METHOD, APPARATUS, AND SYSTEM FOR UPLINK CONTROL INFORMATION RETRANSMISSION

CROSS-REFERENCE TO RELATED APPLICATIONS

The present disclosure claims priority to and the benefit of U.S. Provisional Application No. 63/565,374 filed in the U.S. Patent and Trademark Office on March 14, 2024, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present disclosure relates generally to wireless communications. Particularly, it relates to a method, apparatus and system for uplink control information retransmission.

BACKGROUND

Wireless communications system such as fourth generation (4G) system (for example, Long-Term Evolution (LTE) system), fifth generation (5G) system (for example, New Radio (NR) system) have been deployed to provide various types of applications, such as message, voice, video and other data.

In wireless communication, for data channel, HARQ process is implemented to allow re-transmission and hybrid combining of original and re-transmission of the same data to counterattack the channel impairment and improve the robustness of the system performance.

"HARQ" refers to hybrid automatic repeat request.

This background information is provided to reveal information believed by the applicant to be of possible relevance to the present disclosure. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present disclosure.

SUMMARY

Aspects of the present disclosure provide methods, apparatuses, devices and systems to overcome the shortcomings of the existing uplink control information (UCI) retransmission schemes and provide reliable and efficient retransmission of UCI packets in 6G networks, considering the evolving 3GPP standards and new UCI types, as well as specific methods, apparatuses, devices, and systems for facilitating communications between an apparatus and a device in a wireless network.

According to a first broad aspect of the present disclosure, there is provided herein a method performed at an apparatus in a wireless network. The method according to the first broad aspect of the present disclosure may include: transmitting, to a device, a plurality of code blocks of a first information channel, the plurality of code blocks including first information for managing communication involving at least one of the apparatus or the device; and retransmitting, to the device, one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index.

The proposed method according to the first broad aspect of the present disclosure may overcome several shortcomings of existing UCI retransmission schemes. For example, the proposed method may reduce processing overhead, enhance resource utilization, improve reliability (e.g., ultra-high reliability), minimize latency and provide support for a multitude of diverse applications by retransmitting only necessary code blocks based on payload type (e.g., critical sensing/AI information)

or priority level. For example, processing overhead may be reduced and resource utilization may be enhanced by not retransmitting time-sensitive data (e.g. ACK/NACK).

In some implementations of the method according to the first broad aspect of the present disclosure, retransmitting one or more of the code blocks of the plurality of code blocks includes: retransmitting a first code block of the plurality of code blocks based on the first code block having a first payload type; and not retransmitting a second code block of the plurality of code blocks based on the second code block having a second payload type, wherein the second payload type is different from the first payload type. For example, in some implementations, the first payload type may include sensing information (SSI) and/or artificial intelligence (AI)-related information (AII). On the other hand, the second payload type may include hybrid automatic repeat request (HARQ) acknowledgement and negative acknowledgement (ACK/NACK), a scheduling request (SR) and/or channel state information (CSI).

In some implementations of the method according to the first broad aspect of the present disclosure, each code block of the plurality of code blocks is assigned a respective priority index, and retransmitting one or more of the code blocks of the plurality of code blocks includes: retransmitting a first code block of the plurality of code blocks based on the respective priority index assigned to the first code block being a first priority index; and not retransmitting a second code block of the plurality of code blocks based on the respective priority index assigned to the second code block being a second priority index, wherein the second priority index is different from the first priority index. For example, in such implementations, the first priority index may correspond to a higher priority than the second priority index, e.g., the first priority index may satisfy a priority index threshold and the second priority index may not satisfy the priority index threshold. The respective priority index assigned to each code block of the plurality of code blocks may be preconfigured using radio resource control (RRC) signaling, for example.

In some implementations of the method according to the first broad aspect of the present disclosure, retransmitting one or more of the code blocks of the plurality of code blocks includes, for each code block of the plurality of code blocks: determining whether the respective priority index assigned to the code block satisfies a priority index threshold; and selectively retransmitting the code block based on the determining. For example, in some implementations, retransmitting the first code block comprises retransmitting the first code block after determining the first priority index satisfies the priority index threshold.

In some implementations of the method according to the first broad aspect of the present disclosure, retransmitting one or more of the code blocks of the plurality of code blocks includes: determining a set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks, wherein resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks; and retransmitting one or more of the code blocks of the plurality of code blocks using the set of one or more retransmission resources. For example, in some implementations, resources of the set of retransmission resources may be shared among multiple code blocks of the plurality of code blocks in a contention-based manner in which a same retransmission resource of the set is allocated for potential retransmissions for two or more of the code blocks of the plurality of code blocks. Such implementations have several potential benefits, such as providing flexibility and enhanced resource utilization by optimizing resource allocation for both initial transmission and potential retransmissions.

In some implementations of the method according to the first broad aspect of the present disclosure, transmitting the plurality of code blocks to the device includes: determining a set of transmission resources allocated for initial transmission of

the plurality of code blocks, wherein resources of the set of transmission resources are exclusively allocated for each code block of the plurality of code blocks; and transmitting the plurality of code blocks to the device using the set of transmission resources.

In some implementations of the method according to the first broad aspect of the present disclosure, the apparatus receives resource allocation information from the device, wherein the resource allocation information indicates the set of transmission resources allocated for initial transmission of the plurality of code blocks; and the set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks. In such implementations, the apparatus may determine the set of transmission resources and the set of one or more retransmission resources based on the resource allocation information. In some implementations, the resource allocation information may be received via Radio Resource Control (RRC) signaling and/or Downlink Control Information (DCI), for example.

In some implementations of the method according to the first broad aspect of the present disclosure, the apparatus may determine the set of one or more retransmission resources using one or more pre-configured rules to determine the set of one or more retransmission resources. For example, the one or more pre-configured rules may include one or more rules for determining one or more retransmission resource positions based on an offset relative to a Physical Downlink Control Channel (PDCCH) transmission or a Physical Downlink Shared Channel (PDSCH) transmission.

In some implementations of the method according to the first broad aspect of the present disclosure, multiple retransmission resource options are configured for each retransmission. In such implementations, determining the set of one or more retransmission resources may involve determining, for each code block to be retransmitted, a particular retransmission resource to be used for retransmission of the code block from among the multiple retransmission resource options configured for each retransmission. Such implementations may provide flexibility that allows non-overlapping resources to be allocated for all packets requiring retransmission.

In some implementations of the method according to the first broad aspect of the present disclosure, retransmitting one or more of the code blocks of the plurality of code blocks includes, for each code block to be retransmitted, retransmitting the code block using a fixed payload size based on the payload type of the code block.

In some implementations of the method according to the first broad aspect of the present disclosure, a set of two or more fixed payload size options may be configured for retransmissions. In such implementations, retransmitting one or more of the code blocks of the plurality of code blocks may include, for each code block to be retransmitted, retransmitting the code block using a particular fixed payload size selected from among the set of two or more fixed payload size options.

In some implementations of the method according to the first broad aspect of the present disclosure, for each code block to be retransmitted, retransmitting the code block using a particular fixed payload size selected from among the set of two or more fixed payload size options includes selecting the particular fixed payload size from among the set of two or more fixed payload size options based on at least one of the payload type of the content block or a transmission mode to be used for the retransmission of the code block.

In some implementations of the method according to the first broad aspect of the present disclosure, retransmitting one or more of the code blocks of the plurality of code blocks includes retransmitting the one or more of the code blocks in response to detecting a retransmission trigger. In some implementations, detecting a retransmission trigger may involve receiving, from the device, retransmission scheduling information for the one or more of the code blocks. For example, in some

implementations, the retransmission scheduling information for the one or more of the code blocks may include at least one of: transport block retransmission scheduling information indicating one or more transport block indexes corresponding to one or more transport blocks containing the one or more of the code blocks; or code block retransmission scheduling information indicating one or more code block indexes corresponding to the one or more of the code blocks.

In some implementations of the method according to the first broad aspect of the present disclosure, retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index includes, for at least one code block of the one or more of the code blocks: automatically transmitting one or more redundancy versions of the code block without waiting for decoding feedback, from the device, for an initial transmission of the code block. This strategy eliminates the need for decoding feedback before retransmitting, ensuring that time-critical applications receive sufficient code bits within a constrained timeframe. In some implementations, the apparatus receives resource allocation information from the device, wherein the resource allocation information indicates: a transmission resource allocated for the initial transmission of the code block; and a set of one or more retransmission resources allocated for transmission of the one or more redundancy versions of the code block. In some implementations, the resource allocation information may be received via Downlink Control Information (DCI) on a Physical Downlink Control Channel (PDCCH), for example.

In some implementations of the method according to the first broad aspect of the present disclosure, for each code block of the at least one code block, a total number of transmissions for the code block, inclusive of the initial transmission of the code block and the one or more transmissions of redundancy versions of the code block at step 740, may be restricted to a maximum value, T_{max}, wherein $T_{max} \leq 4$.

In some implementations of the method according to the first broad aspect of the present disclosure, a maximum number of redundancy versions defined for each code block of the one or more of the code blocks is 2. This limitation significantly simplifies the channel coding design and reduces the associated encoding and decoding complexity.

In some implementations of the method according to the first broad aspect of the present disclosure, transmitting the plurality of code blocks includes, for at least one code block of the plurality of code blocks, transmitting the at least one code block to the device using a modulation and coding scheme (MCS) selected from a first set of MCS options, wherein the first set of MCS options is selected from a plurality of sets of MCS options based on the payload type of the code block.

In some implementations of the method according to the first broad aspect of the present disclosure, the plurality of sets of MCS options may include: the first set of MCS options; and at least a second set of MCS options, wherein MCS options in the first set of MCS options are more conservative in terms of at least one of coding rate or modulation order relative to corresponding MCS options in the second set of MCS options.

In some implementations of the method according to the first broad aspect of the present disclosure, transmitting the plurality of code blocks includes, for at least one code block of the plurality of code blocks, transmitting the at least one code block to the device using a modulation and coding scheme (MCS) selected from a first set of MCS options using a first set of pre-configured rules for MCS selection. In such implementations, retransmitting one or more of the code blocks of the plurality of code blocks may include, for the at least one code block of the plurality of code blocks, retransmitting one or more of the at least one code block using a MCS selected from the first set of MCS options using a second set of pre-configured rules for MCS selection, wherein the second set of pre-configured rules for MCS selection is different from the first set of pre-configured rules

for MCS selection. For example, in some implementations, the second set of pre-configured rules for MCS selection may be more conservative than the first set of pre-configured rules for MCS selection in that, in at least some cases, the second set of pre-configured rules for MCS selection prescribes selection of an MCS option having at least one of lower coding rate or lower modulation order than an MCS option that would otherwise be prescribed for selection by the first set of pre-configured rules for MCS selection.

In some implementations of the method according to the first broad aspect of the present disclosure, the first information channel may be configured to carry at least one of: control information; physical-layer data; sensing information (SSI); artificial intelligence (AI)-related information (AII); transmission mode and phase information; quality of service indicator (QoSI); or positioning reference signal (PRS), for example.

In some implementations of the method according to the first broad aspect of the present disclosure, the first information may be associated with at least one of: physical-layer data transport; sensing; intra-radio access network (RAN) communication; or artificial intelligence (AI) or machine learning (ML).

In some implementations of the method according to the first broad aspect of the present disclosure, the transmitting and retransmitting is done in a downlink direction, an uplink direction, or a sidelink direction.

According to a second broad aspect of the present disclosure there is provided an apparatus including means to perform methods mentioned in this disclosure, including at least the proposed method according to the first broad aspect of the present disclosure described above and elsewhere herein. For example, the apparatus includes at least one processor coupled with a computer-readable medium. The computer-readable medium stores thereon computer executable instructions that when executed cause the apparatus to perform a method consistent with the implementations described above and herein. A non-limiting example of the apparatus is a user equipment (UE) or any other suitable terminal side device. In some implementations, the apparatus includes a chip, e.g., an integrated circuit (IC) chip. In some implementations, the apparatus does not execute instructions by a processor to perform the methods, e.g., the apparatus may include circuitry such as a field-programmable gate array (FPGA), a graphical processing unit (GPU), or an application-specific integrated circuit (ASIC), that performs the methods. More generally, the apparatus may include modules or units or means to perform the methods.

According to a third broad aspect of the present disclosure, there is provided herein a method performed at a device in a wireless network. The method according to the third broad aspect of the present disclosure may include: receiving, from an apparatus, a plurality of code blocks of a first information channel, the plurality of code blocks including first information for managing communication involving at least one of the apparatus or the device; and receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks, the one or more retransmitted code blocks having been retransmitted based on at least one of payload type or priority index.

The proposed method according to the third broad aspect of the present disclosure may overcome several shortcomings of existing UCI retransmission schemes. For example, the proposed method may reduce processing overhead, enhance resource utilization, improve reliability (e.g., ultra-high reliability), minimize latency and provide support for a multitude of diverse applications by retransmitting only necessary code blocks based on payload type (e.g., critical sensing/AI information) or priority level. For example, processing overhead may be reduced and resource utilization may be enhanced by not retransmitting time-sensitive data (e.g. ACK/NACK).

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes: receiving a first code block of the plurality of code blocks, wherein the first code block was retransmitted based on the first code block having a first payload type; and not receiving a second code block of the plurality of code blocks, wherein the second code block was not retransmitted based on the second code block having a second payload type, wherein the second payload type is different from the first payload type.

In some implementations of the method according to the third broad aspect of the present disclosure, the first payload type includes at least one of: sensing information (SSI); or artificial intelligence (AI)-related information (AII).

In some implementations of the method according to the third broad aspect of the present disclosure, the second payload type includes at least one of: hybrid automatic repeat request (HARQ) acknowledgement and negative acknowledgement (ACK/NACK); a scheduling request (SR); or channel state information (CSI).

In some implementations of the method according to the third broad aspect of the present disclosure, each code block of the plurality of code blocks is assigned a respective priority index, and receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes: receiving a first code block of the plurality of code blocks, wherein the first code block was retransmitted based on the respective priority index assigned to the first code block being a first priority index; and not receiving a second code block of the plurality of code blocks, wherein the second code block was not retransmitted based on the respective priority index assigned to the second code block being a second priority index, wherein the second priority index is different from the first priority index.

In some implementations of the method according to the third broad aspect of the present disclosure, the respective priority index assigned to each code block of the plurality of code blocks is preconfigured using radio resource control (RRC) signaling.

In some implementations of the method according to the third broad aspect of the present disclosure, the first priority index corresponds to a higher priority than the second priority index.

In some implementations of the method according to the third broad aspect of the present disclosure, the first priority index satisfies a priority index threshold and the second priority index does not satisfy the priority index threshold.

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes receiving, from the apparatus the one or more retransmitted code blocks having been retransmitted based on having respective priority indexes that satisfy a priority index threshold.

In some implementations of the method according to the third broad aspect of the present disclosure, the priority index threshold is configured via at least one of Radio Resource Control (RRC) signaling or Downlink Control Information (DCI).

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes: determining a set of one or more retransmission resources to allocate for retransmission of the code blocks of the plurality of code blocks, wherein resources

of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks; and receiving the one or more of the code blocks of the plurality of code blocks using the set of one or more retransmission resources.

In some implementations of the method according to the third broad aspect of the present disclosure, resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks in a contention-based manner in which a same retransmission resource of the set is allocated for potential retransmissions for two or more of the code blocks of the plurality of code blocks.

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, the plurality of code blocks includes: determining a set of transmission resources to allocate for initial transmission of the plurality of code blocks, wherein resources of the set of transmission resources are exclusively allocated for each code block of the plurality of code blocks; and receiving, from the apparatus, the plurality of code blocks using the set of transmission resources.

In some implementations of the method according to the third broad aspect of the present disclosure, the method further includes transmitting, to the apparatus, resource allocation information indicating: the set of transmission resources allocated for initial transmission of the plurality of code blocks; and the set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks.

In some implementations of the method according to the third broad aspect of the present disclosure, the resource allocation information is transmitted via at least one of Radio Resource Control (RRC) signaling or Downlink Control Information (DCI).

In some implementations of the method according to the third broad aspect of the present disclosure, determining the set of one or more retransmission resources includes determining the set of one or more retransmission resources using one or more pre-configured rules to determine the set of one or more retransmission resources.

In some implementations of the method according to the third broad aspect of the present disclosure, the one or more pre-configured rules include one or more rules for determining one or more retransmission resource positions based on an offset relative to a Physical Downlink Control Channel (PDCCH) transmission or a Physical Downlink Shared Channel (PDSCH) transmission.

In some implementations of the method according to the third broad aspect of the present disclosure, multiple retransmission resource options are configured for each retransmission, and determining the set of one or more retransmission resources includes performing blind detection to determine, for each retransmitted code block, a particular retransmission resource used for retransmission of the code block from among the multiple retransmission resource options configured for each retransmission.

In some implementations of the method according to the third broad aspect of the present disclosure, each retransmitted code block of the one or more of the code blocks is retransmitted using a fixed payload size based on the payload type of the code block.

In some implementations of the method according to the third broad aspect of the present disclosure, a set of two or more fixed payload size options is configured for retransmissions, and receiving, from the apparatus, one or more

retransmitted code blocks of the plurality of code blocks includes determining, for each retransmitted code block, a particular fixed payload size selected from among the set of two or more fixed payload size options.

In some implementations of the method according to the third broad aspect of the present disclosure, determining, for each retransmitted code block, a particular fixed payload size selected from among the set of two or more fixed payload size options includes: selecting the particular fixed payload size from among the set of two or more fixed payload size options based on at least one of the payload type of the content block or a transmission mode to be used for the retransmission of the code block.

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes: detecting a retransmission trigger; transmitting, to the apparatus, retransmission scheduling information for the one or more of the code blocks; and receiving the one or more retransmitted code blocks of the plurality of code blocks in accordance with the scheduling information.

In some implementations of the method according to the third broad aspect of the present disclosure, detecting the retransmission trigger includes detecting the retransmission trigger based on decoding feedback for the plurality of code blocks.

In some implementations of the method according to the third broad aspect of the present disclosure, the retransmission scheduling information for the one or more of the code blocks includes at least one of: transport block retransmission scheduling information indicating one or more transport block indexes corresponding to one or more transport blocks containing the one or more of the code blocks; or code block retransmission scheduling information indicating one or more code block indexes corresponding to the one or more of the code blocks.

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes, for at least one code block of the one or more of the code blocks: receiving one or more redundancy versions of the code block automatically retransmitted without waiting for decoding feedback for an initial transmission of the code block.

In some implementations of the method according to the third broad aspect of the present disclosure, the method further includes transmitting, to the apparatus, resource allocation information indicating: a transmission resource allocated for the initial transmission of the code block; and a set of one or more retransmission resources allocated for transmission of the one or more redundancy versions of the code block.

In some implementations of the method according to the third broad aspect of the present disclosure, the resource allocation information is transmitted via Downlink Control Information (DCI) on a Physical Downlink Control Channel (PDCCH).

In some implementations of the method according to the third broad aspect of the present disclosure, for each code block of the at least one code block, a total number of transmissions for the code block, inclusive of the initial transmission of the code block and the one or more transmissions of redundancy versions of the code block, is restricted to a maximum value, Tmax, wherein $Tmax \leq 4$.

In some implementations of the method according to the third broad aspect of the present disclosure, a maximum number of redundancy versions defined for each code block of the one or more of the code blocks is 2.

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, the plurality of code blocks includes, for at least one code block of the plurality of code blocks, receiving the at least one code block from the apparatus using a modulation and coding scheme (MCS) selected from a first set of MCS options, wherein the first set of MCS options is selected from a plurality of sets of MCS options based on the payload type of the code block.

In some implementations of the method according to the third broad aspect of the present disclosure, the plurality of sets of MCS options includes: the first set of MCS options; and at least a second set of MCS options, wherein MCS options in the first set of MCS options are more conservative in terms of at least one of coding rate or modulation order relative to corresponding MCS options in the second set of MCS options.

In some implementations of the method according to the third broad aspect of the present disclosure, receiving, from the apparatus, the plurality of code blocks includes, for at least one code block of the plurality of code blocks, receiving the at least one code block from the apparatus using a modulation and coding scheme (MCS) selected from a first set of MCS options using a first set of pre-configured rules for MCS selection; and receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks includes, for the at least one code block of the plurality of code blocks, receiving one or more of the at least one code block using a MCS selected from the first set of MCS options using a second set of pre-configured rules for MCS selection, wherein the second set of pre-configured rules for MCS selection is different from the first set of pre-configured rules for MCS selection.

In some implementations of the method according to the third broad aspect of the present disclosure, the second set of pre-configured rules for MCS selection is more conservative than the first set of pre-configured rules for MCS selection in that, in at least some cases, the second set of pre-configured rules for MCS selection prescribes selection of an MCS option having at least one of lower coding rate or lower modulation order than an MCS option that would otherwise be prescribed for selection by the first set of pre-configured rules for MCS selection.

In some implementations of the method according to the third broad aspect of the present disclosure, the first information channel is configured to carry at least one of: control information; physical-layer data; sensing information (SSI); artificial intelligence (AI)-related information (AII); transmission mode and phase information; quality of service indicator (QoSI); or positioning reference signal (PRS).

In some implementations of the method according to the third broad aspect of the present disclosure, the receiving of the plurality of code blocks and the receiving of one or more retransmitted code blocks is done in a downlink direction, an uplink direction, or a sidelink direction.

In some implementations of the method according to the third broad aspect of the present disclosure, the first information is associated with at least one of: physical-layer data transport; sensing; intra-radio access network (RAN) communication; or artificial intelligence (AI) or machine learning (ML).

According to a fourth broad aspect of the disclosure there is provided a device including means to perform methods mentioned in this disclosure, including at least the proposed method according to the third broad aspect of the present

disclosure described above and elsewhere herein. For example, the device includes at least one processor coupled with a computer-readable medium. The computer-readable medium stores thereon computer executable instructions that when executed cause the device to perform a method consistent with the implementations described above and herein. A non-limiting example of the device is a base station (BS) or any other suitable network side device. In some implementations, the device includes a chip, e.g., an integrated circuit (IC) chip. In some implementations, the device does not execute instructions by a processor to perform the methods, e.g., the device may include circuitry such as a field-programmable gate array (FPGA), a graphical processing unit (GPU), or an application-specific integrated circuit (ASIC), that performs the methods. More generally, the device may include modules or units or means to perform the methods.

According to an aspect of the disclosure, there is provided a computer-readable storage medium. The computer-readable storage medium stores computer executable instructions that, when executed, cause a computer to perform a method as described above or elsewhere in the present disclosure. The computer-readable storage medium may be non-transitory.

According to an aspect of the disclosure, there is provided a computer-program. The computer program includes computer executable instructions that, when executed, cause a computer to perform a method as described above or elsewhere in the present disclosure.

In some aspects of the present disclosure, there is provided an element/chipset system including means (e.g., at least one processor) to implement the method implemented by (or at) a UE of the present disclosure. The apparatus/chipset system may be the UE (that is, a terminal side device) or a module/component in the UE. In details, the at least one processor may execute instructions stored in a computer-readable medium to implement the method.

In some aspects of the present disclosure, there is provided an element/chipset system including means (e.g., at least one processor) to implement the method implemented by (or at) a network side device of the present disclosure. The apparatus/chipset system may be the network side device (e.g., a BS) or a module/component in the device. In details, the at least one processor may execute instructions stored in a computer-readable medium to implement the method.

In some aspects of the present disclosure, there is provided a system including at least one of an element in (or at) a UE of the present disclosure, or an element in (or at) a network device of the present disclosure.

In some aspects of the present disclosure, there is provided a method performed by a system including at least one of an element in (or at) a UE of the present disclosure, or an element in (or at) a network device of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present embodiments, and the advantages thereof, reference is now made, by way of example, to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a communication system in which embodiments of the present disclosure may occur.

FIG. 2 is another schematic diagram of a communication system in which embodiments of the present disclosure may occur.

FIG. 3 is a block diagram illustrating units or modules in a device in which embodiments of the present disclosure may occur.

FIG. 4 is a block diagram illustrating units or modules in a device in which embodiments of the present disclosure may occur.

FIG. 5 is a trellis graph illustrating an example of a polar code with N=8, K=4 that may be used in some embodiments of the present disclosure.

FIG. 6 is a block diagram illustrating procedures to determine uplink control information (UCI) formats and configurations in an existing wireless communication network.

FIG. 7 is a block diagram illustrating an example of contention-based retransmission resource sharing for UCI retransmissions, in accordance with implementations of the present disclosure.

FIG. 8 is a signal flow diagram illustrating an example method for facilitating communications between an apparatus and a device in a wireless network, in accordance with implementations of the present disclosure.

DETAILED DESCRIPTION

In the following specific example embodiments of this disclosure will now be explained.

Aspects of the present disclosure provide methods, apparatuses, devices and systems to overcome the shortcomings of the existing design of uplink control information (UCI) payloads, as well as specific methods, apparatuses, devices, and systems for facilitating communications between an apparatus and a device in a wireless network. The methods, apparatuses, devices, and systems proposed in the present disclosure may provide a single, unified, and/or configurable transmission scheme for (control) information that may be used for managing (network) communications (e.g., UCI, extended UCI, or some other information that controls/manages communications between an apparatus and a device in the network). The proposed scheme may reduce processing overhead, enhance resource utilization, and align with overall objectives of future networks (e.g., 6G), such as ultra-high reliability, low latency, and support for a multitude of diverse applications. According to some implementations of the present disclosure, an apparatus (e.g., user equipment (UE)) may transmit, to a device (e.g., base station), first information used for managing communication involving at least one of the apparatus or the device. The first information may include a content and a header associated with the content. The header may be indicative of at least one of a characteristic of the content, or a manner in which the content is transmitted. The first information may be generated according to configuration information indicating the manner in which the content is to be concatenated in the first information. In other words, the content may be concatenated in the first information in accordance with the configuration information. In some implementations, the content may be concatenated in the first information based on at least one of content type, or priority level. In some implementations, a payload subblock to which the content belongs may be concatenated in the first information in accordance with the configuration information (e.g., concatenated based on content type and/or priority level). The payload subblock may refer to a group of contents that are related in a certain manner, such as a group of contents having the same content type and/or a group of contents having the same priority level.

FIG. 1 illustrates an example communication system in which embodiments of the present disclosure may occur.

Referring to FIG. 1, as an illustrative example without limitation, a simplified schematic illustration of a communication system is provided. The communication system 100 (which may be a wireless system) comprises a radio access network 120. The radio access network (RAN) 120 may be a next generation (e.g. sixth generation (6G) or later) radio access network, or a legacy (e.g. 5Gor 4G) radio access network. One or more communication electronic device (ED) 110a, 110b, 110c, 110d, 110e, 110f, 110g, 110h, 110i, 110j (generically referred to as 110) may be interconnected to one another or connected to one or more network nodes (170a, 170b, generically referred to as 170) in the radio access network 120. A core network 130 may be a part of the communication system and may be dependent or independent of the radio access technology used in the communication system 100. The communication system 100 may also comprise a public switched telephone network (PSTN) 140, the internet 150, and other networks 160.

In general, the communication system 100 enables multiple wireless or wired elements to communicate data and other content. The communication system 100 may provide content, such as voice, data, video, and/or text, via broadcast, multicast, groupcast, unicast, etc. And the communication system 100 may provide a wide range of communication services and applications (such as earth monitoring, remote sensing, passive sensing and positioning, navigation and tracking, autonomous delivery and mobility, etc.) The services and/or applications may be mobile broadband (MBB) services, ultra-reliable low-latency communication (URLLC) services, or machine type communication (MTC) services.

The communication system 100 may operate by sharing resources, such as carrier spectrum bandwidth, between its constituent elements.

FIG. 2 illustrates more detailed example for communication system 100.

The communication system 100 may include a terrestrial communication system and/or a non-terrestrial communication system. The communication system 100 may provide a high degree of availability and robustness through a joint operation of a terrestrial communication system and a non-terrestrial communication system. For example, integrating a non-terrestrial communication system (or components thereof) into a terrestrial communication system can result in what may be considered a heterogeneous network comprising multiple layers. The heterogeneous network may achieve better overall performance through efficient multi-link joint operation, more flexible functionality sharing, and faster physical layer link switching between terrestrial networks and non- terrestrial networks.

The terrestrial communication system and the non-terrestrial communication system could be considered sub-systems of the communication system.

Same as in the example shown in FIG. 1, in the example shown in FIG. 2, the communication system 100 may include ED 110a, 110b, 110c, 110d (generically referred to as ED 110), and RAN 120a, 120b. In addition, the communication system 100 may also include a non-terrestrial communication network 120c. The communication system 100 may also include one or more of a core network 130, a public switched telephone network (PSTN) 140, the Internet 150, and other networks 160. The RANs 120a, 120b include respective RAN nodes such as base stations (BSs) 170a, 170b, which may be generically referred to as terrestrial transmit and receive points (T-TRPs) 170a, 170b. In one implementation, the non-terrestrial communication network 120c includes a RAN node such as an access node (or base station) 172, which may be generically referred to as a non-terrestrial transmit and receive point (NT-TRP) 172. As may be surmised on the basis of similarity in reference numerals, the non-terrestrial communication network 120c may be considered to be a radio access network, with operational aspects in common with the RANs 120a, 120b. In another implementations, the non-terrestrial communication network 120c may include at

least one non-terrestrial network (NTN) device and at least one corresponding terrestrial network device, wherein the at least one non-terrestrial network device works as a transport layer device and the at least one corresponding terrestrial network device works as a RAN node, which communicates with the ED via the non-terrestrial network device. In addition, there may be a NTN gateway in the ground (i.e., referred as a terrestrial network device) also as a transport layer device to communication with both the NTN device, and the RAN node communicates with the ED via the NTN device and the NTN gateway. In some implementations, the NTN gateway and the RAN node may be located in the same device.

Any ED 110 may be alternatively or additionally configured to interface, access, or communicate with any T-TRP 170a,170b and NT-TRP 172, the Internet 150, the core network 130, the PSTN 140, the other networks 160, or any combination of the preceding. In some examples, ED 110a may communicate an uplink (UL) and/or downlink (DL) transmission over a terrestrial air interface 190a with T-TRP 170a. In some examples, the EDs 110a, 110b, 110c, and 110d may also communicate directly with one another via one or more sidelink (SL) air interfaces 190b. In some examples, ED 110d may communicate an uplink and/or downlink transmission over a non-terrestrial air interface 190c with NT-TRP 172.

The air interfaces 190a and 190b may use similar communication technology, such as any suitable radio access technology. For example, the communication system 100 may implement one or more channel access methods, such as code division multiple access (CDMA), space division multiple access (SDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), or single-carrier FDMA (SC-FDMA, also known as discrete Fourier transform spread OFDMA, DFT-s-OFDMA) in the air interfaces 190a and 190b. The air interfaces 190a and 190b may utilize other higher dimension signal spaces, which may involve a combination of orthogonal and/or non-orthogonal dimensions.

The non-terrestrial air interface 190c can enable communication between the ED 110d and one or multiple NT-TRPs 172 via a wireless link or simply a link. For some examples, the link is a dedicated connection for unicast transmission, a connection for broadcast transmission, or a connection between a group of EDs 110 and one or multiple NT-TRPs 172 for multicast transmission.

The RANs 120a and 120b are in communication with the core network 130 to provide the EDs 110a 110b, and 110c with various services such as voice, data, and other services. The RANs 120a and 120b and/or the core network 130 may be in direct or indirect communication with one or more other RANs (not shown), which may or may not be directly served by core network 130, and may or may not employ the same radio access technology as RAN 120a, RAN 120b or both. The core network 130 may also serve as a gateway access between (i) the RANs 120a and 120b or EDs 110a 110b, and 110c or both, and (ii) other networks (such as the PSTN 140, the Internet 150, and the other networks 160). In addition, some or all of the EDs 110a 110b, and 110c may include functionality for communicating with different wireless networks over different wireless links using different wireless technologies and/or protocols. Instead of wireless communication (or in addition thereto), the EDs 110a 110b, and 110c may communicate via wired communication channels to a service provider or switch (not shown), and to the Internet 150. PSTN 140 may include circuit switched telephone networks for providing plain old telephone service (POTS). Internet 150 may include a network of computers and subnets (intranets) or both, and incorporate protocols, such as Internet Protocol (IP), Transmission Control Protocol (TCP), User Datagram Protocol (UDP). EDs 110a 110b, and 110c may be multimode devices capable of operation according to multiple radio access technologies, and incorporate multiple transceivers necessary to support such.

In addition, the communication system 100 may comprise a sensing agent (not shown in the figure) to manage the sensed data from ED110 and or the T-TRP 170 and/or NT-TRP 172. In one implementation, the sensing agent is located in the T-

TRP 170 and/or NT-TRP 172. In another implementation, the sensing agent is a separate node which has interface to communicate with the core network 130 and/or the RAN 120 (e.g., the T-TRP 170 and/or NT-TRP 172).

FIG. 3 illustrates example of an Apparatus 310 wirelessly communicating with at least one of two apparatuses (e.g., Apparatus 320a and Apparatus 320b, referred as Apparatus 320) in a communication system, e.g., the communication system 100, according to one embodiment. The Apparatus 310 may be a UE (e.g., ED 110 in FIG. 3). The Apparatus 320a may be a terrestrial network device (e.g., T-TRP 170 as shown in FIG. 3), and Apparatus 320b may be a non-terrestrial network device (e.g., NT-TRP 172 as shown in FIG. 3). However, this is not necessary. For example, Apparatus 320a may be a NT-TRP, and 320b may be a T-TRP, both Apparatus 320a and 320b may be T-TRPs or NT-TRPs, according to present disclosure. In the following, the ED 110 as an example of the Apparatus 310 is described, and T-TRP 170 as an example of Apparatus 320a is described, and NT-TRP 172 as an example of Apparatus 320a is described. Although only one Apparatus 310, one Apparatus 320a and one Apparatus 320b Please note that the number of Apparatus 310 (e.g. ED 110) could be one or more, and the number of Apparatus 320a and/or 320b could be one or more. For example, one ED110 may be served by only one T-TRP 170 (or one NT-TRP172), by more than one T-TRP 170, by more than one NT-TRP 172, or by one or more T-TRP 170 and one or more NT-TRP172.

The ED 110 is used to connect persons, objects, machines, etc. The ED 110 may be widely used in various scenarios including, for example, cellular communications, device-to-device (D2D), vehicle to everything (V2X), peer-to-peer (P2P), machine-to-machine (M2M), MTC, internet of things (IoT), virtual reality (VR), augmented reality (AR), mixed reality (MR), metaverse, digital twin, industrial control, self-driving, remote medical, smart grid, smart furniture, smart office, smart wearable, smart transportation, smart city, drones, robots, remote sensing, passive sensing, positioning, navigation and tracking, autonomous delivery and mobility, etc.

Each ED 110 represents any suitable end user device for wireless operation and may include such devices (or may be referred to but not limited to) as a user equipment/ terminal device (UE), a wireless transmit/receive unit (WTRU), a mobile station, a fixed or mobile subscriber unit, a cellular telephone, a station (STA), a MTC device, a personal digital assistant (PDA), a smartphone, a laptop, a computer, a tablet, a wireless sensor, a consumer electronics device, a smart book, a vehicle, a car, a truck, a bus, a train, or an IoT device, wearable devices (such as a watch, a pair of glasses, head mounted equipment, etc.), an industrial device, or an apparatus in (e.g. communication module, modem, or chip) or comprising the forgoing devices, among other possibilities. Future generation EDs 110 may be referred to using other terms. The base station 170a and 170b is a T-TRP and will hereafter be referred to as T-TRP 170. Also shown in FIG. 3, a non-terrestrial (NT) device will hereafter be referred to as NT-TRP 172. Each ED 110 connected to T-TRP 170 and/or NT-TRP 172 can be dynamically or semi-statically turned-on (i.e., established, activated, or enabled), turned-off (i.e., released, deactivated, or disabled) and/or configured in response to one of more of: connection availability and connection necessity.

As shown in FIG. 3, the ED 110 include at least one processor 210. Only one processor 210 is illustrated to avoid congestion in the drawing. The ED 110 may further include a transmitter 201 and a receiver 203 coupled to one or more antennas 204. Only one antenna 204 is illustrated to avoid congestion in the drawing. One, some, or all of the antennas 204 may alternatively be panels. The transmitter 201 and the receiver 203 may be integrated, e.g. as a transceiver. The transceiver is configured to modulate data or other content for transmission by at least one antenna 204 or network interface controller (NIC). The transceiver is also configured to demodulate data or other content received by the at least one antenna 204. Each transceiver includes any suitable structure for generating signals for wireless or wired transmission and/or processing signals received

wirelessly or by wire. Each antenna 204 includes any suitable structure for transmitting and/or receiving wireless or wired signals. The ED 110 may include at least one memory 208. Only the transmitter 201, receiver 203, processor 210, memory 208, and antenna 204 is illustrated for simplicity, but the ED 110 may include one or more other components.

The memory 208 stores instructions. The memory 208 may also stores data used, generated, or collected by the ED 110. For example, the memory 208 could store software instructions or modules configured to implement some or all of the functionality and/or embodiments described herein and that are executed by one or more processing unit(s) (e.g., a processor 210). Each memory 208 includes any suitable volatile and/or non-volatile storage and retrieval device(s). Any suitable type of memory may be used, such as random access memory (RAM), read only memory (ROM), hard disk, optical disc, subscriber identity module (SIM) card, memory stick, secure digital (SD) memory card, on-processor cache, and the like.

The ED 110 may further include one or more input/output devices (not shown) or interfaces (such as a wired interface to the Internet 150 in FIG. 1). The input/output devices or interfaces permit interaction with a user or other devices in the network. Each input/output device or interface includes any suitable structure for providing information to or receiving information from a user, and/or for network interface communications. Suitable structures include, for example, a speaker, microphone, keypad, keyboard, display, touch screen, etc.

The processor 210 performs (or controlling the ED110 to perform) operations described herein as being performed by the ED110. As illustrated below and elsewhere in the present disclosure. For example, the processor 210 performs or controls the ED110 to perform receiving transport blocks (TBs), using a resource for decoding of one of the received TBs, releasing the resource for decoding of another of the received TBs, and/or receiving configuration information configuring a resource. In details, the operation may include those operations related to preparing a transmission for uplink transmission to the NT-TRP 172 and/or the T-TRP 170; those operations related to processing downlink transmissions received from the NT-TRP 172 and/or the T-TRP 170; and those operations related to processing sidelink transmission to and from another ED 110. Processing operations related to preparing a transmission for uplink transmission may include operations such as encoding, modulating, transmit beamforming, and generating symbols for transmission. Processing operations related to processing downlink transmissions may include operations such as receive beamforming, demodulating and decoding received symbols. Processing operations related to processing sidelink transmissions may include operations such as transmit/receive beamforming, modulating/demodulating and encoding/decoding symbols. Depending upon the embodiment, a downlink transmission may be received by the receiver 203, possibly using receive beamforming, and the processor 210 may extract signaling from the downlink transmission (e.g. by detecting and/or decoding the signaling). An example of signaling may be a reference signal transmitted by the NT-TRP 172 and/or by the T-TRP 170. In some embodiments, the processor 210 implements the transmit beamforming and/or the receive beamforming based on the indication of beam direction, e.g. beam angle information (BAI), received from the T-TRP 170. In some embodiments, the processor 210 may perform operations relating to network access (e.g. initial access) and/or downlink synchronization, such as operations relating to detecting a synchronization sequence, decoding and obtaining the system information, etc. In some embodiments, the processor 210 may perform channel estimation, e.g. using a reference signal received from the NT-TRP 172 and/or from the T-TRP 170.

Although not illustrated, the processor 210 may form part of the transmitter 201 and/or part of the receiver 203. Although not illustrated, the memory 208 may form part of the processor 210.

The processor 210, the processing components of the transmitter 201, and the processing components of the receiver 203 may each be implemented by the same or different one or more processors that are configured to execute

instructions stored in a memory (e.g. in the memory 208). Alternatively, some or all of the processor 210, the processing components of the transmitter 201, and the processing components of the receiver 203 may each be implemented using dedicated circuitry, such as a programmed field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), or a hardware accelerator such as a graphics processing unit (GPU) or an artificial intelligence (AI) accelerator.

In some implementations, the ED 110 may an apparatus (also called component) for example, communication module, modem, chip, or chipset, it includes at least one processor 210, and an interface or at least one pin. In this scenario, the transmitter 201 and receiver 203 may be replaced by the interface or at least one pin, wherein the interface or at least one pin is to connect the apparatus (e.g., chip) and other apparatus (e.g., chip, memory, or bus). Accordingly, the transmitting information to the NT-TRP 172 and/or the T-TRP 170 and/or another ED 110 may be referred as transmitting information to the interface or at least one pin, or as transmitting information to the NT-TRP 172 and/or the T-TRP 170 and/or another ED 110 via the interface or at least one pin, and receiving information from the NT-TRP 172 and/or the T-TRP 170 and/or another ED 110 may be referred as receiving information from the interface or at least one pin, or as receiving information from the NT-TRP 172 and/or the T-TRP 170 and/or another ED 110 via the interface or at least one pin. The information may include control signaling and/or data.

As shown in FIG. 3, the T-TRP 170 include at least one processor 260. Only one processor 260 is illustrated to avoid congestion in the drawing. The T-TRP 170 may further include at least one transmitter 252 and at least one receiver 254 coupled to one or more antennas 256. Only one antenna 256 is illustrated to avoid congestion in the drawing. One, some, or all of the antennas 256 may alternatively be panels. The transmitter 252 and the receiver 254 may be integrated as a transceiver. The T-TRP 170 may further include at least one memory 258. The T-TRP 170 may further include scheduler 253. Only the transmitter 252, receiver 254, processor 260, memory 258, antenna 256 and scheduler 253 are illustrated for simplicity, but the T-TRP may include one or more other components.

The T-TRP 170 may be known by other names in some implementations, such as a base station, a base transceiver station (BTS), a radio base station, a network node, a network device, a device on the network side, a transmit/receive node, a Node B, an evolved NodeB (eNodeB or eNB), a Home eNodeB, a next Generation NodeB (gNB), a transmission point (TP), a site controller, an access point (AP), a wireless router, a relay station, a terrestrial node, a terrestrial network device, a terrestrial base station, a base band unit (BBU), a remote radio unit (RRU), an active antenna unit (AAU), a remote radio head (RRH), a central unit (CU), a distributed unit (DU), a positioning node, among other possibilities. The T-TRP 170 may be a macro base station (BS), a pico BS, a relay node, a donor node, or the like, or combinations thereof. The T-TRP 170 may refer to the forgoing devices or refer to apparatus (e.g. a communication module, a modem, or a chip) in the forgoing devices.

In some embodiments, the parts of the T-TRP 170 may be distributed. For example, some of the modules of the T-TRP 170 may be located remote from the equipment that houses the antennas 256 for the T-TRP 170, and may be coupled to the equipment that houses the antennas 256 over a communication link (not shown) sometimes known as front haul, such as common public radio interface (CPRI). Therefore, in some embodiments, the term T-TRP 170 may also refer to modules on the network side that perform processing operations, such as determining the location of the ED 110, resource allocation (scheduling), message generation, and encoding/decoding, and that are not necessarily part of the equipment that houses the antennas 256 of the T-TRP 170. The modules may also be coupled to other T-TRPs. In some embodiments, the T-TRP 170 may actually be a plurality of T-TRPs that are operating together to serve the ED 110, e.g. through the use of coordinated multipoint transmissions.

The processor 260 performs operations including those related to: preparing a transmission for downlink transmission to the ED 110, processing an uplink transmission received from the ED 110, preparing a transmission for backhaul transmission to the T-TRP 170 and/or NT-TRP 172, and processing a transmission received over backhaul from the T-TRP 170 and/or NT-TRP 172. Processing operations related to preparing a transmission for downlink or backhaul transmission may include operations such as encoding, modulating, precoding (e.g. multiple input multiple output (MIMO) precoding), transmit beamforming, and generating symbols for transmission. Processing operations related to processing received transmissions in the uplink or over backhaul may include operations such as receive beamforming, demodulating received symbols, and decoding received symbols. The processor 260 may also perform operations relating to network access (e.g. initial access) and/or downlink synchronization, such as generating the content of synchronization signal blocks (SSBs), generating the system information, etc. In some embodiments, the processor 260 also generates an indication of beam direction, e.g. BAI, which may be scheduled for transmission by a scheduler 253. The processor 260 performs other network-side processing operations described herein, such as determining the location of the ED 110, determining where to deploy the NT-TRP 172, etc. In some embodiments, the processor 260 may generate signaling, e.g. to configure one or more parameters of the ED 110 and/or one or more parameters of the NT-TRP 172. Any signaling generated by the processor 260 is sent by the transmitter 252.

The scheduler 253 may be coupled to the processor 260 or integrated in the processor 260. The scheduler 253 may be included within or operated separately from the T-TRP 170. The scheduler 253 may schedule uplink, downlink, sidelink, and/or backhaul transmissions, including issuing scheduling grants and/or configuring scheduling-free (e.g., "configured grant") resources.

The memory 258 is configured to store information, and optionally data. The memory 258 stores instructions and data used, generated, or collected by the T-TRP 170. For example, the memory 258 could store software instructions or modules configured to implement some or all of the functionality and/or embodiments described herein and that are executed by the processor 260.

Although not illustrated, the processor 260 may form part of the transmitter 252 and/or part of the receiver 254. Also, although not illustrated, the processor 260 may implement the scheduler 253. Although not illustrated, the memory 258 may form part of the processor 260.

The processor 260, the scheduler 253, the processing components of the transmitter 252, and the processing components of the receiver 254 may each be implemented by the same or different one or more processors that are configured to execute instructions stored in a memory, e.g. in the memory 258. Alternatively, some or all of the processor 260, the scheduler 253, the processing components of the transmitter 252, and the processing components of the receiver 254 may be implemented using dedicated circuitry, such as a programmed FPGA, a hardware accelerator (e.g., a GPU or AI accelerator), or an ASIC.

When the T-TRP 170 is an apparatus (also called as component, for example, communication module, modem, chip, or chipset in a device, it includes at least one processor, and an interface or at least one pin. In this scenario, the transmitter 252 and receiver 254 may be replaced by the interface or at least one pin, wherein the interface or at least one pin is to connect the apparatus (e.g., chip) and other apparatus (e.g., chip, memory, or bus). Accordingly, the transmitting information to the NT-TRP 172 and/or the T-TRP 170 and/or ED 110 may be referred as transmitting information to the interface or at least one pin, and receiving information from the NT-TRP 172 and/or the T-TRP 170 and/or ED 110 may be referred as receiving information from the interface or at least one pin. The information may include control signaling and/or data.

Although the NT-TRP 172 is illustrated as a drone only as an example, the NT-TRP 172 may be implemented in any suitable non-terrestrial form, such as satellites and high altitude platforms, including international mobile telecommunication base stations and unmanned aerial vehicles, for example. Also, the NT-TRP 172 may be known by other names in some implementations, such as a non-terrestrial node, a non-terrestrial network device, or a non-terrestrial base station.

As shown in FIG. 3, The T-TRP 170 may further include at least one transmitter 252 and at least one receiver 254 coupled to one or more antennas 256. Only one antenna 256 is illustrated to avoid congestion in the drawing. One, some, or all of the antennas 256 may alternatively be panels. The transmitter 252 and the receiver 254 may be integrated as a transceiver. The T-TRP 170 may further include at least one memory 258. The T-TRP 170 may further include scheduler 253. Only the transmitter 252, receiver 254, processor 260, memory 258, antenna 256 and scheduler 253 are illustrated for simplicity, but the T-TRP may include one or more other components.

As shown in FIG. 3, the NT-TRP 172 include at least one processor 276. Only one processor 276 is illustrated to avoid congestion in the drawing. The NT-TRP 172 may include a transmitter 272 and a receiver 274 coupled to one or more antennas 280. Only one antenna 280 is illustrated to avoid congestion in the drawing. One, some, or all of the antennas may alternatively be panels. The transmitter 272 and the receiver 274 may be integrated as a transceiver. The NT-TRP 172 may further include at least one memory 278. The NT-TRP 172 may further include scheduler. Only the transmitter 272, receiver 274, processor 276, memory 278, antenna 280 are illustrated for simplicity, but the NT-TRP may include one or more other components.

The NT-TRP 172 include a processor 276 for performing operations including those related to: preparing a transmission for downlink transmission to the ED 110, processing an uplink transmission received from the ED 110, preparing a transmission for backhaul transmission to T-TRP 170 and/or another NT-TRP 172, and processing a transmission received over backhaul from the T-TRP 170 and/or another NT-TRP 172. Processing operations related to preparing a transmission for downlink or backhaul transmission may include operations such as encoding, modulating, precoding (e.g. MIMO precoding), transmit beamforming, and generating symbols for transmission. Processing operations related to processing received transmissions in the uplink or over backhaul may include operations such as receive beamforming, demodulating received symbols, and decoding received symbols. In some embodiments, the processor 276 implements the transmit beamforming and/or receive beamforming based on beam direction information (e.g. BAI) received from the T-TRP 170. In some embodiments, the processor 276 may generate signaling, e.g. to configure one or more parameters of the ED 110. In some embodiments, the NT-TRP 172 implements physical layer processing, but does not implement higher layer functions such as functions at the medium access control (MAC) or radio link control (RLC) layer. As this is only an example, more generally, the NT-TRP 172 may implement higher layer functions in addition to physical layer processing.

The memory 278 is configured to store information and optionally data. The memory 258 stores instructions and data used, generated, or collected by the NT-TRP 172. For example, the memory 278 could store software instructions or modules configured to implement some or all of the functionality and/or embodiments described herein and that are executed by the processor 276.

Although not illustrated, the processor 276 may form part of the transmitter 272 and/or part of the receiver 274. Although not illustrated, the memory 278 may form part of the processor 276.

The processor 276, the processing components of the transmitter 272, and the processing components of the receiver 274 may each be implemented by the same or different one or more processors that are configured to execute instructions stored in a memory, e.g. in the memory 278. Alternatively, some or all of the processor 276, the processing components of the transmitter 272, and the processing components of the receiver 274 may be implemented using dedicated circuitry, such as a programmed FPGA, a hardware accelerator (e.g., a GPU or AI accelerator), or an ASIC. In some embodiments, the NT-TRP 172 may actually be a plurality of NT-TRPs that are operating together to serve the ED 110, e.g. through coordinated multipoint transmissions.

When the NT-TRP 172 is an apparatus (e.g. communication module, modem, chip, or chipset) in a device, it includes at least one processor, and an interface or at least one pin. In this scenario, the transmitter 272 and receiver 257 may be replaced by the interface or at least one pin, wherein the interface or at least one pin is to connect the apparatus (e.g., chip) and other apparatus (e.g., chip, memory, or bus). Accordingly, the transmitting information to the T-TRP 170 and/or another NT-TRP 172 and/or ED 110 may be referred as transmitting information to the interface or at least one pin, and receiving information from the T-TRP 170 and/or another NT-TRP 172 and/or ED 110 may be referred as receiving information from the interface or at least one pin. The information may include control signaling and/or data.

Note that "transmit/receive point (TRP)", as used herein, may refer to a T-TRP or a NT-TRP. A T-TRP may alternatively be called a terrestrial network TRP ("TN TRP") and a NT-TRP may alternatively be called a non-terrestrial network TRP ("NTN TRP"). The T-TRP 170, the NT-TRP 172, and/or the ED 110 may include other components, but these have been omitted for the sake of clarity.

Note that "signaling", as used herein, may alternatively be called control signaling, control message, control information, or message for simplicity. Signaling between a BS (e.g., the network node 170) and a terminal or sensing device (e.g., ED 110), or signaling between different terminal or sensing device (e.g., between ED 110i and ED110j) may be carried in physical layer signaling (also called as dynamic signaling), which is transmitted in a physical layer control channel. For downlink the physical layer signaling may be known as downlink control information (DCI) which is transmitted in a physical downlink control channel (PDCCH). For uplink, the physical layer signaling may be known as uplink control information (UCI) which is transmitted in a physical uplink control channel (PUCCH). For sidelink, signaling between different terminal or sensing device (e.g., between ED 110i and ED110j) may be known as sidelink control information (SCI) which is transmitted in a physical sidelink control channel (PSCCH). Signaling may be carried in a higher-layer (e.g., higher than physical layer) signaling, which is transmitted in a physical layer data channel, e.g. in a physical downlink shared channel (PDSCH) for downlink signaling, in a physical uplink shared channel (PUSCH) for uplink signaling, and in a physical sidelink shared channel (PSSCH) for sidelink signaling. Higher-layer signaling may also called static signaling, or semi-static signaling. Higher-layer signaling may be radio resource control (RRC) protocol signaling or media access control – control element (MAC-CE) signaling. Signaling may be included in a combination of physical layer signaling and higher layer signaling.

It should be noted that in present disclosure, "information", when different from "message", may be carried in one single message, or be carried in more than one separate message.

Channel coding is an indispensable module in communications systems that encode K source bits into N code bits to provide error correction capability against adversary channel condition such as noise and interference. The code rate is $R=K/N$. In practice, the code rate R is selected according to channel quality.

Polar codes are capacity-achieving codes and thus a great breakthrough in coding theory. As code length approaches infinity, the synthesized channels (or subchannels) become either noiseless or pure noise. The noiseless subchannels are utilized to transport information, and their proportion is proven to achieve the channel capacity defined by Shannon. The above-mentioned channel polarization phenomenon occurs under successive cancellation (SC) or SC-based decoding, which has a relatively low complexity.

Low-density parity-check (LDPC) codes are capacity-approaching codes. LDPC codes are usually defined by a parity-check matrix, which has far more zeros than ones, thus having low density. By properly designing the positions of ones in the matrix, the decoding performance can be improved. Although LDPC codes can be viewed as a type of random codes, introducing structures can facilitate its hardware implementations of both encoder and decoder. Quasi-cyclic is such a structure that first defines a smaller base matrix or base graph (BG), and then perform "lifting" by replacing its ones with a cyclic shifted version of identity matrix.

Rate matching is performed after channel encoding, by either puncturing/shortening or repeating some code bits. The purpose is to obtain a code bit sequence of desired length for transmission over limited channel resources.

Channel interleaver is applied after channel encoding and rate matching by permuting the code bits. The purpose is to provide stable or superior performance under high-order modulation or in fading channel.

Hybrid automatic repeat request (HARQ) is a mechanism to provide reliable wireless transmission. It combines forward error correction (FEC) and automatic repeat request (ARQ). In HARQ, the initial transmission is a FEC code word with CRC bits to support error detection at the receiver. If a decoding error is detected, the receiver will send back a NACK signaling to inform the transmitter of the error, and request for a retransmission. The retransmitted bits can be directly selected from the initially transmitted bits, or incrementally generated code bits which form a longer code word with the initially transmitted bits. The former is called chase-combining HARQ (CC-HARQ) and the latter is called incremental-redundancy HARQ (IR-HARQ). Typically, IR-HARQ outperforms CC-HARQ with the additional coding gain from incremental redundancy.

Requirements for channel coding in wireless communications

In wireless communications, channel quality is constantly changing due to the fading effects at both fast and slow scale. Accordingly, channel coding has always been designed to adapt to the channel states. Modulation coding scheme (MCS) adaptation is a powerful method to combat varying channel states, in which the modulation order and code length and coding rate can be changed in real time. Therefore, it requires that a channel coding scheme can flexibly change the code length and code rate in a fine-grained way, and at the same time achieve good error correction performance in all possible configurations. This fine-grained flexibility of channel codes is one of the most challenging problem for engineers in this domain.

At the same time, the complexity of both encoding and decoding algorithms need to be sufficiently low. In hardware, complexity can be evaluated through measuring chip area and energy efficiency. They are related to algorithmic complexity, but are more closely related to cell phone's cost and battery life. Therefore, we need to reduce implementation complexity when we design coding schemes.

In future network, there are several scenarios to be supported, such as immersive communication, massive communication and hyper reliable and low-latency communication. The KPIs that are related to channel coding include coding gain, reliability, throughput, latency and their tradeoffs. For example, the throughput requirement of future network may reach

above 1Tbps, and the energy efficiency should decrease to 1pJ/bit. Meanwhile, the coding scheme needs to support flexible rate matching and IR-HARQ schemes. It is required, but a very challenging task, to design a code ensemble to fulfill all these KPIs and capabilities.

Preliminaries of polar coding

Polar codes are linear block codes. For a polar code of length N, its generator matrix is G_N, and its encoding process is $x_1^N = u_1^N G_N$, where $u_1^N = [u_1, u_2, \ldots, u_N]$ is the binary information vector, $x_1^N = [x_1, x_2, \ldots, x_N]$ is the binary code vector. The $N \times N$ binary matrix $G_N = F_2^{\otimes n}$, where $F_2 = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$ is the polarization kernel matrix, $n = \log_2 N$, and $\otimes$ is Kronecker product.

Typically, there are K information bits to be encoded into N code bits. Obviously, we have $K<N$ to obtain a code rate $R=K/N<1$. That implies only part of u_1^N is used to carry information bits, and the rest are called frozen bits. Denote by I the information bit set (or information set), and F the frozen bit set (or frozen set), respectively. Sometimes, there is an additional PC bit set, denoted by P. The frozen bits are known (usually all zeros) before decoding, so they do not carry any information. The PC bits are parity-check bits of a subset of information bits, therefore are known once the associated information bits are decoded. The decoding of polar codes is actually trying to recover all information bits.

The code length M may not always be the power of 2, i.e., $M<N$. In practice, puncturing and shortening are used to reduce transmitted code bits from N to M. For convenience, we call N the mother code length, and M the code length from now on. In particular, punctured bits are untransmitted bits unknown to the decoder, but shortened bits are untransmitted bits known to the decoder (usually all zeros).

An example of a polar code with $N=8$, $K=4$ is shown in the trellis graph 400 depicted in FIG. 4. Each "butterfly" in the graph is a polarization, i.e., $x_1^2 = u_1^2 \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$. In this example, the information set is $I = \{u_4, u_6, u_7, u_8\}$, and the frozen set is $F = \{u_1, u_2, u_3, u_5\}$.

Successive cancellation (SC) is the basic decoding algorithm for polar codes, where all the frozen bits and information bits are decoded sequentially, i.e., bit by bit. The preceding bits are always decoded first.

Successive cancellation list (SCL) is an enhanced decoding algorithm for polar codes, where multiple (let's say L) SC decoding instances are executed. Each instance is called a "decoding path". When decoding each binary bit, both "0" and "1" branches are extended to each path, creating $2L$ paths. Then, all $2L$ paths are compared, where the most likely L paths are kept, and the least likely L paths are discarded (or pruned). This path extension and pruning operations are performed during decoding every information bit, until all information bits are decoded. At last, the most likely path is selected as the decoding output.

CRC-aided successive cancellation list (CA-SCL) works almost the same as SCL, except that in the last step, the most likely path that passes CRC check is selected as the decoding output.

Parity-check successive cancellation list (PC-SCL) works almost the same as SCL, except that when decoding parity-check (PC) bits, the parity check value of its associated preceding bits is used as the bit decision result. PC bits are a new type of bits in addition to frozen bits and information bits.

Preliminaries of LDPC codes

Low Density Parity Check (LDPC) code is a channel coding scheme very close to Shannon line, and features good performance and low complexity. Currently, LDPC has been adopted as data channel coding schemes by 3GPP 5G New Radio (NR) and IEEE 802.11 systems.

The LDPC code is encoded by through a parity-check matrix. A widely-adopted LDPC code has a QC structure, and a shifting value of each block is designed to avoid a bad structure such as a short circle, and improve a code distance. At present, the main decoding algorithms for LDPC codes are Min-Sum (MS) and Belief Propagation (BP). In terms of decoding performance, the BP decoding algorithm is better, but it has a large amount of information storage and a complex computation overhead, which is not convenient to hardware implementation. Therefore, Offset-MS and Normalized-MS decoding algorithms are used in realistic communication systems. The LDPC codes implemented in practice is to extend the "1" in the basic graph (BG) by a square matrix, which is a cyclic shifted version of an identity matrix. The BG of QC-LDPC code can be defined by BG=(X, Y, F), where X corresponds to a variable, Y corresponds to a check equation, and F is its edge connections. The Tanner graph is obtained after QC lifting with an expansion factor Z_c. That is, a bipartite graph G=(V, C, E), where V is a variable node, C is a check node, E is a connected edge, and a corresponding parity matrix column quantity $N=|V|=Z_c\,|X|$. The quantity of rows of the check matrix $M=|C|=Z_c\,|Y|$, and a quantity of non-zero elements of the check matrix is $|E|=Z|F|$.

5G data channels support information block length ranging from 1 to 8448. The standard describes two parity-check matrices: BG1 and BG2. The same base graph, lifted by different lifting sizes, can adapt to a wide set of different code rates and lengths. To achieve this, one only needs to store the Lifting Size and Shifting Value lists in the look-up tables, and rate matching and IR-HARQ based on the tables.

In NR LDPC codes, a codeword before rate matching (referred as a mother codeword) typically consists of three disjoint portions or parts, i.e., systematic bits, core parity check bits and extended parity check bits. In NR LDPC code, four different redundancy versions (RVs) including RV0, RV1, RV2 and RV3 are generated after rate matching. In initial transmission, RV0 is normally selected in which most of the systematic bits are included in the set of coded bits. Meanwhile, depending on the effective code rate, part of core parity bits or all core parity check bits and extended parity bits are included in RV0. As a result, RV0 has the highest self-decodable ability among all RVs (i.e., RV0 can be self-decodable at highest code rate). In retransmission, the transmitter may select RV1, RV2 or RV3. Nevertheless, only RV3 is self-decodable, while RV1 and RV2 are not self-decodable at high code rate. The main reason is that, at some code rates, RV1 and RV2 may only consist of parity check bits, resulting in unsuccessfully decoding at the receiver.

One or more steps of the methods provided in this disclosure herein may be performed by corresponding units or modules, according to FIG. 5. FIG. 5 illustrates units or modules in a device or apparatus, such as in the ED 110, in the T-TRP 170, or in the NT-TRP 172. For example, a signal may be transmitted by a transmitting unit or by a transmitting module. A signal may be received by a receiving unit or by a receiving module. A signal may be processed by a processing unit or a processing module. Other steps may be performed by an artificial intelligence (AI) or machine learning (ML) module. The respective units or modules may be implemented using hardware, one or more components or devices that execute software, or a combination thereof. For instance, one or more of the units or modules may be a circuit such as an integrated circuit. Examples of an integrated circuit includes a programmed FPGA, a GPU, or an ASIC. For instance, one or more of the units or modules may be logical such as a logical function performed by a circuit, by a portion of an integrated circuit, or by software instructions executed by a processor. It will be appreciated that where the modules are implemented using software for execution by a processor for

example, the modules may be retrieved by a processor, in whole or part as needed, individually or together for processing, in single or multiple instances, and that the modules themselves may include instructions for further deployment and instantiation.

Additional details regarding the EDs 110, the T-TRP 170, and the NT-TRP 172 are known to those of skill in the art. As such, these details are omitted here.

The present disclosure is aimed at devices such as UEs, IoT devices, cars, etc. The type of network scenarios envisioned may include terrestrial TRPs such as base-stations and/or non-terrestrial TRPs such as drones, balloons, high-altitude platform stations (HAPS), satellites, and any such devices that support radio access technologies such as 5G NR, future 6G or other technologies.

For illustrative purposes, specific example embodiments will now be explained in greater detail in conjunction with the figures and above mentioned system, ED and TRP.

It should be noted that, in the present disclosure, the terms "apparatus" and "device" may be simply used to more easily distinguish between the entities. "Apparatus" may include the ED 110 illustrated above, and may refer to any suitable end user device or UE for wireless operation and may include devices such as (but not limited to) a smartphone, a laptop, a computer, a tablet, a wireless sensor, a consumer electronics device, a smart book, a vehicle, a car, a truck, a bus, a train, an IoT device, an industrial device, a cellular telephone, a station (STA), a machine type communication (MTC) device, a personal digital assistant (PDA), a wireless transmit/receive unit (WTRU), a mobile station, a fixed or mobile subscriber unit, or an element (e.g. communication module, modem, chip, or chipset) in any of the forgoing devices. "Device" may refer to a base station or any similar type of network side device or apparatus therein, and may include the base station 170a and 170b, T-TRP 170, and/or NT-TRP 172 illustrated above, or an element (e.g. communication module, modem, chip, function, or chipset) in any of the forgoing devices.

The embodiments set forth herein represent information sufficient to practice the claimed subject matter and illustrate ways of practicing such subject matter. Upon reading the following description in light of the accompanying figures, those of skill in the art will understand the concepts of the claimed subject matter and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

In traditional cellular systems, the UE can receive, detect and measure reference signals such as SS/PBCH blocks and NZP-CSI-RS. Such reference signals are based on pseudo random noise (PRN) binary sequences such as Gold sequences and those sequences may be initialized using common or UE-specific scrambling identities. As an example, primary synchronisation signal (PSS) and secondary synchronisation signal (SSS) sequences are initialized using the physical cell identity (PCI) value, which is a common scrambling identity. NZP-CSI-RS sequences are initialized using UE-specific scrambling identities, which are configured by the network to the UE.

Non-terrestrial networks are introduced by introducing several enhancements on the timing relationships for the Timing Advance, the reference timing for channel state information (CSI) resources, the transmission timing of DCIs scheduling PUSCH, the transmission timing of Random Access response carried by a PUSCH, the transmission timing of HARQ-ACK on a PUCCH.

NTN support was introduced allowing UEs to support DL/UL communication with satellites using the so-called "bent-pipe" scenario, where a ground station transmits signals towards satellites in space, and satellites reflect signals back to UEs on the ground. Dedicating signaling related to NTN was introduced in order to assist UEs with NTN operation. Higher-layer signaling such as RRC introduces signaling satellite ephemeris, satellite position, satellite signal polarization, timing advance offsets, satellite System Information Block (SIB), satellite epochs in order to support NTN operation. Other features that were introduced were the extension of hybrid automatic repeat request (HARQ) processes to 32 in order to accommodate for large propagation delay scenarios and the disabling of HARQ-ACK feedback.

The current design of Physical Uplink Control Channel (PUCCH) utilizes format-specific rules for resource mapping. Format 1 dictates that UCI symbols occupy odd-numbered symbols within the PUCCH allocation. Formats 3 and 4 define the number of Demodulation Reference Signals (DMRS) based on PUCCH length and hopping behavior. While this approach offers a degree of simplicity, it lacks flexibility in adapting to diverse channel conditions.

The procedures to determine UCI formats and configurations in current cellular systems are summarized in FIG. 6.

FIG. 6 is a block diagram illustrating procedures 500 to determine unlink control information (UCI) formats and configurations in an wireless communication network. A UE (not explicitly illustrated in FIG. 6) may obtain resource indicator (e.g., physical uplink control channel (PUCCH) resource indicator) included in downlink control information (DCI) received from a base station (not explicitly illustrated in FIG. 6), the resource indicator indicates a PUCCH resource in a PUCCH resource set. Based on this resource indicator and the number of UCI payload bits (which may indicate the UCI size), the UE may determine one of PUCCH resource sets configured via RRC, and a resource in the determined PUCCH resource set that is to carry the UCI, for example using physical resource block (PRB) identifiers and/or symbol identifiers. For example, an index of starting PRB/PRB offset may be indicated using a PRB identifier. The resource in the PUCCH resource set may be "PUCCH resource" that may be defined based on one or more of various parameters illustrated in FIG. 6, such as parameters related to cyclic shift for sequence, time-domain OCC, frequency-domain OCC, C-RNTI scrambling, frequency hopping, additional DMRS, modulation BPSK or QPSK, maximum channel coding rate, the number of slots, etc.

One of the five distinct UCI formats (e.g., Format 0, Format 1, Format 2, Format 3, Format 4) may be selected based on how many bits of information would be carried and what parameters would be included in the UCI. In other words, different UCI format may use different parameters. For example, in the case of FIG. 6, PRB identifiers (e.g., startingPRB/PRB offset) that may indicate starting PRB/PRB offset and/or symbol identifiers (e.g., startingSymbolIndex) that may indicate starting symbol may be used for or associated with all of the five UCI formats. However, parameter related to cyclic shift for sequence (e.g., initialCyclicShift) may be used for or associated with Format 0 and Format 1 only; parameters related to time-domain OCC (e.g., timeDomainOCC) may be used for or associated with Format 1 only; parameters related to frequency-domain OCC, C-RNTI scrambling, frequency hopping, and maximum channel coding rate may be used for or associated with Format 2, Format 3, and Format 4 only; parameters related to additional DMRS may be used for or associated with Format 3 and Format 4 only; parameters related to modulation BPSK or QPSK and the number of slots may be used for or associated with Format 1, Format 2, Format 3, and Format 4 only.

The following paragraph illustrates limitations of the above UCI formats and designs, including limitations related to flexibility and efficiency.

The current design of Physical Uplink Control Channel (PUCCH) utilizes five distinct UCI formats for transmitting various control information elements. While this approach offers some level of functionality, it suffers from limitations that could hinder future flexibility and efficiency:

- The current design relies on a predefined set of nine combinations of UCI content. This approach becomes increasingly complex as new control information types emerge (e.g., sensing reports, AI-driven control signals, enhanced CSI). With the addition of just a few new content types, the number of combinations could potentially explode to around 40, significantly increasing the complexity of format selection and resource allocation.

- The distinction between some formats has diminished with evolving standards. For instance, Format 4 was initially distinguished from formats 2 and 3 by its specific multi-user multiplexing capability with a length-2,4 spreading factor. However, formats 2 and 3 now offer similar capabilities. This convergence suggests the potential for a more unified approach to format design.

- Several properties of the UCI transmission, such as payload size, symbol duration, bandwidth, modulation scheme, spreading sequence usage, and resource mapping, are currently tied to specific formats. While some of these properties offer flexibility within their respective formats, others lack the ability for dynamic configuration.

- The current approach utilizes distinct methods for code bit generation, signal formation, and resource mapping for PUCCH and PUSCH. This can be further simplified by exploring a unified design with flexible configuration capabilities for both channels.

The design of uplink control information (UCI) in current cellular systems incorporates a multifaceted approach. The Physical Uplink Control Channel (PUCCH) utilizes format-specific rules for multiplexing and resource mapping, offering flexibility to cater to diverse UCI requirements. These rules govern aspects such as frequency division multiplexing schemes and cyclic prefix allocation techniques within each format. Conversely, UCI transmitted on the Physical Uplink Shared Channel (PUSCH) adheres to a more unified approach, aligning with data traffic for streamlined implementation.

As the standard continues to evolve, a significant trend emerges. Previously format-specific features, such as multi-user multiplexing capability, are becoming increasingly prevalent across all PUCCH formats. This convergence signifies a move towards a more unified and versatile UCI transmission scheme, blurring the lines between formats. This trend suggests a potential future where a single, configurable PUCCH design might be sufficient.

The ongoing shift towards unification in UCI design is likely to extend into future network. By adopting a more unified approach, the future network can potentially achieve significant efficiency gains. A single, configurable UCI transmission scheme could simplify system design, reduce processing overhead, and enhance resource utilization. This evolution aligns with the broader goals of the future network, which include ultra-high reliability, low latency, and support for a multitude of diverse applications.

To address this challenge, this disclosure proposes a novel mechanism for flexible configuration of the order of UCI payload bits in future network. This approach leverages Downlink Control Information (DCI) to dynamically specify the order of bits within the UCI payload, akin to how data channels handle information. This shift towards flexible configuration aligns with the broader trend of unified and adaptable resource utilization in future network.

In the present disclosure, "order", such as order of content, UCI content or UCI payload, may be considered or understood as a location of content in the information used for managing communication involving at least one of the apparatus or the device (e.g., UCI, extended UCI, or any other suitable information that controls or manages communications in the network). The location of the content may be an absolute position or a relative position of the content within the information used for managing communication involving at least one of the apparatus or the device. The relative position of the content may be understood as the position of a particular content relative to the position of another content within the information. In some implementations, when the "order" is used for a plurality of contents in the information, it represents the relative location of each of the plurality of contents in the information.

In some implementations of the present disclosure, "managing communication" may be considered or understood as "controlling communication". For example, in some implementations, information used for managing communication may be considered or understood as information used for controlling communication between apparatus(es) and device(s) in the network, such as uplink control information (UCI).

By adopting a more flexible and configurable approach to UCI format design in future network, the system can achieve significant efficiency gains. Dynamic allocation of resources based on real-time requirements can optimize spectrum utilization and cater to diverse UCI demands.

In future network, the uplink control information (UCI) technology is expected to evolve from the current standard to provide greater flexibility and efficiency in transmitting various types of control information. While some aspects of the UCI payload content may remain unchanged, such as the inclusion of HARQ ACK/NACK, scheduling request (SR), and channel state information (CSI), new types of UCI payloads may be added to support emerging use cases and applications.

Put another way, according to some implementations of the present disclosure, content type of a content (to be) included in information used for managing communication involving at least one of the apparatus or the device may include HARQ ACK/NACK, a SR, CSI, and/or one or more new content types. In some implementations, the one or more new content types may include sensing information (SSI), artificial intelligence (AI)-related information (AII), transmission mode and phase information, quality of service indicator (QoSI), and/or positioning reference signal (PRS).

In future network, the CSI payload content may still consist of Channel Quality Indicator (CQI), Precoding Matrix Indicator (PMI), Rank Indicator (RI), Secondary Synchronization Signal Received Power Indicator (SSBRI), Layer Interference (LI), and Reference Signal Received Power (L1-RSRP). However, new CSI parameters may be introduced to provide more accurate and fine-grained channel information, such as the Channel Covariance Matrix (CCM), Precoding Type Indicator (PTI), or RI-based PMI.

The resource allocation scheme for uplink control information (UCI) in future network is expected to retain a similar structure as in current cellular systems. This approach leverages a combination of semi-static configuration through Radio Resource Control (RRC) signaling and dynamic allocation via Downlink Control Information (DCI).

- Semi-static Configuration for Periodic UCI: Similar to current cellular systems, certain periodic UCI content, particularly Scheduling Requests (SR) and Channel State Information (CSI) reports, will likely continue to be semi-statically configured in RRC. This configuration includes parameters such as periodicity, offset, and for

periodic CSI/SR reports, partial information derived from the specific CSI or SR configuration itself. This approach provides a foundation for predictable and efficient transmission of recurring control information.

- Dynamic Allocation for HARQ-ACK: Dynamic allocation using DCI remains crucial for Hybrid Automatic Repeat Request (HARQ) ACK/NACK signals. This ensures timely and accurate feedback on the success or failure of downlink data transmissions.
    - Common PUCCH Resource Allocation: In scenarios where an RRC connection is not yet established, a common PUCCH resource allocation for HARQ-ACKs might be pre-configured and signaled through System Information Block 1 (SIB1).
    - Dedicated PUCCH Resource Allocation: Once an RRC connection is established, dedicated PUCCH resources can be dynamically signaled by DCI. These resources are selected from a pool of pre-configured PUCCH resource sets defined by RRC. Each resource set may contain multiple (typically 8 or more) individual resource configurations. Finally, the specific UCI payload itself can further influence the selection of the appropriate PUCCH resource within the chosen set through DCI.

By maintaining a balance between semi-static configuration and dynamic allocation, our new solution can achieve efficient utilization of uplink control channels while ensuring timely transmission of critical control information like HARQ feedback and periodic reports.

In the new solution, PUCCH can benefit from a unified resource mapping scheme with dynamic pattern selection. This approach leverages Radio Resource Control (RRC) signaling to pre-define a set of DMRS resource patterns. These patterns can encompass various configurations, including:

- Number of DMRS Symbols: The pattern can specify the number of DMRS symbols for different PUCCH lengths. This aligns with the current behavior of formats 3 and 4 for lengths 10 to 14, allowing for adaptation based on channel estimation requirements.
- DMRS Symbol Placement: The pattern can define the specific locations of DMRS symbols within the PUCCH allocation. This could include options for placing them in specific slots or subcarriers, offering flexibility beyond the current format-specific rules in formats 1, 3, and 4.

Addressing these limitations in new UCI design can pave the way for a more scalable, adaptable, and efficient control channel architecture.

Accordingly, a method is provided in the disclosure. In the method, an uplink control information procedure, e.g., uplink control information signal generation and resource mapping, is provided.

Design Principles for Uplink Control Information (UCI) in our solutioninclude:

- UCI retransmission

This disclosure proposes techniques for reliable and efficient retransmission of UCI packets in future networks, considering the evolving 3GPP standards and new UCI types. The key aspects of the UCI retransmission are summarized below:

Selective Retransmission

- Retransmits only necessary packets based on payload type (e.g., critical sensing/AI information) or priority level.
- Time-sensitive data (e.g., ACK/NACK) is not retransmitted due to reduced effectiveness.

Resource Allocation and Scheduling

- Optimizes resource allocation for both initial transmission and potential retransmissions.
- Uses contention-based allocation for retransmissions and leverages TB/CB indices for scheduling.
- Offers options for fixed or limited payload sizes and blind detection for flexibility.

Blind Retransmission

- Enables faster delivery of time-critical data by transmitting redundant versions (RVs) with or following the initial transmission.
- Limits the total number of transmissions (initial + retransmissions) to avoid excessive overhead.
- Restricts the number of RVs used for channel coding to simplify design and reduce complexity.

Reliability Enhancement

- Defines a new, more conservative MCS table for novel UCI types with stricter reliability requirements.
- Implements different MCS selection strategies for initial transmissions (aggressive) and retransmissions (conservative).
- Suggests integration with higher-layer protocols (RLC/PDCP) for improved error control and retransmission tailored to specific payload types.

According to some implementations of the present disclosure, information used for managing communication involving at least one of the apparatus or the device (e.g., UCI designed discussed above or a new type of (control) information that may be used to manage network communications) may be transmitted in a channel configured to carry at least one of: control information, physical-layer data, sensing information (SSI), artificial intelligence (AI)-related information (AII), transmission mode and phase information, quality of service indicator (QoSI), or positioning reference signal (PRS).

In some implementations, the channel configured to carry control information may include existing control channels, for example but not limited to PUCCH, PDCCH, and/or PSCCH. In some implementations, the channel configured to carry control information may include a type of control channels that are different from existing control channels, e.g., a control channel that is configured to carry a particular type of control information, a control channel that is introduced in future networks (e.g., 6G network).

In some implementations, the channel configured to carry physical-layer data may include existing data channels, for example but not limited to PUSCH, PDSCH, and/or PSSCH. In some implementations, the channel configured to carry

physical-layer data may include a type of data channels that are different from existing data channels, e.g., a data channel that is configured to carry a particular type of physical-layer data, a data channel that is introduced in new networks.

In some implementations, the channel configured to carry sensing information (SSI) may be a channel that carries sensing data (e.g., angular, range, position data), such as the followings:

- multipath indication (e.g., the number of paths, path index, path direction, power value of each path, time delay of each path), and the indication can be relative to a reference value, or directly absolute value;
- angle indication;
- phase indication (e.g., per path, per path group);
- doppler indication;
- position indication;
- range indication;
- trajectory indication; and/or
- environment (e.g., ground truth, anchor point information, point cloud, clutter, norm direction, reflection direction, object shape/location/size).

In some implementations, the channel configured to carry artificial intelligence (AI)-related information (AII) may be a channel that carries AI data (dataset, model weights, gradients), such as the followings:

- dataset and related information (e.g., index, ID, group index, group ID, type index);
- (AI) model, weights, and related information (e.g., index, ID, group index, group ID, type index);
- gradients, and its information (e.g., index, ID, group index, group ID, type index);
- mapping relationship between any two of the dataset information, model/weights information and gradients information (in the form of tables, or a pair of IDs);
- convergence status, and maximum time allowed for training and inference; and/or
- type of AI data (e.g., beam management information, enhanced positioning information, CSI prediction information, CSI compression information, life cycle management for AI-related procedures).

In some implementations, the channel configured to carry quality of service indicator (QoSI) and/or positioning reference signal (PRS) may be a channel dedicated for data related to quality of service and/or PRS.

According to some implementations of the present disclosure, information used for managing communication involving at least one of the apparatus or the device (e.g., UCI designed discussed above or a new type of (control) information that manages network communications) may be transmitted using a traffic that is in a downlink direction, an uplink direction, or a sidelink direction. In some implementations, the traffic may be a traffic that is different from network traffics used in existing networks (e.g., the traffic is new traffic).

In some implementations, the above-noted traffic may be associated with physical-layer data transport, sensing, intra-radio access network (RAN) communication and/or artificial intelligence (AI) or machine learning (ML). In other words, the traffic may include content such as AI/ML data (dataset, model weights, gradients), sensing data (angular, range, position), intra-RAN data, and/or other data generated in physical layer (physical-layer data).

In some implementations, the AI/ML data may include one of more of the followings:

- dataset and related information (e.g., index, ID, group index, group ID, type index);
- (AI) model, weights, and related information (e.g., index, ID, group index, group ID, type index);
- gradients, and its information (e.g., index, ID, group index, group ID, type index);
- mapping relationship between any two of the dataset information, model/weights information and gradients information (in the form of tables, or a pair of IDs);
- convergence status, and maximum time allowed for training and inference; and/or
- type of AI data (e.g., beam management information, enhanced positioning information, CSI prediction information, CSI compression information, life cycle management for AI-related procedures).

In some implementations, the sensing data may include one of more of the followings:

- multipath indication (e.g., the number of paths, path index, path direction, power value of each path, time delay of each path), and the indication can be relative to a reference value, or directly absolute value;
- angle indication;
- phase indication (e.g., per path, per path group);
- doppler indication;
- position indication;
- range indication;
- trajectory indication; and/or
- environment (e.g., ground truth, anchor point information, point cloud, clutter, norm direction, reflection direction, object shape/location/size).

In some implementations, the above-noted traffic (used for transmission of information used for managing communications) may be lossless. The traffic may be lossless if the traffic is associated with information such as scheduling request, HARQ/ACK, DCI indicators, and/or CSI. For example, CRC bits may be attached to the data, to thereby detect any error. In the case that any error is detected, the transmitted/received data cannot be used or trusted.

In some implementations, the above-noted traffic (used for transmission of information used for managing communications) may be lossy. The traffic may be lossy if the traffic is associated with information, such as extended CSI, or AI/sensing data, is error-tolerant, and thus need not to be lossless. For lossy traffics, fewer CRC bits or no CRC bits may be attached to the data being transmitted. Therefore, whether an error has occurred may not be identifiable for some portion of the data.

In some implementations, the above-noted traffic (used for transmission of information used for managing communications) may be considered and/or referred to as "extended UCI", "extended DCI", "extended SCI", "intra-RAN data", or "physical layer data". In some implementations, compared to the traffic associated with existing control channels, the above-noted traffic may be larger and may not require high reliability (e.g., same level of high reliability as the existing ones). In some implementations, compared to the traffic associated with existing data channels, the above-noted traffic may be generated in the physical layer. The above-noted traffic may only involve data generated in physical layer and may be used to assist physical-layer functions only. Therefore, the above-noted traffic may not need to be sent to higher layers. On the other hand, the existing data channels may be generated and transmitted over a layer other than the physical layer (e.g., higher layer) and used to assist, for example, higher-layer functions.

Selective Retransmission

In one possible implementation, selective UCI retransmission scheme is provided.

This section explores retransmission methods tailored for the future uplink control information (UCI) considering the evolving 3rd generation partnership project (3GPP) standards and the introduction of novel UCI types. These techniques aim to guarantee reliable communication and elevate system performance by incorporating Hybrid Automatic Repeat Request (HARQ), Automatic Repeat Request (ARQ), or repetition mechanisms as required.

Payload-Type-based Retransmission Strategy

- Certain recently introduced UCI types, such as those carrying sensing information (SSI) or AI information (AII), might necessitate retransmissions for successful decoding at the base station (BS). Upon detecting a decoding error, the BS can initiate a retransmission request directed towards the user equipment (UE). Conversely, time-critical payload types encompassing Acknowledgement/Non-Acknowledgment (ACK/NACK), Scheduling Request (SR), and Channel State Information (CSI) do not require retransmissions even in the case of decoding failures due to their diminished utility upon re-transmission.

Priority-Based Retransmission Strategy

- Each UCI packet is assigned a priority index, and the retransmission process is solely applicable to packets having high priority. This prioritization can be pre-configured via Radio Resource Control (RRC) for each UCI payload and its corresponding transmissions. Optionally, a threshold priority index can be established to select UCI packets for retransmission. Consequently, all UCI code blocks that fail to decode and possess a higher (or equal) priority index compared to the threshold will be retransmitted.

Resource Allocation and Scheduling

In another possible implementation, UCI retransmission resource allocation and scheduling scheme is presented.

Efficient spectrum utilization necessitates effective resource allocation and scheduling strategies for both initial UCI transmissions and potential retransmissions. To achieve flexibility and optimize resource utilization, contention-based resource allocation can be employed for retransmission scenarios. In such cases, rather than relying on HARQ process ID based scheduling, UCI Transmission Block (TB) index or Code Block (CB) index can be utilized to designate the specific packet targeted for retransmission.

Initial Transmission and Retransmission Resource Configuration

Resource allocation for both initial UCI transmissions and potential retransmissions can be jointly configured by the base station (BS) via Radio Resource Control (RRC) and/or Downlink Control Information (DCI). While initial transmission resources can be exclusively allocated for each UCI packet, retransmission resources can be shared among multiple UCI retransmissions. This sharing often employs a contention-based approach, where the same resource is allocated for potential retransmissions. However, individual UCI packets only require retransmission upon failed initial transmission decoding.

FIG. 7 is a block diagram illustrating an example 600 of contention-based retransmission resource sharing for UCI retransmissions, in accordance with implementations of the present disclosure. In particular, in the illustrated example 600, three initial transmission resources 602, 604 and 606 are exclusively allocated for the initial transmission of three UCI code

blocks UCI 1, UCI 2 and UCI 3, respectively. On the other hand, only a single retransmission resource 608 is allocated for potential retransmission of the three UCI code blocks. If initial transmission decoding fails for only one of the three UCI code blocks, then that UCI code block may be retransmitted using the retransmission resource 608. However, if initial transmission decoding fails for two or more of the UCI code blocks, then some contention resolution mechanism may be used to determine which UCI code block is retransmitted using the retransmission resource 608. For example, the contention resolution mechanism may be based on payload type and/or priority index as described herein.

Pre-configured rules can be established to determine the timing and frequency resource allocation for each UCI retransmission. These rules may define the offset relative to a Physical Downlink Control Channel (PDCCH) transmission or a Physical Downlink Shared Channel (PDSCH) transmission. In some cases, multiple time and frequency resource options may be configured for a single UCI retransmission. This flexibility allows the BS to allocate non-overlapping resources for all packets requiring retransmission. However, this approach necessitates blind detection at the BS, where the receiver searches for possible resource positions and attempts to decode the UCI packet without prior knowledge of its location.

To alleviate design complexity (e.g., reduce blind detection overhead at the BS), the system can limit the allowable payload sizes by employing a relatively fixed payload size based on the UCI content. The payload size can be pre-configured, ideally by the BS via RRC, or determined based on configurations like bandwidth part and transmission modes. If a UE has fewer payload bits to encode, zero-padding can be used to achieve the target payload size. Alternatively, the number of possible payload sizes can be limited to a few discrete options (e.g., 2, 3, 4). This limitation can be derived from factors such as UCI content or the chosen transmission mode.

Retransmission Scheduling Strategies

- UCI Transport Block (TB) Index Scheduling: During retransmission scheduling, the BS can leverage the TB index of the UCI. This approach instructs the UE to prioritize encoding and transmitting non-retransmitted TBs in subsequent transmissions. Additionally, the UE can skip time-sensitive payload types to maintain overall system efficiency.

- Code Block (CB) Index or Content-Based Retransmission: Beyond TB index scheduling, the BS can also schedule UCI retransmissions based on CB indices or the specific UCI content. This approach offers more granular control over the retransmitted information. By only resending critical data, this strategy reduces unnecessary redundancy within the system.

Blind Retransmission

In another possible implementation, UCI blind retransmission is presented.

Blind Retransmission Strategy: In specific scenarios, the UE may employ a blind retransmission approach, transmitting subsequent Redundancy Versions (RVs) concurrently with or right after the initial transmission. This strategy eliminates the need for decoding feedback before retransmitting, ensuring that time-critical applications receive sufficient code bits within a constrained timeframe. To facilitate seamless coordination between transmissions, the BS allocates resources for both the initial transmission and subsequent retransmissions beforehand via DCI on the PDCCH.

The total number of transmissions, encompassing both the initial transmission and potential retransmissions, can be restricted to a small value, such as T_{max} = 2, 3 or 4. Upon reaching the maximum transmission limit (T_{max}), the packet is discarded, and no further retransmissions are attempted.

Furthermore, a maximum number of RVs can be implemented for UCI channel coding as well. For instance, the number of RVs designed for polar codes or Low-Density Parity-Check (LDPC) codes in UCI transmissions can be limited to just 2. This limitation significantly simplifies UCI channel coding design and reduces the associated encoding and decoding complexity.

Reliability Enhancement

In another possible implementation, UCI retransmission reliability enhancement is presented.

MCS Selection for Different UCI Types

Certain extended UCI types or novel traffic categories may possess unique characteristics and reliability demands that differ from existing data and control traffic. For instance, the required reliability for these new UCI types might be stricter than data traffic but relaxed compared to control channels. To illustrate, if the data and control channel reliability requirements are 10^{-1} (1e-1) and 10^{-5} (1e-5), respectively, a new special traffic type might necessitate a reliability target of 10^{-3} (1e-3).

Consequently, a new MCS table with a more conservative approach compared to existing data traffic MCS tables should be defined for these UCI types. This new table would prioritize link reliability over throughput.

MCS Selection for Initial and Retransmitted UCI Packets

The MCS selection rules can be differentiated for initial UCI transmissions and subsequent retransmissions. The initial transmission can leverage a more aggressive strategy, favoring a higher MCS index to maximize throughput. Conversely, retransmissions can employ a more conservative approach, utilizing a lower MCS index to enhance the likelihood of successful decoding.

Integration with higher layers:

To further improve the reliability of UCI retransmission, the error control mechanisms can be integrated with higher-layer protocols such as RLC or PDCP. By doing so, 6G networks can benefit from enhanced error detection capabilities and efficient retransmission strategies tailored to different payload types and their unique requirements.

In conclusion, this embodiment delves into methods for UCI retransmission in new uplink control information technology with a focus on time-sensitive payload types and emerging UCI classes. By incorporating HARQ, ARQ, or repetition mechanisms when necessary, these techniques ensure reliable communication while maintaining overall system efficiency in accordance with 3GPP standards.

These four possible implementations present techniques for reliable and efficient retransmission of uplink control information (UCI) packets in future networks. They consider both adherences to evolving 3GPP standards and the introduction of new UCI types. To ensure reliable communication, selective retransmission is based on payload type (critical data) or priority level, while time-sensitive data is excluded due to limited benefit. Resource allocation is optimized for both initial transmissions and retransmissions using contention-based approaches and leveraging TB/CB indices for scheduling. Flexibility is provided

through configurable payload sizes and blind detection options. For time-critical applications, blind retransmission transmits redundant data concurrently with or following the initial transmission. The number of transmissions and code repetitions are limited to control overhead ratio. Furthermore, reliability is enhanced by defining a new, conservative MCS table for novel UCI types and using different MCS selection strategies for initial transmissions and retransmissions. Finally, integration with higher-layer protocols is suggested for improved error control tailored to specific payloads.

In summary, implementations according to the present disclosure may include at least one of the following features:

- Selective UCI retransmission based on payload type and/or priority index
- Initial transmission and retransmission resource allocation
- UCI blind retransmission
- UCI retransmission reliability enhancement

FIG. 8 is a signal flow diagram illustrating an example method 700 for facilitating communications between an apparatus 702 and a device 701 in a wireless network, in accordance with implementations of the present disclosure.

The example method is comprised of steps 710, 720, 730 and 740. Some of these steps may be optional in some implementations, as discussed in further detail below. It should be understood that, in some implementations, the order of one or more steps 710, 720, 730 and 740 may be changed.

At step 720, the apparatus 702 (e.g., UE or any other suitable terminal side device) may transmit, to the device 701 (e.g., BS or any other suitable network side device), a plurality of code blocks of a first information channel. In some implementations, the plurality of code blocks may include first information for managing communication involving at least one of the apparatus 702 or the device 701, for example.

In some implementations, the first information channel may be configured to carry at least one of: control information; physical-layer data; sensing information (SSI); artificial intelligence (AI)-related information (AII); transmission mode and phase information; quality of service indicator (QoSI); or positioning reference signal (PRS), for example.

In some implementations, the first information may be associated with at least one of: physical-layer data transport; sensing; intra-radio access network (RAN) communication; or artificial intelligence (AI) or machine learning (ML).

At step 740, the apparatus 702 may selectively retransmit, to the device 701, one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index.

In some implementations, the transmitting and retransmitting is done in a downlink direction, an uplink direction, or a sidelink direction.

In some implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 comprises: retransmitting a first code block of the plurality of code blocks based on the first code block having a first payload type; and not retransmitting a second code block of the plurality of code blocks based on the second code block having a second payload type, wherein the second payload type is different from the first payload type. For example, in some

implementations, the first payload type may include sensing information (SSI) and/or artificial intelligence (AI)-related information (AII). On the other hand, the second payload type may include hybrid automatic repeat request (HARQ) acknowledgement and negative acknowledgement (ACK/NACK), a scheduling request (SR) and/or channel state information (CSI).

In some implementations, each code block of the plurality of code blocks is assigned a respective priority index, and selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 comprises: retransmitting a first code block of the plurality of code blocks based on the respective priority index assigned to the first code block being a first priority index; and not retransmitting a second code block of the plurality of code blocks based on the respective priority index assigned to the second code block being a second priority index, wherein the second priority index is different from the first priority index. For example, in such implementations, the first priority index may correspond to a higher priority than the second priority index, e.g., the first priority index may satisfy a priority index threshold and the second priority index may not satisfy the priority index threshold. The respective priority index assigned to each code block of the plurality of code blocks may be preconfigured using radio resource control (RRC) signaling, for example.

In some implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 comprises, for each code block of the plurality of code blocks: determining whether the respective priority index assigned to the code block satisfies a priority index threshold; and selectively retransmitting the code block based on the determining. For example, in some implementations, retransmitting the first code block comprises retransmitting the first code block after determining the first priority index satisfies the priority index threshold.

In some implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 comprises: determining a set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks, wherein resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks; and selectively retransmitting one or more of the code blocks of the plurality of code blocks using the set of one or more retransmission resources. For example, in some implementations, resources of the set of retransmission resources may be shared among multiple code blocks of the plurality of code blocks in a contention-based manner in which a same retransmission resource of the set is allocated for potential retransmissions for two or more of the code blocks of the plurality of code blocks.

In some implementations, transmitting the plurality of code blocks to the device 701 at step 720 comprises: determining a set of transmission resources allocated for initial transmission of the plurality of code blocks, wherein resources of the set of transmission resources are exclusively allocated for each code block of the plurality of code blocks; and transmitting the plurality of code blocks to the device 701 using the set of transmission resources.

In some implementations, the apparatus 702 receives resource allocation information from the device 701 at step 710, wherein the resource allocation information indicates the set of transmission resources allocated for initial transmission of the plurality of code blocks; and the set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks. In such implementations, the apparatus 702 may determine the set of transmission resources and the set of one or more retransmission resources based on the resource allocation information. In some implementations, the resource allocation information received at step 710 may be received via Radio Resource Control (RRC) signaling and/or Downlink Control Information (DCI), for example.

In some implementations, the apparatus 702 may determine the set of one or more retransmission resources using one or more pre-configured rules to determine the set of one or more retransmission resources. For example, the one or more pre-configured rules may include one or more rules for determining one or more retransmission resource positions based on an offset relative to a Physical Downlink Control Channel (PDCCH) transmission or a Physical Downlink Shared Channel (PDSCH) transmission.

In some implementations, multiple retransmission resource options are configured for each retransmission. In such implementations, determining the set of one or more retransmission resources may involve determining, for each code block to be retransmitted, a particular retransmission resource to be used for retransmission of the code block from among the multiple retransmission resource options configured for each retransmission.

In some implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 comprises, for each code block to be retransmitted, retransmitting the code block using a fixed payload size based on the payload type of the code block.

In some implementations, a set of two or more fixed payload size options may be configured for retransmissions. In such implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 may comprise, for each code block to be retransmitted, retransmitting the code block using a particular fixed payload size selected from among the set of two or more fixed payload size options.

In some implementations, for each code block to be retransmitted, retransmitting the code block using a particular fixed payload size selected from among the set of two or more fixed payload size options comprises selecting the particular fixed payload size from among the set of two or more fixed payload size options based on at least one of the payload type of the code block or a transmission mode to be used for the retransmission of the code block. For example, a fixed payload size of 1 bit per code block group/transport block (CBG/TB) may be selected for retransmission of an ACK/NACK payload type. In such embodiments, the payload size may be fixed at 1 bit per CBG/TB once the initial transmission of a code block having the ACK/NACK payload type is scheduled. Another example is that for certain basic/fallback transmission mode(s), the payload size may be fixed for simplicity.

In some implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 involves selectively retransmitting the one or more of the code blocks in response to detecting a retransmission trigger. In some implementations, detecting a retransmission trigger may involve receiving, from the device 701, retransmission scheduling information for the one or more of the code blocks, as indicated at step 730. For example, in some implementations, the retransmission scheduling information for the one or more of the code blocks may include at least one of: transport block retransmission scheduling information indicating one or more transport block indexes corresponding to one or more transport blocks containing the one or more of the code blocks; or code block retransmission scheduling information indicating one or more code block indexes corresponding to the one or more of the code blocks.

In some implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index comprises, for at least one code block of the one or more of the code blocks: automatically transmitting one or more redundancy versions of the code block without waiting for decoding feedback, from the device, for an initial transmission of the code block. For example, in some implementations, the apparatus 702 receives resource allocation information from the device 701 at step 710, wherein the resource allocation information indicates a

transmission resource allocated for the initial transmission of the code block; and a set of one or more retransmission resources allocated for transmission of the one or more redundancy versions of the code block. In some implementations, the resource allocation information received at step 710 may be received via Downlink Control Information (DCI) on a Physical Downlink Control Channel (PDCCH), for example.

In some implementations, for each code block of the at least one code block, a total number of transmissions for the code block, inclusive of the initial transmission of the code block at step 720 and the one or more transmissions of redundancy versions of the code block at step 740, may be restricted to a maximum value, T_{max}, wherein $T_{max} \leq 4$.

In some implementations, a maximum number of redundancy versions defined for each code block of the one or more of the code blocks is 2.

In some implementations, transmitting the plurality of code blocks at step 720 comprises, for at least one code block of the plurality of code blocks, transmitting the at least one code block to the device 701 using a modulation and coding scheme (MCS) selected from a first set of MCS options, wherein the first set of MCS options is selected from a plurality of sets of MCS options based on the payload type of the code block.

In some implementations, the plurality of sets of MCS options may include: the first set of MCS options; and at least a second set of MCS options, wherein MCS options in the first set of MCS options are more conservative in terms of at least one of coding rate or modulation order relative to corresponding MCS options in the second set of MCS options.

In some implementations, transmitting the plurality of code blocks at step 720 comprises, for at least one code block of the plurality of code blocks, transmitting the at least one code block to the device 701 using a modulation and coding scheme (MCS) selected from a first set of MCS options using a first set of pre-configured rules for MCS selection. In such implementations, selectively retransmitting one or more of the code blocks of the plurality of code blocks at step 740 may comprise, for the at least one code block of the plurality of code blocks, selectively retransmitting one or more of the at least one code block using a MCS selected from the first set of MCS options using a second set of pre-configured rules for MCS selection, wherein the second set of pre-configured rules for MCS selection is different from the first set of pre-configured rules for MCS selection. For example, in some implementations, the second set of pre-configured rules for MCS selection may be more conservative than the first set of pre-configured rules for MCS selection in that, in at least some cases, the second set of pre-configured rules for MCS selection prescribes selection of an MCS option having at least one of lower coding rate or lower modulation order than an MCS option that would otherwise be prescribed for selection by the first set of pre-configured rules for MCS selection.

In some aspects of the present disclosure, there is provided an apparatus/chipset system comprising means (e.g., at least one processor) to implement a method implemented by (or at) a UE of the present disclosure. The apparatus/chipset system may be the UE (that is, a terminal device) or a module/component in the UE. In details, the at least one processor may execute instructions stored in a computer-readable medium to implement the method.

In some aspects of the present disclosure, there is provided an apparatus/chipset system comprising means (e.g., at least one processor) to implement the method implemented by (or at) a network device (e.g., base station) of the present disclosure. The apparatus/chipset system may be the network device or a module/component in the network device. In details, the at least one processor may execute instructions stored in a computer-readable medium to implement the method. In some aspects

of the present disclosure, there is provided a system comprising at least one of an apparatus in (or at) a UE of the present disclosure, or an apparatus in (or at) a network device of the present disclosure.

In some aspects of the present disclosure, there is provided a method performed by a system comprising at least one of an apparatus in (or at) a UE of the present disclosure, and an apparatus in (or at) a network device of the present disclosure.

In some aspects of the present disclosure, there is provided a computer program comprising instructions. The instructions, when executed by a processor, may cause the processor to implement a method of the present disclosure.

In some aspects of the present disclosure, there is provided a non-transitory computer-readable medium storing instructions, the instructions, when executed by a processor, may cause the processor to implement a method of the present disclosure.

The solutions described in the disclosure is applicable to a next generation (e.g. sixth generation (6G) or later) network, or a legacy (e.g. 5G, 4G) network.

It will be appreciated that any module, component, or device disclosed herein that executes instructions may include, or otherwise have access to, a non-transitory computer/processor readable storage medium or media for storage of information, such as computer/processor readable instructions, data structures, program modules and/or other data. A non-exhaustive list of examples of non-transitory computer/processor readable storage media includes magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, optical disks such as compact disc read-only memory (CD-ROM), digital video discs or digital versatile discs (i.e., DVDs), Blu-ray Disc™, or other optical storage, volatile and non-volatile, removable and non-removable media implemented in any method or technology, random-access memory (RAM), read-only memory (ROM), electrically erasable programmable read-only memory (EEPROM), flash memory or other memory technology. Any such non-transitory computer/processor storage media may be part of a device/apparatus or accessible or connectable thereto. Computer/processor readable/executable instructions to implement a method, an application or a module described herein may be stored or otherwise held by such non-transitory computer/processor readable storage media.

It could be noted that the message in the disclosure could be replaced with information, which may be carried in one single message, or be carried in more than one separate message.

Without special noting, the terms "apparatus" and "device" are used exchangeable, and the terms "identity" and "identifier" are sued exchangeable.

In the disclosure, the word "a" or "an" when used in conjunction with the term "comprising" or "including" in the claims and/or the specification may mean "one", but it is also consistent with the meaning of "one or more", "at least one", and "one or more than one" unless the content clearly dictates otherwise. Similarly, the word "another" may mean at least a second or more unless the content clearly dictates otherwise.

In the disclosure, the words "first", "second", etc., when used before a same term (e.g., ED, or an operating step) does not mean an order or a sequence of the term. For example, the "first ED" and the "second ED", means two different EDs without specially indicated, and similarly, the "first step" and the "second step" means two different operating steps without

specially indicated, but does not mean the first step have to happen before the second step. The real order depends on the logic of the two steps.

The terms "coupled", "coupling" or "connected" as used herein can have several different meanings depending on the context in which these terms are used. For example, as used herein, the terms coupled, coupling, or connected can indicate that two elements or devices are directly connected to one another or connected to one another through one or more intermediate elements or devices via a mechanical element depending on the particular context.

Note that the expression "at least one of A or B", as used herein, is interchangeable with the expression "A and/or B". It refers to a list in which you may select A or B or both A and B. Similarly, "at least one of A, B, or C", as used herein, is interchangeable with "A and/or B and/or C" or "A, B, and/or C". It refers to a list in which you may select: A or B or C, or both A and B, or both A and C, or both B and C, or all of A, B and C. The same principle applies for longer lists having a same format.

The present disclosure encompasses various embodiments, including not only method embodiments, but also other embodiments such as apparatus embodiments and embodiments related to non-transitory computer readable storage media. Embodiments may incorporate, individually or in combinations, the features disclosed herein.

The term "receive", "detect" and "decode" as used herein can have several different meanings depending on the context in which these terms are used. For example, without special note, the term "receive" may indicate that information (e.g., DCI, or MAC-CE, RRC signaling or TB) is received successfully by the receiving node, which means the receiving side correctly detect and decode it. In this scenario, "receive" may cover "detect" and "decode" or may indicates same thing, e.g., "receive paging" means decoding paging correctly and obtaining the paging successfully, accordingly, "the receiving side does not receive paging" means the receiving side does not detect and/or decoding the paging. "paging is not received" means the receiving side tries to detect and/or decoding the paging, but not obtain the paging successfully. The term "receive" may sometimes indicate that a signal arrives at the receiving side, but does not mean the information in the signal is detected and decoded correctly, then the receiving side need perform detecting and decoding on the signal to obtain the information carried in the signal. In this scenario, "receive", "detect" and "decode" may indicate different procedure at receiving side to obtain the information.

Although this disclosure refers to illustrative embodiments, this is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the disclosure, will be apparent to persons skilled in the art upon reference to the description. When combining two or more embodiments, not all the features in the embodiments to be combined are necessary for the combination.

Features disclosed herein in the context of any particular embodiments may also or instead be implemented in other embodiments. Method embodiments, for example, may also or instead be implemented in apparatus, system, and/or computer program product embodiments. In addition, although embodiments are described primarily in the context of methods and apparatus, other implementations are also contemplated, as instructions stored on one or more non-transitory computer-readable media, for example. Such media could store programming or instructions to perform any of various methods consistent with the present disclosure.

ACRONYMS AND ABBREVIATIONS

Full Name	Acronym/Abbreviation/Initialism
Long Term Evolution	LTE
New Radio	NR
Forward error correction	FEC
Multiple Access	MA
Quality of Service	QoS
low-density parity check codes	LDPC
cyclic redundancy check	CRC
Parity check	PC
ultra-reliable low latency communications	uRLLC
Enhanced mobile broadband	eMBB
massive Machine Type Communications	mMTC
non-terrestrial networks	NTN
Internet of Things	IoT
Bit Error Rate	BER
Block Error Rate	BLER
Packet Error Rate	PER
Spectral Efficiency	SE
Hybrid automatic repeat request	HARQ
Incremental-redundancy HARQ	IR-HARQ
Channel Quality Indicator	CQI
Modulation Coding Scheme	MCS
gNodeB or 5G base station	gNB
user equipment	UE
Radio Resource Control	RRC
Radio Network Temporary Identifier	RNTI
Uplink Control Information	UCI
Downlink Control Information	DCI
Physical Broadcast Channel	PBCH
Half-radio frame bit	HRF

Full Name	Acronym/Abbreviation/Initialism
Synchronization Signal Block	SSB
unequal error protection	UEP
variable node	VN
check node	CN
Log-likelihood ratio	LLR
Successive cancellation	SC
Successive cancellation list	SCL
CRC-aided successive cancellation list	CA-SCL
Parity-check successive cancellation list	PC-SCL

CLAIMS

1. A method performed at an apparatus comprising:

transmitting, to a device, a plurality of code blocks of a first information channel, the plurality of code blocks comprising first information for managing communication involving at least one of the apparatus or the device; and

retransmitting, to the device, one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index.

2. The method of claim 1, wherein retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index comprises:

retransmitting a first code block of the plurality of code blocks based on the first code block having a first payload type.

3. The method of claim 2, wherein the first payload type comprises at least one of:

sensing information (SSI); or

artificial intelligence (AI)-related information (AII).

4. The method of claim 2 or 3, wherein the second payload type comprises at least one of:

hybrid automatic repeat request (HARQ) acknowledgement and negative acknowledgement (ACK/NACK);

a scheduling request (SR); or

channel state information (CSI).

5. The method of claim 1, wherein:

each code block of the plurality of code blocks is assigned a respective priority index; and

retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index comprises:

retransmitting a first code block of the plurality of code blocks based on the respective priority index assigned to the first code block being a first priority index.

6. The method of claim 5, wherein the respective priority index assigned to each code block of the plurality of code blocks is preconfigured using radio resource control (RRC) signaling.

7. The method of any claim 5 or claim 6, wherein the first priority index corresponds to a higher priority than priority of the other code blocks in the plurality of code blocks.

8. The method of any one of claims 5 to 7, wherein:

the first priority index satisfies a priority index threshold.

9. The method of any one of claims 5 to 7, wherein retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index comprises, for each code block of the plurality of code blocks:

determining whether the respective priority index assigned to the code block satisfies a priority index threshold; and

selectively retransmitting the code block based on the determining.

10. The method of claim 9, wherein retransmitting the first code block comprises retransmitting the first code block after determining the first priority index satisfies the priority index threshold.

11. The method of any one of claims 1 to 10, wherein retransmitting one or more of the code blocks of the plurality of code blocks comprises:

determining a set of one or more retransmission resources allocated for retransmission of code blocks of the plurality of code blocks, wherein resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks; and

retransmitting the one or more of the code blocks of the plurality of code blocks using the set of one or more retransmission resources.

12. The method of claim 11, wherein resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks in a contention-based manner in which a same retransmission resource of the set is allocated for potential retransmissions for two or more of the code blocks of the plurality of code blocks.

13. The method of claim 11 or claim 12, wherein transmitting, to the device, the plurality of code blocks comprises:

determining a set of transmission resources allocated for initial transmission of the plurality of code blocks, wherein resources of the set of transmission resources are exclusively allocated for each code block of the plurality of code blocks; and

transmitting, to the device, the plurality of code blocks using the set of transmission resources.

14. The method of claim 13, wherein determining the set of transmission resources and determining the set of retransmission resources comprises:

receiving, from the device, resource allocation information indicating:

the set of transmission resources allocated for initial transmission of the plurality of code blocks; and

the set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks; and

determining the set of transmission resources and the set of one or more retransmission resources based on the resource allocation information.

15. The method of claim 14, wherein the resource allocation information is received via at least one of Radio Resource Control (RRC) signaling or Downlink Control Information (DCI).

16. The method of any one of claims 11 to 13, wherein determining the set of one or more retransmission resources comprises determining the set of one or more retransmission resources using one or more pre-configured rules to determine the set of one or more retransmission resources.

17. The method of claim 16, wherein the one or more pre-configured rules comprise one or more rules for determining one or more retransmission resource positions based on an offset relative to a Physical Downlink Control Channel (PDCCH) transmission or a Physical Downlink Shared Channel (PDSCH) transmission.

18. The method of any one of claims 11 to 13, wherein:

multiple retransmission resource options are configured for each retransmission; and

determining the set of one or more retransmission resources comprises determining, for each code block to be retransmitted, a particular retransmission resource to be used for retransmission of the code block from among the multiple retransmission resource options configured for each retransmission.

19. The method of any one of claims 11 to 18, wherein selectively retransmitting one or more of the code blocks of the plurality of code blocks comprises, for each code block to be retransmitted, retransmitting the code block using a fixed payload size based on the payload type of the code block.

20. The method of any one of claims 11 to 18, wherein:

a set of two or more fixed payload size options is configured for retransmissions; and

selectively retransmitting one or more of the code blocks of the plurality of code blocks comprises, for each code block to be retransmitted, retransmitting the code block using a particular fixed payload size selected from among the set of two or more fixed payload size options.

21. The method of claim 20, wherein, for each code block to be retransmitted, retransmitting the code block using a particular fixed payload size selected from among the set of two or more fixed payload size options comprises:

selecting the particular fixed payload size from among the set of two or more fixed payload size options based on at least one of the payload type of the content block or a transmission mode to be used for the retransmission of the code block.

22. The method of any one of claims 1 to 21, wherein selectively retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index comprises:

detecting a retransmission trigger; and

selectively retransmitting, to the device, the one or more of the code blocks in response to the retransmission trigger.

23. The method of claim 22, wherein detecting the retransmission trigger comprises:

receiving, from the device, retransmission scheduling information for the one or more of the code blocks.

24. The method of claim 23, wherein the retransmission scheduling information for the one or more of the code blocks comprises at least one of:

transport block retransmission scheduling information indicating one or more transport block indexes corresponding to one or more transport blocks containing the one or more of the code blocks; or

code block retransmission scheduling information indicating one or more code block indexes corresponding to the one or more of the code blocks.

25. The method of any one of claims 1 to 10, wherein retransmitting one or more of the code blocks of the plurality of code blocks based on at least one of payload type or priority index comprises, for at least one code block of the one or more of the code blocks:

automatically transmitting one or more redundancy versions of the code block without waiting for decoding feedback, from the device, for an initial transmission of the code block.

26. The method of claim 25, further comprising:

receiving, from the device, resource allocation information indicating:

a transmission resource allocated for the initial transmission of the code block; and

a set of one or more retransmission resources allocated for transmission of the one or more redundancy versions of the code block.

27. The method of claim 26, wherein the resource allocation information is received via Downlink Control Information (DCI) on a Physical Downlink Control Channel (PDCCH).

28. The method of any one of claims 25 to 27, wherein, for each code block of the at least one code block, a total number of transmissions for the code block, inclusive of the initial transmission of the code block and the one or more transmissions of redundancy versions of the code block, is restricted to a maximum value, T_{max}, wherein $T_{max} \leq 4$.

29. The method of any one of claims 25 to 28, wherein a maximum number of redundancy versions defined for each code block of the one or more of the code blocks is 2.

30. The method of any one of claims 1 to 10, wherein transmitting, to the device, the plurality of code blocks comprises, for at least one code block of the plurality of code blocks:

transmitting the at least one code block to the device using a modulation and coding scheme (MCS) selected from a first set of MCS options, wherein the first set of MCS options is selected from a plurality of sets of MCS options based on the payload type of the code block.

31. The method of claim 30, wherein the plurality of sets of MCS options comprises:

the first set of MCS options; and

at least a second set of MCS options, wherein MCS options in the first set of MCS options are more conservative in terms of at least one of coding rate or modulation order relative to corresponding MCS options in the second set of MCS options.

32. The method of any one of claims 1 to 10, wherein:

transmitting, to the device, the plurality of code blocks comprises, for at least one code block of the plurality of code blocks, transmitting the at least one code block to the device using a modulation and coding scheme (MCS) selected from a first set of MCS options using a first set of pre-configured rules for MCS selection; and

retransmitting one or more of the code blocks of the plurality of code blocks comprises, for the at least one code block of the plurality of code blocks, retransmitting one or more of the at least one code block using a MCS selected from the first set of MCS options using a second set of pre-configured rules for MCS selection, wherein the second set of pre-configured rules for MCS selection is different from the first set of pre-configured rules for MCS selection.

33. The method of claim 32, wherein the second set of pre-configured rules for MCS selection is more conservative than the first set of pre-configured rules for MCS selection in that, in at least some cases, the second set of pre-configured rules for MCS selection prescribes selection of an MCS option having at least one of lower coding rate or lower modulation order than an MCS option that would otherwise be prescribed for selection by the first set of pre-configured rules for MCS selection.

34. The method of any one of claims 1 to 33, wherein the first information channel is configured to carry at least one of:
control information;
physical-layer data;
sensing information (SSI);
artificial intelligence (AI)-related information (AII);
transmission mode and phase information;
quality of service indicator (QoSI); or
positioning reference signal (PRS).

35. The method of any one of claims 1 to 33, wherein the transmitting and retransmitting is done in a downlink direction, an uplink direction, or a sidelink direction.

36. The method of claim 34, wherein the first information is associated with at least one of:
physical-layer data transport;
sensing;
intra-radio access network (RAN) communication; or
artificial intelligence (AI) or machine learning (ML).

37. An apparatus comprising:
at least one processor coupled with a computer-readable medium storing computer-executable instructions that, when executed, cause the apparatus to perform the method of any one of claims 1 to 36.

38. A method performed at a device comprising:
receiving, from an apparatus, a plurality of code blocks of a first information channel, the plurality of code blocks comprising first information for managing communication involving at least one of the apparatus or the device; and
receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks, the one or more retransmitted code blocks having been retransmitted based on at least one of payload type or priority index.

39. The method of claim 38, wherein receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises:
receiving a first code block of the plurality of code blocks, wherein the first code block was retransmitted based on the first code block having a first payload type.

40. The method of claim 39, wherein the first payload type comprises at least one of:
sensing information (SSI); or
artificial intelligence (AI)-related information (AII).

41. The method of claim 39 or claim 40, wherein the second payload type comprises at least one of:
hybrid automatic repeat request (HARQ) acknowledgement and negative acknowledgement (ACK/NACK);
a scheduling request (SR); or

channel state information (CSI).

42. The method of claim 38, wherein:

each code block of the plurality of code blocks is assigned a respective priority index; and

receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises:

receiving a first code block of the plurality of code blocks, wherein the first code block was retransmitted based on the respective priority index assigned to the first code block being a first priority index.

43. The method of claim 42, wherein the respective priority index assigned to each code block of the plurality of code blocks is preconfigured using radio resource control (RRC) signaling.

44. The method of any claim 42 or claim 43, wherein the first priority index corresponds to a higher priority than priority of other code blocks in the plurality of code blocks.

45. The method of any one of claims 42 to 44, wherein:

the first priority index satisfies a priority index threshold.

46. The method of any one of claims 38, wherein receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises:

receiving, from the apparatus the one or more retransmitted code blocks having been retransmitted based on having respective priority indexes that satisfy a priority index threshold.

47. The method of claim 46, wherein the priority index threshold is configured via at least one of Radio Resource Control (RRC) signaling or Downlink Control Information (DCI).

48. The method of any one of claims 38 to 47, wherein receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises:

determining a set of one or more retransmission resources to allocate for retransmission of the code blocks of the plurality of code blocks, wherein resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks; and

receiving the one or more of the code blocks of the plurality of code blocks using the set of one or more retransmission resources.

49. The method of claim 48, wherein resources of the set of retransmission resources are shared among multiple code blocks of the plurality of code blocks in a contention-based manner in which a same retransmission resource of the set is allocated for potential retransmissions for two or more of the code blocks of the plurality of code blocks.

50. The method of claim 48 or claim 49, wherein receiving, from the apparatus, the plurality of code blocks comprises:

determining a set of transmission resources to allocate for initial transmission of the plurality of code blocks, wherein resources of the set of transmission resources are exclusively allocated for each code block of the plurality of code blocks; and

receiving, from the apparatus, the plurality of code blocks using the set of transmission resources.

51. The method of claim 50, further comprising:

transmitting, to the apparatus, resource allocation information indicating:

the set of transmission resources allocated for initial transmission of the plurality of code blocks; and

the set of one or more retransmission resources allocated for retransmission of the code blocks of the plurality of code blocks.

52. The method of claim 51, wherein the resource allocation information is transmitted via at least one of Radio Resource Control (RRC) signaling or Downlink Control Information (DCI).

53. The method of any one of claims 48 to 50, wherein determining the set of one or more retransmission resources comprises determining the set of one or more retransmission resources using one or more pre-configured rules to determine the set of one or more retransmission resources.

54. The method of claim 53, wherein the one or more pre-configured rules comprise one or more rules for determining one or more retransmission resource positions based on an offset relative to a Physical Downlink Control Channel (PDCCH) transmission or a Physical Downlink Shared Channel (PDSCH) transmission.

55. The method of any one of claims 48 to 50, wherein:

multiple retransmission resource options are configured for each retransmission; and

determining the set of one or more retransmission resources comprises performing blind detection to determine, for each retransmitted code block, a particular retransmission resource used for retransmission of the code block from among the multiple retransmission resource options configured for each retransmission.

56. The method of any one of claims 48 to 55, wherein each retransmitted code block of the one or more of the code blocks is retransmitted using a fixed payload size based on the payload type of the code block.

57. The method of any one of claims 48 to 55, wherein:

a set of two or more fixed payload size options is configured for retransmissions; and

receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises determining, for each retransmitted code block, a particular fixed payload size selected from among the set of two or more fixed payload size options.

58. The method of claim 57, wherein determining, for each retransmitted code block, a particular fixed payload size selected from among the set of two or more fixed payload size options comprises:

selecting the particular fixed payload size from among the set of two or more fixed payload size options based on at least one of the payload type of the content block or a transmission mode to be used for the retransmission of the code block.

59. The method of any one of claims 38 to 58, wherein receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises:

detecting a retransmission trigger;

transmitting, to the apparatus, retransmission scheduling information for the one or more of the code blocks; and

receiving the one or more retransmitted code blocks of the plurality of code blocks in accordance with the scheduling information.

60. The method of claim 59, wherein detecting the retransmission trigger comprises:

detecting the retransmission trigger based on decoding feedback for the plurality of code blocks.

61. The method of claim 60, wherein the retransmission scheduling information for the one or more of the code blocks comprises at least one of:

transport block retransmission scheduling information indicating one or more transport block indexes corresponding to one or more transport blocks containing the one or more of the code blocks; or

code block retransmission scheduling information indicating one or more code block indexes corresponding to the one or more of the code blocks.

62. The method of any one of claims 38 to 47, wherein receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises, for at least one code block of the one or more of the code blocks:

receiving one or more redundancy versions of the code block automatically retransmitted without waiting for decoding feedback for an initial transmission of the code block.

63. The method of claim 61, further comprising:

transmitting, to the apparatus, resource allocation information indicating:

a transmission resource allocated for the initial transmission of the code block; and

a set of one or more retransmission resources allocated for transmission of the one or more redundancy versions of the code block.

64. The method of claim 63, wherein the resource allocation information is transmitted via Downlink Control Information (DCI) on a Physical Downlink Control Channel (PDCCH).

65. The method of any one of claims 62 to 64, wherein, for each code block of the at least one code block, a total number of transmissions for the code block, inclusive of the initial transmission of the code block and the one or more transmissions of redundancy versions of the code block, is restricted to a maximum value, T_{max}, wherein $T_{max} \leq 4$.

66. The method of any one of claims 62 to 65, wherein a maximum number of redundancy versions defined for each code block of the one or more of the code blocks is 2.

67. The method of any one of claims 38 to 47, wherein receiving, from the apparatus, the plurality of code blocks comprises, for at least one code block of the plurality of code blocks:

receiving the at least one code block from the apparatus using a modulation and coding scheme (MCS) selected from a first set of MCS options, wherein the first set of MCS options is selected from a plurality of sets of MCS options based on the payload type of the code block.

68. The method of claim 67, wherein the plurality of sets of MCS options comprises:

the first set of MCS options; and

at least a second set of MCS options, wherein MCS options in the first set of MCS options are more conservative in terms of at least one of coding rate or modulation order relative to corresponding MCS options in the second set of MCS options.

69. The method of any one of claims 38 to 47, wherein:

receiving, from the apparatus, the plurality of code blocks comprises, for at least one code block of the plurality of code blocks, receiving the at least one code block from the apparatus using a modulation and coding scheme (MCS) selected from a first set of MCS options using a first set of pre-configured rules for MCS selection; and

receiving, from the apparatus, one or more retransmitted code blocks of the plurality of code blocks comprises, for the at least one code block of the plurality of code blocks, receiving one or more of the at least one code block using a MCS selected from the first set of MCS options using a second set of pre-configured rules for MCS selection, wherein the second set of pre-configured rules for MCS selection is different from the first set of pre-configured rules for MCS selection.

70. The method of claim 69, wherein the second set of pre-configured rules for MCS selection is more conservative than the first set of pre-configured rules for MCS selection in that, in at least some cases, the second set of pre-configured rules for MCS selection prescribes selection of an MCS option having at least one of lower coding rate or lower modulation order than an MCS option that would otherwise be prescribed for selection by the first set of pre-configured rules for MCS selection.

71. The method of any one of claims 38 to 70, wherein the first information channel is configured to carry at least one of:

control information;

physical-layer data;

sensing information (SSI);

artificial intelligence (AI)-related information (AII);

transmission mode and phase information;

quality of service indicator (QoSI); or

positioning reference signal (PRS).

72. The method of any one of claims 38 to 70, wherein the receiving of the plurality of code blocks and the receiving of one or more retransmitted code blocks is done in a downlink direction, an uplink direction, or a sidelink direction.

73. The method of claim 71, wherein the first information is associated with at least one of:

physical-layer data transport;

sensing;

intra-radio access network (RAN) communication; or

artificial intelligence (AI) or machine learning (ML).

74. A device comprising:

at least one processor coupled with a computer-readable medium storing computer-executable instructions that, when executed, cause the device to perform the method of any one of claims 38 to 73.

75. A non-transitory computer-readable storage medium, wherein the computer-readable storage medium stores computer-executable instructions that, when executed by a computer, enable the computer to perform the method of any one of claims 1 to 37 or claims 38 to 74.