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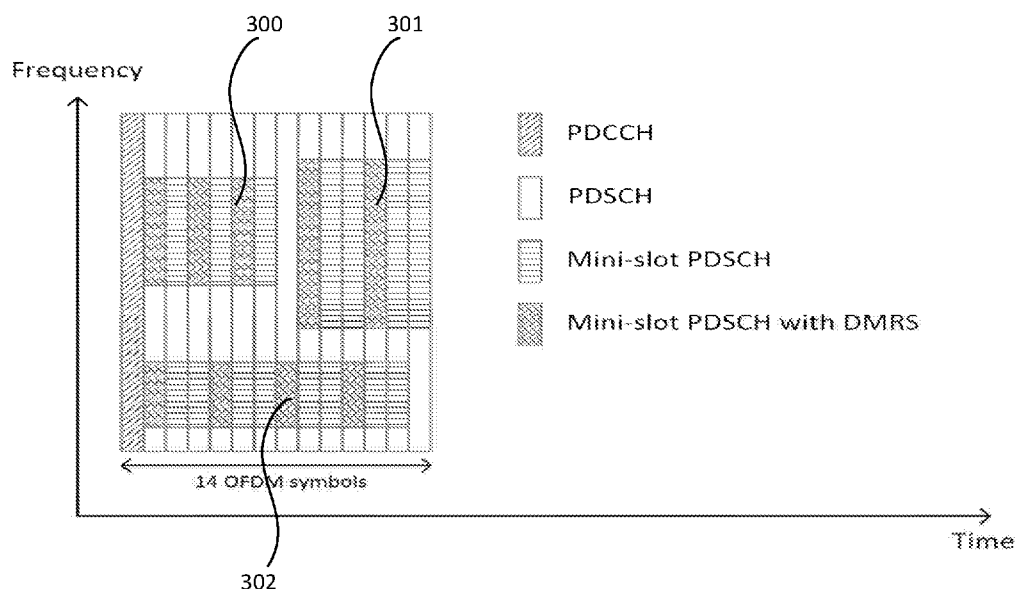


Figure 3

(57) Abstract: Methods and systems for aggregating mini-slots in an OFDM transmission system. Mini-slots are aggregated in time and/or frequency and utilised to carry data. Aggregation may permit configuration of DMRS transmission to suit overhead and channel conditions.

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Slot Aggregation

Technical Field

[0001] The current disclosure relates to aggregation of mini-slots in a wireless communication system.

5 Background

[0002] Wireless communication systems, such as the third-generation (3G) of mobile telephone standards and technology are well known. Such 3G standards and technology have been developed by the Third Generation Partnership Project (3GPP). The 3rd generation of wireless communications has generally been developed to
10 support macro-cell mobile phone communications. Communication systems and networks have developed towards a broadband and mobile system.

[0003] The 3rd Generation Partnership Project has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network
15 where one or more macro-cells are supported by a base station known as an eNodeB or eNB (evolved NodeB). More recently, LTE is evolving further towards the so-called 5G or NR (new radio) systems where one or more cells are supported by a base station known as a gNB.

[0004] NR proposes an OFDM transmission format for the wireless link of the system.
20 OFDM systems utilise a number of sub-carriers spaced in frequency, each of which is modulated independently. Demodulation of the set of the sub-carriers allows recovery of the signals. Time slots are defined for the scheduling of transmissions, which each slot comprising a number of OFDM symbols. NR has proposed 7 or 14 OFDM symbols per slot. The sub-carriers, or frequency resources, within each slot may be utilised to
25 carry one or more channel over the link. Also, each slot may contain all uplink, all downlink, or a mixture of directions.

[0005] NR also proposes mini-slots (TR 38.912) which may comprise from 1 to (slot-length-1) OFDM symbols to improve scheduling flexibility. Each mini-slot may start at any OFDM symbol within a slot (provided the resources are not pre-allocated to
30 channels, for example PDCCH). Some configurations may be limited to systems over 6GHz, or to a minimum mini-slot length of 2 OFDM symbols.

[0006] 5G proposes a range of services to be provided, including Enhanced Mobile Broadband (eMBB) for high data rate transmission, Ultra-Reliable Low Latency Communication (URLLC) for devices requiring low latency and high link reliability, and Massive Machine-Type Communication (mMTC) to support a large number of low-power devices for a long life-time requiring highly energy efficient communication.

[0007] TR 38.913 defines latency as *“The time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point via the radio interface in both uplink and downlink.”* For URLLC, the target for user plane latency is 0.5ms for uplink (UL), and 0.5ms for downlink (DL).

[0008] TR 38.913 defines Reliability as *“Reliability can be evaluated by the success probability of transmitting X bytes within a certain delay, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface, at a certain channel quality (e.g., coverage-edge).”* For URLLC, a reliability requirement for one transmission of a packet is defined as 1×10^{-5} for 32 bytes with a user plane latency of 1ms.

[0009] The following disclosure addresses the efficient use of mini-slots for the provision of eMBB and URLLC services.

[0010] The present invention is seeking to solve at least some of the outstanding problems in this domain.

Summary

[0011] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0012] There is provided a method of downlink data transmission from a base station to a UE in a cellular communication system utilising an OFDM modulation format, the method comprising the steps of defining a plurality of mini-slots, each mini-slot comprising one or more OFDM symbols; aggregating a plurality of the defined mini-slots into an aggregation of mini-slots; transmitting an indication of scheduling of the

aggregation of mini-slots from the base station to the UE; mapping data for transmission into the aggregation of mini-slots; and transmitting the mapped data in the mini-slots according to the scheduling.

5 [0013] The plurality of mini-slots that are aggregated may be contiguous or non-contiguous in time and/or frequency.

[0014] Each mini-slot may comprise a DMRS in the first OFDM symbol.

[0015] The aggregation may be defined according to a desired repetition rate for the DMRS.

10 [0016] The indication of scheduling may be transmitted in DCI in a PDCCH of the slot in which the first of the aggregated mini-slots occurs.

[0017] The DCI may include an indication of the number of mini-slots to aggregate.

[0018] The DCI may include an indication of aggregation pattern in time and/or frequency.

15 [0019] The mini-slots may be aggregated according to a pre-defined aggregation pattern.

[0020] The pre-defined aggregation pattern may be transmitted to a UE using higher layer signalling, particularly RRC signalling.

[0021] The pre-defined aggregation pattern may be one of a plurality of pre-defined aggregation patterns transmitted to the UE.

20 [0022] The mini-slots may be aggregated and scheduled to pre-empt previously-scheduled transmissions, wherein the indication of scheduling is transmitted on a PDCCH in the first OFDM symbol of the aggregated mini-slots.

[0023] The aggregated mini-slots may carry a URLLC service.

[0024] Each of the aggregated mini-slots may be located in the same slot.

25 [0025] The aggregated mini-slots may be located in more than one slot.

[0026] Aggregated mini-slots may be further aggregated to a set of aggregated mini-slots.

[0027] Mapping data may comprise mapping a transport block to aggregation of mini-slots.

[0028] The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

Brief description of the drawings

[0029] Further details, aspects and embodiments of the invention will be described, by way of example only, with reference to the drawings. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. Like reference numerals have been included in the respective drawings to ease understanding.

Figure 1 shows examples of mini-slots;

Figure 2 shows an example of URLLC scheduling;

Figure 3 shows examples of contiguous intra-slot aggregation;

Figure 4 shows examples of non-contiguous intra-slot aggregation;

Figure 5 shows an example of non-contiguous and contiguous intra-slot aggregation;

Figure 6 shows an example of URLLC frequency aggregation;

Figure 7 shows an example of inter-slot aggregation; and

Figure 8 shows an example of combined intra- and inter-slot aggregation.

Detailed description of the preferred embodiments

[0030] Those skilled in the art will recognise and appreciate that the specifics of the examples described are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings.

[0031] The following disclosure provides systems and methods to utilise mini-slots in the NR system to improve efficiency. Mini-slots may be aggregated to carry services while providing flexibility in the carriage of control channels.

[0032] The following description is given in the context of a cellular communication system, comprising land-based network components and remote User Equipment (UE). In particular reference is made to a wireless channel between a base station of the land-based network and the UE. Transmissions from the base station to the UE

are in the downlink direction, and transmissions from the UE to the base station are in the uplink direction. The base station may comprise, or be connected to, a gNB which performs network management and control functions.

[0033] Figure 1 shows diagram of a slot comprising 14 OFDM symbols. The PDCCH is carried by the first OFDM symbol, which channel includes control and scheduling information (in the DCI) for the slot. However, in certain examples scheduled transmissions may be later pre-empted by further PDCCH transmissions within the slot (for example as described with reference to Figure 2 below).

[0034] The remaining 13 symbols are available for carriage of the PDSCH. In Figure 1 three mini-slots are defined to carry data on the PDSCH. Each mini-slot utilises different time and frequency resources as required for the data to be carried. The first OFDM symbol of each mini-slot contains the Demodulation Reference Signals (DMRS). Multiple UEs can be scheduled within each mini-slot if required.

[0035] Figure 2 shows an example of the transmission of a URLLC service which aims to provide ultra low latency. As with Figure 1 scheduling information is transmitted in the PDCCH for the slot, and a first mini-slot 200 is defined and transmitted. However, a second mini-slot 201 is defined by transmission of a further PDCCH to define a mini-slot which pre-empts the traffic originally scheduled for the resources where the second mini-slot is located. In the first OFDM symbol of the second mini-slot the PDCCH and DMRS are transmitted, following by the PDSCH of the mini-slot in the second OFDM symbol. The traffic originally scheduled for the pre-empted location must be re-scheduled in a later slot.

[0036] In the following discussion mini-slots may be aggregated to provide more efficient carriage of data. Aggregating mini-slots may reduce control overheads as one DCI can schedule multiple mini-slots, and may allow time and frequency diversity to improve channel quality. Aggregation of mini-slots may also allow greater control of DMRS placement by allowing the gNB to adapt DMRS positions and/or density according to requirements.

[0037] The following disclosure is given with reference to two principle families of aggregation; contiguous, and non-contiguous but the principles described herein apply in general and are not limited to any particular example. Aggregation refers to the grouping of multiple mini-slots and allocation of data to be transmitted (for example

one or more transport block (TB)) across the group of mini-slots, rather than allocating to a single mini-slot. Principally, one TB is mapped across all mini-slots in the aggregation. However, for spatial multiplexing multiple TBs can be mapped to an aggregation of mini-slots. As described in the various examples, mini-slots within a single slot may be aggregated (intra-slot aggregation), or mini slots from multiple slots may be aggregated (inter-slot aggregation).

[0038] Figure 3 shows a slot used to transmit three groups of contiguously aggregated mini-slots. Contiguous aggregation describes a configuration in which mini-slots are transmitted on a continuous series of OFDM symbols using the same frequency range. Aggregation 300 comprises three mini-slots, each of which is two OFDM symbols in length, aggregation 301 comprises two mini-slots of three OFDM symbols, and aggregation 302 comprises four mini-slots of three OFDM symbols.

[0039] Each of the DMRSs is transmitted in the first OFDM symbol of each mini-slot, such that each aggregation carries a plurality of DMRS signals. In principle the DMRS can be located anywhere, but the current NR proposal is for transmission in the first OFDM symbol.

[0040] The aggregation of multiple mini-slots, each carrying a DMRS allows the system to define the spacing (in time) of DMRS according to system requirements. Longer mini-slots leads to larger spacing between DMRS signals, whereas smaller mini-slots leads to smaller spacings. For example, if it is identified that the channel is changing only slowly over time longer mini-slots can be utilised to increase the DMRS spacing. Similarly, for a given channel coherence time increasing the sub-carrier spacing shortens the OFDM symbols. DMRS can thus be spaced a greater number of mini-slots apart, which corresponds to the same spacing in time.

[0041] Commonly, the position and size of each mini-slot is indicated in the DCI carried on PDCCH at the start of each slot, although some services may use mini-slots which are defined after transmissions of the PDCCH for a slot. This may be achieved by indicating the start position and length of each mini-slot, or the start position and end position. To enable aggregation, the level of aggregation is also to be specified.

[0042] Any appropriate mechanism may be utilised to specify these parameters, but three examples are provided below.

[0043] In a first example, the start position of each aggregation may be indicated, together with the length of the mini-slots in each aggregation, and the number of mini-slots aggregated. Figure 3 would be represented as:-

	302	301	300
Start Position	1	8	1
Length	3	3	2
Aggregation Level	4	2	3

- 5 [0044] In a second example, the start position of each aggregation may be indicated, together with the end position of the first mini-slot of each aggregation, and the number of mini-slots aggregated. Figure 3 would be represented as:-

	302	301	300
Start Position	1	8	1
End Position	3	10	2
Aggregation Level	4	2	3

- 10 [0045] In a third example, the start position of each aggregation may be indicated, together with the end position of the aggregation, and the number of mini-slots aggregated. Figure 3 would be represented as:-

	302	301	300
Start Position	1	8	1
End Position	12	13	6
Aggregation Level	4	2	3

- [0046] Each of these examples provide sufficient information for the UE to reconstruct the required mini-slot structure such that the signals can be received and decoded.
- 15 Other methods of configuration may also be utilised, for example the gNB may configure the UE using higher layer signalling which may indicate that a UE should use a predefined aggregation level in a semi-static manner.

[0047] Contiguous aggregation in frequency can be performed, but this does not provide flexibility of DMRS placement.

- 20 [0048] Figure 4 shows a set of examples of non-contiguous mini-slot aggregation. With non-contiguous aggregation at least one OFDM symbol exists between each consecutive mini-slot assigned to an aggregation. Each example of figure 4 shows the transmission of mini-slots for three UEs, but each mini-slot could also be utilised for different data channels from a single UE.

[0049] In Figure 4(a) each aggregation of mini-slots is non-contiguous in time. This provides the advantages described hereinbefore to allow definition of preferable DMRS transmission spacing, and may also benefit from time diversity over the wireless channel as the mini-slots are more widely spaced in time (although a slowly-changing channel, allowing greater DMRS spacing, implies less gain from time-diversity). In Figure 4(b) each aggregation of mini-slot is non-contiguous in frequency, providing frequency-diversity over the wireless channel. Finally, in Figure 4(c) each aggregation is non-contiguous in time and frequency.

[0050] If the gNB has information about the performance of the wireless channel (in frequency and/or time) the arrangement of each mini-slot can be selected to attempt to optimise the channel. For example, if a channel is quickly varying in time time-diversity may be preferred, but if a channel has strong frequency fading, frequency diversity may be preferred.

[0051] As with the discussion of Figure 3, the location of the mini-slots and aggregation may be transmitted in a DCI on the PDCCH using similar techniques to the examples above, or another mechanism. For example the gNB may use RRC or other higher-layer signalling to semi-statically configure mini-slots and aggregation.

[0052] A combination of contiguous and non-contiguous aggregation can also be utilised to combine the advantages described hereinbefore. Figure 5 shows an aggregation of four mini-slots. Two sets 500, 501 of two mini-slots are continuously aggregated in time, and those two sets 500, 501 are non-contiguously aggregated in time and frequency. Such an arrangement may be indicated using additional fields in the DCI, for example indicating the number of contiguous aggregations to use, and the pattern of non-contiguous aggregations.

[0053] The aggregation techniques described hereinbefore may be applied to mini-slots which are scheduled after the DCI for a slot and which pre-empt already-scheduled transmissions. For example, URLLC transmissions may pre-empt other transmissions due to the low latency requirements of the URLLC service.

[0054] For URLLC, contiguous or non-contiguous aggregation in time may be utilised, but non-contiguous may be disadvantageous as latency may be increased. Non-contiguous frequency aggregation may therefore be preferable, as shown in the example of Figure 6. For pre-empted mini-slots the PDCCH must be sent within the

mini-slot itself. In the example of Figure 6 PDCCH is transmitted in one of the aggregated mini-slots since this provides sufficient capacity to indicate the aggregation configuration. The other mini-slots comprise a DMRS in the first OFDM system, but no PDCCH.

5 [0055] Aggregation for pre-empted mini-slots may be less advantageous due to the increased disruption of other traffic, but also non-contiguous aggregation may be used to fit transmissions around other on-going transmissions and thus minimise pre-emption.

[0056] The above discussion has been in relation to aggregation within a single slot,
10 but aggregation could be performed over multiple slots. These can be termed intra-slot aggregation and inter-slot aggregation. Scheduling must be such that interference with PDCCH (which may be of varying length) is avoided.

[0057] As noted above, mini-slots from multiple slots can be aggregated. The resource allocation can be the same or different in each slot. For example, a frequency-hopping
15 pattern can be defined for each UE such that the frequency resources of each mini-slot varies according to the pattern.

[0058] Figure 7 illustrates an example of aggregating mini-slots from multiple slots. In the example, three mini-slots using varying frequency resources are aggregated for UE1, and three mini-slots using the same frequency resources are aggregated for
20 UE2.

[0059] The frequency resource pattern for UE1 in Figure 7 is shown for example only and any appropriate pattern may be utilised. Similarly, the mini-slots do not need to use the same time resources in each slot, but those resources may vary. For example, time and frequency resources may be selected dependent on channel performance,
25 or to make the best use of resources. The resources may be defined dynamically, or time-frequency hopping patterns may be defined per UE by the gNB via higher layer signalling (or other communication means). Furthermore, the mini-slots do not need to be from a contiguous series of slots, but may use a non-contiguous series.

[0060] An intra-slot aggregation of mini-slots can also be itself aggregated through
30 inter-slot aggregation. For example, the intra-slot aggregation example of Figure 5 can be aggregated over N slots. That is, the intra-slot aggregation repeats every kth slot for a total of N aggregated slots. Figure 8 shows an example in which UE2 is scheduled

with intra-slot aggregation of 4 mini-slots and inter-slot aggregation over 3 slots ($N = 3, K = 1$), where in every slot the same resources are allocated. UE1 is scheduled for non-contiguous intra-slot mini-slot aggregation and inter-slot aggregation over 3 slots where every 2nd slot the intra-slot aggregation resources are the same ($N = 3, K = 2$).

5 [0061] The inter-slot aggregation of mini-slots can be configured in the DCI by indicating the number of aggregations. The time-frequency hopping pattern for inter slot aggregation can be signalled via higher layers signalling to the UEs, or configured dynamically also in the DCI.

[0062] As explained above, each mini-slot in an aggregation is of the same length.
10 However, in order to allow for greater flexibility the scheduling information may include an additional indication that one or more mini-slots in an aggregated set are of a different length. For example, a flag may indicate the final mini-slot has one extra OFDM symbol. Although signalling overhead would increase, it is also possible for each mini-slot in an aggregation to be defined with a specific length, thus allowing
15 complete flexibility in the structure of the aggregation.

[0063] Although not shown in detail any of the devices or apparatus that form part of the network may include at least a processor, a storage unit and a communications interface, wherein the processor unit, storage unit, and communications interface are configured to perform the method of any aspect of the present invention. Further
20 options and choices are described below.

[0064] The signal processing functionality of the embodiments of the invention especially the gNB and the UE may be achieved using computing systems or architectures known to those who are skilled in the relevant art. Computing systems such as, a desktop, laptop or notebook computer, hand-held computing device (PDA,
25 cell phone, palmtop, etc.), mainframe, server, client, or any other type of special or general purpose computing device as may be desirable or appropriate for a given application or environment can be used. The computing system can include one or more processors which can be implemented using a general or special-purpose processing engine such as, for example, a microprocessor, microcontroller or other
30 control module.

[0065] The computing system can also include a main memory, such as random access memory (RAM) or other dynamic memory, for storing information and

instructions to be executed by a processor. Such a main memory also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor. The computing system may likewise include a read only memory (ROM) or other static storage device for storing static information and instructions for a processor.

[0066] The computing system may also include an information storage system which may include, for example, a media drive and a removable storage interface. The media drive may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a compact disc (CD) or digital video drive (DVD) read or write drive (R or RW), or other removable or fixed media drive. Storage media may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive. The storage media may include a computer-readable storage medium having particular computer software or data stored therein.

[0067] In alternative embodiments, an information storage system may include other similar components for allowing computer programs or other instructions or data to be loaded into the computing system. Such components may include, for example, a removable storage unit and an interface, such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units and interfaces that allow software and data to be transferred from the removable storage unit to computing system.

[0068] The computing system can also include a communications interface. Such a communications interface can be used to allow software and data to be transferred between a computing system and external devices. Examples of communications interfaces can include a modem, a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a universal serial bus (USB) port), a PCMCIA slot and card, etc. Software and data transferred via a communications interface are in the form of signals which can be electronic, electromagnetic, and optical or other signals capable of being received by a communications interface medium.

[0069] In this document, the terms 'computer program product', 'computer-readable medium' and the like may be used generally to refer to tangible media such as, for example, a memory, storage device, or storage unit. These and other forms of computer-readable media may store one or more instructions for use by the processor comprising the computer system to cause the processor to perform specified operations. Such instructions, generally referred to as 'computer program code' (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system to perform functions of embodiments of the present invention. Note that the code may directly cause a processor to perform specified operations, be compiled to do so, and/or be combined with other software, hardware, and/or firmware elements (e.g., libraries for performing standard functions) to do so.

[0070] The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory

[0071] In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system using, for example, removable storage drive. A control module (in this example, software instructions or executable computer program code), when executed by the processor in the computer system, causes a processor to perform the functions of the invention as described herein.

[0072] Furthermore, the inventive concept can be applied to any circuit for performing signal processing functionality within a network element. It is further envisaged that, for example, a semiconductor manufacturer may employ the inventive concept in a design of a stand-alone device, such as a microcontroller of a digital signal processor (DSP), or application-specific integrated circuit (ASIC) and/or any other sub-system element.

[0073] It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to a single processing logic. However, the inventive concept may equally be implemented by way of a plurality of different functional units and processors to provide the signal processing functionality. Thus, references to specific functional units are only to be seen as references to

suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organisation.

[0074] Aspects of the invention may be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented, at least partly, as computer software running on one or more data processors and/or digital signal processors or configurable module components such as FPGA devices. Thus, the elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed, the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units.

[0075] Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' does not exclude the presence of other elements or steps.

[0076] Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather indicates that the feature is equally applicable to other claim categories, as appropriate.

[0077] Furthermore, the order of features in the claims does not imply any specific order in which the features must be performed and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to 'a', 'an', 'first', 'second', etc. do not preclude a plurality.

[0078] Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with
5 particular embodiments, one skilled in the art would recognise that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' or "including" does not exclude the presence of other elements.

5 Claims

1. A method of downlink data transmission from a base station to a UE in a cellular communication system utilising an OFDM modulation format, the method comprising the steps of
 - 10 defining a plurality of mini-slots, each mini-slot comprising one or more OFDM symbols;
 - aggregating a plurality of the defined mini-slots into an aggregation of mini-slots;
 - transmitting an indication of scheduling of the aggregation of mini-slots from
15 the base station to the UE;
 - mapping data for transmission into the aggregation of mini-slots; and
 - transmitting the mapped data in the mini-slots according to the scheduling.
2. A method of downlink data transmission according to claim 1, wherein the plurality of mini-slots that are aggregated are contiguous in time.
- 20 3. A method of downlink data transmission according to claim 1 or claim 2, wherein the plurality of mini-slots that are aggregated are contiguous in frequency.
4. A method of downlink data transmission according to claim 1, wherein the plurality of mini-slots that are aggregated are non-contiguous in time.
5. A method of downlink data transmission according to claim 1 or claim 4,
25 wherein the plurality of mini-slots that are aggregated are non-contiguous in frequency.
6. A method of downlink data transmission according to any preceding claim, wherein each mini-slot comprises a DMRS in the first OFDM symbol.
7. A method of downlink data transmission according to claim 4, wherein the aggregation is defined according to a desired repetition rate for the DMRS.
- 30 8. A method of downlink data transmission according to any preceding claim, wherein the indication of scheduling is transmitted in DCI in a PDCCH of the slot in which the first of the aggregated mini-slots occurs.

- 5 9. A method of downlink data transmission according to claim 8, wherein the DCI includes an indication of the number of mini-slots to aggregate.
10. A method of downlink data transmission according to claim 8, wherein the DCI includes an indication of aggregation pattern in time and/or frequency.
11. A method of downlink data transmission according to any of claims 1 to 7,
10 wherein the mini-slots are aggregated according to a pre-defined aggregation pattern.
12. A method of downlink data transmission according to claim 11, wherein the pre-defined aggregation pattern is transmitted to a UE using higher layer signalling, particularly RRC signalling.
- 15 13. A method of downlink data transmission according to Claim 12, wherein the pre-defined aggregation pattern is one of a plurality of pre-defined aggregation patterns transmitted to the UE.
14. A method of downlink data transmission according to claim 1, wherein the mini-slots are aggregated and scheduled to pre-empt previously-scheduled
20 transmissions, wherein the indication of scheduling is transmitted on a PDCCH in the first OFDM symbol of the aggregated mini-slots.
15. A method of downlink data transmission according to claim 14, wherein the aggregated mini-slots carry a URLLC service.
16. A method of downlink data transmission according to any preceding claim,
25 wherein each of the aggregated mini-slots is located in the same slot.
17. A method of downlink data transmission according to any preceding claim, wherein the aggregated mini-slots are located in more than one slot.
18. A method of downlink data transmission according to any preceding,
wherein aggregated mini-slots are further aggregated to a set of aggregated mini-
30 slots.
19. A method of downlink data transmission according to any preceding claim, wherein mapping data comprises mapping a transport block to aggregation of mini-slots.

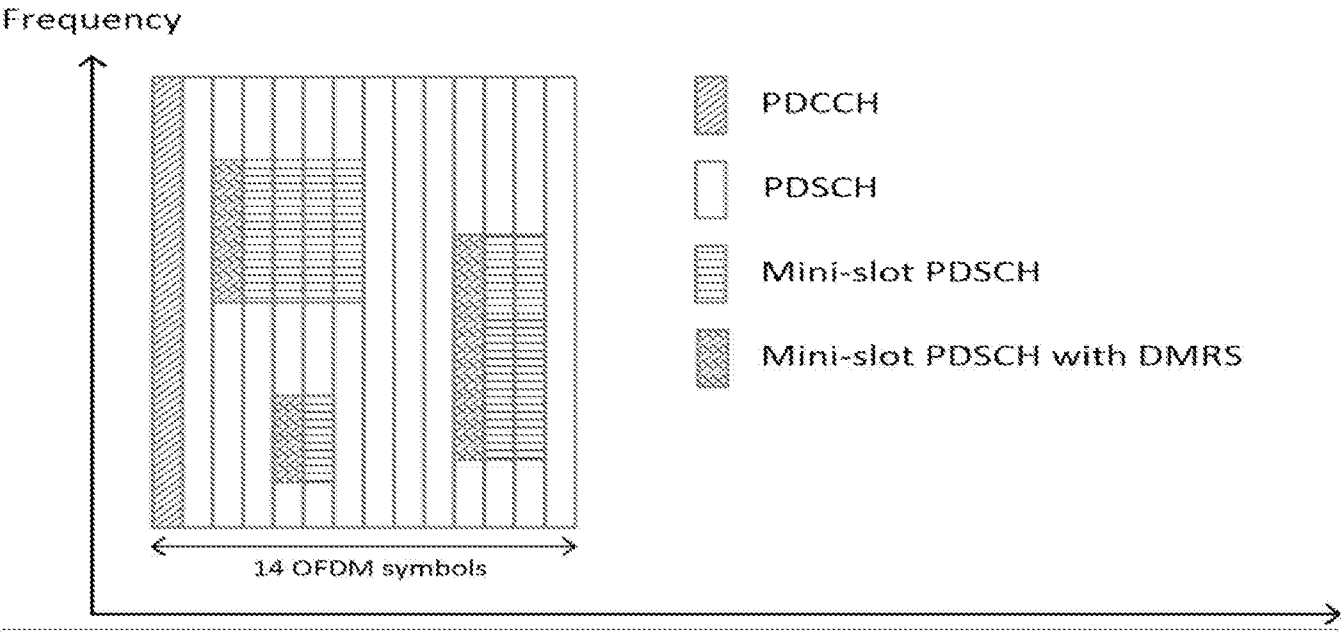


Figure 1

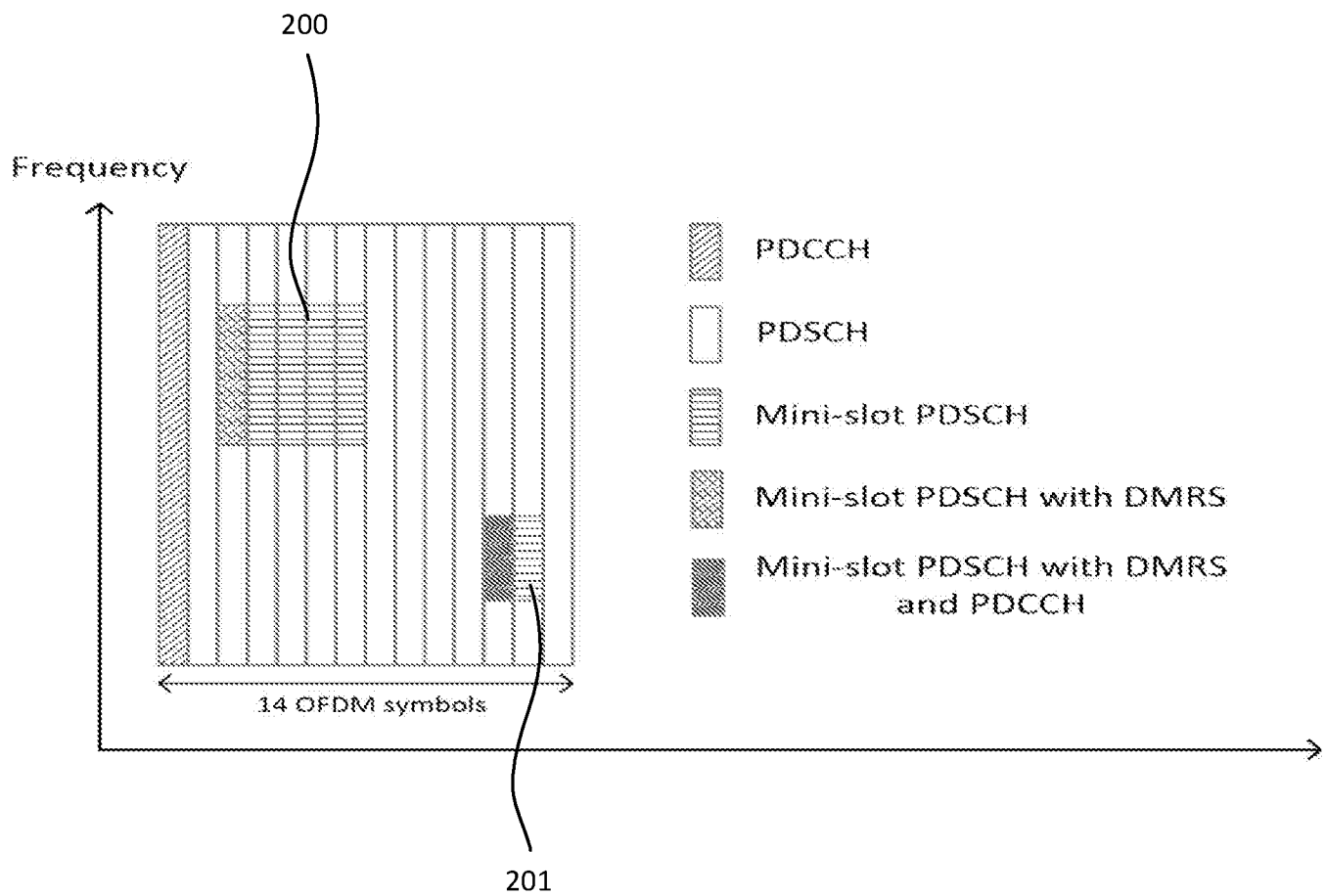


Figure 2

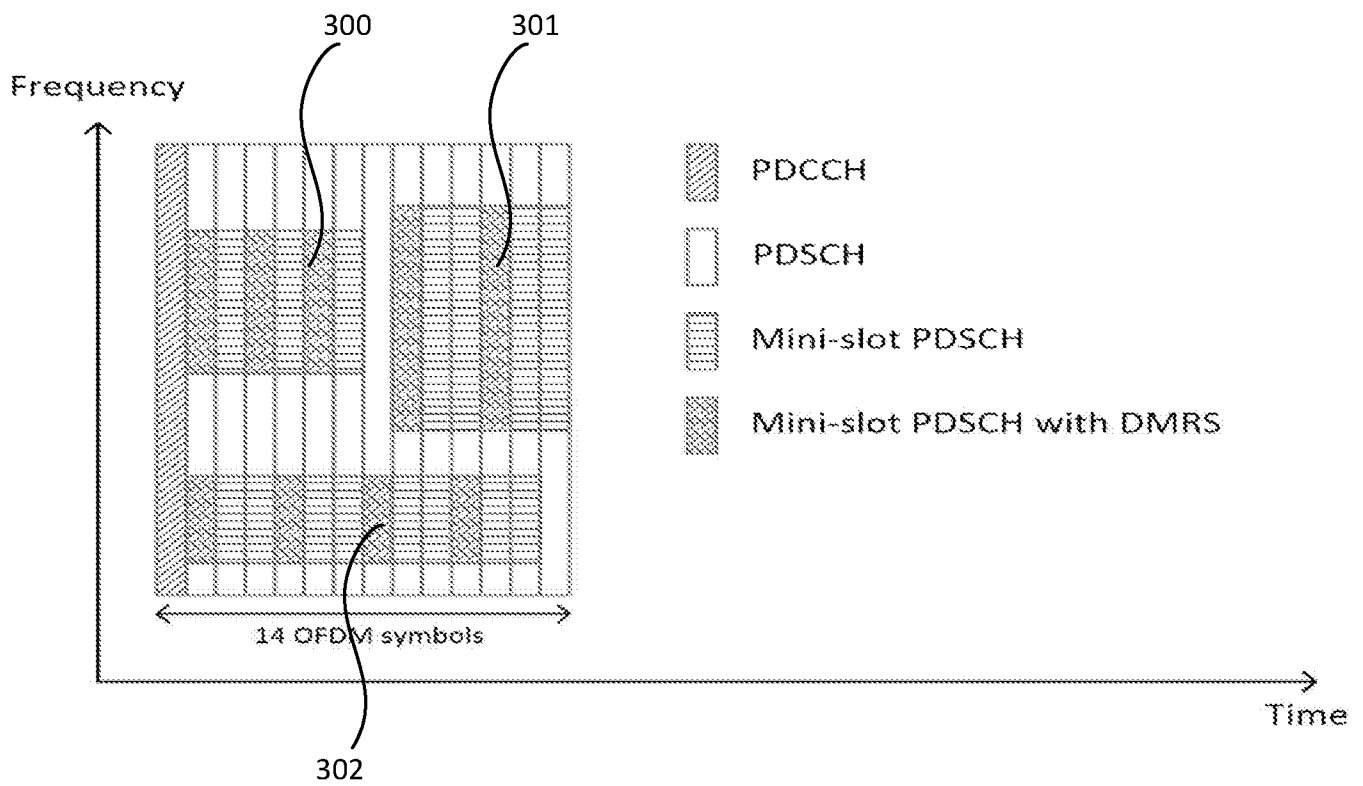


Figure 3

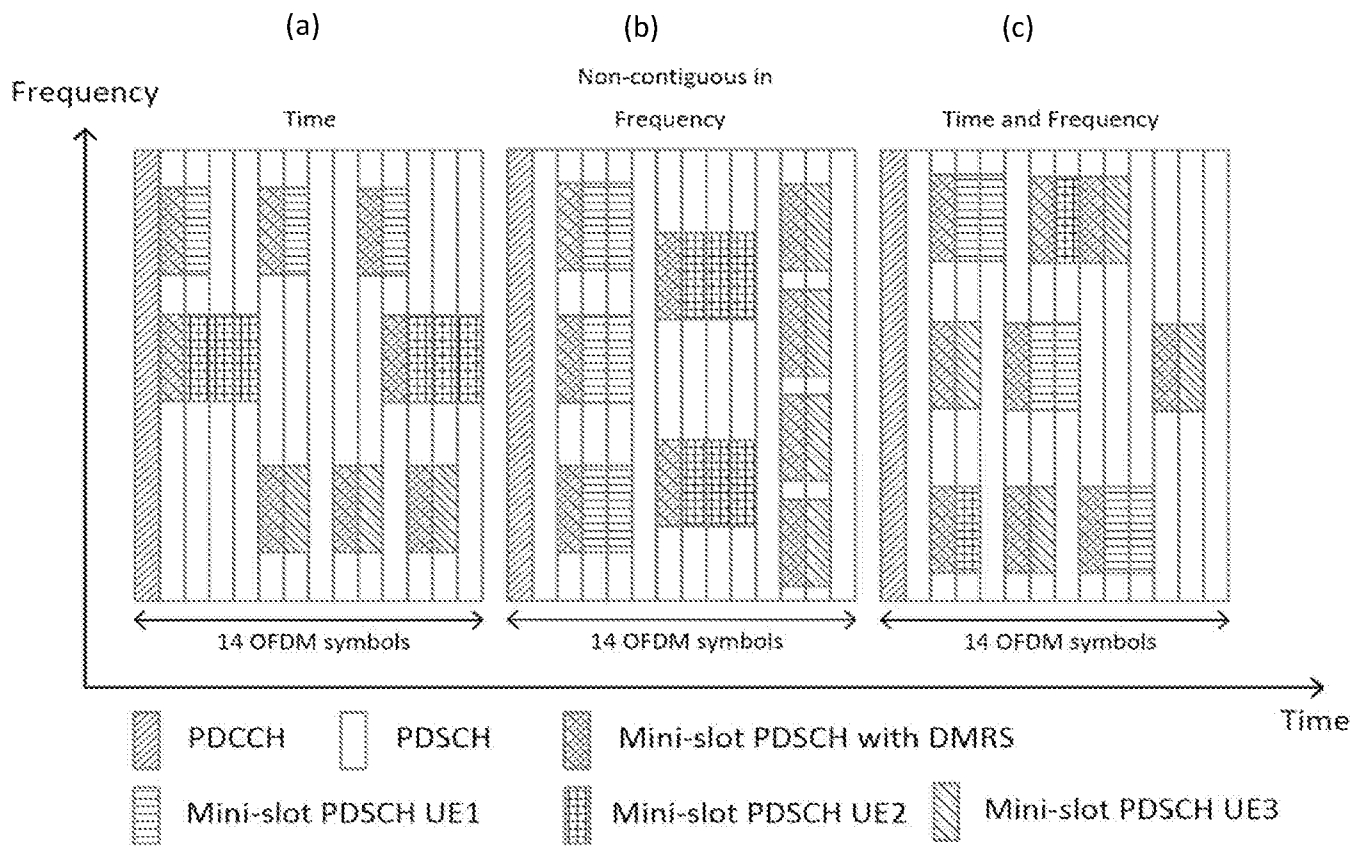


Figure 4

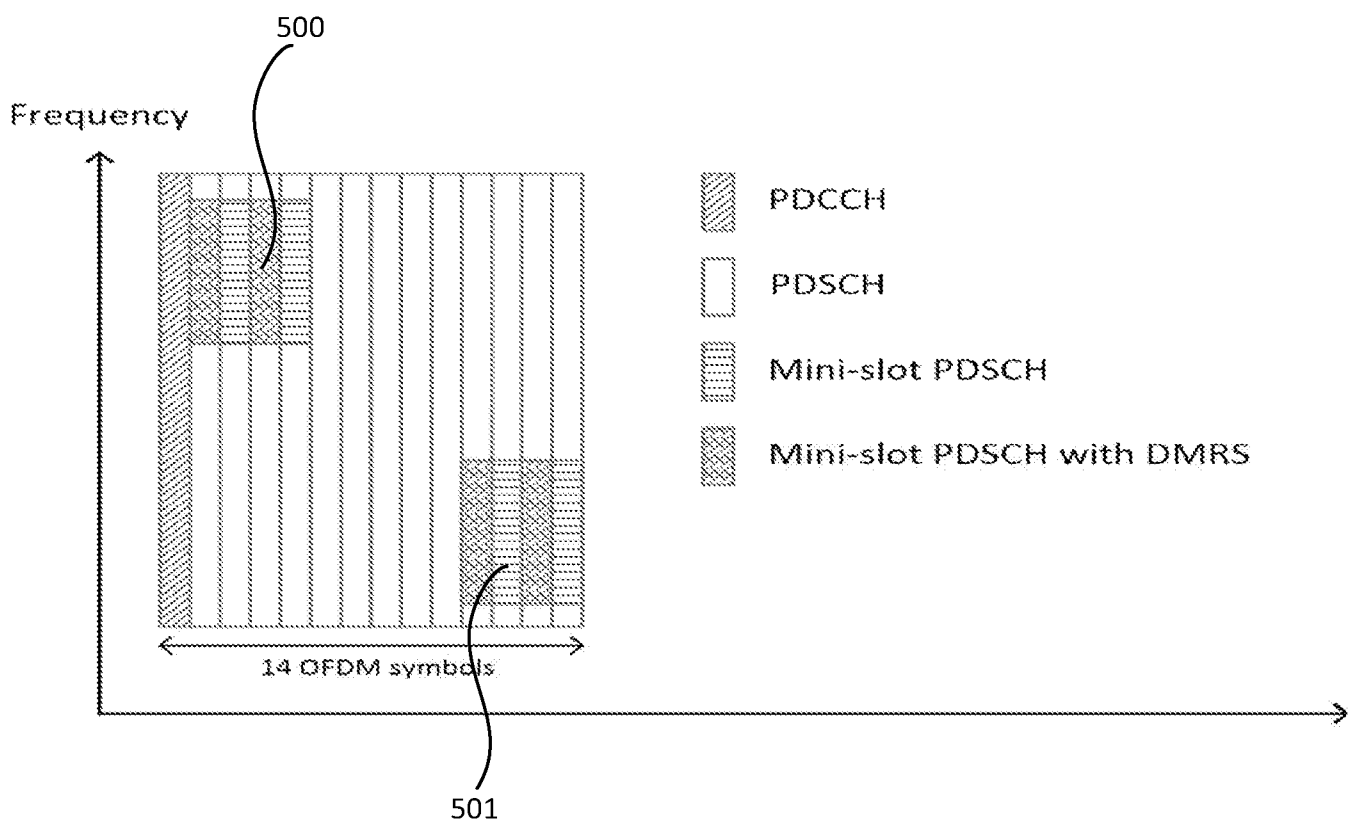


Figure 5

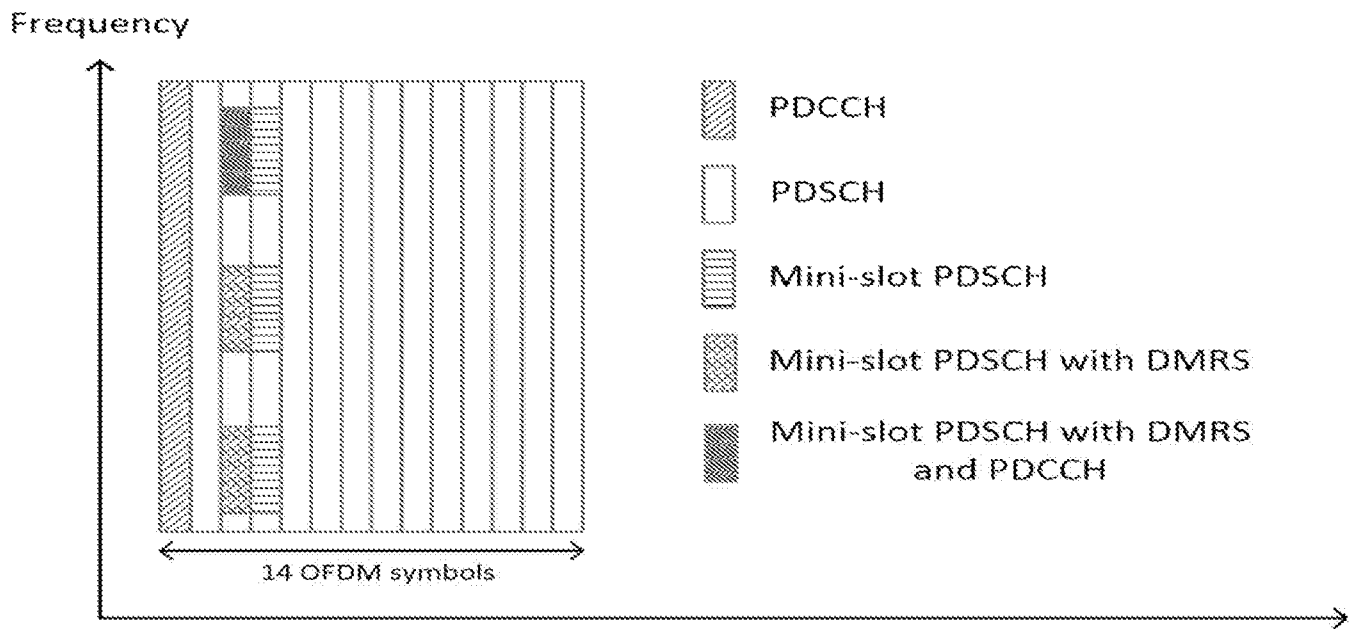


Figure 6

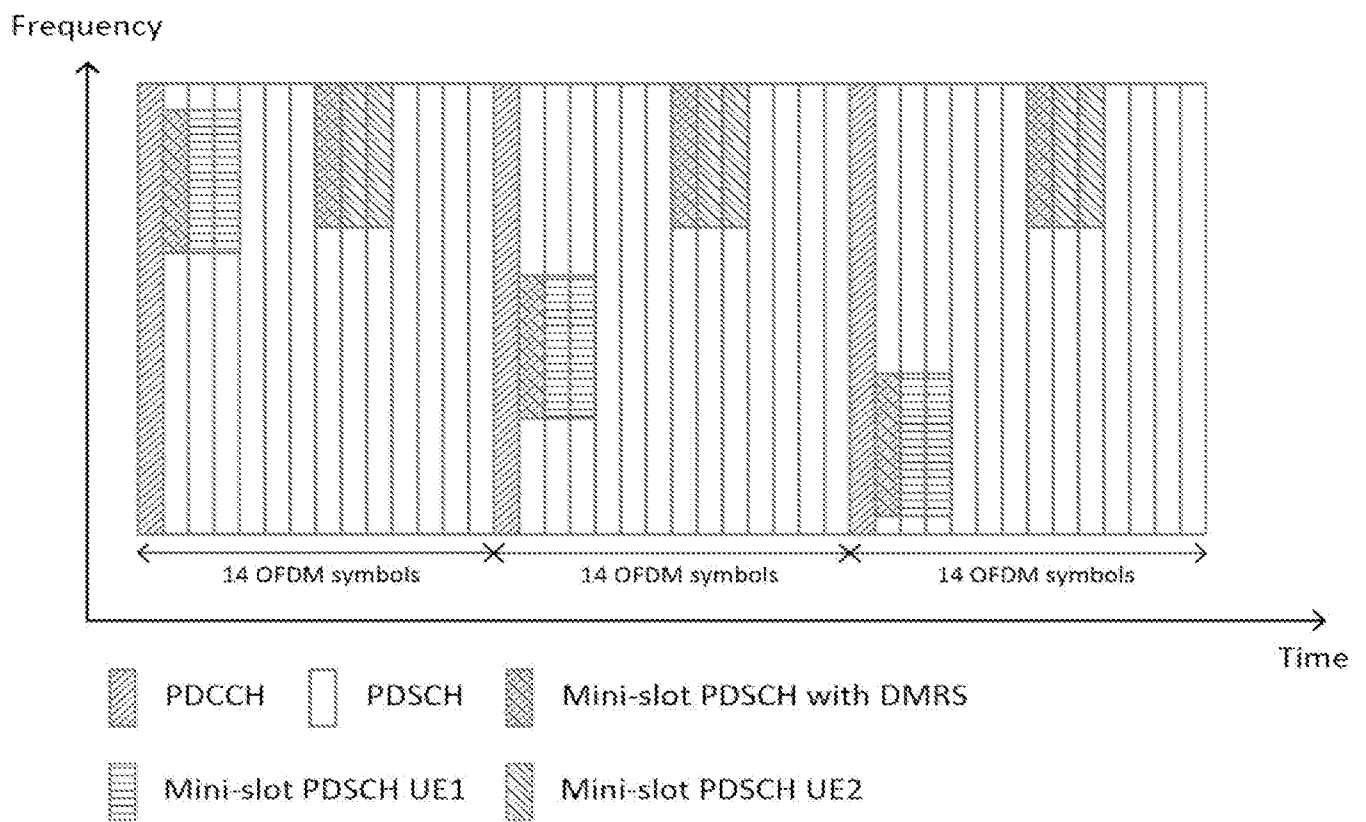


Figure 7

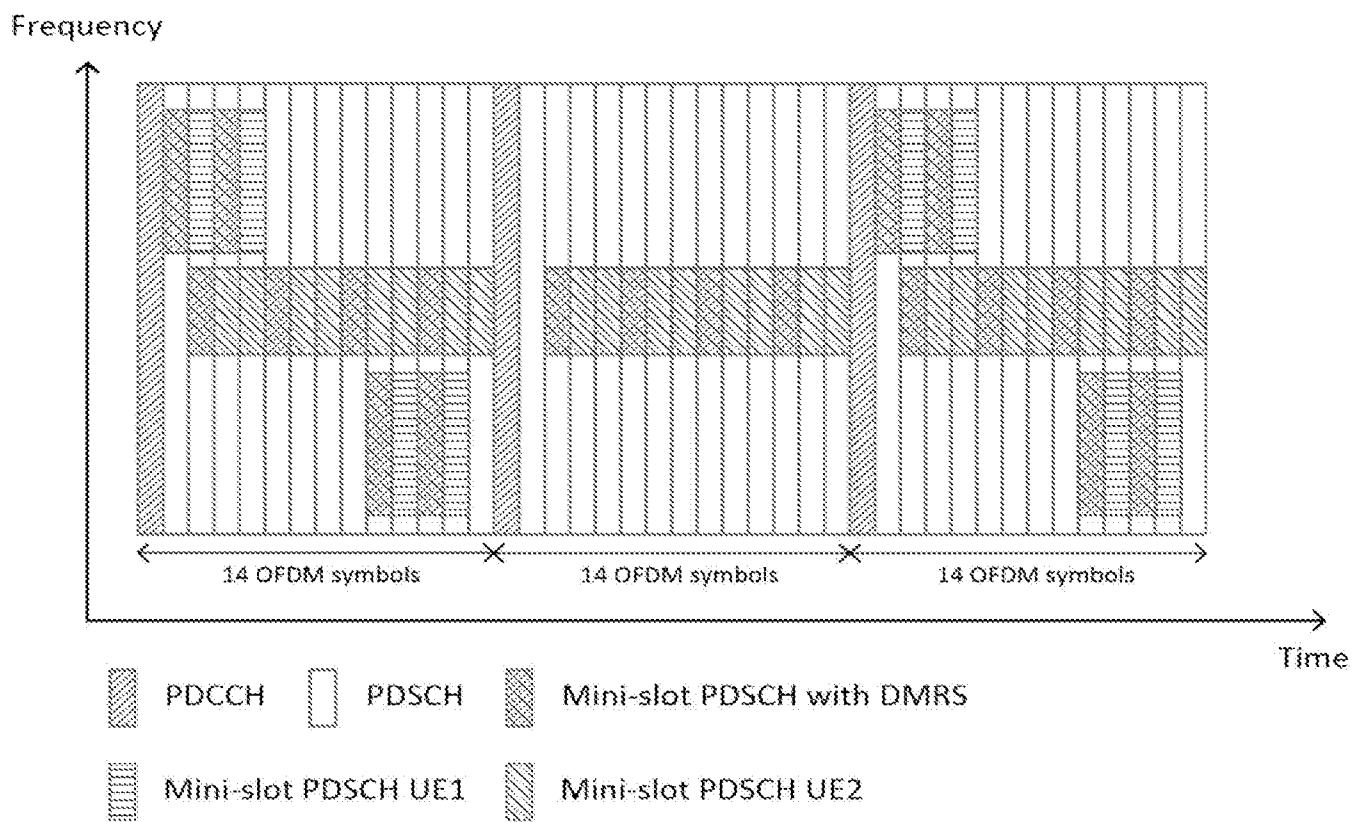


Figure 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/099515

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)i; H04W 72/12(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04L; H04B

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)

CNPAT,WPI,EPODOC,CNKI,3GPP: mini-slot, mini w slot, aggregat+, downlink, OFDM, symbol, scheduling

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	US 2017244535 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 24 August 2017 (2017-08-24) description, paragraphs [0061], [0068], [0070], [0081], [0111]-[0113], [0130], figures 1A, 5B, 5C	1-19
X	CN 106793123 A (YULONG COMPUTER TELECOMMUNICATION SCIENTIFIC SHENZHEN CO., LTD.) 31 May 2017 (2017-05-31) description, paragraphs [0002]-[0025], [0039]-[0061], figures 1-3	1-19
X	AT&T; "Multiplexing between PDCCH and PDSCH for various data durations;" 3GPP TSG RAN WG1 AH_NR Meeting #89 R1-1707729; 19 May 2017 (2017-05-19), sections 2, 4-6	1-19
A	NTT DOCOMO, INC.; "Mini-slot designs for NR;" 3GPP TSG RAN WG1 AH_NR Meeting R1-1700617; 20 January 2017 (2017-01-20), the whole document	1-19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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

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

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"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

27 September 2018

Date of mailing of the international search report

25 October 2018

Name and mailing address of the ISA/CN

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WANG,Manli

Telephone No. **86-(10)-53961741**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2018/099515

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2017244535	A1	24 August 2017	WO	2017143925	A1	31 August 2017
CN	106793123	A	31 May 2017	WO	2018121154	A1	05 July 2018