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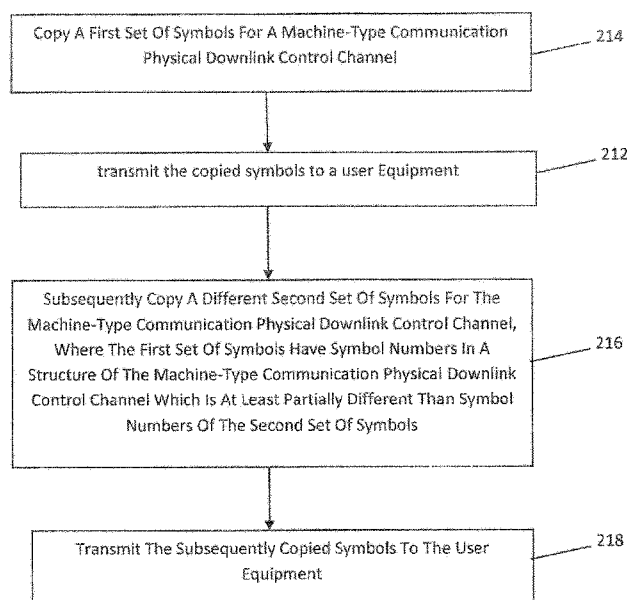


Fig. 6

(57) Abstract: A method for repetition of symbols for a machine-type communication comprising copying a first subset of symbols for a physical downlink control channel for multiple subcarriers in a first transmission in a first subframe; and subsequently copying a different second subset of symbols for the physical downlink control channel, for the multiple subcarriers, in a second transmission in a second subframe.

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Downlink Transmission On LTE Control Channel Region

BACKGROUND

Technical Field

[0001] The example and non-limiting embodiments relate generally to wireless transmissions and, more particularly, to transmission on a control channel region.

Brief Description of Prior Developments

[0002] 3GPP has introduced a suite of two complementary narrowband LTE IoT technologies in Release 13: eMTC (enhanced machine-type communication) and NB-IoT (narrowband Internet of Things). Both are optimized for lower complexity/power, deeper coverage, and higher device density, while seamlessly coexisting with other LTE services such as regular mobile broadband. In Release 16, in regard to eMTC, a feature on supporting stand-alone eMTC is being introduced.

DETAILED DESCRIPTION OF EMBODIMENT

[0003] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

	3GPP	third generation partnership project
20	BL	Bandwidth Limited
	CE	Coverage Enhancement
	CRS	Cell Specific Reference Signal
	DL	Downlink
	eMTC	Enhanced Machine Type Communications
25	FDD	Frequency Division Duplex
	IoT	Internet of Things

	LTE	Long Term Evolution
	MIB	Master Information Block
	MPDCCH	MTC Physical Downlink Control Channel
	MTC	Machine-Type Communication
5	NB-IoT	Narrowband IoT
	NR	New Radio (5G)
	OFDM	Orthogonal Frequency Division Multiplex
	OTDOA	Observed Time Difference of Arrival
	PDSCH	Physical Downlink Data Channel
10	PRB	Physical Resource Block
	RE	Resource Element
	RRC	Radio Resource Control
	RS	Reference Signal
	SIB	System Information Block
15	SINR	Signal to Interference plus Noise Ratio
	TDD	Time Division Duplex
	UE	User Equipment

[0004] Turning to FIG. 1, this figure shows a block diagram of one possible and non-limiting example system in which the example
20 embodiments may be practiced. A user equipment (UE) 110, radio access network (RAN) node 170, and network element(s) 190 are illustrated. In FIG. 1, a user equipment (UE) 110 is in wireless communication with a wireless network 100. A UE is a wireless device that can access a wireless network. The UE 110 includes

one or more processors 120, one or more memories 125, and one or more transceivers 130 (or at least either a transmitter or a receiver) interconnected through one or more buses 127. Each of the one or more transceivers 130 includes a receiver, Rx, 132 and a transmitter, Tx, 133. The one or more buses 127 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers 130 are connected to one or more antennas 128. The one or more memories 125 include computer program code 123. The UE 110 includes a module 140, comprising one of or both parts 140-1 and/or 140-2, which may be implemented in a number of ways. The module 140 may be implemented in hardware as module 140-1, such as being implemented as part of the one or more processors 120. The module 140-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the module 140 may be implemented as module 140-2, which is implemented as computer program code 123 and is executed by the one or more processors 120. For instance, the one or more memories 125 and the computer program code 123 may be configured to, with the one or more processors 120, cause the user equipment 110 to perform one or more of the operations as described herein. The UE 110 communicates with RAN node 170 via a wireless link 111.

[0005] The RAN node 170 is a base station that provides access by wireless devices such as the UE 110 to the wireless network 100. The RAN node 170 may be, for instance, a base station for 4G LTE or 5G. The RAN node 170 may be an eNB (evolved NodeB) base station, for LTE (long term evolution), or any other suitable base station. In 5G, the RAN node 170 may be a NG-RAN node, which is defined as either a gNB or an ng-eNB.

[0006] The RAN node 170 includes one or more processors 152, one or more memories 155, one or more network interfaces (N/W

I/F(s)) 161, and one or more transceivers 160 interconnected through one or more buses 157. Each of the one or more transceivers 160 includes a receiver, Rx, 162 and a transmitter, Tx, 163. The one or more transceivers 160 are connected to one
5 or more antennas 158. The one or more memories 155 include computer program code 153.

[0007] The RAN node 170 includes a module 150, comprising one of or both parts 150-1 and/or 150-2, which may be implemented in a number of ways. The module 150 may be implemented in hardware
10 as module 150-1, such as being implemented as part of the one or more processors 152. The module 150-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the module 150 may be implemented as module 150-2, which is implemented as
15 computer program code 153 and is executed by the one or more processors 152. For instance, the one or more memories 155 and the computer program code 153 are configured to, with the one or more processors 152, cause the RAN node 170 to perform one or more of the operations as described herein.

20 [0008] The one or more network interfaces 161 communicate over a network such as via the links 176 and 131. Two or more base stations or access points 170 communicate using, e.g., link 176. The link 176 may be wired or wireless or both and may implement, e.g., an Xn interface for 5G, an X1 interface for
25 LTE, or other suitable interface for other standards.

[0009] The one or more buses 157 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless
30 channels, and the like. For example, the one or more transceivers 160 may be implemented as a remote radio head (RRH) 195 for LTE or a distributed unit (DU) 195 for gNB implementation for 5G, with the other elements of the RAN node 170 possibly

being physically in a different location from the RRH/DU, and the one or more buses 157 could be implemented in part as, e.g., fiber optic cable or other suitable network connection to connect the other elements (e.g., a central unit (CU), gNB-CU) of the RAN node 170.

[0010] It is noted that description herein indicates that "cells" perform functions, but it should be clear that the base station that forms the cell will perform the functions. The cell makes up part of a base station. That is, there can be multiple cells per base station. For instance, there could be three cells for a single carrier frequency and associated bandwidth, each cell covering one-third of a 360 degree area so that the single base station's coverage area covers an approximate oval or circle. Furthermore, each cell can correspond to a single carrier and a base station may use multiple carriers. So if there are three 120 degree cells per carrier and two carriers, then the base station has a total of 6 cells.

[0011] The wireless network 100 may include a network element or elements 190 that may include core network functionality, and which provides connectivity via a link or links 181 with a further network, such as a telephone network and/or a data communications network (e.g., the Internet). Such core network functionality for 5G may include access and mobility management function(s) (AMF(S)) and/or user plane functions (UPF(s)) and/or session management function(s) (SMF(s)). Such core network functionality for LTE may include MME (Mobility Management Entity)/SGW (Serving Gateway) functionality. These are merely example functions that may be supported by the network element(s) 190, and note that both 5G and LTE functions might be supported. The RAN node 170 is coupled via a link 131 to a network element 190. The link 131 may be implemented as, e.g., an NG interface for 5G, or an S1 interface for LTE, or other suitable interface for other standards. The network element 190 includes one or

more processors 175, one or more memories 171, and one or more network interfaces (N/W I/F(s)) 180, interconnected through one or more buses 185. The one or more memories 171 include computer program code 173. The one or more memories 171 and the computer
5 program code 173 are configured to, with the one or more processors 175, cause the network element 190 to perform one or more operations.

[0012] The wireless network 100 may implement network virtualization, which is the process of combining hardware and
10 software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization involves platform virtualization, often combined with resource virtualization. Network virtualization is categorized as either external, combining many networks, or
15 parts of networks, into a virtual unit, or internal, providing network-like functionality to software containers on a single system. Note that the virtualized entities that result from the network virtualization are still implemented, at some level, using hardware such as processors 152 or 175 and memories 155
20 and 171, and also such virtualized entities create technical effects.

[0013] The computer readable memories 125, 155, and 171 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology,
25 such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The computer readable memories 125, 155, and 171 may be means for performing storage functions. The processors 120, 152, and 175 may be of
30 any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples. The processors 120, 152, and 175 may be means

for performing functions, such as controlling the UE 110, RAN node 170, and other functions as described herein.

[0014] In general, the various embodiments of the user equipment 110 can include, but are not limited to, stand-alone
5 eMTC devices, cellular telephones such as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices
10 having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, tablets with wireless communication capabilities, vehicles, as well as portable units or terminals that incorporate
15 combinations of such functions.

[0015] Having thus introduced one suitable but non-limiting technical context for the practice of the example embodiments of this invention, the example embodiments will now be described with greater specificity.

20 [0016] Features as described herein propose to cycle through different MPDCCH (MTC Physical Downlink Control Channel) mapping onto the LTE downlink (DL) control channel region in time and/or frequency. In other words, features as described herein may be used to change which MPDCCH time and frequency region is to be
25 copied. Fig. 2 illustrates mapping of a MTC Physical Downlink Control Channel (MPDCCH) 200 versus a legacy LTE control region 202. This shows mapping with 12 subcarriers and 14 OFDM symbols (symbols 0-13). The mapping might only be different in frequency, but not in time. The mapping might only be different
30 in time, but not frequency. Also, as noted above the mapping might be different in both time and frequency.

[0017] A UE may be informed that the LTE control channel region 202 will be used for MPDCCH extension (i.e. some MPDCCH symbols will be copied onto the LTE DL control region 202. As illustrated in Fig. 5, the base station or node 170 may transmit a signal 210 to the UE 110 with this information/notification. This notification may be informed using, for example, the SIB, MIB, or RRC signaling. Different MPDCCH symbol(s) may then be copied onto the LTE DL control region 202. This may depend on the absolute subframe number. As illustrated in Fig. 5, the base station or node 170 may then transmit 212a the copies symbols to the UE 110.

[0018] Referring also to Fig. 3, which illustrates Time-varying mapping of MPDCCH into legacy control region 202, with features as described herein the same mapping may be used for Ych consecutive subframes. For example, given the mapping [{#7, #8}, {#3, #4}, {#10, #11}], MPDCCH OFDM symbols #7 and #8 are first copied to OFDM symbols #0 and #1. Thus, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers, is copied. This is also then done for Ych consecutive subframes, as illustrated in Fig. 3, where MPDCCH OFDM symbols #3 and #4 are subsequently copied to OFDM symbols #0 and #1, then MPDCCH OFDM symbols #10 and #11 are subsequently copied to OFDM symbols #0 and #1, and so on. The consecutive transmissions to the UE are indicated by 212a, 212b for example. Note that UE can determine the mapping using the parameter Ych and the subframe number (either absolute or relative to another reference parameter such as the radio frame number). In addition, Ych may be configured such that the same mapping is always used.

[0019] The mapping configuration indicates the sequence of MPDCCH OFDM symbol(s) that are copied to the legacy LTE control region (indicated by the RRC parameter startSymbolBR-r13) in a cyclical manner and the parameter Ych. In one example embodiment, the configuration contains only OFDM symbol(s) (such

as symbol or symbol pairs for example) that have a same Cell Specific Reference Signal (CRS) mapping as OFDM symbols in the legacy LTE control region 202, such as #0 and #1, and [{#7, #8}, {#3, #4}, {#10, #11}] for example. In another example
5 embodiment, the configuration may also contain OFDM symbol(s) without CRS, where the CRS locations in these OFDM symbols are punctured when copying the Resource Elements (RES) to the legacy LTE control region. In some embodiments, the sequence of MPDCCH OFDM symbol(s) may be fixed in the specification, and only the
10 parameter Ych is indicated in the configuration. In one example embodiment, the parameter Ych is configurable per Coverage Enhancement (CE) mode. In another example embodiment, the parameter Ych is given by the configured number of hopping subframes. In another example embodiment, the parameter Ych is
15 different for FDD and TDD.

[0020] In an alternate example embodiment, the mapping may depend on Coverage Enhancement (CE) mode or the maximum number of repetitions configured for the MPDCCH. For example, a UE in a CE mode A may have a different pattern than a UE in CE mode B.
20 In another example, a UE with a maximum of four (4) repetitions for the MPDCCH may always use a same mapping, while a UE with a maximum of eight (8) repetitions for the MPDCCH may alternate between two (2) different mappings. These are merely examples and should not be considered as limiting.

25 [0021] In an alternate example embodiment, the mapping may be specific to Physical Resource Block (PRB), a group of PRBs (e.g. a MPDCCH narrowband or narrowbands), or MPDCCH resource set. For example, if two MPDCCH resource sets are specified for the UE search space, then each set may have a different mapping as
30 shown in Fig. 4. Fig. 4 illustrates mapping of MPDCCH into legacy control region for different MPDCCH resource sets; in this example MPDCCH resource set #1 versus MPDCCH resource set #2.

[0022] All or part of the mapping configuration may be defined in a specification or given by higher layer signaling, such as SIB or RRC signaling for example. The configuration may be cell or UE specific. Furthermore, different mappings may apply in different RRC state such as, for example, one mapping or configuration in idle mode and one mapping or configuration in RRC connected mode). In one example embodiment, different mapping tables may be defined and signaled via higher layer signaling. The UE may cycle through the entries in the table; with each entry valid for Y_{ch} subframes. In another example embodiment, the mapping may be determined implicitly. For example, the mapping may be determined by cycling through all MPDCCH symbols or by cycling through starting from every K^{th} symbol, or by cycling through symbols defined in a specification.

[0023] A feature as provided herein may be SINR improvement for most or all MPDCCH symbols rather than Signal to Interference plus Noise Ratio (SINR) improvement for only a small subset of MPDCCH symbols. This ensures that the Log-Likelihood Ratio and reliability generated for MPDCCH decoding are more balanced among all MPDCCH symbols; which improves decoding performance.

[0024] As noted above, in Release 16, in regard to eMTC, a feature on supporting stand-alone eMTC is being introduced. This feature enables the use of LTE control channel region for DL transmission (MPDCCH/PDSCH) to (Bandwidth-Limited/Coverage Enhancement) BL/CE UEs. It could be used in stand-alone eMTC deployment (such as with only eMTC UE in the system for example); using either its own carrier or multiplexed into NR carrier. Since there is no legacy LTE UE in the system, the LTE control region is not needed, and it would benefit eMTC UE to be able to extend the MPDCCH/PDSCH transmission into the legacy LTE control channel region.

[0025] In RAN1#95, it was agreed that for MPDCCH transmission in LTE control region, part of the MPDCCH are mapped into the

LTE DL control region. This means that part of the MPDCCH will be copied into the LTE control channel region. In this case, the size of the LTE control channel region is 2 symbols (the minimum size for 1.4MHz channel bandwidth). Extending the MPDCCH
5 into the LTE control channel region will provide a gain of approximately 0.7 dB, which could be significant in reducing the number of repetitions required for eMTC UE in coverage enhancement mode. Note that this improvement is backward-compatible to pre-Rel-16 UE, which will simply ignore the legacy
10 LTE control channel region. Stand-alone eMTC enables the use of LTE control channel region for DL transmission (MPDCCH/PDSCH) to BL/CE UEs. In RAN1#95, it was agreed that, for MPDCCH, part of the MPDCCH will be copied into the LTE DL control region. This mapping is done in a predefined and static manner. While this
15 mapping may be sufficient when the number of repetition for the MPDCCH is small, it is suboptimal for large number of repetition. This is because the same MPDCCH symbols are always copied, thus improving the SINR on only a small subset of MPDCCH symbols. There are several 3GPP contributions discussing the static
20 mapping of MPDCCH onto the LTE DL control region, such as:

R1-1812140 DL transmission on LTE control channel region; Huawei, HiSilicon

R1-1812459 Standalone deployment for eMTC; Intel Corporation

25 R1-1812927 Consideration on the usage of LTE control channel region; Nokia, Nokia Shanghai Bell

[0026] They do not, however, disclose the non-static copying as described herein. As described herein, it is more beneficial to cycle through different OFDM symbols to provide some amount
30 of SINR improvement for most or all MPDCCH symbols rather than large amount of SINR improvement for only a small number of MPDCCH symbols. Referring also to Fig. 6, features as described

herein may comprise copying, as indicated by block 214 a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; transmit the copied symbols to a user equipment as indicated by block 212; subsequently copy, as indicated by block 216, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and transmit the subsequently copied symbols to the user equipment as indicated by block 218.

[0027] Referring also to Fig. 7, as indicated by block 220 the UE 110 may receive the signal 210 indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension. The UE may then receive the downlink transmission 212 as indicated by block 222; and based upon the receipt of the signal indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension as indicated by block 224.

[0028] An example method may comprise: copying, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type

communication physical downlink control channel; transmitting the first transmission to a user equipment in a first subframe; subsequently coping, for a repetition, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and transmitting the second transmission to the user equipment in a second subframe.

[0029] An example embodiment may be provided in an apparatus comprising: at least one processor; and at least one non-transitory memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to: copy, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; transmit the first transmission a user equipment in a first subframe; subsequently copy, for a repetition, of a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set

of symbols; and transmit the second transmission to the user equipment in a second subframe.

[0030] An example embodiment may be provided in a non-transitory program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine for performing operations, the operations comprising: copying, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; transmitting the first transmission to a user equipment in a first subframe; subsequently copying, for a repetition, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers which is at least partially different than symbol numbers of the second set of symbols; and transmitting the second transmission to the user equipment in a second subframe.

[0031] An example method may comprise: copy a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; transmit the copied first set of symbols to a user equipment in a first subframe; subsequently copy a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the

machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and transmit the copied second set of symbols to the user equipment in a second subframe.

- 5 [0032] The first set of symbols may be copied to symbol locations in a legacy long term evolution control channel region. The second set of symbols may be copied to symbol locations in the legacy long term evolution control channel region. The method may further comprise transmitting an indication to a user
- 10 equipment indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension. A same mapping may be used for Ych consecutive subframes. A mapping configuration may indicate a sequence of the sets of
- 15 symbols that are copied to a legacy LTE control region in a cyclical manner and the parameter Ych. The legacy long term evolution control channel region may be indicated by a RRC parameter startSymbolBR-r13. The mapping configuration may contain only OFDM symbols that have a same Cell Specific
- 20 Reference Signal (CRS) mapping as OFDM symbols in the legacy LTE control region. The mapping configuration may contain OFDM symbols without CRS, where the CRS locations in the OFDM symbols are punctured when copying the Resource Elements to the legacy LTE control region. A sequence of sets of MPDCCH OFDM symbols
- 25 may be fixed, and the parameter Ych is indicated in the mapping configuration. The parameter Ych may be configurable separately for each coverage enhancement mode. The parameter Ych may be given by a configured number of hopping subframes. The parameter Ych may be different for Frequency Division Duplex and Time
- 30 Division Duplex. The mapping may be specific to at least one of Physical Resource Block (PRB), a group of PRBs, or a MPDCCH resource set. All or part of the mapping configuration may be at least one of: defined in a specification, or given by higher layer signaling. Different mapping tables may be defined and

signaled to a user equipment with a higher layer signaling. The method may further comprise repeating the following at least once: subsequently copy another different set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers, where the another set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the another different set of symbols have symbol numbers in the structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the first and second set of symbols; and transmit the copied another different set of symbols to the user equipment.

[0033] An example embodiment may be provided in an apparatus comprising: at least one processor; and at least one non-transitory memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to: copy a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; transmit the copied first set of symbols to a user equipment in a first subframe; subsequently copy a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and transmit the copied second set of symbols to the user equipment in a second subframe.

[0034] An example embodiment may be provided in a non-transitory program storage device readable by a machine,

tangibly embodying a program of instructions executable by the machine for performing operations, the operations comprising: copying a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; transmitting the copied first set of symbols to a user equipment in a first subframe; subsequently copying a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and transmitting the copied second set of symbols to the user equipment in a second subframe.

[0035] An example method may comprise: receiving a signal indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension; receiving a downlink transmission; and based upon the receipt of the signal indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension.

[0036] An example embodiment may be provided in an apparatus comprising: at least one processor; and at least one non-transitory memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to: receive a signal

indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension; receive a downlink transmission; and based upon the receipt of the signal indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, use the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension.

5 [0037] An example embodiment may be provided in a non-transitory program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine for performing operations, the operations comprising: receiving a signal indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension; receiving a downlink transmission; and based upon the receipt of the signal indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension.

[0038] An example embodiment may be provided in an apparatus comprising: means for copying, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel; means for transmitting the first transmission to a user equipment in a first subframe; means for subsequently copying, for a repetition, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission,

where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and means for transmitting the second transmission to the user equipment in a second subframe.

[0039] An example embodiment may be provided in an apparatus comprising: means for receiving an indication indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension; means for receiving a downlink transmission; and means for, based upon the receipt of the indication indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension.

[0040] As used in this application, the term "circuitry" may refer to one or more or all of the following:

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

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

as a mobile phone or server, to perform various functions) and

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

[0041] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0042] Embodiments herein may be implemented in software (executed by one or more processors), hardware (e.g., an application specific integrated circuit), or a combination of software and hardware. In an example embodiment, the software (e.g., application logic, an instruction set) is maintained on any one of various conventional computer-readable media. In the context of this document, a "computer-readable medium" may be any media or means that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer, with one example of a computer described and depicted, e.g., in FIG. 1. A computer-readable medium may comprise a computer-readable storage medium (e.g., memories 125, 155, 171 or other device) that may be any media or means that can contain, store, and/or transport the instructions

for use by or in connection with an instruction execution system, apparatus, or device, such as a computer. A computer-readable storage medium does not comprise propagating signals.

[0043] If desired, the different functions discussed herein
5 may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined.

[0044] Although various aspects are set out above, other aspects comprise other combinations of features from the
10 described embodiments, and not solely the combinations described above.

[0045] It is also noted herein that while the above describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several
15 variations and modifications which may be made without departing from the scope of the present invention. It should be understood that the foregoing description is only illustrative. Various alternatives and modifications can be devised by those skilled in the art. For example, features recited in the various
20 dependent claims could be combined with each other in any suitable combination(s). In addition, features from different embodiments described above could be selectively combined into a new embodiment. Accordingly, the description is intended to embrace all such alternatives, modifications and variances which
25 fall within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A method comprising:

5 copy, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel;

10 transmit the first transmission to a user equipment in a first subframe;

15 subsequently copy, for a repetition, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control
20 channel which is at least partially different than symbol numbers of the second set of symbols; and

 transmit the second transmission to the user equipment in a second subframe.

25 2. A method as in claim 1 where the first set of symbols are copied to symbol locations in a legacy long term evolution control channel region.

 3. A method as in claim 2 where the second set of symbols are copied to symbol locations in the legacy long term evolution control channel region.

4. A method as in claim 1 further comprising transmitting an indication, to the user equipment, indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension.
5. A method as in claim 1 where a same mapping is used for Ych consecutive subframes.
6. A method as in claim 1 where a mapping configuration indicates a sequence of the sets of symbols that are copied to a legacy LTE control region in a cyclical manner and the parameter Ych.
7. A method as in claim 2 where the legacy long term evolution control channel region is indicated by a RRC parameter *startSymbolBR-r13*.
8. A method as in claim 6 where the mapping configuration contains OFDM symbols that have a same Cell Specific Reference Signal (CRS) mapping as OFDM symbols in the legacy LTE control region.
9. A method as in claim 6 where the mapping configuration contain OFDM symbols without CRS, where the CRS locations in the OFDM symbols are punctured when copying the Resource Elements to the legacy LTE control region.
10. A method as in claim 6 where a sequence of sets of MPDCCH OFDM symbols is fixed, and the parameter Ych is indicated in the mapping configuration.
11. A method as in claim 6 where the parameter Ych is configurable separately for each coverage enhancement mode.
12. A method as in claim 6 where the parameter Ych is given by a configured number of hopping subframes.

13. A method as in claim 6 where the parameter Ych is different for Frequency Division Duplex and Time Division Duplex.

14. A method as in claims 1-6 where mapping is specific to at least one of Physical Resource Block (PRB), a group of PRBs, or
5 a MPDCCH resource set.

15. A method as in claim 6 where all or part of the mapping configuration is at least one of:

defined in a specification, or

given by higher layer signaling.

10 16. A method as in claim 6 where different mapping tables are defined and signaled to a user equipment with a higher layer signaling.

17. A method as in claim 1 further comprising repeating the following at least once:

15 Copy, for a repetition, another different set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in another transmission, where the another set of symbols is less than all of the symbols in the machine-type communication
20 physical downlink control channel, and where the another different set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the first and second set of symbols; and

25 transmit the another transmission to the user equipment.

18. An apparatus comprising:

at least one processor; and

at least one non-transitory memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to:

5 copy, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type
10 communication physical downlink control channel;

transmit the first transmission to a user equipment in a first subframe;

subsequently copy, for a repetition, a different second set of symbols for the machine-type
15 communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of
20 symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and

transmit the second transmission to the user equipment
25 in a second subframe.

19. An apparatus as in claim 18 where the first set of symbols are copied to symbol locations in a legacy long term evolution control channel region.

20. An apparatus as in claim 19 where the second set of symbols
30 are copied to symbol locations in the legacy long term evolution control channel region.

21. An apparatus as in claim 18 where the at least one processor and the at least one memory including the computer code are further configured to cause the apparatus to transmit an indication to the user equipment indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension.
22. An apparatus as in claim 18 where a same mapping is used for Ych consecutive subframes.
23. An apparatus as in claim 18 where a mapping configuration indicates a sequence of the sets of symbols that are copied to a legacy LTE control region in a cyclical manner and the parameter Ych.
24. An apparatus as in claim 19 where the legacy long term evolution control channel region is indicated by a RRC parameter *startSymbolBR-r13*.
25. An apparatus as in claim 23 where the mapping configuration contains OFDM symbols that have a same Cell Specific Reference Signal (CRS) mapping as OFDM symbols in the legacy LTE control region.
26. An apparatus as in claim 23 where the mapping configuration contain OFDM symbols without CRS, where the CRS locations in the OFDM symbols are punctured when copying the Resource Elements to the legacy LTE control region.
27. An apparatus as in claim 23 where a sequence of sets of MPDCCH OFDM symbols is fixed, and the parameter Ych is indicated in the mapping configuration.
28. An apparatus as in claim 23 where the parameter Ych is configurable separately for each coverage enhancement mode.

29. An apparatus as in claim 23 where the parameter Y_{ch} is given by a configured number of hopping subframes.

30. An apparatus as in claim 23 where the parameter Y_{ch} is different for Frequency Division Duplex and Time Division Duplex.

31. An apparatus as in claims 18-23 where mapping is specific to at least one of Physical Resource Block (PRB), a group of PRBs, or a MPDCCH resource set.

32. An apparatus as in claim 23 where all or part of the mapping configuration is at least one of:

defined in a specification, or

given by higher layer signaling.

33. An apparatus as in claim 23 where different mapping tables are defined and signaled to a user equipment with a higher layer signaling.

34. An apparatus as in claim 18 further comprising repeating the following at least once:

copy, for a repetition, another different set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in another transmission, where the another set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the another different set of symbols have symbol numbers which is at least partially different than symbol numbers of the first and second set of symbols; and

transmit the another transmission to the user equipment.

35. A non-transitory program storage device readable by a machine, tangibly embodying a program of instructions executable

by the machine for performing operations, the operations comprising:

copying, for a repetition, a first set of symbols for a machine-type communication physical downlink control channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel;

transmitting the first transmission to a user equipment in a first subframe;

subsequently copying, for a repetition, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the second set of symbols is less than all of the symbols in the machine-type communication physical downlink control channel, and where the first set of symbols have symbol numbers which is at least partially different than symbol numbers of the second set of symbols; and

transmitting the second transmission to the user equipment in a second subframe.

36. A non-transitory program storage device as in claim 35 where the first set of symbols are copied to symbol locations in a legacy long term evolution control channel region.

37. A non-transitory program storage device as in claim 36 where the second set of symbols are copied to symbol locations in the legacy long term evolution control channel region.

38. A non-transitory program storage device as in claim 35, the operations further comprising transmitting an indication to the user equipment indicating that a long term evolution control

channel region in a transmission will be used for machine-type communication physical downlink control channel extension.

39. A non-transitory program storage device as in claim 35 where a same mapping is used for Y_{ch} consecutive subframes.

5 40. A non-transitory program storage device as in claim 35 where a mapping configuration indicates a sequence of the sets of symbols that are copied to a legacy LTE control region in a cyclical manner and the parameter Y_{ch} .

10 41. A non-transitory program storage device as in claim 36 where the legacy long term evolution control channel region is indicated by a RRC parameter *startSymbolBR-r13*.

15 42. A non-transitory program storage device as in claim 40 where the mapping configuration contains OFDM symbols that have a same Cell Specific Reference Signal (CRS) mapping as OFDM symbols in the legacy LTE control region.

43. A non-transitory program storage device as in claim 40 where the mapping configuration contain OFDM symbols without CRS, where the CRS locations in the OFDM symbols are punctured when copying the Resource Elements to the legacy LTE control region.

20 44. A non-transitory program storage device as in claim 40 where a sequence of sets of MPDCCH OFDM symbols is fixed, and the parameter Y_{ch} is indicated in the mapping configuration.

25 45. A non-transitory program storage device as in claim 40 where the parameter Y_{ch} is configurable separately for each coverage enhancement mode.

46. A non-transitory program storage device as in claim 40 where the parameter Y_{ch} is given by a configured number of hopping subframes.

47. A non-transitory program storage device as in claim 40 where the parameter Ych is different for Frequency Division Duplex and Time Division Duplex.

48. A non-transitory program storage device as in claims 35-40
5 where mapping is specific to at least one of Physical Resource Block (PRB), a group of PRBs, or a MPDCCH resource set.

49. A non-transitory program storage device as in claim 40 where all or part of the mapping configuration is at least one of:

defined in a specification, or

10 given by higher layer signaling.

50. A non-transitory program storage device as in claim 40 where different mapping tables are defined and signaled to a user equipment with a higher layer signaling.

51. A non-transitory program storage device as in claim 35
15 further comprising repeating the following at least once:

copy, for a repetition, another different set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in another transmission, where the another set of symbols is less than
20 all of the symbols in the machine-type communication physical downlink control channel, and where the another different set of symbols have symbol numbers which is at least partially different than symbol numbers of the first and second set of symbols; and

25 transmit the another transmission to the user equipment.

52. A method comprising:

receiving an indication indicating that a long term evolution control channel region in a transmission will be

used for machine-type communication physical downlink control channel extension;

receiving a downlink transmission; and

5 based upon the receipt of the indication indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control
10 channel extension.

53. An apparatus comprising:

at least one processor; and

at least one non-transitory memory including computer program code, the at least one memory and the computer
15 program code configured to, with the at least one processor, cause the apparatus to:

receive an indication indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension;
20

receive a downlink transmission; and

based upon the receipt of the indication indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, use the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension.
25

54. A non-transitory program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine for performing operations, the operations comprising:

5 receiving an indication indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension;

receiving a downlink transmission; and

10 based upon the receipt of the indication indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the
15 machine-type communication physical downlink control channel extension.

55. An apparatus comprising:

means for copying, for a repetition, a first set of symbols for a machine-type communication physical downlink control
20 channel, for multiple subcarriers in a first transmission, where the first set of symbols is less than all of the symbols of the machine-type communication physical downlink control channel;

means for transmitting the first transmission to a user
25 equipment in a first subframe;

means for subsequently copying, for a repetition, a different second set of symbols for the machine-type communication physical downlink control channel, for the multiple subcarriers in a second transmission, where the
30 second set of symbols is less than all of the symbols in the machine-type communication physical downlink control

channel, and where the first set of symbols have symbol numbers in a structure of the machine-type communication physical downlink control channel which is at least partially different than symbol numbers of the second set of symbols; and

means for transmitting the second transmission to the user equipment in a second subframe.

56. An apparatus comprising:

means for receiving an indication indicating that a long term evolution control channel region in a transmission will be used for machine-type communication physical downlink control channel extension;

means for receiving a downlink transmission; and

means for, based upon the receipt of the indication indicating that the long term evolution control channel region will be used for the machine-type communication physical downlink control channel extension, using the long term evolution control channel region in the downlink transmission as the machine-type communication physical downlink control channel extension.

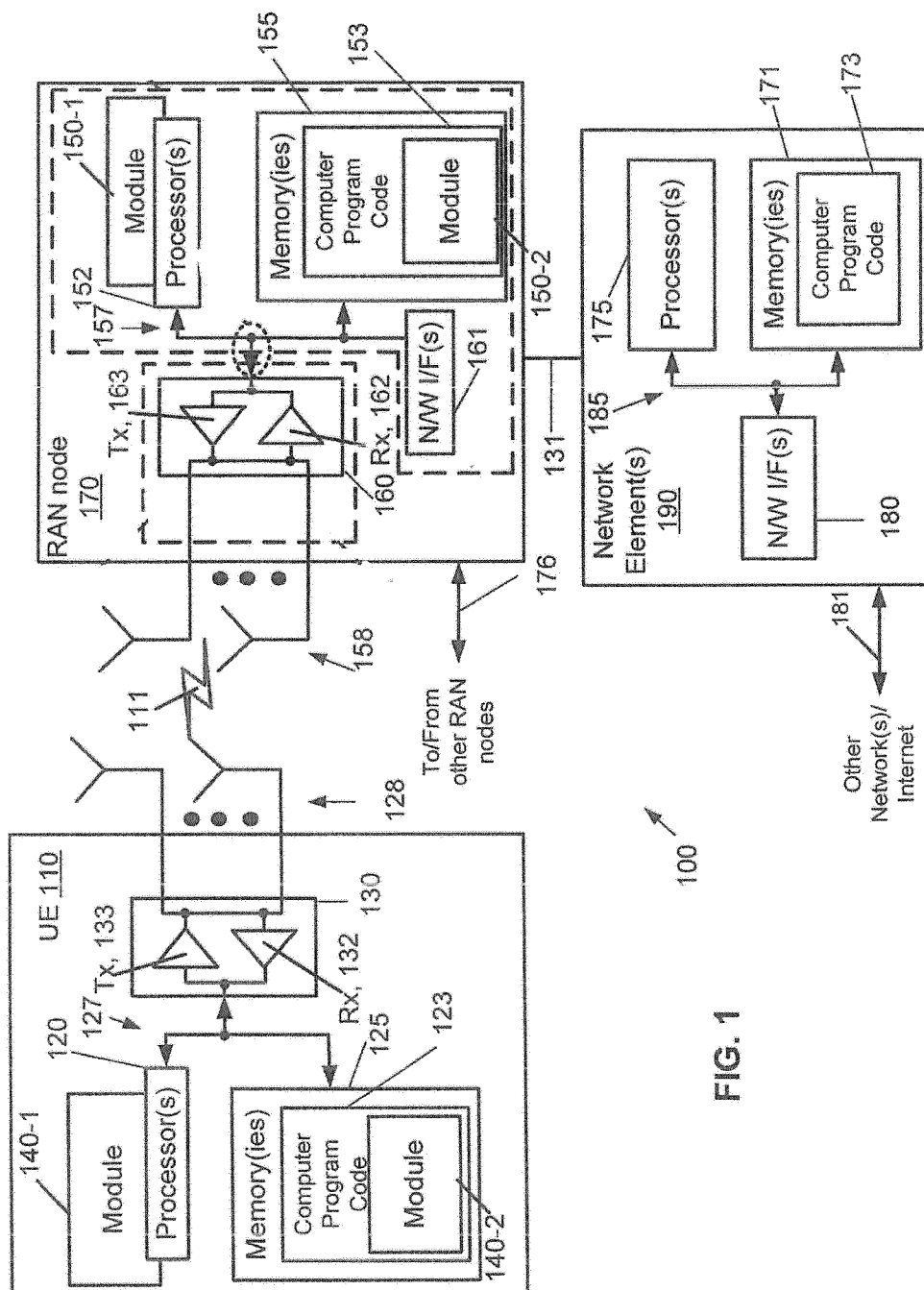


FIG. 1

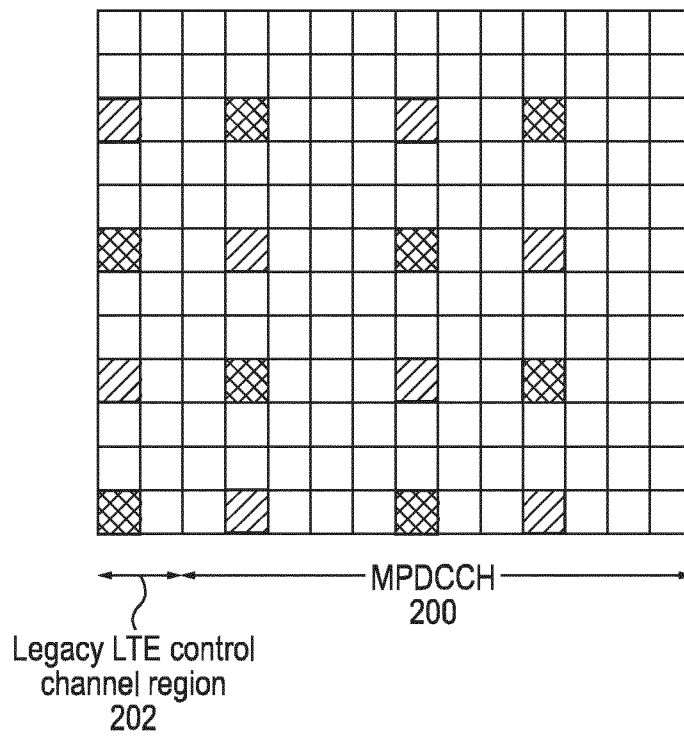


FIG. 2

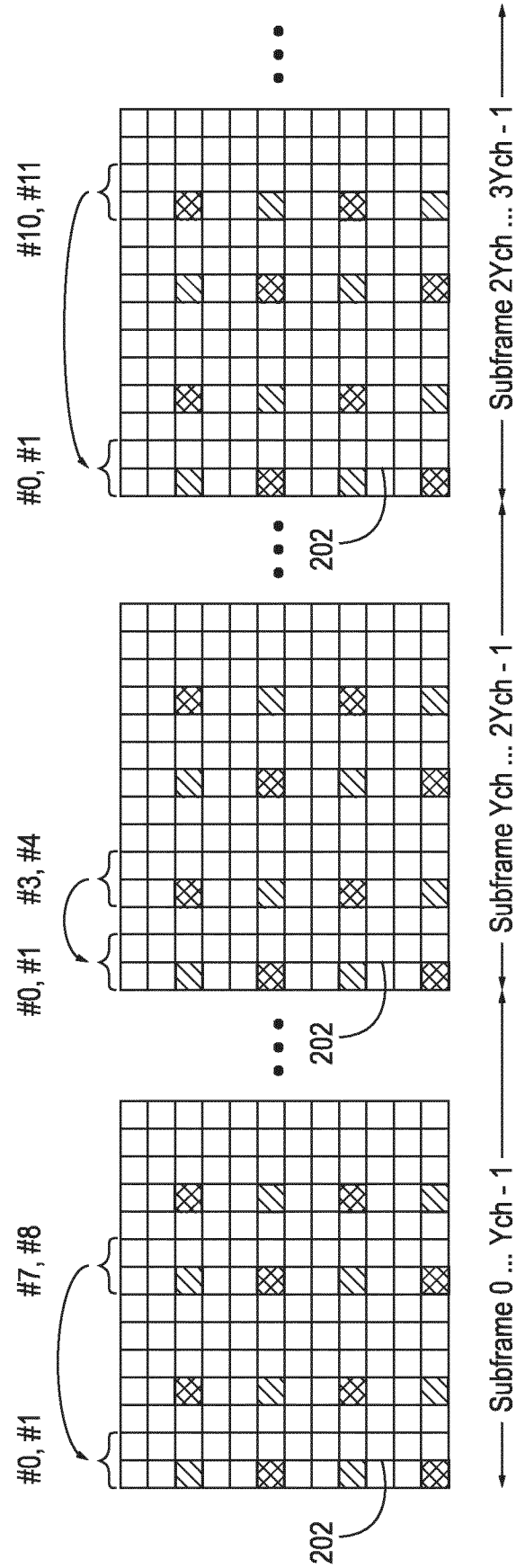


FIG. 3

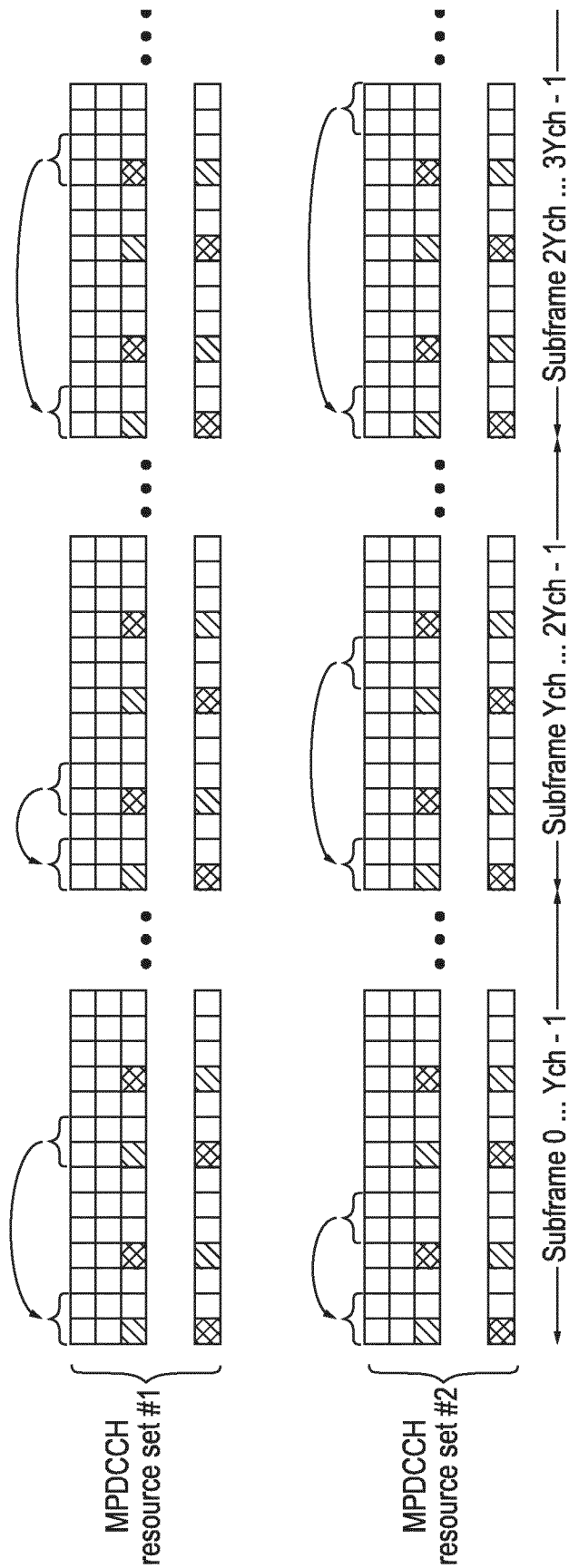


FIG. 4

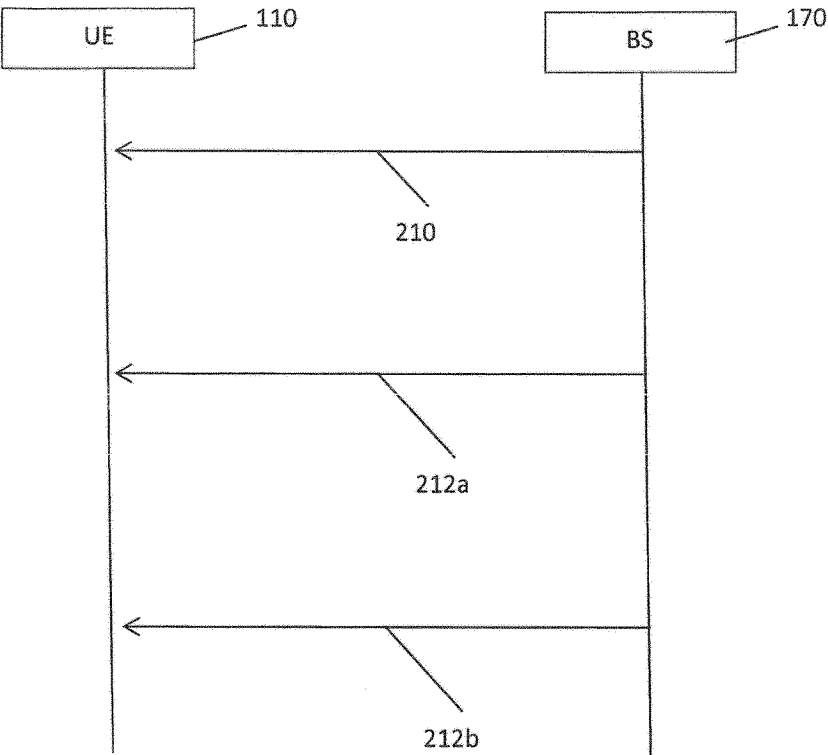


Fig. 5

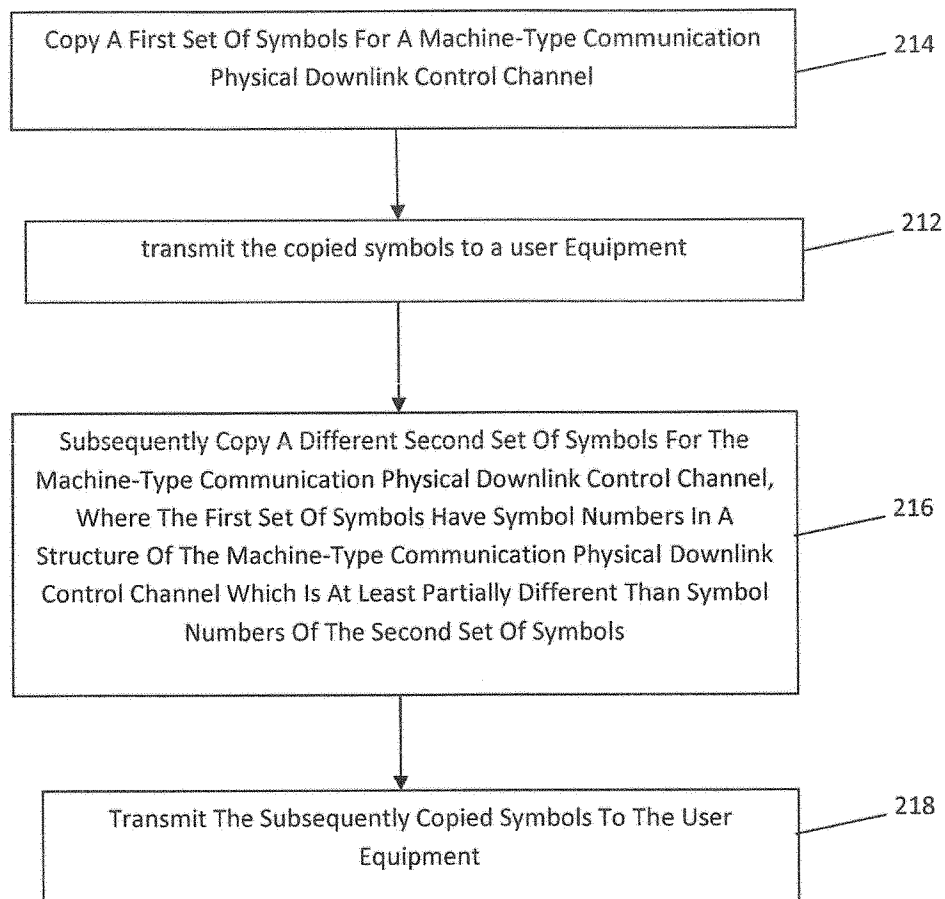


Fig. 6

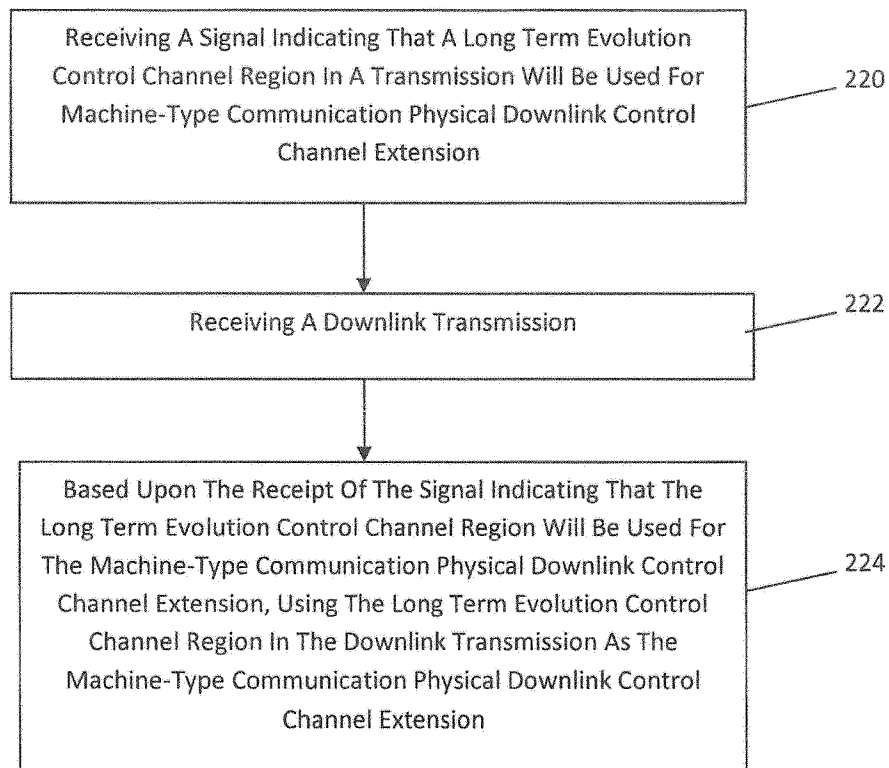


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/053432

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/08
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

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.
X	US 2018/367185 A1 (YI YUNJUNG [KR] ET AL) 20 December 2018 (2018-12-20) paragraph [0028] - paragraph [0098]; figure 4; table 3	1-56
X	US 2018/270634 A1 (KIM BONGHOE [KR] ET AL) 20 September 2018 (2018-09-20) paragraph [0051] - paragraph [0163] paragraph [0197] - paragraph [0297]; figures 9,10,12 ----- -/-	1-11, 13-28, 30-45, 47-56

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

☒ See patent family annex.

* Special categories of cited documents :

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"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

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"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

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Date of the actual completion of the international search

11 May 2020

Date of mailing of the international search report

20/05/2020

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/053432

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/245323 A1 (YOU HYANGSUN [KR] ET AL) 27 August 2015 (2015-08-27) paragraph [0077] - paragraph [0094] paragraph [0107] - paragraph [0189] paragraph [0206] - paragraph [0231]; figure 5 -----	1-11, 13-28, 30-45, 47-56

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/053432

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2018367185 A1	20-12-2018	US 2018367185 A1	20-12-2018
		WO 2017078458 A1	11-05-2017

US 2018270634 A1	20-09-2018	US 2018270634 A1	20-09-2018
		US 2019239047 A1	01-08-2019
		WO 2016114626 A1	21-07-2016

US 2015245323 A1	27-08-2015	NONE	
