

CODED-BIT ALLOCATION FOR UPLINK CONTROL INFORMATION (UCI) SEGMENTATION**CLAIM OF PRIORITY UNDER 35 U.S.C. §119**

[0001] This application claims priority to U.S. Application No. 16/218,167, filed December 12, 2018, which claims priority to and benefit of U.S. Provisional Patent Application Serial No. 62/617,097, filed January 12, 2018, both assigned to the assignee hereof and hereby expressly incorporated by reference herein.

BACKGROUND**Field of the Disclosure**

[0002] Certain aspects of the present disclosure generally relate to wireless communications and, more particularly, to methods and apparatus for coded-bit allocation for uplink control information (UCI) segmentation.

Description of Related Art

[0003] 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.

[0004] 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).

[0005] 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.

[0006] 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.

BRIEF SUMMARY

[0007] 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.

[0008] Certain aspects of the present disclosure provide a method for wireless communications in a network. The method generally includes generating coded bits of uplink control information (UCI) to be transmitted as one or more segments, applying one or more rules to ensure an integer number of bits are allocated to each of the one or more segments, and transmitting the UCI in the segments according to the assignment.

[0009] Certain aspects of the present disclosure provide a method for wireless communications in a network. The method generally includes taking one or more actions to ensure an integer number of coded bits of uplink control information (UCI) from a user equipment (UE) are assigned to one or more segments and receiving the UCI in the segments according to the assignment.

[0010] Numerous other aspects are provided including methods, apparatus, systems, computer program products, and processing systems.

[0011] 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

[0012] 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.

[0013] FIG. 1 is a block diagram conceptually illustrating an example telecommunications system, in accordance with certain aspects of the present disclosure.

[0014] FIG. 2 is a block diagram illustrating an example logical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0015] FIG. 3 is a diagram illustrating an example physical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0016] FIG. 4 is a block diagram conceptually illustrating a design of an example BS and user equipment (UE), in accordance with certain aspects of the present disclosure.

[0017] FIG. 5 is a diagram showing examples for implementing a communication protocol stack, in accordance with certain aspects of the present disclosure.

[0018] FIG. 6 illustrates a block diagram of an example wireless device in accordance with certain aspects of the present disclosure.

[0019] FIG. 7 is a simplified block diagram illustrating an encoder, in accordance with certain aspects of the present disclosure.

[0020] FIG. 8 is a simplified block diagram illustrating a decoder, in accordance with certain aspects of the present disclosure.

[0021] FIG. 9 illustrates an example of a frame format for a new radio (NR) system, in accordance with certain aspects of the present disclosure.

[0022] FIG. 10 illustrates example operations for wireless communications, in accordance with certain aspects of the present disclosure.

[0023] FIG. 10A illustrates example components capable of performing the operations shown in FIG. 10.

[0024] FIG. 11 illustrates example operations for wireless communications, in accordance with certain aspects of the present disclosure.

[0025] FIG. 11A illustrates example components capable of performing the operations shown in FIG. 11.

[0026] 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 described in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

[0027] Aspects of the present disclosure provide apparatus, methods, processing systems, and computer readable mediums for multi-slice networks, such as new radio (NR) (new radio access technology or 5G technology).

[0028] New radio (NR) may refer to radios configured to operate according to a new air interface (e.g., other than Orthogonal Frequency Divisional Multiple Access (OFDMA)-based air interfaces) or fixed transport layer (e.g., other than Internet Protocol (IP)). NR may include Enhanced mobile broadband (eMBB) techniques targeting wide bandwidth (e.g. 80 MHz and larger) communications, millimeter wave (mmW) techniques targeting high carrier frequency (e.g. 27 GHz or beyond) communications, massive MTC (mMTC) techniques targeting non-backward compatible MTC techniques, and 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 the respective quality of service (QoS) requirements. In addition, these services may co-exist in the same subframe.

[0029] Aspects of the present disclosure relate to a rate-matching scheme for control channels using polar codes. Rate matching is a process whereby the number of bits to be transmitted is matched to the available bandwidth of the number of bits allowed to be transmitted. In certain instances, the amount of data to be transmitted is less than the available bandwidth, in which case all the data to be transmitted (and one or more copies of the data) will be transmitted (a technique called repetition). In other instances, the amount of data to be transmitted exceeds the available bandwidth, in which case a

certain portion of the data to be transmitted will be omitted from the transmission (a technique called puncturing).

[0030] In NR, polar codes may be used to encode a stream of bits for transmission. However, in some cases, using a traditional rate matching scheme (e.g., for TBCC codes) may lead to performance loss when used with polar codes. Thus, aspects of the present disclosure propose an efficient rate-matching scheme to be used to rate-match a stream of bits encoded using a polar code.

[0031] 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 described 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 described herein may be embodied by one or more elements of a claim.

[0032] 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.

[0033] 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.

[0034] 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). New Radio (NR) (e.g., 5G radio access) is an example of an emerging telecommunication standard. NR is a set of enhancements to the LTE mobile standard promulgated by 3GPP. “LTE” refers generally to LTE, LTE-Advanced (LTE-A), LTE in an unlicensed spectrum (LTE-whitespace), etc. 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

[0035] 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 improving device discovery in a multi-slice network. In some cases, the

network 100 may be a multi-slice network, each slice defines as a composition of adequately configured network functions, network applications, and underlying cloud infrastructures that are bundled together to meet the requirement of a specific use case or business model.

[0036] 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, 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.

[0037] 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.

[0038] 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 an 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.

[0039] 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.

[0040] 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).

[0041] 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.

[0042] 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.

[0043] 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 the Internet or a cellular network) via a wired or wireless communication link. Some UEs may be considered Internet-of-Things (IoT) devices.

[0044] 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.

[0045] 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.

[0046] While aspects of the examples described herein may be associated with LTE technologies, aspects of the present disclosure may be applicable with other wireless communications systems, such as NR/5G.

[0047] 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 75 kHz over a 0.1ms duration. Each radio frame may consist of 2 half frames, each half frame consisting of 5 subframes, with a length of 10ms. Consequently, each subframe may have a length of 1 ms. 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 reference to FIGs. 9 and 10. 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 as CUs and/or DUs.

[0048] 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.

[0049] 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.

[0050] 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.

[0051] 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.”

[0052] 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.

[0053] 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).

[0054] 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.

[0055] The architecture may enable cooperation between and among TRPs 208. For example, cooperation may be preset within a TRP and/or across TRPs via the ANC 202. According to aspects, no inter-TRP interface may be needed/present.

[0056] 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).

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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, MOD/DEMOD 454, processors 466, 458, 464, and/or controller/processor 480 of the UE 120 and/or antennas 434, MOD/DEMOD 432, processors 430, 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. 10 and 11.

[0061] 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.

[0062] 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.

[0063] 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 (DEMOS) 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] 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).

[0070] 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.

[0071] 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.

[0072] 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.

[0073] 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.

[0074] Additionally, the wireless communications device 602 may also include an encoder 622 for use in encoding signals for transmission. The encoder may also store the encoded signals in a circular buffer (not shown) and perform rate matching on the encoded signals (e.g., by implementing operations 1600, shown in FIG. 16). Further, the wireless communication device 602 may include a decoder 624 for use in decoding received signals.

[0075] 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.

[0076] 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 wireless device (e.g., BS 110 or a UE 120) receives a message 702 for transmission. The message 702 may contain data and/or encoded voice or other content directed to the receiving device. 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. 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 of the present disclosure described in more detail 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.

[0077] 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 a user equipment, at a 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. 7) 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 symbols 808 to a demapper 812, which produces a bitstream 814 representative of the encoded message.

[0078] 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).

[0079] FIG. 9 is a diagram showing an example of a frame format 900 for NR. The transmission timeline for each of the downlink and uplink may be partitioned into units

of radio frames. Each radio frame may have a predetermined duration (e.g., 10 ms) and may be partitioned into 10 subframes, each of 1 ms, with indices of 0 through 9. Each subframe may include a variable number of slots depending on the subcarrier spacing. Each slot may include a variable number of symbol periods (e.g., 7 or 14 symbols) depending on the subcarrier spacing. The symbol periods in each slot may be assigned indices. A mini-slot, which may be referred to as a sub-slot structure, refers to a transmit time interval having a duration less than a slot (e.g., 2, 4, or 7 symbols).

[0080] Each symbol in a slot may indicate a link direction (e.g., DL, UL, or flexible) for data transmission and the link direction for each subframe may be dynamically switched. The link directions may be based on the slot format. Each slot may include DL/UL data as well as DL/UL control information.

[0081] In NR, a synchronization signal (SS) block is transmitted. The SS block includes a PSS, an SSS, and a two symbol PBCH. The SS block can be transmitted in a fixed slot location, such as the symbols 0-3 as shown in FIG. 9. The PSS and SSS may be used by UEs for cell search and acquisition. The PSS may provide half-frame timing, the SS may provide the CP length and frame timing. The PSS and SSS may provide the cell identity. The PBCH carries some basic system information, such as downlink system bandwidth, timing information within a radio frame, SS burst set periodicity, system frame number, etc. The SS blocks may be organized into SS bursts to support beam sweeping. Further system information such as, remaining minimum system information (RMSI), system information blocks (SIBs), other system information (OSI) can be transmitted on a physical downlink shared channel (PDSCH) in certain subframes.

[0082] 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).

[0083] 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

[0084] As noted above, polar codes may be used to encode a stream of bits for transmission. Polar codes are the first provably 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.

[0085] 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 , also referred to as a Hadamard matrix of order n . For example, Equation (1) shows the resulting generator matrix for $n=3$.

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

[0086] According to certain aspects, a codeword may be generated (e.g., by a BS) 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 (e.g., using techniques described herein) and transmitted by a base station over a wireless medium and received by a UE.

[0087] When the received vectors are decoded (e.g., by the UE) 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.

[0088] 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 $N \cdot C$ 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.

EXAMPLE UPLINK CONTROL INFORMATION SEGMENTATION FOR POLAR CODES

[0089] In previously known wireless communications techniques using NR-polar codes, uplink control information (UCI) may be segmented into two segments with equal segment sizes (with a single zero-padding bit inserted at the beginning of the first segment if needed), for certain ranges of K (before segmentation) and R , e.g., $K \geq$ a first threshold (e.g., 352) and $R \leq$ a second threshold (e.g., 0.4). Exact values may be determined after future study of wireless communications using NR-polar codes. Segmentation of large UCI may be desirable, in order to reduce the decoding complexity at low coding gain loss.

[0090] A CRC is calculated using a polynomial and based on the first segment (and not the second segment) and is appended to the first segment. A CRC is calculated using the same polynomial based on the second segment (and not the first segment) and appended to the second segment.

[0091] UCI payload size can be very large, for example, up to 927 bits of data is transmitted per calculation of Type-II CSI with $L=4$, $\text{rank}=2$, 18 subbands for a single CSI reporting. If multiple CSI reporting is triggered, then more data is transmitted than when a single CSI is triggered.

[0092] According to aspects of the present disclosure, a maximum supported mother code length of polar codes (N_{max}) for UL may be used as a parameter in determining whether to segment data for transmission.

[0093] In aspects of the present disclosure, a wireless device may determine to segment a set of K data bits, based on K being greater than a parameter (e.g., $K > K_{\text{max}}$), regardless of the rate (e.g., K/M , where M is the number of bits transmitted in the transmission) to be used in transmitting the K bits.

[0094] According to aspects of the present disclosure, K_{max} can be pre-defined or configurable, i.e. $K_{\text{max}} = \alpha * N_{\text{max}}$.

[0095] In previously known techniques, padding added to a 1st packet, if K is odd, may be insufficient to make the segmented packets (e.g., the 1st and 2nd packets) the same size.

[0096] According to aspects of the present disclosure, a set of data bits may be segmented into more than two segments.

[0097] In aspects of the present disclosure, a wireless device may determine to segment a set of K data bits based on K being greater than a threshold number of data bits (i.e., $K > K_{thr}$), a coding rate (R) for the transmission being greater than a threshold (i.e., $R > R_{thr}$), and a coded bit length (M) being greater than a threshold ($M > M_{thr}$). For example, a wireless device may be configured with a threshold number of data bits $K_{thr}=384$, a threshold coding rate $R=0.2$, and a threshold coded bit length $M_{thr} = N_{max}$ (i.e., the maximum mother code length of polar codes supported by the wireless device). In the example, the wireless device determines to transmit 400 bits of data, and the wireless device determines that channel conditions indicate the code rate for the transmission should be 0.4. Still in the example, if encoding the 400 bits of data with a coding rate of 0.4 results in a coded bit length M that is greater than the maximum supported code length of polar codes of the wireless device (N_{max}), then the wireless device determines to segment the 400 bits of data into two or more segments before encoding and transmitting the data.

[0098] According to aspects of the present disclosure, a wireless device may determine to segment a set of K data bits based on K being greater than a threshold number of data bits (i.e., $K > K_{thr}$) and a coded bit length (M) being greater than a threshold ($M > M_{thr}$). For example, a wireless device may be configured with a threshold number of data bits $K_{thr}=384$ and a threshold coded bit length $M_{thr} = N_{max} + N_{max}/16$ (i.e., $1.0625 \times$ the maximum mother code length of polar codes supported by the wireless device). In the example, the wireless device determines to transmit 400 bits of data, and the wireless device determines that the 400 data bits will be encoded in $1.1 \times N_{max}$ encoded bits. Still in the example, the wireless device determines to segment the 400 bits of data into two or more segments before encoding and transmitting the data, based on the number of data bits being greater than the threshold number of data bits (i.e., $K_{thr}=384$) and the number of coded bits being greater than the threshold coded bit length $M_{thr}=N_{max}+N_{max}/16$.

[0099] According to aspects of the present disclosure, a wireless device may determine to segment a set of K data bits based on comparing a coding rate, R_{seg} , for transmitting the data with segmentation being less than a coding rate, R_{noseg} , for transmitting the data without segmentation. The coding rate, R_{seg} , for transmitting the data with segmentation may be calculated as:

$$R_{\text{seg}} = ((K/2) + \text{CRC}) / \min(2^{\text{order}_{\text{seg}}}, (M/2))$$

[0100] While the coding rate, R_{noseg} , for transmitting the data without segmentation may be calculated as: $R_{\text{noseg}} = (K + \text{CRC}) / \min(2^{\text{order}}, (M))$. Where CRC is a length of a CRC (e.g., 16 bits) calculated based on the K data bits, $2^{\text{order}_{\text{seg}}}$ represents a mother code length of a polar code after rate matching with segmentation, 2^{order} represents a mother code length of a polar code after rate matching without segmentation, and M represents a coded bit length.

[0101] In aspects of the present disclosure, when a coded bit length, M, is an odd number before segmentation, the 1st packet and 2nd packet are constructed with a number of bits $M' = \lfloor M/2 \rfloor$, i.e., M/2 rounded down to the next integer. This may enable using a same code construction for the two packets. The extra one bit (because M is an odd number) is allocated to either the 1st or 2nd packet, and is done by readout from the circular buffer.

[0102] According to aspects of the present disclosure, division of M coded bits into $L > 2$ segmented packets, i.e. $M' = \lfloor M/L \rfloor$. If $\text{mod}(M, L) > 0$, then the 1st through $\text{mod}(M, L)$ packets are each allocated with one extra bit.

EXAMPLE CODED-BIT ALLOCATION UCI SEGMENTATION

[0103] In NR, large UCI payloads of sufficiently low rate may be segmented into two segments. In some cases, a maximum number of segments that a large ICU payload may be segmented into may be two segments. In some cases, it has been agreed upon that segmentation may be applied when $K \geq 360$ and $M \geq 1088$, where K is a UCI payload size without CRC and M is a total number of coded bits for the UCI payload.

[0104] In some cases when $\pi/2$ BPSK modulation is used to transmit UCI, the number of allocated coded bits might not be a multiple of the number of segments (e.g.

2). Currently NR may not take this into account and may assign a non-integer number of bits to each segment. Accordingly, in one or more cases, method and apparatus are described that provide coded-bit allocation for UCI segmentation that avoids a non-integer number of bits being assigned to each segment.

[0105] In one or more cases, one or more filler bits may be used. Particularly, methods and apparatus may be configured to exclude a number of bits from segmentation as filler bits, setting them to predetermined values. The remaining bits may then be equally allocated to the segments. In some cases, the filler bits, which may also be called padding bits, may be repeated copies of some coded bits.

[0106] In one or more cases, X may be a number of available bits and S a number of segments. In one example, X may be equal to 1089 and S may be set to two. Further, $(X \bmod S)$ when calculated may provide the filler bits that are reserved (padding) and set to a predetermined value (or a copy of coded bits). A value E may be calculated by $E = (X - (X \bmod S))/S$, which will provide a number of coded bits allocated to each segment. For example, when $X=1089$ and $S=2$, E may be equal to 544. In accordance with one or more cases the filler bits, which may also be called the reserved bits, may be at the beginning, end, or distributed throughout the allocation. In the example where $X = 1089$, $S = 2$, $E = 544$, the remaining filler bit may be one. In accordance with one or more cases, this approach may be applied only when segmentation is required. In other cases, this approach may be applied regardless of segmentation, e.g. always reserve $(X \bmod 2)$ bits.

[0107] According to one or more cases, another approach to provide coded-bit allocation UCI segmentation may include allowing segments to have a different number of coded bits. By allowing segments to have a different number of coded bits this approach is somewhat similar to data on PDSCH and PUSCH.

[0108] In one or more cases, X may be a number of available bits and S a number of segments. Further, E may be calculated by either of the followings: $E^+ = \left\lceil \frac{X}{S} \right\rceil$, or $E^- = \left\lfloor \frac{X}{S} \right\rfloor$. Accordingly two values, E^+ and E^- , may be calculated for the number of coded bits and the segment code blocks may get one of the two values. In some cases, $(X \bmod S)$ segments may be allocated E^+ coded bits while the remaining segments may

be allocated E^- bits. For example, X may be 1089 and S may be two. Accordingly, E^+ may be 545 and E^- may be 544. In this example, one segment gets 545 bits and the other segment gets 544 bits. Further, in one or more cases, as show in the above example, the number of coded bits may therefore be different for each segment. In such cases, this difference may affect rate matching of polar codes because of different number for each segment. In some cases, further restriction may be provided. For example, the above approach may be further modified so that segments do not share an resource elements (RE). This restriction is similar to restrictions for data on PDSCH and PUSCH. In some cases, $S * E^-$ may be equivalent to the mod operation of $E = (X - (X \bmod S))/S$ as described above.

[0109] In one or more cases, an eNB may be required to schedule a number of REs so that the number of available of coded bits is divisible by the number of segments. In some cases, additional restriction may be provided. For example, the eNB may be required to schedule a number of REs that is divisible by the number of segments. In one or more cases, the number of REs may be the same as the number of bits when, for example, BPSK modulation is implemented. In other cases, for higher order modulation the number of REs may not be the same as the number of bits.

[0110] In one or more cases, one or more filler REs may be used. Particularly, methods and apparatus may be configured to exclude a number of REs from segmentation as filler REs, setting them to predetermined values. The remaining REs may then be equally allocated to the segments. In some cases, the filler REs, which may also be called padding REs, may be repeated copies of some coded REs.

[0111] For example, a total number of allocated RE may be N_{RE} which may be 1089 and the number of segments S which may be set to two. The number of REs per segment may therefore be determined using $N' = \left\lfloor \frac{N_{RE}}{S} \right\rfloor$. In one example, when N_{RE} is 1089 and S is two N' may be 544. The remaining $(N_{RE} - S.N')$ REs may be set to predetermined values or repeated from the N' REs. For example, when N_{RE} is 1089, S is 2, and N' is 544, the remaining REs may be one.

[0112] FIG. 10 illustrates example operations 1000 for wireless communications, for example, for coded-bit allocation for UCI segmentation, according to aspects of the present disclosure. Operations 1000 may be performed by a wireless communications

device, such as a user equipment 120 and/or wireless communications device 602.

[0113] Operations 1000 begin at 1002 by generating coded bits of uplink control information (UCI) to be transmitted as one or more segments. At 1004, the operations 1000 include applying one or more rules to ensure an integer number of bits are allocated to each of the one or more segments. At 1006, the operations 1000 include transmitting the UCI in the segments according to the assignment.

[0114] FIG. 11 illustrates example operations 1100 for wireless communications, for example, for coded-bit allocation for UCI segmentation, according to aspects of the present disclosure. Operations 1100 may be performed by a wireless communications device, such as a base station (BS 110) and/or wireless communications device 602.

[0115] Operations 1100 begin at 1102 by taking one or more actions to ensure an integer number of coded bits of uplink control information (UCI) from a user equipment (UE) are assigned to one or more segments. At 1104, the operations 1100 may include receiving the UCI in the segments according to the assignment.

[0116] The methods described 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.

[0117] 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-b-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[0118] 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.

[0119] 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.

[0120] 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. For example, operations 1000 illustrated in FIG. 10, and operations 1100 illustrated in FIG. 11, correspond to means 1000A illustrated in FIG. 10A, means 1100A illustrated in FIG. 11A, respectively.

[0121] For example, means for transmitting and/or means for receiving may comprise one or more of a transmit processor 420, a TX MIMO processor 430, a receive processor 438, or antenna(s) 434 of the base station 110 and/or the transmit processor 464, a TX MIMO processor 466, a receive processor 458, or antenna(s) 452 of the user equipment 120. Additionally, means for generating, means for assigning, means for excluding, means for setting, means for allocating, means for allowing, means for taking, and/or means scheduling for may comprise one or more processors, such as the controller/processor 440 of the base station 110 and/or the controller/processor 480 of the user equipment 120.

[0122] 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.

[0123] 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.

[0124] 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.

[0125] 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.

[0126] 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.

[0127] 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 provide 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.

[0128] 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.