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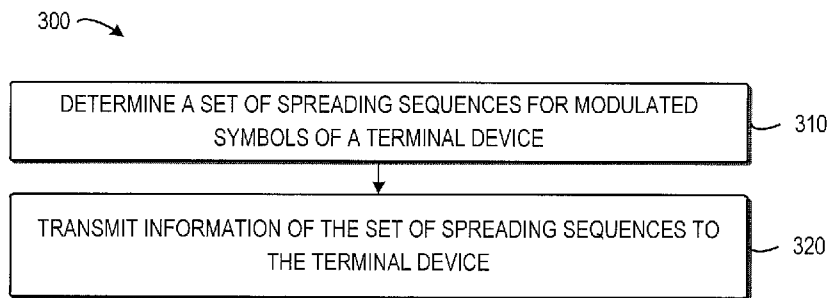


FIG. 3

(57) Abstract: Embodiments of the present disclosure relate to a method, device and computer readable storage medium for modulated symbol spreading. In example embodiments, a network device determines a set of spreading sequences for modulated symbols of a terminal device. One spreading sequence in the set corresponds to one of the modulated symbols. Correspondence of the set of spreading sequences between the modulated symbols being at least partially different from correspondence of a further set of spreading sequences between further modulated symbols of a further terminal device in communication with the network device. Then, the network device transmits information of the set of spreading sequences is transmitted to the terminal device. In this way, the Peak to Averaged Power Ratio (PAPR) may be reduced effectively and efficiently.



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## MODULATED SYMBOL SPREADING

### FIELD

[0001] Embodiments of the present disclosure generally relate to the field of communications, and in particular, to a method, device and computer readable storage medium for modulated symbol spreading.

### BACKGROUND

[0002] The basic multiple access scheme for New Radio (NR) is orthogonal for both downlink and uplink data transmissions, meaning that time and frequency physical resources of different users are not overlapped, or the signals can be differentiated from an orthogonal spatial/code domain. On the other hand, non-orthogonal multiple-access (NOMA) schemes recently gained wide interest, prompting initial study item on NR, where many NOMA schemes were proposed and evaluated and now are under study. For NOMA, signals from multiple user equipment (UEs) are transmitted simultaneously in the same resources, for example, time domain resources and frequency domain resources. Therefore, there will be interference between transmissions. As the system load increases, this non-orthogonal characteristic is more pronounced. To combat the interference between non-orthogonal transmissions, transmitter side schemes such as spreading (linear or non-linear, with or without sparseness) and interleaving are normally employed to improve the performance and ease the burden of advanced receivers.

[0003] NOMA schemes are beneficial for grant-free transmission due to the availability of plenty of NOMA signatures and the correspondingly low MA signature collision rate for grant-free. In general, the benefits may encompass a variety of use cases or deployment scenarios, including enhanced mobile broadband (eMBB), ultra-reliable low latency communication (URLLC), massive machine type communication (mMTC), and so on. The saving of the signaling also saves UE's power consumption, reduces latency and increases system capacity. However, the conventional NOMA schemes generally have higher Peak to Averaged Power Ratio (PAPR), resulting in undesired non-linear region and difficulty in achieving the required Adjacent Channel Leakage Ratio (ACLR).

### SUMMARY

[0004] In general, example embodiments of the present disclosure provide a method, device and computer readable storage medium for modulated symbol spreading.

[0005] In a first aspect, a method at a network device is provided. A set of spreading sequences for modulated symbols of a terminal device are determined. One spreading sequence in the set corresponds to one of the modulated symbols. Correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device. Information of the set of spreading sequences is transmitted to the terminal device.

[0006] In a second aspect, there is provided a network device which comprises: at least one processor and a memory coupled to the at least one processor. The memory stores instructions therein, the instructions, when executed by the at least one processor, causing the network device to perform acts comprising: determining a set of spreading sequences for modulated symbols of a terminal device, one spreading sequence in the set corresponds to one of the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device; and transmitting information of the set of spreading sequences to the terminal device.

[0007] In a third aspect, a method at a terminal device is provided. Information of a set of spreading sequences for modulated symbols of the terminal device is received from a network device. One spreading sequence in the set corresponds to one of the modulated symbols. Correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device. The set of spreading sequences are determined based on the received information. The modulated symbols are spread based on the set of spreading sequences. A signal comprising the spread modulated symbols is transmitted to the network device.

[0008] In a fourth aspect, there is provided a terminal device which comprises: at least one processor and a memory coupled to the at least one processor. The memory stores instructions therein, the instructions, when executed by the at least one processor, causing

the network device to perform acts comprising: receiving information of a set of spreading sequences for modulated symbols of the terminal device from a network device, one spreading sequence in the set corresponds to one of the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being  
5 at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device; determining the set of spreading sequences based on the received information; spreading the modulated symbols based on the set of spreading sequences; and transmitting a signal comprising the spread modulated symbols to the network device.

10 [0009] In a fifth aspect, there is provided a computer readable storage medium that stores a computer program thereon. The computer program, when executed by a processor, causes the processor to carry out the method according to the first aspect.

[0010] In a sixth aspect, there is provided a computer readable storage medium that stores a computer program thereon. The computer program, when executed by a processor,  
15 causes the processor to carry out the method according to the third aspect.

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

20

## **BRIEF DESCRIPTION OF THE DRAWINGS**

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

25 [0013] FIG. 1 illustrates a communication network in which embodiments of the present disclosure can be implemented;

[0014] FIG. 2 illustrates a diagram of signal processing at a transmitter in accordance with some embodiments of the present disclosure;

[0015] FIG. 3 illustrates a flowchart of a method in accordance with some embodiments of the present disclosure;

30 [0016] FIG. 4 illustrates a flowchart of a method in accordance with some embodiments of the present disclosure;

[0017] FIG. 5 illustrates a diagram of modulated symbol mapping in accordance with some embodiments of the present disclosure;

[0018] FIG. 6 illustrates a diagram of allocation of spreading sequence in accordance with some embodiments of the present disclosure;

5 [0019] FIG. 7 illustrates a flowchart of a method in accordance with some embodiments of the present disclosure;

[0020] FIG. 8 illustrates a diagram of comparison of PAPR performance for an Orthogonal Frequency Division Multiplexing (OFDM) scheme and a conventional NOMA scheme;

10 [0021] FIG. 9 illustrates a diagram of comparison of PAPR performance for the proposed NOMA scheme, an OFDM scheme and a conventional NOMA scheme; and

[0022] FIG. 10 illustrates a simplified block diagram of a device that is suitable for implementing embodiments of the present disclosure.

15 [0023] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

## DETAILED DESCRIPTION

[0024] Principle of the present disclosure will now be described with reference to some example embodiments. It is to be understood that these embodiments are described only  
20 for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below.

[0025] In the following description and claims, unless defined otherwise, all technical and  
25 scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0026] As used herein, the term “communication network” refers to a network that follows any suitable communication standards or protocols such as long term evolution (LTE), LTE-Advanced (LTE-A) and 5G NR, and employs any suitable communication  
30 technologies, including, for example, Multiple-Input Multiple-Output (MIMO), OFDM, time division multiplexing (TDM), frequency division multiplexing (FDM), code division

multiplexing (CDM), Bluetooth, ZigBee, machine type communication (MTC), eMBB, mMTC and uRLLC technologies. For the purpose of discussion, in some embodiments, the LTE network, the LTE-A network, the 5G NR network or any combination thereof is taken as an example of the communication network.

5 [0027] As used herein, the term “network device” refers to any suitable device at a network side of a communication network. The network device may include any suitable device in an access network of the communication network, for example, including a base station (BS), a relay, an access point (AP), a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a gigabit NodeB (gNB), a Remote Radio Module (RRU), a radio header  
10 (RH), a remote radio head (RRH), a low power node such as a femto, a pico, and the like. For the purpose of discussion, in some embodiments, the eNB is taken as an example of the network device.

[0028] The network device may also include any suitable device in a core network, for example, including multi-standard radio (MSR) radio equipment such as MSR BSs,  
15 network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), Multi-cell/multicast Coordination Entities (MCEs), Mobile Switching Centers (MSCs) and MMEs, Operation and Management (O&M) nodes, Operation Support System (OSS) nodes, Self-Organization Network (SON) nodes, positioning nodes, such as Enhanced Serving Mobile Location Centers (E-SMLCs), and/or Mobile Data Terminals  
20 (MDTs).

[0029] As used herein, the term “terminal device” refers to a device capable of, configured for, arranged for, and/or operable for communications with a network device or a further terminal device in a communication network. The communications may involve transmitting and/or receiving wireless signals using electromagnetic signals, radio waves,  
25 infrared signals, and/or other types of signals suitable for conveying information over air. In some embodiments, the terminal device may be configured to transmit and/or receive information without direct human interaction. For example, the terminal device may transmit information to the network device on predetermined schedules, when triggered by an internal or external event, or in response to requests from the network side.

30 [0030] Examples of the terminal device include, but are not limited to, user equipment (UE) such as smart phones, wireless-enabled tablet computers, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), and/or wireless customer-premises equipment

(CPE). For the purpose of discussion, in the following, some embodiments will be described with reference to UEs as examples of the terminal devices, and the terms “terminal device” and “user equipment” (UE) may be used interchangeably in the context of the present disclosure.

5 [0031] As used herein, the term “cell” refers to an area covered by radio signals transmitted by a network device. The terminal device within the cell may be served by the network device and access the communication network via the network device.

[0032] As used herein, the term “circuitry” may refer to one or more or all of the following:

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

(b) combinations of hardware circuits and software, such as (as applicable): (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile  
15 phone or server, to perform various functions) and

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

20 [0033] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and  
25 if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0034] 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. The term “includes”  
30 and its variants are to be read as open terms that mean “includes, but is not limited to”. The term “based on” is to be read as “based at least in part on”. The term “one embodiment” and “an embodiment” are to be read as “at least one embodiment”. The

term “another embodiment” is to be read as “at least one other embodiment”. Other definitions, explicit and implicit, may be included below.

[0035] FIG. 1 illustrates a communication network 100 in which embodiments of the present disclosure can be implemented. The communication network 100 may comply with any suitable protocol or standard that already exists or will be developed in the future. In some embodiments, the communication network 100 may be the LTE (or LTE-A) network, the NR network or combination thereof.

[0036] The communication network 100 comprises a network device 110. The network device 110 serves two terminal devices (including a first terminal device 120 and a second terminal device 130) in a cell 111. It is to be understood that the numbers of network devices and terminal devices are shown only for the purpose of illustration without suggesting any limitation. The communication network 100 may include any suitable numbers of network devices and terminal devices.

[0037] The first and second terminal devices 120 and 130 may communicate with the network device 110 or with each other via the network device 110. The communication may utilize any suitable technology that already exists or will be developed in the future.

[0038] When operating as a transmitter, either the first terminal device 120 or the second terminal device 130 preforms signal processing before transmitting. FIG. 2 illustrates a diagram 200 of data processing at a transmitter.

[0039] As shown, data from a terminal device (for example, the first terminal device 120) may be encoded, for example, through channel encoding 210, and then modulated 220. Thus, modulated symbols of the terminal device can be obtained. The modulated symbols are mapped on one single OFDM symbol physical resource. Then, the modulated symbols are spread 230 with spreading sequence(s). The spread modulated symbols are scrambled 240, precoded 250 and then mapped 260 to allocated resource (for example, resource elements (REs)). Thus, a signal comprising the spread modulated symbols can be obtained and then can be transmitted to a receiver, for example, the network device 110.

[0040] Conventionally, differentiations of spreading based NOMA schemes are mainly in terms of construction of spreading sequences, spreading length, etc. On the other hand, they have similar transmitter side structure from high level, where each modulated symbol is spread by a sequence and then mapped to the resource elements.

[0041] As a result, in each OFDM symbol, the symbols in the frequency domain are not

independently identically distributed but correlation is introduced due to single spreading sequence used, which causes much higher PAPR than that with Orthogonal Multiple Access (OMA). This is shown in FIG. 8 which illustrates a diagram of comparison of PAPR performance for OFDM and conventional NOMA schemes. In FIG. 8, the curve 810 represents the PAPR performance of the OFDM scheme, and the curve 820 represents the PAPR performance of the conventional NOMA scheme, where the spreading factor (SF) is 6. As can be seen, the conventional NOMA scheme generally has a higher PAPR than the OFDM scheme.

[0042] Generally, a higher PAPR means that on the average the operating point of PA must be lower to avoid the non-linear region and to achieve the require ACLR. This results in efficiency reduction. Therefore, it is important to reduce PAPR for spreading based schemes.

[0043] Additionally, conventional NOMA schemes are sensitive for other cell interference. This is because small spreading factor (SF), for example, 6, results too small amount sequences for sufficient reuse between cells.

[0044] Embodiments of the present disclosure provide a new scheme for spreading signals. In each OFDM symbol, it is proposed to use per modulated symbol based different spreading sequences. Different terminal devices are configured with different spreading sequences for spreading a modulated symbol having the same index in frequency domain. Accordingly, sequence collision can be avoided for all other modulated symbols. In this way, the PAPR can be reduced and inter-cell randomization can be provided for spreading based NOMA schemes.

[0045] More details will be discussed below in connection with embodiments of FIGs. 3 to 10. FIG. 3 illustrates a flowchart of a method 300 in accordance with some embodiments of the present disclosure. The method 300 can be implemented at the network device 110 as shown in FIG. 1. For the purpose of discussion, the method 300 will be described with reference to FIG. 1.

[0046] At 310, the network device 110 determines a set of spreading sequences for modulated symbols of a terminal device. The terminal device may be the terminal device 120 or 130 shown in FIG. 1, or may be other suitable terminal device in communication with the network device 110 but not shown in FIG. 1. For purpose of discussion, in some embodiments, the terminal device is discussed with the terminal device 120. It is to be

understood that this is for purpose of discussion, rather than limitation.

[0047] In the set of spreading sequences, one spreading sequence corresponds to one of the modulated symbols. The set of spreading sequences are at least partially different from a further set of spreading sequences used by a further terminal device in communication with the network device. In the above example where the terminal device is the terminal device 120, the further terminal device may be, for example, the terminal device 130.

[0048] The set of spreading sequences may be determined in a variety of ways. In some embodiments, all available spreading sequences may be divided to multiple groups (also referred to as “sequence groups” in embodiments of the present disclosure). The number of sequences within each group (also referred to as “sequence number” in embodiments of the present disclosure) is equal to the number of modulated symbols that could be transmitted in each OFDM symbol. The network device 110 may determine the set of spreading sequences based on these groups.

[0049] In some embodiments, the number of sequences within each group may be determined from the allocated frequency domain resources and the spreading factor. The terminal device 120 is allocated with (or selects) one group index  $x$  and one sequence index  $y$  within the group for the 1<sup>st</sup> modulated symbol. Then, for the  $n^{\text{th}}$  modulated symbol in the same OFDM symbol, the principle may be that the spreading sequence is in the same sequence group with that for the 1<sup>st</sup> OFDM symbol, and the sequence index is implicitly decided from  $(y+n-1) \bmod Y$ , where  $Y$  is the number of sequences in the same group.

[0050] The spreading sequences within the same sequence group have low cross correlation, and have better correlation properties than that for inter-group sequences, which facilitate the network device 110 to control the interference for terminal devices served by the network device 110. In some embodiments, if the number of the terminal devices are less than a predetermined number, for example, in the case that there are only the terminal devices 120 and 130 are served by the network device 110, the network device 110 may allocate the terminal devices 120 and 130 with sequences in the same sequence group to have lower inter-UE interference.

[0051] In some embodiments, if the terminal device 120 is allocated with  $N$  Physical Resource Blocks (PRBs), it can be determined that there are  $N*Z$  REs in frequency domain, where  $Z$  indicates the number of REs per PRB, for example, 12. In this case, the network

device 110 may determine the sequence number by dividing the number of resource elements by the spreading factor (SF), denoted as “K”. For example, the sequence number (denoted as “Y”) may be calculated as:

$$Y=N*Z/K. \quad (1)$$

5 [0052] It should be noted Y is also the number of modulated symbols that are transmitted in an OFDM symbol.

[0053] In the embodiments, assuming the number of available spreading sequences is M, the M spreading sequences may be divided to be X groups, where

$$X= \text{floor} (M/Y)=\text{floor} (M/(N*Z/K)). \quad (2)$$

10 [0054] The terminal device 120 may be allocated with (or select by itself) a spreading sequence with a group index (x) and a sequence index (y), which can be denoted as a two-dimensional index (x, y). In one embodiment, (x1, y1) is configured for the 1<sup>st</sup> modulated symbol, which indicates that the spreading sequence for the 1<sup>st</sup> modulated symbol is the y1<sup>th</sup> spreading sequence in the sequence group x1. In this case, for the n-th  
15 modulated symbol, the index of the spreading sequence may be determined as (x1, (y1+n-1) mod Y), where 1<=n<= Y. This means that the spreading sequence for the n-th modulated symbol is the ((y1+n-1) mod Y)<sup>th</sup> spreading sequence in the same sequence group x1. It is to be understood that these modulated symbols refer to the modulated symbols mapping on the same OFDM symbol.

20 [0055] In some embodiments, to further randomize the spreading sequences from different physical resource, e.g., the first symbol, second symbol..., in time domain, the starting spreading sequence may be changing according to the mapped symbol number. For example, there is an offset between the sequences for the 1<sup>st</sup> modulated symbol for different OFDM symbols.

25 [0056] Furthermore, in order to randomize the inter-cell interference, per-cell different spreading sequences may be allocated within each group. For example, the group index may be determined by cell identification (ID). Alternatively, the per-cell different sequence index may be employed.

[0057] It is to be understood the above embodiments for determining of the set of  
30 spreading sequences are described for purpose of discussion, rather than suggesting any limitation. Other embodiments of determination of the set of spreading sequences will be

discussed with reference to FIG. 4 below.

[0058] At 320, the network device 110 transmits information of the set of spreading sequences to the terminal device 120, for example a spreading sequence group index. In some embodiments, the network device 110 may transmit, to the terminal device 120, the information of the set of spreading sequences via a downlink control channel, for example, Physical Downlink Control Channel (PDCCH). Alternatively, in some embodiments, the information of the set of spreading sequences may be transmitted via a high level signaling, such as Radio Resource Control (RRC) signaling or Medium Access Control (MAC) signaling. The network device also transmits information of a sequence index within the sequence group to the terminal device. Similarly, the information can be transmitted via either PDCCH, or RRC signaling, or MAC signaling. In some embodiments, the terminal device might autonomously select one group and one sequence in the group as the spreading sequence for the first modulated symbol. For other modulated symbols, the spreading sequence is from the same sequence group and determined based on the modulated symbol index. In another embodiment, the sequences in each group might be different for different terminal devices, and are determined by the terminal device ID.

[0059] In some embodiments, the network device 110 may transmit indices of spreading sequences in the set. The indices indicate those sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups. For example, if there are 6 spreading sequences in the set, the indices thereof may be two-dimensional indices, such as  $(x_1, y_1)$ ,  $(x_2, y_2)$ ,  $(x_3, y_3)$ ,  $(x_4, y_4)$ ,  $(x_5, y_5)$  and  $(x_6, y_6)$ . In this case,  $x_1, x_2, \dots, x_6$  are group indices and  $y_1, y_2, \dots, y_6$  are sequence indices. The group indices indicate sequence groups from which the spreading sequences are selected. The sequence indices indicate positions of the spreading sequences in the respective sequence groups.

[0060] Alternatively, in some embodiments, the network device 110 may transmit indices of spreading sequences in the set, grouping information and sequence information. The indices indicate sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups. The grouping information indicates division of sequence groups, and the sequence information indicates spreading sequences in each sequence group. In this case, upon receipt of such information, the terminal device 120 can determine the set of spreading sequences to be used directly, without the need of determining grouping information and the sequence

information by itself.

[0061] In some embodiments, after receiving the information, the terminal device 120 may understand the set of spreading sequences are assigned for modulated symbols, and may spread the modulated symbols by applying, to one modulated symbol, a corresponding spreading sequence in the set of spreading sequences. More specifically, the terminal device uses the indicated sequence within the indicated sequence group to spread the first modulated symbol in each OFDM symbol. For other modulated symbols, the spreading sequence is from the same sequence group and determined based on the modulated symbol index. Then, the terminal device 120 may transmit a signal comprising the spread modulated symbols to the network device 110. In this case, the network device 110 may receive the signal from the terminal device 120. Since the signal comprises the modulated symbols that have been spread by the set of spreading sequences, and the set of spreading sequences are at least partially different from a further set of spreading sequences used by a further terminal device in communication with the network device, randomization of the spreading of the modulation symbols of different terminal devices can be achieved. In this way, the PAPR of the proposed NOMA scheme can be reduced effectively and efficiently.

[0062] FIG. 4 illustrates a flowchart of a method 400 for determining the set of spreading sequences in accordance with some embodiments of the present disclosure. Method 400 can be for example performed at the network device 110 or other suitable device.

[0063] At 410, the network device 110 determines a sequence number for a sequence group based on bandwidth allocated to the terminal device 120 and a spreading factor used by the terminal device 120. The sequence number indicates the number of spreading sequences to be included in the sequence group.

[0064] In some embodiments, the network device 110 may determine the number of resource elements (REs) in an uplink symbol allocated to the terminal device. For example, if the terminal device 120 is allocated with N Physical Resource Blocks (PRBs), it can be determined that there are N\*Z REs in frequency domain, where Z indicates the number of REs per PRB, for example, 12. Then, the network device 110 may determine the sequence number by dividing the number of resource elements by the spreading factor (SF). For example, assuming  $SF = K$ , the sequence number (denoted as "Y") may be calculated as:  $Y = N * Z / K$ .

[0065] At 420, the network device 110 determines a plurality of sequence groups from a predefined sequence pool. The number of spreading sequences in each sequence group equals to the sequence number. The sequence pool may comprise a plurality of spreading sequences. The set of spreading sequences for the modulated symbols of the terminal  
5 device 120 may be determined from the available spreading sequences included in the sequence pool.

[0066] The sequence pool may be predefined or implemented in a variety of ways. In some embodiments, the sequence pool may comprise a plurality of spreading sequences constructed by Quadrature Phase Shift Keying (QPSK) constellation. Table 1 shows an  
10 example of the sequence pool.

Table 1:  $\varphi(n)$  for SF=6

$u$	$\varphi(0), \dots, \varphi(5)$					
0	-1	-3	3	-3	3	-3
1	-1	3	-1	1	1	1
2	3	-1	-3	-3	1	3
3	3	-1	-1	1	-1	-1
4	-1	-1	-3	1	-3	-1
5	1	3	-3	-1	-3	3
6	-3	3	-1	-1	1	-3
7	-1	-3	-3	1	3	3
8	3	-1	-1	3	1	3
9	3	-3	3	1	-1	1
10	-3	1	-3	-3	-3	-3
11	-3	-3	-3	1	-3	-3
12	3	-3	1	-1	-3	-3
13	3	-3	3	-1	-1	-3
14	3	-1	1	3	3	1
15	-1	1	-1	-3	1	1
16	-3	-1	-3	-1	3	3
17	1	-1	3	-3	3	3
18	1	3	1	1	-3	3
19	-1	-3	-1	-1	3	-3
20	3	-1	-3	-1	-1	-3
21	3	1	3	-3	-3	1
22	1	3	-1	-1	1	-1
23	-3	1	-3	3	3	3
24	1	3	-3	3	-3	3
25	-1	-1	1	-3	1	-1
26	1	-3	-1	-1	3	1
27	-3	-1	-1	3	1	1
28	-1	3	-3	-3	-3	3
29	3	1	-1	1	3	1

[0067] Table 1 includes of the construction of the spreading sequences, denoted as  $\bar{r}_u(n)$  which can be calculated below:

$$\bar{r}_u(n) = \exp\left(\frac{j\varphi(n)\pi}{4}\right), \quad 0 \leq n \leq SF - 1 \tag{3}$$

where  $u$  represents a root for a spreading sequence, and  $SF$  indicates the spreading factor.

- 5 [0068] In the example shown with respect to Table 1, there are P (for example, P=30) roots and for each root, there are Q available cyclic shifts (for example, Q=6), for example, the sequence corresponding to the first cyclic shift is  $\{\varphi(0), \varphi(1), \dots, \varphi(SF-1)\}$ , and the

sequence corresponding to the second cyclic shift is  $\{\varphi(1), \varphi(2), \dots, \varphi(SF-1), \varphi(0)\}$ , and so on. Therefore, there are totally  $P*Q$  sequences available for spreading. In this example, there are  $30*6=180$  available spreading sequences.

[0069] In some embodiments, the network device 110 may determine the total number of available spreading sequences in the predefined sequence pool. The network device 110 may further determine a group number based on the total number of the available spreading sequences and the sequence number for a sequence group. Then, the network device 110 may divide the available spreading sequences into the sequence groups based on the group number.

[0070] FIG. 5 illustrates a diagram 500 of mapping between NOMA resource allocation and modulated symbols in accordance with some embodiments of the present disclosure. As shown in FIG. 5, there illustrates  $N$  PRBs 510-560 allocated to the terminal device 120 in an uplink symbol, where  $N = 6$ . The  $N$  PRBs 510-560 are indexed with 1 to 6, respectively. Assuming there are 12 modulated symbols for each OFDM symbol, the symbol index of the 12 modulated symbols is shown as 1 to 12, respectively. Suppose the spreading factor is  $K$  (for example  $K=6$ ), then the number of sequence in a group (that is, the sequence number) would be  $Y=(N*12)/K = (6*12)/6 = 12$ , corresponding to 12 modulate symbols. The number of the total available sequence group is  $P*Q/Y=180/12=15$ . In this case, the sequences for 2 roots are put in the same group. The sequences in the same group are selected with low cross correlation.

[0071] It is to be understood that the above examples of concrete values are described for discussion, rather than limitation. In other embodiments of the present disclosure, any suitable values can be applied.

[0072] Still referring to FIG. 4, at 430, the network device 110 selects one of the sequence groups for the modulated symbols of the terminal device. In some embodiments, the network device 110 may select a first spreading sequence for a first modulated symbol of the modulated symbols within the selected sequence group. For example, the selection may be performed based on identification of the terminal device. Then, the network device 110 may determine remaining spreading sequences in the selected sequence group for remaining modulated symbols of the modulated symbols.

[0073] In some embodiments, the spreading sequences in the determined sequence group are sorted in a predetermined order. Thus, the remaining spreading sequences may be

assigned to the remaining modulated symbols by cyclic shift according to the predetermined order. This will be further discussed with respect to embodiments shown in FIG. 6.

[0074] FIG. 6 illustrates a diagram 600 of allocation of spreading sequence in accordance with some embodiments of the present disclosure. As shown, there are 12 spreading sequences S1, S2, ..., S11, S12 in one sequence group 610. Based on the available groups and the sequences within the group, the terminal device 120 may be configured with one group and one spreading sequence within the group for the 1<sup>st</sup> modulated symbol in each OFDM symbol. For the subsequent modulated symbols, the terminal device 120 may determine the spreading sequences sequentially in the same group according to modulated symbol index. As one example, if the network device 110 configures the spreading sequence S9 from the sequence group 610 for the first modulation symbol 621 for the terminal device 120, then the network device 110 may use the spreading sequence S6 for the modulated symbol 626, so on and so forth. Thus, the network device 110 may determine the set of spreading sequences {S9, S10, S11, S12, S1, S2, S3, S4, S5, S6, S7, S8} for modulated symbols (denoted as b1, b2, b3, b4, b5, b6, b7, b8, b9, b10, b11 and b12, respectively) of the terminal device 120. The correspondence between the set of spreading sequences and the modulated symbols is shown in Table 2.

Table 2

Spreading Sequences	Modulated Symbols
S9	b1
S10	b2
S11	b3
S12	b4
S1	b5
S2	b6
S3	b7
S4	b8
S5	b9
S6	b10

S7	b11
S8	b12

[0075] According to embodiments of the present disclosure, for the terminal device 130, correspondence between the set of spreading sequences and the modulated symbols is at least partially different from the correspondence of the terminal device 120. In the above  
 5 embodiments, the network device 110 may determine the set of spreading sequences {S11, S12, S1, S2, S3, S4, S5, S6, S7, S8, S9, S10} for modulated symbols (denoted as c1, c2, c3, c4, c5, c6, c7, c8, c9, c10, c11 and c12, respectively) of the terminal device 120. The correspondence between the set of spreading sequences and the modulated symbols is shown in Table 3.

10

Table 3

Spreading Sequences	Modulated Symbols
S11	c1
S12	c2
S1	c3
S2	c4
S3	c5
S4	c6
S5	c7
S6	c8
S7	c9
S8	c10
S9	c11
S10	c12

[0076] Comparing Tables 2 and 3, it can be seen that for the first modulated symbol b1 of the terminal device 120, the spreading sequence is determined as S9, while for the first

modulated symbol c1 of the terminal device 130, the spreading sequence is determined as S11. As for the second modulated symbol b2 of the terminal device 120, the spreading sequence is determined as S10, while for the first modulated symbol c2 of the terminal device 130, the spreading sequence is determined as S12. Thus, the correspondences of the set of spreading sequences between the modulated symbols for different terminal devices are at least partially different. As a result, randomization of the spreading of the modulation symbols of different terminal devices can be achieved.

[0077] With embodiments of the present disclosure, the network device 110 may configure different terminal devices with different spreading sequences for spreading the same modulated symbol (for example, the first modulated symbol or modulated symbol having a specific index) in frequency domain. As such, sequence collision will not happen for all other modulated symbols.

[0078] In some embodiments, if the terminal device 120 selects the sequence group and sequence index itself, the network device 110 may take identification of the terminal device (UE-ID) as another determination factor, so that the sequence collision might happen for only part of the modulated symbols.

[0079] Additionally or alternatively, in some embodiments, a long sequence may be defined according to allocated bandwidth (BW) and the spreading sequence is part of the long sequence. For example, in the case 12 PRB allocation with SF=6, length of long sequence is 144 (12x12) and length of the spreading sequence is 6. The first modulated symbol may be spread by cyclic sift of first 6 elements of long sequence and the second symbol may be spread by cyclic sift of next 6 elements of the long sequence. It is to be understood that the above examples of concrete values are described for discussion, rather than limitation. In other embodiments of the present disclosure, any suitable values can be applied.

[0080] FIG. 7 illustrates a flowchart of a method 700 in accordance with some embodiments of the present disclosure. The method 700 can be implemented at the terminal device 120 or 130 as shown in FIG. 1. For the purpose of discussion, the method 700 will be described with reference to FIG. 1.

[0081] At 710, the terminal device 120 receives information of a set of spreading sequences for modulated symbols of the terminal device 120 from a network device. One spreading sequence in the set corresponds to one of the modulated symbols. The

correspondence between the set of spreading sequences and the modulated symbols are at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device (for example, the terminal device 130) in communication with the network device 110.

5 [0082] In some embodiments, the terminal device 120 may receive the information of the set of spreading sequences via a downlink control channel, for example, PDCCH. Alternatively, in some embodiments, terminal device 120 may receive the information of the set of spreading sequences via a high level signaling, such as RRC signaling or MAC signaling.

10 [0083] At 720, the terminal device 120 determines the set of spreading sequences based on the received information.

[0084] In some embodiments, the terminal device 120 may receive at 710 indices of spreading sequences in the set. The indices indicate sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective  
15 sequence groups. In this case, at 720, the terminal device may determine a sequence number for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device. The sequence number indicates the number of spreading sequences to be included in the sequence group. The terminal device 120 may further determine sequence groups from a predefined sequence pool, each sequence  
20 group including the sequence number of spreading sequences. Then, the terminal device 120 may determine the set of spreading sequences from the sequence groups based on the indices.

[0085] Alternatively, in some embodiments, the terminal device 120 may receive, at 710, indices of spreading sequences in the set, grouping information and sequence information.  
25 The indices indicate sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups. The grouping information indicates division of sequence groups, and the sequence information indicates spreading sequences in each sequence group. In this case, at 720, the terminal device 120 may determine the sequence groups based on the grouping information and the sequence  
30 information, and determine the set of spreading sequences from the sequence groups based on the indices.

[0086] At 730, the terminal device 120 spreads the modulated symbols based on the set of

spreading sequences, for example, by applying, to one of the modulated symbols, a corresponding spreading sequence in the set of spreading sequences.

[0087] At 740, the terminal device 120 transmits a signal comprising the spread modulated symbols to the network device 110. For example, the terminal device 120 may transmit the signal via Physical Uplink Shared Channel (PUSCH).

[0088] Since the signal comprises the modulated symbols that have been spread by the set of spreading sequences, and the set of spreading sequences are at least partially different from a set of spreading sequences used by a further terminal device 130, randomization of the spreading of the modulation symbols of different terminal devices 120 and 130 can be achieved. In this way, the PAPR of the proposed NOMA scheme can be reduced effectively and efficiently.

[0089] FIG. 9 illustrates a diagram of comparison of PAPR performance for proposed NOMA, OFDM and conventional NOMA schemes. In FIG. 9, the curve 910 represents the PAPR performance of the OFDM scheme, the curve 920 represents the PAPR performance of the conventional NOMA scheme (SF = 6), and the curve 930 represents the PAPR performance of the proposed NOMA scheme. From the evaluated performance shown in FIG. 9, the proposed NOMA scheme achieves better PAPR performance than the OFDM scheme, and much lower PAPR than the conventional NOMA scheme. Thus, comparing with the conventional NOMA scheme which uses the same spreading sequence for all modulated symbols in each OFDM symbol, the proposed NOMA scheme advantageously reduces PAPR and thus improves efficiency of the communication network 100.

[0090] In some embodiments, an apparatus capable of performing the method 300 and/or 400 (for example, at the network device 110) may comprise means for performing the respective steps of the method 300 and/or 400. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

[0091] In some embodiments, the apparatus comprises: means for determining, at a network device, a set of spreading sequences for modulated symbols of a terminal device, one spreading sequence in the set corresponding to one of the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading

sequences and further modulated symbols of a further terminal device in communication with the network device; and means for transmitting information of the set of spreading sequences to the terminal device.

5 [0092] In some embodiments, the means for determining the set of spreading sequences for modulated symbols may comprise: means for determining a sequence number for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device, the sequence number indicating the number of spreading sequences to be included in the sequence group; means for determining a plurality of sequence groups from a predefined sequence pool, each sequence group including the  
10 sequence number of spreading sequences; and means for selecting, from the plurality of sequence groups, a sequence group for the modulated symbols of the terminal device.

[0093] In some embodiments, the means for determining the sequence number for the sequence group may comprise: means for determining the number of resource elements in an uplink symbol allocated to the terminal device; and means for determining the sequence  
15 number by dividing the number of resource elements by the spreading factor.

[0094] In some embodiments, the means for determining the plurality of sequence groups from the predefined sequence pool may comprise: means for determining the total number of available spreading sequences in the predefined sequence pool; means for determining a group number based on the total number of the available spreading sequences and the  
20 sequence number for a sequence group; and means for dividing the available spreading sequences into the sequence groups based on the group number.

[0095] In some embodiments, the means for selecting one of the sequence groups for the modulated symbols of the terminal device may comprise: means for selecting a first spreading sequence for a first modulated symbol of the modulated symbols within the  
25 selected sequence group; and means for determining remaining spreading sequences in the selected sequence group for remaining modulated symbols of the modulated symbols.

[0096] In some embodiments, spreading sequences in the determined sequence group are sorted in a predetermined order, and the remaining spreading sequences are assigned to the remaining modulated symbols by cyclic shift according to the predetermined order.

30 [0097] In some embodiments, the means for selecting the first spreading sequence may comprise: means for selecting, based on identification of the terminal device, the first spreading sequence from available spreading sequences in the predefined sequence pool.

[0098] In some embodiments, the means for transmitting the information of the set of spreading sequences may comprise: means for transmitting indices of spreading sequences in the set, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups; or  
5 means for transmitting indices of spreading sequences in the set, grouping information and sequence information, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups, the grouping information indicating division of sequence groups, and the sequence information indicating spreading sequences in each sequence group.

10 [0099] In some embodiments, the apparatus may further comprise means for receiving a signal from the terminal device, the signal comprising the modulated symbols that have been spread by the set of spreading sequences.

[00100] In some embodiments, an apparatus capable of performing the method 700 (for example, at the terminal device 120 or 130) may comprise means for performing the  
15 respective steps of the method 700. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

[00101] In some embodiments, the apparatus comprises: means for receiving, at a terminal device, information of a set of spreading sequences for modulated symbols of the terminal device from a network device, one spreading sequence in the set corresponding to one of  
20 the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device; means for determining the set of spreading sequences based on the received information; means for spreading the modulated symbols  
25 based on the set of spreading sequences; and means for transmitting a signal comprising the spread modulated symbols to the network device.

[00102] In some embodiments, the means for receiving the information of the set of spreading sequences may comprise: means for receiving indices of spreading sequences in the set, the indices indicating sequence groups from which the spreading sequences are  
30 selected and positions of the spreading sequences in the respective sequence groups.

[00103] In some embodiments, the means for determining the set of spreading sequences based on the received information comprises: means for determining a sequence number

for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device, the sequence number indicating the number of spreading sequences to be included in the sequence group; means for determining sequence groups from a predefined sequence pool, each sequence group including the sequence number of spreading sequences; and means for determining the set of spreading sequences from the sequence groups based on the indices.

[00104] In some embodiments, the means for receiving the information of the set of spreading sequences may comprise: means for receiving indices of spreading sequences in the set, grouping information and sequence information, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups, the grouping information indicating division of sequence groups, and the sequence information indicating spreading sequences in each sequence group.

[00105] In some embodiments, the means for determining the set of spreading sequences based on the received information comprises: means for determining the sequence groups based on the grouping information and the sequence information; and means for determining the set of spreading sequences from the sequence groups based on the indices.

[00106] FIG. 10 is a simplified block diagram of a device 1000 that is suitable for implementing embodiments of the present disclosure. The device 1000 can be implemented at or as at least a part of the network device 110 or the terminal device 120 or 130 as shown in FIG. 1.

[00107] As shown, the device 1000 includes a processor 1010, a memory 1020 coupled to the processor 1010, a communication module 1040 coupled to the processor 1010, and a communication interface (not shown) coupled to the communication module 1040. The memory 1010 stores at least a program 1030. The communication module 1040 is for bidirectional communications. The communication interface may represent any interface that is necessary for communication with other network elements, such as X2 interface for bidirectional communications between eNBs, S1 interface for communication between a Mobility Management Entity (MME)/Serving Gateway (S-GW) and the eNB, Un interface for communication between the eNB and a relay node (RN), or Uu interface for communication between the eNB and a UE.

[00108] The program 1030 is assumed to include program instructions that, when executed

by the associated processor 1010, enable the device 1000 to operate in accordance with the embodiments of the present disclosure, as discussed herein with reference to FIGs. 3-4 or FIG. 7. The embodiments herein may be implemented by computer software executable by the processor 1010 of the device 1000, or by hardware, or by a combination of software and hardware. The processor 1010 may be configured to implement various embodiments of the present disclosure.

[00109] The memory 1010 may be of any type suitable to the local technical network and may be implemented using any suitable data storage technology, such as a non-transitory computer readable storage medium, semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, as non-limiting examples. While only one memory 1010 is shown in the device 1000, there may be several physically distinct memory modules in the device 1000. The processor 1010 may be of any type suitable to the local technical network, 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. The device 1000 may have multiple processors, such as an application specific integrated circuit chip that is slaved in time to a clock which synchronizes the main processor.

[00110] Generally, various embodiments of the present disclosure may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device. While various aspects of embodiments of the present disclosure are illustrated and described as block diagrams, flowcharts, or using some other pictorial representations, it is to be understood that the block, apparatus, system, technique or method described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[00111] The present disclosure also provides at least one computer program product tangibly stored on a non-transitory computer readable storage medium. The computer program product includes computer-executable instructions, such as those included in program modules, being executed in a device on a target real or virtual processor, to carry out the method 300-400 or the method 700 as described above with reference to FIGs. 3-4

or FIG. 7. Generally, program modules include routines, programs, libraries, objects, classes, components, data structures, or the like that perform particular tasks or implement particular abstract data types. The functionality of the program modules may be combined or split between program modules as desired in various embodiments.

5 Machine-executable instructions for program modules may be executed within a local or distributed device. In a distributed device, program modules may be located in both local and remote storage media.

[00112] Program code for carrying out methods of the present disclosure may be written in any combination of one or more programming languages. These program codes may be provided to a processor or controller of a general purpose computer, special purpose  
10 computer, or other programmable data processing apparatus, such that the program codes, when executed by the processor or controller, cause the functions/operations specified in the flowcharts and/or block diagrams to be implemented. The program code may execute entirely on a machine, partly on the machine, as a stand-alone software package, partly on  
15 the machine and partly on a remote machine or entirely on the remote machine or server.

[00113] In the context of the present disclosure, the computer program codes or related data may be carried by any suitable carrier to enable the device, apparatus or processor to perform various processes and operations as described above. Examples of the carrier include a signal, computer readable media.

20 [00114] The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable medium may include but not limited to an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the computer readable storage medium would include an electrical connection  
25 having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

30 [00115] Further, while operations are depicted in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable

results. In certain circumstances, multitasking and parallel processing may be advantageous. Likewise, while several specific implementation details are contained in the above discussions, these should not be construed as limitations on the scope of the present disclosure, but rather as descriptions of features that may be specific to particular  
5 embodiments. Certain features that are described in the context of separate embodiments may also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment may also be implemented in multiple embodiments separately or in any suitable sub-combination.

[00116] Although the present disclosure has been described in languages specific to  
10 structural features and/or methodological acts, it is to be understood that the present disclosure defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

**WHAT IS CLAIMED IS:**

1. A method, comprising:

determining, at a network device, a set of spreading sequences for modulated symbols of a terminal device, one spreading sequence in the set corresponding to one of the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device; and

transmitting information of the set of spreading sequences to the terminal device.

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2. The method of claim 1, wherein determining the set of spreading sequences for modulated symbols comprises:

determining a sequence number for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device, the sequence number indicating the number of spreading sequences to be included in the sequence group;

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determining a plurality of sequence groups from a predefined sequence pool, each sequence group including the sequence number of spreading sequences; and

selecting, from the plurality of sequence groups, a sequence group for the modulated symbols of the terminal device.

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3. The method of claim 2, wherein determining the sequence number for the sequence group comprising:

determining the number of resource elements in an uplink symbol allocated to the terminal device; and

25

determining the sequence number by dividing the number of resource elements by the spreading factor.

4. The method of claim 2, wherein determining the plurality of sequence groups from the predefined sequence pool comprises:

30

determining the total number of available spreading sequences in the predefined sequence pool;

determining a group number based on the total number of the available spreading

sequences and the sequence number for a sequence group; and

dividing the available spreading sequences into the sequence groups based on the group number.

5           5. The method of claim 2, wherein selecting the sequence group for the modulated symbols of the terminal device comprises:

selecting a first spreading sequence for a first modulated symbol of the modulated symbols within the selected sequence group; and

10           determining remaining spreading sequences in the selected sequence group for remaining modulated symbols of the modulated symbols.

6. The method of claim 5, wherein spreading sequences in the determined sequence group are sorted in a predetermined order, and wherein the remaining spreading sequences are assigned to the remaining modulated symbols by cyclic shift according to the  
15           predetermined order.

7. The method of claim 5, wherein selecting the first spreading sequence comprises:

selecting, based on identification of the terminal device, the first spreading sequence from available spreading sequences in the predefined sequence pool.

20

8. The method of claim 1, wherein transmitting the information of the set of spreading sequences comprises one of:

25           transmitting indices of spreading sequences in the set, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups; and

30           transmitting indices of spreading sequences in the set, grouping information and sequence information, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups, the grouping information indicating division of sequence groups, and the sequence information indicating spreading sequences in each sequence group.

9. The method of claim 1, further comprising:

receiving a signal from the terminal device, the signal comprising the modulated symbols that have been spread by the set of spreading sequences.

10. A method, comprising:

receiving, at a terminal device, information of a set of spreading sequences for modulated symbols of the terminal device from a network device, one spreading sequence  
5 in the set corresponding to one of the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device;

determining the set of spreading sequences based on the received information;

10 spreading the modulated symbols based on the set of spreading sequences; and

transmitting a signal comprising the spread modulated symbols to the network device.

11. The method of claim 10, wherein receiving the information of the set of spreading sequences comprises:  
15

receiving indices of spreading sequences in the set, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups.

20 12. The method of claim 11, wherein determining the set of spreading sequences based on the received information comprises:

determining a sequence number for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device, the sequence number indicating the number of spreading sequences to be included in the sequence  
25 group;

determining sequence groups from a predefined sequence pool, each sequence group including the sequence number of spreading sequences; and

determining the set of spreading sequences from the sequence groups based on the indices.  
30

13. The method of claim 10, wherein receiving the information of the set of spreading sequences comprises:

receiving indices of spreading sequences in the set, grouping information and sequence information, the indices indicating sequence groups from which the spreading

sequences are selected and positions of the spreading sequences in the respective sequence groups, the grouping information indicating division of sequence groups, and the sequence information indicating spreading sequences in each sequence group.

5           14. The method of claim 13, wherein determining the set of spreading sequences based on the received information comprises:

                  determining the sequence groups based on the grouping information and the sequence information; and

                  determining the set of spreading sequences from the sequence groups based on the  
10 indices.

                  15. A network device comprising:

                  at least one processor; and

                  a memory coupled to the at least one processor, the memory storing instructions  
15 therein, the instructions, when executed by the at least one processor, causing the network device to perform acts comprising:

                  determining a set of spreading sequences for modulated symbols of a terminal device, one spreading sequence in the set corresponding to one of the modulated symbols, correspondence between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a  
20 further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device; and

                  transmitting information of the set of spreading sequences to the terminal device.

25

                  16. The network device of claim 15, wherein determining the set of spreading sequences for modulated symbols comprises:

                  determining a sequence number for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device, the sequence  
30 number indicating the number of spreading sequences to be included in the sequence group;

                  determining a plurality of sequence groups from a predefined sequence pool, each sequence group including the sequence number of spreading sequences; and

                  selecting, from the plurality of sequence groups, a sequence group for the

modulated symbols of the terminal device.

17. The network device of claim 16, wherein determining the sequence number for the sequence group comprising:

5 determining the number of resource elements in an uplink symbol allocated to the terminal device; and

determining the sequence number by dividing the number of resource elements by the spreading factor.

10 18. The network device of claim 16, wherein determining the plurality of sequence groups from the predefined sequence pool comprises:

determining the total number of available spreading sequences in the predefined sequence pool;

15 determining a group number based on the total number of the available spreading sequences and the sequence number for a sequence group; and

dividing the available spreading sequences into the sequence groups based on the group number.

19. The network device of claim 16, wherein selecting the sequence group for the modulated symbols of the terminal device comprises:

20 selecting a first spreading sequence for a first modulated symbol of the modulated symbols within the selected sequence group; and

determining remaining spreading sequences in the selected sequence group for remaining modulated symbols of the modulated symbols.

25

20. The network device of claim 19, wherein spreading sequences in the determined sequence group are sorted in a predetermined order, and wherein the remaining spreading sequences are assigned to the remaining modulated symbols by cyclic shift according to the predetermined order.

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21. The network device of claim 19, wherein selecting the first spreading sequence comprises:

selecting, based on identification of the terminal device, the first spreading sequence from available spreading sequences in the predefined sequence pool.

22. The network device of claim 15, wherein transmitting the information of the set of spreading sequences comprises one of:

transmitting indices of spreading sequences in the set, the indices indicating  
5 sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups; and

transmitting indices of spreading sequences in the set, grouping information and  
sequence information, the indices indicating sequence groups from which the spreading  
sequences are selected and positions of the spreading sequences in the respective sequence  
10 groups, the grouping information indicating division of sequence groups, and the sequence information indicating spreading sequences in each sequence group.

23. The network device of claim 15, wherein the acts further comprise:

receiving a signal from the terminal device, the signal comprising the modulated  
15 symbols that have been spread by the set of spreading sequences.

24. A terminal device, comprising:

at least one processor; and

a memory coupled to the at least one processor, the memory storing instructions  
20 therein, the instructions, when executed by the at least one processor, causing the terminal device to perform acts comprising:

receiving, at a terminal device, information of a set of spreading sequences  
for modulated symbols of the terminal device from a network device, one spreading  
sequence in the set corresponding to one of the modulated symbols, correspondence  
25 between the set of spreading sequences and the modulated symbols being at least partially different from correspondence between a further set of spreading sequences and further modulated symbols of a further terminal device in communication with the network device;

determining the set of spreading sequences based on the received information;  
30 spreading the modulated symbols based on the set of spreading sequences;  
and

transmitting a signal comprising the spread modulated symbols to the network device.

25. The terminal device of claim 24, wherein receiving the information of the set of spreading sequences comprises:

receiving indices of spreading sequences in the set, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups.

26. The terminal device of claim 25, wherein determining the set of spreading sequences based on the received information comprises:

determining a sequence number for a sequence group based on bandwidth allocated to the terminal device and a spreading factor used by the terminal device, the sequence number indicating the number of spreading sequences to be included in the sequence group;

determining sequence groups from a predefined sequence pool, each sequence group including the sequence number of spreading sequences; and

determining the set of spreading sequences from the sequence groups based on the indices.

27. The terminal device of claim 22, wherein receiving the information of the set of spreading sequences comprises:

receiving indices of spreading sequences in the set, grouping information and sequence information, the indices indicating sequence groups from which the spreading sequences are selected and positions of the spreading sequences in the respective sequence groups, the grouping information indicating division of sequence groups, and the sequence information indicating spreading sequences in each sequence group.

28. The terminal device of claim 27, wherein determining the set of spreading sequences based on the received information comprises:

determining the sequence groups based on the grouping information and the sequence information; and

determining the set of spreading sequences from the sequence groups based on the indices.

29. A computer readable storage medium storing a computer program thereon, the computer program, when executed by a processor, causing the processor to carry out the

method according to any of claims 1 to 9.

30. A computer readable storage medium storing a computer program thereon, the  
computer program, when executed by a processor, causing the processor to carry out the  
5 method according to any of claims 10 to 14.

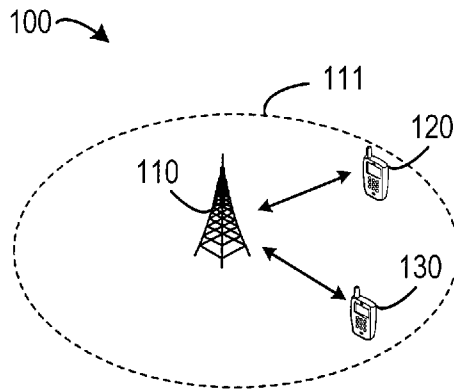


FIG. 1

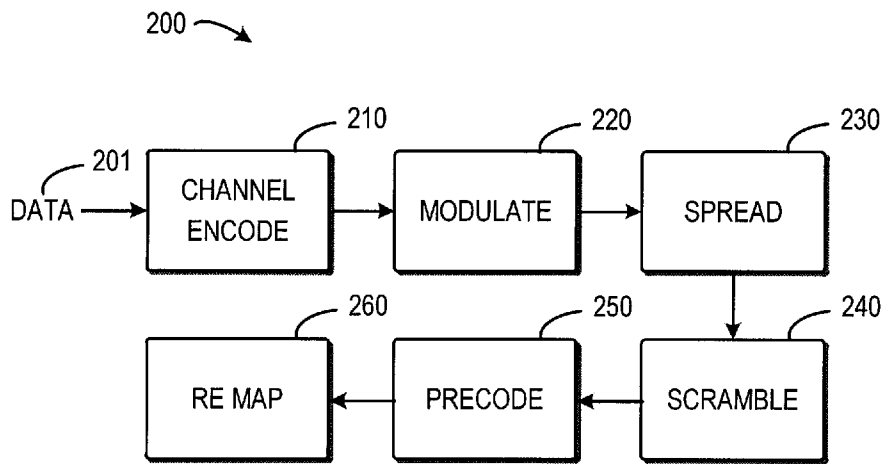


FIG. 2

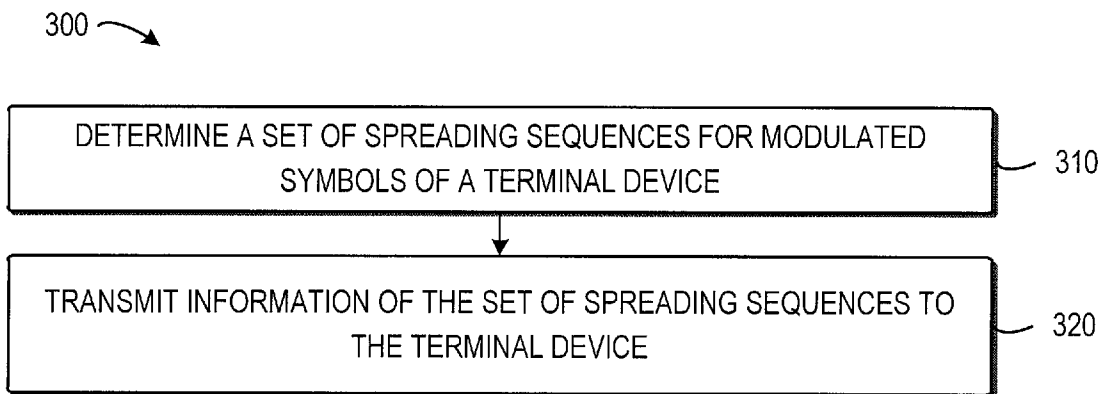


FIG. 3

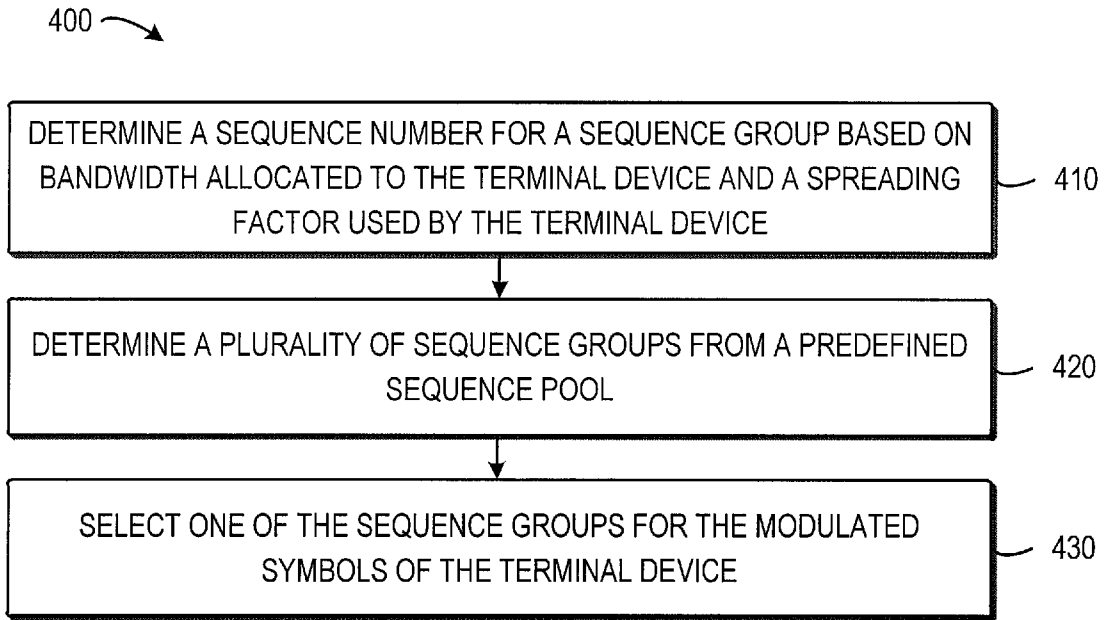


FIG. 4

500 ↗

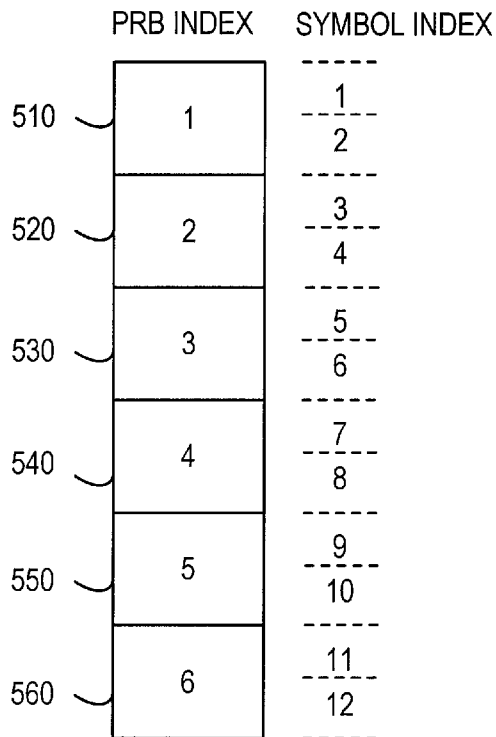


FIG. 5

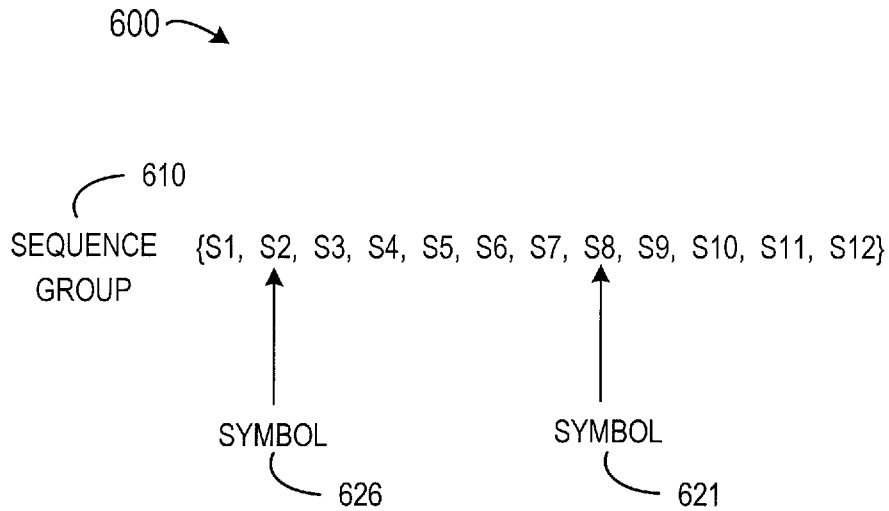


FIG. 6

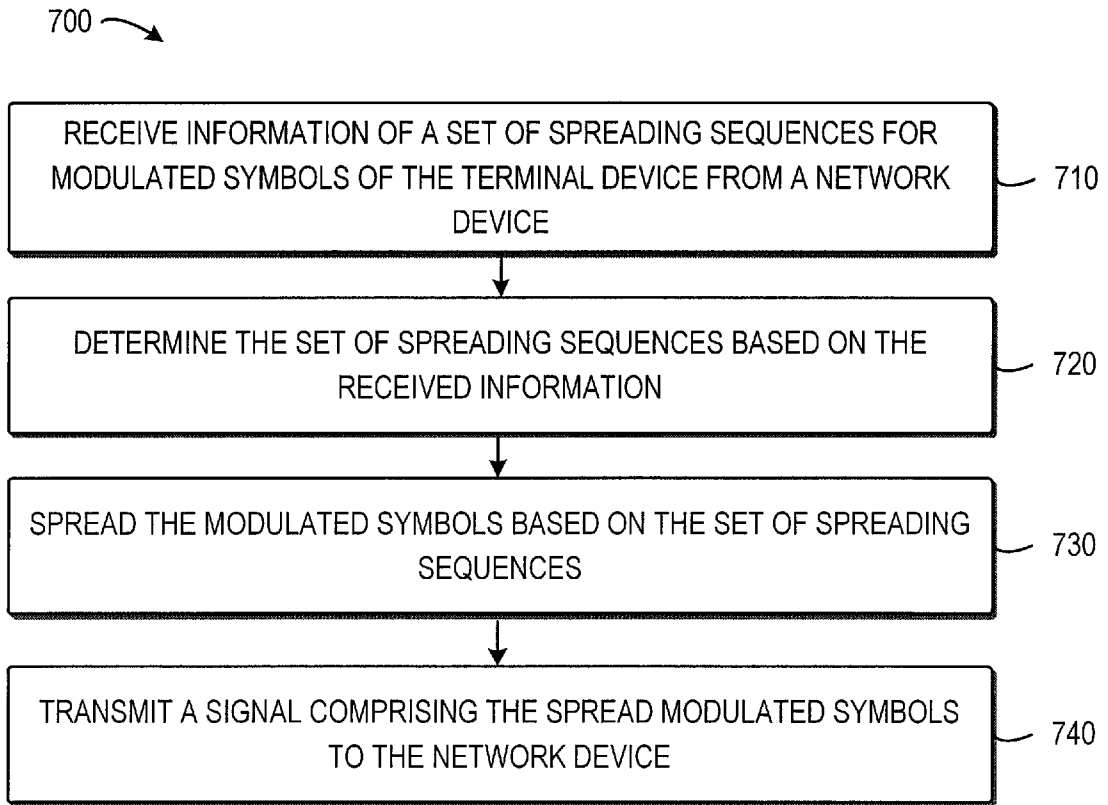


FIG. 7

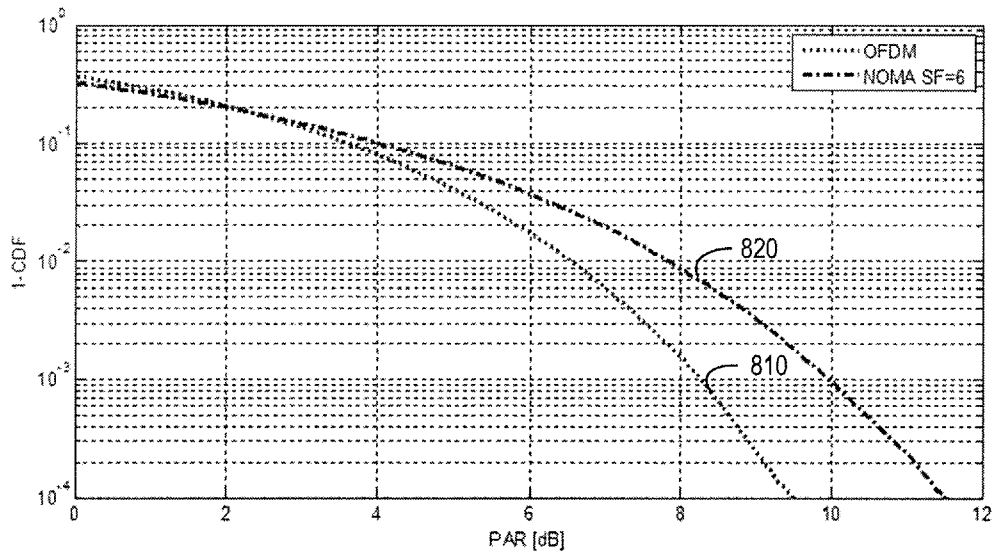


FIG. 8

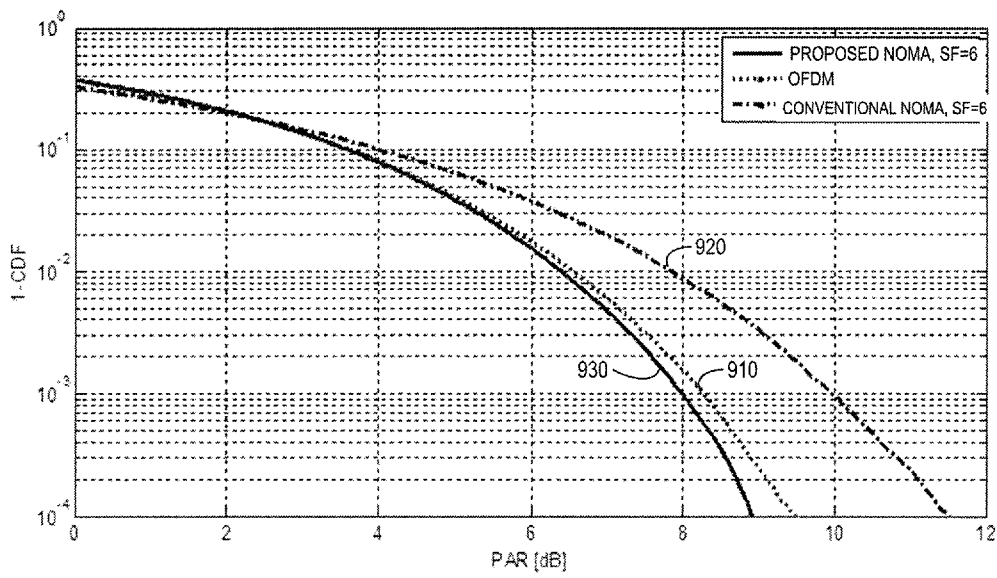


FIG. 9

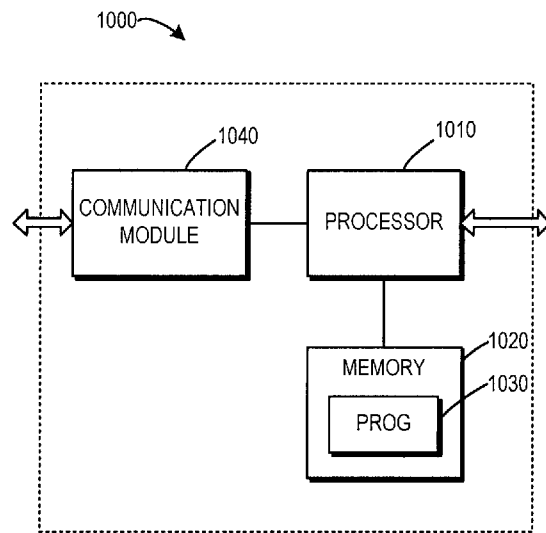


FIG. 10

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/092426

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
H04L 27/26(2006.01)i; H04L 5/00(2006.01)i		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) H04L; H04W		
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) EPODOC,WPL,CNPAT,CNKI,3GPP: spread+, sequence?, code?, set, group, assign+, allocate, modulate, modulation, symbol?, level, wise, correspond+, NOMA, user?, UE?, transmitter, different, PAPR, PAR		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016352478 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 01 December 2016 (2016-12-01) claims 1-32, description, paragraph [0042]	1-30
A	WO 2017123365 A2 (QUALCOMM INCORPORATED) 20 July 2017 (2017-07-20) the whole document	1-30
A	CN 105634702 A (ZTE CORPORATION) 01 June 2016 (2016-06-01) the whole document	1-30
A	CN 108123903 A (NOKIA SHANGHAI BELL CO., LTD.) 05 June 2018 (2018-06-05) the whole document	1-30
A	ZTE et al. "Summary of offline email discussion on Tx side processing and receiver types for clarification" 3GPP TSG RAN WG1 Meeting #92bis R1-1805535, 20 April 2018 (2018-04-20), the whole document	1-30
A	ZTE et al. "Transmitter side processing schemes for NOMA" 3GPP TSG RAN WG1 Meeting #92 R1-1801415, 02 March 2018 (2018-03-02), the whole document	1-30
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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 <b>23 February 2019</b>		Date of mailing of the international search report <b>22 March 2019</b>
Name and mailing address of the ISA/CN <b>National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China</b>		Authorized officer <b>LIU,Shan</b>
Facsimile No. (86-10)62019451		Telephone No. 86-10-53961626

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

International application No.

**PCT/CN2018/092426**

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				EP 3292670 A1	14 March 2018
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				IN201847020985 A	15 June 2018
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CN	108123903	A	05 June 2018	WO 2018100428 A1	07 June 2018