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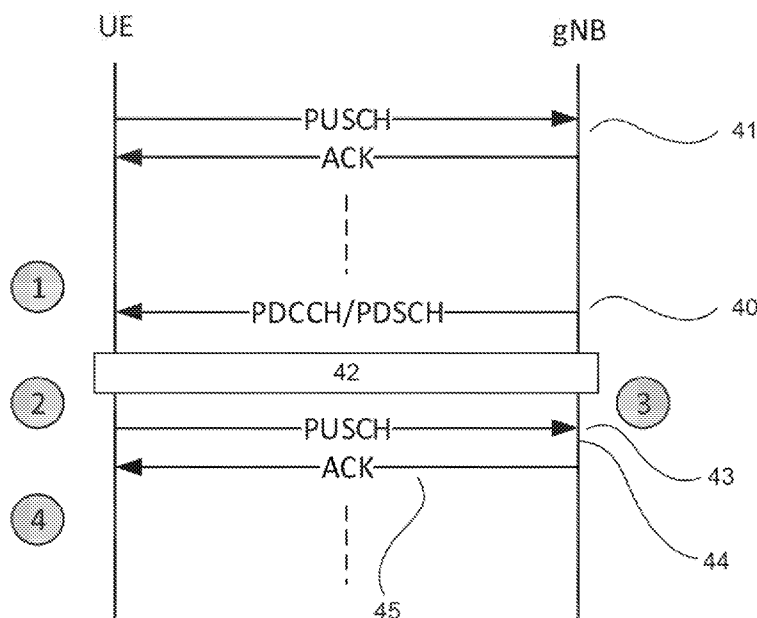


Figure 4

(57) Abstract: Methods and apparatus for non-orthogonal multiple access. UEs have control over the selection of transmission parameters for uplink transmissions to reduce the control overhead compared to the network retaining control. Uplink transmissions may include an indication of parameters of the transmission, for example, modulation coding scheme.

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Multiple Access Techniques in a Cellular Network

Technical Field

[1] The following disclosure relates to multiple access techniques in a cellular network, and in particular to non-orthogonal multiple access for an uplink channel in a cellular network.

Background

[2] 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 support macro-cell mobile phone communications. Communication systems and networks have developed towards a broadband and mobile system.

[3] In cellular wireless communication systems User Equipment (UE) is connected by a wireless link to a Radio Access Network (RAN). The RAN comprises a set of base stations which provide wireless links to the UEs located in cells covered by the base station, and an interface to a Core Network (CN) which provides overall network control. As will be appreciated the RAN and CN each conduct respective functions in relation to the overall network. For convenience the term cellular network will be used to refer to the combined RAN & CN, and it will be understood that the term is used to refer to the respective system for performing the disclosed function.

[4] The 3rd Generation Partnership Project has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Terrestrial Radio Access Network, (E-UTRAN), for a mobile access network 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. NR is proposed to utilise an Orthogonal Frequency Division Multiplexed (OFDM) physical transmission format.

[5] A trend in wireless communications is towards the provision of lower latency and higher reliability services. For example, NR is intended to support Ultra-reliable and low-latency communications (URLLC). A user-plane latency of 1ms has been proposed with a reliability of 99.99999%). Other proposed types of services include enhanced Mobile BroadBand (eMBB) for high data rate transmission, and massive Machine-Type Communication (mMTC) to support a large number of devices over a long life-time with highly energy efficient communication channels.

[6] Communications over the physical wireless link are defined by a number of channels, for example in the uplink direction the Physical Uplink Shared Channel (PUSCH) is utilised for transmissions from a UE to a base station. The PUSCH is transmitted using a set of time (slot) and frequency resources. In a conventional system only one UE transmits signals on each set of time and frequency resources, such that there is no overlap between transmissions. In a conventional system applying spatial multiplexing, only one UE per spatial layer transmits signals on each set of time and frequency resources. Although such allocation of resources reduces interference between UEs, the capacity is limited by the available resources.

[7] Techniques such as Non-Orthogonal Multiple Access (NOMA) may be utilised to increase the capacity of the available time and frequency resources by permitting more than one UE to transmit on a particular resource. Figure 1 shows an example of NOMA transmission in which a number of PUSCHs are transmitted on overlapping resources. Each transmission includes a

Multiple Access (MA) signature to identify the transmitting UE, and may include a DMRS to assist with demodulation of the signals.

[8] At the base station the lower power signal appears as noise on the higher power signal. The higher power signal can be demodulated directly by removing the noise, and then the higher power signal can be subtracted from the received signal to recover the lower power signal. Such receivers are known as Successive Interference Cancellation (SIC) receivers, but other reception techniques may also be utilised.

[9] The advantage of NOMA techniques is an improved resource efficiency as uplink resources are utilised for more than one UE transmission.

[10] mMTC services are often characterised by large numbers of devices, transmitting small packets (typically 10 – 75 bytes) of data infrequently. For example, a cell may be expected to support many thousands of devices. In such situations the overhead of a signalling channel to configure uplink communications (for example scheduling, and Modulation Coding Scheme (MCS)) can be prohibitive and thus grant-free transmission may be utilised for the uplink. Similarly, the number of devices may be much larger than the number of MA signatures that are available, hence preventing the unique identification of UEs.

[11] UEs may also transmit without first switching to RRC_CONNECTED state (from RRC_IDLE or RRC_INACTIVE), thus removing the ability to use RRC for configuration of the UE's transmission parameters.

[12] There is therefore a requirement for an improved system of NOMA uplink transmission.

Summary

[13] 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.

[14] There is provided a method of uplink data transmission from a UE to a base station in a wireless cellular communications network, in which uplink transmissions utilise a Non-Orthogonal Multiple Access (NOMA) protocol, the method comprising the steps of the UE selecting a modulation coding scheme for use with an uplink data transmission; and transmitting an uplink transmission, including an indication of the selected modulation coding scheme, utilising the modulation coding scheme; wherein the uplink transmission is transmitted utilising a grant-free transmission protocol.

[15] The modulation coding scheme may be selected from a subset of modulation coding schemes, wherein the subset of modulation coding schemes is a set selected from a larger set of modulation coding schemes available to the UE.

[16] The indication of the modulation coding scheme may be transmitted in an uplink control information report.

[17] The modulation coding scheme may be selected dependent upon the performance of a previous set of uplink grant-free NOMA transmissions.

[18] The modulation coding scheme may be selected by selecting a modulation coding scheme with an increased or decreased robustness depending on the failure or success respectively of previously uplink grant-free NOMA transmissions.

- [19] The modulation coding scheme may be selected from an ordered list of coding schemes, ordered by robustness, each coding scheme having a robustness index.
- [20] A coding scheme having a robustness index higher or lower than the robustness index of the coding scheme used for a previous transmission may be selected, dependent on the failure or success respectively of at least one previous transmission.
- [21] The robustness index may be higher or lower by a first or second step size respectively.
- [22] The robustness index may be higher if m consecutive uplink transmissions are not successfully acknowledged.
- [23] The robustness index may be lower if n consecutive uplink transmissions are successfully acknowledged.
- [24] The modulation coding scheme may be selected dependent on downlink performance information obtained from a downlink synchronisation.
- [25] The modulation coding scheme may be selected dependent on a BLER value.
- [26] The uplink transmission may comprise a multiple access signature.
- [27] The modulation coding scheme may be selected independently of the base station.
- [28] A CRC of the uplink transmission may be scrambled utilising an identifier of the UE.
- [29] The identifier may be the UEs xRNTI or UE ID.
- [30] The indication of modulation coding scheme may be provided in a dedicated field within the PUSCH channel.
- [31] The dedicated field may comprise 2 to 5 bits.
- [32] The format of the indication of modulation coding scheme may be defined by at least one RRC configuration message.
- [33] The RRC configuration message may comprise a set of parameters including *betaOffsetMCS-Index0*, *betaOffsetMCS-Index1* which respectively provide indexes $I_{offset,0}^{MCS}$, $I_{offset,1}^{MCS}$ for the UE to use if the UE multiplexes up to 2 MCS bits, or more than 2 and up to 5 MCS bits in the PUSCH, respectively.
- [34] Parameters for use by the UE in an algorithm to select the modulation coding scheme may be defined by the base station.

[35] There is also provided a mobile device for performing the methods described herein.

[36] 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

[37] 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.

[38] Figure 1 shows an example of NOMA transmission;

[39] Figure 2 shows a method of uplink transmission;

[40] Figure 3 shows a method of reception;

[41] Figure 4 shows a method of uplink transmission; and

[42] Figure 5 shows a method of reception.

Detailed description of the preferred embodiments

[43] 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.

[44] As set out above, overhead concerns may prevent the use of grant-based UL NOMA transmission, particularly for devices utilizing mMTC type services, thus restricting the ability of a base station to select and configure parameters of UL transmissions. Furthermore, each MA signature may be used by a plurality of UEs, thus preventing the identification of a UE based on the MA signature.

[45] One method for identifying a UE is to include the UE's xRNTI or UE ID within a UCI multiplexed within the PUSCH transmission. Although this allows direct identification of the UE, it may require an overhead of 16 or 24 bits on a 10 – 150 byte payload. In addition these bits have to be encoded in a robust and fixed MCS hence further increasing the overhead. An alternative which does not require any additional overhead is to scramble the CRC of a transmission using the UE identifier. Although in this case the UE can only be identified after data demodulation and CRC checking, the reduced overhead may be more attractive, particularly for small transmission sizes.

[46] Figure 2 shows a flow chart of a method for the transmission of signals from a UE to a base station. At step 20 the UE prepares the required data for transmission on the PUSCH, including an MA signature selected from a set of MA signatures allocated to the UE. The UE may select the MA signature at random. At step 21 the UE scrambles the CRC of the prepared data utilizing the UE's xRNTI or UE ID, and at step 22 the message is transmitted on the PUSCH using a grant-free transmission protocol. A plurality of UEs connected to a particular base station may be utilizing the method of Figure 2 simultaneously, and thus resources may be occupied by occupied by more than one UE's transmission. Similarly, more than one message may be transmitted utilizing the same MA signature.

[47] Figure 3 shows a method for decoding a received transmission and identifying the transmitting UE. At step 30 the base station receives a NOMA transmission from one or more UE and detects the MA signature. Since each MA signature may be shared between more than one UE this signature allows the base station to identify a group of UEs which the transmission may have been received, but not the UE uniquely.

[48] At step 31 the base station demodulates the received signal using a blind detection algorithm. At this stage of the process the base station does not know the identity of the transmitting UEs, nor the MCS used for the transmission. An SIC type receiver may be utilized to demodulate the received signals and recover each of the overlapping transmissions. Due to the lack of knowledge of the base station about the received signals a large number of options may have to be tested by the base station during the blind demodulation process. That is, the blind demodulation may be performed over a large search space. The use of an SIC receiver to recover a plurality of NOMA signals may make this process more challenging.

[49] Once the signals have been recovered, at step 32 the CRC is checked and descrambled to identify the UE's xRNTI or UE ID which was used by the UE to scramble the CRC.

[50] The search space for the demodulation process can be reduced by selecting a unique MCS for all relevant devices. The blind demodulation process thus only needs to test this MCS. However, the selected MCS would have to be the MCS with the most robust performance as it will be used in all situations and so must support the worst-case link conditions. Typically a QPSK MCS with low code rate would be utilized which is robust but has poor spectral efficiency.

[51] The standards (for example TS 28.214, Table 6.1.4.1-1) define a set of possible MCS schemes. In order to reduce the set of MCSs that must be tested in the blind demodulation process a subset of the MCSs may be allocated to a UE transmitting NOMA traffic such that the search space is reduced. This scheme provides the flexibility to select an appropriate MCS for the link conditions, but balances this with demodulation complexity. When transmitting a NOMA message, for example using the process of Figure 1, the UE selects an appropriate MCS from the assigned subset.

[52] Due to the infrequent nature of mMTC transmissions the base station is unlikely to have sufficient signals from the UE to be aware of the current channel conditions and hence select an appropriate MCS. Also, the overhead of transmitting configuration messages to each UE is likely to be large. In contrast, prior to transmitting the UE has to synchronize on the downlink channel and therefore he has recent knowledge of the downlink channel conditions. The downlink conditions are a reasonable indicator of uplink channel conditions and can thus be utilized to guide selection of an appropriate MCS independent of the base station.

[53] The UE may select the MCS utilizing any appropriate process. In an example, a UE may be preconfigured with a particular MCS. For example, a low-end UE transmitting small amounts of data may always utilize a simple MCS such as QPSK.

[54] Figure 4 shows a method for selecting an MCS for a NOMA UL transmission. At step 40, prior to a NOMA transmission, the UE wakes up and performs DL synchronization. Based on the measured DL SINR, and optionally ACK/NACK history for previous PUSCH transmissions (41) the UE selects an appropriate MCS at step 42.

[55] At step 43 the UE utilizes the selected MCS for transmission of data on PUSCH, for example as described in relation to Figure 2. The transmitted message may include an indication of the selected MCS which may be utilized by the base station at step 44 to demodulate the received signal. Once demodulated the base station transmits an ACK/NACK at step 45.

[56] The UE may update its ACK/NACK history for use in future transmissions, and may then return to sleep.

[57] As explained above, the MCS for each UL NOMA transmission is selected by the UE (that is, the UE performs link rate adaptation). Although the MCS selection could be based on conventional BER or BLER statistics, this is unlikely to be effective in mMTC-type systems where small transmissions are made infrequently such that the link characteristics can change extensively between transmissions.

[58] Set out below is a process that may be utilized to select an MCS for an UL NOMA transmission, for example within the method of Figure 4. The method utilizes recent PUSCH transmission results to increment or decrement the MCS selected which may be expressed as follows:-

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    If
        lastmTxFailed
    then
        MCS = max(MCS - K1, MCSmin)
    end
    If
        lastnTxSucceeded
    then
        MCS = min(MCS + K2, MCSmax)
    end

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MCS_{min} is the index of the most robust MCS (for example, 0 for NR OMA) available, and MCS_{max} is the index of highest throughput MCS.

$lastTxFailed = 1$ if last NOMA Tx of this UE was not ACK-ed, 0 otherwise.

$K1$ and $K2$ are integer values ≥ 1 .

$lastmTxFailed = 1$ if last m NOMA UL transmissions have failed, m is a configurable integer ≥ 1 .

$lastnTxSucceeded = 1$ if last n NOMA UL transmissions have been successful, n is a configurable integer ≥ 1 .

[59] The process thus increments or decrements the MCS, when ordered according to robustness, according to the success or failure of a configurable number of recent PUSCH transmissions. As set out above, if the ACK/NACK history is not available (for example ACK-free transmissions, or insufficient previous transmissions) the MCS can be selected based on signal quality from a downlink synchronization or other assessment of channel quality (e.g. DL SINR, DL RSRP, DL RSSI or any equivalent value).

[60] In general, the selection of MCS may be stated as being based on recent events related to the transmission channel.

[61] The selected MCS may be indicated in the PUSCH utilizing the "UCI reporting in physical uplink shared channel" (clause 9.3 in TS 38.213) process in which the UE multiplexes the UCI information in the PUSCH.

[62] New offset values, specific for signaling MCS, may be defined for a UE to determine a number of resources for multiplexing the indication of MCS in a PUSCH. The offset values may be signaled to the UE either using a DCI format scheduling the PUSCH transmission or by higher layers. In particular, a new set of parameters $\beta_{OffsetMCS-Index0}$, $\beta_{OffsetMCS-Index1}$ respectively provide indexes $I_{offset,0}^{MCS}$, $I_{offset,1}^{MCS}$ for the UE to use if the UE multiplexes up to 2 MCS bits, or more than 2 and up to 5 MCS bits in the PUSCH, respectively.

[63] Figure 5 shows a flowchart of a method of NOMA PUSCH reception when the PUSCH includes an indication of MCS. At step 50 the base station detects the MA signature (which as set out above allows identification of a group of UEs to which the transmitting UE belongs), and then at step 51 the base station demodulates the MCS field. The indicated MCS is utilised at step 52 to demodulate and recover the received signals, for example utilising an SIC receiver. Since the MCS is known, there is no penalty at this stage to the lack of knowledge of the particular UE which transmitted the signal. The UE may be identified at step 53 after CRC checking and descrambling from which the xRNTI or UE ID utilised to scramble the CRC can be recovered.

[64] 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 options and choices are described below.

[65] 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, 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 control module.

[66] 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.

[67] 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.

[68] 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.

[69] 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.

[70] 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.

[71] 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. 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.

[72] 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.

[73] 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.

[74] 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.

[75] 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. 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 recognise 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.

[76] 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.

[77] 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.

[78] 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 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.

Claims

1. A method of uplink data transmission from a UE to a base station in a wireless cellular communications network, in which uplink transmissions utilise a Non-Orthogonal Multiple Access (NOMA) protocol, the method comprising the steps of
the UE selecting a modulation coding scheme for use with an uplink data transmission;
and
transmitting an uplink transmission, including an indication of the selected modulation coding scheme, utilising the modulation coding scheme;
wherein the uplink transmission is transmitted utilising a grant-free transmission protocol.
2. A method according to claim 1, wherein the modulation coding scheme is selected from a subset of modulation coding schemes, wherein the subset of modulation coding schemes is a set selected from a larger set of modulation coding schemes available to the UE.
3. A method according to claim 1 or claim 2, wherein the indication of the modulation coding scheme is transmitted in an uplink control information report.
4. A method according to any preceding claim, wherein the modulation coding scheme is selected dependent upon the performance of a previous set of uplink grant-free NOMA transmissions.
5. A method according to any preceding claim, wherein the modulation coding scheme is selected by selecting a modulation coding scheme with an increased or decreased robustness depending on the failure or success respectively of previously uplink grant-free NOMA transmissions.
6. A method according to any of claims 1 to 4, wherein the modulation coding scheme is selected from an ordered list of coding schemes, ordered by robustness, each coding scheme having a robustness index.
7. A method according to claim 6, wherein a coding scheme having a robustness index higher or lower than the robustness index of the coding scheme used for a previous transmission is selected, dependent on the failure or success respectively of at least one previous transmission.
8. A method according to claim 7, wherein the robustness index is higher or lower by a first or second step size respectively.
9. A method according to claim 7, wherein the robustness index is higher if m consecutive uplink transmissions are not successfully acknowledged.
10. A method according to claim 7, wherein the robustness index is lower if n consecutive uplink transmissions are successfully acknowledged.
11. A method according to any preceding claim, wherein the modulation coding scheme is selected dependent on downlink performance information obtained from a downlink synchronisation.

12. A method according to any preceding claim, wherein the modulation coding scheme is selected dependent on a BLER value.
13. A method according to any preceding claim, wherein the uplink transmission comprises a multiple access signature.
14. A method according to any preceding claim wherein the modulation coding scheme is selected independently of the base station.
15. A method according to any preceding claim, wherein a CRC of the uplink transmission is scrambled utilising an identifier of the UE.
16. A method according to claim 14, wherein the identifier is the UEs xRNTI or UE ID.
17. A method according to any preceding claim, in which the indication of modulation coding scheme is provided in a dedicated field within the PUSCH channel.
18. A method according to claim 17, wherein the dedicated field comprises 2 to 5 bits.
19. A method according to any preceding claim, wherein the format of the indication of modulation coding scheme is defined by at least one RRC configuration message.
20. A method according to claim 19, wherein the RRC configuration message comprises a set of parameters including *betaOffsetMCS-Index0*, *betaOffsetMCS-Index1* which respectively provide indexes $I_{offset,0}^{MCS}$, $I_{offset,1}^{MCS}$ for the UE to use if the UE multiplexes up to 2 MCS bits, or more than 2 and up to 5 MCS bits in the PUSCH, respectively.
21. A method according to any preceding claim, wherein parameters for use by the UE in an algorithm to select the modulation coding scheme are defined by the base station.
22. A mobile device for performing the method of any of claims 1 to 21.

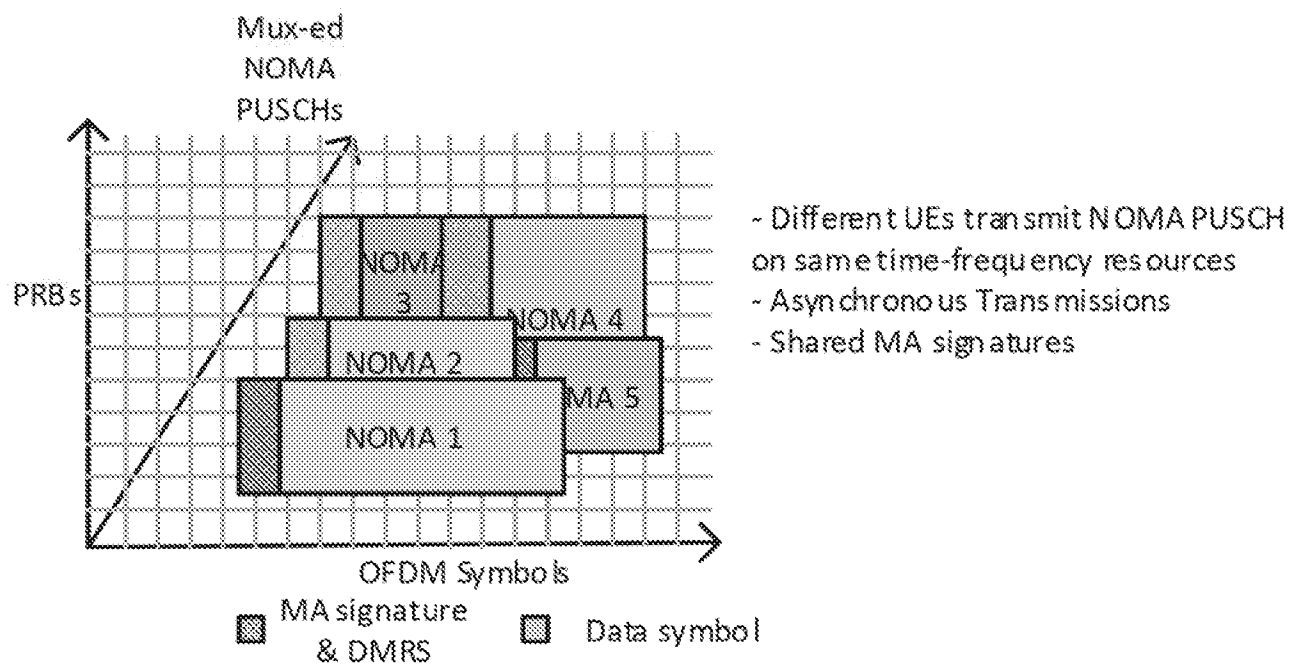


Figure 1

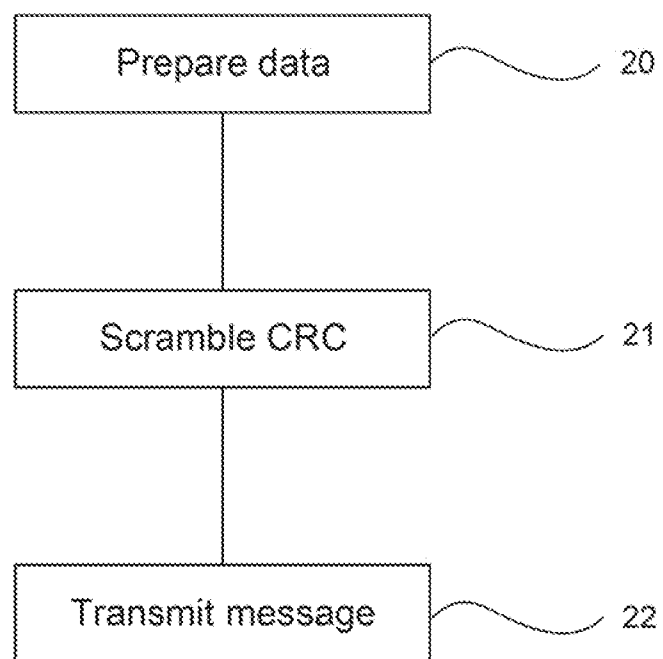


Figure 2

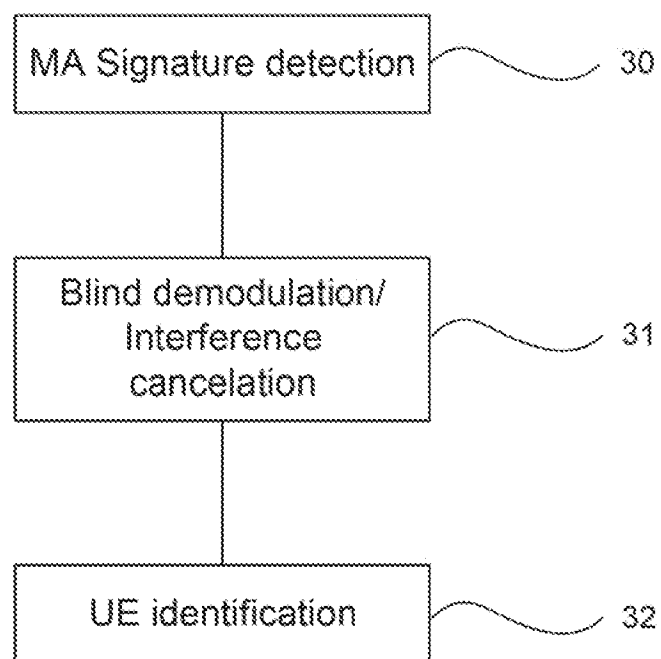


Figure 3

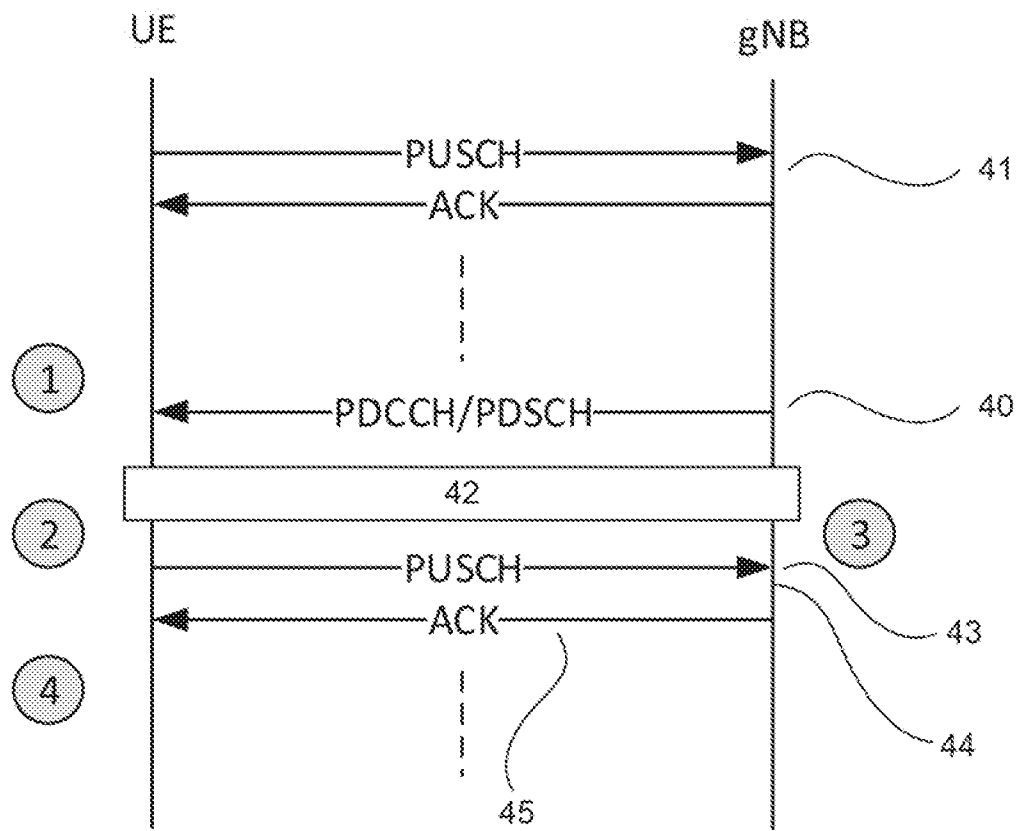


Figure 4

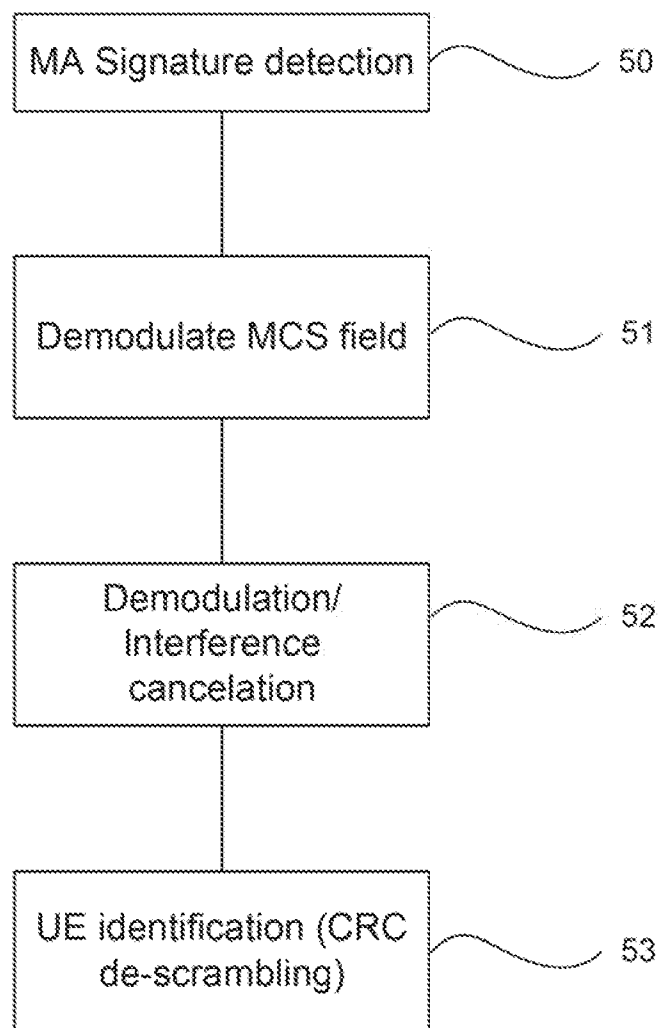


Figure 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2019/086233

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(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 H04Q H04L

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, CNKI, WPI, EPDOC, GOOGLE, 3GPP: NOMA, MCS, select+, grant-free, uplink, subset, previous, robustness, index, BLER, CRC, PUSCH, eMBB, mMTC, URLLC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NOKIA et al. ""Procedures to be considered for NOMA operation"" 3GPP TSG RAN WG1 Meeting #92bis, R1-1804464, 20 April 2018 (2018-04-20), page 3, paragraphs 6-8	1-22
A	US 2018070335 A1 (SAMSUNG ELECTRONICS CO., LTD.) 08 March 2018 (2018-03-08) the whole document	1-22
A	WO 2017211219 A1 (NTT DOCOMO, INC.) 14 December 2017 (2017-12-14) the whole document	1-22
A	US 2018019838 A1 (SAMSUNG ELECTRONICS CO., LTD.) 18 January 2018 (2018-01-18) the whole document	1-22

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

02 July 2019

Date of mailing of the international search report

25 July 2019

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2019/086233

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2018070335	A1	08 March 2018	WO	2018048237	A1	15 March 2018
WO	2017211219	A1	14 December 2017	CN	107465489	A	12 December 2017
				CN	109075918	A	21 December 2018
US	2018019838	A1	18 January 2018	CN	107623951	A	23 January 2018
				KR	20180007584	A	23 January 2018
				EP	3270534	A1	17 January 2018