# TECHNIQUES FOR UPLINK CAPACITY ENHANCEMENTS

## TECHNICAL FIELD

**[0001]** The present disclosure relates to wireless communications, and more specifically to techniques for uplink (UL) capacity enhancements.

## BACKGROUND

**[0002]** A wireless communications system may include one or multiple network communication devices, such as base stations, which may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers, or the like)). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

## SUMMARY

**[0003]** An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be

construed in the same manner as the phrase “based at least in part on.” Further, as used herein, including in the claims, a “set” may include one or more elements.

**[0004]** A UE for wireless communication is described. The UE may be configured to, capable of, or operable to multiplex UL data associated with the UE in one or more of a time domain or a frequency domain according to at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data associated with the UE over a physical UL shared channel (PUSCH).

**[0005]** A method for wireless communication performed by a UE is described. The method may be configured to, capable of, or operable to multiplex UL data associated with the UE in one or more of a time domain or a frequency domain according to at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data associated with the UE over a PUSCH.

**[0006]** A processor for wireless communication is described. The processor may be configured to, capable of, or operable to multiplex UL data associated with the UE in one or more of a time domain or a frequency domain according to at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data associated with the UE over a PUSCH.

**[0007]** A network equipment (NE) for wireless communication is described. The NE may be configured to, capable of, or operable to multiplex UL data of a plurality of UEs in one or more of a time domain or a frequency domain according to the at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data of the plurality of UEs over a PUSCH.

**[0008]** A method for wireless communication performed by an NE is described. The method may be configured to, capable of, or operable to multiplex UL data of a plurality of UEs in one or more of a time domain or a frequency domain according to the at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data of the plurality of UEs over a PUSCH.

**[0009]** A processor for wireless communication is described. The processor may be configured to, capable of, or operable to multiplex UL data of a plurality of UEs in one or more of a time domain or a frequency domain according to the at least one

orthogonal code sequence and transmit a waveform carrying the multiplexed UL data of the plurality of UEs over a PUSCH.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

**[0011]** Figure 2A illustrates an example of discrete Fourier transform-spread-orthogonal frequency division multiplexing (DFT-s-OFDM) with orthogonal cover codes (OCCs) in the time domain in accordance with aspects of the present disclosure.

**[0012]** Figure 2B illustrates an example of applying OCC before DFT for UL data in accordance with aspects of the present disclosure.

**[0013]** Figure 3A illustrates an example OCC applied in the frequency domain for each resource block (RB) in accordance with aspects of the present disclosure.

**[0014]** Figure 3B illustrates an example of contiguous mapping of resource elements (REs) for applying OCC for length 2 and 4 codes to PUSCH in accordance with aspects of the present disclosure.

**[0015]** Figure 3C illustrates an example of contiguous and non-contiguous scheduling of REs for applying OCC for length 6 codes in accordance with aspects of the present disclosure.

**[0016]** Figure 4 illustrates an example of time and frequency application of OCC sequences in accordance with aspects of the present disclosure.

**[0017]** Figure 5 illustrates an example of a UE in accordance with aspects of the present disclosure.

**[0018]** Figure 6 illustrates an example of a processor in accordance with aspects of the present disclosure.

**[0019]** Figure 7 illustrates an example of an NE in accordance with aspects of the present disclosure.

**[0020]** Figure 8 illustrates a flowchart of a method performed by a UE in accordance with aspects of the present disclosure.

**[0021]** Figure 9 illustrates a flowchart of a method performed by an NE in accordance with aspects of the present disclosure.

## DETAILED DESCRIPTION

**[0022]** A wireless communication system (e.g., a non-terrestrial network (NTN)), including one or more of UEs and NEs may support improved UL coverage, such as repetitions and demodulation reference signal (DMRS) bundling. In some cases, solely applying repetitions to wireless communication (e.g., UL transmission, downlink transmission) may significantly reduce a capacity of the wireless communication system, including throughput of the one or more UEs, by reducing resources available for data both for the one or more UEs, as well as for the entire wireless communication system (e.g., other UEs or NEs). Additionally, solely applying repetitions to wireless communication may increase latency of the wireless communication and, as a result, the one or more UEs may experience higher utilization of UL resources in a time domain before these resource can be released to other UEs.

**[0023]** As an example, in an NTN, a satellite may be configured with a broad geographic coverage area, which may result in numerous UEs being located within the geographic coverage area of the satellite. In some cases, such as wireless communication via a low earth orbit (LEO) satellite, a number of UEs within a geographic coverage area of the LEO satellite may have to coordinate with the LEO satellite (e.g., obtain access to the LEO satellite, obtain an allocation of resources from the LEO satellite, etc.) promptly to perform wireless communication (e.g., transmissions) while in the geographic coverage area of the LEO satellite. The limitation of total spectrum resources available to the NTN may further require significant system capacity efficiency improvements. For instance, some UEs may require higher resources than others, depending on traffic patterns, thus further granularity of resource multiplexing may be needed.

**[0024]** Various aspects of the present disclosure relate to enabling one or more UEs to support use of orthogonal cover codes (OCCs) for UL communication, which may result in increased UL capacity for the one or more UEs as described herein. Further aspects of the present disclosure relate to one or more configurations for applying OCC to a time domain UL data channel while employing Discrete Fourier Transform-Spread-Orthogonal Frequency Division Multiplexing (DFT-s-OFDM) waveform.

**[0025]** Aspects of the present disclosure are described in the context of a wireless communications system.

**[0026]** Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

**[0027]** The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

**[0028]** An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may

be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

**[0029]** The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

**[0030]** A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

**[0031]** An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or TRPs.

**[0032]** The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an

evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

**[0033]** The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

**[0034]** In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

**[0035]** One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu$=0) may be associated with a first subcarrier

spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu$=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu$=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu$=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu$=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu$=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

**[0036]** A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

**[0037]** Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu$=0, $\mu$=1, $\mu$=2, $\mu$=3, $\mu$=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu$=0)

associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

**[0038]** In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

**[0039]** FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu$=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu$=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu$=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu$=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu$=3), which includes 120 kHz subcarrier spacing.

**[0040]** The solutions discussed herein relate to techniques for UL capacity enhancements. According to TS 38.300 (incorporated herein by reference), the downlink transmission waveform is a conventional orthogonal frequency division multiplexing (OFDM) using a Cyclic Prefix (CP). The UL transmission waveform is conventional OFDM using a CP with a transform precoding function performing discrete Fourier transform (DFT) spreading that can be disabled or enabled. For operation with shared spectrum channel access in FR1, the UL transmission waveform subcarrier mapping can map to subcarriers in one or more physical resource block (PRB) interlaces.

**[0041]** In one embodiment, two transmission schemes are supported for physical UL shared channel (PUSCH): codebook-based transmission and non-codebook based transmission. For codebook-based transmission, the gNB provides the UE with a transmit precoding matrix indication in the downlink control information (DCI). The UE uses the indication to select the PUSCH transmit precoder from the codebook. For non-codebook-based transmission, the UE determines its PUSCH precoder based on wideband sounding reference signal (SRS) resource indicator (SRI) field from the DCI.

**[0042]** A closed loop DMRS based spatial multiplexing is supported for PUSCH. For a given UE, up to 4 layer transmissions are supported. The number of code words is one. When transform precoding is used, only a single multiple input- multiple output (MIMO) layer transmission is supported. Transmission durations from 1 to 14 symbols in a slot is supported and aggregation of multiple slots with transport block (TB) repetition is supported.

**[0043]** In one embodiment, two types of frequency hopping are supported, intra-slot frequency hopping, and in case of slot aggregation, inter-slot frequency hopping. Intra-slot and inter-slot frequency hopping are not supported when PRB interlace UL transmission waveform is used.

**[0044]** In one embodiment, PUSCH may be scheduled with DCI on physical downlink control channel (PDCCH), or a semi-static configured grant may be provided over radio resource control (RRC), where two types of operation are supported - the first PUSCH is triggered with a DCI, with subsequent PUSCH transmissions following the RRC configuration and scheduling received on the DCI, or the PUSCH is triggered by data arrival to the UE's transmit buffer and the PUSCH transmissions follow the RRC configuration.

**[0045]** In one embodiment, the UL physical-layer processing of transport channels consists of the following steps - Transport Block CRC attachment; Code block segmentation and Code Block CRC attachment; Channel coding: LDPC coding; Physical-layer hybrid-ARQ processing; Rate matching; Scrambling; Modulation: $\pi/2$ BPSK (with transform precoding only), QPSK, 16QAM, 64QAM and 256QAM; Layer mapping, transform precoding (enabled/disabled by configuration), and pre-coding; Mapping to assigned resources and antenna ports.

**[0046]** In one embodiment, the UE transmits at least one symbol with demodulation reference signal on each layer on each frequency hop in which the PUSCH is transmitted, and up to 3 additional DMRS can be configured by higher layers. Phase

Tracking RS may be transmitted on additional symbols to aid receiver phase tracking. The UL-SCH physical layer model is described in TS 38.202, incorporated herein by reference.

**[0047]** For configured grants operation with shared spectrum channel access, described in clause 10.3, a Configured Grant UL Control Information (CG-UCI) can be transmitted in PUSCH scheduled by configured UL grant.

**[0048]** In one embodiment, according to 3GPP TS 38.211, up to two codewords $q \in \{0,1\}$ can be transmitted. In case of single-codeword transmission, $q = 0$.

**[0049]** For each codeword, the block of bits $b^{(q)}(0), \ldots, b^{(q)}\left(M_{bit}^{(q)} - 1\right)$, where $M_{bit}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0), \ldots, \tilde{b}^{(q)}\left(M_{bit}^{(q)} - 1\right)$ according to the following pseudo code

Set i = 0

while $i < M_{bit}^{(q)}$

if $b^{(q)}(i) = x$ // UCI placeholder bits

$\tilde{b}^{(q)}(i) = 1$

else

if $b^{(q)}(i) = y$ // UCI placeholder bits

$\tilde{b}^{(q)}(i) = \tilde{b}^{(q)}(i-1)$

else

$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$

end if

end if

i = i + 1

end while

**[0050]** where x and y are tags defined, e.g., in TS 38.212 (incorporated herein by reference) and where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{init} = \begin{cases} n_{RNTI} \cdot 2^{16} + n_{RAPID} \cdot 2^{10} + n_{ID} & \text{for msgA on PUSCH} \\ n_{RNTI} \cdot 2^{15} + q \cdot 2^{14} + n_{ID} & \text{otherwise} \end{cases}$$

**[0051]** where $n_{ID} \in \{0,1,\ldots,1023\}$ equals the higher-layer parameter data*ScramblingIdentityPUSCH* if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, SP-CSI-RNTI or CS-RNTI, and the transmission is not scheduled using DCI format 0_0 in a common search space; $n_{ID} \in \{0,1,\ldots,1023\}$ equals the higher-layer parameter msgA-DataScramblingIndex if configured and the PUSCH transmission is triggered by a Type-2 random access procedure as described in clause 8.1A of TS 38.213 (incorporated herein by reference); $n_{ID} = N_{ID}^{cell}$ otherwise; $n_{RAPID}$ is the index of the random-access preamble transmitted for msgA as described in clause 5.1.3A of TS 38.321 (incorporated herein by reference) and where $n_{RNTI}$ equals the RA-RNTI for msgA and otherwise corresponds to the RNTI associated with the PUSCH transmission as described in clause 6.1 of TS 38.214 (incorporated herein by reference) and clause 8.3 of TS 38.213 (incorporated herein by reference).

**[0052]** For each codeword q, the block of scrambled bits $\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}\left(M_{bit}^{(q)}-1\right)$ shall be modulated as described in clause 5.1 using one of the modulation schemes in Table 6.3.1.2-1, resulting in a block of complex-valued modulation symbols $d^{(q)}(0),\ldots,d^{(q)}\left(M_{symb}^{(q)}-1\right)$.

**[0053]** In one embodiment, the complex-valued modulation symbols for each of the codewords to be transmitted shall be mapped onto up to four layers according to Table 7.3.1.3-1. Complex-valued modulation symbols $d^{(q)}(0),\ldots,d^{(q)}\left(M_{symb}^{(q)}-1\right)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)]^T$, $i = 0,1,\ldots,M_{symb}^{layer}-1$ where $\upsilon$ is the number of layers and $M_{symb}^{layer}$ is the number of modulation symbols per layer.

**[0054]** In one embodiment, if transform precoding is not enabled according to 6.1.3 of TS 38.214, $y^{(\lambda)}(i) = x^{(\lambda)}(i)$ for each layer $\lambda = 0,1,\ldots,\upsilon-1$.

**[0055]** If transform precoding is enabled according to 6.1.3 of TS38.214 (in, $\upsilon = 1$ and $\tilde{x}^{(0)}(i)$ depends on the configuration of phase-tracking reference signals.

**[0056]** If the procedure in TS 38.214 indicates that phase-tracking reference signals are not being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}\left(M_{symb}^{layer}-1\right)$ for the single layer $\lambda = 0$ shall be divided into $M_{symb}^{layer}/M_{sc}^{PUSCH}$ sets, each corresponding to one OFDM symbol and $\tilde{x}^{(0)}(i) = x^{(0)}(i)$.

**[0057]** If the procedure in TS 38.214 indicates that phase-tracking reference signals are being used, the block of complex-valued symbols $x^{(0)}(0), \ldots, x^{(0)}\left(M_{\text{symb}}^{\text{layer}} - 1\right)$ shall be divided into sets, each set corresponding to one OFDM symbol, and where set $l$ contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(0)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol $l$ prior to transform precoding, with $i' \in \{0,1, \ldots, M_{\text{sc}}^{\text{PUSCH}} - 1\}$ and $i' \neq m$. The index m of PT-RS samples in set $l$, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and the number of PT-RS groups $N_{\text{group}}^{\text{PT-RS}}$ are defined in clause 6.4.1.2.2.2. The quantity $\varepsilon_l = 1$ when OFDM symbol $l$ contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$.

**[0058]** Transform precoding shall be applied according to

$$y^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} \tilde{x}^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$

$$k = 0, \ldots, M_{\text{sc}}^{\text{PUSCH}} - 1$$

$$l = 0, \ldots, M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}} - 1$$

**[0059]** resulting in a block of complex-valued symbols $y^{(0)}(0), \ldots, y^{(0)}\left(M_{\text{symb}}^{\text{layer}} - 1\right)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfill:

$$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$

**[0060]** where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

**[0061]** In one embodiment, the block of vectors $[y^{(0)}(i) \quad \ldots \quad y^{(\upsilon-1)}(i)]^T$ shall be precoded according to

$$\begin{bmatrix} z^{(p_0)}(i) \\ \vdots \\ z^{(p_{\rho-1})}(i) \end{bmatrix} = W \begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(\upsilon-1)}(i) \end{bmatrix}$$

**[0062]** where $i = 0,1, \ldots, M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. The set of antenna ports $\{p_0, \ldots, p_{\rho-1}\}$ shall be determined according to the procedure in [6, TS 38.214].

**[0063]** For non-codebook-based transmission, the precoding matrix W equals the identity matrix.

**[0064]** For codebook-based transmission, the precoding matrix W depends on the number of antenna ports used for the transmission - for single-layer transmission on a single antenna port, $W = 1$; for transmissions using 2, or 4 antenna ports, W is given by Tables 6.3.1.5-1 to 6.3.1.5-7; for transmissions using 8 antenna ports, W is given by $W_{f(i)} = W'_i$ where the subscripts i and f(i) denote the row of the respective matrix; f(i) is given by Table 6.3.1.5-8; the intermediate precoding matrix $W'$ is given by Tables 6.3.1.5-9 to 6.3.1.5-24, 6.3.1.5-29 to 6.3.1.5-36, and 6.3.1.5-39 to 6.3.1.5-47 with $0_{m\times n}$ representing the all-zero matrix with m rows and n columns; the submatrices $\overline{W}_{m,n}$ are given by Tables 6.3.1.5-25 to 6.3.1.5-28 and 6.3.1.5-37 to 6.3.1.5-38.

**[0065]** The TPMI index used in the tables above is obtained from the DCI scheduling the UL transmission or the higher layer parameters according to the procedure in TS 38.214. When the higher-layer parameter *txConfig* is not configured, the precoding matrix $W = 1$.

**[0066]** In general, the subject matter herein describes the use of orthogonal codes such as OCCs for UL data channel capacity improvement while employing DFT-s-OFDM waveform in order to allocate higher per-UE resources, i.e., basically same time and/or frequency resources are allocated to different UEs that are orthogonal in code domain. This capacity improvement may be needed in NTN since the cell size in NTN is large and many UEs may need to be scheduled at the same time. This disclosure describes how OCCs may be used/selected to multiplex PUSCH transmission of multiple UEs, where we describe the application of OCC sequences in time, frequency or in both domains. Different mapping to apply the OCC sequences in time and frequency are discussed. In addition, OCC sequences of different lengths that may be used for PUSCH transmission are described.

**[0067]** According to a first embodiment, the UL data for multiple users is multiplexed by multiplication with UE specific orthogonal codes, where same time resources are employed for different users, but the data is separated with help of orthogonal codes.

**[0068]** In one embodiment, the UL data is code multiplexed in the time domain, when DFT-s-OFDM waveform is used, as shown in Figure 2A. Figure 2A illustrates an example of DFT-s-OFDM with OCCs in the time domain in accordance with aspects of the present disclosure. In one example, the UL data may be code multiplexed 202 before

applying the DFT 204, i.e., if transform precoding is enabled (Note: if transform precoding is disabled, the UE may not expect to apply an orthogonal code).

**[0069]** For instance, the UL data, after scrambling and modulation, is layer mapped. In case the transform precoding is enabled, the block of complex-valued symbols, e.g., $x^{(\lambda)}(0), \ldots, x^{(\lambda)}\left(M_{\text{symb}}^{\text{layer}} - 1\right)$ for each layer $\lambda$, may be divided into $M_{\text{symb}}^{\text{layer}}/M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one OFDM symbol, where $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer and $M_{sc}^{PUSCH}$ is the number of subcarriers in each OFDM symbol for UL data. The layered data is precoded with the orthogonal sequence as

$$\begin{bmatrix} y_0(l) \\ \vdots \\ y_{M_{sc}^{PUSCH}-1}(l) \end{bmatrix} = w_n(l) \begin{bmatrix} x_0(l) \\ \vdots \\ x_{M_{sc}^{PUSCH}-1}(l) \end{bmatrix}$$

**[0070]** where $w_n(ml)$ 220 is the orthogonal codes corresponding to the $lth$ 222 OFDM symbol in a slot 224, as shown in Figure 2B. Figure 2B illustrates an example of applying OCC before DFT for UL data in accordance with aspects of the present disclosure.

**[0071]** In one embodiment, the orthogonal codes are applied to the UL data and also to the phase-tracking reference symbols (PTRS), when PTRS are also used along with transform precoding. In this case, the block of complex-valued symbols, e.g., $x^{(\lambda)}(0), \ldots, x^{(\lambda)}\left(M_{\text{symb}}^{\text{layer}} - 1\right)$ for each layer $\lambda$, may be divided into sets, each set corresponding to one OFDM symbol, and where set $l$ contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(\lambda)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol $l$ prior to applying orthogonal codes, with $i' \in \{0,1, \ldots, M_{\text{sc}}^{\text{PUSCH}} - 1\}$, where $N_{\text{samp}}^{\text{group}}$ is the number of samples per PT-RS group, and $N_{\text{group}}^{\text{PT-RS}}$ defines the number of PT-RS groups. The quantity $\varepsilon_l = 1$ when OFDM symbol $l$ contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$. In one implementation, the UL data is first multiplied with orthogonal codes as shown in Figure 2B, and then before the application of the transform precoding (DFT), the PTRS are added in the time domain as described above.

**[0072]** In one embodiment, the orthogonal cover codes are applied after the inverse DFT (IDFT) 206 operation before insertion of cyclic prefix 208. In this case, the reference signals are also precoded with the orthogonal codes, whereas at the receiver

side, first the received signal is firstly decoded with the orthogonal codes after removal of cyclic prefix.

**[0073]** In one embodiment, the length of the orthogonal codes may be up to a slot length, as shown in Figure 2B, where different combinations of the codes may be defined up to a maximum length of slot. Defining OCCs up to slot length with combinations up to slot length provide flexibility to the network to multiplex same time resources for a maximum of slot length users, e.g., 14 users. In the event where less number of time domain resources, e.g., less than slot length, are to be allocated to UEs, the network may choose a code corresponding to the allocated length of time domain symbols in a slot; however, this may also limit the number of UEs to be time domain code multiplexed, i.e., maximum users up to length of allocated number of time domain symbols in a slot.

**[0074]** In one embodiment, to achieve this full flexibility to multiplex up to slot length UEs, a table specifying the orthogonal codes may be specified, where different combinations of codes for all symbol length may be defined in form of a table in order to provide flexibility to schedule any number of resources to a UE and also to choose the number of UEs to be multiplexed. The table may comprise of an index that corresponds to the length of the code to be used while another index may be used to indicate the specific code to be used from the list of the codes, as shown in Table 1.

**[0075]** In one implementation, the type of orthogonal cover codes that are used for code multiplex of data in the time domain are based on the discrete Fourier transform, (as are used for NR UL control channel), as shown in Table 1. However, unlike the UL control channel, the length of the codes may further be extended up to slot length. Note that $N_{\mathrm{sym},l}^{\mathrm{PUSCH}}$ in Table 1 defines the number of UL time domain data symbols that may be used by the network to schedule the data in one slot while employing OCC, where the maximum number may be the slot length.

**Table 1: Orthogonal sequences $w_n(l) = e^{j2\pi\phi(l)/N_{\text{sym,l}}^{\text{PUSCH}}}$ for PUSCH**

| Index ($N_{\text{sym},l}^{\text{PUSCH}}$) | $\phi$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | $i=0$ | $i=1$ | $i=2$ | $i=3$ | $i=4$ | $i=5$ | $i=6$ |
| 1 | [0] | - | - | - | - | - | - |
| 2 | [0 0] | [0 1] | - | - | - | - | - |
| 3 | [0 0 0] | [0 1 2] | [0 2 1] | - | - | - | - |
| 4 | [0 0 0 0] | [0 2 0 2] | [0 0 2 2] | [0 2 2 0] | - | - | - |
| 5 | [0 0 0 0 0] | [0 1 2 3 4] | [0 2 4 1 3] | [0 3 1 4 2] | [0 4 3 2 1] | - | - |
| 6 | [0 0 0 0 0 0] | [0 1 2 3 4 5] | [0 2 4 0 2 4] | [0 3 0 3 0 3] | [0 4 2 0 4 2] | [0 5 4 3 2 1] | - |
| 7 | [0 0 0 0 0 0 0] | [0 1 2 3 4 5 6] | [0 2 4 6 1 3 5] | [0 3 6 2 5 1 4] | [0 4 1 5 2 6 3] | [0 5 3 1 6 4 2] | [0 6 5 4 3 2 1] |

**[0076]** The choice of orthogonal codes plays a crucial role on the performance of OCC systems. The codes need to be carefully designed to ensure orthogonality and minimize cross-correlation between codes assigned to different users. Therefore, in one implementation, the type of orthogonal cover codes that are used for code multiplex of data in the time domain are based on the Golay orthogonal sequence, as Golay codes have good auto correlation properties and minimal cross-correlation. Similar to DFT based OCC, a slot length OCC based on Golay codes may be generated and specified as form of a table, where the network may select the appropriate code to be used for scheduling of resources.

**[0077]** In another implementation, OCC based on Walsh-Hadamard codes may be used for code multiplexing of PUSCH data in the time domain. For instance, multiple tables are specified for OCC to be used for UL, where each table would define the OCC for a specific length code, while index may define the number of available codes for that length. An example of Walsh-Hadamard based OCC for PUSCH symbols length $l = 8$ is shown in Table 2. Similarly, different tables of length 2, 4, and 12 may be generated.

**Table 2: A Walsh-Hadamard based OCC for PUSCH symbols length $l = 8$ and used for up to 8 UE's data code multiplexing in the time domain**

| $n$ | $w_n(l)$ |
|---|---|
| 0 | $[+1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1]$ |
| 1 | $[+1 \quad +1 \quad +1 \quad +1 \quad -1 \quad -1 \quad -1 \quad -1]$ |
| 2 | $[+1 \quad +1 \quad -1 \quad -1 \quad -1 \quad -1 \quad +1 \quad +1]$ |
| 3 | $[+1 \quad +1 \quad -1 \quad -1 \quad +1 \quad +1 \quad -1 \quad -1]$ |
| 4 | $[+1 \quad -1 \quad -1 \quad +1 \quad +1 \quad -1 \quad -1 \quad +1]$ |
| 5 | $[+1 \quad -1 \quad -1 \quad +1 \quad -1 \quad +1 \quad +1 \quad -1]$ |
| 6 | $[+1 \quad -1 \quad +1 \quad -1 \quad -1 \quad +1 \quad -1 \quad +1]$ |
| 7 | $[+1 \quad -1 \quad +1 \quad -1 \quad +1 \quad -1 \quad +1 \quad -1]$ |

**[0078]** According to a second embodiment, the orthogonal codes (e.g., OCC) may be applied in the frequency domain to the UL data, where multiple users would use the same frequency resources, but the data is separated with help of orthogonal codes in the frequency domain. In the case of DFT-s-OFDM waveform, the OCC may be applied after the application of transform precoding (DFT) in the frequency domain, for example, once the virtual resource blocks have been mapped to the physical resource blocks. For instance, for each antenna port used for transmission of the PUSCH, a block of complex-valued symbols $z^{(p)}(0), \ldots, z^{(p)}(M^{\text{ap}}_{\text{symb}} - 1)$ (derived from one of the configured modulation scheme (e.g., BPSK, QAM) and precoded after the application of transform precoding if enabled) is multiplied with the amplitude scaling factor $\beta_{\text{PUSCH}}$ to align with the transmit power.

**[0079]** The resulting symbols are then mapped in a sequence starting with $z^{(p)}(0)$ to resource elements $(k', l)_{p,\mu}$ in the assigned virtual resource blocks for PUSCH transmission, where mapping is not carried out on the corresponding physical resource blocks that are to be used for transmission of associated reference signals, e.g., DMRS intended for other co-scheduled UEs. The mapping to resource elements $(k', l)_{p,\mu}$ allocated for PUSCH is carried out in the increasing order of the index $k'$ over the assigned virtual resource blocks, where $k'$ (subcarrier index) = 0 is the first subcarrier in the lowest-numbered virtual resource block, and then the index $l$ (symbol index), with the starting position given by TS 38.214. Based on the type of mapping, i,e., interleave or non-interleave mapping, the complex valued symbols are mapped from virtual resource blocks to physical resource blocks. After the data symbols have been mapped to physical resource blocks, the OCC are applied as

$$\begin{bmatrix} t^{(p)}(0 \\ \vdots \\ t^{(p)}(M_{\text{symb}}^{\text{ap}} - 1) \end{bmatrix} = w_n(f) \begin{bmatrix} z^{(p)}(0) \\ \vdots \\ z^{(p)}(M_{\text{symb}}^{\text{ap}} - 1) \end{bmatrix}$$

**[0080]** In one implementation, when PTRS are enabled along with transform precoding and OCC are also configured in the frequency domain, the UL data along with PTRS would be code multiplexed in the frequency domain, since the PRTS are added in the time domain before applying the DFT. In one implementation, the OCC may be applied once the data after frequency domain precoding is mapped to the virtual resource block, i.e., before applying interleave or non-interleave mapping.

**[0081]** In one implementation, when code multiplexing in frequency domain is enabled for PUSCH along with transform precoding, this implies that only the PUSCH data is to be multiplexed with OCC. Whereas, the other reference signals such as DMRS and CSI-RS may not be code multiplexed along with the PUSCH data.

**[0082]** In one embodiment, different lengths of orthogonal codes may be realized to apply an OCC in the frequency domain in order to have lower PAPR or to provide more flexibility in scheduling the frequency domain resources. For example, code length of multiples of 2 may be defined and specified in the form of table, where length 2, 4, 6, and 12 codes may be used. For this purpose, either of (or a combination of) Walsh-Hadamard codes, or DFT-based or Golay codes may be used as OCC. Different implementations of OCC of length 2, 4, and 12 are shown in Tables 3, 4, 5, and 6.

**Table 3: Walsh-Hadamard or DFT based length 2 orthogonal sequences $w_n(f)$ for FD-OCC based PUSCH**

| $n$ | $w_n(f)$ |
|---|---|
| 0 | $[+1 \quad +1]$ |
| 1 | $[+1 \quad -1]$ |

**Table 4: Walsh-Hadamard based length 4 orthogonal sequences $w_n(f)$ for FD-OCC based PUSCH**

| $n$ | $w_n(f)$ |
|---|---|
| 0 | $[+1 \quad +1 \quad +1 \quad +1]$ |
| 1 | $[+1 \quad -1 \quad +1 \quad -1]$ |
| 2 | $[+1 \quad +1 \quad -1 \quad -1]$ |
| 3 | $[+1 \quad -1 \quad -1 \quad +1]$ |

**Table 5: DFT based length 4 orthogonal sequences $w_n(f)$ for FD-OCC based PUSCH**

| $n$ | $w_n(f)$ |
|---|---|
| 0 | $[+1 \quad +1 \quad +1 \quad +1]$ |
| 1 | $[+1 \quad -j \quad -1 \quad +j]$ |
| 2 | $[+1 \quad -1 \quad +1 \quad -1]$ |
| 3 | $[+1 \quad +j \quad -1 \quad -j]$ |

**Table 6: DFT based length 12 orthogonal sequences $w_n(f)$ for FD-OCC based PUSCH**

| $n$ | $w_n(f)$ |
|---|---|
| 0 | $[+1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1 \quad +1]$ |
| 1 | $[+1 \quad -j \quad -1 \quad +j \quad +1 \quad -j \quad -1 \quad +j \quad +1 \quad -j \quad -1 \quad +j]$ |
| 2 | $[+1 \quad -1 \quad +1 \quad -1 \quad +1 \quad -1 \quad +1 \quad -1 \quad +1 \quad -1 \quad +1 \quad -1]$ |
| 3 | $[+1 \quad +j \quad -1 \quad -j \quad +1 \quad +j \quad -1 \quad -j \quad +1 \quad +j \quad -1 \quad -j]$ |

**[0083]** Depending on the maximum number of UEs to be multiplexed and also based on the acceptable peak to average power ratio (PAPR) requirement for a coverage area, different types of RE mapping for applying OCC to PUSCH may be realized.

**[0084]** In one implementation, at most one RB length OCC may be used for code multiplexing of the UL data of different UEs, where depending on the number of UEs for which UL data is to be multiplexed in the frequency domain, the number of codes may be specified in the form of a table. The UEs may be scheduled to use one of the codes from the table, where the UE would apply the selected code to all the elements in an RB, as shown in Figure 3A. Figure 3A illustrates an example OCC applied in the frequency domain for each RB in accordance with aspects of the present disclosure. Note that a resource block length may provide frequency domain code multiplexing of

up to 12 UEs. In one implementation, when a UE is scheduled with multiple RBs 302 and also frequency domain OCC 304, then the UE applies the selected code sequence to all of the RBs 302. Alternatively, a UE may be scheduled different RB length code sequences for different RBs 302.

**[0085]** In one embodiment, contiguous type RE scheduling is used to apply OCC in the frequency domain, where a comb like structure may be employed. For example, when such mapping is scheduled, then consecutive REs within an RB are used for the application of OCC in the frequency domain, and a gap of same length of RBs may be used to apply the OCC again. For example, as shown in Figure 3B, which illustrates an example of contiguous mapping of REs for applying OCC for length 2 and 4 codes to PUSCH in accordance with aspects of the present disclosure, 2 contiguous REs 306 are used for the application of length 2 code, where next OCC are applied after the gap of 2 REs. In this case, a total of 6 REs within RBs are scheduled for the length 2 code. Similarly, in the same figure, an example of length 4 code with 4 contiguous REs 308 is applied.

**[0086]** In one embodiment, non-contiguous type RE scheduling is used to apply OCC in the frequency domain, where a UE may be scheduled to apply an OCC in an RB with some RE gap in between. For example, as shown in Figure 3C, which illustrates an example of contiguous and non-contiguous scheduling of REs for applying OCC for length 6 codes in accordance with aspects of the present disclosure, a 6 length OCC 310 is to be applied with non-continuous mapping 312, where every other/alternative RE is used to apply the OCC. A UE may be configured with such a gap along with the code.

**[0087]** In one implementation, the number of frequency resources to be scheduled may be limited to length of OCC that are to be applied. For example, if a length 4 code is to be used, then a UE may be scheduled to use at the most 4 REs within an RB. Hence, an RB may be divided into 3 sets of 4 REs, where length 4 code may be used for each set of REs in an RB. This would imply that when configured with such application of frequency domain OCC, then a UE would be allocated only a fixed set of RE corresponding to the length of code within one RB.

**[0088]** According to a third embodiment, the OCC sequences are applied to PUSCH transmission in both frequency 402 and time 404 domain, as shown in Figure 4, which

illustrates an example of time and frequency application of OCC sequences in accordance with aspects of the present disclosure, to increase the UL capacity as it may provide more flexibility to accommodate the number of users with reduce signaling effort. For instance, index four OCCs (four orthogonal codes are defined) defined for frequency and time domain may multiplex up to 16 UEs, thus enhancing the capacity by 16 times. Defining low number of codes may require less bits to indicate the corresponding OCC sequence to be used for PUSCH. For example, a four index code would require two bits to indicate to a UE to select the OCC sequence.

**[0089]** Figure 5 illustrates an example of a UE 500 in accordance with aspects of the present disclosure. The UE 500 may include a processor 502, a memory 504, a controller 506, and a transceiver 508. The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

**[0090]** The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

**[0091]** The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 502 may be configured to operate the memory 504. In some other implementations, the memory 504 may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in the memory 504 to cause the UE 500 to perform various functions of the present disclosure.

**[0092]** The memory 504 may include volatile or non-volatile memory. The memory 504 may store computer-readable, computer-executable code including instructions when executed by the processor 502 cause the UE 500 to perform various functions

described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 504 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

**[0093]** In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to cause the UE 500 to perform one or more of the functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504). For example, the processor 502 may support wireless communication at the UE 500 in accordance with examples as disclosed herein.

**[0094]** The UE 500 may be configured to support a means to receive an indication of a network access restriction enforcement capability of a UE, receive a handover request for the UE, determine network access restriction information for the UE, transmit the network access restriction information to a network entity associated with a different network, and transmit a handover command comprising the network access restriction information to a base station associated with the UE for processing the handover request according to the network access restriction information.

**[0095]** In one embodiment, the UE 500 may be configured to support a means to multiplex UL data associated with the UE in one or more of a time domain or a frequency domain according to at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data associated with the UE over a PUSCH.

**[0096]** In one embodiment, the UE 500 may be configured to support a means to receive, from a network entity, a configuration comprising a set of one or more orthogonal code sequences, including the at least one orthogonal code sequence.

**[0097]** In one embodiment, the UE 500 may be configured to support a means to select the at least one orthogonal code sequence of the set of one or more orthogonal code sequences.

**[0098]** In one embodiment, the at least one orthogonal code sequence is orthogonal among a plurality of different UEs.

**[0099]** In one embodiment, the UE 500 may be configured to support a means to apply the at least one orthogonal code sequence to the UL data of the plurality of UEs and a set of one or more phase-tracking reference symbols.

**[0100]** In one embodiment, the UE 500 may be configured to support a means to apply the at least one orthogonal code sequence to the UL data of the plurality of UEs subsequent to applying an IDFT.

**[0101]** In one embodiment, a length of the at least one orthogonal code sequence is less than or equal to a length of a slot. In one embodiment, the UE 500 may be configured to support a means to generate the at least one orthogonal code sequence based at least in part on applying a discrete Fourier transform.

**[0102]** In one embodiment, the UE 500 may be configured to support a means to generate the at least one orthogonal code sequence based at least in part on applying a Walsh-Hadamard transform.

**[0103]** In one embodiment, the UE 500 may be configured to support a means to generate the at least one orthogonal code sequence based at least in part on a Golay orthogonal sequence.

**[0104]** In one embodiment, the UE 500 may be configured to support a means to apply different lengths of orthogonal code sequences in the frequency domain.

**[0105]** In one embodiment, the at least one orthogonal code sequence has a length of one resource block.

**[0106]** In one embodiment, the UE 500 may be configured to support a means to apply the at least one orthogonal code sequence in the frequency domain using contiguous-type resource element mapping.

**[0107]** In one embodiment, at least one orthogonal sequence of same length is applied on consecutive resource elements of a resource block with no gap in between.

**[0108]** In one embodiment, the UE 500 may be configured to support a means to apply the at least one orthogonal code sequence in the frequency domain using non-contiguous-type resource element mapping.

**[0109]** In one embodiment, at least one orthogonal sequence of same length is applied with a gap of resource elements within a resource block. In one embodiment, a

number of resources to be scheduled is limited to a length of the at least one orthogonal code sequence. In one embodiment, the at least one orthogonal code sequence comprises at least one orthogonal cover code sequence. In one embodiment, the waveform comprises a DFT-s-OFDM waveform.

**[0110]** The controller 506 may manage input and output signals for the UE 500. The controller 506 may also manage peripherals not integrated into the UE 500. In some implementations, the controller 506 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 506 may be implemented as part of the processor 502.

**[0111]** In some implementations, the UE 500 may include at least one transceiver 508. In some other implementations, the UE 500 may have more than one transceiver 508. The transceiver 508 may represent a wireless transceiver. The transceiver 508 may include one or more receiver chains 510, one or more transmitter chains 512, or a combination thereof.

**[0112]** A receiver chain 510 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 510 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 510 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 510 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 510 may include at least one decoder for decoding and processing the demodulated signal to receive the transmitted data.

**[0113]** A transmitter chain 512 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 512 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 512 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain

512 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

**[0114]** Figure 6 illustrates an example of a processor 600 in accordance with aspects of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

**[0115]** The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600)) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

**[0116]** The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

**[0117]** The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data within the processor 600. The controller 602 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 600.

**[0118]** The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600) or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

**[0119]** The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

**[0120]** The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 606 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 606 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

**[0121]** The processor 600 may support wireless communication in accordance with examples as disclosed herein. In one embodiment, the processor 600 may be configured to or operable to support a means to multiplex UL data associated with the UE in one or more of a time domain or a frequency domain according to at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data associated with the UE over a PUSCH.

**[0122]** In one embodiment, the processor 600 may be configured to or operable to support a means to receive, from a network entity, a configuration comprising a set of one or more orthogonal code sequences, including the at least one orthogonal code sequence.

**[0123]** In one embodiment, the processor 600 may be configured to or operable to support a means to select the at least one orthogonal code sequence of the set of one or more orthogonal code sequences.

**[0124]** In one embodiment, the at least one orthogonal code sequence is orthogonal among a plurality of different UEs.

**[0125]** In one embodiment, the processor 600 may be configured to or operable to support a means to apply the at least one orthogonal code sequence to the UL data of the plurality of UEs and a set of one or more phase-tracking reference symbols.

**[0126]** In one embodiment, the processor 600 may be configured to or operable to support a means to apply the at least one orthogonal code sequence to the UL data of the plurality of UEs subsequent to applying an IDFT.

**[0127]** In one embodiment, a length of the at least one orthogonal code sequence is less than or equal to a length of a slot. In one embodiment, the processor 600 may be configured to or operable to support a means to generate the at least one orthogonal code sequence based at least in part on applying a discrete Fourier transform.

**[0128]** In one embodiment, the processor 600 may be configured to or operable to support a means to generate the at least one orthogonal code sequence based at least in part on applying a Walsh-Hadamard transform.

**[0129]** In one embodiment, the processor 600 may be configured to or operable to support a means to generate the at least one orthogonal code sequence based at least in part on a Golay orthogonal sequence.

**[0130]** In one embodiment, the processor 600 may be configured to or operable to support a means to apply different lengths of orthogonal code sequences in the frequency domain.

**[0131]** In one embodiment, the at least one orthogonal code sequence has a length of one resource block.

**[0132]** In one embodiment, the processor 600 may be configured to or operable to support a means to apply the at least one orthogonal code sequence in the frequency domain using contiguous-type resource element mapping.

**[0133]** In one embodiment, at least one orthogonal sequence of same length is applied on consecutive resource elements of a resource block with no gap in between.

**[0134]** In one embodiment, the processor 600 may be configured to or operable to support a means to apply the at least one orthogonal code sequence in the frequency domain using non-contiguous-type resource element mapping.

**[0135]** In one embodiment, at least one orthogonal sequence of same length is applied with a gap of resource elements within a resource block. In one embodiment, a number of resources to be scheduled is limited to a length of the at least one orthogonal code sequence. In one embodiment, the at least one orthogonal code sequence

comprises at least one orthogonal cover code sequence. In one embodiment, the waveform comprises a DFT-s-OFDM waveform.

**[0136]** Figure 7 illustrates an example of a NE 700 in accordance with aspects of the present disclosure. The NE 700 may include a processor 702, a memory 704, a controller 706, and a transceiver 708. The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

**[0137]** The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

**[0138]** The NE 700 may be configured to support a means to multiplex UL data of a plurality of UEs in one or more of a time domain or a frequency domain according to the at least one orthogonal code sequence and transmit a waveform carrying the multiplexed UL data of the plurality of UEs over a PUSCH.

**[0139]** The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 702 may be configured to operate the memory 704. In some other implementations, the memory 704 may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in the memory 704 to cause the NE 700 to perform various functions of the present disclosure.

**[0140]** The memory 704 may include volatile or non-volatile memory. The memory 704 may store computer-readable, computer-executable code including instructions when executed by the processor 702 causes the NE 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 704 or another type of memory. Computer-readable media

includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

**[0141]** In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to cause the NE 700 to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704). For example, the processor 702 may support wireless communication at the NE 700 in accordance with examples as disclosed herein.

**[0142]** The controller 706 may manage input and output signals for the NE 700. The controller 706 may also manage peripherals not integrated into the NE 700. In some implementations, the controller 706 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 706 may be implemented as part of the processor 702.

**[0143]** In some implementations, the NE 700 may include at least one transceiver 708. In some other implementations, the NE 700 may have more than one transceiver 708. The transceiver 708 may represent a wireless transceiver. The transceiver 708 may include one or more receiver chains 710, one or more transmitter chains 712, or a combination thereof.

**[0144]** A receiver chain 710 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 710 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 710 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 710 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 710 may include at least one decoder for decoding and processing the demodulated signal to receive the transmitted data.

**[0145]** A transmitter chain 712 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 712 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to

support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 712 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 712 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

**[0146]** Figure 8 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions.

**[0147]** At 802, the method may multiplex UL data associated with the UE in one or more of a time domain or a frequency domain according to at least one orthogonal code sequence. The operations of 802 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 802 may be performed by a UE as described with reference to Figure 5.

**[0148]** At 804, the method may transmit a waveform carrying the multiplexed UL data associated with the UE over a PUSCH. The operations of 804 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 804 may be performed by a UE as described with reference to Figure 5.

**[0149]** Figure 9 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method may be implemented by an NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

**[0150]** At 902, the method may multiplex UL data of a plurality of UEs in one or more of a time domain or a frequency domain according to the at least one orthogonal code sequence. The operations of 902 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 902 may be performed by an NE as described with reference to Figure 7.

**[0151]** At 904, the method may transmit a waveform carrying the multiplexed UL data of the plurality of UEs over a PUSCH. The operations of 904 may be performed in

accordance with examples as described herein. In some implementations, aspects of the operations of 904 may be performed by an NE as described with reference to Figure 7.

**[0152]** It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

**[0153]** The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.