2D communication device is allocated a same resource bock as that of the first terminal device (the $i$th CUE in this example), and $x_{i,j}=0$ otherwise; n is the number of terminal devices in the set of D2D communication devices, $h_{\mathrm{DB}}^j$

denoting channel gain from the $j$th D2D transmitter to the network node and it is indicated by the second channel state information; $P_C^i$ denoting transmission power of the first terminal device, $h_{CB}^i$ denoting channel gain from the first terminal device to the network node and it is indicated by the first channel state information, and $N$ denoting the received noise power at the network node.

**[0078]** As one example, similar as that described above with reference to DL communication, the network node may make determination at block 320 under the following conditions shown in Equation (4), in order to guarantee an acceptable performance for the UL of the first terminal device:

$$\begin{aligned} &\min \sum_i P_D^i \\ &s.t.\ \gamma_{ENB}^{UL}(i) \ge \gamma_{\min}^i\ \forall i \in C \\ &\qquad \sum_i x_{i,j} \le 1,\ x_{i,j} \in \{0,1\}, \forall i \in C \\ &\qquad \sum_j x_{i,j} \le 1,\ x_{i,j} \in \{0,1\}, \forall j \in D \\ &\qquad P_D^i > 0 \end{aligned} \tag{4}$$

**[0079]** In one embodiment, at block 320, the network node may perform the determination by solving an optimization problem shown in Equation (4a) below:

$$\begin{aligned} &\min \sum_{j=1,\ldots,n} P_D^j \\ &s.t.\ \sum_{j=1,\ldots,n} P_D^j h_{DB}^j x_j \le (P_C h_{CB}) / \gamma_{\min} - N \\ &\qquad x_j = 0,1 \\ &\qquad P_D^j \ge 0 \end{aligned} \tag{4a}$$

wherein $x_j$=1 if the jth D2D communication device is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; $P_C$ denoting transmission power of the first terminal device, $h_{CB}$ denoting channel gain from the first terminal device to the network node and it is indicated by the first channel state information, and $\gamma_{\min}$ denoting the predefined threshold for the first terminal device.

**[0080]** Similar as the implementation of a DL scenario, at block 320, the network node may determine the resource allocation and the first transmission power by solving a simplified problem, i.e., a change-making problem shown in Equation (4b):

$$\min \sum_{j=1}^{n} x_j$$
$$s.t.\ \sum_{j=1}^{n} w_j x_j = C$$
$$x_j = 0,1 \tag{4b}$$

Equation (4b) has a same form as Equation (2b), the difference is that $w_j = P_D^j h_{DB}^j$, and C= $(P_C h_{CB}) / \gamma_{\min} - N$.

**[0081]** In one embodiment, the determined first transmission power at block 320 is a maximum transmission power allowed for the D2D communication. That is, the D2D device can only transmit with a power equal to or lower than the first transmission power.

**[0082]** As shown in FIG. 3c, in another embodiment, the method 300 may further comprise a block 340, where the network node transmit the determined resource allocation for the D2D communication and the first transmission power to the set of D2D communication devices. The block 340 is not always needed. If the set of D2D communication devices have no D2D traffic currently, the network may not transmit the resource allocation and the first transmission power to them. In another embodiment, the network node may indicate a determined modulation and coding scheme to the DUE instead.

**[0083]** Alternatively or additionally, in one embodiment, the method 300 may comprise blocks 350-370. At block 350, the network node obtains a third channel state information of a channel from a transmitter of the cellular communication between the first terminal device and the network node to a D2D communication device in the set of D2D communication devices, and a fourth channel state information of a channel for the D2D communication of the D2D communication device. In one embodiment, the network node may obtain the third and/or fourth channel state information from a DUE (e.g., DUE 109 shown in FIG. 1). For example, the DUE may measure a cellular transmission (e.g., pilots, RS) from the network node (DL) or the first terminal device (UL), and report the estimated channel gain to the network node as the third channel state information. In another embodiment, the network node may obtain the third channel state information by measuring a signal from the DUE. The DUE can also measure the D2D link and report it to the network node as the fourth channel state information.

**[0084]** At block 360, the network node may determine a SINR for the D2D communication of the DUE based on the determined first transmission power at block 320, the third channel state information and the fourth channel state information obtained at block 350. In one embodiment, the SINR for the DUE may be calculated as Equation (5):

$$\gamma_D^{DL}(j) = \frac{P_D^j h_{DD}^j}{N + P_B h_{BD}^j x_j} \tag{5}$$

where $P_B$ denotes transmitting power of network node, $P_D^i$ denotes transmitting power of the jth D2D transmitter (i.e., the DUE for which SINR is calculated), $h_{BD}^j$ is channel power gain between eNB and the DUE, $h_{DD}^j$ denotes channel gain for the D2D communication, $N$ denotes is the received noise power at DUE side; and $x_j$ indicates whether D2D link $j$ reuses the cellular DL resource, if same RBs is used both the DUE j and the cellular communication, $x_j$=1, otherwise $x_j$=0. In Equation (5), transmission from the eNB is considered as interference to the DUE.

**[0085]** Alternatively, in another embodiment, the SINR for the DUE may be calculated using Equation (6) by taking into account interference from uplink transmission of one or more cellular UEs:

$$\gamma_D^{UL}(j) = \frac{P_D^j h_{DD}^j}{N + \sum_i P_c^i h_{CD}^i x_{i,j}} \tag{6}$$

where $P_C^i$ denotes transmitting power of $i$ CUE, $h_{CD}^j$ is channel power gain between the *i*th cellular UE and the DUE, $h_{DD}^j$ denotes channel gain for the D2D communication, $N$ denotes is the received noise power at DUE side; and $x_{i,j}$ indicates whether D2D link $j$ reuses the UL resource for the *i*th CUE, if same RBs is used, $x_j$=1, otherwise $x_j$=0. In Equation (6), UL transmissions from one or more CUEs are considered as interferences to the DUE.

**[0086]** At block 370, the network node may transmit the SINR determined at block 360 to the D2D communication device.

**[0087]** Reference is now made to FIG. 4 which illustrates an example of signaling flow according to an embodiment of the present disclosure. As shown in FIG. 4, in downlink, for example in a pilot time slot of the special sub-frame, the eNB sends pilot signals which can be measured by both the CUE and the D2D devices (shown as 401-403). UEs may estimate a path loss or a channel response between themselves and the eNB based on the received downlink pilot signal from the eNB (shown as 404 and 405). For example, the UEs may measure received signal strength of the pilot signal. In an embodiment, UEs may transmit a pilot signal back to the eNB, using an uplink pilot time slot at 406 and 407. At 408, the eNB may measure the channel gain between itself and the UE based on the received pilot signals (e.g., strength of the pilot signals). The D2D receivers (Rx) may also measure the channel gain between themselves and the CUEs, as well as the gain between themselves and the D2D transmitters (Tx) at 409 by listening to the uplink pilot signals sent by the CUEs and D2D Tx respectively. At 410, a D2D device (e.g., the D2D receiver) may report the Channel gain for D2D communication to the eNB. After acquisition of the channel gains of the interested channels, at 411, the eNB may determine resource allocation CUE and DUE and transmission power for D2D devices, for example, as described with reference to method 300. In one embodiment, the eNB may send calculated resource allocation information to the CUE at 412. In another embodiment, the eNB may also send the calculated SINR and resource allocation to a DUE (e.g., a D2D receiver, or a D2D transmitter, or both) at 413. Based on the indicated resource allocation and transmission power, data transmission/reception may be performed by the CUE and the DUEs at 414. For example, CUE can start UL transmission process on a specific time slot and an allocated RB, while DUE can transmit to its peer in a D2D pair with an indicated specific power.

**[0088]** Reference is now made to FIGs.5a-5b, which show flowcharts of a method 500 implemented at a D2D terminal device (also referred to as DUE hereafter, e.g., DUE 108 or 109 of FIG. 1). As illustrated in FIG.5a, the method 500 includes a block 510, where the DUE receives a configuration for the D2D communication from a network node, the configuration indicating a transmission power or a SINR, and a resource allocation for the D2D communication. In one embodiment, the indicated transmission power is the maximum transmission power allowed for the DUE, and/or, the SINR is a maximum SINR for the DUE. At block 520, the DUE selects a modulation and coding scheme (MCS) for the D2D communication based on the received configuration; and at block 530, the DUE conducts the D2D communication according to the resource allocation and the selected MCS.

**[0089]** In one embodiment, at block 520, the DUE may select, from a predefined set of modulation and coding schemes, a highest modulation and coding scheme supportable by the configuration at block 5201, and/or, select a coding scheme not included in the predefined set of modulation and coding schemes if the indicated transmission power or SINR is below a threshold at 5202, as shown in FIG. 5b. This enables automatic adaptive modulation and coding (AMC) at the DUE side based on the indicated transmission power or SINR. AMC is one of the most important techniques for improving system capacity, and it is a channel-aware technique that adapts the modulation. In a conventional cellular system, the eNB may adjusting modulation and coding scheme (MCS) according channel condition which can be reported back by users, for example via channel quality indicator (CQI) report. With the embodiment of the disclosure, AMC can be performed at the DUE side based on the transmission power and/or SINR indicated by the eNB.

**[0090]** For example, the DUE may utilize the received SINR as a targeted SINR for its D2D communication to select a modulation scheme and a coding rate. An example of the predefined set of MCSs is shown in FIG. 6 and each MCS corresponds to a specific SINR value. A transmitter of a D2D pair may select coding rate and modulation scheme for an allocated RB, for example it may choose the maximized MCS and coding which can be supported by the indicated targeted SINR with an aim to ensure normal communication for both CUE and the D2D pair.

**[0091]** In one embodiment, if the indicated SINR is lower than a threshold, for example a SINR corresponds to the lowest MCS in the predefined set of MCSs, the DUE may use a predefined special coding scheme for its D2D communication. The predefined special coding scheme may be a coding scheme not included in the predefined set of modulation and coding schemes. For example, if the received SINR from the eNB is lower than -5.1 dB (corresponding to the lowest MCS of QPSK+ 1/8 coding rate), no MCS in the predefined set of MCS can be used, and in this case, the DUE may fall back to a predefined coding scheme at block 5202. The predefined special coding scheme provides a data rate lower than that supported by the lowest MCS of the predefined set of MCS. Though embodiments of the disclosure are not limited to any specific predefined coding scheme, as one example it could be a repetition coding scheme. A repetition coding scheme repeats source bits before coding, and the repetition can further increase redundancy to compensate fading of a wireless channel. The DUE can pre-define a specific repetition rule for this purpose. In one embodiment, the D2D transmitter may determine to use a repetition coding scheme and inform it to a corresponding D2D receiver via signaling, before the D2D data communication starts.

**[0092]** Optionally, in one embodiment, the method 500 may further comprise a block 540, where the DUE transmits a first signal and a second signal to the network node, the first signal indicating channel state information of a channel from a transmitter (the eNB for DL, or a CUE for UL) of cellular communication to the terminal device, and the second signal indicating channel state information of a channel for the D2D communication of the terminal device. In one embodiment, the first signal and the second signal may provide to the eNB the third channel state information and the fourth channel state information used by the eNB at block 360 of method 300.

**[0093]** Reference is now made to FIG. 7, which illustrates a schematic block diagram of an apparatus 700 in a wireless communication network (e.g., the wireless communication network 100 shown in FIG. 1). The apparatus may be implemented as/in a network node, e.g., the eNB

101 shown in FIG. 1. The apparatus 700 is operable to carry out the example method 300 described with reference to FIGs. 3a-3c and possibly any other processes or methods. It is also to be understood that the method 300 is not necessarily carried out by the apparatus 700. At least some steps of the method 300 can be performed by one or more other entities.

[0094] As illustrated in FIG. 7, the apparatus 700 includes a first obtaining unit 701, configured to obtain a first channel state information of a channel between the network node (e.g., the eNB 101 of FIG. 1) and a first terminal device (e.g., CUE 105 of FIG. 1) in cellular communication with the network node, and a second channel state information of a channel from a set of device to device D2D communication devices (e.g., DUEs 106-109 of FIG. 1) to a receiver of the cellular communication between the network node and the first terminal device; a determining unit 702, configured to determine a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and a first transmitting unit 703, configured to transmit the determined resource allocation for the cellular communication to the first terminal device.

[0095] In one embodiment, units 701, 702 and 703 can be configured to perform the operations of blocks 310, 320 and 330 of method 300, respectively, and therefore, descriptions with respect to blocks 310-330 provided with reference to method 300 and FIGs. 3a-3c also apply here and details will not be repeated. Likewise, descriptions with respect to the first channel state information, the second channel state information, and the predefined performance threshold provided with reference to method 300 may also apply here in some embodiments, and therefore details will not be repeated.

[0096] Similar as that described with reference to block 320 of method 300, determining unit 702 may be configured to perform the determination under at least one of the following conditions: total transmission power for the D2D communication of the set of D2D communication devices is minimized, a physical resource block is allocated to no more than one terminal device in the cellular communication with the network node, and a physical resource block is allocated to no more than one D2D pair for the D2D communication. One example of the conditions applied can be found in Equation (2) or (4).

[0097] In another embodiment, the determining unit 702 may comprises a calculating unit 7021, configured to calculate a set of signal to interference and noise power ratios SINR for the cellular communication between the first terminal device and the network node based on at least the first channel state information, the second channel state information, and an adjustable transmission power for the D2D communication; a SINR selecting unit 7022, configured to select, from the calculated set of SINR, a minimum SINR above the predefined performance threshold; and a power determining unit 7023, configured to determine the first transmission power for the D2D communication as a transmission power corresponding to the selected minimum SINR.

**[0098]** Alternatively, in another embodiment, the determining unit 702 may be configured to determine the resource allocation and the first transmission power by solving an optimization problem shown in Equation (2a), (2b), (4a) or (4b).

**[0099]** In one embodiment, the determined first transmission power by the determining unit 702 is a maximum transmission power allowed for the D2D communication.

**[00100]** Optionally, in another embodiment, the apparatus 700 may further comprise a second transmitting unit 704, configured to transmit the determined resource allocation for the D2D communication and the first transmission power to the set of D2D communication devices.

**[00101]** Alternatively or additionally, in still another embodiment, the apparatus 700 may comprise a second obtaining unit 705, configured to obtain a third channel state information of a channel from a transmitter of the cellular communication between the first terminal device and the network node to a D2D communication device in the set of D2D communication devices, and a fourth channel state information of a channel for the D2D communication of the D2D communication device; a SINR determining unit 706, configured to determine a signal to interference and noise power ratios SINR for the D2D communication of the D2D communication device based on the determined first transmission power, the third channel state information and the fourth channel state information; and a third transmitting unit 707, configured to transmitting the determined SINR to the D2D communication device.

**[00102]** FIG. 8 illustrates a schematic block diagram of an apparatus 800. The apparatus 800 may be implemented as/in a terminal device, for example the D2D terminal device 108 or 109 shown in FIG. 1. The apparatus 800 may be operable to carry out the example method 500 described with reference to FIGs.5a-5b and possibly any other processes or methods. It is to be understood that the method 500 is not necessarily carried out by the apparatus 800. At least some steps of the method 500 may be performed by one or more other entities.

**[00103]** Particularly, as illustrated in FIG. 8, the apparatus 800 includes a receiving unit 801, configured to receive a configuration for the D2D communication from a network node (e.g., the eNB 101 shown in FIG. 1), the configuration indicating a transmission power or a signal to noise and interference power ratio SINR, and a resource allocation for the D2D communication; a MCS selecting unit 802, configured to select a modulation and coding scheme for the D2D communication based on the received configuration; and a D2D communication unit 803, configured to conduct the D2D communication according to the resource allocation and the selected modulation and coding scheme.

**[00104]** In some embodiments, the apparatus 800 may be operable to carry out the example method 500 described with reference to FIGs.5a-5b, and therefore, relevant descriptions provided with reference to method 500 also apply here.

**[00105]** In one embodiment, the MCS selecting unit 802 may be configured to select the MCS by at least one of: selecting, from a predefined set of modulation and coding schemes, a highest modulation and coding scheme supportable by the configuration; and selecting a coding scheme not included in the predefined set of modulation and coding schemes if the indicated transmission power or SINR is below a threshold.

**[00106]** As shown in FIG. 8, in some embodiments, the apparatus 800 may further comprises a feedback unit 804, configured to transmit a first signal and a second signal to the network node, the first signal indicating channel state information of a channel from a transmitter (e.g., CUE 105 or eNB 101 shown in FIG. 1) of cellular communication to the terminal device, and the second signal indicating channel state information of a channel for the D2D communication of the terminal device.

**[00107]** FIG. 9 illustrates a simplified block diagram of an apparatus 910 that may be embodied in/as a network node, e.g., the eNB 101 shown in FIG. 1, and an apparatus 920 that may be embodied in/as a terminal device, e.g., one of the D2D terminal devices 106-109 shown in FIG. 1.

**[00108]** The apparatus 910 may include at least one processor 911, such as a data processor (DP) and at least one memory (MEM) 912 coupled to the processor 911. The apparatus 910 may further include a transmitter TX and receiver RX 913 coupled to the processor 911. The MEM 912 may be non-transitory machine readable storage medium and it may store a program (PROG) 914. The PROG 914 may include instructions that, when executed on the associated processor 911, enable the apparatus 910 to operate in accordance with the embodiments of the present disclosure, for example to perform the method 300. A combination of the at least one processor 911 and the at least one MEM 912 may form processing means 915 adapted to implement various embodiments of the present disclosure, e.g., method 300.

**[00109]** The apparatus 920 includes at least one processor 921, such as a DP, and at least one MEM 922 coupled to the processor 921. The apparatus 920 may further include a suitable TX/ RX 923 coupled to the processor 921. The MEM 922 may be non-transitory machine readable storage medium and it may store a PROG 924. The PROG 924 may include instructions that, when executed on the associated processor 921, enable the apparatus 920 to operate in accordance with the embodiments of the present disclosure, for example to perform the method 500. A combination of the at least one processor 921 and the at least one MEM 922 may form processing means 925 adapted to implement various embodiments of the present disclosure, e.g., the method 500.

**[00110]** Various embodiments of the present disclosure may be implemented by computer program executable by one or more of the processors 911 and 921, software, firmware, hardware or in a combination thereof.

**[00111]** The MEMs 912 and 922 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory terminal devices, magnetic memory terminal devices and systems, optical memory terminal devices and systems, fixed memory and removable memory, as non-limiting examples.

**[00112]** The processors 911 and 921 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors DSPs and processors based on multicore processor architecture, as non-limiting examples.

**[00113]** Although some of the above description is made in the context of a wireless system operating in an unlicensed band, it should not be construed as limiting the spirit and scope of the present disclosure. The principle and concept of the present disclosure may be more generally applicable to other wireless systems.

**[00114]** In addition, the present disclosure may also provide a memory containing the computer program as mentioned above, which includes machine-readable media and machine-readable transmission media. The machine-readable media may also be called computer-readable media, and may include machine-readable storage media, for example, magnetic disks, magnetic tape, optical disks, phase change memory, or an electronic memory terminal device like a random access memory (RAM), read only memory (ROM), flash memory devices, CD-ROM, DVD, Blue-ray disc and the like. The machine-readable transmission media may also be called a carrier, and may include, for example, electrical, optical, radio, acoustical or other form of propagated signals – such as carrier waves, infrared signals, and the like.

**[00115]** The techniques described herein may be implemented by various means so that an apparatus implementing one or more functions of a corresponding apparatus described with an embodiment includes not only prior art means, but also means for implementing the one or more functions of the corresponding apparatus described with the embodiment and it may include separate means for each separate function, or means that may be configured to perform two or more functions. For example, these techniques may be implemented in hardware (one or more apparatuses), firmware (one or more apparatuses), software (one or more modules), or combinations thereof. For a firmware or software, implementation may be made through modules (e.g., procedures, functions, and so on) that perform the functions described herein.

**[00116]** Example embodiments herein have been described above with reference to block diagrams and flowchart illustrations of methods and apparatuses. It will be understood that each block of the block diagrams and flowchart illustrations, and combinations of blocks in the block diagrams and flowchart illustrations, respectively, can be implemented by various means including computer program instructions. These computer program instructions may be loaded onto a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks.

**[00117]** Further, while operations are depicted in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Likewise, while several specific implementation details are contained in the above discussions, these should not be construed as limitations on the scope of the subject matter described herein, but rather as descriptions of features that may be specific to particular embodiments. Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain 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 sub-combination or variation of a sub-combination.

**[00118]** It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The above described embodiments are given for describing rather than limiting the disclosure, and it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the disclosure as those skilled in the art readily understand. Such modifications and variations are considered to be within the scope of the disclosure and the appended claims. The protection scope of the disclosure is defined by the accompanying claims.

**WHAT IS CLAIMED IS:**

1. A method implemented at a network node, comprising:

obtaining a first channel state information of a channel between the network node and a first terminal device in cellular communication with the network node, and a second channel state information of a channel from a set of device to device D2D communication devices to a receiver of the cellular communication between the network node and the first terminal device;

determining a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and

transmitting the determined resource allocation for the cellular communication to the first terminal device.

2. The method according to Claim 1, wherein said determining is performed under at least one of the following conditions:

total transmission power for the D2D communication of the set of D2D communication devices is minimized,

a physical resource block is allocated to no more than one terminal device in the cellular communication with the network node, and

a physical resource block is allocated to no more than one D2D pair for the D2D communication.

3. The method according to Claim 1, wherein said determining comprises:

calculating a set of signal to interference and noise power ratios SINR for the cellular communication between the first terminal device and the network node based on at least the first channel state information, the second channel state information, and an adjustable transmission power for the D2D communication; and

selecting, from the calculated set of SINR, a minimum SINR above the predefined performance threshold; and

determining the first transmission power for the D2D communication as a transmission power corresponding to the selected minimum SINR.

4. The method according to Claim 1, wherein said determining comprises: determining the resource allocation and the first transmission power by solving an optimization problem:

$$\min \sum_{j=1,\dots,n} P_D^j$$
$$s.t. \sum_{j=1,\dots,n} P_D^j h_{DC}^j x_j \le (P_B h_{BC}) / \gamma_{\min} - N$$
$$x_j = 0,1$$
$$P_D^j \ge 0$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_j$=1 if the $j$th D2D transmitter is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; $n$ is the number of terminal devices in the set of D2D communication devices; $h_{\mathrm{DC}}^j$ denotes channel gain from the $j$th D2D transmitter in the set of D2D communication devices to the first terminal device and it is indicated by the second channel state information; $P_B$ denotes transmission power of the network node; $h_{BC}$ denotes channel gain from the network node to the first terminal device and it is indicated by the first channel state information, $\gamma_{\min}$ denoting the predefined performance threshold for the first terminal device, and $N$ denoting the received noise power at the first terminal device.

5. The method according to Claim 1, wherein said determining comprises: determining the resource allocation and the first transmission power by solving an optimization problem:

$$\min \sum_{j=1,\dots,n} P_D^j$$
$$s.t. \sum_{j=1,\dots,n} P_D^j h_{DB}^j x_j \le (P_C h_{CB}) / \gamma_{\min} - N$$
$$x_j = 0,1$$
$$P_D^j \ge 0$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_j$=1 if the $j$th D2D transmitter is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; n is the number of terminal devices in the set of D2D communication devices, $h_{\mathrm{DB}}^j$ denoting channel gain from the $j$th D2D transmitter to the network node and it is indicated by the second channel state information; $P_C$ denoting transmission power of the first terminal device, $h_{CB}$ denoting channel gain from the first terminal device to the network node and it is indicated by the first channel state information,

$\gamma_{min}$ denoting the predefined threshold for the first terminal device, and $N$ denoting the received noise power at the network node.

6. The method according to any of Claims 1-5, wherein the determined first transmission power is a maximum transmission power allowed for the D2D communication.

7. The method according to any of Claims 1-5, further comprising:

transmitting the determined resource allocation for the D2D communication and the first transmission power to the set of D2D communication devices.

8. The method according to any of Claims 1-5, further comprising:

obtaining a third channel state information of a channel from a transmitter of the cellular communication between the first terminal device and the network node to a D2D communication device in the set of D2D communication devices, and a fourth channel state information of a channel for the D2D communication of the D2D communication device;

determining a signal to interference and noise power ratios SINR for the D2D communication of the D2D communication device based on the determined first transmission power, the third channel state information and the fourth channel state information; and

transmitting the determined SINR to the D2D communication device.

9. A method implemented at a terminal device in device to device D2D communication controlled by a network node, comprising:

receiving a configuration for the D2D communication from the network node, the configuration indicating a transmission power or a signal to noise and interference power ratio SINR, and a resource allocation for the D2D communication;

selecting a modulation and coding scheme for the D2D communication based on the received configuration; and

conducting the D2D communication according to the resource allocation and the selected modulation and coding scheme.

10. The method according to Claim 10, wherein said selecting a modulation and coding scheme for the D2D communication based on the received configuration comprises at least one of:

selecting, from a predefined set of modulation and coding schemes, a highest modulation and coding scheme supportable by the configuration; and selecting a coding scheme not included in the predefined set of modulation and coding schemes if the indicated transmission power or SINR is below a threshold.

11. The method according to Claim 10, further comprises:

transmitting a first signal and a second signal to the network node, the first signal indicating channel state information of a channel from a transmitter of cellular communication to the terminal device, and the second signal indicating channel state information of a channel for the D2D communication of the terminal device.

12. A network node, comprising:

a first obtaining unit, configured to obtain a first channel state information of a channel between the network node and a first terminal device in cellular communication with the network node, and a second channel state information of a channel from a set of device to device D2D communication devices to a receiver of the cellular communication between the network node and the first terminal device;

a determining unit, configured to determine a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and

a first transmitting unit, configured to transmit the determined resource allocation for the cellular communication to the first terminal device.

13. The network node according to Claim 12, wherein said determining unit is configured to perform the determination under at least one of the following conditions:

total transmission power for the D2D communication of the set of D2D communication devices is minimized,

a physical resource block is allocated to no more than one terminal device in the cellular communication with the network node, and

a physical resource block is allocated to no more than one D2D pair for the D2D communication.

14. The network node according to Claim 12, wherein said determining unit comprises:

a calculating unit, configured to calculate a set of signal to interference and noise power ratios SINR for the cellular communication between the first terminal device and the network node based on at least the first channel state information, the second channel state information, and an adjustable transmission power for the D2D communication; and

a SINR selecting unit, configured to select, from the calculated set of SINR, a minimum SINR above the predefined performance threshold; and

a power determining unit, configured to determine the first transmission power for the D2D communication as a transmission power corresponding to the selected minimum SINR.

15. The network node according to Claim 12, wherein said determining unit is configured to determine the resource allocation and the first transmission power by solving aoptimization problem:

$$\min \sum_{j=1,\ldots n} P_D^j$$
$$s.t. \sum_{j=1,\ldots n} P_D^j h_{DC}^j x_j \le (P_B h_{BC}) / \gamma_{\min} - N$$
$$x_j = 0,1$$
$$P_D^j \ge 0$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_j$=1 if the $j$th D2D transmitter is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; $n$ is the number of terminal devices in the set of D2D communication devices; $h_{\mathrm{DC}}^j$ denotes channel gain from the $j$th D2D transmitter in the set of D2D communication devices to the first terminal device and it is indicated by the second channel state information; $P_B$ denotes transmission power of the network node; $h_{BC}$ denotes channel gain from the network node to the first terminal device and it is indicated by the first channel state information, $\gamma_{\min}$ denoting the predefined performance threshold for the first terminal device, and $N$ denoting the received noise power at the first terminal device.

16. The network node according to Claim 12, wherein said determining unit is configured to determine the resource allocation and the first transmission power by solving an optimization problem:

$$\min \sum_{j=1,\ldots\ldots n} P_D^j$$
$$s.t. \sum_{j=1,\ldots,n} P_D^j h_{DB}^j x_j \le (P_C h_{CB}) / \gamma_{\min} - N$$
$$x_j = 0,1$$
$$P_D^j \ge 0$$

wherein $P_D^j$ denotes a transmitting power for the $j$th D2D transmitter in the set of D2D communication devices; $x_j$=1 if the $j$th D2D transmitter is allocated a same resource bock as that of the first terminal device, and $x_j$=0 otherwise; n is the number of terminal devices in the set of D2D communication devices, $h_{DB}^j$ denoting channel gain from the $j$th D2D transmitter to the network node and it is indicated by the second channel state information; $P_C$ denoting transmission power of the first terminal device, $h_{CB}$ denoting channel gain from the first terminal device to the network node and it is indicated by the first channel state information, $\gamma_{\min}$ denoting the predefined threshold for the first terminal device, and $N$ denoting the received noise power at the network node.

17. The network node according to any of Claims 12-16, wherein the determined first transmission power by the determining unit is a maximum transmission power allowed for the D2D communication.

18. The network node according to any of Claims 12-16, further comprising a second transmitting unit, configured to transmit the determined resource allocation for the D2D communication and the first transmission power to the set of D2D communication devices.

19. The network node according to any of Claims 12-16, further comprising:

a second obtaining unit, configured to obtain a third channel state information of a channel from a transmitter of the cellular communication between the first terminal device and the network node to a D2D communication device in the set of D2D communication devices, and a fourth channel state information of a channel for the D2D communication of the D2D communication device;

a SINR determining unit, configured to determine a signal to interference and noise power ratios SINR for the D2D communication of the D2D communication device based on the determined first transmission power, the third channel state information and the fourth channel state information; and

a third transmitting unit, configured to transmitting the determined SINR to the D2D communication device.

20. A device in device to device D2D terminal device, comprising:

a receiving unit, configured to receive a configuration for the D2D communication from a network node, the configuration indicating a transmission power or a signal to noise and interference power ratio SINR, and a resource allocation for the D2D communication;

a MCS selecting unit, configured to select a modulation and coding scheme for the D2D communication based on the received configuration; and

a D2D communication unit, configured to conduct the D2D communication according to the resource allocation and the selected modulation and coding scheme.

21. The D2D terminal device according to Claim 20, wherein said MCS selecting unit is configured to select the MCS by at least one of:

selecting, from a predefined set of modulation and coding schemes, a highest modulation and coding scheme supportable by the configuration; and

selecting a coding scheme not included in the predefined set of modulation and coding schemes if the indicated transmission power or SINR is below a threshold.

22. The D2D terminal device according to Claim 20, further comprises:

a feedback unit, configured to transmit a first signal and a second signal to the network node, the first signal indicating channel state information of a channel from a transmitter of cellular communication to the terminal device, and the second signal indicating channel state information of a channel for the D2D communication of the terminal device.

23. An apparatus implemented at a network node, the apparatus comprising:

at least one processor; and

at least one memory including computer program code;

the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to perform:

obtaining a first channel state information of a channel between the network node and a first terminal device in cellular communication with the network node, and a second channel state information of a channel from a set of device to device D2D communication devices to a receiver of the cellular communication between the network node and the first terminal device;

determining a resource allocation for both the cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold; and

transmitting the determined resource allocation for the cellular communication to the first terminal device.

24. An apparatus implemented at a terminal device, the apparatus comprising:

at least one processor; and

at least one memory including computer program code;

the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to perform:

receiving a configuration for the D2D communication from the network node, the configuration indicating a transmission power or a signal to noise and interference power ratio SINR, and a resource allocation for the D2D communication;

selecting a modulation and coding scheme for the D2D communication based on the received configuration; and

conducting the D2D communication according to the resource allocation and the selected modulation and coding scheme.

25. An apparatus comprising means for performing a method according to at least one of claims 1 to 8.

26. An apparatus comprising means for performing a method according to at least one of claims 9 to 11.

27. A computer program product comprising at least one computer readable non-transitory memory medium having program code stored thereon, the program code which, when executed by an apparatus, causes the apparatus to perform a method according to at least one of claims 1 to 8.

28. A computer program product comprising at least one computer readable non-transitory memory medium having program code stored thereon, the program code which, when executed by an apparatus, causes the apparatus to perform a method according to at least one of claims 9 to 11.

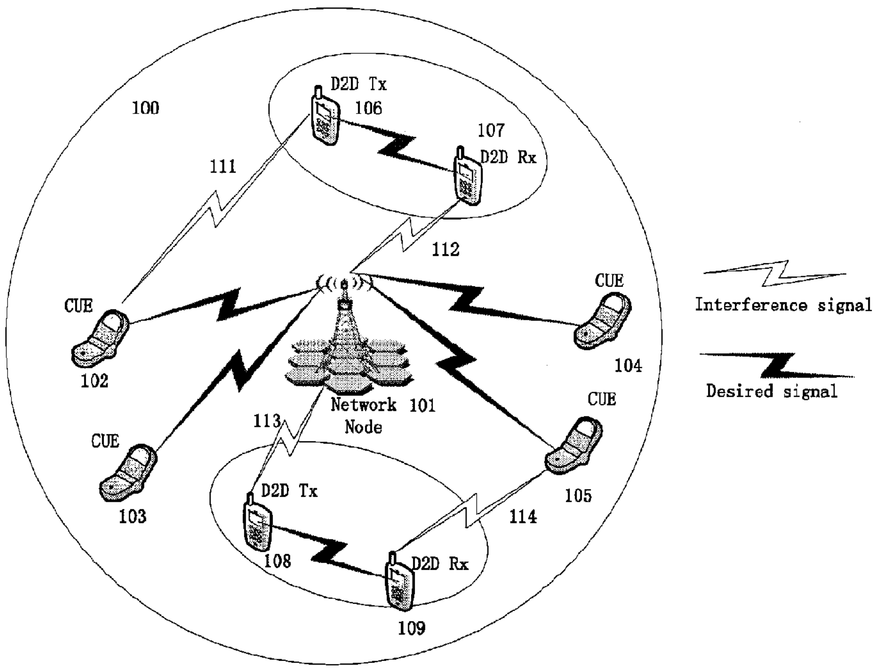

100
D2D Tx
106
107
D2D Rx
111
112
CUE
CUE
Interference signal
102
104
Desired signal
CUE
CUE
113
Network Node 101
103
D2D Tx
105
114
108
D2D Rx
109

FIG. 1

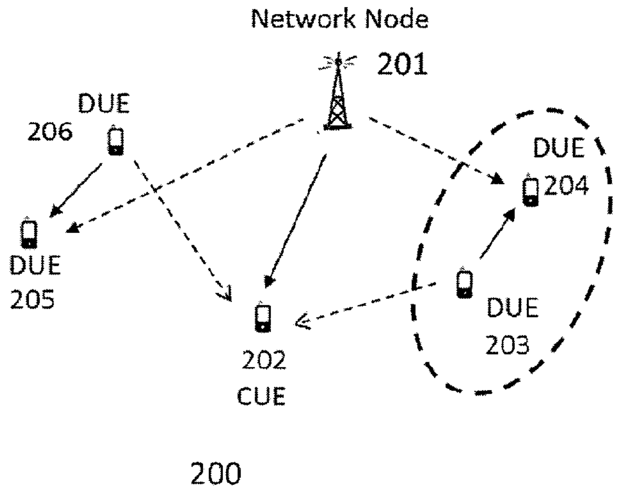

Network Node
201
DUE
206
DUE
204
DUE
205
DUE
203
202
CUE
200

FIG. 2a

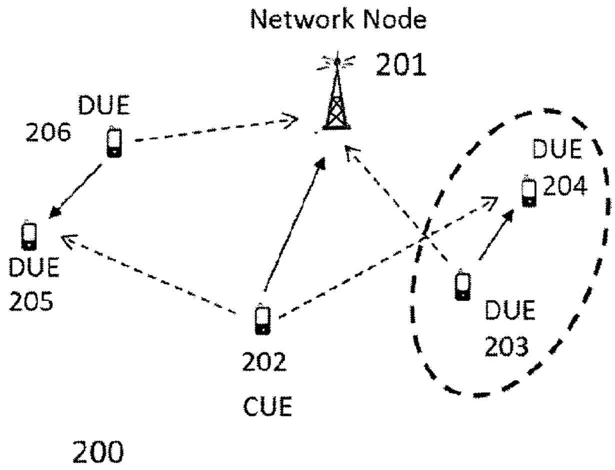

Network Node
201
DUE
206
DUE
204
DUE
205
DUE
203
202
CUE
200

FIG. 2b

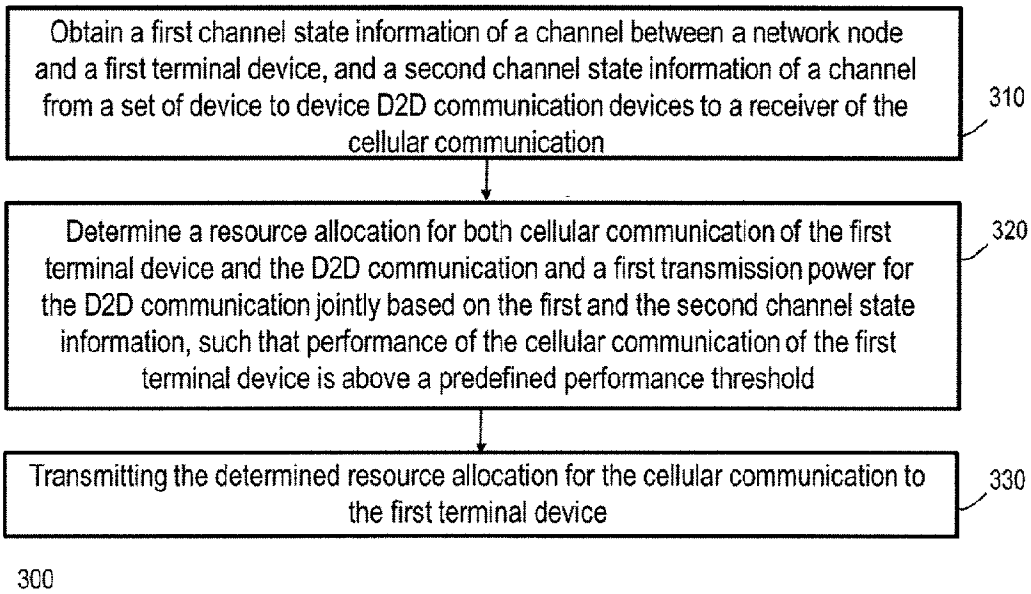

Obtain a first channel state information of a channel between a network node and a first terminal device, and a second channel state information of a channel from a set of device to device D2D communication devices to a receiver of the cellular communication
310
Determine a resource allocation for both cellular communication of the first terminal device and the D2D communication and a first transmission power for the D2D communication jointly based on the first and the second channel state information, such that performance of the cellular communication of the first terminal device is above a predefined performance threshold
320
Transmitting the determined resource allocation for the cellular communication to the first terminal device
330
300

FIG. 3a

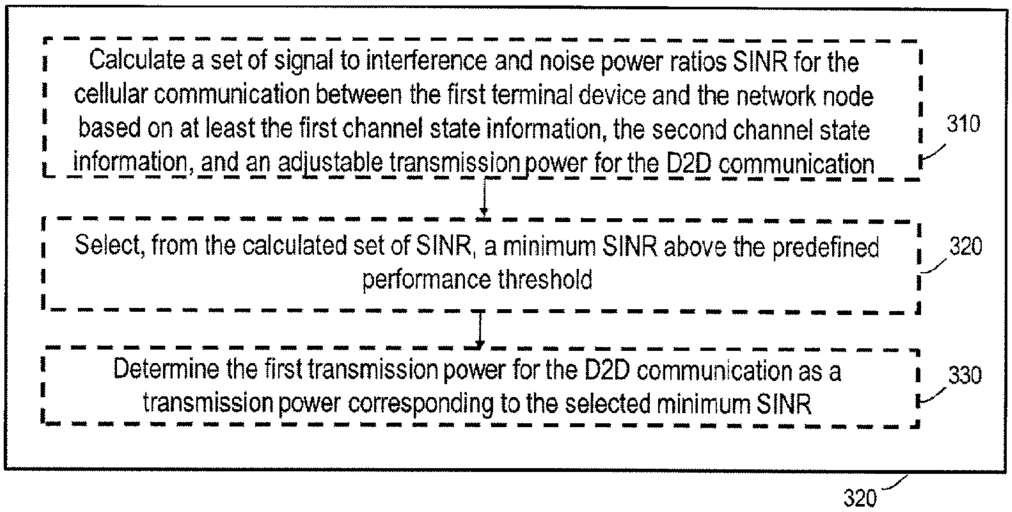

Calculate a set of signal to interference and noise power ratios SINR for the cellular communication between the first terminal device and the network node based on at least the first channel state information, the second channel state information, and an adjustable transmission power for the D2D communication
310
Select, from the calculated set of SINR, a minimum SINR above the predefined performance threshold
320
Determine the first transmission power for the D2D communication as a transmission power corresponding to the selected minimum SINR
330
320

FIG. 3b

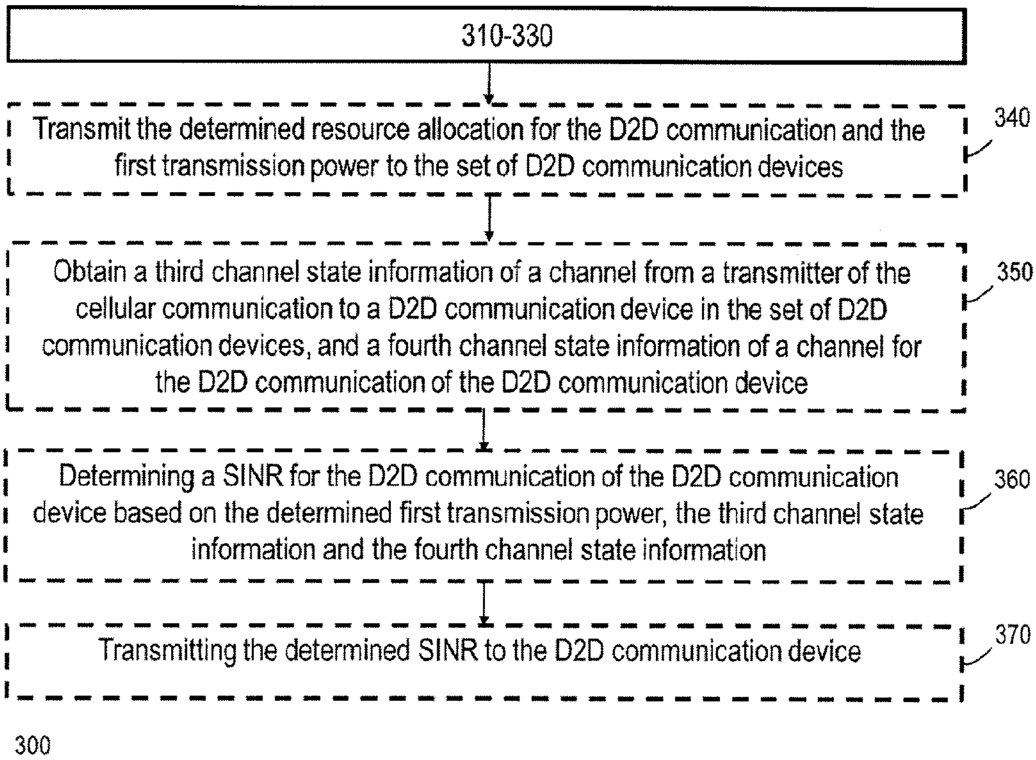

310-330
Transmit the determined resource allocation for the D2D communication and the first transmission power to the set of D2D communication devices
340
Obtain a third channel state information of a channel from a transmitter of the cellular communication to a D2D communication device in the set of D2D communication devices, and a fourth channel state information of a channel for the D2D communication of the D2D communication device
350
Determining a SINR for the D2D communication of the D2D communication device based on the determined first transmission power, the third channel state information and the fourth channel state information
360
Transmitting the determined SINR to the D2D communication device
370
300

FIG. 3c

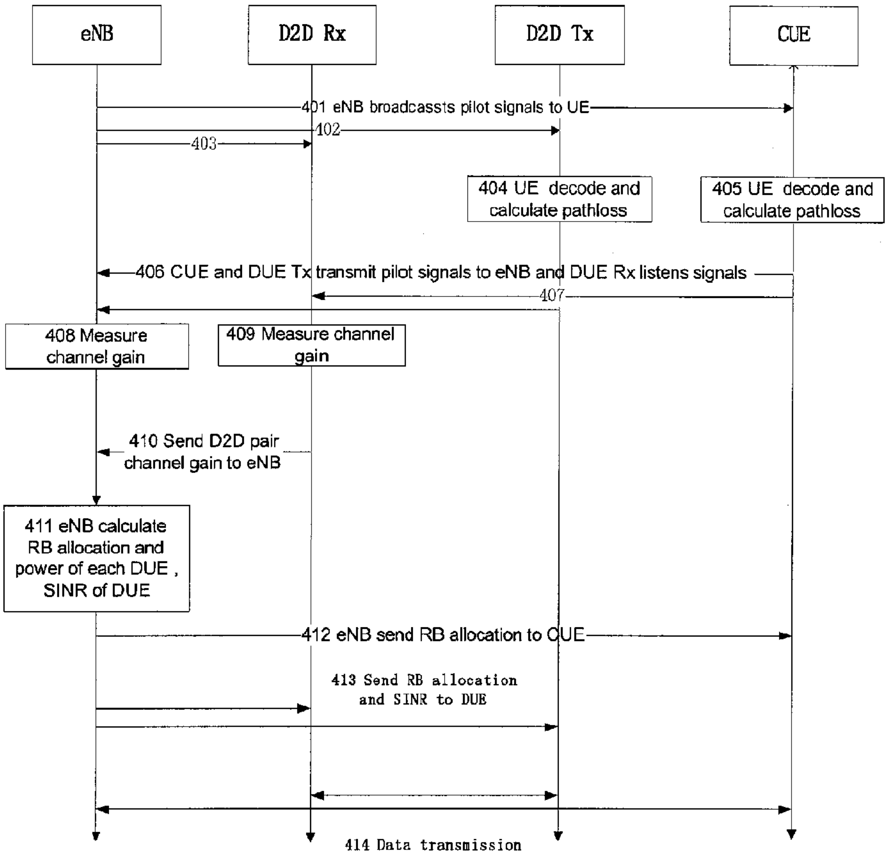

eNB
D2D Rx
D2D Tx
CUE
401 eNB broadcassts pilot signals to UE
402
403
404 UE decode and calculate pathloss
405 UE decode and calculate pathloss
406 CUE and DUE Tx transmit pilot signals to eNB and DUE Rx listens signals
407
408 Measure channel gain
409 Measure channel gain
410 Send D2D pair channel gain to eNB
411 eNB calculate RB allocation and power of each DUE , SINR of DUE
412 eNB send RB allocation to CUE
413 Send RB allocation and SINR to DUE
414 Data transmission

FIG. 4

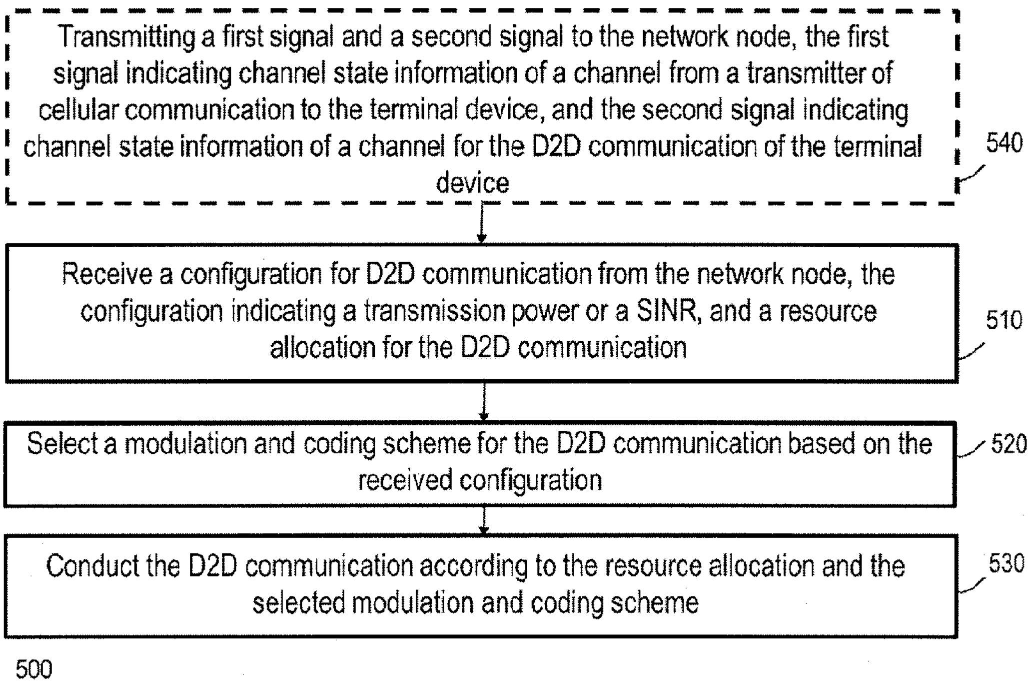

Transmitting a first signal and a second signal to the network node, the first signal indicating channel state information of a channel from a transmitter of cellular communication to the terminal device, and the second signal indicating channel state information of a channel for the D2D communication of the terminal device
540
Receive a configuration for D2D communication from the network node, the configuration indicating a transmission power or a SINR, and a resource allocation for the D2D communication
510
Select a modulation and coding scheme for the D2D communication based on the received configuration
520
Conduct the D2D communication according to the resource allocation and the selected modulation and coding scheme
530
500

FIG. 5a

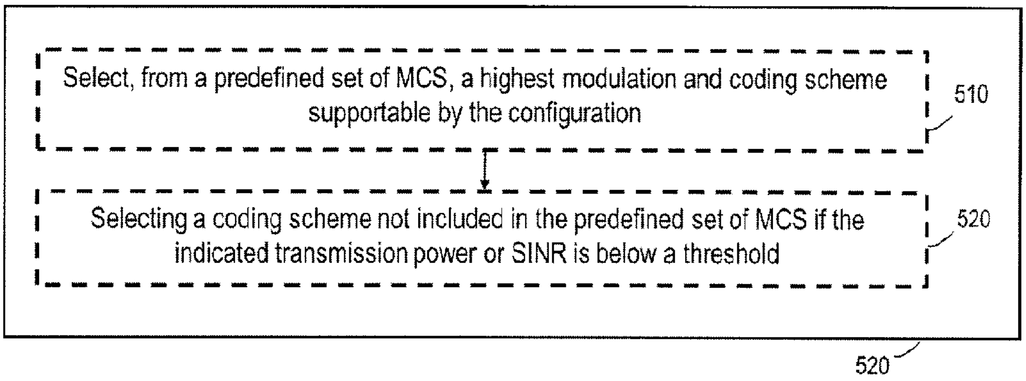
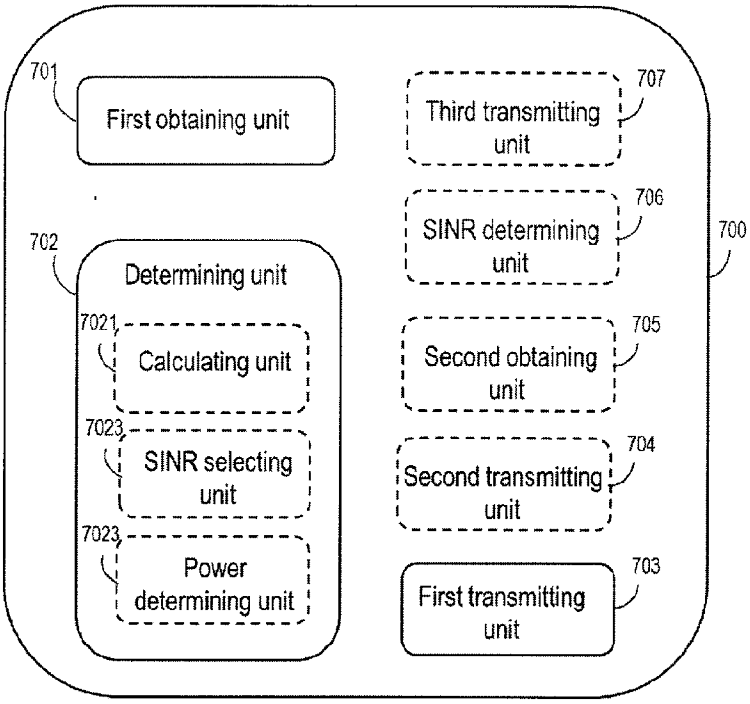



FIG. 5b

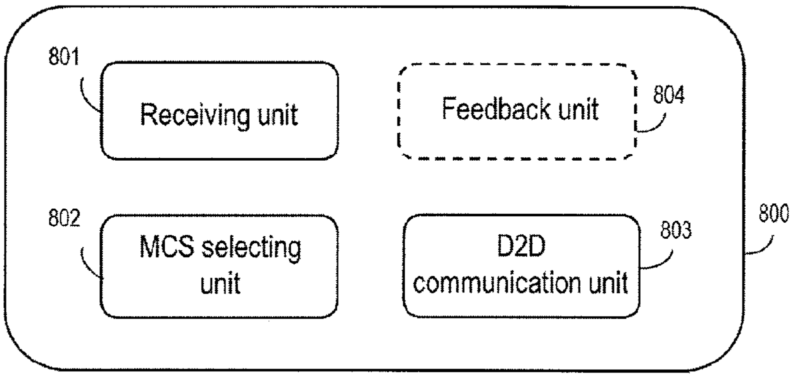
| Modulation | Coding rate | SNR(dB) |
|---|---|---|
| X | - | $-\infty$ |
| QPSK | 1/8 | -5.1 |
| | 1/5 | -2.9 |
| | 1/4 | -1.7 |
| | 1/3 | -1 |
| | 1/2 | 2 |
| | 2/3 | 4.3 |
| | 3/4 | 5.5 |
| | 4/5 | 6.2 |
| 16QAM | 1/2 | 7.9 |
| | 2/3 | 11.3 |
| | 3/4 | 12.2 |
| | 4/5 | 12.8 |
| 64QAM | 2/3 | 15.3 |
| | 3/4 | 17.5 |
| | 4/5 | 18.6 |

FIG. 6



701
First obtaining unit
707
Third transmitting unit
706
SINR determining unit
700
702
Determining unit
7021
Calculating unit
7023
SINR selecting unit
7023
Power determining unit
705
Second obtaining unit
704
Second transmitting unit
703
First transmitting unit


FIG. 7



801
Receiving unit
Feedback unit
804
802
MCS selecting unit
D2D communication unit
803
800


FIG. 8

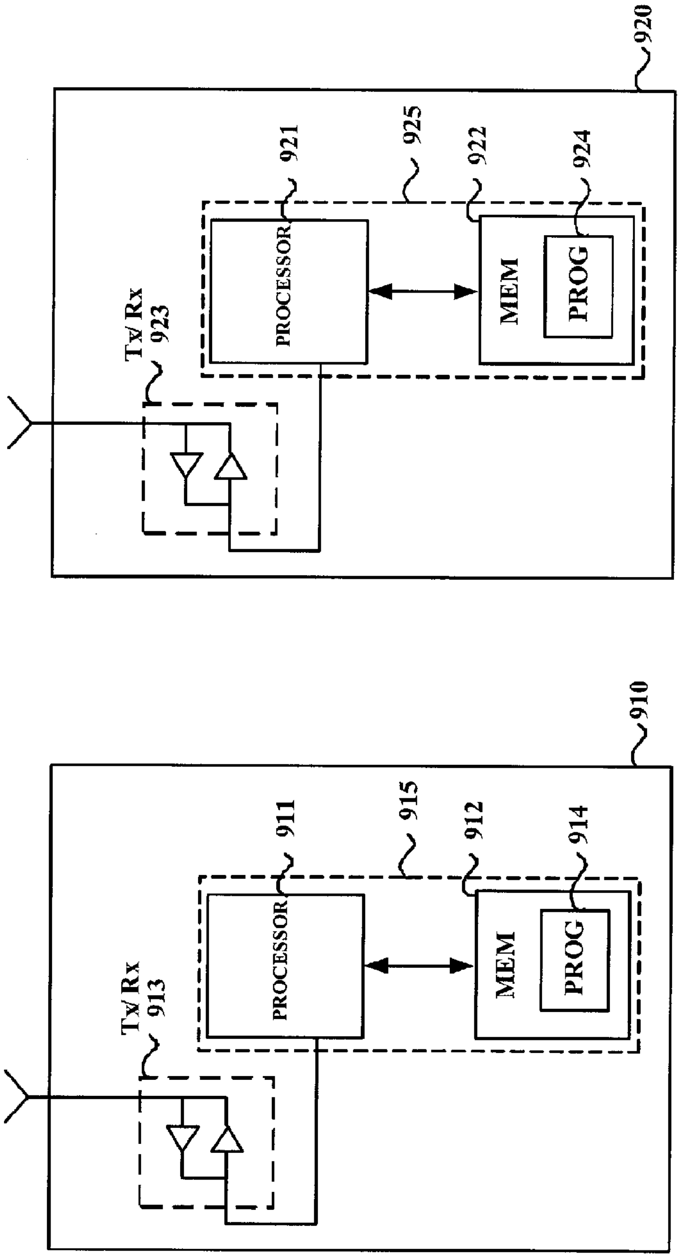

920
925
921
922
924
Tx/ Rx
923
PROCESSOR
MEM
PROG
910
915
911
912
914
Tx/ Rx
913
PROCESSOR
MEM
PROG

FIG. 9

## INTERNATIONAL SEARCH REPORT

International application No.
**PCT/CN2016/083277**

### A. CLASSIFICATION OF SUBJECT MATTER

H04W 16/18(2009.01)i

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

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04L; H04Q; G06F

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)

CNTXT;CPRSABS;SIPOABS;CNKI;DWPI;VEN: cellular communication, resource allocation, power, device to device, D2D, channel state information, CSI, interfere

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | CN 104244265 A (UNIV BEIJING POSTS & TELECOM) 24 December 2014 (2014-12-24) description, paragraphs [0077]-[0083], [0111]-[0123], figures 1-4 | 1, 6, 7, 9, 12, 17, 18, 20, 23-28 |
| A | CN 102883451 A (UNIV NANJING POSTS & TELECOM) 16 January 2013 (2013-01-16) the whole document | 1-28 |
| A | EP 2665321 A1 (ERICSSON TELEFON AB L M) 20 November 2013 (2013-11-20) the whole document | 1-28 |

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

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

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| **17 January 2017** | **15 February 2017** |

| Name and mailing address of the ISA/CN | Authorized officer |
|---|---|
| **STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA**<br>**6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088**<br>**China** | **LIU,Yongzhe** |
| Facsimile No. **(86-10)62019451** | Telephone No. **(86-10)62412024** |

# INTERNATIONAL SEARCH REPORT
**Information on patent family members**

International application No.
**PCT/CN2016/083277**

| Patent document cited in search report | | | Publication date (day/month/year) | Patent family member(s) | | | Publication date (day/month/year) |
|---|---|---|---|---|---|---|---|
| CN | 104244265 | A | 24 December 2014 | None | | | |
| CN | 102883451 | A | 16 January 2013 | CN | 102883451 | B | 15 April 2015 |
| EP | 2665321 | A1 | 20 November 2013 | CN | 104335657 | A | 04 February 2015 |
| | | | | MX | 2014013896 | A | 16 January 2015 |
| | | | | US | 2015117239 | A1 | 30 April 2015 |
| | | | | WO | 2013171114 | A1 | 21 November 2013 |
| | | | | JP | 2015524190 | A | 20 August 2015 |
| | | | | ID | 201501796 | A | 08 May 2015 |