(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 August 2016 (11.08.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/125022 A1

(51) International Patent Classification:
H04L 5/00 (2006.01) *H04W 72/04* (2009.01)
H04W 16/02 (2009.01)

(21) International Application Number:
PCT/IB2016/000253

(22) International Filing Date:
20 January 2016 (20.01.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
201510060829.5 5 February 2015 (05.02.2015) CN

(71) Applicant: **ALCATEL LUCENT** [FR/FR]; 148/152 route de la Reine, 92100 Boulogne-Billancourt (FR).

(72) Inventors: **WONG, Shin Horng**; 2 Fox Croft Walk, Chippenham Wiltshire SN15 3YB (GB). **BAKER, Matthew**; 12 Fir Tree Close, Rough Common, Canterbury Kent CT2 9DB (GB). **CHEN, Yu**; 388# Ningqiao RD, Pudong Jinqiao, Shanghai 201206 (CN).

(74) Agent: **BERTHIER, Karine**; Alcatel-Lucent International, 148/152 route de la Reine, 92100 Boulogne-Billancourt (FR).

(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))*

(54) Title: METHOD OF AND APPARATUS FOR ALLOCATING SUB-BAND IN MACHINE TYPE COMMUNICATION BASED COMMUNICATION SYSTEM

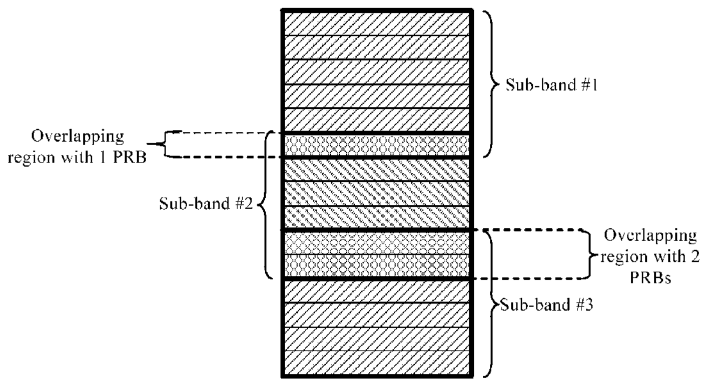

Fig.5

(57) Abstract: The invention provides methods of and apparatuses for allocating a sub-band in a machine type communication based communication system. The method includes: - determining the number of remaining PRBs P_R in a system bandwidth in the equation of $P_R = N_{PRB}$ MOD $N_{Sub\text{-}band}$, wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and MOD represents a remainder operation; determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of $N_{TOTAL\_OVERLAP} = N_{Subband} - P_R$; determining the number of overlapping regions with max($N_{OVERLAP}$), $S_{MAX\_OVERLAP}$ in the equation of $S_{MAX\_OVERLAP}$ = FLOOR($N_{TOTAL\_OVERLAP}$ /max($N_{OVERLAP}$)), wherein max($N_{OVERLAP}$) represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and FLOOR represents a rounding-down operation; determining the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of $N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}$ *max($N_{OVERLAP}$)); and determining a sub-band arrangement pattern in the system bandwidth based upon the determined number of overlapping regions with max($N_{OVERLAP}$), $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition and a predetermined rule.

WO 2016/125022 A1

Method of and Apparatus for Allocating Sub-band in Machine Type Communication based Communication System

Field of the invention

The present disclosure relates to a machine type communication based communication system and particularly to methods of and apparatuses for determining a sub-band arrangement pattern and allocating a sub-band.

Background of the invention

A Machine Type Communication (MTC) device is a User Equipment (UE) used by a machine for a specific application. In the 3GPP Rel-12, a working item on a Low Complexity MTC (LC-MTC) UE was concluded where the complexity (cost) of the MTC UE is reduced by approximately 50%. In the 3GPP Rel-13, another working item is agreed on to further reduce the complexity of the MTC UE so as to enhance a coverage area and to improve power consumption of the MTC UE.

A general technique to reduce the complexity of the MTC UE is to reduce a Radio Frequency (RF) bandwidth of the LC-MTC UE to 1.4 MHz (operating with 6 Physical Resource Blocks (PRBs) (where a PRB is a unit of resource allocation in the frequency domain)). The LC-MTC UE is expected to operate in any system bandwidth and shall be able to co-exist with legacy UEs. It is also expected that the LC-MTC UE can retune its frequency to operate in different sub-bands within a larger system bandwidth to thereby allow both frequency multiplexing among the LC-MTC UEs and frequency multiplexing with the legacy UEs.

The LTE is currently defined to operate in channel bandwidths of {1.4, 3, 5, 10, 15, 20} MHz including {6, 15, 25, 50, 75 100} PRBs respectively. With the exception of the 1.4 MHz system bandwidth, all the total numbers of PRBs in all the other system bandwidths cannot be equally divided by 6 PRBs (i.e., the size of a sub-band), thereby leaving some remaining PRBs (< 6 PRBs). Fig.1 illustrates an example of a 3 MHz system bandwidth with 15 PRBs, including two full non-overlapping sub-bands and three remaining PRBs. These remaining PRBs do not form a sub-band and thus may be wasteful.

Summary of the invention

In the Ran1#79, it was proposed that the sub-bands can overlap with each other. Fig.2 illustrates an example where Sub-band #1 overlaps with Sub-band #2. However the problems with this solution are as follows:

1) More bits may be required to indicate sub-band locations if the sub-bands can overlap without any constraints. For example in a system bandwidth with 100 PRBs, non-overlapping sub-band allocation will require 4 bits (16 possible locations) to indicate sub-band locations, and overlapping sub-band allocation will require 7 bits (96 possible locations) to indicate sub-band locations. If the sub-bands are dynamically allocated, then this will increase the size of Downlink Control Information (DCI).

2) In the downlink, a Direct Current (DC) sub-carrier of a UE reception bandwidth is not used in order to avoid a distortion effect in a receiver. If two sub-bands overlap with each other too much, then it will be highly possible that there are multiple DC sub-carriers in a 6-PRB space, that is, a sub-carrier which is not a central sub-carrier for some UE may have to be unused because the sub-carrier may be a central sub-carrier for another UE. Fig.3 illustrates an example where some sub-carriers (denoted with arrows) of the sub-band 2 would have to be unused because they are central sub-carriers for a UE that is scheduled in the sub-band 1, even if the UE that is scheduled in the sub-band 1 is only allocated the top two PRBs.

The inventors of the invention have realized that more bits may be required to indicate sub-band locations if sub-bands are allowed to overlap without any constraints. Hereupon the invention proposes a more advantageous sub-band arrangement pattern with such an essential idea that the locations of respective sub-bands in a system width are arranged so that two sub-bands overlap with each other by no more than half the size of a sub-band, so a central sub-carrier of a sub-band will not be included in another sub-band, and moreover the number of bits required to indicate a sub-band location can be reduced.

According to an aspect of the invention, there is proposed in an embodiment a method, in an eNB of a machine type communication based communication system, of allocating a sub-band to a UE, the method including the steps of:

- determining the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

- determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

- determining the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation;

- determining the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}*\mathbf{max}(N_{OVERLAP}));\ \text{and}$$

- determining a sub-band arrangement pattern in the system bandwidth based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$,

$S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition and a predetermined rule.

In an embodiment, the method may further include the steps of:

- allocating for respective UEs sub-bands corresponding thereto based upon the determined sub-band arrangement pattern; and

- transmitting an EPDCCH carrying downlink control information including sub-band indicators corresponding to the respective UEs.

The predetermined rule may include minimization of the number of overlapping regions in a sub-band.

In an embodiment, the predetermined rule may include any one of:

(1) sub-bands with overlapping regions are determined sequentially starting from a sub-band at an edge;

(2) sub-bands with overlapping regions are determined respectively based upon a generated random sequence; and

(3) sub-bands with overlapping regions are determined sequentially upward or downward starting from a sub-band with a specific number.

In an embodiment, the method may further include the steps of:

- providing respective UEs with information about sub-bands with overlapping regions, wherein the information includes which sub-bands overlap with next sub-bands, and the numbers of their overlapping PRBs.

In an embodiment, the method may further include the steps of:

- judging whether the determined number of remaining PRBs P_R in the system bandwidth is above a threshold; and

- if yes, then performing the step of determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ and the subsequent steps.

According to another aspect of the invention, there is proposed in an embodiment a method, in a UE of a machine type communication based communication system, of determining locations of sub-bands, the method including the steps of:

- determining the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

- determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

- determining the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation;

- determining the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}{*}\mathbf{max}(N_{OVERLAP})); \text{ and}$$

- receiving an EPDCCH, and obtaining a sub-band indicator corresponding to the UE from downlink control information carried by the EPDCCH; and

- determining locations of sub-bands allocated to the UE based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition according to the obtained sub-band indicator corresponding to the UE.

In an embodiment, the method may further include the steps of:

- receiving information about sub-bands with overlapping regions from an eNB, wherein the information includes which sub-bands overlap with next sub-bands, and the numbers of their overlapping PRBs;

wherein the step of determining the locations of the sub-bands allocated to the UE includes:

- determining the locations of the sub-bands allocated to the UE, based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under the predetermined constraint condition according to the received information about the sub-bands with overlapping regions, and the obtained sub-band indicator corresponding to the UE.

According to a further aspect of the invention, there is proposed in an embodiment an apparatus, in an eNB of a machine type communication based communication system, for allocating a sub-band to a UE, the apparatus including:

a first calculating unit configured:

to determine the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

to determine the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

to determine the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation; and

to determine the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}*\mathbf{max}(N_{OVERLAP})); \text{ and}$$

a first determining unit configured to determine a sub-band arrangement pattern in the system bandwidth based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition and a predetermined rule.

According to a further aspect of the invention, there is proposed in an embodiment an apparatus, in a UE of a machine type communication based communication system, for determining locations of sub-bands, the apparatus including:

a second calculating unit configured:

to determine the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

to determine the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

to determine the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation; and

to determine the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}{*}\mathbf{max}(N_{OVERLAP}));$$

a receiving unit configured to receive an EPDCCH, and to obtain a sub-band indicator corresponding to the UE from downlink control information carried by the EPDCCH; and a second determining unit configured to determine locations of sub-bands allocated to the UE based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition according to the obtained sub-band indicator corresponding to the UE.

The respective aspects of the invention will become more apparent from the following description of particular embodiments thereof.

Brief description of drawings

The other features, objects and advantages of the invention will become more apparent upon review of the following detailed description of non-limiting embodiments thereof given with reference to the drawings in which:

Fig.1 illustrates a schematic diagram of the arrangement pattern of sub-bands in the 3MHz system bandwidth with 15 PRBs;

Fig.2 illustrates a schematic diagram of two sub-bands overlapping with each other in the system bandwidth;

Fig.3 illustrates a schematic diagram of two sub-bands overlapping with each other in the system bandwidth, wherein the DC sub-carrier of the sub-band 1 is included in the sub-band 2;

Fig.4 illustrates a flow chart of a method of determining a sub-band arrangement pattern and allocating a sub-band according to an embodiment of the invention;

Fig.5 illustrates a schematic diagram of an arrangement pattern of sub-bands in a 3MHz system bandwidth with 15 PRBs according to an embodiment of the invention; and

Fig.6 illustrates a schematic diagram of an arrangement pattern of sub-bands in a 10MHz system bandwidth with 50 PRBs according to an embodiment of the invention.

Throughout the drawings, like or similar reference numerals will represent like or corresponding components or features.

Detailed description of embodiments

The respective embodiments of the technical solutions according to the invention will be described below taking a 3MHz system bandwidth with 15 PRBs and a 10MHz system bandwidth with 50 PRBs respectively as examples.

Example 1: 3MHz system bandwidth with 15 PRBs

Referring to Fig.4, at the eNB side, firstly in the step S401, the number of remaining PRBs P_R in the system bandwidth is determined in Equation (1) of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band} \qquad (1)$$

Wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, which is 15 in this embodiment, and $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, which is typically 6. MOD represents a remainder operation, so $P_R = 3$ in this embodiment.

Then in the step S402, in order to accommodate an additional sub-band, the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ is determined in Equation (2) of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R \qquad (2)$$

In this embodiment, $N_{TOTAL\_OVERLAP} = 3$.

Next in the step S403, the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, is determined in Equation (3) of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})) \qquad (3)$$

Wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of DC components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation. An overlapping region refers to a region with shared PRBs between two sub-bands. In this embodiment, in order to ensure that the number of DC components in each sub-band will not exceed one, $N_{OVERLAP} < N_{Subband}/2 = 3$, so $\mathbf{max}(N_{OVERLAP}) = 2$, and $S_{MAX\_OVERLAP} = 1$.

Then in the step S404, the number of remaining overlapping PRBs N_{REMAIN_OVERLA} is determined in Equation (4) of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP} * \mathbf{max}(N_{OVERLAP})) \quad (4)$$

In this embodiment, $N_{REMAIN\_OVERLAP} = 1$.

As can be apparent from the steps S403 and S404, in this embodiment, there shall be one overlapping region with 2 PRBs, and one overlapping region with 1 PRB.

Next in the step S405, a sub-band arrangement pattern in the system bandwidth as illustrated in Fig.5 is determined based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition and a predetermined rule.

The predetermined constraint condition can be to minimize the number of overlapping regions in a sub-band.

For example, the predetermined rule can be any one of:

(1) Sub-bands with overlapping regions are determined sequentially starting from a sub-band at an edge;

(2) Sub-bands with overlapping regions are determined sequentially upward or downward starting from a sub-band with a specific number; and

(3) Sub-bands with overlapping regions are determined respectively based upon a generated random sequence.

For the rule (1), sub-bands with overlapping regions can be determined sequentially downward starting from a sub-band at an upper edge, or sub-bands with overlapping regions can be determined sequentially upward starting from a sub-band at a lower edge. As can be appreciated, the rule (1) can be applied as long as the eNB and UE sides agree in advance upon determining sub-bands with overlapping region sequentially starting from a sub-band at an upper/lower edge, and for example, they can agree in advance upon determining firstly an overlapping region with 1 PRB and then an overlapping region with 2

PRBs, or vice versa. Thus in this case, the eNB will not provide the UE with any information about the sub-bands with overlapping regions.

Alike the rule (2) can be applied as long as the eNB and UE sides agree in advance upon determining sub-bands with overlapping region sequentially upward or downward starting from a sub-band with a specific number, so the eNB will not provide the UE with any information about the sub-bands with overlapping regions.

For the rule (3), the eNB determines sub-bands with overlapping regions respectively based upon a generated random sequence, so the eNB will provide the UE with information about the sub-bands with overlapping regions, for example, in a broadcast message after determining the sub-bands with overlapping regions, wherein the information can include, for example, which sub-bands overlap with next sub-bands, and the numbers of their overlapping PRBs.

As can be appreciated, the predetermined rule will not be limited to the several predetermined rules listed above, but any other appropriate rules can be applicable to the inventive idea.

As can be appreciated, there are only three sub-bands in this embodiment, so there will be two overlapping regions in the sub-band 2.

Advantageously after the number of remaining PRBs P_R in the system bandwidth is determined in the step S401, the eNB can further judge whether the number of remaining PRBs P_R is above a threshold, and if yes, then the eNB will perform the step S402 and the subsequent steps.

After the sub-band arrangement pattern as illustrated in Fig.5 is determined, the eNB allocates for the respective UEs the sub-bands corresponding thereto in the step S406. Then in the step S407, the eNB transmits an EPDCCH carrying downlink control information including sub-band indicators corresponding to the respective UEs, wherein the sub-band indicator includes, for example, information about sequence numbers of the sub-bands allocated to the respective UE, and an indicator of PRBs available in the sub-bands.

At the UE side, alike the UE determines the number of overlapping regions with **max**($N_{OVERLAP}$), $S_{MAX\_OVERLAP}$, and the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in Equations (1) to (4) above.

Then the UE receives an EPDCCH, and obtains a sub-band indicator corresponding to the UE from downlink control information carried by the EPDCCH.

Next the UE determines locations of sub-bands allocated to the UE based upon the determined number of overlapping regions with **max**($N_{OVERLAP}$), $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition according to the obtained sub-band indicator corresponding to the UE.

The predetermined constraint condition can include, for example, minimization of the number of overlapping regions in a sub-band.

As can be appreciated, in the case described above where the predetermined rule is the rule (3), the UE further receives information about sub-bands with overlapping regions from the eNB. Then the UE determines the locations of the sub-bands allocated to the UE based upon the determined number of overlapping regions with **max**($N_{OVERLAP}$), $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under the predetermined constraint condition according to the received information about the sub-bands with overlapping regions, and the obtained sub-band indicator corresponding to the UE.

Example 2: 10MHz system bandwidth with 50 PRBs

Alike the number of remaining PRBs P_R =2 in the system bandwidth; the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ =4; the number of overlapping regions with **max**($N_{OVERLAP}$), $S_{MAX\_OVERLAP}$ = 2; and the number of remaining overlapping PRBs N_{REMAIN_OVERLA} =0 are determined in Equations (1) to (4). Thus in this embodiment, there shall be two overlapping regions with two PRBs.

Under a predetermined constraint condition to minimize the number of overlapping regions in a sub-band, two overlapping regions shall be avoided from being placed in the same sub-band, that is, there will be at most one overlapping region in a sub-band. Additionally if the sub-band 3 and the sub-band 8 are determined as sub-bands with overlapping regions under the rule (3) above, then a sub-band arrangement pattern as illustrated in Fig.6 shall be obtained. In this embodiment, only 4 bits will be required to indicate the sub-band locations in contrast to 6 bits required to indicate sub-band locations in the conventional scheme without any constraints, so the technical solution according to the invention can reduce in effect the number of required bits.

With the technical solution according to the invention, the number of bits required to indicate sub-band locations can be reduced in effect.

In one or more illustrative designs, the functions described in this application can be performed in hardware, software, firmware or any combination thereof. If the functions are performed in software, then they can be stored on a computer readable medium as one or more instructions or codes or transmitted as one or more instructions or codes on a computer readable medium including a computer storage medium or a communication medium, wherein the communication medium includes any medium over which computer program is transported from one place to another. The storage medium can be any available medium accessible to a general purpose or proprietary computer. The computer readable medium can include but will not be limited to, for example, an RAM, an ROM, an EEPROM, a CD-ROM or other optical disk storage devices, magnetic disk storage devices or other magnetic storage devices or any other medium which can carry or storage a desirable program code module in the form of an instruction or data structure accessible to a general purpose or proprietary computer or a general purpose or proprietary processor. Moreover the any medium can also be referred to as a computer readable medium. For example, if the software is transmitted from a website, a server or another remote source over a coaxial cable, an optical fiber cable, a twisted-pair, a Digital Subscriber Line (DSL) or radio technologies, e.g., infrared, radio or microwave or the like, then a coaxial cable, an optical fiber cable, a twisted-pair, a DSL or radio technologies, e.g., infrared, radio or microwave or the like will also be encompassed in the definition of the medium.

Various exemplary logic blocks, modules and circuits described in this disclosure can be embodied or executed in a general purpose processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA) or another programmable logic device, discrete gate or transistor logic, discrete hardware component or any combination to perform the functions described here. Respective elements in the apparatus disclosed in this context can be embodied in discrete hardware components or can be integrated on a single hardware component, e.g., a processor. The general purpose can be a microprocessor, or the processor can be any general processor, controller, micro controller or state machine. The processor can alternatively be embodied in a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, a combination of one or more microprocessors and DSP cores or any other such a structure.

Those ordinarily skilled in the art shall further appreciate that the various exemplary logic blocks, modules, circuits and algorithm steps described in connection with the embodiments of this application can be embodied in electronic hardware, computer software or a combination of both. In order to clearly represent such interchangeability between hardware and software, the various exemplary components, blocks, modules, circuits and steps have been described above in general in terms of their functions. Whether the functions are performed in hardware or software can be decided by a particular application or a design constraint condition imposed on the entire system. Those skilled in the art can implement the functions described here for respective particular applications with numerous modifications, but such an implementation decision shall not be taken as a departure from the scope of the invention.

The foregoing description of this disclosure is intended to enable any ordinarily skilled in the art to make or use the invention. Various modifications of this disclosure will be obvious to those ordinarily skilled in the art, and the general principle defined in this context can also be applicable to other variants without departing from the spirit and the scope of the invention. Accordingly the invention will not be limited to the examples and the designs described in this context but can be consistent with the broadest scope of the principle and the novel features disclosed in this context.

CLAIMS

1. A method, in an eNB of a machine type communication based communication system, of allocating a sub-band to a UE, the method comprising the steps of:

- determining the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

- determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

- determining the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation;

- determining the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}*\mathbf{max}(N_{OVERLAP})); \text{ and}$$

- determining a sub-band arrangement pattern in the system bandwidth based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition and a predetermined rule.

2. The method according to claim 1, wherein the method further comprises the steps of:

- allocating for respective UEs sub-bands corresponding thereto based upon the determined sub-band arrangement pattern; and

- transmitting an EPDCCH carrying downlink control information including sub-band indicators corresponding to the respective UEs.

3. The method according to claim 1, wherein the predetermined constraint condition comprises minimization of the number of overlapping regions in a sub-band.

4. The method according to claim 1, wherein the predetermined rule includes any one of:

(1) sub-bands with overlapping regions are determined sequentially starting from a sub-band at an edge;

(2) sub-bands with overlapping regions are determined respectively based upon a generated random sequence; and

(3) sub-bands with overlapping regions are determined sequentially upward or downward starting from a sub-band with a specific number.

5. The method according to claim 1, wherein the method further comprises the steps of:

- providing respective UEs with information about sub-bands with overlapping regions, wherein the information includes which sub-bands overlap with next sub-bands, and the numbers of their overlapping PRBs.

6. The method according to claim 1, wherein the method further comprises the steps of:

- judging whether the determined number of remaining PRBs P_R in the system bandwidth is above a threshold; and

- if yes, then performing the step of determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ and the subsequent steps.

7. A method, in a UE of a machine type communication based communication system, of determining locations of sub-bands, the method comprising the steps of:

- determining the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB} \textbf{ MOD } N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

- determining the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

- determining the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation;

- determining the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}*\mathbf{max}(N_{OVERLAP})); \text{ and}$$

- receiving an EPDCCH, and obtaining a sub-band indicator corresponding to the UE from downlink control information carried by the EPDCCH; and

- determining locations of sub-bands allocated to the UE based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition according to the obtained sub-band indicator corresponding to the UE.

8. The method according to claim 7, wherein the method further comprises the steps of:

- receiving information about sub-bands with overlapping regions from an eNB, wherein the information includes which sub-bands overlap with next sub-bands, and the numbers of their overlapping PRBs;

wherein the step of determining the locations of the sub-bands allocated to the UE comprises:

- determining the locations of the sub-bands allocated to the UE, based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under the predetermined constraint condition according to the received information about the sub-bands with overlapping regions, and the obtained sub-band indicator corresponding to the UE.

9. The method according to claim 7, wherein the predetermined constraint condition includes minimization of the number of overlapping regions in a sub-band.

10. An apparatus, in an eNB of a machine type communication based communication system, for allocating a sub-band to a UE, the apparatus comprising:

a first calculating unit configured:

to determine the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

to determine the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

to determine the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation; and

to determine the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}*\mathbf{max}(N_{OVERLAP})); \text{ and}$$

a first determining unit configured to determine a sub-band arrangement pattern in the system bandwidth based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition and a predetermined rule.

11. The apparatus according to claim 10, wherein the apparatus further comprises:

an allocating unit configured to allocate respective UEs sub-bands corresponding thereto based upon the determined sub-band arrangement pattern; and

a first transmitting unit configured to transmit an EPDCCH carrying downlink control information including sub-band indicators corresponding to the respective UEs.

12. The apparatus according to claim 10, wherein the predetermined constraint condition comprises minimization of the number of overlapping regions in a sub-band.

13. The apparatus according to claim 10, wherein the predetermined rule includes any one of:

(1) sub-bands with overlapping regions are determined sequentially starting from a sub-band at an edge;

(2) sub-bands with overlapping regions are determined respectively based upon a generated random sequence; and

(3) sub-bands with overlapping regions are determined sequentially upward or downward starting from a sub-band with a specific number.

14. The apparatus according to claim 10, wherein the apparatus further comprises:

a second transmitting unit configured to provide respective UEs with information about sub-bands with overlapping regions, wherein the information includes which sub-bands overlap with next sub-bands, and the numbers of their overlapping PRBs.

15. An apparatus, in a UE of a machine type communication based

communication system, for determining locations of sub-bands, the apparatus comprising:

a second calculating unit configured:

to determine the number of remaining PRBs P_R in a system bandwidth in the equation of:

$$P_R = N_{PRB}\ \mathbf{MOD}\ N_{Sub\text{-}band},$$

wherein N_{PRB} represents the total number of sub-bands in the system bandwidth, $N_{Sub\text{-}band}$ represents the number of PRBs in a sub-band, and **MOD** represents a remainder operation;

to determine the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$ in the equation of:

$$N_{TOTAL\_OVERLAP} = N_{Subband} - P_R;$$

to determine the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$ in the equation of:

$$S_{MAX\_OVERLAP} = \mathbf{FLOOR}(N_{TOTAL\_OVERLAP}/\mathbf{max}(N_{OVERLAP})),$$

wherein $\mathbf{max}(N_{OVERLAP})$ represents the largest number of overlapping PRBs ensuring that the number of direct current components in each sub-band will not exceed one, and **FLOOR** represents a rounding-down operation; and

to determine the number of remaining overlapping PRBs N_{REMAIN_OVERLA} in the equation of:

$$N_{REMAIN\_OVERLAP} = (N_{TOTAL\_OVERLAP} - S_{MAX\_OVERLAP}{*}\mathbf{max}(N_{OVERLAP}));$$

a receiving unit configured to receive an EPDCCH, and to obtain a sub-band indicator corresponding to the UE from downlink control information carried by the EPDCCH; and

a second determining unit configured to determine locations of sub-bands allocated to the UE based upon the determined number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$, and the determined number of remaining overlapping PRBs N_{REMAIN_OVERLA} under a predetermined constraint condition according to the obtained sub-band indicator corresponding to the UE.

FIGURE

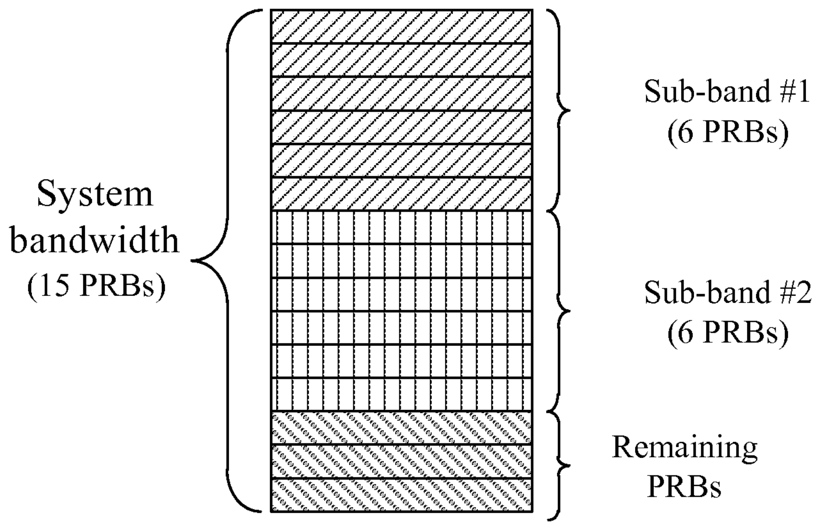

Fig.1

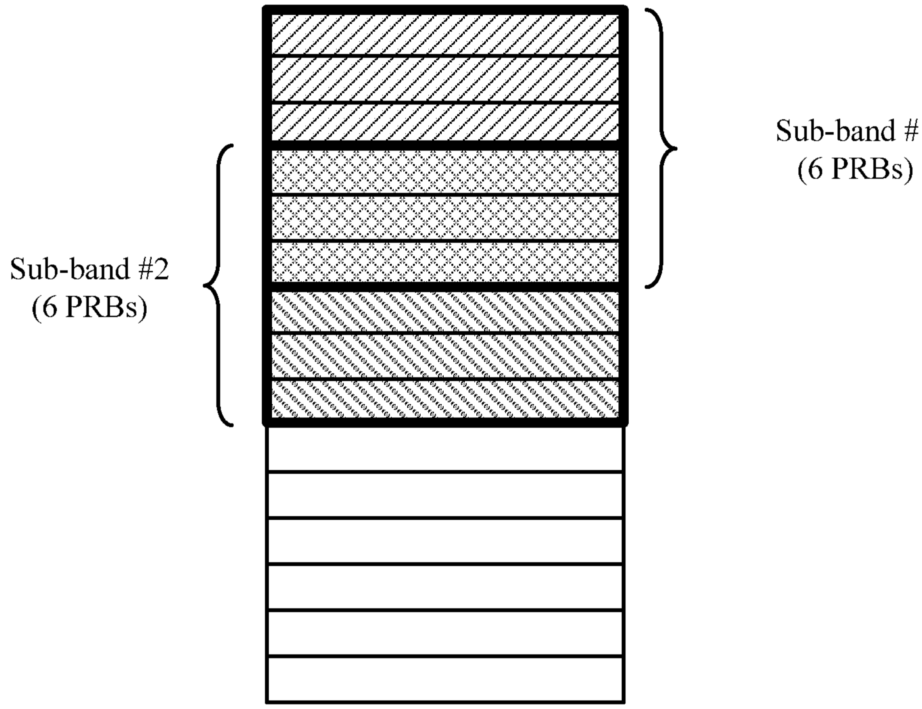

Fig.2

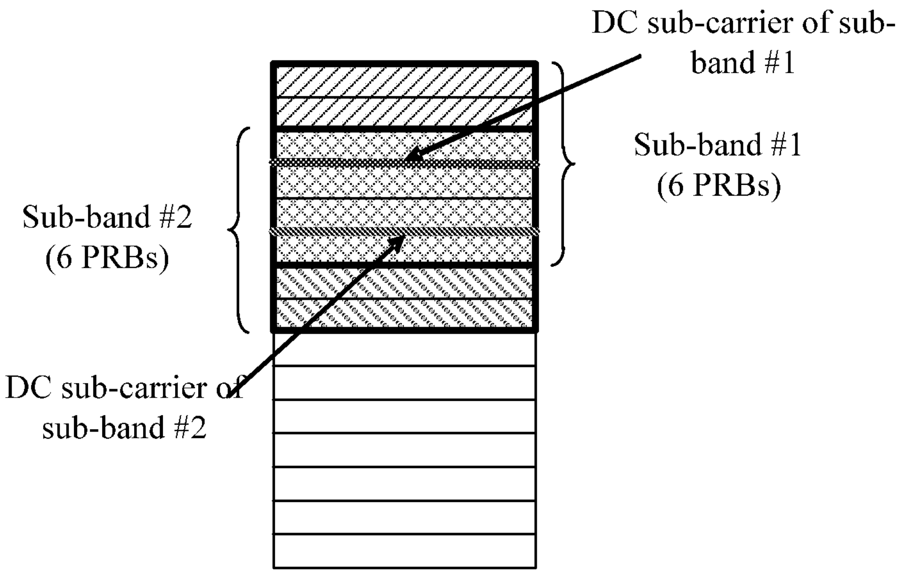
DC sub-carrier of sub-band #1
Sub-band #1 (6 PRBs)
Sub-band #2 (6 PRBs)
DC sub-carrier of sub-band #2

Fig.3

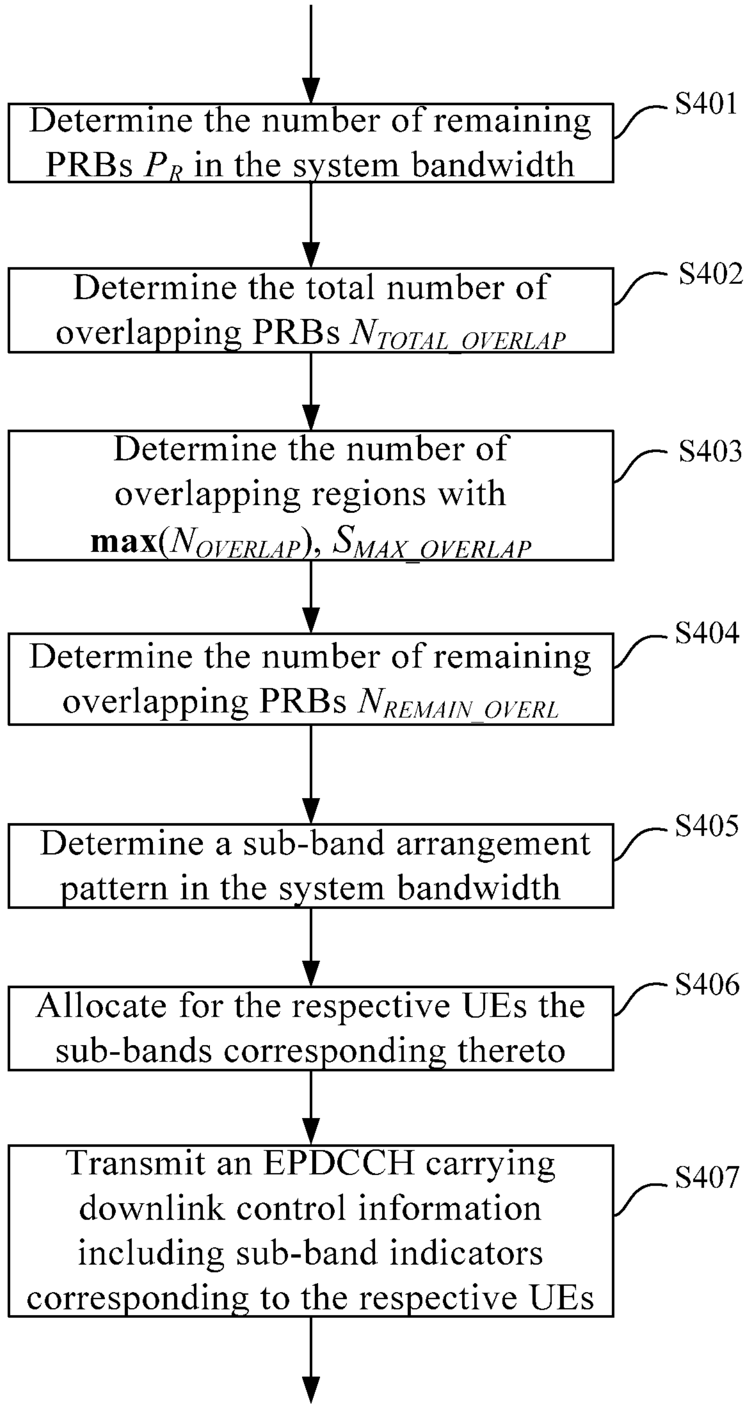
Determine the number of remaining PRBs P_R in the system bandwidth
S401
Determine the total number of overlapping PRBs $N_{TOTAL\_OVERLAP}$
S402
Determine the number of overlapping regions with $\mathbf{max}(N_{OVERLAP})$, $S_{MAX\_OVERLAP}$
S403
Determine the number of remaining overlapping PRBs N_{REMAIN_OVERL}
S404
Determine a sub-band arrangement pattern in the system bandwidth
S405
Allocate for the respective UEs the sub-bands corresponding thereto
S406
Transmit an EPDCCH carrying downlink control information including sub-band indicators corresponding to the respective UEs
S407

Fig.4

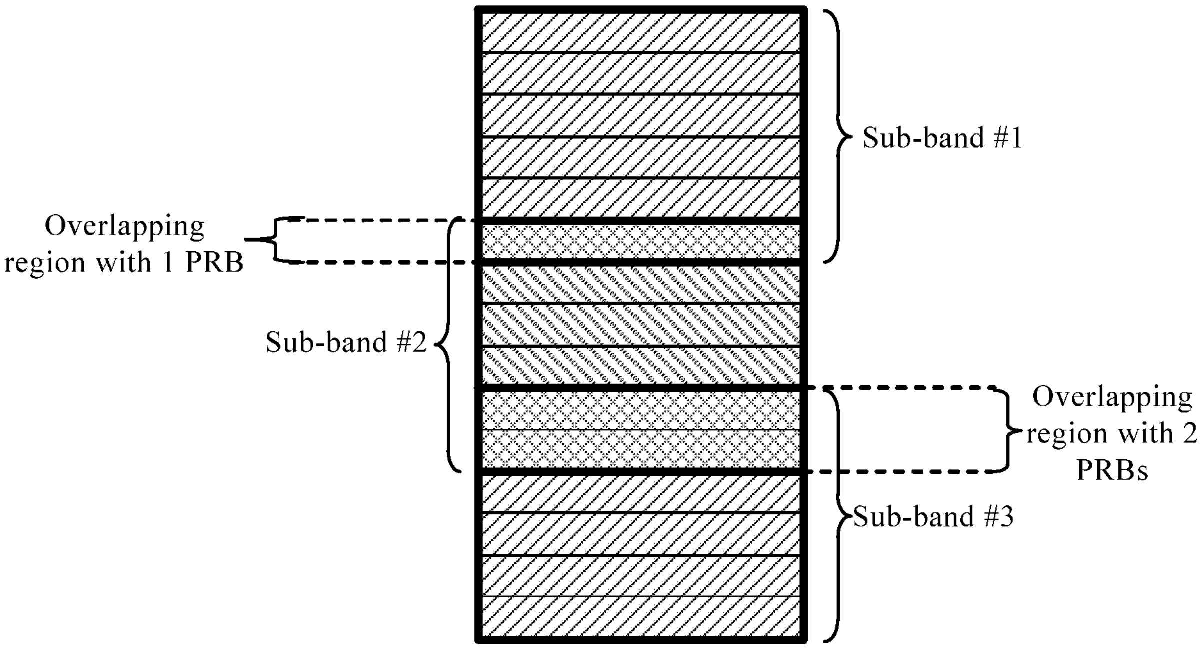
Sub-band #1
Overlapping region with 1 PRB
Sub-band #2
Overlapping region with 2 PRBs
Sub-band #3

Fig.5

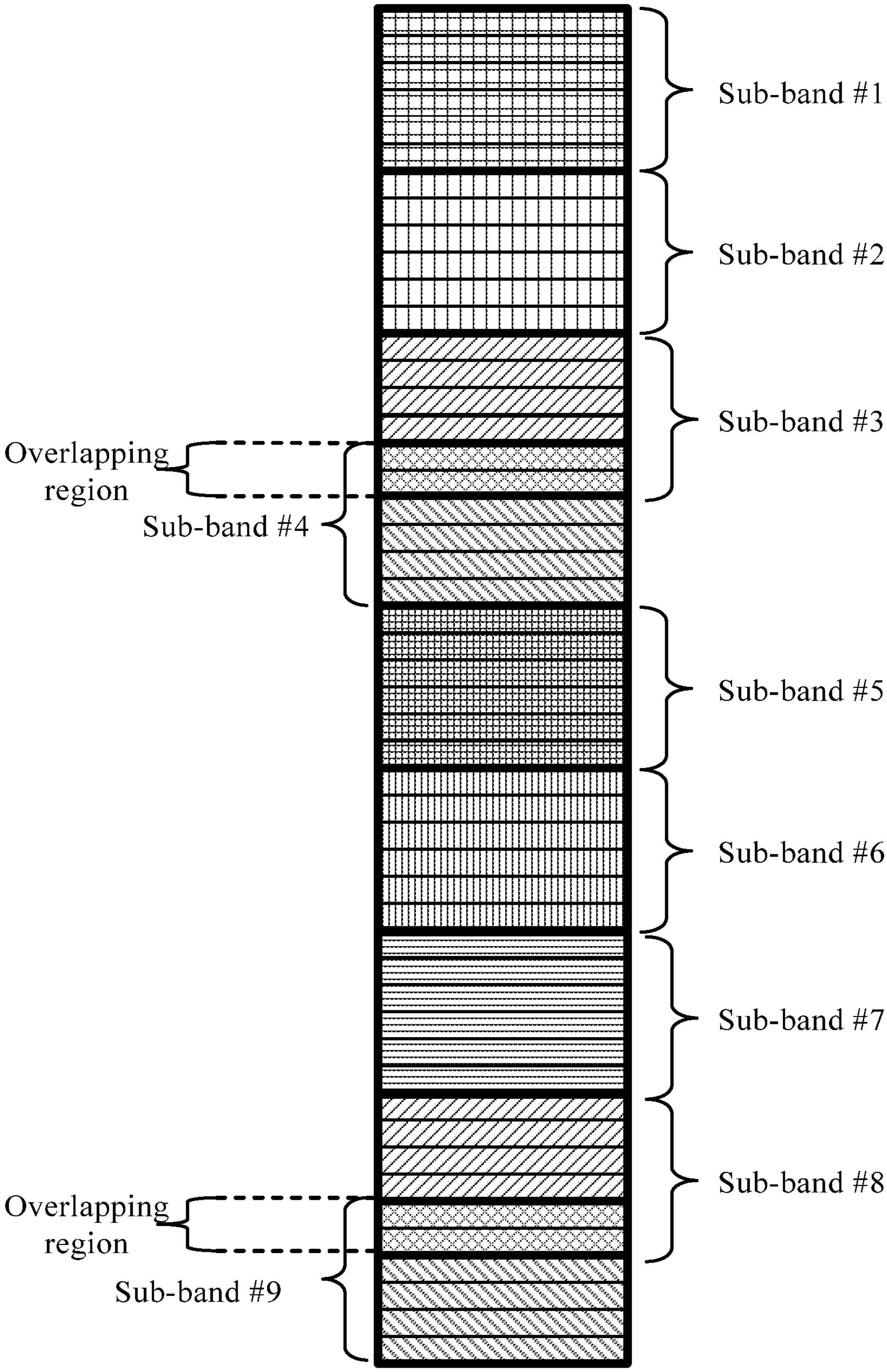
Sub-band #1
Sub-band #2
Sub-band #3
Overlapping region
Sub-band #4
Sub-band #5
Sub-band #6
Sub-band #7
Sub-band #8
Overlapping region
Sub-band #9

Fig.6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/000253

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00 H04W16/02 H04W72/04
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Alcatel-Lucent: "3GPP TSG RAN WG1 Meeting #79 Considerations on bandwidth reduced operation for Rel-13 MTC UE", , 17 November 2014 (2014-11-17), XP055270475, Retrieved from the Internet: URL:http://www.3gpp.org/DynaReport/TDocExMtg--R1-79--30666.htm [retrieved on 2016-05-03] Section 2 -----	1-15
A	US 2013/322363 A1 (CHEN WANSHI [US] ET AL) 5 December 2013 (2013-12-05) paragraph [0137] - paragraph [0138] paragraph [0143] - paragraph [0164] figures 11-16 ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 May 2016	23/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tanbourgi, Ralph

3

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Ericsson: "3GPP TSG-RAN WG1 Meeting #79 Physical resource allocation for MTC R1-144559", , 17 November 2014 (2014-11-17), XP055270476, Retrieved from the Internet: URL:http://www.3gpp.org/DynaReport/TDocExMtg--R1-79--30666.htm [retrieved on 2016-05-03] Section 5	1-15

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2016/000253

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013322363 A1	05-12-2013	CN 104380820 A	25-02-2015
		EP 2853127 A2	01-04-2015
		KR 20150013722 A	05-02-2015
		US 2013322363 A1	05-12-2013
		WO 2013173673 A2	21-11-2013