

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2015390318 B2**

(54) Title
Wireless communication method, eNodB and user equipment

(51) International Patent Classification(s)
H04W 72/04 (2009.01)

(21) Application No: **2015390318**

(22) Date of Filing: **2015.04.10**

(87) WIPO No: **WO16/161618**

(43) Publication Date: **2016.10.13**

(44) Accepted Journal Date: **2020.01.16**

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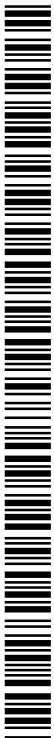
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(56) Related Art
WO 2016028126 A1



- (51) International Patent Classification: **H04W 72/04** (2009.01)
- (21) International Application Number: PCT/CN2015/076262
- (22) International Filing Date: 10 April 2015 (10.04.2015)
- (25) Filing Language: English
- (26) Publication Language: English
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))



WO 2016/161618 A1

(54) Title: WIRELESS COMMUNICATION METHOD, ENODB AND USER EQUIPMENT

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Transmitting DCI to a UE, wherein the DCI is designed based on a coverage enhancement level for the UE

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Fig. 1

(57) Abstract: Provided are wireless communication methods, an eNB and a UE. The wireless communication method performed by an eNB comprises transmitting downlink control information (DCI) to a user equipment (UE), wherein the DCI is designed based on a coverage enhancement level for the UE.

WIRELESS COMMUNICATION METHOD, ENODB AND USER EQUIPMENT

BACKGROUND

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1. Technical Field

The present disclosure relates to the field of wireless communication, and in particular, to wireless communication methods, an eNode B (eNB) and a user equipment (UE).

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2. Description of the Related Art

Machine-Type Communication (MTC) is a new type of communication in 3GPP in release 12 and an important revenue stream for operators. The coverage enhancement technique is quite useful for some MTC UEs like sensors in the basement which has large loss on signal strength due to penetration loss. For MTC with coverage enhancement, repetition is a basic solution to enhance the coverage.

20 SUMMARY

One non-limiting and exemplary embodiment provides an approach to design downlink control information (DCI) for a UE which may need coverage enhancement.

25 In a first general aspect of the present disclosure, there is provided a wireless communication method, comprising generating a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth
30 and the time domain information field indicating a number of repetitions in a time

domain, and transmitting the generated DCI to a user equipment (UE), wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

5 In a second general aspect of the present disclosure, there is provided wireless communication apparatus, comprising control information generating circuitry which, in operation, generates a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain, and a transmitter which, in operation, transmits the generated DCI to a user equipment (UE), wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

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In a third general aspect of the present disclosure, there is provided a wireless communication method, comprising receiving a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain, wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

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In a fourth general aspect of the present disclosure, there is provided a wireless communication apparatus, comprising receiver which, in operation, receives a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in frequency domain within a narrowband

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which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain, wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

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In a fifth general aspect of the present disclosure, there is provided an integrated circuitry comprising circuitry, which, in operation, controls: generating a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain, and transmitting the generated DCI to a user equipment (UE), wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

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In a sixth general aspect of the present disclosure, there is provided an integrated circuitry, which, in operation, controls: receiving a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

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It should be noted that general or specific embodiments may be implemented as a system, a method, an integrated circuit, a computer program, a storage medium, or any selective combination thereof.

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Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF DRAWINGS

The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings, in which:

Fig. 1 schematically illustrates a flowchart of a wireless communication method for an eNB according to an embodiment of the present disclosure;

Fig. 2 schematically illustrates a flowchart of a wireless communication method for a UE according to an embodiment of the present disclosure;

Fig. 3 schematically illustrates a block diagram of an eNB for wireless communication according to an embodiment of the present disclosure; and

Fig. 4 schematically illustrates a block diagram of a UE for wireless communication according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part thereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. It will be readily understood that the

aspects of the present disclosure can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

- 5 In the present disclosure, MTC may be taken as an example to describe the principle of the present disclosure; however, it is noted that the wireless communication methods disclosed in the present disclosure can not only be applied to MTC, but also be applied to other wireless communications such as other communications conforming to LTE specifications as long as those wireless communications may require coverage enhancement (CE). Accordingly, the UEs are not limited to MTC UEs, but can be any other UEs that can perform the communication methods described in the present disclosure.

15 For wireless communication with coverage enhancement (for example, 15 dB for MTC), repetitions of a channel to be transmitted (e.g. PDSCH (Physical Downlink Shared Channel) or PUSCH (Physical Uplink Shared Channel)) can be a basic solution to enhance the coverage. The DCI (Downlink Control Information) for a channel with coverage enhancement may need to indicate resource assignment in both time and frequency domain. How to design DCI with relatively small size to for example assign 20 resources for such a channel with coverage enhancement becomes an important issue of the wireless communication with coverage enhancement.

25 For example, for a MTC UE, DCI size is quite important as it heavily impacts active time of the UE. Active time means the period that the UE's RF/baseband is keeping working status to transmit or receive physical signals. It reflects the UE's power consumption and is mainly related with repetitions in time domain. Smaller DCI size can mean that the UE will use less time to receive the DCI. For example, assuming each repetition of a small DCI is transmitted by one ECCE (Enhanced Control Channel Element, 36 REs (Resource Element) per ECCE), QPSK (Quadrature Phase Shift

Keying), 1/3 coding rate and full occupation of narrowband (6 PRBs) are used, and total repetition times are 96, then the UE only needs 4 subframes to receive such DCI.

5 However, assuming one PRB pair transmits each repetition of DCI with larger size, full occupation of narrowband is used, and total repetition times are 96, then the UE will need 16 subframes to receive such DCI. So it is meaningful to design DCI with smaller size. Such DCI could also be transmitted by less resource like 1 ECCE instead of 1 PRB pair.

10 Furthermore, one ECCE can only carry 24 bits, which also means it can only support 8-bit payload size assuming CRC (Cyclic Redundancy Check) uses 16 bits. So DCI payload size requirement is quite tight assuming less resource like 1 ECCE to transmit DCI. One bit or 2 bit increase will require more ECCEs for DCI transmission.

15 In view of the above, how to design DCI with relatively small size for such a channel with coverage enhancement is an important issue for the wireless communication with coverage enhancement.

20 An embodiment of the present disclosure provides a wireless communication method 100 performed by an eNB, as shown in Fig. 1 which schematically illustrates a flowchart of the wireless communication method 100 according to an embodiment of the present disclosure. The wireless communication method 100 can comprise a step 101 of transmitting DCI to a UE, wherein the DCI is designed based on a coverage enhancement level for the UE.

25 Situations of UEs with CE may be different due to environment, distance to the eNB, penetration loss and so on. Therefore, the wireless communication design may need to consider different coverage enhancement levels like 5dB, 10dB or 15dB. Accordingly, the DCI can be designed based on the coverage enhancement level for
30 the UE. It is noted that, if any field (for example, a resource assignment field) in the

DCI is designed based on the coverage enhancement level, the DCI is considered to be designed based on the coverage enhancement level. For example, as described later in detail, a resource assignment field in DCI contains an index associated with the coverage enhancement level, and thus such a DCI is considered to be designed based on the coverage enhancement level.

In an exemplary embodiment, the DCI can use different sizes for different sets of coverage enhancement levels. For example, the coverage enhancement levels can be divided into two sets by comparing the coverage enhancement levels with a predetermined level. If a coverage enhancement level is larger than the predetermined level, the coverage enhancement level is considered to be a large coverage enhancement level and is assigned to a large CE level set. If a coverage enhancement level is smaller than the predetermined level, the coverage enhancement level is considered to be a small coverage enhancement level and is assigned to a small CE level set. The coverage enhancement level of a UE can be configured by the RRC layer, and the predetermined level can be specified or configured by the RRC layer.

For example, for a small coverage enhancement level, a payload size of 26 bits for the DCI can be used; and for a large coverage enhancement level, a payload size of 11 bits for the DCI can be used.

Table 1 indicates that two different DCIs (DCI 1 and DCI 2) are designed for small coverage enhancement levels and large coverage enhancement levels respectively.

Table 1

	DCI 1 (small coverage enhancement level)	DCI 2 (large enhancement level)
		Target is to reduce DCI size as much as possible
Contents	Resource indication (6 bits); MCS (5 bits); New data indicator (1 bit); Redundancy version (2 bits); HARQ process number (3 bits); TPC command for PUCCH (2bits); Antenna port(s), scrambling identity and number of layers (3 bits); SRS request (1 bit); HARQ-ACK resource offset (2 bits);	Resource indication (6 bits); New data indicator (1 bit); MCS (2 bits); HARQ process number (1 bit); Antenna port(s), scrambling identity and number of layers (1 bit)
Payload size	26 bits	11 bits

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In the example of Table 1, DCI 2 for large CE level has much smaller size since many features like SRS request are not required.

Table 2 indicates that a common DCI is designed for both small coverage enhancement levels and large coverage enhancement levels, but the field interpretation is different among different CE levels.

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Table 2

	Common DCI (applied to all CE UEs)
Contents	Resource indication (6 bits); MCS (5 bits for small coverage enhancement level; 2 bits for large coverage enhancement level); New data indicator (1 bit); Redundancy version (2 bits) –such field does not exist for large coverage enhancement; HARQ process number (3 bits for small coverage enhancement level and 1 bit for large coverage enhancement level); TPC command for PUCCH (2bits for small coverage enhancement level and such field does not exist for large coverage enhancement); Antenna port(s), scrambling identity and number of layers (3 bits for small coverage enhancement level and 1 bit for large coverage enhancement); SRS request (1 bit for small coverage enhancement level and such field does not exist for large coverage enhancement); HARQ-ACK resource offset (2 bits for small coverage enhancement level and such field does not exist for large coverage enhancement)
Payload size	26 bits or 11 bits depending on the coverage enhancement level

As exemplarily shown in Table 1 and Table 2, when the DCI uses different sizes for different sets of coverage enhancement levels, the DCI for the large coverage enhancement levels can use much less bits. It is noted that the small coverage enhancement level herein also comprises the case of no coverage enhancement.

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In addition or alternatively, in an embodiment of the present disclosure, the coverage enhancement of a channel (e.g., PDSCH or PUSCH) scheduled by the DCI with the coverage enhancement level can be realized at least by repetitions in time domain and/or repetitions in frequency domain with a repetition number which represents the total number of repetitions of the channel, and a resource assignment field in the DCI uses a single index associated with the repetition number to jointly indicate resource assignment in both time domain and frequency domain. This embodiment is another exemplary way of designing the DCI based on the coverage enhancement level for the UE.

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Repetition is an effective way to enhance the coverage of a channel. The repetition can happen in time domain, for example, multiple subframes can be used to transmit a transport block repeatedly. The repetition can also happen in frequency domain, for example, multiple PRBs in frequency domain are used to transport a transport block. Aggregation in frequency domain is a way of repetitions in frequency domain. Obviously, the repetition can also happen in both time domain and frequency domain. The DCI scheduling a channel (e.g. PUSCH or PDCCH) requiring coverage enhancement may need to indicate resource assignment in both time domain and frequency domain. The resource assignment can be indicated in a resource assignment field. For example, the resource assignment field may need to indicate how many subframes and how many PRBs in frequency domain are used for repetition. Optionally, the resource assignment field may also need to indicate the resource positions in frequency domain. The total number of repetitions (the repetition number) can be the product of the subframe number in time domain and the PRB number in frequency domain in unit of PRB pair. For example, 100 repetitions (PRB pairs) can be

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reflected by 2 PRB x 50 subframes, that is, the repetition number is 100. Alternatively, the repetition number can also be in unit of PRB. For example, 200 repetitions (PRBs) can be reflected by 2 PRB x 100 slots (50 subframes). In the present disclosure, the unit of PRB pair is used to present the repetition number.

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An example of resource assignment field design is separate indications for time domain and frequency domain. For example, one field is used to indicate the number of subframes in time domain and another field is used to indicate the number and/or positions of PRBs in frequency domain for example within the narrowband (6 PRBs).

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Table 3 illustrates one example of such separate indications.

Table 3

	Repetitions in time domain	Number of PRBs in frequency domain	Total PRB pair number (repetition number)
	1	1	1
	1	2	2
	1	3	3
	1	4	4
	1	5	5
	1	6	6
	2	1	2
	2	2	4
	2	3	6
	2	4	8
	2	5	10
	2	6	12
	4	1	4
	4	2	8
	4	3	12
	4	4	16
	4	5	20
	4	6	24
Required field size	2 bits	3 bits	

In the example of Table 3, 2 bits are used to indicate repetitions in time domain and 3 bits are used to indicate repetitions in frequency domain. Thus, totally 5 bits are needed for the resource assignment field. It is noted that, in this example, only PRB number in frequency domain is indicated, but the resource position(s) in frequency

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domain is not indicated. The resource position(s) can be for example configured by the RRC layer or based on identity (ID) of the UE.

5 Table 4 illustrates another example of separate indications, in which the resource position(s) in frequency domain is indicated.

Table 4

	Repetitions in time domain	Number of PRBs in frequency domain	Position in frequency domain	Total PRB pair number (repetition number)
	1	1	6 candidates	1
	1	2	5 candidates	2
	1	3	4 candidates	3
	1	4	3 candidates	4
	1	5	2 candidates	5
	1	6	1 candidates	6
	2	1	6 candidates	2
	2	2	5 candidates	4
	2	3	4 candidates	6
	2	4	3 candidates	8
	2	5	2 candidates	10
	2	6	1 candidates	12
	4	1	6 candidates	4
	4	2	5 candidates	8
	4	3	4 candidates	12
	4	4	3 candidates	16
	4	5	2 candidates	20
	4	6	1 candidates	24
Required field size	2 bits		5 bits	

10 In the example of Table 4, 2 bits are used to indicate repetitions in time domain and 5 bits are used to indicate repetitions in frequency domain. Thus, totally 7 bits are needed for the resource assignment field.

15 The benefit of such a separate indication approach as exemplarily shown in Table 3 and Table 4 is flexibility on resource assignment. However, it has the problem that the field size for resource assignment is relatively large so that the DCI size may be large as well, and the UE's active time to for example receive PDSCH is not optimized.

In an embodiment of the present disclosure, a joint indication of resource assignment is proposed, that is, a resource assignment field in the DCI uses a single index associated with the repetition number to jointly indicate resource assignment in both time domain and frequency domain. It is noted that one repetition number can correspond to one or more indexes to represent one or more specific resource assignment ways for the one repetition number. Joint indication may reduce the field size for resource assignment. For example, in the example of Table 3, if two more repetition possibilities (for example, 6 and 8 repetitions) are added in time domain, then there needs 3 bits to indicate 5 possibilities (1, 2, 4, 6 and 8). Therefore, totally 6 bits (3 bits for time domain and 3 bits for frequency domain) are needed if the separation indication approach is used. However, if a joint indication is used, then only 5 bits are needed to indicate 30 possibilities (5 in time domain x 6 in frequency domain). One bit is saved. The 5 bits constitute an index associated with the repetition number. Optionally, in this embodiment, transport block size can also be determined by the index associated with the repetition number in the resource assignment field. For example, a smaller repetition number can indicate smaller transport block size, and a larger repetition number can indicate larger transport block size.

In a further embodiment, the same number of repetitions in time domain is used for one and the same value of the repetition number. In other words, only one combination of repetition number in time domain and repetition number (number of PRBs) in frequency domain is used for one repetition number. For example, assuming the repetition number is 8, the resource assignment may be 2 PRBs in time domain x 4 subframes in time domain (simplified as 2 PRBs x 4 subframes) or 4 PRBs x 2 subframe. However, according to this embodiment, for the repetition number of 8, only one possibility of repetition number in time domain can be used and the UE knows it in advance. For example, the repetition number in time domain can be either 4 subframes or 2 subframes, and accordingly the repetition number in frequency domain can be either 2 PRBs or 4 PRBs. The selection of repetition number in time domain or frequency

domain for each repetition number can be for example configured by the RRC layer or specified in the standard. Therefore, when the UE receives an index corresponding to the repetition number, it can determine the repetition number in time domain and the repetition number in frequency domain. In this way, the size of the resource assignment field can be reduced since only one combination of repetition number in time domain and repetition number in frequency domain needs to be indicated for one repetition number. Table 5 illustrates a specific example of the embodiment that each repetition number only has one combination of repetition number in time domain and repetition number in frequency domain in the context of Table 3.

Table 5

	Repetitions in time domain	Number of PRBs in frequency domain	Total PRB pair number (repetition number)	Index in DCI
	1	1	1	0
	1	2	2	1
	1	3	3	2
	1	4	4	3
	1	5	5	4
	1	6	6	5
	2	4	8	6
	2	5	10	7
	2	6	12	8
	4	4	16	9
	4	5	20	10
	4	6	24	11
Required field size				3 bits

In Table 5, each repetition number only has one combination of repetition number in time domain and repetition number in frequency domain; therefore, only 3 bits are needed for the resource assignment field, which saves 2 bits compared with the approach show in Table 3.

Table 6 illustrates another specific example of the embodiment that each repetition number only has one combination of repetition number in time domain and repetition number in frequency domain in the context of Table 4.

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Table 6

	Repetitions in time domain	Number of PRBs in frequency domain	Position in frequency domain	Total PRB pair number (repetition number)	Index in DCI
	1	1	6 candidates	1	0-5
	1	2	5 candidates	2	6-10
	1	3	4 candidates	3	11-14
	1	4	3 candidates	4	15-17
	1	5	2 candidates	5	18-19
	1	6	1 candidates	6	20
	2	4	3 candidates	8	21-23
	2	5	2 candidates	10	24-25
	2	6	1 candidates	12	26
	4	4	3 candidates	16	27-29
	4	5	2 candidates	20	30-31
	4	6	1 candidates	24	32
Required field size					5 bits

In Table 6, each repetition number only has one combination of repetition number in time domain and repetition number in frequency domain; therefore, only 5 bits are needed for the resource assignment field, which saves 2 bits compared with the approach show in Table 4.

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It is reasonable that each repetition number has only one combination of repetition number in time domain and repetition number in frequency domain base on the reason that there is almost no performance difference between different combinations of repetition number in time domain and repetition number in frequency domain. For example, there is almost no performance difference between 2 PRBs x 4 subframes and 4 PRB x 2 subframe for resource assignment. First, frequency hopping is disabled within "multiple subframes" to realize symbol-level combining based on current 3GPP agreements (refer to "Draft Report of 3GPP TSG RAN WG1 #80 v0.2.0"). In other

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words, the resources should keep the same position in frequency domain within “multiple subframes”. For example, the value of “multiple subframes” can be 4. Second, the total repetition times are the same, for example, 2 PRBs x 4 subframes can realize 8 repetitions and 4 PRB x 2 subframe can also realize 8 repetitions.

5 Therefore, the embodiment that each repetition number has only one combination of repetition number in time domain and repetition number in frequency domain can reduce the field size of resource assignment while remaining the performance almost unchanged.

10 In a further embodiment, the least possible repetitions in time domain can be assigned for one and the same value of the repetition number. In other words, repetitions in time domain should be used as less as possible to reduce the UE’s active time and thus reduce the UE’s power consumption. The UE’s active time is related to repetition number in time domain. The smaller the repetition number in time domain is, the less

15 the UE’s active time is. For example, for the total repetition number of 8, the resource assignment of “4 PRBs x 2 subframes” should be used assuming narrowband of total 6 PRBs in frequency domain according to the embodiment since repetitions of 2 subframes in time domain are the least possible repetitions and the UE’s active time is the least in this case. For example, “2 PRBs x 4 subframes” has more repetitions in

20 time domain but less repetitions in frequency domain, and “4 PRBs x 2 subframes” has more repetitions in frequency domain but less repetitions in time domain. Therefore, the UE’s active time caused by receptions is larger in the case of “2 PRBs x 4 subframes” than in the case of “4 PRBs x 2 subframes”. The UE keeps active for 4 subframes in case of “2 PRBs x 4 subframes” but only needs to keep active for 2
25 subframes in case of “4 PRBs x 2 subframes”. As specific examples, the embodiment can be applied to Table 5 and Table 6.

In a further embodiment, only a proper subset of all possible resource positions in frequency domain are considered as frequency position candidates of the resource
30 assignment for at least one value of the repetition number. In other words, only limited

resource candidates (not all possible resource positions) are kept in frequency domain since there is no much scheduling gain within narrowband. In this way, the size of the resource assignment field can be further reduced. Table 7 is an example of limited resource candidates in frequency domain in context of Table 6.

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Table 7

	Repetitions in time domain	Number of PRBs in time domain	Position in frequency domain	Total PRB pair number (repetition number)	Index in DCI
	1	1	X1, Y1, Z1	1	0-2
	1	2	X2, Y2, Z2	2	3-5
	1	3	X3, Y3	3	6-7
	1	4	X4	4	8
	1	5	X5	5	8
	1	6	X6	6	10
	2	4	X7	8	11
	2	5	X8	10	12
	2	6	X9	12	13
	4	4	X10	16	14
	4	5	X11	20	15
	4	6	X12	24	16
Required field size					4 bits

In Table 7, for the repetition number 1, only 3 candidates (X1, Y1 and Z1) out of 6 candidates (assuming narrowband) are considered; for the repetition number 2, only 3 candidates (X2, Y2 and Z2) out of 5 candidates are considered; and so on. In this example, only 4 bits are needed and thus 1 bit is further saved compared with Table 6. The set of resource candidates (i.e., proper subset of all possible resource positions) can be configured by the RRC layer or determined based on ID of the UE.

15 The above embodiments can be used to any uplink channel (e.g. PUSCH) or downlink channel (e.g. PDSCH) for any enhancement level or repetition number. In an example, the above embodiments are used to a downlink channel for a small enhancement level or repetition number. Whether the coverage enhancement level is large or small can

be determined by comparing it with a predetermined level. The predetermined level can be configured by the RRC layer or specified. In some embodiments, the coverage enhancement level can also be configured by the RRC layer. It is noted that the above coverage enhancement level also comprises the case of no enhancement, and the repetition number also comprises the case of no repetition. For example, the first lines in Tables 3-7 represent no repetition.

In a further embodiment, if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is a downlink channel, all possible resources in frequency domain are assigned in the resource assignment. In other words, if the coverage enhancement level is large, full occupation of the resources (for example 6 PRBs of narrowband) in frequency domain can be used in a downlink channel in order to reduce the UE's active time. Table 8 illustrates an example of full occupation of frequency resources.

Table 8

Repetitions in time domain	Number of PRBs in frequency domain	Index in DCI
8	6	0
20	6	1
40	6	2
100	6	3
200	6	4
400	6	5
800	6	6
1000	6	7
Required field size		3 bits
Resource assignment size in separation indications (time + frequency)		6 bits Time domain: 4 bits Frequency domain: 2 bits

In Table 8, all 6 PRBs of narrowband are occupied in time domain, and only 3 bits are needed to indicate resource assignment, which saves 3 bits compared with the

separate indication approach. In addition, according to this embodiment, the UE's active time can be reduced.

In a further embodiment, if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is an uplink channel, only one resource in frequency domain is assigned in the resource assignment. 1 PRB transmission in frequency domain can realize the largest power spectral density (PSD) in uplink. Optionally, the one resource in frequency domain can be configured by the RRC layer or based on ID of the UE. Alternatively, limited resource candidates in frequency domain can be configured for the resource assignment of the one resource. Table 7 illustrates an example of 1 PRB transmission combined with limited resource candidates in frequency domain.

Table 9

Repetitions in time domain	Number of PRBs in frequency domain	Position in frequency domain	Index in DCI
8	1	X,Y,Z	0-2
20	1	X,Y,Z	3-5
40	1	X,Y,Z	6-8
100	1	X,Y,Z	9-11
200	1	X,Y,Z	12-14
400	1	X,Y,Z	15-17
800	1	X,Y,Z	18-20
1000	1	X,Y,Z	21-23
Required field size			5 bits
Resource assignment size in separate indications (time + frequency)			6 bits Time domain: 4 bits Frequency domain: 2 bits

In Table 9, 1 PRB transmission and 3 resource candidates in frequency domain are used in the uplink for each large repetition number. In other words, only repetitions in

time domain have multiple options, for example 8, 20, 40, 100 and so on. The field size for resource assignment is reduced from 6 bits to 5 bits. It is note that the set of resource candidates {x, y, z} can be configured by the RRC layer or determined based on ID of the UE.

5

In an embodiment, the resource assignment field can be interpreted based on whether the coverage enhancement level is large or small. In other words, different sets of coverage enhancement levels can use different designs of the resource assignment field. For example, for a small coverage level, the interpretation of the resource assignment field can use any of Tables 5-7; for a large coverage level, the interpretation of the resource assignment field can use Table 8 for downlink and Table 9 for uplink. In this example, it assumes that the UE knows the coverage enhancement level in advance in order to determine which table should be used. For example, the UE can know the information by RRC configuration.

10

15

In another embodiment, all possible repetition numbers should be covered in one table in case the UE does not know the coverage enhancement level for example during system information block (SIB) acquisition or random access period as it is common information that should be used for all UEs. For example, Table 10 illustrates an exemplary table that contains all possible repetition numbers (from 1 repetition in time domain to 1000 repetitions in time domain). Therefore, the UE can interpret the resource assignment field even if it does not know the coverage enhancement level.

20

Table 10

Repetitions in time domain	Number of PRBs in frequency domain	Position in frequency domain	Index in DCI
1	1	X1,Y1,Z1	0-2
1	2	X2,Y2,Z2	3-5
1	4	Only one candidate in the following	6
1	6		7
2	4		8
2	6		9
4	4		10
4	6		11
8	6		12
20	6		13
40	6		14
100	6		15
200	6		16
400	6		17
800	6		18
1000	6		19
Required field size			5 bits
Resource assignment size in separate indications (time + frequency)			6 bits Time domain: 4 bits Frequency domain: 2 bits

As shown in Table 10, the field size for resource assignment is reduced from 6 bits to 5 bits compared with the separate indication approach. It is noted that Table 10 is only an example of the solution covering all possible repetition numbers. The technical features described in the other embodiments can also be applied to the solution covering all possible repetition numbers unless the context indicates otherwise.

According to embodiments of the present disclosure, the DCI size can be reduced. In some embodiments, the active time of the UE can be reduced and/or the PSD can be increased. It is noted that the above embodiments can be combined unless the context indicates otherwise. For example, the embodiments of different DCI size for different sets of coverage enhancement levels can be combined with any of the other embodiments.

In addition, at the UE side, an embodiment of the present disclosure provides a wireless communication method 200 performed by a UE, as shown in Fig. 2 which schematically illustrates a flowchart of the wireless communication method 200 according to an embodiment of the present disclosure. The wireless communication method comprises a step 201 of receiving downlink control information (DCI) transmitted from an eNB, wherein the DCI is designed based on a coverage enhancement level for the UE. It is noted that the above descriptions for the wireless communication 100 can also applied to the wireless communication method 100, which will not repeated here.

Further, embodiments of the present disclosure also provide an eNB and a UE to perform the above described communication methods. Fig. 3 schematically illustrates a block diagram of an eNB 300 for wireless communication according to an embodiment of the present disclosure. The eNB 300 can comprise a transmitting unit 301 configured to to transmit downlink control information (DCI) to a UE, wherein the DCI is designed based on a coverage enhancement level for the UE.

The eNB 300 according to the present disclosure may optionally include a CPU (Central Processing Unit) 310 for executing related programs to process various data and control operations of respective units in the eNB 300, a ROM (Read Only Memory) 313 for storing various programs required for performing various process and control by the CPU 310, a RAM (Random Access Memory) 315 for storing intermediate data temporarily produced in the procedure of process and control by the CPU 310, and/or a

storage unit 317 for storing various programs, data and so on. The above transmitting unit 301, CPU 310, ROM 313, RAM 315 and/or storage unit 317 etc. may be interconnected via data and/or command bus 320 and transfer signals between one another.

5

Respective units as described above do not limit the scope of the present disclosure. According to one implementation of the disclosure, the functions of the above transmitting unit 301 may be implemented by hardware, and the above CPU 310, ROM 313, RAM 315 and/or storage unit 317 may not be necessary. Alternatively, the functions of the above transmitting unit 301 may also be implemented by functional software in combination with the above CPU 310, ROM 313, RAM 315 and/or storage unit 317 etc.

10

Fig. 4 schematically illustrates a block diagram of an UE 400 for wireless communication according to an embodiment of the present disclosure. The UE 400 can comprise a receiving unit configured to receive downlink control information (DCI) transmitted from an eNB, wherein the DCI is designed based on a coverage enhancement level for the UE.

15

The UE 400 according to the present disclosure may optionally include a CPU (Central Processing Unit) 410 for executing related programs to process various data and control operations of respective units in the UE 400, a ROM (Read Only Memory) 413 for storing various programs required for performing various process and control by the CPU 410, a RAM (Random Access Memory) 415 for storing intermediate data temporarily produced in the procedure of process and control by the CPU 410, and/or a storage unit 417 for storing various programs, data and so on. The above receiving unit 401, CPU 410, ROM 413, RAM 415 and/or storage unit 417 etc. may be interconnected via data and/or command bus 420 and transfer signals between one another.

20
25

Respective units as described above do not limit the scope of the present disclosure. According to one implementation of the disclosure, the functions of the above receiving unit 401 may be implemented by hardware, and the above CPU 410, ROM 413, RAM 415 and/or storage unit 417 may not be necessary. Alternatively, the functions of the above receiving unit 401 may also be implemented by functional software in combination with the above CPU 410, ROM 413, RAM 415 and/or storage unit 417 etc.

It is noted that the above descriptions for the communication methods can also applied to the UE or eNB, which will not repeated herein.

The present disclosure can be realized by software, hardware, or software in cooperation with hardware. Each functional block used in the description of each embodiment described above can be realized by an LSI as an integrated circuit, and each process described in the each embodiment may be controlled by LSI. They may be individually formed as chips, or one chip may be formed so as to include a part or all of the functional blocks. They may include a data input and output coupled thereto. The LSI here may be referred to as an IC, a system LSI, a super LSI, or an ultra LSI depending on a difference in the degree of integration. However, the technique of implementing an integrated circuit is not limited to the LSI and may be realized by using a dedicated circuit or a general-purpose processor. In addition, a FPGA (Field Programmable Gate Array) that can be programmed after the manufacture of the LSI or a reconfigurable processor in which the connections and the settings of circuits cells disposed inside the LSI can be reconfigured may be used.

It is noted that the present disclosure intends to be variously changed or modified by those skilled in the art based on the description presented in the specification and known technologies without departing from the content and the scope of the present disclosure, and such changes and applications fall within the scope that claimed to be protected. Furthermore, in a range not departing from the content of the disclosure, the constituent elements of the above-described embodiments may be arbitrarily combined.

Embodiments of the present disclosure can at least provide the following subject matters.

1. A wireless communication method performed by an eNode B (eNB),
5 comprising:

transmitting downlink control information (DCI) to a user equipment (UE),
wherein

the DCI is designed based on a coverage enhancement level for the UE.

2. The wireless communication method according to 1, wherein

10 the coverage enhancement of a channel scheduled by the DCI with the coverage enhancement level is realized at least by repetitions in time domain and/or repetitions in frequency domain with a repetition number which represents the total number of repetitions of the channel, and

a resource assignment field in the DCI uses a single index associated with the
15 repetition number to jointly indicate resource assignment in both time domain and frequency domain.

3. The wireless communication method according to 2, wherein

the same number of repetitions in time domain is used for one and the same value of the repetition number.

20 4. The wireless communication method according to 2, wherein

the least possible repetitions in time domain are assigned for one and the same value of the repetition number.

5. The wireless communication method according to 2, wherein

25 only a proper subset of all possible resource positions in frequency domain are considered as frequency position candidates of the resource assignment for at least one value of the repetition number.

6. The wireless communication method according to 2, wherein

30 if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is a downlink channel, all possible resources in frequency domain are assigned in the resource assignment.

7. The wireless communication method according to 2, wherein
if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is an uplink channel, only one resource in frequency domain is assigned in the resource assignment.

5 8. The wireless communication method according to 7, wherein
the one resource in frequency domain is configured by the RRC layer or based on ID of the UE.

9. The wireless communication method according to 7, wherein
if the coverage enhancement level is smaller than the predetermined level, the
10 least possible repetitions in time domain are assigned for one and the same value of the repetition number.

10. The wireless communication method according to 2, wherein
transport block size is determined by the index associated with the repetition number in the resource assignment field.

15 11. The wireless communication method according to 1, wherein
the DCI uses different sizes for different sets of coverage enhancement levels.

12. A wireless communication method performed by a user equipment (UE),
comprising:

receiving downlink control information (DCI) transmitted from an eNode B (eNB),
20 wherein

the DCI is designed based on a coverage enhancement level for the UE.

13. The wireless communication method according to 12, wherein
the coverage enhancement of a channel scheduled by the DCI with the
coverage enhancement level is realized at least by repetitions in time domain and/or
25 repetitions in frequency domain with a repetition number which represents the total number of repetitions of the channel, and

a resource assignment field in the DCI uses a single index associated with the repetition number to jointly indicate resource assignment in both time domain and frequency domain.

14. The wireless communication method according to 13, wherein the same number of repetitions in time domain is used for one and the same value of the repetition number.

5 15. The wireless communication method according to 13, wherein the least possible repetitions in time domain are assigned for one and the same value of the repetition number.

10 16. The wireless communication method according to 13, wherein only a proper subset of all possible resource positions in frequency domain are considered as frequency position candidates of the resource assignment for at least one value of the repetition number.

17. The wireless communication method according to 13, wherein if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is a downlink channel, all possible resources in frequency domain are assigned in the resource assignment.

15 18. The wireless communication method according to 13, wherein if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is an uplink channel, only one resource in frequency domain is assigned in the resource assignment.

20 19. The wireless communication method according to 18, wherein the one resource in frequency domain is configured by the RRC layer or based on ID of the UE.

25 20. The wireless communication method according to 18, wherein if the coverage enhancement level is smaller than the predetermined level, the least possible repetitions in time domain are assigned for one and the same value of the repetition number.

21. The wireless communication method according to 13, wherein transport block size is determined by the index associated with the repetition number in the resource assignment field.

30 22. The wireless communication method according to 12, wherein the DCI uses different sizes for different sets of coverage enhancement levels.

23. An eNode B (eNB) for wireless communication, comprising:
a transmitting unit configured to transmit downlink control information (DCI) to a user equipment (UE), wherein
the DCI is designed based on a coverage enhancement level for the UE.

5 24. The eNB according to 23, wherein
the coverage enhancement of a channel scheduled by the DCI with the coverage enhancement level is realized at least by repetitions in time domain and/or repetitions in frequency domain with a repetition number which represents the total number of repetitions of the channel, and

10 a resource assignment field in the DCI uses a single index associated with the repetition number to jointly indicate resource assignment in both time domain and frequency domain.

25. The eNB according to 24, wherein
the same number of repetitions in time domain is used for one and the same
15 value of the repetition number.

26. The eNB according to 24, wherein
the least possible repetitions in time domain are assigned for one and the same
value of the repetition number.

27. The eNB according to 24, wherein
20 only a proper subset of all possible resource positions in frequency domain are considered as frequency position candidates of the resource assignment for at least one value of the repetition number.

28. The eNB according to 24, wherein
if the coverage enhancement level is larger than a predetermined level and the
25 channel scheduled by the DCI is a downlink channel, all possible resources in frequency domain are assigned in the resource assignment.

29. The eNB according to 24, wherein
if the coverage enhancement level is larger than a predetermined level and the
channel scheduled by the DCI is an uplink channel, only one resource in frequency
30 domain is assigned in the resource assignment.

30. The eNB according to 29, wherein
the one resource in frequency domain is configured by the RRC layer or based
on ID of the UE.

31. The eNB according to 29, wherein
5 if the coverage enhancement level is smaller than the predetermined level, the
least possible repetitions in time domain are assigned for one and the same value of
the repetition number.

32. The eNB according to 24, wherein
transport block size is determined by the index associated with the repetition
10 number in the resource assignment field.

33. The eNB according to 23, wherein
the DCI uses different sizes for different sets of coverage enhancement levels.

34. A user equipment (UE) for wireless communication, comprising:
a receiving unit configured to receive downlink control information (DCI)
15 transmitted from an eNode B (eNB), wherein
the DCI is designed based on a coverage enhancement level for the UE.

35. The UE according to 34, wherein
the coverage enhancement of a channel scheduled by the DCI with the
coverage enhancement level is realized at least by repetitions in time domain and/or
20 repetitions in frequency domain with a repetition number which represents the total
number of repetitions of the channel, and

a resource assignment field in the DCI uses a single index associated with the
repetition number to jointly indicate resource assignment in both time domain and
frequency domain.

25 36. The UE according to 35, wherein
the same number of repetitions in time domain is used for one and the same
value of the repetition number.

37. The UE according to 35, wherein
the least possible repetitions in time domain are assigned for one and the same
30 value of the repetition number.

38. The UE according to 35, wherein
only a proper subset of all possible resource positions in frequency domain are considered as frequency position candidates of the resource assignment for at least one value of the repetition number.

5 39. The UE according to 35, wherein
if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is a downlink channel, all possible resources in frequency domain are assigned in the resource assignment.

10 40. The UE according to 35, wherein
if the coverage enhancement level is larger than a predetermined level and the channel scheduled by the DCI is an uplink channel, only one resource in frequency domain is assigned in the resource assignment.

15 41. The UE according to 40, wherein
the one resource in frequency domain is configured by the RRC layer or based on ID of the UE.

20 42. The UE according to 40, wherein
if the coverage enhancement level is smaller than the predetermined level, the least possible repetitions in time domain are assigned for one and the same value of the repetition number.

23. The UE according to 35, wherein
transport block size is determined by the index associated with the repetition number in the resource assignment field.

25 44. The UE according to 34, wherein
the DCI uses different sizes for different sets of coverage enhancement levels.

In addition, embodiments of the present disclosure can also provide an integrated circuit which comprises module(s) for performing the step(s) in the above respective communication methods. Further, embodiments of the present can also provide a computer readable storage medium having stored thereon a computer program

containing a program code which, when executed on a computing device, performs the step(s) of the above respective communication methods.

CLAIMS

1. A wireless communication method, comprising:
5 generating a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain; and
10 transmitting the generated DCI to a user equipment (UE);
wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.
2. The wireless communication method according to claim 1, wherein
15 the frequency domain information field further indicating a position of PRBs in frequency domain within the narrowband.
3. The wireless communication method according to claim 1, wherein the narrowband is composed of 6 PRBs.
4. The wireless communication method according to claim 1, wherein the first
20 CE is a large CE, and the second CE is a small CE.
5. The wireless communication method according to claim 1, wherein the first CE is used when a CE is larger than a threshold.
6. The wireless communication method according to claim 1, wherein one or more content(s) included in the first DCI is same as content(s) included in
25 the second DCI, the one or more content(s) included in the first DCI format having fewer bits than the content(s) included in the second DCI.
7. The wireless communication method according to claim 1, wherein the second DCI includes all contents of the first DCI and some additional contents.
- 30 8. A wireless communication apparatus, comprising:

control information generating circuitry which, in operation, generates a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain; and

transmitter which, in operation, transmits the generated DCI to a user equipment (UE);

wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

9. The wireless communication apparatus according to claim 8, wherein the frequency domain information field further indicating a position of PRBs in frequency domain within the narrowband.

10. The wireless communication apparatus according to claim 8, wherein the narrowband is composed of 6 PRBs.

11. The wireless communication apparatus according to claim 8, wherein the first CE is a large CE, and the second CE is a small CE.

12. The wireless communication apparatus according to claim 8, wherein the first CE is used when a CE is larger than a threshold.

13. The wireless communication apparatus according to claim 8, wherein one or more content(s) included in the first DCI is same as content(s) included in the second DCI, the one or more content(s) included in the first DCI having fewer bits than the content(s) included in the second DCI.

14. The wireless communication apparatus according to claim 8, wherein the second DCI includes all contents of the first DCI and some additional contents.

15. A wireless communication method, comprising:

receiving a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain

information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain

wherein the first DCI is used for a first coverage enhancement (CE), and
5 a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

16. The wireless communication method according to claim 15, wherein
the frequency domain information field further indicating a position of PRBs in
frequency domain within the narrowband.

10 17. The wireless communication method according to claim 15, wherein
the narrowband is composed of 6 PRBs.

18. The wireless communication method according to claim 15, wherein
the first CE is a large CE, and the second CE is a small CE.

19. The wireless communication method according to claim 15, wherein
15 The first CE is used when a CE is larger than a threshold.

20. The wireless communication method according to claim 15, wherein
one or more content(s) included in the first DCI is same as content(s) included in
the second DCI, the one or more content(s) included in the first DCI having fewer bits
than the content(s) included in the second DCI.

20 21. The wireless communication method according to claim 15, wherein
the second DCI includes all contents of the first DCI and some additional
contents.

22. A wireless communication apparatus, comprising:

receiver which, in operation, receives a first downlink control information (DCI)
25 that includes a frequency domain information field and a time domain information field,
the frequency domain information field indicating a number of physical resource blocks
(PRBs) in frequency domain within a narrowband which is a part of whole bandwidth
and the time domain information field indicating a number of repetitions in a time
domain;

30 wherein the first DCI is used for a first coverage enhancement (CE), and

a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

23. The wireless communication apparatus according to claim 22, wherein the frequency domain information field further indicating a position of PRBs in
5 frequency domain within the narrowband.

24. The wireless communication apparatus according to claim 22, wherein the narrowband is composed of 6 PRBs.

25. The wireless communication apparatus according to claim 22, wherein the first CE is a large CE, and the second CE is a small CE.

10 26. The wireless communication apparatus according to claim 22, wherein the first CE is used when a CE is larger than a threshold.

27. The wireless communication apparatus according to claim 22, wherein one or more content(s) included in the first DCI is same as content(s) included in the second DCI, the one or more content(s) included in the first DCI having fewer bits
15 than the content(s) included in the second DCI.

28. The wireless communication apparatus according to claim 22, wherein the second DCI format includes all contents of the first DCI format and some additional contents.

29. An integrated circuitry comprising:

20 circuitry, which, in operation, controls:

generating a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain
25 information field indicating a number of repetitions in a time domain; and

transmitting the generated DCI to a user equipment (UE);

wherein the first DCI is used for a first coverage enhancement (CE), and a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

30 30. An integrated circuitry comprising:

circuitry, which, in operation, controls:

receiving a first downlink control information (DCI) that includes a frequency domain information field and a time domain information field, the frequency domain information field indicating a number of physical resource blocks (PRBs) in a frequency domain within a narrowband which is a part of whole bandwidth and the time domain information field indicating a number of repetitions in a time domain

5

wherein the first DCI is used for a first coverage enhancement (CE), and

a number of bits for the first DCI is larger than that of a second DCI format which is used for a second CE.

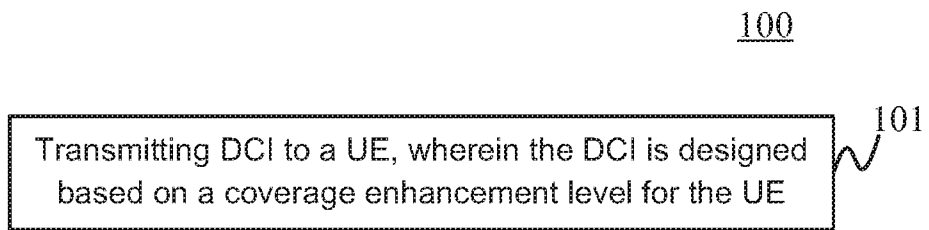


Fig. 1

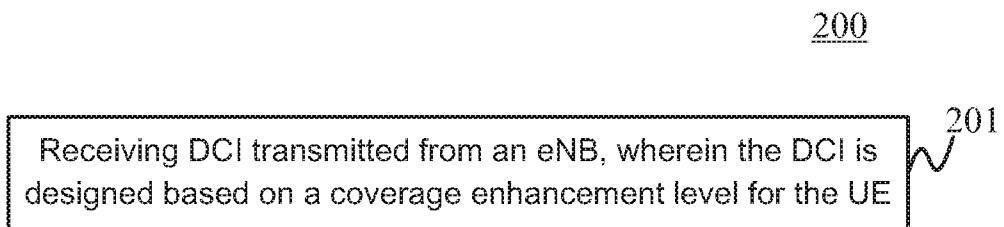


Fig. 2

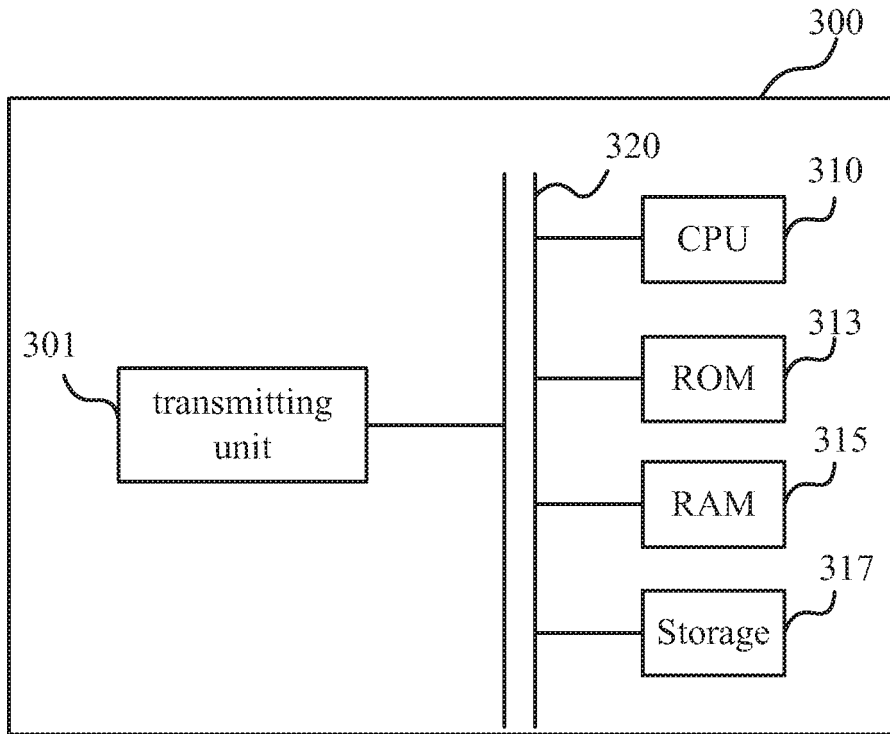


Fig. 3

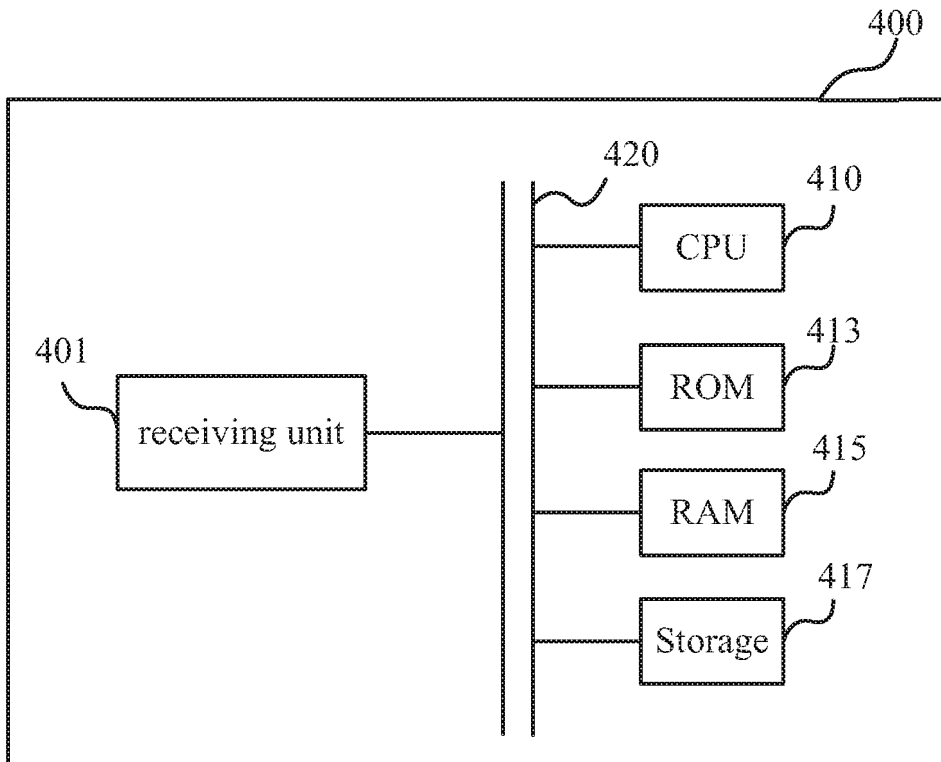


Fig. 4