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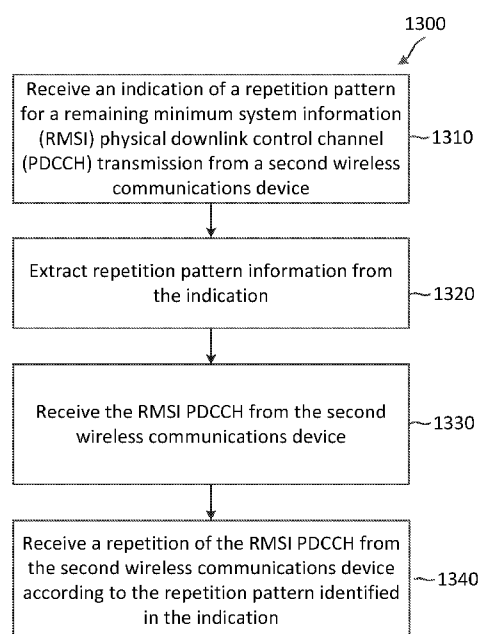


FIG. 13

(57) Abstract: Wireless communications systems and methods related to monitoring for and decoding RMSI PDCCH. A first wireless communication device receives repetition pattern information in a resource allocation table from a second wireless communications device. The information in the table identifies the frequencies and relative times when RMSI PDCCH signals will be repeated by the second wireless communications device. The first wireless communications device monitors for the repetitions at the identified times and frequencies. In some examples, every RMSI PDCCH repetition is monitored. In other examples, blind decoding is performed on only the first RMSI PDCCH. In still other examples blind decoding is performed on a varying number of repetitions determined by the success or failure of the blind decoding.

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NR-U FOR 6GHZ BAND-RMSI PDCCH REPETITION FOR LPI MODE

TECHNICAL FIELD

[0001] This application relates to wireless communication systems, and more particularly to improved downlink control channel communications, through coverage enhancement, in a wireless communication network.

INTRODUCTION

[0002] Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). A wireless multiple-access communications system may include a number of base stations (BSs), each simultaneously supporting communications for multiple communication devices, which may be otherwise known as user equipment (UE).

[0003] To meet the growing demands for expanded mobile broadband connectivity, wireless communication technologies are advancing from the long term evolution (LTE) technology to a next generation new radio (NR) technology. NR is designed to operate over a wide array of spectrum bands, for example, from low-frequency bands below about 1 gigahertz (GHz) and mid-frequency bands from about 1 GHz to about 6 GHz, to high-frequency bands such as millimeter wave (mmWave) bands. NR is also designed to operate across different spectrum types, from licensed spectrum to unlicensed and shared spectrum. Spectrum sharing enables operators to opportunistically aggregate spectrums to dynamically support high-bandwidth services. Spectrum sharing can extend the benefit of NR technologies to operating entities that may not have access to a licensed spectrum.

[0004] For example, the 6GHz unlicensed band is approved for use with NR technology, albeit with lower maximum power and a lower maximum power spectral density (PSD) than other bands. This lower power limit reduces the link budget, however, which particularly becomes an issue for lower power modes. Thus, there is a need to provide a way to improve the coverage of certain types of information transmitted between a BS and a UE within the framework of this reduced power budget.

BRIEF SUMMARY OF SOME EXAMPLES

[0005] The following summarizes some aspects of the present disclosure to provide a basic understanding of the discussed technology. This summary is not an extensive overview of all contemplated features of the disclosure, and is intended neither to identify key or critical elements of all aspects of the disclosure nor to delineate the scope of any or all aspects of the disclosure. Its sole purpose is to present some concepts of one or more aspects of the disclosure in summary form as a prelude to the more detailed description that is presented later.

[0006] For example, in an aspect of the disclosure, a method of wireless communication includes receiving, by a first wireless communications device in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode. The method further includes receiving, by the first wireless communications device, the RMSI PDCCH from the second wireless communications device. The method further includes receiving, by the first wireless communications device, a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

[0007] In an additional aspect of the disclosure, a first wireless communications device includes a transceiver configured to receive in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode. The wireless communications device further includes a transceiver configured to receive the RMSI PDCCH from the second wireless communications device. The wireless communications device further includes a transceiver configured to receive a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

[0008] In an additional aspect of the disclosure, a non-transitory computer-readable medium having program code recorded thereon, the program code includes code for causing a first wireless communications device to in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode. The non-transitory computer-readable medium further comprising code for causing the first wireless communications device to receive the RMSI PDCCH from the second wireless communications device. The non-

transitory computer-readable medium further comprising code for causing the first wireless communications device to receive a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

[0009] In an additional aspect of the disclosure, a first wireless communications device comprises means for receiving in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode. The first wireless communications device further comprises means for receiving the RMSI PDCCH from the second wireless communications device. The first wireless communications device further comprises means for receiving a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

[0010] Other aspects, features, and embodiments will become apparent to those of ordinary skill in the art, upon reviewing the following description of specific, exemplary embodiments in conjunction with the accompanying figures. While features may be discussed relative to certain embodiments and figures below, all embodiments can include one or more of the advantageous features discussed herein. In other words, while one or more embodiments may be discussed as having certain advantageous features, one or more of such features may also be used in accordance with the various embodiments discussed herein. In similar fashion, while exemplary embodiments may be discussed below as device, system, or method embodiments it should be understood that such exemplary embodiments can be implemented in various devices, systems, and methods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 illustrates a wireless communication network according to some embodiments of the present disclosure.

[0012] FIG. 2 illustrates a transmission frame for a communication network according to some embodiments of the present disclosure.

[0013] FIG. 3 illustrates a block diagram of a user equipment (UE) according to some embodiments of the present disclosure.

[0014] FIG. 4 illustrates a block diagram of an exemplary base station (BS) according to some embodiments of the present disclosure.

[0015] FIG. 5 illustrates a transmission frame structure for a communication network according to some embodiments of the present disclosure.

[0016] FIG. 6 illustrates a transmission frame for a communication network according to some embodiments of the present disclosure.

[0017] FIG. 7 illustrates a transmission frame for a communication network according to some embodiments of the present disclosure.

[0018] FIG. 8 illustrates a resource allocation table according to some embodiments of the present disclosure.

[0019] FIG. 9 illustrates a resource allocation table according to some embodiments of the present disclosure.

[0020] FIG. 10 illustrates a signaling diagram of a scheme for RMSI PDCCH monitoring according to some embodiments of the present disclosure.

[0021] FIG. 11 illustrates a signaling diagram of a scheme for RMSI PDCCH monitoring according to some embodiments of the present disclosure.

[0022] FIG. 12 illustrates a signaling diagram of a scheme for RMSI PDCCH monitoring according to some embodiments of the present disclosure.

[0023] FIG. 13 illustrates a flow diagram of a wireless communication method according to some embodiments of the present disclosure.

[0024] FIG. 14 illustrates a flow diagram of a wireless communication method according to some embodiments of the present disclosure.

[0025] FIG. 15 illustrates a flow diagram of a wireless communication method according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0026] The detailed description set forth below, in connection with the appended drawings, is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of the various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0027] This disclosure relates generally to wireless communications systems, also referred to as wireless communications networks. In various embodiments, the techniques and apparatus may be used for wireless communication networks such as code division multiple access (CDMA) networks, time division multiple access (TDMA) networks, frequency division multiple access

(FDMA) networks, orthogonal FDMA (OFDMA) networks, single-carrier FDMA (SC-FDMA) networks, LTE networks, Global System for Mobile Communications (GSM) networks, 5th Generation (5G) or new radio (NR) networks, as well as other communications networks. As described herein, the terms “networks” and “systems” may be used interchangeably.

[0028] An OFDMA network may implement a radio technology such as evolved UTRA (E-UTRA), Institute of Electrical and Electronics Engineers (IEEE) 802.11, IEEE 802.16, IEEE 802.20, orthogonal frequency division multiplexing (OFDM) and the like. UTRA, E-UTRA, and GSM are part of universal mobile telecommunication system (UMTS). In particular, LTE is a release of UMTS that uses E-UTRA. UTRA, E-UTRA, GSM, UMTS and LTE are described in documents provided from an organization named “3rd Generation Partnership Project” (3GPP), and cdma2000 is described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). These various radio technologies and standards are known or are being developed. For example, the 3rd Generation Partnership Project (3GPP) is a collaboration between groups of telecommunications associations that aims to define a globally applicable third generation (3G) mobile phone specification. 3GPP long term evolution (LTE) is a 3GPP project which was aimed at improving the UMTS mobile phone standard. The 3GPP may define specifications for the next generation of mobile networks, mobile systems, and mobile devices. The present disclosure is concerned with the evolution of wireless technologies from LTE, 4G, 5G, NR, and beyond with shared access to wireless spectrum between networks using a collection of new and different radio access technologies or radio air interfaces.

[0029] In particular, 5G networks contemplate diverse deployments, diverse spectrum, and diverse services and devices that may be implemented using an OFDM-based unified, air interface. In order to achieve these goals, further enhancements to LTE and LTE-A are considered in addition to development of the new radio technology for 5G NR networks. The 5G NR will be capable of scaling to provide coverage (1) to a massive Internet of things (IoTs) with an ultra-high density (e.g., ~1M nodes/km²), ultra-low complexity (e.g., ~10s of bits/sec), ultra-low energy (e.g., ~10+ years of battery life), and deep coverage with the capability to reach challenging locations; (2) including mission-critical control with strong security to safeguard sensitive personal, financial, or classified information, ultra-high reliability (e.g., ~99.9999% reliability), ultra-low latency (e.g., ~1 ms), and users with wide ranges of mobility or lack thereof; and (3) with enhanced mobile broadband including extreme high capacity (e.g., ~10 Tbps/km²), extreme data rates (e.g., multi-Gbps rate, 100+ Mbps user experienced rates), and deep awareness with advanced discovery and optimizations.

[0030] The 5G NR may be implemented to use optimized OFDM-based waveforms with scalable numerology and transmission time interval (TTI); having a common, flexible framework to efficiently multiplex services and features with a dynamic, low-latency time division duplex (TDD)/frequency division duplex (FDD) design; and with advanced wireless technologies, such as massive multiple input, multiple output (MIMO), robust millimeter wave (mmWave) transmissions, advanced channel coding, and device-centric mobility. Scalability of the numerology in 5G NR, with scaling of subcarrier spacing, may efficiently address operating diverse services across diverse spectrum and diverse deployments. For example, in various outdoor and macro coverage deployments of less than 3GHz FDD/TDD implementations, subcarrier spacing may occur with 15 kHz, for example over 1, 5, 10, 20 MHz, and the like bandwidth (BW). For other various outdoor and small cell coverage deployments of TDD greater than 3 GHz, subcarrier spacing may occur with 30 kHz over 80/100 MHz BW. For other various indoor wideband implementations, using a TDD over the unlicensed portion of the 5 GHz band, the subcarrier spacing may occur with 60 kHz over a 160 MHz BW. Finally, for various deployments transmitting with mmWave components at a TDD of 28 GHz, subcarrier spacing may occur with 120 kHz over a 500 MHz BW.

[0031] The scalable numerology of the 5G NR facilitates scalable TTI for diverse latency and quality of service (QoS) requirements. For example, shorter TTI may be used for low latency and high reliability, while longer TTI may be used for higher spectral efficiency. The efficient multiplexing of long and short TTIs to allow transmissions to start on symbol boundaries. 5G NR also contemplates a self-contained integrated subframe design with uplink/downlink scheduling information, data, and acknowledgement in the same subframe. The self-contained integrated subframe supports communications in unlicensed or contention-based shared spectrum, adaptive uplink/downlink that may be flexibly configured on a per-cell basis to dynamically switch between uplink and downlink to meet the current traffic needs.

[0032] Various other aspects and features of the disclosure are further described below. It should be apparent that the teachings herein may be embodied in a wide variety of forms and that any specific structure, function, or both being disclosed herein is merely representative and not limiting. Based on the teachings herein one of an ordinary level of skill in the art should appreciate that an aspect disclosed herein may be implemented independently of any other aspects and that two or more of these aspects may be combined in various ways. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, such an apparatus may be implemented or such a method may be practiced using other structure, functionality, or structure and functionality in addition to or other than one or more of the aspects set forth herein. For example, a method may be implemented as part of a system, device, apparatus,

and/or as instructions stored on a computer readable medium for execution on a processor or computer. Furthermore, an aspect may comprise at least one element of a claim.

[0033] Communications can be in the form of radio frames. A radio frame may be divided into a plurality of subframe, which can be divided into one or more slots. Each slot may be further divided into mini-slots. At the smallest level (e.g., within a slot), a resource element (RE) comprises a single subcarrier in the frequency domain, and a single OFDM symbol in the time domain. A resource element group (REG) may be comprised of a number of REs (e.g., 12) within a single OFDM symbol. A control channel element (CCE) comprises a group of REGs.

[0034] In NR, PDCCH is transmitted over a Control Resource Set (CORESET). A CORESET is a set of CCEs which is used to carry PDCCH transmissions, for example 1, 2, 4, 8, or 16 CCEs. A CORESET is generally limited to span less than the full frequency range of a radio frame. Each CORESET has an associated CCE to REG mapping. Frequencies within a CORESET can be contiguous or non-contiguous. A CORESET may span one or more OFDM symbol time periods. A set of potential PDCCH candidates is called a search space and is associated with a CORESET and can have configurable monitoring occasions defined. A BS may configure a UE with one or more search spaces for PDCCH monitoring based on the predefined CORESET. The UE may perform blind decoding in the search spaces to search for DL control information from the BS. For example, a BS may configure a UE with the BWPs, the CORESETS, and/or the PDCCH search spaces via RRC configurations.

[0035] BSs can broadcast system information associated with the network including a master information block (MIB) and remaining minimum system information (RMSI) to facilitate initial network access. A BS can indicate to a UE scheduling for RMSI to be transmitted to a UE by RMSI PDCCH. When using a part of the spectrum that has reduced power requirements, it may be advantageous to increase the bandwidth of RMSI PDCCH or otherwise enhance the coverage of RMSI PDCCH in time (or in time and frequency) to ensure reliable delivery to the UE. This may be particularly useful in lower-power modes, such as low-power indoor (LPI) mode. As used herein, the LPI mode may refer to a mode that has a maximum allowed equivalent isotropically radiated power (EIRP) and power spectral density (PSD) that is low enough that a BS may use it in communicating with a UE without contacting an automated frequency coordination (AFC) function. This is in contrast with a standard power (SP) mode, that may utilize an AFC function to coordinate what the maximum PSD and EIRP are for each frequency. The LPI mode may have lower EIRP and PSD maximum, with the UE transmit power being less than the BS transmit power. Another mode, very low-power (VLP) mode, has yet further PSD and EIRP limitations than those imposed on devices operating in LPI mode.

[0036] The present application describes mechanisms for providing repetitions of RMSI PDCCH so as to increase the effective bandwidth of the RMSI PDCCH waveform transmission (e.g., to mimic carrier aggregation). RMSI PDCCH repetitions may be in repetitions in time, either within a window of time or across windows of time. RMSI PDCCH repetitions may alternatively be repetitions in frequency, such as in an instance of time. As yet another example, both time and frequency repetitions may be used together. To facilitate this expanded coverage capability for RMSI PDCCH transmissions, according to embodiments of the present disclosure a BS can indicate to the UE when and at what frequency repetitions may occur by sending information to that effect in an MIB. The MIB may be, therefore, used to explicitly identify the repetition in time and/or frequency. This may be done by adding one or more fields to an allocation table, such as a frequency domain resource assignment (FDRA) table (such as with the same or similar format to the table provided in Section 13 of Version 16.1.0 of 3GPP TS 38.213, or equivalent), as well as including all explicit signaling in rows that have been historically reserved in the FDRA table.

[0037] For example, an additional column may specify a time repetition pattern (where used), the additional column being one column more than that currently in use. Alternatively, a frequency repetition pattern may be specified in the field/column currently used for identifying the number of RBs for a CORESET. This may be signaled a variety of ways, including for example by specifying a sequence of values, starting with a number of RBs for a first CORESET, a number of RBs as a gap, then a next number of RBs for a second CORESET, another gap, and so forth until the last number of RBs for a last CORESET is provided. This would indicate, to the UE, the number of RMSI PDCCH replicated across frequencies (e.g., different CORESETs corresponding to different RMSI PDCCHs). Moreover, the modified table may alternatively signal a combination of frequency and time repetitions for the UE to monitor. The UE can monitor the indicated repetitions according to the information in the MIB.

[0038] As another example, a UE may perform blind decoding on all or a subset of the repetitions indicated (e.g., in the MIB). To facilitate this, the BS may signal the repetition pattern in a table, such as the FDRA table in the MIB. Instead of relying upon currently reserved rows of the table, however, in some embodiments the frequency and/or time repetitions may be signaled in additional columns of the table that have not previously been included in such tables. One of the new columns may indicate the time repetition pattern by indicating the number of repetitions in time and the periodicity of the repetitions (whether intra-slot or inter-slot, for example). Another of the new columns may indicate the frequency repetition pattern by including an array with the number of frequency repetitions and the number of RBs as a guard band between each repetition (e.g., a sequence similar to that noted above that indicates a number of RMSI PDCCH replicated across

frequencies). Again, the modified table may signal a combination of frequency and time repetitions for the UE to attempt to blind decode. In this way, a legacy UE receiving the table will be able to use all of the legacy fields of the table, while updated UEs will be able to access the additional information of the new columns. While discussed with respect to rows and columns, aspects of the present disclosure may be implemented another way or combination of ways in order to signal to UEs what resources to look for replicated RMSI PDCCHs.

[0039] Using the blind decoding hypotheses support multiple power modes. For example, a UE may begin with a hypothesis that no repetitions of the RMSI PDCCH exists, and therefore just perform blind decoding on the first RMSI PDCCH. This may be done, for example, based on the information signaled in the legacy fields of a table (e.g., in MIB). If the blind decoding succeeds, then no further blind decoding may be necessary on any repetitions of the RMSI PDCCH.

Alternatively, the UE may act according to a different hypothesis that assumes repetition occurs according to the additional parameters signaled in one or both of the new columns (e.g., for some combination of time and/or frequency repetition of the RMSI PDCCH). The UE may soft combine all of the monitored resource blocks across time and/or frequency according to the signaled repetition pattern and then do blind decoding.

[0040] In some examples, the blind decoding hypothesis may need to extend across slots (e.g., where a time repetition pattern signaled in the MIB indicates that some of the replicated RMSI PDCCHs will occur in different slots from each other). In such examples, the first hypothesis may be performed at or after the start of each slot where the RMSI PDCCH is scheduled to occur. Across the slots, the UE may soft combine the duplicates of the RMSI PDCCHs monitored at each of the occasions identified in the table and then attempt blind decoding once all collected (e.g., buffered or otherwise stored). If blind decoding fails, the UE may puncture the first slot and soft combine the remaining RMSI PDCCHs in the remaining slot(s) and attempt blind decoding again. This may be repeated until the decoding is successful or the last RMSI PDCCH is left.

[0041] In yet other examples related to the different blind decoding hypotheses, the UE may try the first hypothesis (e.g., no repetition) for a set period of time (e.g., on the order of multiple slots), and then try the next hypothesis (e.g., repetition) for another set period of time. Another example may try both hypotheses within the same slot, as described in some of the examples above.

[0042] Aspects of the present disclosure can provide several benefits. For example, configuring a UE to monitor for RMSI PDCCH where the CORESETs cover different frequency ranges can provide frequency diversity. Such frequency diversity can help make the communication more robust, as any frequency-dependent weakness in the channel could be mitigated. Further, by repeating RMSI PDCCH in frequency, the effective power utilized can be increased without

exceeding the allowed power budget. This can make RMSI PDCCH more reliable. Further, repeating in time may allow coverage enhancement without increasing transmit power to stay within the allowed power budget for a given power mode (such as LPI mode). Embodiments may provide flexibility in the locations in time and frequency of the repetitions, allowing the BS and UE to optimize RMSI PDCCH transmission for the present condition in the communication environment.

[0043] FIG. 1 illustrates a wireless communication network 100 according to some aspects of the present disclosure. The network 100 may be a 5G network. The network 100 includes a number of base stations (BSs) 105 (individually labeled as 105a, 105b, 105c, 105d, 105e, and 105f) and other network entities. A BS 105 may be a station that communicates with UEs 115 and may also be referred to as an evolved node B (eNB), a next generation eNB (gNB), an access point, and the like. Each BS 105 may provide communication coverage for a particular geographic area. In 3GPP, the term “cell” can refer to this particular geographic coverage area of a BS 105 and/or a BS subsystem serving the coverage area, depending on the context in which the term is used.

[0044] A BS 105 may provide communication coverage for a macro cell or a small cell, such as a pico cell or a femto cell, and/or other types of cell. A macro cell generally covers a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscriptions with the network provider. A small cell, such as a pico cell, would generally cover a relatively smaller geographic area and may allow unrestricted access by UEs with service subscriptions with the network provider. A small cell, such as a femto cell, would also generally cover a relatively small geographic area (e.g., a home) and, in addition to unrestricted access, may also provide restricted access by UEs having an association with the femto cell (e.g., UEs in a closed subscriber group (CSG), UEs for users in the home, and the like). A BS for a macro cell may be referred to as a macro BS. A BS for a small cell may be referred to as a small cell BS, a pico BS, a femto BS or a home BS. In the example shown in FIG. 1, the BSs 105d and 105e may be regular macro BSs, while the BSs 105a-105c may be macro BSs enabled with one of three dimension (3D), full dimension (FD), or massive MIMO. The BSs 105a-105c may take advantage of their higher dimension MIMO capabilities to exploit 3D beamforming in both elevation and azimuth beamforming to increase coverage and capacity. The BS 105f may be a small cell BS which may be a home node or portable access point. A BS 105 may support one or multiple (e.g., two, three, four, and the like) cells.

[0045] The network 100 may support synchronous or asynchronous operation. For synchronous operation, the BSs may have similar frame timing, and transmissions from different BSs may be

approximately aligned in time. For asynchronous operation, the BSs may have different frame timing, and transmissions from different BSs may not be aligned in time.

[0046] The UEs 115 are dispersed throughout the wireless network 100, and each UE 115 may be stationary or mobile. A UE 115 may also be referred to as a terminal, a mobile station, a subscriber unit, a station, or the like. A UE 115 may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a tablet computer, a laptop computer, a cordless phone, a wireless local loop (WLL) station, or the like. In one aspect, a UE 115 may be a device that includes a Universal Integrated Circuit Card (UICC). In another aspect, a UE may be a device that does not include a UICC. In some aspects, the UEs 115 that do not include UICCs may also be referred to as IoT devices or internet of everything (IoE) devices. The UEs 115a-115d are examples of mobile smart phone-type devices accessing network 100. A UE 115 may also be a machine specifically configured for connected communication, including machine type communication (MTC), enhanced MTC (eMTC), narrowband IoT (NB-IoT) and the like. The UEs 115e-115k are examples of various machines configured for communication that access the network 100. A UE 115 may be able to communicate with any type of the BSs, whether macro BS, small cell, or the like. In FIG. 1, a lightning bolt (e.g., communication links) indicates wireless transmissions between a UE 115 and a serving BS 105, which is a BS designated to serve the UE 115 on the downlink and/or uplink, or desired transmission between BSs, and backhaul transmissions between BSs.

[0047] In operation, the BSs 105a-105c may serve the UEs 115a and 115b using 3D beamforming and coordinated spatial techniques, such as coordinated multipoint (CoMP) or multi-connectivity. The macro BS 105d may perform backhaul communications with the BSs 105a-105c, as well as small cell, the BS 105f. The macro BS 105d may also transmits multicast services which are subscribed to and received by the UEs 115c and 115d. Such multicast services may include mobile television or stream video, or may include other services for providing community information, such as weather emergencies or alerts, such as Amber alerts or gray alerts.

[0048] The BSs 105 may also communicate with a core network. The core network may provide user authentication, access authorization, tracking, Internet Protocol (IP) connectivity, and other access, routing, or mobility functions. At least some of the BSs 105 (e.g., which may be an example of a gNB or an access node controller (ANC)) may interface with the core network through backhaul links (e.g., NG-C, NG-U, etc.) and may perform radio configuration and scheduling for communication with the UEs 115. In various examples, the BSs 105 may communicate, either directly or indirectly (e.g., through core network), with each other over backhaul links (e.g., X1, X2, etc.), which may be wired or wireless communication links.

[0049] The network 100 may also support mission critical communications with ultra-reliable and redundant links for mission critical devices, such as the UE 115e, which may be a drone. Redundant communication links with the UE 115e may include links from the macro BSs 105d and 105e, as well as links from the small cell BS 105f. Other machine type devices, such as the UE 115f (e.g., a thermometer), the UE 115g (e.g., smart meter), and UE 115h (e.g., wearable device) may communicate through the network 100 either directly with BSs, such as the small cell BS 105f, and the macro BS 105e, or in multi-hop configurations by communicating with another user device which relays its information to the network, such as the UE 115f communicating temperature measurement information to the smart meter, the UE 115g, which is then reported to the network through the small cell BS 105f. The network 100 may also provide additional network efficiency through dynamic, low-latency TDD/FDD communications, such as in a vehicle-to-vehicle (V2V)

[0050] In some implementations, the network 100 utilizes OFDM-based waveforms for communications. An OFDM-based system may partition the system BW into multiple (K) orthogonal subcarriers, which are also commonly referred to as subcarriers, tones, bins, or the like. Each subcarrier may be modulated with data. In some instances, the subcarrier spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system BW. The system BW may also be partitioned into subbands. In other instances, the subcarrier spacing and/or the duration of TTIs may be scalable.

[0051] In some aspects, the BSs 105 can assign or schedule transmission resources (e.g., in the form of time-frequency resource blocks (RB)) for downlink (DL) and uplink (UL) transmissions in the network 100. DL refers to the transmission direction from a BS 105 to a UE 115, whereas UL refers to the transmission direction from a UE 115 to a BS 105. As noted above, the communication can be in the form of radio frames. A radio frame may be divided into a plurality of subframes or slots, for example, about 10. Each slot may be further divided into mini-slots. In a FDD mode, simultaneous UL and DL transmissions may occur in different frequency bands. For example, each subframe includes a UL subframe in a UL frequency band and a DL subframe in a DL frequency band. In a TDD mode, UL and DL transmissions occur at different time periods using the same frequency band. For example, a subset of the subframes (e.g., DL subframes) in a radio frame may be used for DL transmissions and another subset of the subframes (e.g., UL subframes) in the radio frame may be used for UL transmissions.

[0052] The DL subframes and the UL subframes can be further divided into several regions. For example, each DL or UL subframe may have pre-defined regions for transmissions of reference signals, control information, and data. Reference signals are predetermined signals that facilitate the communications between the BSs 105 and the UEs 115. For example, a reference signal can have a

particular pilot pattern or structure, where pilot tones may span across an operational BW or frequency band, each positioned at a pre-defined time and a pre-defined frequency. For example, a BS 105 may transmit cell specific reference signals (CRSs) and/or channel state information – reference signals (CSI-RSs) to enable a UE 115 to estimate a DL channel. Similarly, a UE 115 may transmit sounding reference signals (SRSs) to enable a BS 105 to estimate a UL channel. Control information may include resource assignments and protocol controls. Data may include protocol data and/or operational data. Control information, such as PDCCH etc., has been discussed above and will be described further below with respect to embodiments of the present disclosure. In some embodiments, the BSs 105 and the UEs 115 may communicate using self-contained subframes. A self-contained subframe may include a portion for DL communication and a portion for UL communication. A self-contained subframe can be DL-centric or UL-centric. A DL-centric subframe may include a longer duration for DL communication than for UL communication. A UL-centric subframe may include a longer duration for UL communication than for UL communication.

[0053] In some aspects, the network 100 may be an NR network deployed over a licensed spectrum. The BSs 105 can transmit synchronization signals (e.g., including a primary synchronization signal (PSS) and a secondary synchronization signal (SSS)) in the network 100 to facilitate synchronization. The BSs 105 can broadcast system information associated with the network 100 (e.g., including a master information block (MIB), remaining minimum system information (RMSI), and other system information (OSI)) to facilitate initial network access. In some instances, the BSs 105 may broadcast the PSS, the SSS, and/or the MIB in the form of synchronization signal blocks (SSBs) over a physical broadcast channel (PBCH) and may broadcast the RMSI and/or the OSI over a physical downlink shared channel (PDSCH).

[0054] In some aspects, a UE 115 attempting to access the network 100 may perform an initial cell search by detecting a PSS from a BS 105. The PSS may enable synchronization of period timing and may indicate a physical layer identity value. The UE 115 may then receive a SSS. The SSS may enable radio frame synchronization, and may provide a cell identity value, which may be combined with the physical layer identity value to identify the cell. The PSS and the SSS may be located in a central portion of a carrier or any suitable frequencies within the carrier.

[0055] After receiving the PSS and SSS, the UE 115 may receive a MIB. The MIB may include system information for initial network access and scheduling information for RMSI and/or OSI. After decoding the MIB, the UE 115 may receive RMSI and/or OSI. The RMSI and/or OSI may include radio resource control (RRC) information related to random access channel (RACH) procedures, paging, control resource set (CORESET) for physical downlink control channel

(PDCCH) monitoring, physical uplink control channel (PUCCH), physical uplink shared channel (PUSCH), power control, and SRS.

[0056] After obtaining the MIB, the RMSI and/or the OSI, the UE 115 can perform a random access procedure to establish a connection with the BS 105. For the random access procedure, the UE 115 may transmit a random access preamble and the BS 105 may respond with a random access response. Upon receiving the random access response, the UE 115 may transmit a connection request to the BS 105 and the BS 105 may respond with a connection response (e.g., contention resolution message).

[0057] After establishing a connection, the UE 115 and the BS 105 can enter a normal operation stage, where operational data may be exchanged. For example, the BS 105 may schedule the UE 115 for UL and/or DL communications. The BS 105 may transmit UL and/or DL scheduling grants to the UE 115 via a PDCCH. The BS 105 may transmit a DL communication signal to the UE 115 via a PDSCH according to a DL scheduling grant. The UE 115 may transmit a UL communication signal to the BS 105 via a PUSCH and/or PUCCH according to a UL scheduling grant.

[0058] In some aspects, the network 100 may operate over a system BW or a component carrier (CC) BW. The network 100 may partition the system BW into multiple bandwidth parts (BWPs) (e.g., portions). A BS 105 may dynamically assign a UE 115 to operate over a certain BWP (e.g., a certain portion of the system BW). The assigned BWP may be referred to as the active BWP. The UE 115 may monitor the active BWP for signaling information from the BS 105. The BS 105 may schedule the UE 115 for UL or DL communications in the active BWP. In some embodiments, a BS 105 may assign a pair of BWPs within the CC to a UE 115 for UL and DL communications. For example, the BWP pair may include one BWP for UL communications and one BWP for DL communications. The BS 105 may additionally configure the UE 115 with one or more CORESETs in a BWP. A CORESET may include a set of frequency resources spanning a number of symbols in time. The BS 105 may configure the UE 115 with one or more search spaces for PDCCH monitoring based on the CORESETs. The UE 115 may perform blind decoding in the search spaces to search for DL control information from the BS. In an example, the BS 105 may configure the UE 115 with the BWPs, the CORESETs, and/or the PDCCH search spaces via RRC configurations. Mechanisms for configuring search spaces are described in greater detail herein.

[0059] In some aspects, the network 100 may operate over a shared channel, which may include shared frequency bands or unlicensed frequency bands. For example, the network 100 may be an NR-U network. In such an embodiment, the BSs 105 and the UEs 115 may be operated by multiple network operating entities. To avoid collisions, the BSs 105 and the UEs 115 may employ a listen-before-talk (LBT) procedure to monitor for transmission opportunities (TXOPs) in the shared

channel. For example, a BS 105 may acquire or reserve a TXOP or a channel occupancy time (COT) in the shared channel by performing a CAT4 LBT. A CAT4 LBT refers to an LBT with a random backoff and a variable contention window. Upon passing the LBT, the BS 105 may schedule one or more UEs 115 for DL communications and/or UL communications within the acquired COT.

[0060] For example, the 6GHz band is being made available for unlicensed use (e.g., in addition to other unlicensed bands such as 5 GHz). So as to not disrupt incumbent licensed use in the band, power levels are limited depending on the context. Allowed power levels are determined by the mode of operation and the context. Currently, in the 5.925-6.425 GHz and 6.525-6.875 GHz sub-band unlicensed access points are permitted to transmit both indoors and outdoors under the control of an automated frequency control (AFC) function at higher EIRP and PSD. This is called “Standard-Power” (SP) access. A standard power access point (e.g. a BS) may be allowed 36 dBm maximum equivalent isotropic radiated power (EIRP) and 23 dBm/MHz maximum EIRP power spectral density (PSD). Meanwhile, in Low-Power indoor (LPI) access mode, a Low-Power access point may be allowed 30 dBm maximum EIRP and 5 dBm/MHz maximum EIRP PSD across the entire 1,200 MHz of the 6GHz band, without being under the control of an AFC function. In general, clients (e.g. UEs) are allowed 6 dB less power than access points in each respective mode (SP and LPI). These power limitations are lower than the 5 GHz band, for example, and may come at the expense of reduced link budget, which particularly becomes an issue for lower power modes.

[0061] According to embodiments of the present disclosure, a UE 115 attempting to access the network 100 via NR-U, such as the 6 GHz band, may receive a modified MIB. The MIB may include system information for initial network access and scheduling information for RMSI and/or OSI. For example, the MIB may include one or more additional fields in a table of the MIB used to identify the CORESET on which RMSI PDCCH is repeated. In some examples, the table may utilize additional rows that would have been reserved otherwise to signal the time and/or frequency repetition details of the RMSI PDCCH. In other examples, the table may utilize additional columns to identify the time and/or frequency repetition details, so that legacy UEs may also be supported in operating with the table information in the MIB.

[0062] After decoding the MIB, the UE 115 may monitor the identified CORESET(s) for the repetitions of the RMSI PDCCH. In some examples, the UE 115 may locate the RMSI PDCCHs as explicitly indicated in the MIB, while in other examples the UE 115 may implement one or more blind decoding hypotheses to obtain the RMSI PDCCHs. This may start with a hypothesis of no repetition. If successful, the UE 115 proceeds according to the information it locates in the identified RMSI and/or OSI. Otherwise, the UE 115 may proceed with another hypothesis that

includes soft combining the information observed at the resource elements at which RMSI PDCCH is repeated according to embodiments of the present disclosure, and then blind decoding is attempted. If that also fails, then the UE 115 may start puncturing specific instances of the repeated RMSI PDCCHs monitored (e.g., starting with the first) and repeat the soft combining and decoding until successful, as will be discussed in more detail with respect to further figures below. Once obtained, the RMSI may include information as noted above and the UE 115 may proceed with establishing a connection.

[0063] FIG. 2 is a timing diagram illustrating a transmission frame structure 200 according to some embodiments of the present disclosure. The transmission frame structure 200 may be employed by BSs such as the BSs 105 and UEs such as the UEs 115 in a network such as the network 100 for communications. In particular, the BS may communicate with the UE using time-frequency resources configured as shown in the transmission frame structure 200. In FIG. 2, the x-axes represent time in some arbitrary units and the y-axes represent frequency in some arbitrary units. The transmission frame structure 200 includes a radio frame 201. The duration of the radio frame 201 may vary depending on the embodiments. In an example, the radio frame 201 may have a duration of about ten milliseconds. The radio frame 201 includes M number of slots 202, where M may be any suitable positive integer. In an example, M may be about 10.

[0064] Each slot 202 includes a number of subcarriers 204 in frequency and a number of symbols 206 in time. The number of subcarriers 204 and/or the number of symbols 206 in a slot 202 may vary depending on the embodiments, for example, based on the channel bandwidth, the subcarrier spacing (SCS), and/or the cyclic prefix (CP) mode. One subcarrier 204 in frequency and one symbol 206 in time forms one resource element (RE) 212 for transmission.

[0065] The UE 115 may perform blind decoding in the search spaces to search for DL control information (e.g., slot format information and/or scheduling information) from the BS 105. In some examples, the UE 115 may search a subset of the search spaces based on certain rules, for example, associated with the UE 115's channel estimation and/or blind decoding capabilities. One such example of DL control information the UE 115 may be blind decoding for is a RMSI PDCCH from the BS 105. For example, according to embodiments of the present disclosure, a RMSI PDCCH may be repeated across the and/or frequency in order to increase coverage for the RMSI PDCCH while remaining within a specified PSD and EIRP (e.g., according to a low power mode such as LPI mode). The particular repetition pattern for RMSI PDCCH may be signaled by the BS 105 in one or more MIBs, such as in a modified FDRA table as will be discussed in more detail below.

[0066] FIG. 3 is a block diagram of an exemplary UE 300 according to embodiments of the present disclosure. The UE 300 may be a UE 115 in the network 100 as discussed above in FIG. 1. As

shown, the UE 300 may include a processor 302, a memory 304, a RMSI PDCCH monitor module 308, a transceiver 310 including a modem subsystem 312 and a radio frequency (RF) unit 314, and one or more antennas 316. These elements may be in direct or indirect communication with each other, for example via one or more buses.

[0067] The processor 302 may include a central processing unit (CPU), a digital signal processor (DSP), an application specific integrated circuit (ASIC), a controller, a field programmable gate array (FPGA) device, another hardware device, a firmware device, or any combination thereof configured to perform the operations described herein. The processor 302 may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0068] The memory 304 may include a cache memory (e.g., a cache memory of the processor 302), random access memory (RAM), magnetoresistive RAM (MRAM), read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read only memory (EPROM), electrically erasable programmable read only memory (EEPROM), flash memory, solid state memory device, hard disk drives, other forms of volatile and non-volatile memory, or a combination of different types of memory. In an embodiment, the memory 304 includes a non-transitory computer-readable medium. The memory 404 may store, or have recorded thereon, instructions 306. The instructions 306 may include instructions that, when executed by the processor 302, cause the processor 302 to perform the operations described herein with reference to the UEs 115 in connection with embodiments of the present disclosure, for example, aspects of FIG. 5-15. Instructions 306 may also be referred to as program code. The program code may be for causing a wireless communication device to perform these operations, for example by causing one or more processors (such as processor 302) to control or command the wireless communication device to do so. The terms “instructions” and “code” should be interpreted broadly to include any type of computer-readable statement(s). For example, the terms “instructions” and “code” may refer to one or more programs, routines, sub-routines, functions, procedures, etc. “Instructions” and “code” may include a single computer-readable statement or many computer-readable statements.

[0069] The RMSI PDCCH monitor module 308 may be implemented via hardware, software, or combinations thereof. For example, the RMSI PDCCH monitor module 308 may be implemented as a processor, circuit, and/or instructions 306 stored in the memory 304 and executed by the processor 302. In some examples, the RMSI PDCCH monitor module 308 can be integrated within the modem subsystem 312. For example, the RMSI PDCCH monitor module 308 can be implemented

by a combination of software components (e.g., executed by a DSP or a general processor) and hardware components (e.g., logic gates and circuitry) within the modem subsystem 312.

[0070] The RMSI PDCCH monitor module 308 may be used for various aspects of the present disclosure, for example, aspects of FIGS. 5-14. The RMSI PDCCH monitor module 308 is configured to receive a repetition pattern from a BS (e.g., BS 105 in FIG. 1). The repetition pattern may be contained, for example, in a table conveyed in an MIB from the BS 105. The repetition pattern may indicate the time and frequency repetitions of RMSI PDCCH transmissions from the BS. The MIB may be, therefore, used to explicitly identify the repetition in time and/or frequency. The RMSI PDCCH monitor module 308 may access this information via one or more additional fields of an allocation table, such as an FDRA table (or equivalent). This may be accessed via rows that have been historically reserved in the FDRA table, as well as in an additional column.

[0071] For example, an additional column (beyond that currently in use, for example) may specify a time repetition pattern (where used) that the RMSI PDCCH monitor module 308 accesses. Alternatively, a frequency repetition pattern may be specified in the field/column currently used for identifying the number of RBs for a CORESET. This may be signaled a variety of ways, including for example by specifying a sequence of values, starting with a number of RBs for a first CORESET, a number of RBs as a gap, then a next number of RBs for a second CORESET, another gap, and so forth until the last number of RBs for a last CORESET is provided. The RMSI PDCCH monitor module 308 may access this information and determine from it the number of RMSI PDCCH replicated across frequencies (e.g., different CORESETs corresponding to different RMSI PDCCHs). Moreover, the modified table may alternatively signal a combination of frequency and time repetitions for the RMSI PDCCH monitor module 308 to monitor. The UE 300, for example by way of the RMSI PDCCH monitor module 308, can monitor the indicated repetitions according to the information in the MIB.

[0072] In other examples, the MIB may be used to signal repetitions of RMSI PDCCH in time and/or frequency that is compatible for multiple power modes, such as SP and LPI modes. The RMSI PDCCH monitor module 308 may use the information signaled in the MIB to perform blind decoding on all or a subset of the repetitions indicated (obtained from) the MIB according to one or more hypotheses. Similar to the other example, the RMSI PDCCH monitor module 308 may access the additional information regarding repetition in a modified form of the FDRA table (as one example of a table). Instead of relying upon currently reserved rows of the table, however, in some embodiments the frequency and/or time repetitions may be signaled in additional columns of the table that have not previously been included in such tables. One of the new columns may indicate the time repetition pattern by indicating the number of repetitions in time and the periodicity of the

repetitions (whether intra-slot or inter-slot, for example). Another of the new columns may indicate the frequency repetition pattern by including an array with the number of frequency repetitions and the number of RBs as a guard band between each repetition (e.g., a sequence similar to that noted above that indicates a number of RMSI PDCCH replicated across frequencies). In this way, a legacy UE receiving the table will be able to use all of the legacy fields of the table, while updated UEs will be able to access the additional information of the new columns. While discussed with respect to rows and columns, aspects of the present disclosure may be implemented another way or combination of ways in order to signal to UEs what resources to look for replicated RMSI PDCCHs.

[0073] The RMSI PDCCH monitor module 308 may access the RMSI PDCCH information in the modified table. In one example of the blind decoding aspects, the RMSI PDCCH monitor module 308 may operate according to a first hypothesis that assumes no repetition of the RMSI PDCCH (e.g., the repetitions that would be signaled in additional/new fields of the table). For example, the first hypothesis assumes that no repetitions of the RMSI PDCCH exists, and therefore the RMSI PDCCH monitor module 308 causes the UE 300 to perform blind decoding on the first RMSI PDCCH identified in the legacy fields of the table from the MIB. If the blind decoding succeeds, then the RMSI PDCCH monitor module 308 does not cause further blind decoding (e.g., such as on any repetitions of the RMSI PDCCH identified in the added fields of the table).

[0074] The RMSI PDCCH monitor module 308 may act according to a second hypothesis that assumes repetition occurs according to the additional parameters signaled in one or both of the new columns (e.g., for some combination of time and/or frequency repetition of the RMSI PDCCH). The RMSI PDCCH monitor module 308 may cause the UE 300 to soft combine all of the monitored resource elements across time and/or frequency according to the signaled repetition pattern and then do blind decoding (e.g., by the RMSI PDCCH monitor module 308 or some other processor or controller of the UE 300).

[0075] In some examples, the blind decoding hypothesis may extend across slots (e.g., where a time repetition pattern signaled in the MIB indicates that some of the replicated RMSI PDCCHs will occur in different slots from each other). In such examples, the RMSI PDCCH monitor module 308 may attempt the first hypothesis at or after the start of each slot where the RMSI PDCCH is scheduled to occur. Across the slots, the RMSI PDCCH monitor module 308 may soft combine the duplicates of the RMSI PDCCHs monitored at each of the occasions identified in the table and then attempt blind decoding once all collected (e.g., buffered or otherwise stored). If blind decoding fails, the RMSI PDCCH monitor module 308 may puncture the first slot and soft combine the

remaining RMSI PDCCHs in the remaining slot(s) and attempt blind decoding again. This may be repeated until the decoding is successful or the last RMSI PDCCH is left.

[0076] As shown, the transceiver 310 may include the modem subsystem 312 and the RF unit 314. The transceiver 310 can be configured to communicate bi-directionally with other devices, such as the BSs 105. The modem subsystem 312 may be configured to modulate and/or encode the data from the memory 304 according to a modulation and coding scheme (MCS), e.g., a low-density parity check (LDPC) coding scheme, a turbo coding scheme, a convolutional coding scheme, a digital beamforming scheme, etc. The RF unit 314 may be configured to process (e.g., perform analog to digital conversion or digital to analog conversion, etc.) modulated/encoded data from the modem subsystem 312 (on outbound transmissions) or of transmissions originating from another source such as a UE 115 or a BS 105. The RF unit 314 may be further configured to perform analog beamforming in conjunction with the digital beamforming. Although shown as integrated together in transceiver 310, the modem subsystem 312 and the RF unit 314 may be separate devices that are coupled together at the UE 115 to enable the UE 115 to communicate with other devices.

[0077] The RF unit 314 may provide the modulated and/or processed data, e.g. data packets (or, more generally, data messages that may contain one or more data packets and other information), to the antennas 316 for transmission to one or more other devices. The antennas 316 may further receive data messages transmitted from other devices, such as MIB and RMSI PDCCHs according to embodiments of the present disclosure. The antennas 316 may provide the received data messages for processing and/or demodulation at the transceiver 310, and provide the information to the RMSI PDCCH monitor module 308. The antennas 316 may include multiple antennas of similar or different designs in order to sustain multiple transmission links. The RF unit 314 may configure the antennas 316.

[0078] In an embodiment, the UE 300 can include multiple transceivers 310 implementing different Radio Access Technologies (RATs) (e.g., NR and LTE). In an embodiment, the UE 300 can include a single transceiver 310 implementing multiple RATs (e.g., NR and LTE). In an embodiment, the transceiver 310 can include various components, where different combinations of components can implement RATs.

[0079] FIG. 4 is a block diagram of an exemplary BS 400 according to embodiments of the present disclosure. The BS 400 may be a BS 105 in the network 100 as discussed above in FIG. 1. As shown, the BS 400 may include a processor 402, a memory 404, a RMSI PDCCH module 408, a transceiver 410 including a modem subsystem 412 and a RF unit 414, and one or more antennas 416. These elements may be in direct or indirect communication with each other, for example via one or more buses.

[0080] The processor 402 may have various features as a specific-type processor. For example, these may include a CPU, a DSP, an ASIC, a controller, a FPGA device, another hardware device, a firmware device, or any combination thereof configured to perform the operations described herein. The processor 402 may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0081] The memory 404 may include a cache memory (e.g., a cache memory of the processor 402), RAM, MRAM, ROM, PROM, EPROM, EEPROM, flash memory, a solid state memory device, one or more hard disk drives, memristor-based arrays, other forms of volatile and non-volatile memory, or a combination of different types of memory. In some embodiments, the memory 404 may include a non-transitory computer-readable medium. The memory 404 may store instructions 406. The instructions 406 may include instructions that, when executed by the processor 402, cause the processor 402 to perform operations described herein, for example, aspects of FIGS. 2-3 and 6-11. Instructions 406 may also be referred to as code, which may be interpreted broadly to include any type of computer-readable statement(s) as discussed above with respect to FIG. 4.

[0082] The RMSI PDCCH module 408 may be implemented via hardware, software, or combinations thereof. For example, the RMSI PDCCH module 408 may be implemented as a processor, circuit, and/or instructions 406 stored in the memory 404 and executed by the processor 402. In some examples, the RMSI PDCCH module 408 can be integrated within the modem subsystem 412. For example, the RMSI PDCCH module 408 can be implemented by a combination of software components (e.g., executed by a DSP or a general processor) and hardware components (e.g., logic gates and circuitry) within the modem subsystem 412.

[0083] The RMSI PDCCH module 408 may be used for various aspects of the present disclosure, for example, aspects of FIGS. 5-15. The RMSI PDCCH module 408 is configured to transmit a repetition pattern to a UE (e.g., UE 115 in FIG. 1). The repetition pattern may indicate the number of time repetitions and the periodicity of the repetitions. The repetition pattern may also indicate the number of frequency repetitions and the guard band between each. The repetition pattern may include both time and frequency repetitions together. The repetition pattern may be signaled via the MIB, such as in an FDRA table as discussed above. Accordingly, the RMSI PDCCH module 408 may populate the modified portions of the FDRA table with the repetition pattern information that will be signaled to one or more UEs 115. This may include, in some embodiments, the explicit signaling via MIB that a UE 115 may implement. This may include in other embodiments the signaling that may be used by different UEs 115 in different power modes, where a given UE 115

may operate according to one or more hypothesis for blind decoding as discussed above and further below.

[0084] In some embodiments, the RMSI PDCCH module 408 may use one or more inputs or states to determine when and how to activate RMSI PDCCH repetitions. For example, the RMSI PDCCH module 408 may consider channel quality measurements, either direct or indirect. This may include, for example, the RMSI PDCCH module 408 selecting a repetition pattern with more time and/or frequency repetitions in environments where the channel quality information indicates a poor channel, and a repetition pattern (or no repetition pattern at all) in environments where the channel quality information indicates a much better channel. In addition or alternatively, the RMSI PDCCH module 408 may consider the operating mode of the BS and the UE (e.g. standard-power, low-power indoor, or very low-power modes). In other examples, the RMSI PDCCH module 408 selects the repetitions for a UE 115 according to a preset determination.

[0085] As shown, the transceiver 410 may include the modem subsystem 412 and the RF unit 414. The transceiver 410 can be configured to communicate bi-directionally with other devices, such as the UEs 115 and/or another core network element. The modem subsystem 412 may be configured to modulate and/or encode data according to a MCS, e.g., a LDPC coding scheme, a turbo coding scheme, a convolutional coding scheme, a digital beamforming scheme, etc. The RF unit 414 may be configured to process (e.g., perform analog to digital conversion or digital to analog conversion, etc.) modulated/encoded data from the modem subsystem 412 (on outbound transmissions) or of transmissions originating from another source such as a UE 115 or 400, such as on the MIB and RMSI PDCCH according to embodiments of the present disclosure. The RF unit 414 may be further configured to perform analog beamforming in conjunction with the digital beamforming. Although shown as integrated together in transceiver 410, the modem subsystem 412 and/or the RF unit 414 may be separate devices that are coupled together at the BS 105 to enable the BS 105 to communicate with other devices.

[0086] The RF unit 414 may provide the modulated and/or processed data, e.g. data packets (or, more generally, data messages that may contain one or more data packets and other information), to the antennas 416 for transmission to one or more other devices. This may include, for example, transmission of information to complete attachment to a network and communication with a UE 115 or 400 according to embodiments of the present disclosure. The antennas 416 may further receive data messages transmitted from other devices and provide the received data messages for processing and/or demodulation at the transceiver 410. The antennas 416 may include multiple antennas of similar or different designs in order to sustain multiple transmission links.

[0087] In an embodiment, the BS 400 can include multiple transceivers 410 implementing different RATs (e.g., NR and LTE). In an embodiment, the BS 400 can include a single transceiver 410 implementing multiple RATs (e.g., NR and LTE). In an embodiment, the transceiver 410 can include various components, where different combinations of components can implement RATs.

[0088] FIG. 5 illustrates a transmission frame structure 500 according to some embodiments of the present disclosure. The transmission frame structure 500 may be employed by BSs such as the BSs 400 or 105 and UEs such as the UEs 300 or 115 in a network, such as the network 100, for communications. In particular, the BS 400 may communicate with the UE 300 using time-frequency resources configured as shown in the transmission frame structure 500. In FIG. 5, the x-axes represent time in some arbitrary units and the y-axes represent frequency in some arbitrary units.

[0089] FIG. 5 illustrates four repetitions of RMSI PDCCH (RMSI PDSCH is not illustrated for simplicity and clarity in demonstrating aspects of the present disclosure). The four repetitions are exemplary – many other amounts of repetitions may occur according to embodiments of the present disclosure. Each RMSI PDCCH (510, 512, 514, and 516 as the examples in FIG. 5) may span a number of symbols represented by time span 504, such as 1-3 symbols in some examples. Each RMSI PDCCH (510, 512, 514, and 516) may span a bandwidth of some number of RBs represented by bandwidth 506. This may also be referred to as the PDCCH RMSI CORESET, or RMSI CORESET. The bandwidth 406 may be identified by one or more fields of a table, such as an FDRA table, in an MIB from a BS 400.

[0090] BS 400 may configure the UE 300 to monitor each repetition in time of RMSI PDCCH (such as the repetitions shown in timing diagram 500). The RMSI PDCCH repetitions may be inter-slot, or intra-slot, or both. For example, a slot may end at time 550, in which case the RMSI PDCCH repetitions would occur both inter-slot and intra-slot. Alternatively, the entire timing diagram 500 may be within a single slot, in which case each repetition would be intra-slot. Finally, it is anticipated that the periodicity of repetitions could be such that repetitions only occur inter-slot.

[0091] As illustrated in FIG. 5, the BS 400 may transmit RMSI PDCCH repeated in the time domain, with no repetitions in the frequency domain. The BS 400 may indicate to the UE the periodicity 502 of the repetitions, and the number of repetitions in time. The manner in which this may be done will be described in more detail with respect to the FIGS. 8-15 (e.g., explicitly indicated in one type of MIB table or another type of MIB table for use with hypothesis testing). UE 300 may decode all or a subset of the RMSI PDCCH repetitions as will be described with reference to FIGS. 10-15.

[0092] Turning now to FIG. 6, a transmission frame structure 600 is illustrated according to some embodiments of the present disclosure. The transmission frame structure 600 may be similar to transmission frame structure 500 (e.g., with RMSI PDCCH spanning a number of symbols in the time domain, and a RMSI CORESET in the frequency domain, etc.). The transmission frame structure 600 may be employed by BSs such as the BSs 400 or 105 and UEs such as the UEs 300 or 115 in a network such as the network 100 for communications.

[0093] As illustrated in FIG. 6, the BS 400 may transmit RMSI PDCCH repetitions in the frequency domain with no repetitions in the time domain. For example, RMSI PDCCH 610, 612, 614, and 616 each occupy time span 604 in the time domain, such as 1-3 symbols within a given slot. RMSI PDCCH 610, 612, 614, and 616 each have a respective bandwidth 606 occupying some number of RBs in the frequency domain. Each repetition in the frequency domain may have a guard band 608 between other repetitions. BS 400 may indicate to UE 300 the number of frequency repetitions, and their guard band size. Each amount may be specified in terms of numbers of RBs, for example. The number of repetitions illustrated in FIG. 6 in the frequency domain is exemplary – other amounts of repetitions may occur according to embodiments of the present disclosure. The manner in which the number of repetitions, sizes and locations may be indicated will be described in more detail with respect to FIGS. 8-15. UE 300 may decode all or a subset of the RMSI PDCCH repetitions as will be described with reference to FIGS. 10-15.

[0094] FIG. 7 is a timing diagram illustrating a transmission frame structure 700 according to some embodiments of the present disclosure. The transmission frame structure 700 is similar to transmission frame structures 500 and 600 in that it includes RMSI PDCCH repetitions in both the time and frequency domains. The transmission frame structure 700 may be employed by BSs such as the BSs 400 or 105 and UEs such as the UEs 300 or 115 in a network such as the network 100 for communications.

[0095] As illustrated in FIG. 7, RMSI PDCCH repetitions may span both time and frequency domains. For example, RMSI PDCCHs 710-740 may be repeated in an array with periodicity 702 in time, length 704 in time, bandwidth 706 in frequency (e.g., in number of RBs), and with guard band 708 in the frequency axis in some number of RBs. BS 400 may indicate these parameters to UE 300 in a manner such as will be described in more detail with respect to FIGS. 8-15. UE 300 may decode all or a subset of the RMSI PDCCH repetitions as will be described with reference to FIGS. 10-15.

[0096] Similar to FIG. 5, time 750 may be a slot division in timing diagram 700. If time 750 is a slot division, then the RMSI PDCCH repetitions as illustrated occur on both an inter-slot and an intra-slot basis. Alternatively, timing diagram 700 may span a single slot, in which case the

illustrated RMSI PDCCH repetitions are intra-slot. As another alternative, the periodicity of repetitions may be inter-slot.

[0097] FIG. 8 is an example of a table 800 according to some embodiments of the present disclosure. As a specific example, the table 800 may be an FDRA table that has been modified as discussed further herein. A BS (e.g. BS 400 or 105) may transmit an FDRA table 800 to a UE (e.g. 300 or 115) as part of an MIB transmission, in order to indicate to the UE 300 the type of repetition pattern, and locations in the time/frequency domains, for RMSI PDCCH.

[0098] As illustrated, FDRA table 800 the first 8 rows (i.e., indexed 0-7 in FIG. 8) used for non-repeating RMSI PDCCH. The FDRA table 800 utilizes the 8 additional rows to contain information for indicating to a UE 300 the RMSI PDCCH repetition parameters according to some embodiments of the present disclosure. The FDRA table 800 contains 6 columns, i.e. one additional column 812 beyond those that normally exist in other non-modified FDRA tables. The columns include index 802, multiplexing pattern 804, RB array 806, number of symbols 808, offset 810, and time pattern 812. The discussion herein will touch on the aspects modified according to embodiments of the present disclosure to identify time and/or frequency repetition parameters for RMSI PDCCH. As such, the fields identified by rows indexed by values 0 to 7, and by columns 802, 804, 806, 808, and 810, may be referred to also as legacy fields.

[0099] New fields correspond to the 8 reserved rows indexed from 8 to 15 in the table 800 as well as the new column, time pattern 812, that together are used to signal repetition patterns in time and/or frequency domains. The particular repetition pattern that a UE 300 should use may be identified via an index value used to index into the proper row of the table 800. For example, the MIB may use 4 bits to identify what index value between 0 and 15 the UE 300 should use in the table 800.

[0100] The rows indexed by values 8 and 9 (identified in the index 802 column) illustrate time domain repetition (with no frequency domain repetition) with the entries in time pattern column 812. The row indexed by the value 8 has a tuple with values {4, 4} in the time pattern 812 column. This represents the periodicity of repetitions and the number of overall repetitions – so, in this example, a periodicity of 4 (e.g., 4 symbols) and a total of 4 repetitions. While in the example the repetition periodicity is specified with symbols being the unit of measurement, other measurements may be used instead. The example indexed by value 9 provides the tuple value {14, 4}, indicating a periodicity of 14 symbols and a total of 4 repetitions.

[0101] As further examples, the rows indexed by values 10 and 11 (identified in the index 802 column) illustrate frequency domain repetition (with no time domain repetition) with the entries in the RB array 806 column (also referred to at times as a number of RBs per CORESET column). For

example, the row indexed by value 10 has a tuple in the RB Array 806 column with the exemplary values {48, 3, 48, 3, 48, 3, 48}. These values provide information that identifies the number of RBs per RMSI PDCCH CORESET, as well as the number of RBs per guard band between frequency domain repetitions. Thus, the first two entries of the tuple, {48, 3}, represents a first CORESET having 48 RBs in bandwidth, and 3 RBs' worth of gap in bandwidth before the next RMSI PDCCH repetition. Because the tuple {48, 3, 48, 3, 48, 3, 48} includes the value {48} four times, this illustrates four repetitions in the frequency domain at a given offset within a slot. These values represent four repetitions of RMSI PDCCH, each 48 RBs in frequency bandwidth, and with a 3 RB guard band between each one. Moreover, the number of RBs per RMSI PDCCH may depend upon the bandwidth of each repetition, such as 20 MHz, 40 MHz, 80 MHz, etc., with more RBs per repetition for the higher bandwidths, and vice versa for the lower bandwidths, further depending upon the subcarrier spacing. As another example of frequency domain repetition, the row indexed by value 11 has a tuple in the RB array 806 column with the exemplary values {192, 25, 192, 25, 192, 25, 192}, which again provides for 4 repetitions in the frequency domain, each repetition of the RMSI PDCCH using 192 RBs, with 25 RBs of guard band between each repetition. Other manners may be used to signal the repetitions and guard band in the frequency domain, such a single number to identify the number of repetitions and a single number to identify the guard band between each repetition.

[0102] As a further example, the rows indexed by values 12-15 provide for different combinations of time and frequency domain repetitions. For example, the row indexed by value 12 has a tuple with values {48, 3, 48} in the RB array 806 column. This means that the RMSI PDCCH is repeated twice in the frequency domain at a given time, with each repetition occupying 48 RBs with a 3 RB gap between them. Further, the row indexed by value 12 has a tuple with values {4, 2} in the time pattern 812 column. This means that the RMSI PDCCH also has a periodicity of 4 symbols and a total of 2 repetitions in the time domain (with two repetitions in the frequency domain at each time domain repetition in this example, pursuant to the field in the RB array 806 column). The example in the row indexed by value 13 is similar, but with 192 RBs per frequency domain repetition and a periodicity of 14 symbols instead of 4. In the example in the row indexed by value 14, there are again two repetitions in the frequency domain for each time domain instance, but with 192 RBs per frequency domain repetition, 25 RBs for the guard band, and a periodicity of 4 symbols in the time domain with 2 total time domain repetitions. The row indexed by value 15 is similar to the row indexed by value 14, but with a periodicity of 14 instead of 4 symbols.

[0103] The values in a given row of the table 800 are exemplary to illustrated aspects of the present disclosure. Depending on the number of symbols in each slot, the exemplary periodicity and

number of time repetitions of RMSI PDCCH in FRDA table 800 may represent repetitions which are either inter-slot, intra-slot, or both. With the information provided by the table 800 in an MIB, a UE 300 is able to locate what frequency and time domain resources within a slot or across slots to monitor/decode in order to obtain the RMSI PDCCH repetitions according to embodiments of the present disclosure. In this manner, the BS 400 may indicate explicitly the repetition information to the UE 300 to use.

[0104] In other embodiments, the UE 300 may use a blind-decoding based repetition approach. A BS 400 implementing this approach may thereby support multiple power modes with one MIB signaling. To support this, a different table structure (e.g., FDRA table) may be provided as illustrated in FIG. 9, which provides an example of a FDRA table 900 according to some embodiments of the present disclosure. A BS (e.g. BS 400 or 105) may transmit an FDRA table 900 to a UE (e.g. 300 or 115) as part of an MIB transmission.

[0105] In FDRA table 900, the first 8 rows (indexed by values 0-7 in the index 902 column) may be used for non-repeating RMSI PDCCH, but unlike FDRA table 800, the table 900 does not utilize the 8 additional rows (e.g., indexed by values 8-15 in the index 902 column) or provide tuples of information in the RB array 906. Instead, FRDA table 900 contains two additional columns, time pattern 912 column and frequency pattern 914 column (which may alternatively be in a different order to each other and/or the other columns, so long as the BS 400 and UE 300 know the order).

[0106] The FDRA table 900 supports so-called legacy UEs (e.g., operating according to a different power mode such as SP mode) without requiring separate signaling for UEs updated to support embodiments of the present disclosure for RMSI PDCCH repetitions. The legacy UEs may not even recognize the additional information in the newly-added columns time pattern 912 and frequency pattern 914. In this way, legacy UEs that are not able to interpret repetition information may still use the first five columns of FDRA table 900, and still function by ignoring any repetitions. Similar to the tuples in time pattern 812 column from FIG. 8, the tuples in the time pattern 912 column of FIG. 9 contain time repetition information for RMSI PDCCH. The tuples indicate the periodicity, and the number of repetitions for a given RMSI PDCCH. Similar again to FIG. 8, some rows may identify repetition in the time domain only, while other rows may identify repetition in the frequency domain only, while yet others may identify repetition in the time and frequency domains.

[0107] For example, the row indexed by the value 0 illustrates an example with repetition in both time and frequency domains. The row indexed by 0 has a tuple with values {4, 2} in the time pattern 912 column, meaning that the RMSI PDCCH repetition has a periodicity of 4 symbols and a total of 2 repetitions in the time domain. Further, the row indexed by value 0 identifies a frequency repetition pattern with the tuple {3, 2} in the frequency pattern 914 column. This identifies the

number of RBs per guard band, and the number of repetitions in the frequency domain. For example, with the tuple {3, 2} there are identified 3 RBs per guard band, and 2 frequency domain repetitions (e.g., of the CORESET 0 for RMSI PDCCH repetition). The rows indexed by values 1, 4, and 5 likewise identify time and frequency domain repetitions. The rows indexed by values 2 and 6 provide examples of rows that specify repetitions in the time domain only (e.g., with no entries in their frequency pattern fields or zero values), and the rows indexed by values 3 and 7 provide examples of rows that specify repetitions in the frequency domain only (e.g., with no entries in their time pattern fields or zero values).

[0108] Depending on the number of symbols in each slot, the exemplary periodicity and number of time repetitions of RMSI PDCCH in FRDA table 900 may represent repetitions which are either inter-slot, intra-slot, or both.

[0109] FIG. 10 is a signaling diagram illustrating a communication method 1000 according to some embodiments of the present disclosure. The method 1000 may be implemented between a BS (e.g., BS 105 or BS 400) and a UE (e.g., the UE 115 or UE 300). In the illustration of FIG. 10, the first device 1002 may be an example of the UE 300 and the second device 1004 may be an example of the BS 400. The method 1000 may employ similar mechanisms as in the structures 200 and/or 500 described above with respect to FIGS. 2 and 5 respectively, and/or method 1400 described herein with respect to FIG. 15. In particular, aspects of FIG. 10 illustrate a scenario where the repetition information is explicitly indicated via MIB.

[0110] At action 1006, the second device 1004 transmits a resource assignment table to the first device 1002. The resource assignment may include configuration information for defining repetitions of RMSI PDCCH in time and/or frequency. In the example of FIG. 10, method 1000 illustrates RMSI PDCCH repetition in time only. The resource assignment table may be a FDRA table similar to tables 800 or 900 in FIGS. 8 and 9 respectively, and thus the action 1006 may involve transmitting the resource assignment table via MIB to the first device 1002.

[0111] The first device 1002 (e.g., UE 300), after receiving the resource assignment table, extracts information from the resource assignment table at block 1008. For example, extracting periodicity of time repetitions, number of time repetitions, bandwidth of each repetition, guard band size of each frequency repetition, and/or number of frequency repetitions. The format of this information may be in one of the forms described with respect to FIGS. 8 or 9, or some other format. In the specific example of FIG. 10, this involves extracting the periodicity and number of repetitions (as the example relates to time domain repetition).

[0112] At action 1010, the second device 1004 transmits the first RMSI PDCCH to the first device 1002.

[0113] At blocks 1012 and 1014, the first and second device respectively wait for the next transmission. The devices may still be performing other actions during this time, but the periodicity of the repetitions identifies the amount of time between RMSI PDCCH 1010 and RMSI PDCCH 1016. The time between repetitions is contained in the resource assignment table which was transmitted at action 1006 (e.g., the periodicity parameter).

[0114] At action 1016, the second device 1004 transmits a RMSI PDCCH to the first device 1002. At block 1018 and 1020, the first device 1002 and second device 1004 each respectively wait for another periodicity time.

[0115] At action 1022, the second device 1004 transmits a RMSI PDCCH to the first device 1002. This method illustrates a first RMSI PDCCH transmission with two repetitions. More or fewer repetitions may be indicated by the second device 1004.

[0116] FIG. 11 is a signaling diagram illustrating a communication method 1100 according to some embodiments of the present disclosure. In contrast to the method 1000, where RMSI PDCCH repetition was over the time domain only, RMSI PDCCH repetition in method 1100 is only over the frequency domain. In the illustration of FIG. 11, the first device 1102 may be an example of the UE 300 and the second device 1104 may be an example of the BS 400. The method 1100 may employ similar mechanisms as in the structure 200 and 600 described above with respect to FIGS. 2 and 6 respectively, and/or method 1400 described herein with respect to FIG. 14.

[0117] At action 1106, the second device 1104 transmits a resource assignment table to the first device 1102. The resource assignment may include configuration information for defining repetitions of RMSI PDCCH in time and/or frequency. In the example of FIG. 11, method 1100 illustrates RMSI PDCCH repetition in frequency only. The resource assignment table may be a FDRA table similar to tables 800 or 900 in FIGS. 8 and 9 respectively, and thus the action 1106 may involve transmitting the resource assignment table via MIB to the first device 1102.

[0118] The first device 1102 (e.g., UE 300), after receiving the resource assignment table, extracts information from the resource assignment table at block 1108. In the specific example of FIG. 11, this includes extracting the bandwidth of each repetition, guard band size of each frequency repetition, and/or number of frequency repetitions.

[0119] At actions 1110, 1112, and 1114, RMSI PDCCH is transmitted at different frequencies. The frequencies on which they are transmitted are those as defined in the resource assignment table, e.g. in terms of number of RBs per RMSI PDCCH repetition and number of RBs per guard band between repetitions. These may be transmitted substantially simultaneously to each other, such as all on the same symbol in time. The first device 1102 receives the RMSI PDCCH repetitions, which

by being repeated in the frequency domain may result in additional transmit power from the second device 1104.

[0120] In further embodiments, aspects of FIGs. 10 and 11 may be combined with respect to scenarios where RMSI PDCCH is repeated in both the time and frequency domains, such as illustrated in FIG. 7 above and identified by some of the rows in FIG. 8's table 800 (such as indexed by values 12-15).

[0121] In other embodiments, the RMSI PDCCH repetitions may be recovered using several UE blind decoding hypotheses. FIG. 12 is a signaling diagram illustrating a communication method 1200 according to some embodiments of the present disclosure based on blind decoding hypotheses aspects. In the illustration of FIG. 12, the first device 1202 may be an example of the UE 300 and the second device 1204 may be an example of the BS 400.

[0122] At action 1206, the second device 1204 transmits a resource assignment table to the first device 1202. The resource assignment may include configuration information for defining repetitions of RMSI PDCCH in time and/or frequency. This may be in an MIB from the second device 1204. Method 1200 may involve RMSI PDCCH repetition in time only, frequency domain repetition only, or a combination of time and frequency domain repetition. The resource assignment table may be a FDRA table similar to table 900 in FIG. 9, for example.

[0123] The first device 1202 (e.g., UE 300), after receiving the repetition pattern in the form of a resource assignment table, extracts information from the repetition pattern at block 1208. For example, extracting periodicity of time repetitions, number of time repetitions, bandwidth of each repetition, guard band size of each frequency repetition, and/or number of frequency repetitions.

[0124] At action 1210, the second device 1204 transmits the first RMSI PDCCH to the first device 1202. Under a default condition, also referred to herein as a first hypothesis for blind decoding, the first device 1202 assumes that no RMSI PDCCH repetition occurs, and instead just looks for the first RMSI PDCCH transmission to occur. This may be based on the legacy fields of the resource assignment table, such as may be used by a legacy UE.

[0125] At action 1212, the first device 1202 may attempt to blind decode the RMSI PDCCH received at action 1210. If the first device 1202 is successful in blind decoding the RMSI PDCCH received at action 1210, then no further blind decoding is necessary and the method 1200 may end. If, instead, the blind decoding is not successful, then the method 1200 proceeds to block 1214 and a second hypothesis that assumes the repetition identified by the resource assignment table (e.g., time, frequency, or a combination of time/frequency domains).

[0126] At block 1214, the first device 1202 buffers the information received at the RMSI PDCCH resources at action 1210 and waits for the next scheduled RMSI PDCCH as identified by the

resource assignment table (if time domain repetitions occur). Alternatively, where the repetitions are in the frequency domain, then the actions at blocks 1214-1228 with respect to receiving and storing RMSI PDCCH repetitions may all occur around the same time with the frequency domain repetitions. Further, there may be a combination of time and frequency domain repetitions.

[0127] As a result of time domain repetitions, the first device 1202 waits at block 1214 and the second device 1204 likewise waits at block 1216 for the specified period of time (e.g., number of symbols specified by the periodicity parameter).

[0128] At action 1218, the second device 1204 repeats the RMSI PDCCH transmission to the first device 1202.

[0129] At action 1220, the first device 1202 may receive the RMSI PDCCH transmitted at action 1218, and at action 1222 buffers the RMSI PDCCH and waits for the next RMSI PDCCH (in situations where yet further repetitions in the time domain were identified from the resource assignment table). Likewise, at action 1224 the second device 1204 waits for the next scheduled transmission occasion for the RMSI PDCCH repetition.

[0130] At action 1226, the second device 1204 repeats the RMSI PDCCH transmission to the first device 1202. In this example, there are three total repetitions in the time domain of the RMSI PDCCH, with a periodicity (e.g., in number of symbols) that the first device 1202 used to determine how long to wait for the next RMSI PDCCH repetition.

[0131] At block 1228, the first device 1202 may soft combine the three RMSI PDCCHs (e.g., the received information at the identified resource blocks). In particular, the first device 1202 may soft combine across all of the monitored resource blocks across time and/or frequency according to the signaled repetition pattern in the resource assignment table. Once the monitored resource blocks are soft combined, the first device 1202 may attempt to blind decode to recover the information contained in the RMSI PDCCH.

[0132] If successful in blind decoding, the method 1200 may end after block 1228. Alternatively, if blind decoding was not successful at block 1228, the method 1200 may proceed to block 1230. At block 1230, the first device 1202 may puncture the first instance of RMSI PDCCH still stored for blind decoding, and then do blind decoding on the remaining soft combined RMSI PDCCH repetitions. For example, a first puncture may drop the RMSI PDCCH repetition received from action 1210 (the first transmission, for example). This may continue, with further repetitions being punctured, until blind decoding is successful or the last RMSI PDCCH repetition remains for decoding.

[0133] In some examples, the second blind decoding hypothesis may need to extend across slots (e.g., where a time repetition pattern signaled in the MIB indicates that some of the replicated RMSI

PDCCHs will occur in different slots from each other). As an example, each of the RMSI PDCCH repetitions transmitted at actions 1210, 1218, and 1226 may occur in different slots from one another (other variations may occur, such as multiple repetitions in a slot, also extending across more than one slot). In such examples, the first hypothesis (as explained with respect to block 1212 above) may be performed at or after the start of each slot where the RMSI PDCCH is scheduled to occur. Across the slots, the first device 1202 may soft combine the duplicates of the RMSI PDCCHs monitored at each of the occasions identified in the table (and received at blocks 1212, 1220, and 1228 in the example of FIG. 12) and then attempt blind decoding once all collected (e.g., buffered or otherwise stored). If blind decoding fails, the first device 1202 may puncture the first slot and soft combine the remaining RMSI PDCCHs in the remaining slot(s) and attempt blind decoding again, as discussed with respect to block 1230 above already. This may be repeated until the decoding is successful or the last RMSI PDCCH is left.

[0134] FIG. 13 is a flow diagram of a communication method 1300 according to some embodiments of the present disclosure. Steps of the method 1300 can be executed by a computing device (e.g., a processor, processing circuit, and/or other suitable component) of a wireless communication device or other suitable means for performing the steps. For example, a wireless communication device, such as the UE 115 or UE 300, and may utilize one or more components, such as the processor 302, the memory 304, the RMSI PDCCH monitor module 308, the transceiver 310, the modem 312, and the one or more antennas 316, to execute the steps of method 1300. The method 1300 may employ similar mechanisms as in the structure described above with respect to FIGS. 5-12. As illustrated, the method 1300 includes a number of enumerated steps, but embodiments of the method 1300 may include additional steps before, after, and in between the enumerated steps. In some embodiments, one or more of the enumerated steps may be omitted or performed in a different order.

[0135] At block 1310, a UE 300 receives an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a BS 400. This repetition pattern indication may be in the form of an FDRA table such as those discussed with respect to FIGS. 8 and 9. As a specific example, the table illustrated in FIG. 8 may be used to explicitly signal to the UE 300 where repetitions will occur.

[0136] At block 1320, the UE 300 extracts repetition pattern information from the indication, which may specify time domain repetitions only, frequency domain repetitions only, or a combination of time and frequency domain repetitions. For example, the UE 300 may extract periodicity of time repetitions, number of time repetitions, bandwidth of each repetition, guard band size of each frequency repetition, and/or number of frequency repetitions.

[0137] At block 1330, the UE 300 receives the RMSI PDCCH from the BS.

[0138] At block 1340, the UE 300 receives a repetition of the RMSI PDCCH from the BS according to the repetition pattern defined in the indication. In some examples, this may be occurring at the same or similar time as block 1330 where the repetition pattern is simply in the frequency domain. In other examples, this may be over time according to the repetition pattern specified in the time domain. In yet other examples, there may be multiple repetitions across frequency at a given time as well as multiple repetitions over time (with multiple repetitions across frequency at each instance).

[0139] With the additional repetitions of RMSI PDCCH, coverage for RMSI PDCCH is enhanced and/or transmit power increased (such as where repeated in frequency), and the UE 300 attempts to decode the RMSI PDCCH combined from the repeated transmissions.

[0140] FIG. 14 is a flow diagram of a communication method 1400 according to some embodiments of the present disclosure. Steps of the method 1400 can be executed by a computing device (e.g., a processor, processing circuit, and/or other suitable component) of a wireless communication device or other suitable means for performing the steps. For example, a wireless communication device, such as the UE 115 or UE 300, and may utilize one or more components, such as the processor 302, the memory 304, the RMSI PDCCH monitor module 308, the transceiver 310, the modem 312, and the one or more antennas 316, to execute the steps of method 1400. The method 1400 may employ similar mechanisms as in the structure described above with respect to FIGS. 5-7 and methods of FIGS. 10-13. As illustrated, the method 1400 includes a number of enumerated steps, but embodiments of the method 1400 may include additional steps before, after, and in between the enumerated steps. In some embodiments, one or more of the enumerated steps may be omitted or performed in a different order.

[0141] At block 1410, a UE 300 receives an indication of a repetition pattern for a RMSI PDCCH transmission from a BS 400. For example, an FDRA table such as FDRA table 800 or 900 contained in an MIB. As a specific example, the table illustrated in FIG. 9 may be used in combination with blind decoding hypotheses as discussed below.

[0142] At block 1420, the UE 300 assumes that no repetition pattern exists according to a first hypothesis. This may involve the UE 300 extracting information regarding where to locate a non-repeating RMSI PDCCH from legacy fields of the resource assignment table (e.g., table 900).

[0143] At block 1430, the UE 300 receives the RMSI PDCCH from the BS 400.

[0144] At block 1440, the UE 300 performs a first blind decoding on the RMSI PDCCH based on the assumption of the first hypothesis, e.g. that no RMSI PDCCH repetitions are occurring.

[0145] At decision block 1450, the UE 300 determines whether the blind decoding was successful. If the blind decoding was successful, then the method 1400 proceeds to block 1460. At block 1460, the UE 300 stops blind decoding. This may allow the UE 300 to run more efficiently when the blind decoding is not necessary, as well as enables the BS 400 to use one MIB that may be applicable to different UEs in different power modes, such as in SP and LPI modes.

[0146] Returning to decision block 1450, if instead the UE 300 determines that the blind decoding was not successful, then the method 1400 proceeds to block 1470. At block 1570, the UE 300 assumes that the repetition pattern exists according to a second hypothesis, as specified according to new fields of the table 900 as received at block 1410.

[0147] At block 1480, the UE 300 performs additional blind decoding on additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions. This may occur in time and/or frequency domains, according to the various examples given with respect to the other figures above.

[0148] The UE 300, as part of the blind decoding of block 1480, may soft combine the RMSI PDCCHs across all of the monitored resource blocks across time and/or frequency according to the signaled repetition pattern in the resource assignment table. Once the monitored resource blocks are soft combined, the UE 300 may attempt to blind decode to recover the information contained in the RMSI PDCCH.

[0149] At decision block 1490, if the blind decoding is successful from block 1480 (e.g., after soft combining the repeated RMSI PDCCH), then the method 1400 proceeds to block 1460 and ends as noted above. If, instead, blind decoding was not successful, then the method 1400 may proceed to block 1495.

[0150] At block 1495, the UE 300 may puncture the first instance of RMSI PDCCH still stored for blind decoding. The method 1400 may then return to block 1480 and do blind decoding on the remaining soft combined RMSI PDCCH repetitions. This may continue (e.g., to decision block 1490, ending at block 1460, or puncturing at block 1495), with further repetitions being punctured, until blind decoding is successful or the last RMSI PDCCH repetition remains for decoding.

[0151] In some examples, the second blind decoding hypothesis may need to extend across slots (e.g., where a time repetition pattern signaled in the MIB indicates that some of the replicated RMSI PDCCHs will occur in different slots from each other). As an example, each of the RMSI PDCCH repetitions may occur in different slots from one another (other variations may occur, such as multiple repetitions in a slot, also extending across more than one slot). In such examples, the first hypothesis may be performed at or after the start of each slot where the RMSI PDCCH is scheduled to occur. Across the slots, the UE 300 may soft combine the duplicates of the RMSI PDCCHs

monitored at each of the occasions identified in the table and then attempt blind decoding once all collected (e.g., buffered or otherwise stored). If blind decoding fails, the UE 300 may puncture the first slot and soft combine the remaining RMSI PDCCHs in the remaining slot(s) and attempt blind decoding again. This may be repeated until the decoding is successful or the last RMSI PDCCH is left.

[0152] FIG. 15 is a flow diagram of a communication method 1500 according to some embodiments of the present disclosure. Steps of the method 1500 can be executed by a computing device (e.g., a processor, processing circuit, and/or other suitable component) of a wireless communication device or other suitable means for performing the steps. For example, a wireless communication device, such as the BS 105 or 400, and may utilize one or more components, such as the processor 402, the memory 404, the RMSI PDCCH module 408, the transceiver 410, the modem 412, and the one or more antennas 416, to execute the steps of method 1500. The method 1500 may employ similar mechanisms as in the structure described above with respect to FIGS. 5-9. As illustrated, the method 1500 includes a number of enumerated steps, but embodiments of the method 1500 may include additional steps before, after, and in between the enumerated steps. In some embodiments, one or more of the enumerated steps may be omitted or performed in a different order.

[0153] At block 1510, a BS 400 prepares an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission to be transmitted to a UE 300. The BS 400 may prepare this repetition pattern indication in the form of an FDRA table such as those discussed with respect to FIGS. 8 and 9.

[0154] At block 1520, the BS 400 transmits the indication to the UE 300, which may specify time domain repetitions only, frequency domain repetitions only, or a combination of time and frequency domain repetitions. The UE 300 may extract this information as discussed with respect to the figures above.

[0155] At block 1530, the BS 400 transmits the RMSI PDCCH to the UE 300. In embodiments where the UE 300 is implementing the two hypothesis, this may be where the UE 300 implements the first hypothesis and stops blind decoding if successful.

[0156] At block 1540, the BS 400 transmits a repetition of the RMSI PDCCH according to the repetition pattern defined in the indication. In some examples, this may be occurring at the same or similar time as block 1530 where the repetition pattern is simply in the frequency domain. In other examples, this may be over time according to the repetition pattern specified in the time domain. In yet other examples, there may be multiple repetitions across frequency at a given time as well as multiple repetitions over time (with multiple repetitions across frequency at each instance). Where

this was an explicit indicate to the UE 300, the UE 300 may use this information to access the RMSI PDCCH with greater coverage and/or power. Where the UE 300 is implementing the hypothesis, the UE 300 may apply the second hypothesis and soft combine the repetitions and attempt blind decoding.

[0157] Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0158] The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (*e.g.*, a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

[0159] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, “or” as used in a list of items (for example, a list of items prefaced by a phrase such as “at least one of” or “one or more of”) indicates an inclusive list such that, for example, a list of [at least one of A, B, or C] means A or B or C or AB or AC or BC or ABC (*i.e.*, A and B and C).

[0160] As those of some skill in this art will by now appreciate and depending on the particular application at hand, many modifications, substitutions and variations can be made in and to the materials, apparatus, configurations and methods of use of the devices of the present disclosure without departing from the spirit and scope thereof. In light of this, the scope of the present

disclosure should not be limited to that of the particular embodiments illustrated and described herein, as they are merely by way of some examples thereof, but rather, should be fully commensurate with that of the claims appended hereafter and their functional equivalents.

WHAT IS CLAIMED IS:

1. A method of wireless communication, comprising:
receiving, by a first wireless communications device in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;
receiving, by the first wireless communications device, the RMSI PDCCH from the second wireless communications device; and
receiving, by the first wireless communications device, a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.
2. The method of claim 1, wherein the indication of the repetition pattern comprises a resource assignment table.
3. The method of claim 2, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.
4. The method of claim 3, further comprising:
extracting, by the first wireless communications device, an identification of the periodicity and the number of repetitions from a field in the resource assignment table.
5. The method of claim 4, wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.
6. The method of claim 3, wherein the periodicity comprises an inter-slot periodicity.
7. The method of claim 3, wherein the periodicity comprises an intra-slot periodicity.
8. The method of claim 3, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.

9. The method of claim 2, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
10. The method of claim 9, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.
11. The method of claim 10, further comprising:
extracting, by the first wireless communications device, the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table.
12. The method of claim 11, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
13. The method of claim 9, wherein the plurality of frequency bands comprises a second frequency band that occupies a larger bandwidth than a first frequency band for the RMSI PDCCH.
14. The method of claim 2, wherein the repetition RMSI PDCCH transmissions are received at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
15. The method of claim 2, further comprising:
assuming, by the first wireless communications device, that no repetition pattern exists; and
performing, by the first wireless communications device, a first blind decoding on the RMSI PDCCH based on the assumption.
16. The method of claim 15, further comprising:
stopping, by the first wireless communications device, the first blind decoding in response to successfully decoding the RMSI PDCCH.
17. The method of claim 15, further comprising:

assuming, by the first wireless communications device in response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists; and

performing, by the first wireless communications device, a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists, the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.

18. The method of claim 17, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.

19. The method of claim 18, further comprising:

extracting, by the first wireless communications device, an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index value.

20. The method of claim 18, wherein the periodicity comprises an intra-slot periodicity.

21. The method of claim 18, wherein the periodicity comprises an inter-slot periodicity.

22. The method of claim 21, further comprising:

repeating, by the first wireless communications device, the first blind decoding on the RMSI PDCCH at each slot according to the periodicity;

soft combining, by the first wireless communications device, additional RMSI PDCCH candidates for the second blind decoding; and

performing, by the first wireless communications device, the second blind decoding on the soft combined additional RMSI PDCCH candidates.

23. The method of claim 22, further comprising:

puncturing, by the first wireless communications device, a first candidate from the soft combined additional RMSI PDCCH candidates in response to the second blind decoding failing; and

performing, by the first wireless communications device, the second blind decoding on the punctured soft combined additional RMSI PDCCH candidates.

24. The method of claim 23, further comprising:
repeating, by the first wireless communications device, the puncturing and the performing the second blind decoding until successfully decoding the RMSI PDCCH.
25. The method of claim 23, further comprising:
repeating, by the first wireless communications device, the puncturing and the performing the second blind decoding until only one additional RMSI PDCCH candidate remains.
26. The method of claim 18, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.
27. The method of claim 17, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
28. The method of claim 27, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.
29. The method of claim 28, further comprising:
extracting, by the first wireless communications device, the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.
30. The method of claim 29, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
31. The method of claim 17, wherein the additional RMSI PDCCH candidates are indicated to be at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

32. The method of claim 17, further comprising:
performing, by the first wireless communications device, the first blind decoding for a first period of time; and
transitioning, by the first wireless communications device in response to the first blind decoding failing, to the performing the second blind decoding after a period of time fails.
33. The method of claim 17, further comprising:
performing, by the first wireless communications device, the first blind decoding in a slot;
and
performing, by the first wireless communications device, the second blind decoding in the same slot.
34. A first wireless communications device, comprising:
a transceiver configured to receive, in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;
the transceiver further configured to receive the RMSI PDCCH from the second wireless communications device; and
the transceiver further configured to receive a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.
35. The first wireless communications device of claim 34, wherein the indication of the repetition pattern comprises a resource assignment table.
36. The first wireless communications device of claim 35, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.
37. The first wireless communications device of claim 36, further comprising:
a processor configured to extract an identification of the periodicity and the number of repetitions from a field in the resource assignment table.

38. The first wireless communications device of claim 37, wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.
39. The first wireless communications device of claim 36, wherein the periodicity comprises an inter-slot periodicity.
40. The first wireless communications device of claim 36, wherein the periodicity comprises an intra-slot periodicity.
41. The first wireless communications device of claim 36, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.
42. The first wireless communications device of claim 35, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
43. The first wireless communications device of claim 42, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.
44. The first wireless communications device of claim 43, further comprising:
a processor configured to extract the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table.
45. The first wireless communications device of claim 44, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
46. The first wireless communications device of claim 42, wherein the plurality of frequency bands comprises a second frequency band that occupies a larger bandwidth than a first frequency band for the RMSI PDCCH.

47. The first wireless communications device of claim 35, wherein the repetition RMSI PDCCH transmissions are received at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
48. The first wireless communications device of claim 35, further comprising:
a processor configured to assume that no repetition pattern exists; and
the processor further configured to perform a first blind decoding on the RMSI PDCCH based on the assumption.
49. The first wireless communications device of claim 48, further comprising:
the processor further configured to stop the first blind decoding in response to successfully decoding the RMSI PDCCH.
50. The first wireless communications device of claim 48, further comprising:
the processor further configured to assume, response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists; and
the processor further configured to perform a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists,
the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.
51. The first wireless communications device of claim 50, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.
52. The first wireless communications device of claim 51, further comprising:
the processor further configured to extract an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index value.
53. The first wireless communications device of claim 51, wherein the periodicity comprises an intra-slot periodicity.

54. The first wireless communications device of claim 51, wherein the periodicity comprises an inter-slot periodicity.
55. The first wireless communications device of claim 54, further comprising:
the processor further configured to repeat the first blind decoding on the RMSI PDCCH at each slot according to the periodicity;
the processor further configured to soft combine additional RMSI PDCCH candidates for the second blind decoding; and
the processor further configured to perform the second blind decoding on the soft combined additional RMSI PDCCH candidates.
56. The first wireless communications device of claim 55, further comprising:
the processor further configured to puncture a first candidate from the soft combined additional RMSI PDCCH candidates in response to the second blind decoding failing; and
the processor further configured to perform the second blind decoding on the punctured soft combined additional RMSI PDCCH candidates.
57. The first wireless communications device of claim 56, further comprising:
the processor further configured to repeat the puncturing and the performing the second blind decoding until successfully decoding the RMSI PDCCH.
58. The first wireless communications device of claim 56, further comprising:
the processor further configured to repeat the puncturing and the performing the second blind decoding until only one additional RMSI PDCCH candidate remains.
59. The first wireless communications device of claim 51, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.
60. The first wireless communications device of claim 50, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
61. The first wireless communications device of claim 60, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the

CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.

62. The first wireless communications device of claim 61, further comprising:
the processor further configured to extract the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.
63. The first wireless communications device of claim 62, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
64. The first wireless communications device of claim 50, wherein the additional RMSI PDCCH candidates are indicated to be at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
65. The first wireless communications device of claim 50, further comprising:
the processor further configured to perform the first blind decoding for a first period of time;
and
the processor further configured to transition, in response to the first blind decoding failing, to the performing the second blind decoding after a period of time fails.
66. The first wireless communications device of claim 50, further comprising:
the processor further configured to perform the first blind decoding in a slot; and
the processor further configured to perform the second blind decoding in the same slot.
67. A non-transitory computer-readable medium having program code recorded thereon, the program code comprising:
code for causing a first wireless communications device to receive, in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;

code for causing the first wireless communications device to receive the RMSI PDCCH from the second wireless communications device; and

code for causing the first wireless communications device to receive a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

68. The non-transitory computer-readable medium of claim 67, wherein the indication of the repetition pattern comprises a resource assignment table.

69. The non-transitory computer-readable medium of claim 68, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.

70. The non-transitory computer-readable medium of claim 69, further comprising:
code for causing the first wireless communications device to extract an identification of the periodicity and the number of repetitions from a field in the resource assignment table.

71. The non-transitory computer-readable medium of claim 70, wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.

72. The non-transitory computer-readable medium of claim 69, wherein the periodicity comprises an inter-slot periodicity.

73. The non-transitory computer-readable medium of claim 69, wherein the periodicity comprises an intra-slot periodicity.

74. The non-transitory computer-readable medium of claim 69, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.

75. The non-transitory computer-readable medium of claim 68, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

76. The non-transitory computer-readable medium of claim 75, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.
77. The non-transitory computer-readable medium of claim 76, further comprising:
code for causing the first wireless communications device to extract the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table.
78. The non-transitory computer-readable medium of claim 77, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
79. The non-transitory computer-readable medium of claim 75, wherein the plurality of frequency bands comprises a second frequency band that occupies a larger bandwidth than a first frequency band for the RMSI PDCCH.
80. The non-transitory computer-readable medium of claim 68, wherein the repetition RMSI PDCCH transmissions are received at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
81. The non-transitory computer-readable medium of claim 68, further comprising:
code for causing the first wireless communications device to assume that no repetition pattern exists; and
code for causing the first wireless communications device to perform a first blind decoding on the RMSI PDCCH based on the assumption.
82. The non-transitory computer-readable medium of claim 81, further comprising:
code for causing the first wireless communications device to stop the first blind decoding in response to successfully decoding the RMSI PDCCH.
83. The non-transitory computer-readable medium of claim 81, further comprising:

code for causing the first wireless communications device to assume, in response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists; and

code for causing the first wireless communications device to perform a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists,

the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.

84. The non-transitory computer-readable medium of claim 83, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.

85. The non-transitory computer-readable medium of claim 84, further comprising:

code for causing the first wireless communications device to extract an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index value.

86. The non-transitory computer-readable medium of claim 84, wherein the periodicity comprises an intra-slot periodicity.

87. The non-transitory computer-readable medium of claim 84, wherein the periodicity comprises an inter-slot periodicity.

88. The non-transitory computer-readable medium of claim 87, further comprising:

code for causing the first wireless communications device to repeat the first blind decoding on the RMSI PDCCH at each slot according to the periodicity;

code for causing the first wireless communications device to soft combine additional RMSI PDCCH candidates for the second blind decoding; and

code for causing the first wireless communications device to perform the second blind decoding on the soft combined additional RMSI PDCCH candidates.

89. The non-transitory computer-readable medium of claim 88, further comprising:

code for causing the first wireless communications device to puncture a first candidate from the soft combined additional RMSI PDCCH candidates in response to the second blind decoding failing; and

code for causing the first wireless communications device to perform the second blind decoding on the punctured soft combined additional RMSI PDCCH candidates.

90. The non-transitory computer-readable medium of claim 89, further comprising:

code for causing the first wireless communications device to repeat the puncturing and the performing the second blind decoding until successfully decoding the RMSI PDCCH.

91. The non-transitory computer-readable medium of claim 89, further comprising:

code for causing the first wireless communications device to repeat the puncturing and the performing the second blind decoding until only one additional RMSI PDCCH candidate remains.

92. The non-transitory computer-readable medium of claim 84, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.

93. The non-transitory computer-readable medium of claim 83, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

94. The non-transitory computer-readable medium of claim 93, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.

95. The non-transitory computer-readable medium of claim 94, further comprising:

code for causing the first wireless communications device to extract the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.

96. The non-transitory computer-readable medium of claim 95, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
97. The non-transitory computer-readable medium of claim 83, wherein the additional RMSI PDCCH candidates are indicated to be at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
98. The non-transitory computer-readable medium of claim 83, further comprising:
code for causing the first wireless communications device to perform the first blind decoding for a first period of time; and
code for causing the first wireless communications device to transition, in response to the first blind decoding failing, to the performing the second blind decoding after a period of time fails.
99. The non-transitory computer-readable medium of claim 83, further comprising:
code for causing the first wireless communications device to perform the first blind decoding in a slot; and
code for causing the first wireless communications device to perform the second blind decoding in the same slot.
100. A first wireless communications device, comprising:
means for receiving, in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;
means for receiving, the RMSI PDCCH from the second wireless communications device;
and
means for receiving a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.
101. The first wireless communications device of claim 100, wherein the indication of the repetition pattern comprises a resource assignment table.

102. The first wireless communications device of claim 101, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.
103. The first wireless communications device of claim 102, further comprising:
means for extracting an identification of the periodicity and the number of repetitions from a field in the resource assignment table.
104. The first wireless communications device of claim 103, wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.
105. The first wireless communications device of claim 102, wherein the periodicity comprises an inter-slot periodicity.
106. The first wireless communications device of claim 102, wherein the periodicity comprises an intra-slot periodicity.
107. The first wireless communications device of claim 102, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.
108. The first wireless communications device of claim 101, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
109. The first wireless communications device of claim 108, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.
110. The first wireless communications device of claim 109, further comprising:
means for extracting the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table.

111. The first wireless communications device of claim 110, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
112. The first wireless communications device of claim 108, wherein the plurality of frequency bands comprises a second frequency band that occupies a larger bandwidth than a first frequency band for the RMSI PDCCH.
113. The first wireless communications device of claim 101, wherein the repetition RMSI PDCCH transmissions are received at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
114. The first wireless communications device of claim 101, further comprising:
means for assuming that no repetition pattern exists; and
means for performing a first blind decoding on the RMSI PDCCH based on the assumption.
115. The first wireless communications device of claim 114, further comprising:
means for stopping the first blind decoding in response to successfully decoding the RMSI PDCCH.
116. The first wireless communications device of claim 114, further comprising:
means for assuming, in response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists; and
means for performing a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists,
the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.
117. The first wireless communications device of claim 116, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions.
118. The first wireless communications device of claim 117, further comprising:

means for extracting an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index value.

119. The first wireless communications device of claim 117, wherein the periodicity comprises an intra-slot periodicity.

120. The first wireless communications device of claim 117, wherein the periodicity comprises an inter-slot periodicity.

121. The first wireless communications device of claim 120, further comprising:

means for repeating the first blind decoding on the RMSI PDCCH at each slot according to the periodicity;

means for soft combining additional RMSI PDCCH candidates for the second blind decoding; and

means for performing the second blind decoding on the soft combined additional RMSI PDCCH candidates.

122. The first wireless communications device of claim 121, further comprising:

means for puncturing a first candidate from the soft combined additional RMSI PDCCH candidates in response to the second blind decoding failing; and

means for performing the second blind decoding on the punctured soft combined additional RMSI PDCCH candidates.

123. The first wireless communications device of claim 122, further comprising:

means for repeating the puncturing and the performing the second blind decoding until successfully decoding the RMSI PDCCH.

124. The first wireless communications device of claim 122, further comprising:

means for repeating the puncturing and the performing the second blind decoding until only one additional RMSI PDCCH candidate remains.

125. The first wireless communications device of claim 117, wherein the periodicity comprises an inter-slot periodicity and an intra-slot periodicity.

126. The first wireless communications device of claim 116, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
127. The first wireless communications device of claim 126, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.
128. The first wireless communications device of claim 127, further comprising:
means for extracting the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.
129. The first wireless communications device of claim 128, wherein the field in the resource assignment table comprises an array of the number of resource blocks for each CORESET and the resource block gap value between each repetition of the CORESET.
130. The first wireless communications device of claim 116, wherein the additional RMSI PDCCH candidates are indicated to be at a plurality of different times according to a periodicity and a number of repetitions, and at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
131. The first wireless communications device of claim 116, further comprising:
means for performing the first blind decoding for a first period of time; and
means for transitioning, by the first wireless communications device in response to the first blind decoding failing, to the performing the second blind decoding after a period of time fails.
132. The first wireless communications device of claim 116, further comprising:
means for performing the first blind decoding in a slot; and
means for performing the second blind decoding in the same slot.

AMENDED CLAIMS

received by the International Bureau on 16 November 2021 (16.11.2021)

1. A method of wireless communication, comprising:
receiving, by a first wireless communications device in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;
receiving, by the first wireless communications device, the RMSI PDCCH from the second wireless communications device; and
receiving, by the first wireless communications device, a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.
2. The method of claim 1, wherein the indication of the repetition pattern comprises a resource assignment table.
3. The method of claim 2, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions,
wherein the periodicity comprises an inter-slot periodicity and/or an intra-slot periodicity.
4. The method of claim 3, further comprising:
extracting, by the first wireless communications device, an identification of the periodicity and the number of repetitions from a field in the resource assignment table,
wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.
5. The method of claim 2, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.
6. The method of claim 5, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET

repetition pattern, and a resource block gap value between each repetition of the CORESET.

7. The method of claim 2, further comprising:
- assuming, by the first wireless communications device, that no repetition pattern exists;
 - performing, by the first wireless communications device, a first blind decoding on the RMSI PDCCH based on the assumption;
 - assuming, by the first wireless communications device in response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists;
 - and
 - performing, by the first wireless communications device, a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists,
 - the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.

8. The method of claim 7, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions,
- wherein the periodicity comprises an inter-slot periodicity and/or an intra-slot periodicity.

9. The method of claim 8, further comprising:
- extracting, by the first wireless communications device, an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index value.

10. The method of claim 7, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

11. The method of claim 10, wherein the CORESET repetition pattern comprises an

identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET, further comprising:

extracting, by the first wireless communications device, the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.

12. A first wireless communications device, comprising:

a transceiver configured to receive, in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;

the transceiver further configured to receive the RMSI PDCCH from the second wireless communications device; and

the transceiver further configured to receive a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

13. The first wireless communications device of claim 12, wherein the indication of the repetition pattern comprises a resource assignment table.

14. The first wireless communications device of claim 13, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions,

wherein the periodicity comprises an inter-slot periodicity and/or an intra-slot periodicity.

15. The first wireless communications device of claim 14, further comprising:

a processor configured to extract an identification of the periodicity and the number of repetitions from a field in the resource assignment table,

wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.

16. The first wireless communications device of claim 13, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

17. The first wireless communications device of claim 16, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.

18. The first wireless communications device of claim 13, further comprising:
a processor configured to assume that no repetition pattern exists;
the processor further configured to perform a first blind decoding on the RMSI PDCCH based on the assumption;
the processor further configured to assume, in response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists; and
the processor further configured to perform a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists,
the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.

19. The first wireless communications device of claim 18, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions,
wherein the periodicity comprises an inter-slot periodicity and/or an intra-slot periodicity.

20. The first wireless communications device of claim 19, further comprising:
the processor further configured to extract an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index

value.

21. The first wireless communications device of claim 18, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

22. The first wireless communications device of claim 21, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET, the processor further configured to:

extract the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.

23. A non-transitory computer-readable medium having program code recorded thereon, the program code comprising:

code for causing a first wireless communications device to receive, in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;

code for causing the first wireless communications device to receive the RMSI PDCCH from the second wireless communications device; and

code for causing the first wireless communications device to receive a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

24. The non-transitory computer-readable medium of claim 23, wherein the indication of the repetition pattern comprises a resource assignment table.

25. A first wireless communications device, comprising:

means for receiving, in a low power indoor (LPI) mode, an indication of a repetition pattern for a remaining minimum system information (RMSI) physical

downlink control channel (PDCCH) transmission from a second wireless communications device in the LPI mode;

means for receiving, the RMSI PDCCH from the second wireless communications device; and

means for receiving a repetition of the RMSI PDCCH from the second wireless communications device according to the repetition pattern identified in the indication.

26. The first wireless communications device of claim 25, wherein the indication of the repetition pattern comprises a resource assignment table.

27. The first wireless communications device of claim 26, wherein the repetition RMSI PDCCH transmissions are received at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions,

wherein the periodicity comprises an inter-slot periodicity and/or an intra-slot periodicity.

28. The first wireless communications device of claim 27, further comprising:
means for extracting an identification of the periodicity and the number of repetitions from a field in the resource assignment table,

wherein the field in the resource assignment table is located under a sixth column of the resource assignment table and accessed via an index value.

29. The first wireless communications device of claim 26, wherein the repetition RMSI PDCCH transmissions are received at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

30. The first wireless communications device of claim 29, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET.

31. The first wireless communications device of claim 26, further comprising:

means for assuming that no repetition pattern exists;

means for performing a first blind decoding on the RMSI PDCCH based on the assumption;

means for assuming, in response to the first blind decoding failing to decode the RMSI PDCCH, that the repetition pattern exists; and

means for performing a second blind decoding on additional RMSI PDCCH candidates in response to the assuming that the repetition pattern exists,

the additional RMSI PDCCH candidates corresponding to the repetition RMSI PDCCH transmissions.

32. The first wireless communications device of claim 31, wherein the additional RMSI PDCCH candidates are indicated to be at a same control resource set (CORESET) as the RMSI PDCCH at different times according to a periodicity and a number of repetitions,

wherein the periodicity comprises an inter-slot periodicity and/or an intra-slot periodicity.

33. The first wireless communications device of claim 32, further comprising:

means for extracting an identification of the periodicity and the number of repetitions from a field in the resource assignment table, the field being located under a sixth column of the resource assignment table and accessed via an index value.

34. The first wireless communications device of claim 31, wherein the additional RMSI PDCCH candidates are indicated to be at a same time as the RMSI PDCCH at a plurality of frequency bands, according to a specified control resource set (CORESET) repetition pattern.

35. The first wireless communications device of claim 34, wherein the CORESET repetition pattern comprises an identification of a number of resource blocks for each CORESET of the CORESET repetition pattern, and a resource block gap value between each repetition of the CORESET, further comprising:

means for extracting the number of resource blocks for each CORESET, and the resource block gap value, from a field in the resource assignment table, the field being located under a seventh column of the resource assignment table and accessed via an index value.

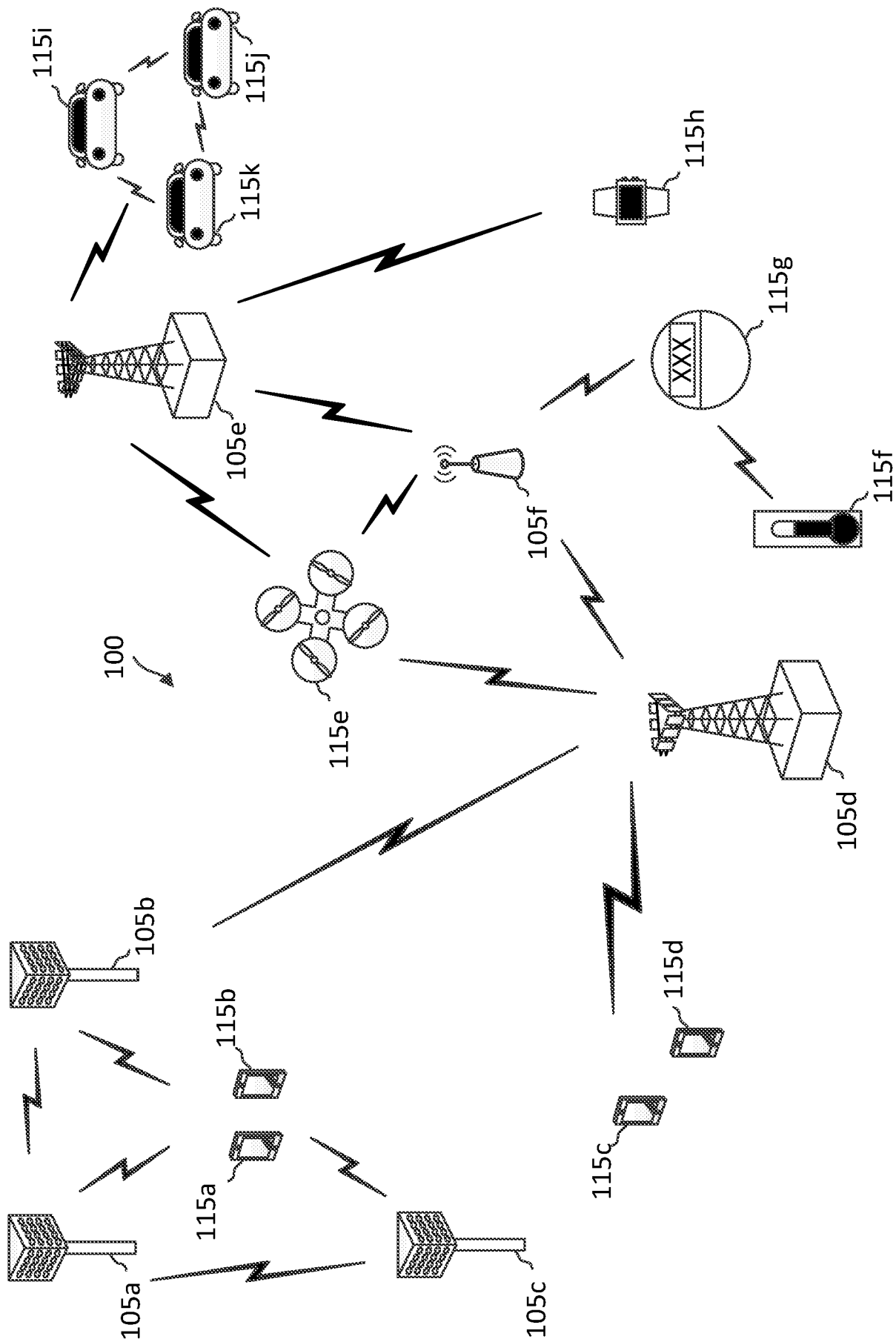


FIG. 1

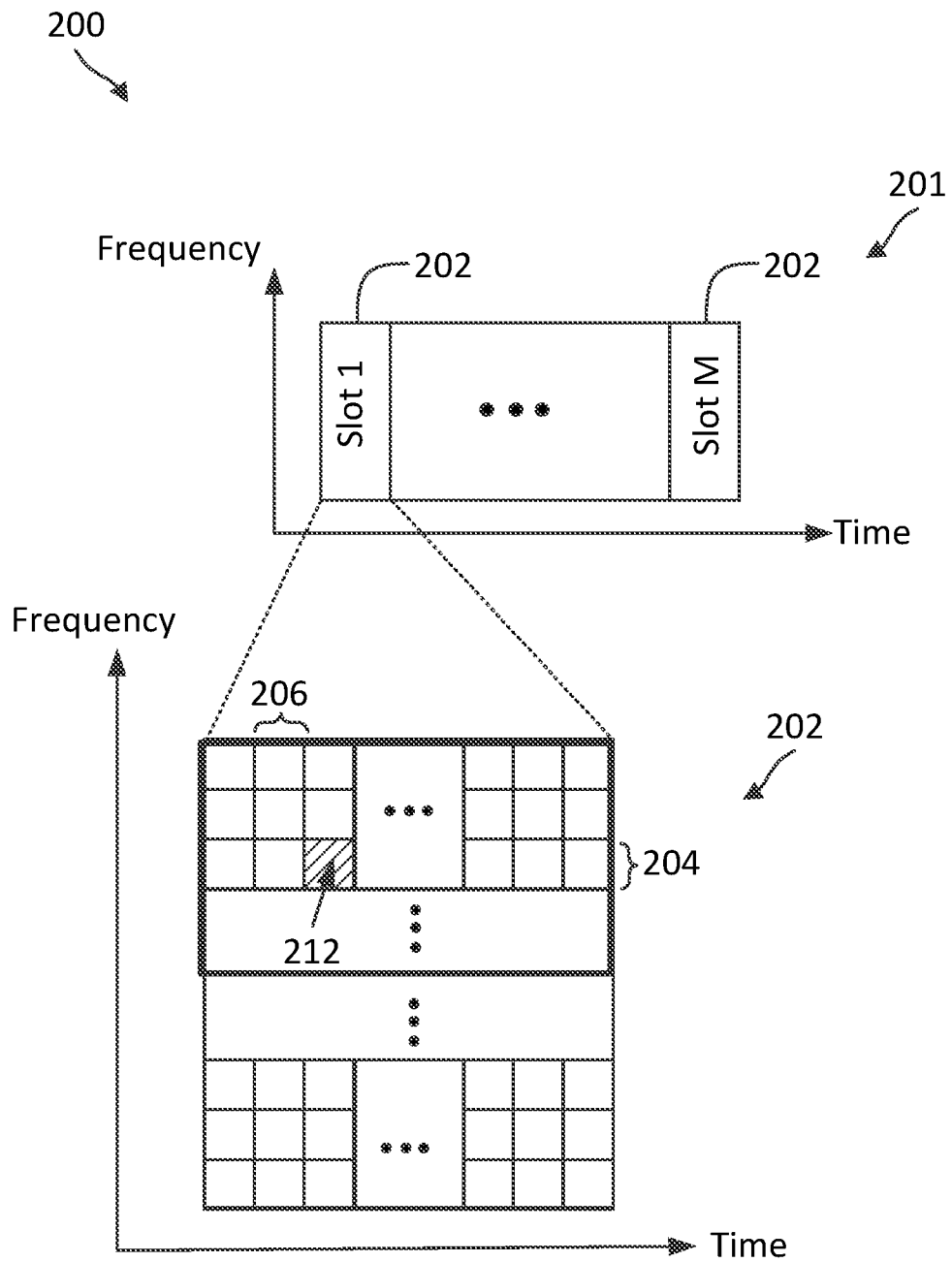


FIG. 2

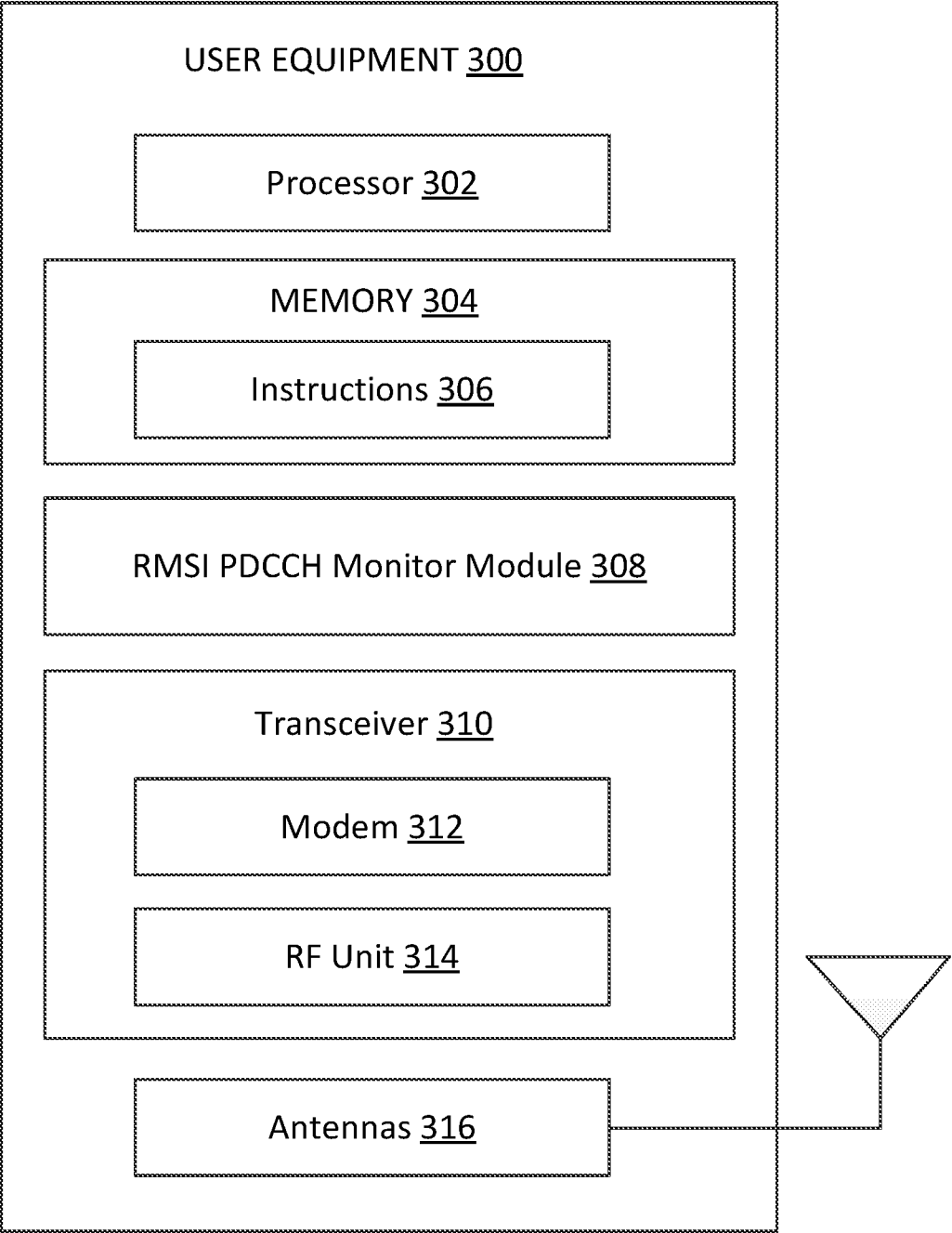


FIG. 3

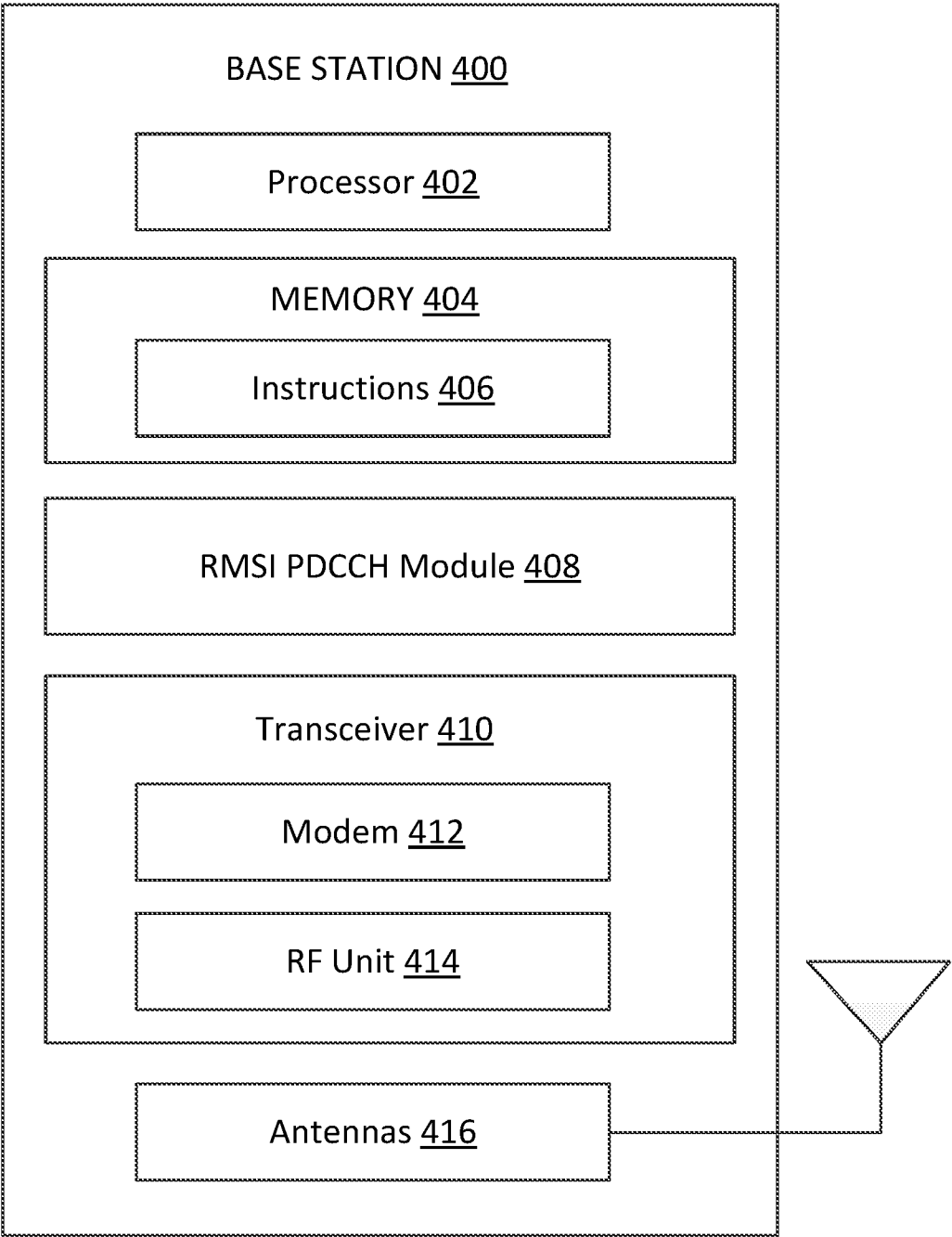


FIG. 4

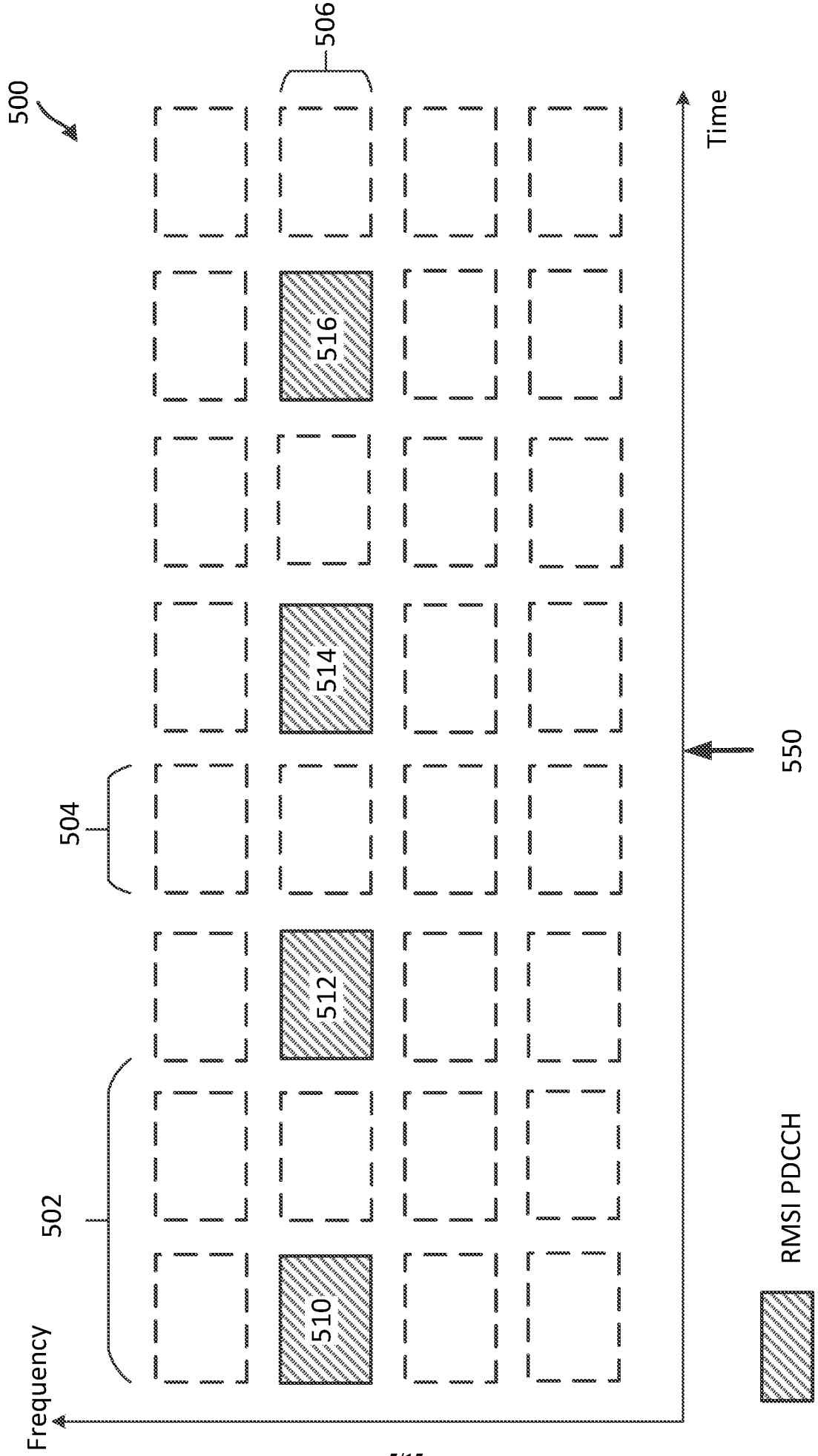


FIG. 5

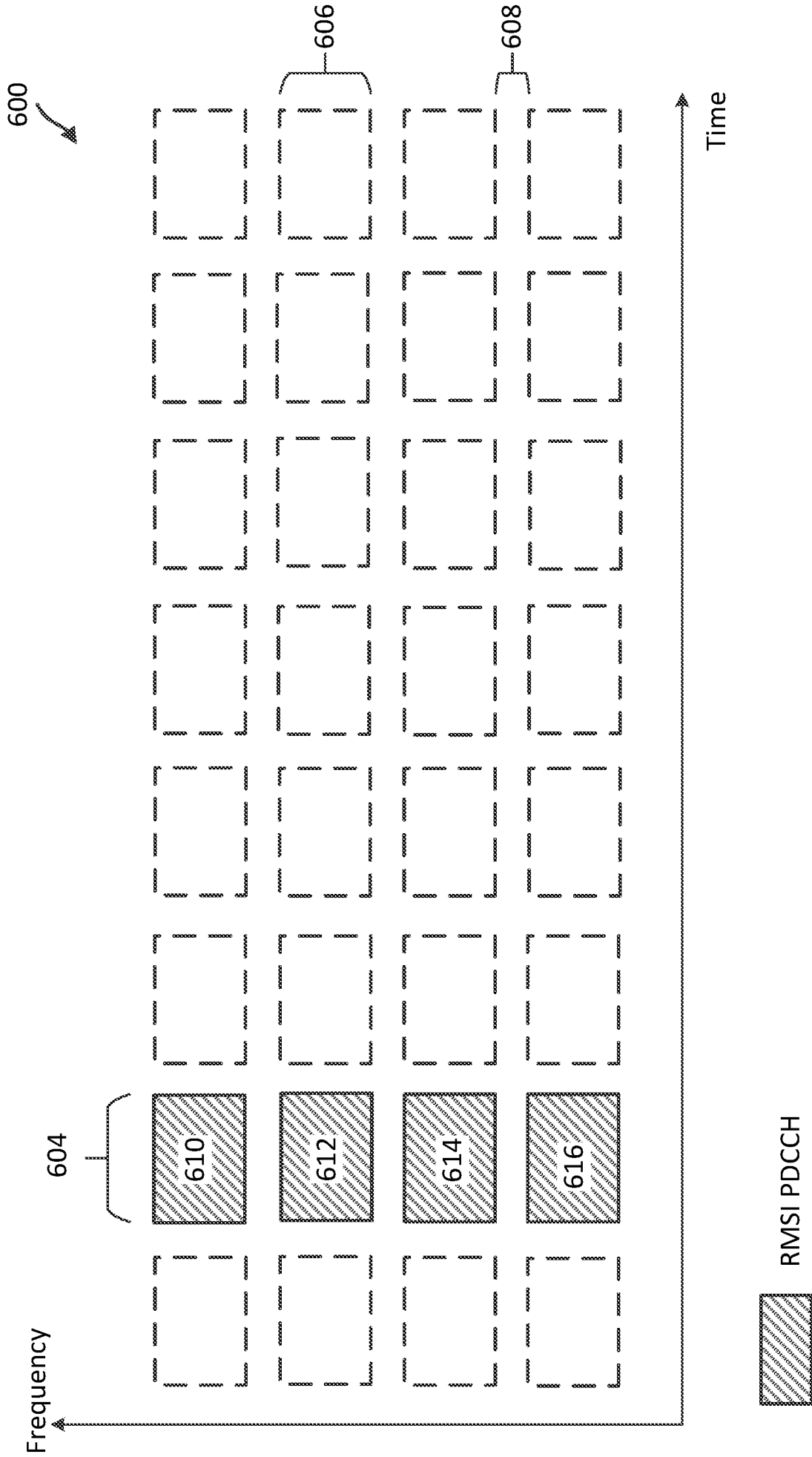


FIG. 6

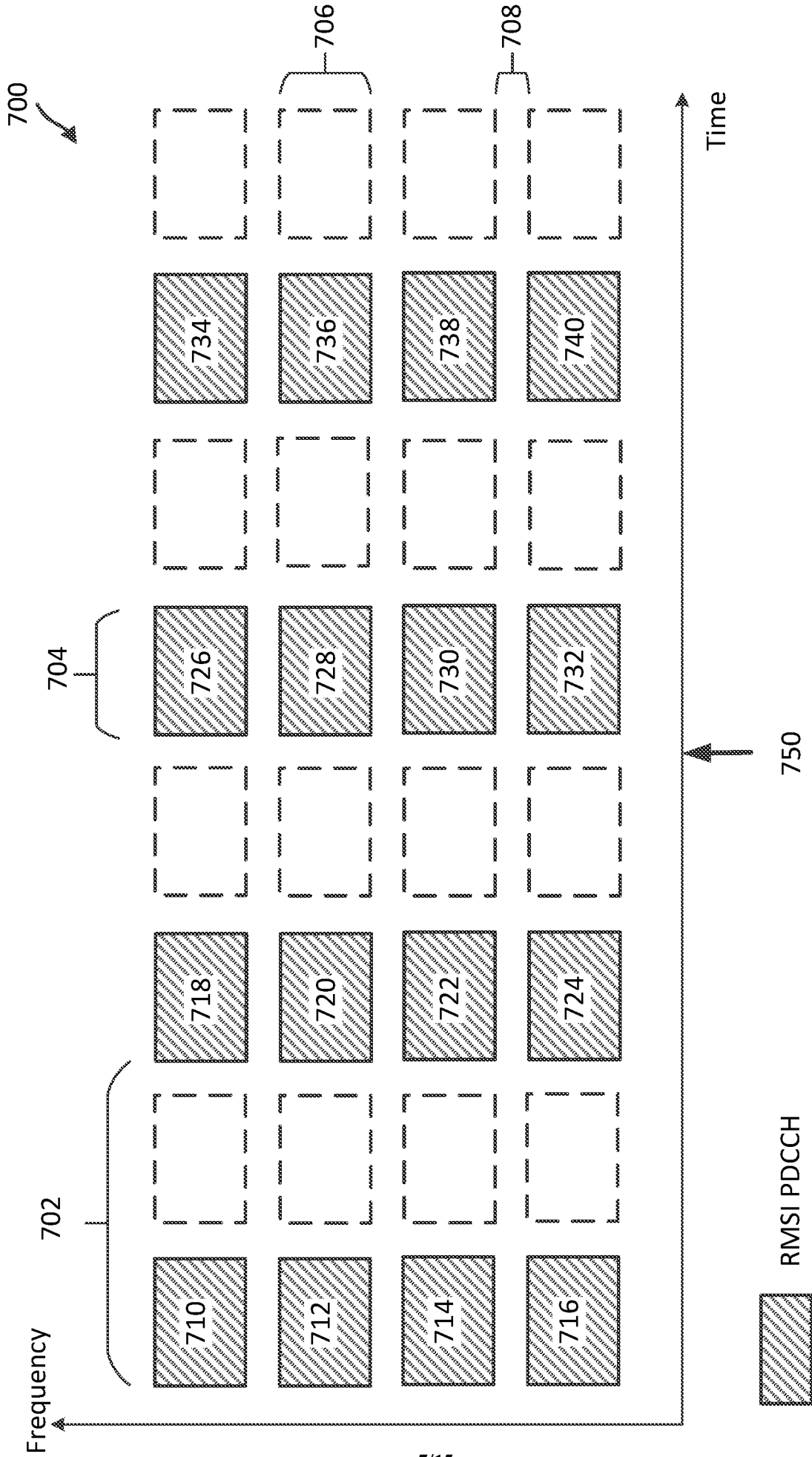


FIG. 7

800
↙

Index 802	Multiplexing pattern 804	RB Array 806	Number of symbols 808	Offset 810	Time pattern 812
0	1	48	1	0	
1	1	48	1	1	
2	1	48	1	2	
3	1	48	1	3	
4	1	48	2	0	
5	1	48	2	1	
6	1	48	2	2	
7	1	48	2	3	
8	1	48	1	0	4, 4
9	1	48	1	0	14, 4
10	1	48, 3, 48, 3, 48, 3, 48	1	0	
11	1	192, 25, 192, 25, 192, 25, 192	1	0	
12	1	48, 3, 48	1	0	4, 2
13	1	48, 3, 48	1	0	14, 2
14	1	192, 25, 192	1	0	4, 2
15	1	192, 25, 192	1	0	14, 2

FIG. 8

900



Index 902	Multiplexing pattern 904	RBs 906	Number of symbols 908	Offset 910	Time pattern 912	Frequency Pattern 914
0	1	48	1	0	4, 2	3, 2
1	1	48	1	1	14, 2	3, 2
2	1	48	1	2	14, 4	
3	1	48	1	3		3, 4
4	1	48	2	0	4, 2	3, 2
5	1	48	2	1	14, 2	3, 2
6	1	48	2	2	14, 4	
7	1	48	2	3		3, 4
8						
9						
10						
11						
12						
13						
14						
15						

FIG. 9

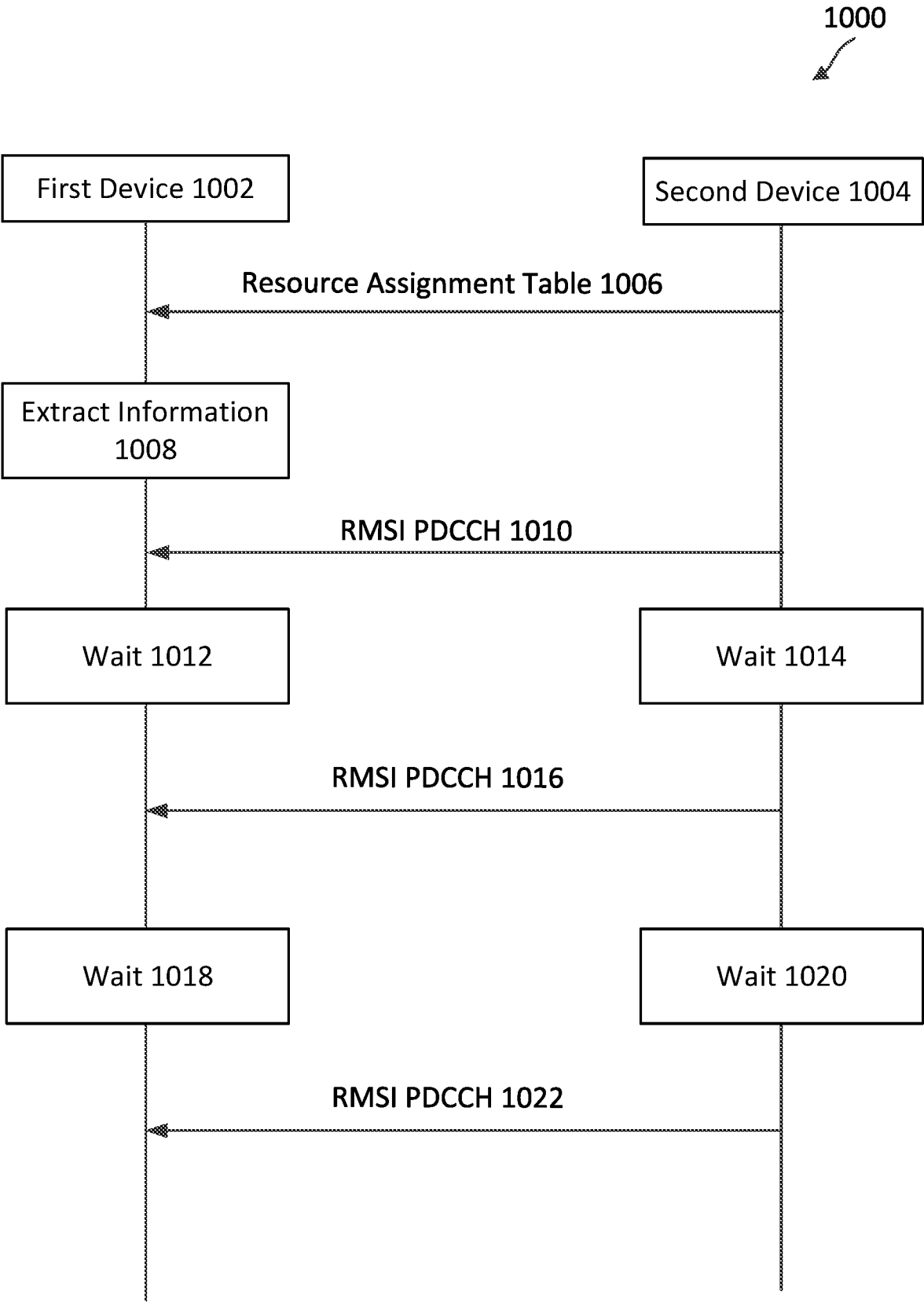


FIG. 10

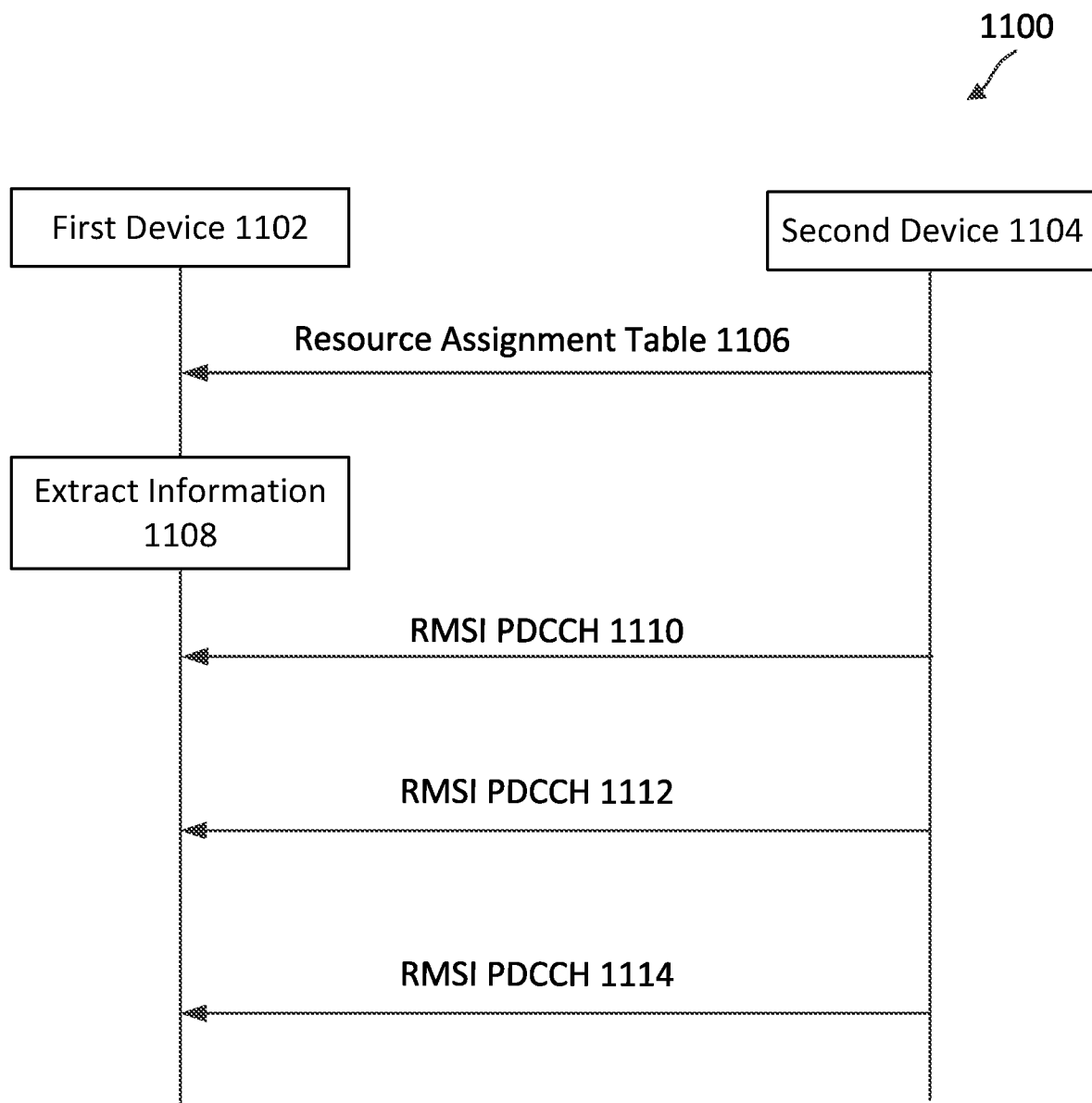


FIG. 11

1200

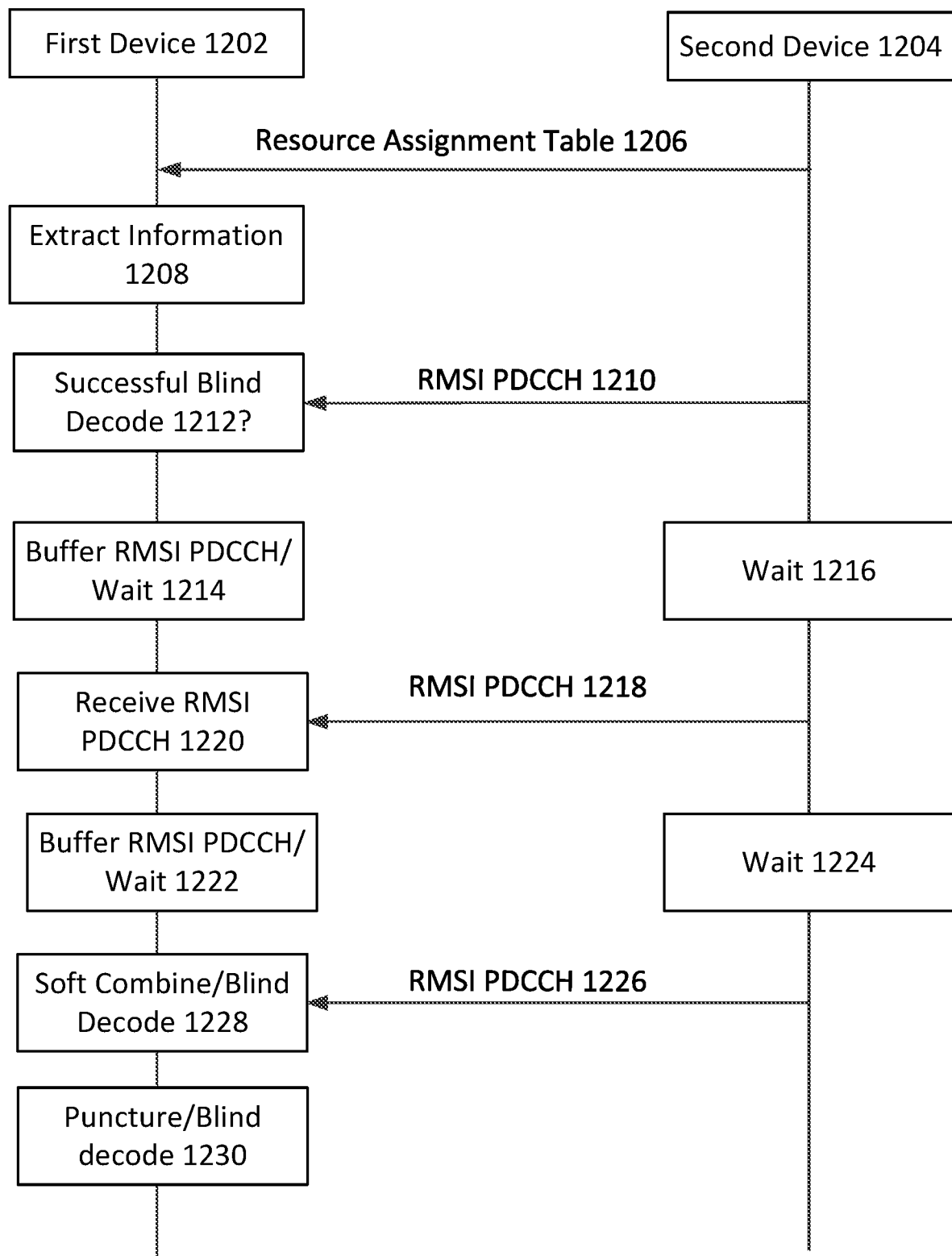


FIG. 12

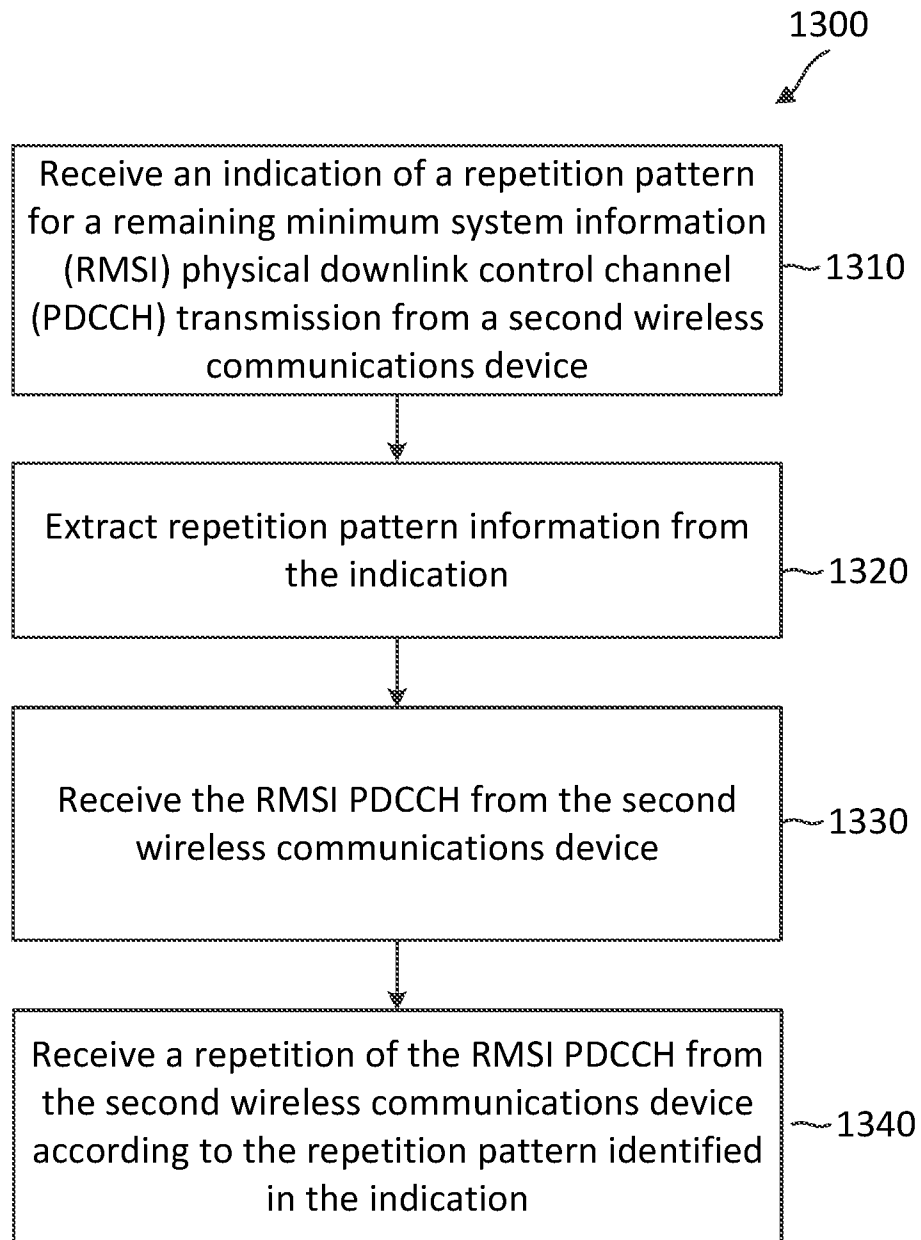


FIG. 13

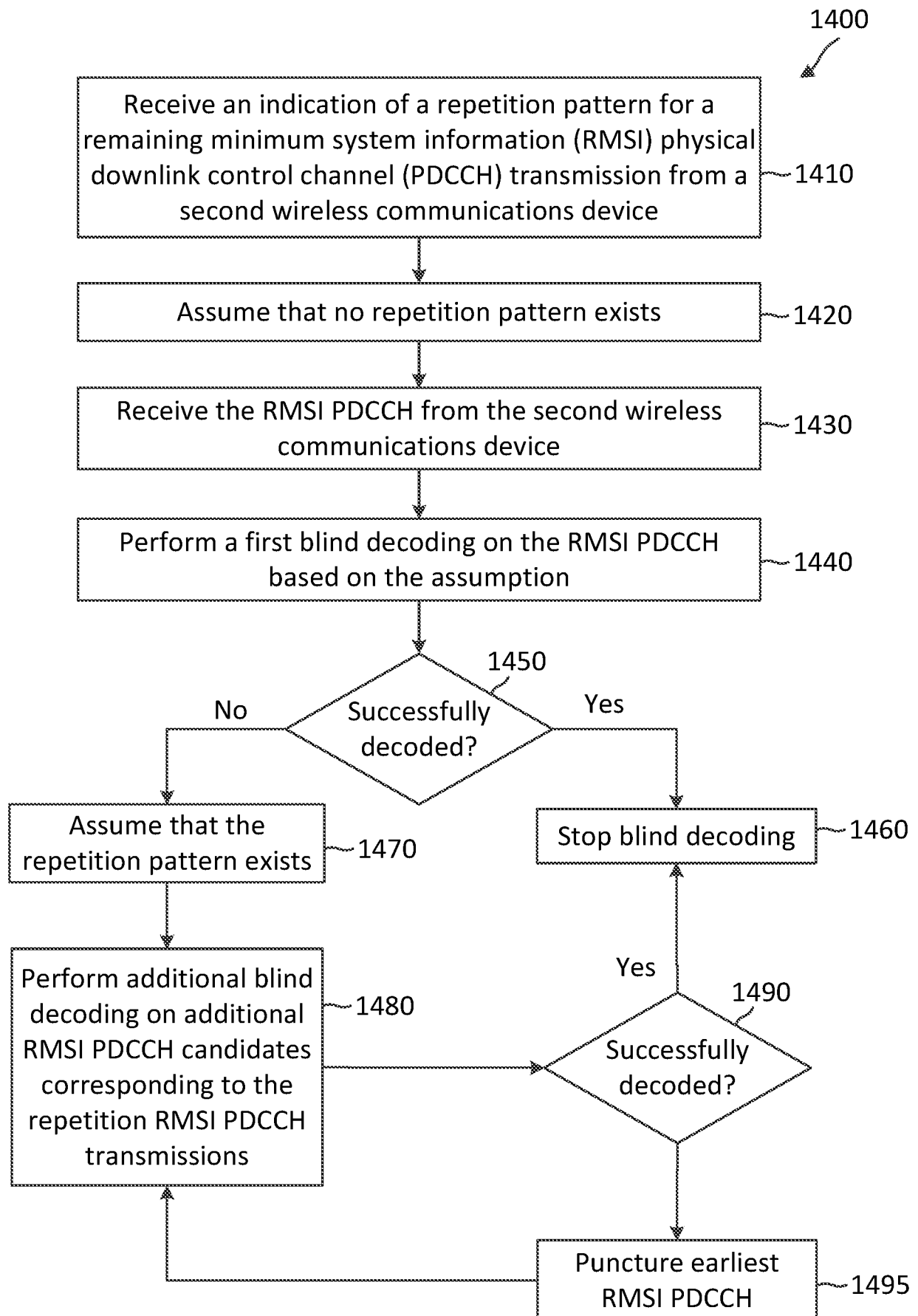


FIG. 14

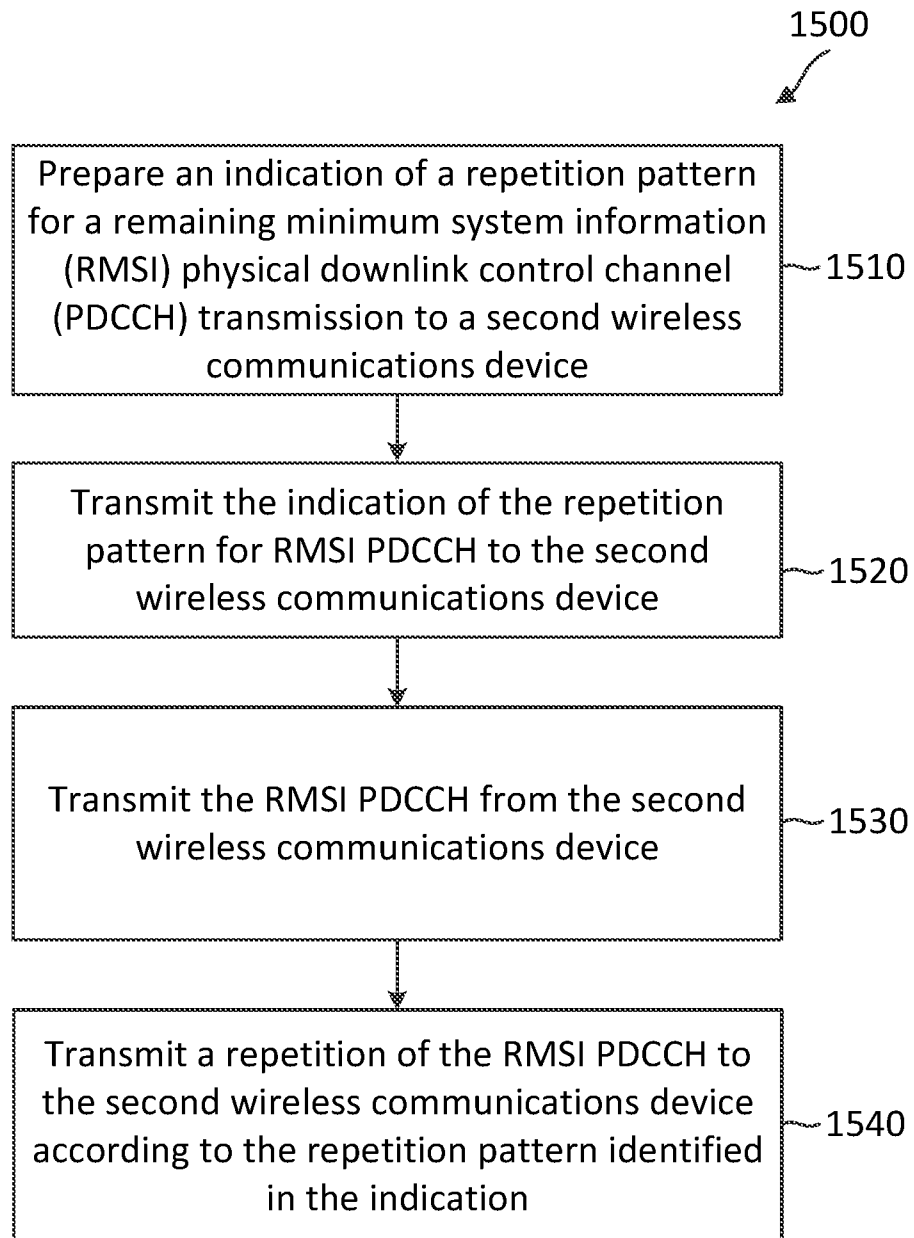


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/102708

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 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, EPODOC, WPI, 3GPP: remaining minimum system information, RMSI, physical downlink control channel, PDCCH, repetition, pattern, indication, LPI, low power, resource, assignment, table																				
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">X</td> <td>WO 2019134636 A1 (TELEFONAKTIEBOLAGET LM ERICSSON PUBL et al.) 11 July 2019 (2019-07-11) description, paragraphs 61-99, and figures 1,5-9</td> <td style="text-align: center;">1-132</td> </tr> <tr> <td style="text-align: center;">A</td> <td>WO 2019098769 A1 (LG ELECTRONICS INC.) 23 May 2019 (2019-05-23) the whole document</td> <td style="text-align: center;">1-132</td> </tr> <tr> <td style="text-align: center;">A</td> <td>US 2019223163 A1 (LG ELECTRONICS INC.) 18 July 2019 (2019-07-18) the whole document</td> <td style="text-align: center;">1-132</td> </tr> <tr> <td style="text-align: center;">A</td> <td>WO 2019033953 A1 (VIVO MOBILE COMMUNICATION CO., LTD.) 21 February 2019 (2019-02-21) the whole document</td> <td style="text-align: center;">1-132</td> </tr> <tr> <td style="text-align: center;">A</td> <td>QUALCOMM INCORPORATED. "Remaining system information delivery consideration" 3GPP TSG RAN WG1 Meeting #92bis R1-1804776, 20 April 2018 (2018-04-20), the whole document</td> <td style="text-align: center;">1-132</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	WO 2019134636 A1 (TELEFONAKTIEBOLAGET LM ERICSSON PUBL et al.) 11 July 2019 (2019-07-11) description, paragraphs 61-99, and figures 1,5-9	1-132	A	WO 2019098769 A1 (LG ELECTRONICS INC.) 23 May 2019 (2019-05-23) the whole document	1-132	A	US 2019223163 A1 (LG ELECTRONICS INC.) 18 July 2019 (2019-07-18) the whole document	1-132	A	WO 2019033953 A1 (VIVO MOBILE COMMUNICATION CO., LTD.) 21 February 2019 (2019-02-21) the whole document	1-132	A	QUALCOMM INCORPORATED. "Remaining system information delivery consideration" 3GPP TSG RAN WG1 Meeting #92bis R1-1804776, 20 April 2018 (2018-04-20), the whole document	1-132
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X	WO 2019134636 A1 (TELEFONAKTIEBOLAGET LM ERICSSON PUBL et al.) 11 July 2019 (2019-07-11) description, paragraphs 61-99, and figures 1,5-9	1-132																		
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Date of the actual completion of the international search 02 April 2021		Date of mailing of the international search report 19 April 2021																		
Name and mailing address of the ISA/CN National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China Facsimile No. (86-10)62019451		Authorized officer AN,Xiaolan Telephone No. 86-(10)-53961732																		

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2020/102708

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2019134636	A1	11 July 2019	US	2020351759	A1	05 November 2020
				KR	20200105503	A	07 September 2020
				EP	3735792	A1	11 November 2020
				CN	111543101	A	14 August 2020
WO	2019098769	A1	23 May 2019	EP	3713136	A1	23 September 2020
				CN	111557081	A	18 August 2020
				JP	2021503795	A	12 February 2021
US	2019223163	A1	18 July 2019	KR	20190060747	A	03 June 2019
				WO	2019098768	A1	23 May 2019
				EP	3515123	A1	24 July 2019
				US	2019289530	A1	19 September 2019
				KR	20190057002	A	27 May 2019
				CN	110603852	A	20 December 2019
				JP	2020507999	A	12 March 2020
WO	2019033953	A1	21 February 2019	US	2020205186	A1	25 June 2020
				CN	109413754	A	01 March 2019
				EP	3672321	A1	24 June 2020