

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

(19) World Intellectual Property Organization

International Bureau

(43) International Publication Date
19 July 2018 (19.07.2018)

(10) International Publication Number

WO 2018/129734 A1

(51) International Patent Classification:

H03M 13/00 (2006.01)

(21) International Application Number:

PCT/CN2017/071255

(22) International Filing Date:

16 January 2017 (16.01.2017)

(25) Filing Language:

English

(26) Publication Language:

English

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: DYNAMIC FROZEN POLAR CODES

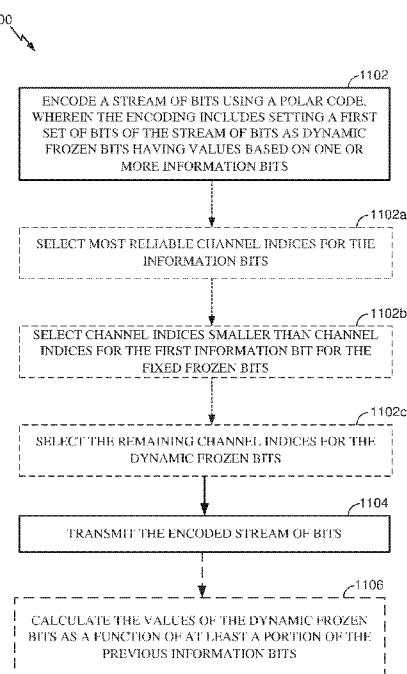


FIG. 11

(57) Abstract: Certain aspects of the present disclosure generally relate to wireless communications and, more particularly, to methods and apparatus for dynamic frozen polar codes, for example, for control channels. An exemplary method may be performed at the encoder. The method generally includes encoding a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and transmitting the encoded stream of bits.

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

DYNAMIC FROZEN POLAR CODES

BACKGROUND

Field of the Disclosure

[0001] Certain aspects of the present disclosure generally relate to wireless communications and, more particularly, to methods and apparatus for dynamic frozen polar codes, for example, for encoding a control channel.

Description of Related Art

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power). Examples of such multiple-access technologies include Long Term Evolution (LTE) systems, code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0003] In some examples, a wireless multiple-access communication system may include a number of base stations, each simultaneously supporting communication for multiple communication devices, otherwise known as user equipment (UEs). In LTE or LTE-A network, a set of one or more base stations may define an e NodeB (eNB). In other examples (e.g., in a next generation or 5G network), a wireless multiple access communication system may include a number of distributed units (DUs) (e.g., edge units (EUs), edge nodes (ENs), radio heads (RHs), smart radio heads (SRHs), transmission reception points (TRPs), etc.) in communication with a number of central units (CUs) (e.g., central nodes (CNs), access node controllers (ANCs), etc.), where a set of one or more distributed units, in communication with a central unit, may define an access node (e.g., a new radio base station (NR BS), a new radio node-B (NR NB), a network node, 5G NB, gNB, etc.). A base station or DU may communicate with a set of

UEs on downlink channels (e.g., for transmissions from a base station or to a UE) and uplink channels (e.g., for transmissions from a UE to a base station or distributed unit).

[0004] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example of an emerging telecommunication standard is new radio (NR), for example, 5G radio access. NR is a set of enhancements to the LTE mobile standard promulgated by Third Generation Partnership Project (3GPP). It is designed to better support mobile broadband Internet access by improving spectral efficiency, lowering costs, improving services, making use of new spectrum, and better integrating with other open standards using OFDMA with a cyclic prefix (CP) on the downlink (DL) and on the uplink (UL) as well as support beamforming, multiple-input multiple-output (MIMO) antenna technology, and carrier aggregation.

[0005] However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in NR technology. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0006] The systems, methods, and devices of the disclosure each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this disclosure as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled “Detailed Description” one will understand how the features of this disclosure provide advantages that include improved communications in a wireless network.

[0007] Certain aspects of the present disclosure provide a method for wireless communications in a network. The method generally includes encoding a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and transmitting the encoded stream of bits.

[0008] Certain aspects of the present disclosure provide an apparatus for wireless communications in a network. The apparatus generally includes means for encoding a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and means for transmitting the encoded stream of bits.

[0009] Certain aspects of the present disclosure provide an apparatus for wireless communications in a network. The apparatus generally includes at least one processor configured to encode a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and a transmitter configured to transmit the encoded stream of bits.

[0010] Certain aspects of the present disclosure provide a computer readable medium having computer executable code stored for wireless communications in a network. The computer executable code generally includes code for encoding a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and code for transmitting the encoded stream of bits.

[0011] Numerous other aspects are provided including methods, apparatus, systems, computer program products, and processing systems.

[0012] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the

appended drawings. It is to be noted, however, that the appended drawings illustrate only certain typical aspects of this disclosure and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

[0014] FIG. 1 is a block diagram illustrating an example telecommunications system, in accordance with certain aspects of the present disclosure.

[0015] FIG. 2 is a block diagram illustrating an example logical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0016] FIG. 3 is a diagram illustrating an example physical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0017] FIG. 4 is a block diagram illustrating a design of an example BS and user equipment (UE), in accordance with certain aspects of the present disclosure.

[0018] FIG. 5 is a diagram showing examples for implementing a communication protocol stack, in accordance with certain aspects of the present disclosure.

[0019] FIG. 6 illustrates a block diagram of an example wireless device in accordance with certain aspects of the present disclosure.

[0020] FIG. 7 is a simplified block diagram illustrating an encoder, in accordance with certain aspects of the present disclosure.

[0021] FIG. 8 is a simplified block diagram illustrating a decoder, in accordance with certain aspects of the present disclosure.

[0022] FIG. 9 illustrates an example of a DL-centric subframe, in accordance with certain aspects of the present disclosure.

[0023] FIG. 10 illustrates an example of an UL-centric subframe, in accordance with certain aspects of the present disclosure.

[0024] FIG. 11 is a flow diagram illustrating example operations by an encoding device for wireless communications in a network, in accordance with certain aspects of the present disclosure.

[0025] FIG. 12 is a flow diagram illustrating example operations by a decoding device wireless communications in a network, in accordance with certain aspects of the present disclosure.

[0026] FIG. 13 is an example flow chart for dynamic froze polar code encoding, in accordance with certain aspects of the present disclosure.

[0027] FIG. 14 is an example of channel selection for information bits, fixed frozen bits, and dynamic frozen bits, in accordance with certain aspects of the present disclosure.

[0028] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

[0029] Aspects of the present disclosure provide apparatus, methods, processing systems, and computer readable mediums for encoding using dynamic frozen polar codes. In aspects, the techniques may be used in multi-slice networks, such as new radio (NR) (new radio access technology or 5G technology).

[0030] NR may support various wireless communication services, such as Enhanced mobile broadband (eMBB) targeting wide bandwidth (e.g. 80 MHz beyond), millimeter wave (mmW) targeting high carrier frequency (e.g. 60 GHz), massive MTC (mMTC) targeting non-backward compatible MTC techniques, and/or mission critical targeting ultra reliable low latency communications (URLLC). These services may include latency and reliability requirements. These services may also have different transmission time intervals (TTI) to meet respective quality of service (QoS) requirements. In addition, these services may co-exist in the same subframe.

[0031] In NR, Polar codes may be used for forward error correction (FEC) to encode information transmitted on control channels. Generally, in Polar encoding, the most reliable channels are selected to carry information, and the rest of the bits are set to a fixed value (e.g., such as 0), which are referred to as “frozen bits”. However, as

disclosed herein, performance can be improved by selecting some frozen bits to have values that depend on the information bits. Thus, aspects of the present disclosure present techniques for Polar encoding using dynamic frozen bits.

[0032] Various aspects of the disclosure are described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the disclosure disclosed herein, whether implemented independently of or combined with any other aspect of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim.

[0033] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects.

[0034] Although particular aspects are described herein, many variations and permutations of these aspects fall within the scope of the disclosure. Although some benefits and advantages of the preferred aspects are mentioned, the scope of the disclosure is not intended to be limited to particular benefits, uses, or objectives. Rather, aspects of the disclosure are intended to be broadly applicable to different wireless technologies, system configurations, networks, and transmission protocols, some of which are illustrated by way of example in the figures and in the following description of the preferred aspects. The detailed description and drawings are merely illustrative of the disclosure rather than limiting, the scope of the disclosure being defined by the appended claims and equivalents thereof.

[0035] The techniques described herein may be used for various wireless communication networks such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other networks. The terms “network” and “system” are often used interchangeably. A CDMA network may implement a radio technology such as universal terrestrial radio access (UTRA), cdma2000, etc. UTRA includes wideband CDMA (WCDMA), time division synchronous CDMA (TD-SCDMA), and other variants of CDMA. cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as global system for mobile communications (GSM). An OFDMA network may implement a radio technology such as evolved UTRA (E-UTRA), ultra mobile broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM®, etc. UTRA and E-UTRA are part of universal mobile telecommunication system (UMTS). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A), in both frequency division duplex (FDD) and time division duplex (TDD), are new releases of UMTS that use E-UTRA, which employs OFDMA on the downlink and SC-FDMA on the uplink. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). cdma2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). The techniques described herein may be used for the wireless networks and radio technologies mentioned above as well as other wireless networks and radio technologies, such as a 5G nextgen/NR network.

EXAMPLE WIRELESS COMMUNICATIONS SYSTEM

[0036] FIG. 1 illustrates an example wireless network 100, such as a new radio (NR) or 5G network, in which aspects of the present disclosure may be performed, for example, for control channel encoding using dynamic frozen polar codes.

[0037] As illustrated in FIG. 1, the wireless network 100 may include a number of BSs 110 and other network entities. A BS may be a station that communicates with UEs. Each BS 110 may provide communication coverage for a particular geographic area. In 3GPP, the term “cell” can refer to a coverage area of a Node B and/or a Node B subsystem serving this coverage area, depending on the context in which the term is used. In NR systems, the term “cell” and eNB, Node B, 5G NB, AP, NR BS, NR BS, a gNB, BS, or TRP may be interchangeable. In some examples, a cell may not

necessarily be stationary, and the geographic area of the cell may move according to the location of a mobile base station. In some examples, the base stations may be interconnected to one another and/or to one or more other base stations or network nodes (not shown) in the wireless network 100 through various types of backhaul interfaces such as a direct physical connection, a virtual network, or the like using any suitable transport network.

[0038] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support a particular radio access technology (RAT) and may operate on one or more frequencies. A RAT may also be referred to as a radio technology, an air interface, etc. A frequency may also be referred to as a carrier, a frequency channel, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between wireless networks of different RATs. In some cases, NR or 5G RAT networks may be deployed, employing a multi-slice network architecture.

[0039] A BS may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cell. A macro cell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by UEs with service subscription. A femto cell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by UEs having association with the femto cell (e.g., UEs in a Closed Subscriber Group (CSG), UEs for users in the home, etc.). A BS for a macro cell may be referred to as a macro BS. A BS for a pico cell may be referred to as a pico BS. A BS for a femto cell may be referred to as a femto BS or a home BS. In the example shown in FIG. 1, the BSs 110a, 110b and 110c may be macro BSs for the macro cells 102a, 102b and 102c, respectively. The BS 110x may be a pico BS for a pico cell 102x. The BSs 110y and 110z may be femto BS for the femto cells 102y and 102z, respectively. A BS may support one or multiple (e.g., three) cells.

[0040] The wireless network 100 may also include relay stations. A relay station is a station that receives a transmission of data and/or other information from an upstream station (e.g., a BS or a UE) and sends a transmission of the data and/or other information to a downstream station (e.g., a UE or a BS). A relay station may also be a

UE that relays transmissions for other UEs. In the example shown in FIG. 1, a relay station 110r may communicate with the BS 110a and a UE 120r in order to facilitate communication between the BS 110a and the UE 120r. A relay station may also be referred to as a relay BS, a relay, etc.

[0041] The wireless network 100 may be a heterogeneous network that includes BSs of different types, e.g., macro BS, pico BS, femto BS, relays, etc. These different types of BSs may have different transmit power levels, different coverage areas, and different impact on interference in the wireless network 100. For example, macro BS may have a high transmit power level (e.g., 20 Watts) whereas pico BS, femto BS, and relays may have a lower transmit power level (e.g., 1 Watt).

[0042] The wireless 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. The techniques described herein may be used for both synchronous and asynchronous operation.

[0043] A network controller 130 may couple to a set of BSs and provide coordination and control for these BSs. The network controller 130 may communicate with the BSs 110 via a backhaul. The BSs 110 may also communicate with one another, e.g., directly or indirectly via wireless or wireline backhaul.

[0044] The UEs 120 (e.g., 120x, 120y, etc.) may be dispersed throughout the wireless network 100, and each UE may be stationary or mobile. A UE may also be referred to as a mobile station, a terminal, an access terminal, a subscriber unit, a station, a Customer Premises Equipment (CPE), a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, a tablet, a camera, a gaming device, a netbook, a smartbook, an ultrabook, a medical device or medical equipment, a biometric sensor/device, a wearable device such as a smart watch, smart clothing, smart glasses, a smart wrist band, smart jewelry (e.g., a smart ring, a smart bracelet, etc.), an entertainment device (e.g., a music device, a video device, a satellite radio, etc.), a vehicular component or sensor, a smart

meter/sensor, industrial manufacturing equipment, a global positioning system device, or any other suitable device that is configured to communicate via a wireless or wired medium. Some UEs may be considered evolved or machine-type communication (MTC) devices or evolved MTC (eMTC) devices. MTC and eMTC UEs include, for example, robots, drones, remote devices, sensors, meters, monitors, location tags, etc., that may communicate with a BS, another device (e.g., remote device), or some other entity. A wireless node may provide, for example, connectivity for or to a network (e.g., a wide area network such as Internet or a cellular network) via a wired or wireless communication link. Some UEs may be considered Internet-of-Things (IoT) devices.

[0045] In FIG. 1, a solid line with double arrows indicates desired transmissions between a UE and a serving BS, which is a BS designated to serve the UE on the downlink and/or uplink. A dashed line with double arrows indicates interfering transmissions between a UE and a BS.

[0046] Certain wireless networks (e.g., LTE) utilize orthogonal frequency division multiplexing (OFDM) on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kHz and the minimum resource allocation (called a ‘resource block’) may be 12 subcarriers (or 180 kHz). Consequently, the nominal FFT size may be equal to 128, 256, 512, 1024 or 2048 for system bandwidth of 1.25, 2.5, 5, 10 or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.08 MHz (i.e., 6 resource blocks), and there may be 1, 2, 4, 8 or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10 or 20 MHz, respectively.

[0047] While aspects of the examples described herein may be associated with LTE technologies, aspects of the present disclosure may be also applicable to other wireless communications systems, such as NR/5G.

[0048] NR may utilize OFDM with a CP on the uplink and downlink and include support for half-duplex operation using TDD. A single component carrier bandwidth of 100 MHz may be supported. NR resource blocks may span 12 sub-carriers with a sub-carrier bandwidth of 60 kHz over a 0.125ms duration. It should be noted that 60kHz is only an example and NR resource blocks may span other subcarrier bandwidths such as 15, 30, 60, 120, 240 kHz.

[0049] Additionally, each radio frame may consist of 40 subframes with a total length of 10ms. Consequently, each subframe may have a length of 0.25ms. Each subframe may indicate a link direction (i.e., DL or UL) for data transmission and the link direction for each subframe may be dynamically switched. Each subframe may include DL/UL data as well as DL/UL control data. UL and DL subframes for NR may be as described in more detail below with respect to FIGs. 6 and 7. Beamforming may be supported and beam direction may be dynamically configured. MIMO transmissions with precoding may also be supported. MIMO configurations in the DL may support up to 8 transmit antennas with multi-layer DL transmissions up to 8 streams and up to 2 streams per UE. Multi-layer transmissions with up to 2 streams per UE may be supported. Aggregation of multiple cells may be supported with up to 8 serving cells. Alternatively, NR may support a different air interface, other than an OFDM-based. NR networks may include entities such CUs and/or DUs.

[0050] In some examples, access to the air interface may be scheduled, wherein a scheduling entity (e.g., a base station) allocates resources for communication among some or all devices and equipment within its service area or cell. Within the present disclosure, as discussed further below, the scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more subordinate entities. That is, for scheduled communication, subordinate entities utilize resources allocated by the scheduling entity. Base stations are not the only entities that may function as a scheduling entity. That is, in some examples, a UE may function as a scheduling entity, scheduling resources for one or more subordinate entities (e.g., one or more other UEs). In this example, the UE is functioning as a scheduling entity, and other UEs utilize resources scheduled by the UE for wireless communication. A UE may function as a scheduling entity in a peer-to-peer (P2P) network, and/or in a mesh

network. In a mesh network example, UEs may optionally communicate directly with one another in addition to communicating with the scheduling entity.

[0051] Thus, in a wireless communication network with a scheduled access to time-frequency resources and having a cellular configuration, a P2P configuration, and a mesh configuration, a scheduling entity and one or more subordinate entities may communicate utilizing the scheduled resources.

[0052] As noted above, a RAN may include a CU and DUs. A NR BS (e.g., gNB, 5G Node B, Node B, transmission reception point (TRP), access point (AP)) may correspond to one or multiple BSs. NR cells can be configured as access cell (ACells) or data only cells (DCells). For example, the RAN (e.g., a central unit or distributed unit) can configure the cells. DCells may be cells used for carrier aggregation or dual connectivity, but not used for initial access, cell selection/reselection, or handover. In some cases DCells may not transmit synchronization signals—in some case cases DCells may transmit SS. NR BSs may transmit downlink signals to UEs indicating the cell type. Based on the cell type indication, the UE may communicate with the NR BS. For example, the UE may determine NR BSs to consider for cell selection, access, handover, and/or measurement based on the indicated cell type.

[0053] FIG. 2 illustrates an example logical architecture of a distributed radio access network (RAN) 200, which may be implemented in the wireless communication system illustrated in FIG. 1. A 5G access node 206 may include an access node controller (ANC) 202. The ANC may be a central unit (CU) of the distributed RAN 200. The backhaul interface to the next generation core network (NG-CN) 204 may terminate at the ANC. The backhaul interface to neighboring next generation access nodes (NG-ANs) may terminate at the ANC. The ANC may include one or more TRPs 208 (which may also be referred to as BSs, NR BSs, Node Bs, 5G NBs, APs, or some other term). As described above, a TRP may be used interchangeably with “cell.”

[0054] The TRPs 208 may be a DU. The TRPs may be connected to one ANC (ANC 202) or more than one ANC (not illustrated). For example, for RAN sharing, radio as a service (RaaS), and service specific AND deployments, the TRP may be connected to more than one ANC. A TRP may include one or more antenna ports. The

TRPs may be configured to individually (e.g., dynamic selection) or jointly (e.g., joint transmission) serve traffic to a UE.

[0055] The local architecture 200 may be used to illustrate fronthaul definition. The architecture may be defined that support fronthauling solutions across different deployment types. For example, the architecture may be based on transmit network capabilities (e.g., bandwidth, latency, and/or jitter).

[0056] The architecture may share features and/or components with LTE. According to aspects, the next generation AN (NG-AN) 210 may support dual connectivity with NR. The NG-AN may share a common fronthaul for LTE and NR.

[0057] The architecture may enable cooperation between and among TRPs 208. For example, cooperation may be present within a TRP and/or across TRPs via the ANC 202. According to aspects, no inter-TRP interface may be needed/present.

[0058] According to aspects, a dynamic configuration of split logical functions may be present within the architecture 200. As will be described in more detail with reference to FIG. 5, the Radio Resource Control (RRC) layer, Packet Data Convergence Protocol (PDCP) layer, Radio Link Control (RLC) layer, Medium Access Control (MAC) layer, and a Physical (PHY) layers may be adaptably placed at the DU or CU (e.g., TRP or ANC, respectively). According to certain aspects, a BS may include a central unit (CU) (e.g., ANC 202) and/or one or more distributed units (e.g., one or more TRPs 208).

[0059] FIG. 3 illustrates an example physical architecture of a distributed RAN 300, according to aspects of the present disclosure. A centralized core network unit (C-CU) 302 may host core network functions. The C-CU may be centrally deployed. C-CU functionality may be offloaded (e.g., to advanced wireless services (AWS)), in an effort to handle peak capacity.

[0060] A centralized RAN unit (C-RU) 304 may host one or more ANC functions. Optionally, the C-RU may host core network functions locally. The C-RU may have distributed deployment. The C-RU may be closer to the network edge.

[0061] A DU 306 may host one or more TRPs (edge node (EN), an edge unit (EU), a radio head (RH), a smart radio head (SRH), or the like). The DU may be located at edges of the network with radio frequency (RF) functionality.

[0062] FIG. 4 illustrates example components of the BS 110 and UE 120 illustrated in FIG. 1, which may be used to implement aspects of the present disclosure. As described above, the BS may include a TRP. One or more components of the BS 110 and UE 120 may be used to practice aspects of the present disclosure. For example, antennas 452, Tx/Rx 222, processors 466, 458, 464, and/or controller/processor 480 of the UE 120 and/or antennas 434, processors 460, 420, 438, and/or controller/processor 440 of the BS 110 may be used to perform the operations described herein and illustrated with reference to FIGs. 11-12.

[0063] According to aspects, for a restricted association scenario, the base station 110 may be the macro BS 110c in FIG. 1, and the UE 120 may be the UE 120y. The base station 110 may also be a base station of some other type. The base station 110 may be equipped with antennas 434a through 434t, and the UE 120 may be equipped with antennas 452a through 452r.

[0064] At the base station 110, a transmit processor 420 may receive data from a data source 412 and control information from a controller/processor 440. The control information may be for the Physical Broadcast Channel (PBCH), Physical Control Format Indicator Channel (PCFICH), Physical Hybrid ARQ Indicator Channel (PHICH), Physical Downlink Control Channel (PDCCH), etc. The data may be for the Physical Downlink Shared Channel (PDSCH), etc. The processor 420 may process (e.g., encode and symbol map) the data and control information to obtain data symbols and control symbols, respectively. The processor 420 may also generate reference symbols, e.g., for the PSS, SSS, and cell-specific reference signal. A transmit (TX) multiple-input multiple-output (MIMO) processor 430 may perform spatial processing (e.g., precoding) on the data symbols, the control symbols, and/or the reference symbols, if applicable, and may provide output symbol streams to the modulators (MODs) 432a through 432t. Each modulator 432 may process a respective output symbol stream (e.g., for OFDM, etc.) to obtain an output sample stream. Each modulator 432 may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink signal. Downlink signals

from modulators 432a through 432t may be transmitted via the antennas 434a through 434t, respectively.

[0065] At the UE 120, the antennas 452a through 452r may receive the downlink signals from the base station 110 and may provide received signals to the demodulators (DEMODs) 454a through 454r, respectively. Each demodulator 454 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples. Each demodulator 454 may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols. A MIMO detector 456 may obtain received symbols from all the demodulators 454a through 454r, perform MIMO detection on the received symbols if applicable, and provide detected symbols. A receive processor 458 may process (e.g., demodulate, deinterleave, and decode) the detected symbols, provide decoded data for the UE 120 to a data sink 460, and provide decoded control information to a controller/processor 480.

[0066] On the uplink, at the UE 120, a transmit processor 464 may receive and process data (e.g., for the Physical Uplink Shared Channel (PUSCH)) from a data source 462 and control information (e.g., for the Physical Uplink Control Channel (PUCCH)) from the controller/processor 480. The transmit processor 464 may also generate reference symbols for a reference signal. The symbols from the transmit processor 464 may be precoded by a TX MIMO processor 466 if applicable, further processed by the demodulators 454a through 454r (e.g., for SC-FDM, etc.), and transmitted to the base station 110. At the BS 110, the uplink signals from the UE 120 may be received by the antennas 434, processed by the modulators 432, detected by a MIMO detector 436 if applicable, and further processed by a receive processor 438 to obtain decoded data and control information sent by the UE 120. The receive processor 438 may provide the decoded data to a data sink 439 and the decoded control information to the controller/processor 440.

[0067] The controllers/processors 440 and 480 may direct the operation at the base station 110 and the UE 120, respectively. The processor 440 and/or other processors and modules at the base station 110 may perform or direct, e.g., the execution of the functional blocks illustrated in FIG. 6, and/or other processes for the techniques described herein. The processor 480 and/or other processors and modules at the UE 120 may also perform or direct, e.g., the execution of the functional blocks illustrated in

FIG. 7, and/or other processes for the techniques described herein. The memories 442 and 482 may store data and program codes for the BS 110 and the UE 120, respectively. A scheduler 444 may schedule UEs for data transmission on the downlink and/or uplink.

[0068] FIG. 5 illustrates a diagram 500 showing examples for implementing a communications protocol stack, according to aspects of the present disclosure. The illustrated communications protocol stacks may be implemented by devices operating in a 5G system (e.g., a system that supports uplink-based mobility). Diagram 500 illustrates a communications protocol stack including a Radio Resource Control (RRC) layer 510, a Packet Data Convergence Protocol (PDCP) layer 515, a Radio Link Control (RLC) layer 520, a Medium Access Control (MAC) layer 525, and a Physical (PHY) layer 530. In various examples the layers of a protocol stack may be implemented as separate modules of software, portions of a processor or ASIC, portions of non-collocated devices connected by a communications link, or various combinations thereof. Collocated and non-collocated implementations may be used, for example, in a protocol stack for a network access device (e.g., ANs, CUs, and/or DUs) or a UE.

[0069] A first option 505-a shows a split implementation of a protocol stack, in which implementation of the protocol stack is split between a centralized network access device (e.g., an ANC 202 in FIG. 2) and distributed network access device (e.g., DU 208 in FIG. 2). In the first option 505-a, an RRC layer 510 and a PDCP layer 515 may be implemented by the central unit, and an RLC layer 520, a MAC layer 525, and a PHY layer 530 may be implemented by the DU. In various examples the CU and the DU may be collocated or non-collocated. The first option 505-a may be useful in a macro cell, micro cell, or pico cell deployment.

[0070] A second option 505-b shows a unified implementation of a protocol stack, in which the protocol stack is implemented in a single network access device (e.g., access node (AN), new radio base station (NR BS), a new radio Node-B (NR NB), a network node (NN), or the like.). In the second option, the RRC layer 510, the PDCP layer 515, the RLC layer 520, the MAC layer 525, and the PHY layer 530 may each be implemented by the AN. The second option 505-b may be useful in a femto cell deployment.

[0071] Regardless of whether a network access device implements part or all of a protocol stack, a UE may implement an entire protocol stack (e.g., the RRC layer 510, the PDCP layer 515, the RLC layer 520, the MAC layer 525, and the PHY layer 530).

[0072] FIG. 6 illustrates various components that may be utilized in a wireless communications device 602 that may be employed within the wireless communication system from FIG. 1. The wireless communications device 602 is an example of a device that may be configured to implement the various methods described herein. The wireless communications device 602 may be an BS 110 from FIG. 1 or any of user equipments 120.

[0073] The wireless communications device 602 may include a processor 604 which controls operation of the wireless communications device 602. The processor 604 may also be referred to as a central processing unit (CPU). Memory 606, which may include both read-only memory (ROM) and random access memory (RAM), provides instructions and data to the processor 604. A portion of the memory 606 may also include non-volatile random access memory (NVRAM). The processor 604 typically performs logical and arithmetic operations based on program instructions stored within the memory 606. The instructions in the memory 606 may be executable to implement the methods described herein.

[0074] The wireless communications device 602 may also include a housing 608 that may include a transmitter 610 and a receiver 612 to allow transmission and reception of data between the wireless device 602 and a remote location. The transmitter 610 and receiver 612 may be combined into a transceiver 614. A single or a plurality of transmit antennas 616 may be attached to the housing 608 and electrically coupled to the transceiver 614. The wireless communications device 602 may also include (not shown) multiple transmitters, multiple receivers, and multiple transceivers.

[0075] The wireless communications device 602 may also include a signal detector 618 that may be used in an effort to detect and quantify the level of signals received by the transceiver 614. The signal detector 618 may detect such signals as total energy, energy per subcarrier per symbol, power spectral density and other signals. The wireless communications device 602 may also include a digital signal processor (DSP) 620 for use in processing signals.

[0076] Additionally, the wireless communications device 602 may also include an encoder 622 for use in encoding signals for transmission. The encoder may select a rate code to encode the signals and may store the encoded signals in a circular buffer (not shown). The encoder may also perform rate matching on the encoded signals, as described below. Further, the wireless communication device 602 may include a decoder 624 for use in decoding received signals, for example, by using Polar encoding with dynamic frozen bits as will be described in more detail below.

[0077] The various components of the wireless communications device 602 may be coupled together by a bus system 626, which may include a power bus, a control signal bus, and a status signal bus in addition to a data bus. The processor 604 may be configured to access instructions stored in the memory 606 to perform connectionless access, in accordance with aspects of the present disclosure discussed below.

[0078] FIG. 7 is a simplified block diagram illustrating an encoder, in accordance with certain aspects of the present disclosure. FIG. 7 illustrates a portion of a radio frequency (RF) modem 704 that may be configured to provide an encoded message for wireless transmission (e.g., using Polar codes described below). In one example, an encoder 706 in a base station (e.g., BS 110) or a UE (e.g., UE 120) on the reverse path receives a message 702 for transmission. The message 702 may contain data and/or encoded voice or other content directed to the receiving device. In aspects, the message 702 is first input into a sequencer 700 that receives the message 702 and output the message 702 as a sequence of bits in a channel index order. In aspects, the sequencer 700 determines the channel index order for the sequence of bits. As discussed further herein, the sequencer 700 may be responsible for determining the channel indices for fixed frozen bits, information bits, and dynamic frozen bits. For example the sequencer 700 may determine the channel indices for the fixed frozen bits, information bits, and dynamic frozen bits as shown in FIG. 14. As will be discussed in more detail herein, the sequencer 700 may determine values for the dynamic frozen bits based on a function of all or a part of the previous information bits. The encoder 706 encodes the message using a suitable modulation and coding scheme (MCS), typically selected based on a configuration defined by the BS 110 or another network entity. In some cases, the encoder 706 may select, from a set of rate codes, a rate code to be used to encode the message. The encoded bitstream 708 may then be stored in circular buffer and rate-

matching may be performed on the stored encoded bitstream, for example, according to aspects presented below. After the encoded bitstream 708 is rate-matched, the encoded bitstream 708 may then be provided to a mapper 710 that generates a sequence of Tx symbols 712 that are modulated, amplified and otherwise processed by Tx chain 714 to produce an RF signal 716 for transmission through antenna 718.

[0079] FIG. 8 is a simplified block diagram illustrating a decoder, in accordance with certain aspects of the present disclosure. FIG. 8 illustrates a portion of a RF modem 810 that may be configured to receive and decode a wirelessly transmitted signal including an encoded message (e.g., a message encoded using a Polar code as described below). In various examples, the modem 810 receiving the signal may reside at the access terminal, at the base station, or at any other suitable apparatus or means for carrying out the described functions. An antenna 802 provides an RF signal 716 (i.e., the RF signal produced in FIG. 4) to an access terminal (e.g., UE 120). An Rx chain 806 processes and demodulates the RF signal 716 and may provide a sequence of demodulated symbols 808 to a demapper 812, which produces a bitstream 814 representative of the encoded message.

[0080] A decoder 816 may then be used to decode m-bit information strings from a bitstream that has been encoded using a coding scheme (e.g., a Polar code). The decoder 816 may comprise a Viterbi decoder, an algebraic decoder, a butterfly decoder, or another suitable decoder. In one example, a Viterbi decoder employs the well-known Viterbi algorithm to find the most likely sequence of signaling states (the Viterbi path) that corresponds to a received bitstream 814. The bitstream 814 may be decoded based on a statistical analysis of LLRs calculated for the bitstream 814. In one example, a Viterbi decoder may compare and select the correct Viterbi path that defines a sequence of signaling states using a likelihood ratio test to generate LLRs from the bitstream 814. Likelihood ratios can be used to statistically compare the fit of a plurality of candidate Viterbi paths using a likelihood ratio test that compares the logarithm of a likelihood ratio for each candidate Viterbi path (i.e. the LLR) to determine which path is more likely to account for the sequence of symbols that produced the bitstream 814. The decoder 816 may then decode the bitstream 814 based on the LLRs to determine the message 818 containing data and/or encoded voice or other content transmitted from the base station (e.g., BS 110). In some cases, the decoder may combine LLRs associated

with lower aggregation levels with LLRs associated with higher aggregation levels and use the combined LLRs to decode the bitstream 814, for example, as described in greater detail below.

[0081] FIG. 9 is a diagram 900 showing an example of a DL-centric subframe, which may be used by one or more devices (e.g., BS 110 and/or UE 120) to communicate in the wireless network 100. The DL-centric subframe may include a control portion 902. The control portion 902 may exist in the initial or beginning portion of the DL-centric subframe. The control portion 902 may include various scheduling information and/or control information corresponding to various portions of the DL-centric subframe. In some configurations, the control portion 902 may be a physical DL control channel (PDCCH), as indicated in FIG. 9. The DL-centric subframe may also include a DL data portion 904. The DL data portion 904 may sometimes be referred to as the payload of the DL-centric subframe. The DL data portion 904 may include the communication resources utilized to communicate DL data from the scheduling entity (e.g., UE or BS) to the subordinate entity (e.g., UE). In some configurations, the DL data portion 904 may be a physical DL shared channel (PDSCH).

[0082] The DL-centric subframe may also include a common UL portion 906. The common UL portion 906 may sometimes be referred to as an UL burst, a common UL burst, and/or various other suitable terms. The common UL portion 906 may include feedback information corresponding to various other portions of the DL-centric subframe. For example, the common UL portion 906 may include feedback information corresponding to the control portion 902. Non-limiting examples of feedback information may include an ACK signal, a NACK signal, a HARQ indicator, and/or various other suitable types of information. The common UL portion 906 may include additional or alternative information, such as information pertaining to random access channel (RACH) procedures, scheduling requests (SRs), and various other suitable types of information. As illustrated in FIG. 9, the end of the DL data portion 904 may be separated in time from the beginning of the common UL portion 906. This time separation may sometimes be referred to as a gap, a guard period, a guard interval, and/or various other suitable terms. This separation provides time for the switch-over from DL communication (e.g., reception operation by the subordinate entity (e.g., UE))

to UL communication (e.g., transmission by the subordinate entity (e.g., UE)). One of ordinary skill in the art will understand that the foregoing is merely one example of a DL-centric subframe and alternative structures having similar features may exist without necessarily deviating from the aspects described herein.

[0083] FIG. 10 is a diagram 1000 showing an example of an UL-centric subframe, which may be used by one or more devices (e.g., BS 110 and/or UE 120) to communicate in the wireless network 100. The UL -centric subframe may include a control portion 1002. The control portion 1002 may exist in the initial or beginning portion of the UL-centric subframe. The control portion 1002 in FIG. 10 may be similar to the control portion described above with reference to FIG. 9. The UL-centric subframe may also include an UL data portion 1004. The UL data portion 1004 may sometimes be referred to as the payload of the UL-centric subframe. The UL portion may refer to the communication resources utilized to communicate UL data from the subordinate entity (e.g., UE) to the scheduling entity (e.g., UE or BS). In some configurations, the control portion 1002 may be a physical DL control channel (PDCCH).

[0084] As illustrated in FIG. 10, the end of the control portion 1002 may be separated in time from the beginning of the UL data portion 1004. This time separation may sometimes be referred to as a gap, guard period, guard interval, and/or various other suitable terms. This separation provides time for the switch-over from DL communication (e.g., reception operation by the scheduling entity) to UL communication (e.g., transmission by the scheduling entity). The UL-centric subframe may also include a common UL portion 1006. The common UL portion 1006 in FIG. 10 may be similar to the common UL portion 1006 described above with reference to FIG. 10. The common UL portion 1006 may additional or alternative include information pertaining to channel quality indicator (CQI), sounding reference signals (SRSs), and various other suitable types of information. One of ordinary skill in the art will understand that the foregoing is merely one example of an UL-centric subframe and alternative structures having similar features may exist without necessarily deviating from the aspects described herein.

[0085] In some circumstances, two or more subordinate entities (e.g., UEs) may communicate with each other using sidelink signals. Real-world applications of such

sidelink communications may include public safety, proximity services, UE-to-network relaying, vehicle-to-vehicle (V2V) communications, Internet of Everything (IoE) communications, IoT communications, mission-critical mesh, and/or various other suitable applications. Generally, a sidelink signal may refer to a signal communicated from one subordinate entity (e.g., UE1) to another subordinate entity (e.g., UE2) without relaying that communication through the scheduling entity (e.g., UE or BS), even though the scheduling entity may be utilized for scheduling and/or control purposes. In some examples, the sidelink signals may be communicated using a licensed spectrum (unlike wireless local area networks, which typically use an unlicensed spectrum).

[0086] A UE may operate in various radio resource configurations, including a configuration associated with transmitting pilots using a dedicated set of resources (e.g., a radio resource control (RRC) dedicated state, etc.) or a configuration associated with transmitting pilots using a common set of resources (e.g., an RRC common state, etc.). When operating in the RRC dedicated state, the UE may select a dedicated set of resources for transmitting a pilot signal to a network. When operating in the RRC common state, the UE may select a common set of resources for transmitting a pilot signal to the network. In either case, a pilot signal transmitted by the UE may be received by one or more network access devices, such as an AN, or a DU, or portions thereof. Each receiving network access device may be configured to receive and measure pilot signals transmitted on the common set of resources, and also receive and measure pilot signals transmitted on dedicated sets of resources allocated to the UEs for which the network access device is a member of a monitoring set of network access devices for the UE. One or more of the receiving network access devices, or a CU to which receiving network access device(s) transmit the measurements of the pilot signals, may use the measurements to identify serving cells for the UEs, or to initiate a change of serving cell for one or more of the UEs.

Example Polar Codes

[0087] As noted above, Polar codes may be used to encode a stream of bits for transmission. Polar codes are a capacity-achieving coding scheme with almost linear (in block length) encoding and decoding complexity. Polar codes are widely considered as a candidate for error-correction in the next-generation wireless systems. Polar codes

have many desirable properties such as deterministic construction (e.g., based on a fast Hadamard transform), very low and predictable error floors, and simple successive-cancellation (SC) based decoding.

[0088] Polar codes are linear block codes of length $N=2^n$ where their generator matrix is constructed using the n^{th} Kronecker power of the matrix $G = \begin{pmatrix} 1 & 0 \\ 1 & 1 \end{pmatrix}$, denoted by G^n . For example, Equation (1) shows the resulting generator matrix for $n=3$.

$$G^{\otimes 3} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \quad \text{Eq. 1}$$

[0089] A codeword may be generated by using the generator matrix to encode a number of input bits (e.g., information bits). For example, given a number of input bits $u=(u_0, u_1, \dots, u_{N-1})$, a resulting codeword vector $x=(x_0, x_1, \dots, x_{N-1})$ may be generated by encoding the input bits using the generator matrix G . This resulting codeword may then be rate matched and transmitted.

[0090] When the received vectors are decoded) using a Successive Cancellation (SC) decoder (e.g., decoder 816), every estimated bit, \hat{u}_i , has a predetermined error probability given that bits u_0^{i-1} were correctly decoded, that tends towards either 0 or 0.5. Moreover, the proportion of estimated bits with a low error probability tends towards the capacity of the underlying channel. Polar codes exploit a phenomenon called channel polarization by using the most reliable K bits to transmit information, while setting, or freezing, the remaining $(N-K)$ bits to a predetermined value, such as 0, for example as explained below.

[0091] For very large N , polar codes transform the channel into N parallel “virtual” channels for the N information bits. If C is the capacity of the channel, then there are almost $N*C$ channels which are completely noise free and there are $N(1 - C)$ channels which are completely noisy. The basic polar coding scheme then involves freezing (i.e., not transmitting) the information bits to be sent along the completely noisy channel and

sending information only along the perfect channels. For short-to-medium N, this polarization may not be complete in the sense there could be several channels which are neither completely useless nor completely noise free (i.e., channels that are in transition). Depending on the rate of transmission, these channels in the transition are either frozen or they are used for transmission.

[0092] In new radio (NR) as described above, Polar codes may be used to encode information. For example, Polar codes may be used as forward error correction (FEC) for control channels (e.g., 5G control channels). Generally, cyclic redundancy check (CRS) bits can be added in the Polar codes to improve the error rate performance and error detection.

[0093] In Polar encoding, the most reliable channels are typically selected to carry information (e.g., information bits), and the rest of the bits are set as a fixed value (e.g., 0). These fixed bits may be referred to as frozen bits. However if some of the frozen bits are selected having values that depend on the information bits, the performance can be improved.

EXAMPLE DYNAMIC FROZEN POLAR CODES

[0094] According to certain aspects, a bit sequence (e.g., ordering or arrangement of bits of a stream of bits) for bits input to a Polar encoder may be determined, where each bit in the bit sequence corresponds to (e.g., is selected/ordered/arranged/set/placed in the bit sequence based on) a channel index having certain reliability metrics.

[0095] FIG. 11 illustrates example operations 1100 for wireless communications. Operations 1100 may be performed by an encoding device, which may be a wireless communications device, such as a base station (e.g., BS 110), a user equipment (e.g., UE 120), and/or other wireless communications device 602.

[0096] Operations 1100 begin at 1102 by encoding a stream of bits using polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits. At 1104, the encoding device transmits the encoded stream of bits.

[0097] For example, setting the dynamic frozen bits may include selecting a second set of bits of the stream of bits as the one or more information bits and a third set of bits of the stream of bits as fixed frozen bits. The information bits may include payload bits and/or cyclic redundancy check (CRC) bits. The selecting may include, at 1102a, selecting most reliable channel indices for the information bits and, at 1102b, selecting channel indices smaller than channel index for the first information bit for the fixed frozen bits. At 1102c, selecting the remaining channel indices for the dynamic frozen bits.

[0098] According to certain aspects, the method further includes, at 1106, calculating the values of the dynamic frozen bits as a function of at least a portion of the previous information bits. For example, the function may be an XOR (exclusive or) function.

[0099] According to certain aspects, the stream of bits may be a code block of a control channel. Each bit in the stream of bits may correspond to a channel indices. The channel indices of the fixed frozen bits, information bits, and/or the dynamic frozen bits may be determined independently for each stream of bits to be encoded.

[0100] FIG. 12 illustrates example operations 1200 for wireless communications. Operations 1200 may be performed by a decoding device, which may be a wireless communications device, such as a base station (e.g., BS 110), user equipment (e.g., 120), and/or wireless communications device 602.

[0101] Operations 1200 begin at 1202 by receiving a polar encoded stream of bits including a first set of dynamic frozen bits having values based on one or more information bits. At 1104, the encoding device decodes the encoded stream of bits, wherein decoding the stream of bits includes decoding the dynamic frozen bits based on one or more previous information bits.

[0102] FIG. 13 is an exemplary wireless device 1302 that may include means for performing the operations 1200 for dynamic frozen polar code encoding described above with respect to FIG. 12, in accordance with certain aspects of the present disclosure. Wireless device 1302 may be a UE such as UE 120 described above or a BS such as BS 110 described above. According to certain aspects, the wireless device 1302

may include one or antenna(s) 1304 for receiving and/or transmitting a stream of bits, which may be an encoded stream of bits. As shown in FIG. 13, the wireless device includes a sequencer 1306 and an encoder 1316. The wireless device 1300 may include bits for encoding. For example, the wireless device 1300 may include a stream of bits corresponding to code blocks of a control channel. Although not shown, wireless device may include a module (e.g., a processor) configured to generate information bits to be encoded for transmission to another wireless device.

[0103] According to certain aspects, sequencer 1306 may include the information bit channel indices determination module 1308 for determining the information channel indices. For example, the information bit channel indices determination module 1308 may select mode reliable channel indices for the information bits. For example, the sequencer 1306 may select (e.g., set) the K most reliable channels as information channel indices, where K is equal to the number of information bits, including payload and CRC bits. Sequencer 1306 may include fixed frozen bit channel indices determination module 1310 configured to determine fixed frozen channel indices. For example, the sequencer 1306 may select (e.g., set) the channels before (e.g., having smaller/lower channel indices) the first information channel as the fixed frozen channel indices. For example, since these channel having the lower channel indices may be lower reliability, these may be used for the frozen bits (e.g., padding). Sequencer 1306 may include dynamic frozen bit channel indices determination module 1312 for determining dynamic frozen channel indices. For example, sequencer 1306 may select the remaining channels (i.e., the channel indices not selected for the information bits or the fixed frozen bits) may be selected (e.g., set) as the dynamic frozen channel indices. FIG. 14 is an example of the channel selection for the information bits, fixed frozen bits, and dynamic frozen bits, in accordance with certain aspects of the present disclosure.

[0104] As used herein, channel indices may refer to virtual channels (e.g., the indices may map to frequency resources). In an example, each channel carries one bit.

[0105] CRC bits can be added to the information bits. For example, as shown in FIG. 13, encoder 1316 includes CRC encoding module 1318. CRC encoding module 1318 may be configured to encode the payload (e.g., by adding CRC bits to the payload). CRC encoder module 1318 may output K information bits. The K information bits can be put in the selected information channels.

[0106] As shown in FIG. 13, the values of the dynamic frozen bits can be calculated. Sequencer 1306 includes dynamic frozen bit value determination module 1314. For example, for a code length of length N bits, the channel index order may be denoted as u_0, u_1, \dots, u_{N-1} . The set of information channels can be denoted as A , where $|A| = K$. For a given dynamic frozen bit, u_i , dynamic frozen bit value determination module 1314 may calculate the value of the bit based on (e.g., dependent on) previous information bits. For example, the value of the dynamic frozen bit may be calculated as:

$$u_i = f(u_{i_1}, u_{i_2}, \dots, u_{i_j})$$

where, $i_1 < i, \dots, i_j < i$; $i_1 \in A, \dots, i_j \in A$, and f is dynamic frozen function. According to certain aspects, the value of the dynamic frozen bit may be based on all or only a portion of the previous information bits. For example, the dynamic frozen function f may be an XOR (exclusive or) function of all of the previous information bits or an XOR function of part of the previous information bits.

[0107] As shown in FIG. 13, encoder 1316 may include Polar code module 1320. For example, after the dynamic frozen bits are calculated, the sequence u_0, u_1, \dots, u_{N-1} may be fed to the Polar code module 1320 which may be configured to perform Polar encoding and output the coded bits. The output coded stream of bits may be transmitted to another wireless device, for example, via the antenna(s) 1304.

[0108] According to certain aspects, a sequencer may select (e.g., determine, set) channel indices for the information bits, frozen bits, and/or dynamic frozen bits. An encoder (e.g., a CRC encoder) may perform encoding on the information bits. The sequencer may also calculate the values of the dynamic frozen bits. For example, the encoder may add CRC bits to payload bits. Another encoder may perform the Polar encoding on the stream of bits including the information bits, frozen bits, and dynamic frozen bits.

[0109] According to certain aspects, each bit in the stream of bits may correspond to a channel index. The channel indices of the information bits, the fixed frozen bits, and/or the dynamic frozen bits may be determined independently for each stream of bits to be encoded (e.g., for each code block). For example, the most reliable channels may

change over time. Thus, the positions (e.g., channel indices), and/or the values of the bits, determined for the information bits and, thus, for the fixed frozen bits and/or the dynamic frozen bits may vary over time as well.

[0110] Although not shown in FIG. 13, a wireless device, such as wireless device 1302 may include a decoder. On the decoding side, the decoder may receive the coded stream of bits. The decoder may decode the stream of bits in order, starting from the lower channel indices. Thus, the decoder may decode the fixed frozen bits first, and then information bits and dynamic frozen bits. In aspects, the decoder may use the information bits to decode the dynamic frozen bits, which may increase the decoding performance.

[0111] The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0112] As used herein, a phrase referring to “at least one of” a list of items refers to any combination of those items, including single members. As an example, “at least one of: a, b, or c” is intended to cover a, b, c, a-b, a-c, b-c, and a-b-c, as well as any combination with multiples of the same element (e.g., a-a, a-a-a, a-a-b, a-a-c, a-b-b, a-c-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[0113] As used herein, the term “determining” encompasses a wide variety of actions. For example, “determining” may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, “determining” may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, “determining” may include resolving, selecting, choosing, establishing and the like.

[0114] In some cases, rather than actually transmitting a frame, a device may have an interface to output a frame for transmission. For example, a processor may output a frame, via a bus interface, to an RF front end for transmission. Similarly, rather than actually receiving a frame, a device may have an interface to obtain a frame received

from another device. For example, a processor may obtain (or receive) a frame, via a bus interface, from an RF front end for transmission.

[0115] The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an application specific integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering.

[0116] For example, means for transmitting, means for receiving, means for determining, means for encoding, means for selecting, means for decoding, means for calculating, and/or means for setting may comprise one or more processors or antennas at the BS 110 or UE 120, such as the transmit processor 220, controller/processor 240, receive processor 238, or antennas 234 at the BS 110 and/or the transmit processor 264, controller/processor 280, receive processor 258, or antennas 252 at the UE 120.

[0117] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device (PLD), 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 commercially available 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, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0118] If implemented in hardware, an example hardware configuration may comprise a processing system in a wireless node. The processing system may be implemented with a bus architecture. The bus may include any number of interconnecting buses and bridges depending on the specific application of the processing system and the overall design constraints. The bus may link together various

circuits including a processor, machine-readable media, and a bus interface. The bus interface may be used to connect a network adapter, among other things, to the processing system via the bus. The network adapter may be used to implement the signal processing functions of the PHY layer. In the case of a user terminal 120 (see FIG. 1), a user interface (e.g., keypad, display, mouse, joystick, etc.) may also be connected to the bus. The bus may also link various other circuits such as timing sources, peripherals, voltage regulators, power management circuits, and the like, which are well known in the art, and therefore, will not be described any further. The processor may be implemented with one or more general-purpose and/or special-purpose processors. Examples include microprocessors, microcontrollers, DSP processors, and other circuitry that can execute software. Those skilled in the art will recognize how best to implement the described functionality for the processing system depending on the particular application and the overall design constraints imposed on the overall system.

[0119] If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer-readable medium. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. The processor may be responsible for managing the bus and general processing, including the execution of software modules stored on the machine-readable storage media. A computer-readable storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. By way of example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer readable storage medium with instructions stored thereon separate from the wireless node, all of which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files. Examples of machine-readable storage media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-

Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product.

[0120] A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. The computer-readable media may comprise a number of software modules. The software modules include instructions that, when executed by an apparatus such as a processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

[0121] Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer-readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0122] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0123] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

CLAIMS

1. A method for wireless communications, comprising:
 - encoding a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and
 - transmitting the encoded stream of bits.
2. The method of claim 1, wherein the encoding further includes:
 - selecting a second set of bits of the stream of bits as the one or more information bits and a third set of bits of the stream of bits as fixed frozen bits.
3. The method of claim 2, wherein the information bits comprise at least one of: payload bits or cyclic redundancy check (CRC) bits.
4. The method of claim 2, wherein:
 - the selecting comprises:
 - selecting most reliable channel indices for the information bits, and
 - selecting channel indices smaller than a channel index for the first information bit for the fixed frozen bits; and
 - setting the first set of bits comprises selecting the remaining channel indices for the dynamic frozen bits.
5. The method of claim 1, wherein the encoding further comprises:
 - calculating the values of the dynamic frozen bits as a function of at least a portion of the previous information bits.
6. The method of claim 5, wherein the function comprises an XOR (exclusive or) function.
7. The method of claim 1, wherein the stream of bits comprises at least one code block of a control channel.
8. The method of claim 2, wherein:

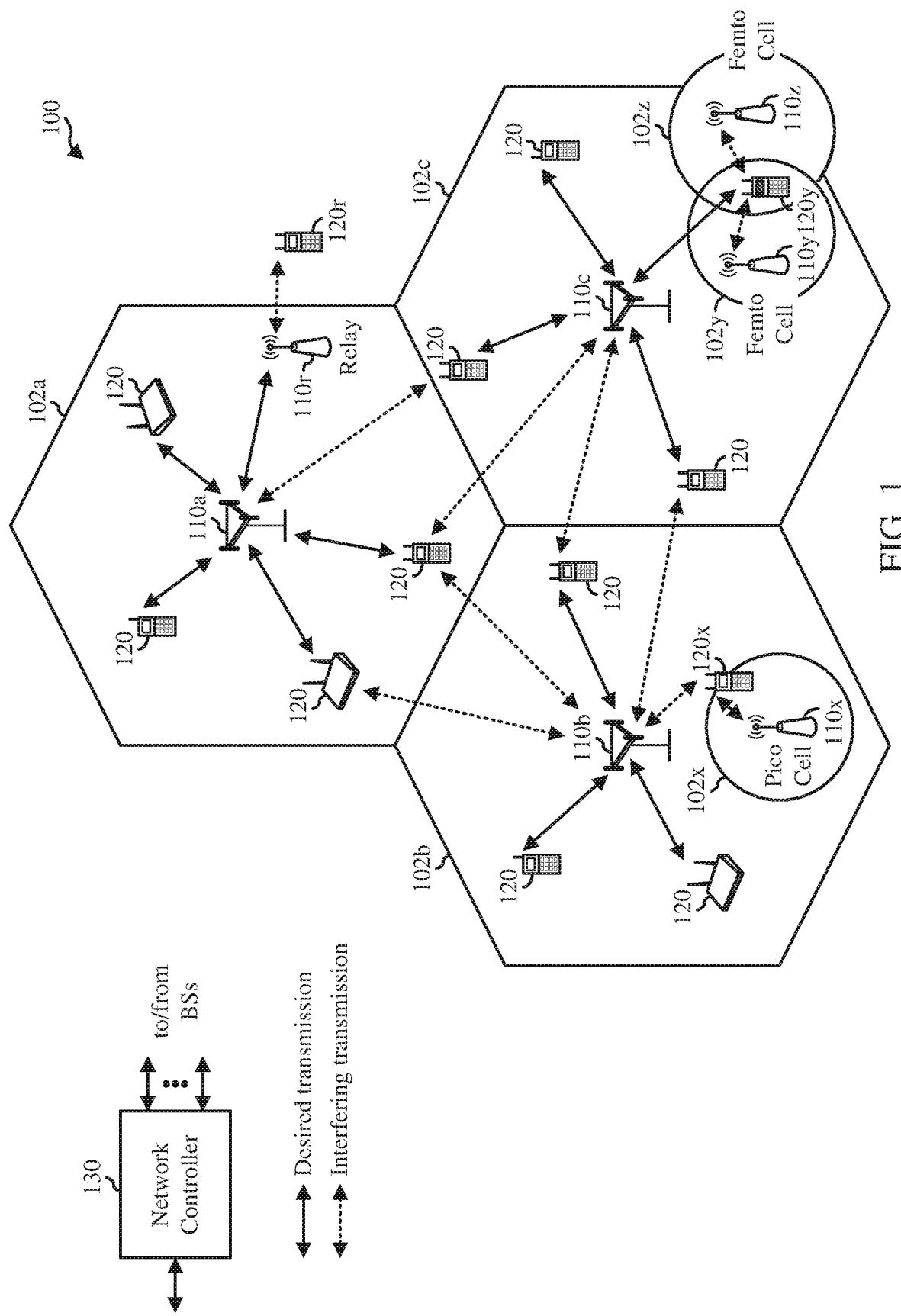
each bit in the stream of bits corresponds to a channel index, and the channel indices of at least one of: the information bits, the fixed frozen bits, or the dynamic frozen bits is determined independently for each stream of bits to be encoded.

9. An apparatus for wireless communications, comprising:
 - means for receiving a plurality of information bits;
 - means for determining dynamic frozen bits having values based on the plurality of information bits;
 - means for determining a bit sequence comprising the information bits and the dynamic frozen bits;
 - means for encoding the bit sequence using a polar code to form an encoded message; and
 - means for transmitting the encoded message, wherein each bit in the bit sequence is associated with a channel index for transmitting the encoded message.
10. The apparatus of claim 9, further comprising:
 - mean for determining fixed frozen bits having values independent of the information bits, and wherein the bit sequence comprises the information bits, the dynamic frozen bits, and the fixed frozen bits.
11. The apparatus of claim 10, wherein the means for determining the bit sequence is operative to:
 - associate the information bits with channel indices corresponding to a set of most reliable channels in the bit sequence,
 - associate the set of fixed frozen bits with channel indices based on a first channel index associated with the information bits in the bit sequence, and
 - associate the dynamic frozen bits with remaining channel indices not associated with the information bits or the fixed frozen bits in the bit sequence.
12. The apparatus of claim 9, further comprising:
 - means for encoding the information bits with cyclic redundancy check (CRC) bits.

13. The apparatus of claim 1, wherein the means for determining dynamic frozen bits having values based on the plurality of information bits comprises means for determining the dynamic frozen bits based on an exclusive or (XOR) function of at least a portion of the information bits.
14. An apparatus for wireless communications, comprising:
 - a sequencer configured to set a first set of bits of a stream of bits as dynamic frozen bits having values based on one or more information bits;
 - an encoder configured to encode the stream of bits using a polar code; and
 - a transmitter configured to transmit the encoded stream of bits.
15. The apparatus of claim 14, wherein the sequencer is further configured to:
 - select a second set of bits of the stream of bits as the one or more information bits and a third set of bits of the stream of bits as fixed frozen bits.
16. The apparatus of claim 15, wherein the encoder is further configured to encode the information bits by adding cyclic redundancy check (CRC) bits to payload bits.
17. The apparatus of claim 15, wherein the sequencer is configured to:
 - select most reliable channel indices for the information bits, and
 - select channel indices smaller than a channel index for the first information bit for the fixed frozen bits; and
 - select the remaining channel indices for the dynamic frozen bits.
18. The apparatus of claim 14, wherein the sequencer is further configured to:
 - calculate the values of the dynamic frozen bits as a function of at least a portion of the previous information bits.
19. The apparatus of claim 18, wherein the function comprises an XOR (exclusive or) function.

20. The apparatus of claim 14, wherein the stream of bits comprises at least one code block of a control channel.
21. The apparatus of claim 15, wherein:
 - each bit in the stream of bits corresponds to a channel index, and
 - the sequencer is configured to determine the channel indices of at least one of the information bits, the fixed frozen bits, or the dynamic frozen bits independently for each stream of bits to be encoded.
22. A computer readable medium having computer executable code stored thereon for wireless communications, comprising:
 - code for encoding a stream of bits using a polar code, wherein the encoding includes setting a first set of bits of the stream of bits as dynamic frozen bits having values based on one or more information bits; and
 - code for transmitting the encoded stream of bits.
23. A method for wireless communications, comprising:
 - receiving a Polar encoded stream of bits including a first set of dynamic frozen bits having values based on one or more information bits; and
 - decoding the encoded stream of bits, wherein the decoding includes decoding the first set of dynamic frozen bits based on one or more previous information bits.
24. An apparatus, processing system, and/or computer readable medium having computer executable code for performing the techniques described herein.

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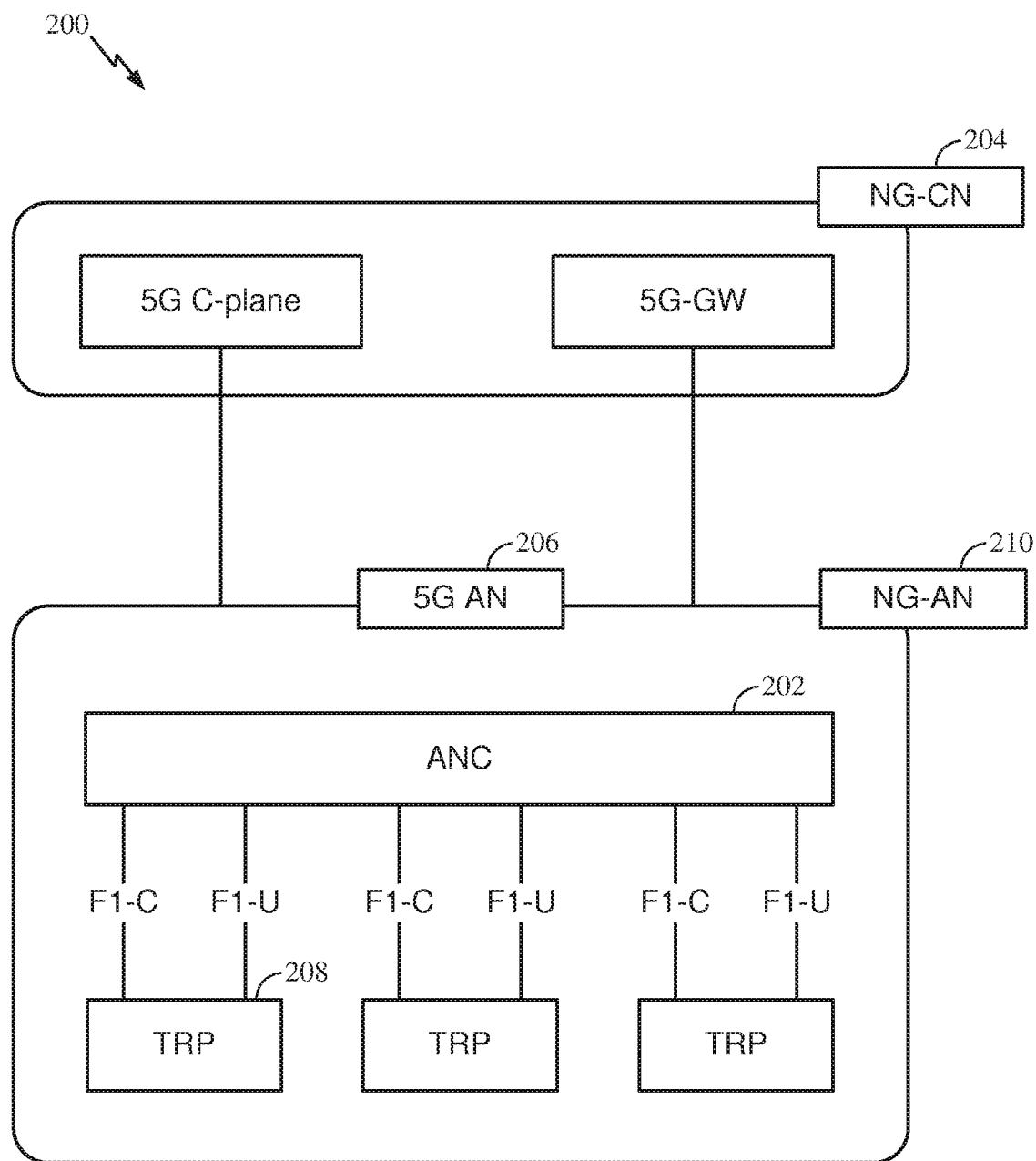


FIG. 2

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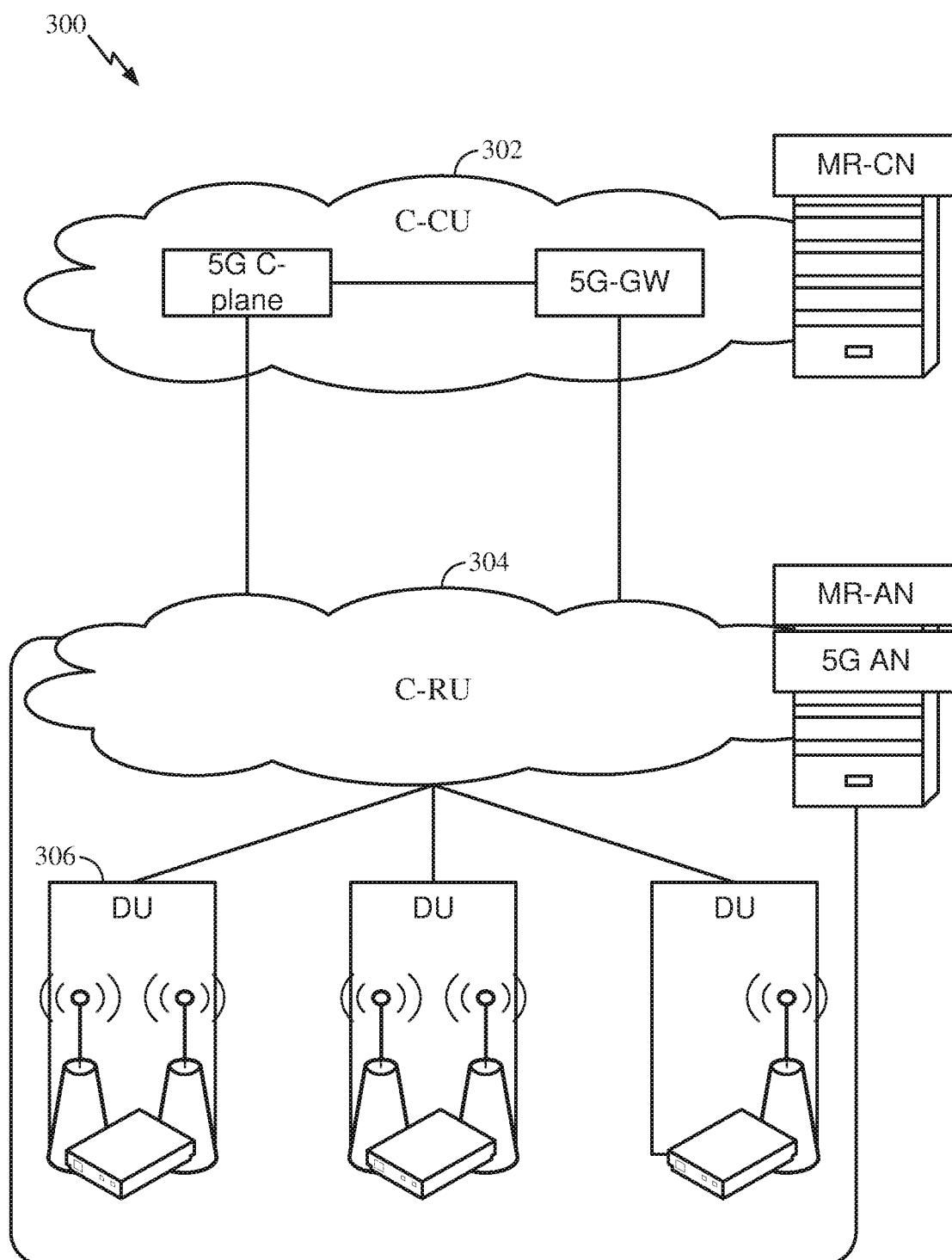


FIG. 3

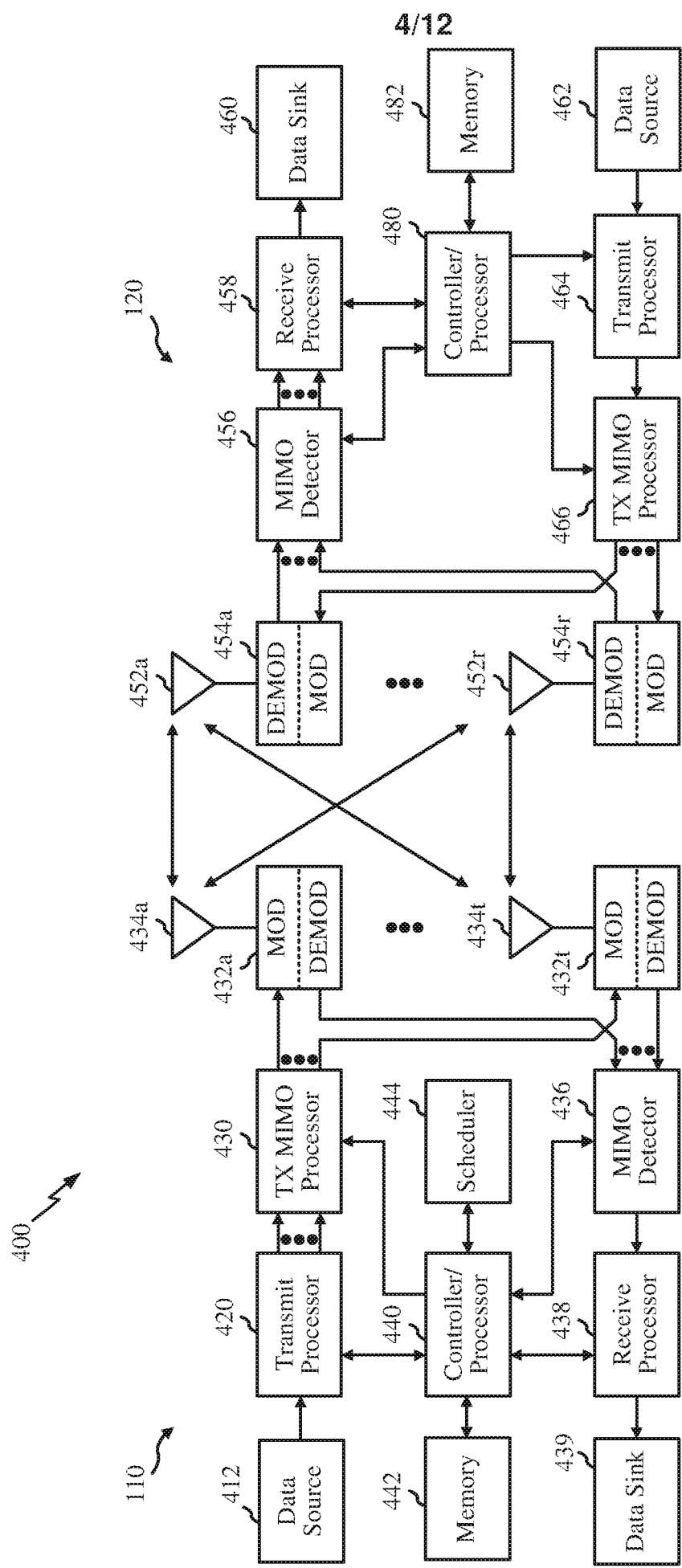


FIG. 4

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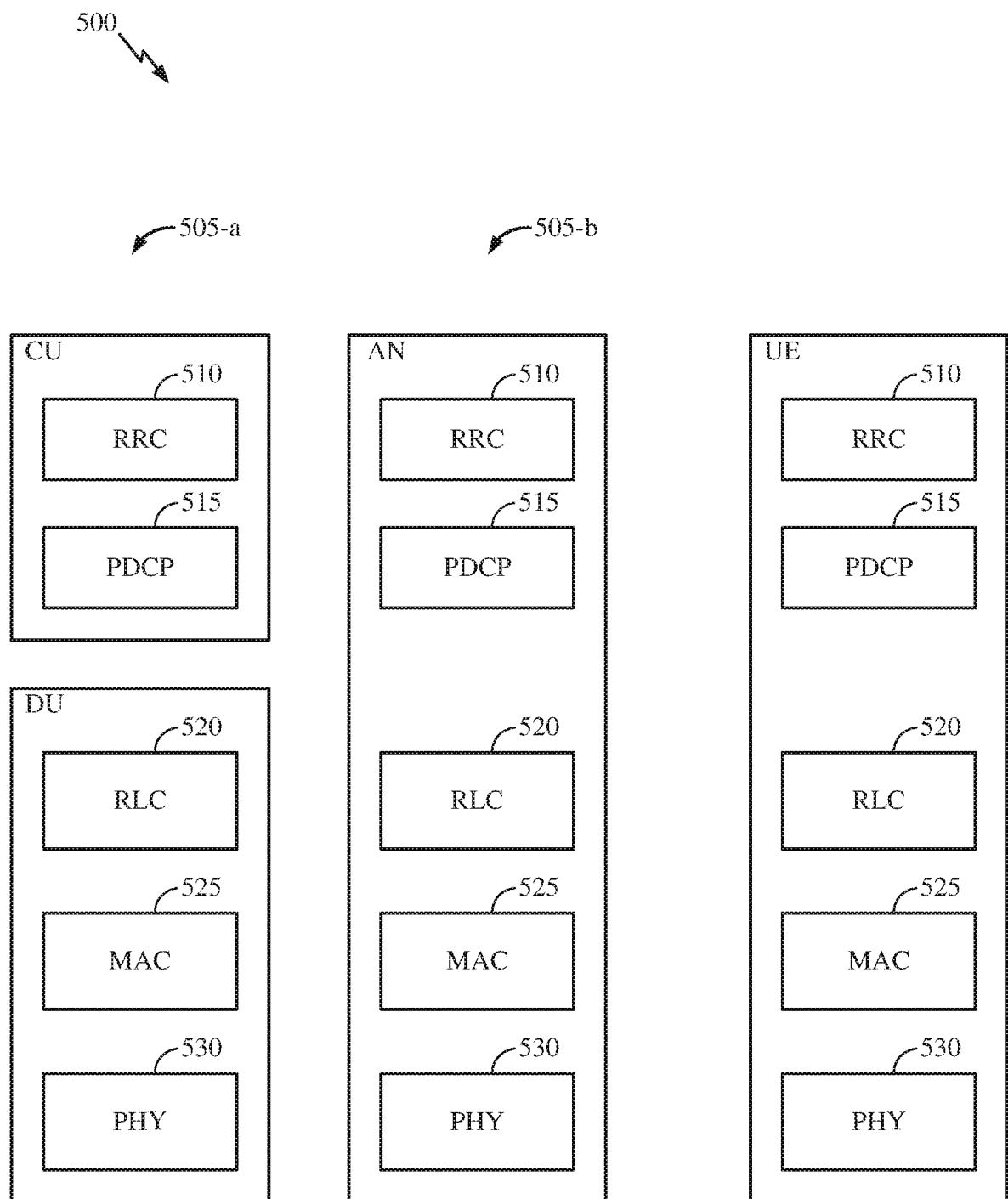


FIG. 5

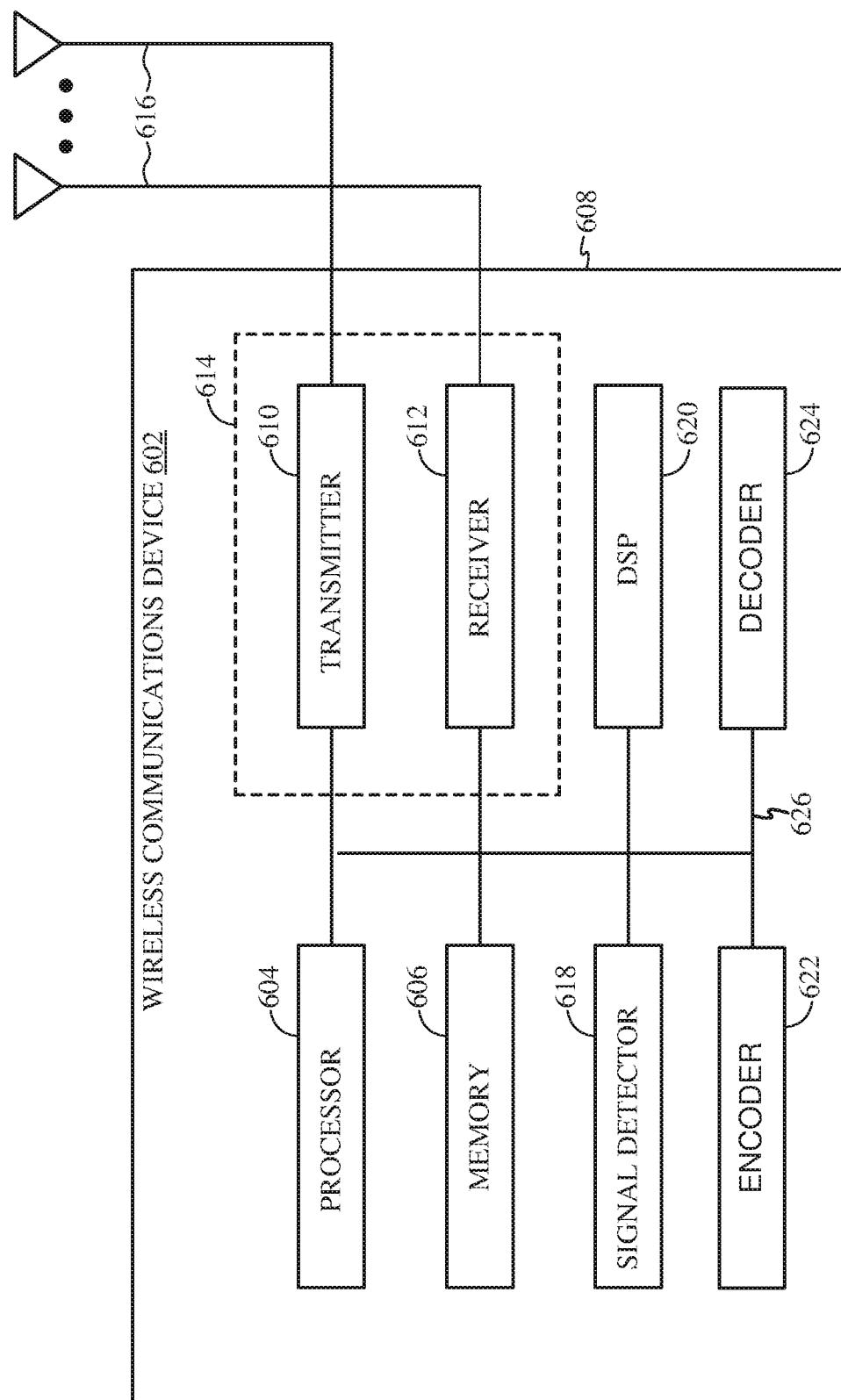


FIG. 6

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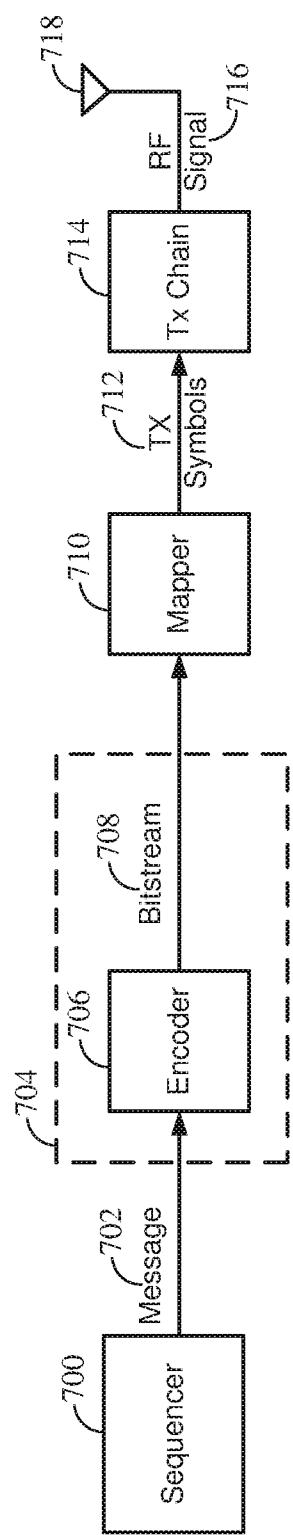


FIG. 7

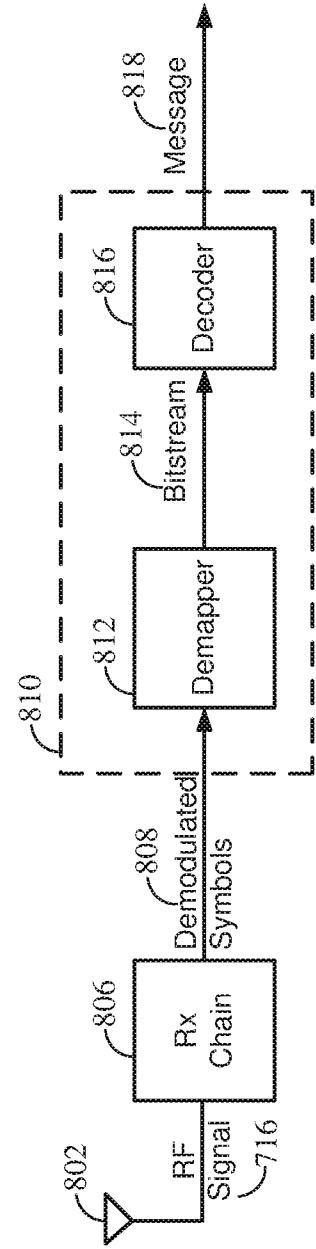


FIG. 8

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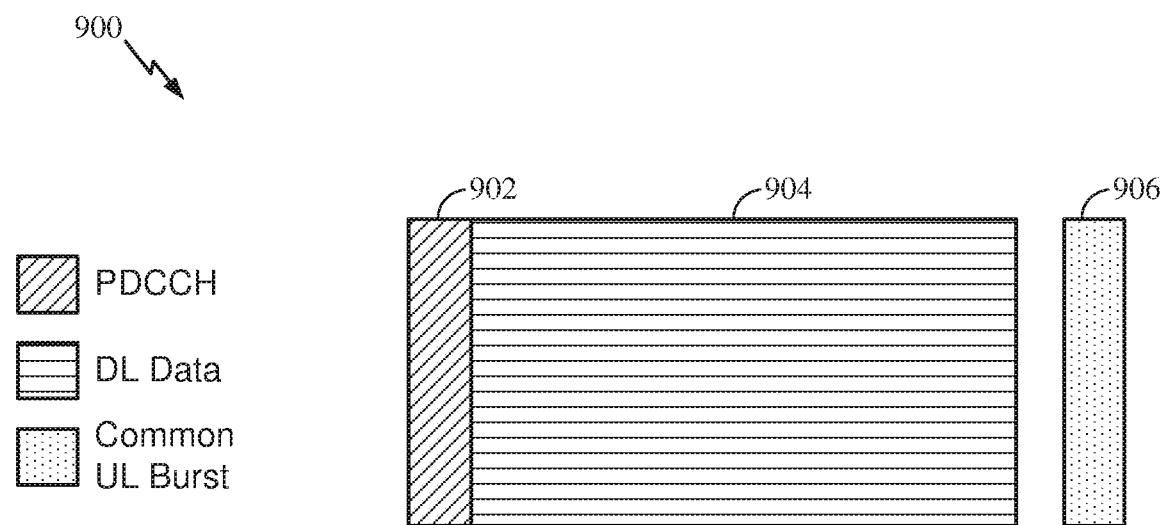


FIG. 9

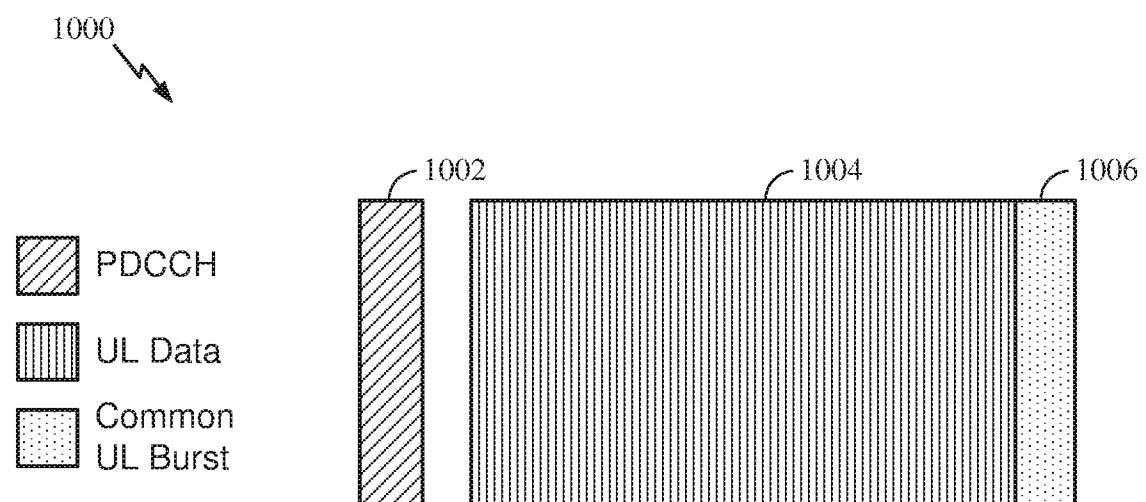


FIG. 10

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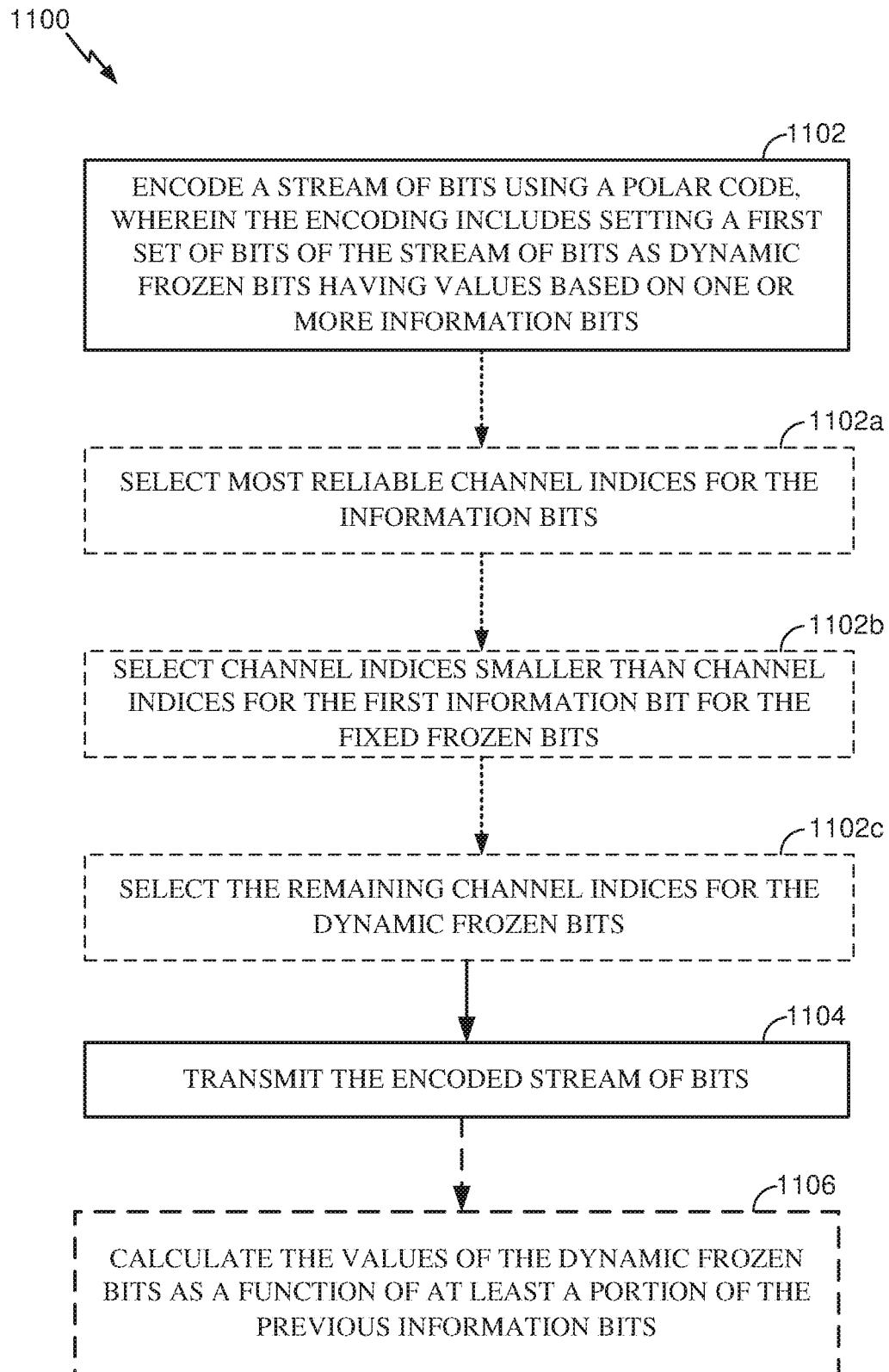


FIG. 11

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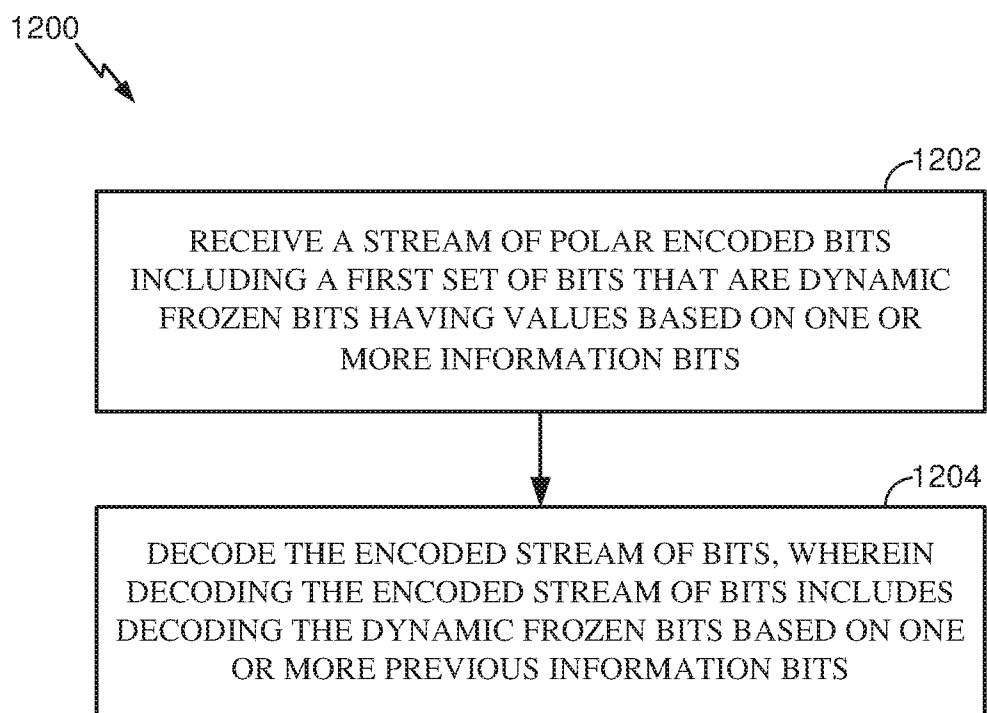
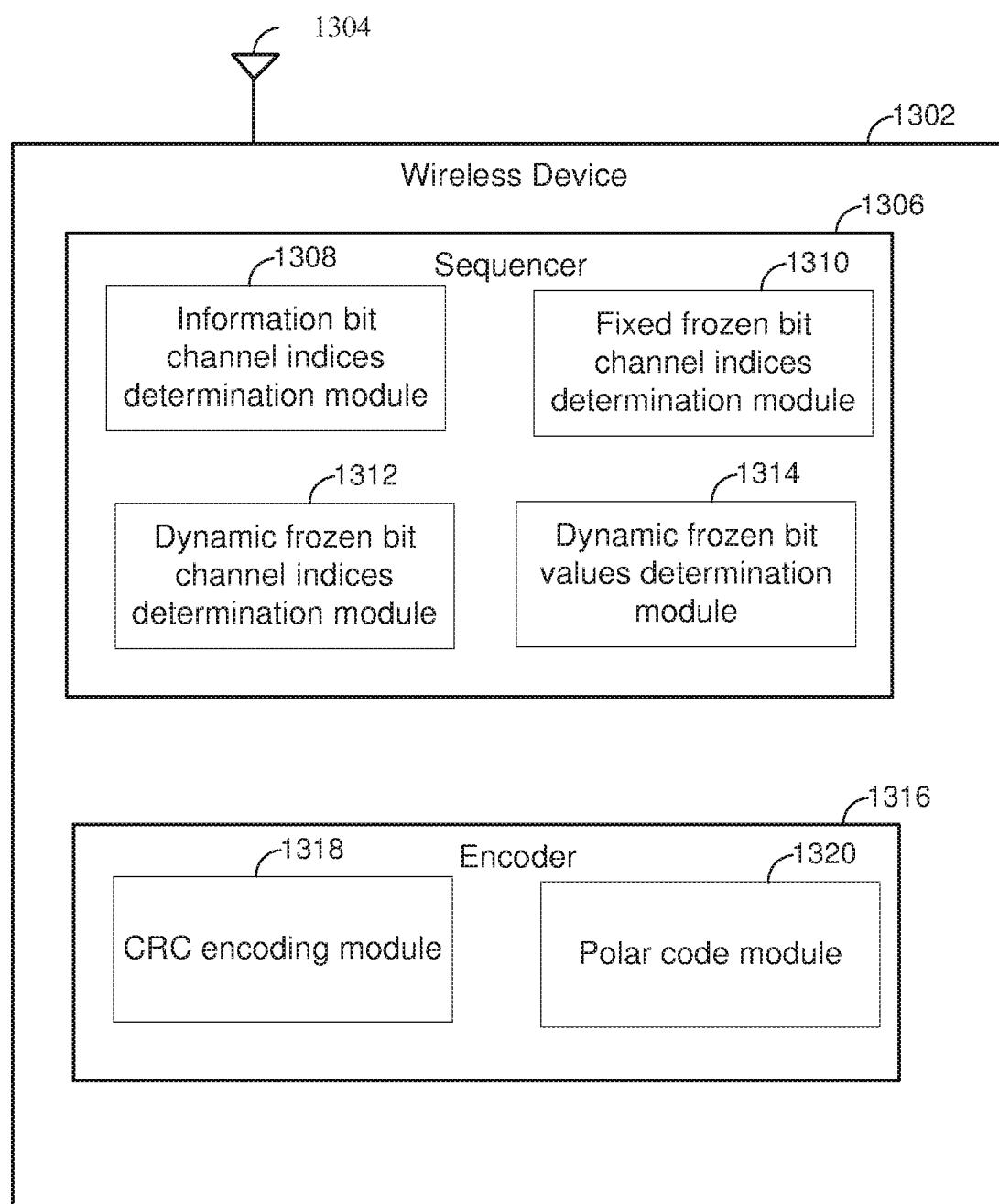


FIG. 12

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**FIG. 13**

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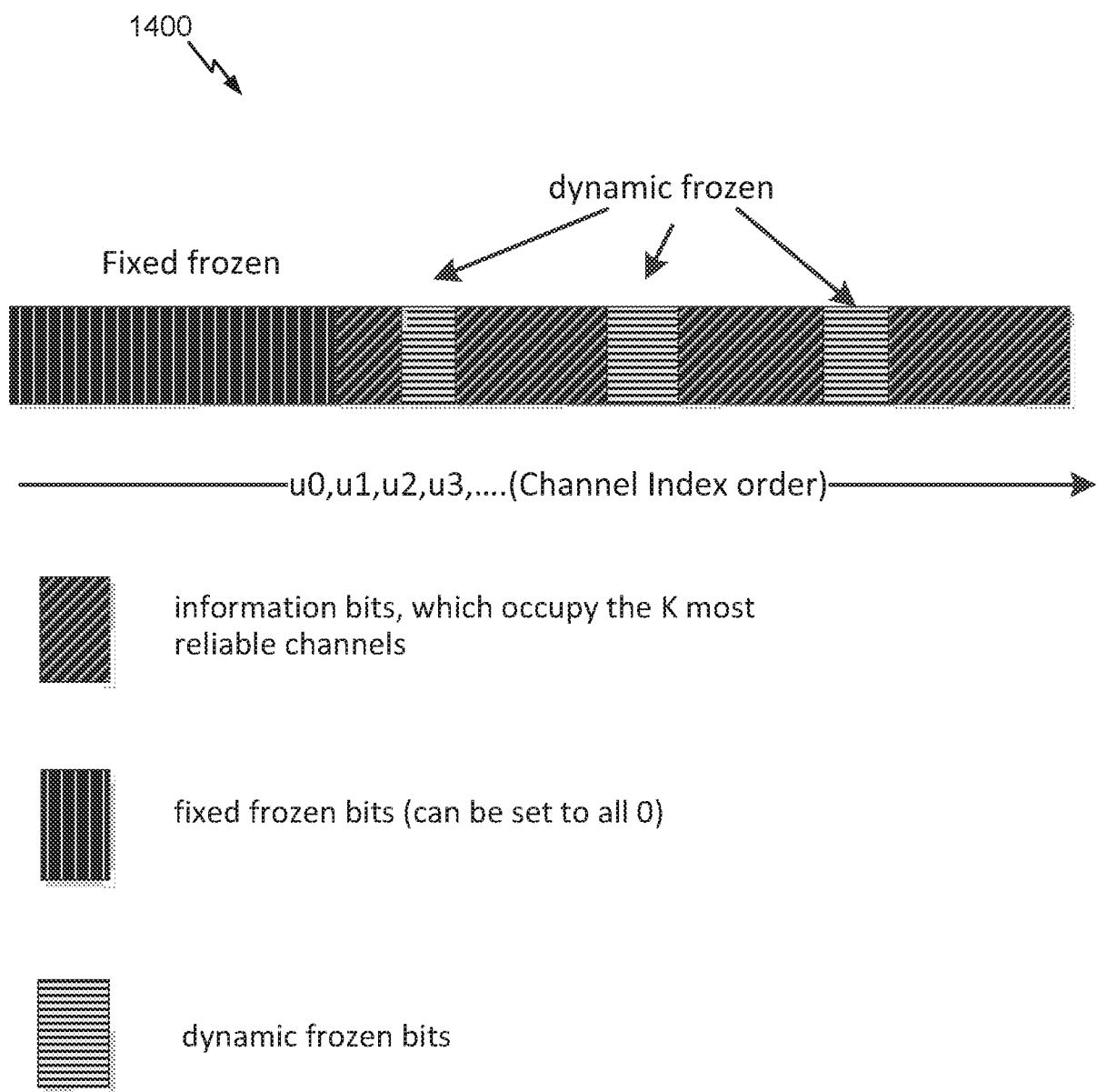


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/071255

A. CLASSIFICATION OF SUBJECT MATTER

H03M 13/00(2006.01)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)

H03M; H04Q; H04W; H04M

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

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

CNPAT,WPI,EPODOC,CNKI,3GPP:polar code,dynamic,frozen,encod+,decod+,channel indice,CRC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015295593 A1 (SAMSUNG ELECTRONICS CO., LTD.) 15 October 2015 (2015-10-15) description, paragraphs [0004]-[0011],[0034]-[0078]	1-24
A	US 2013117344 A1 (GROSS, WARREN ET AL.) 09 May 2013 (2013-05-09) the whole document	1-24
A	CN 103778958 A (SAMSUNG ELECTRONICS CO., LTD. ET AL.) 07 May 2014 (2014-05-07) the whole document	1-24
A	CN 103220001 A (HUAWEI TECHNOLOGIES CO., LTD.) 24 July 2013 (2013-07-24) the whole document	1-24
A	CN 105340183 A (HUAWEI TECHNOLOGIES CO., LTD.) 17 February 2016 (2016-02-17) the whole document	1-24

Further documents are listed in the continuation of Box C.

See patent family annex.

- * Special categories of cited documents:
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- “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- “O” document referring to an oral disclosure, use, exhibition or other means
- “P” document published prior to the international filing date but later than the priority date claimed

- “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- “&” document member of the same patent family

Date of the actual completion of the international search 18 September 2017	Date of mailing of the international search report 12 October 2017
Name and mailing address of the ISA/CN STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China	Authorized officer ZHANG,Xingsu
Facsimile No. (86-10)62019451	Telephone No. (86-10)61648551

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/071255

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					EP	2722993	A1	23 April 2014	
					US	2014108748	A1	17 April 2014	
CN	103220001	A	24 July 2013		WO	2013107140	A1	25 July 2013	
					EP	2802080	A1	12 November 2014	
					US	2014365842	A1	11 December 2014	
CN	105340183	A	17 February 2016		WO	2015058416	A1	30 April 2015	
					US	2016241258	A1	18 August 2016	