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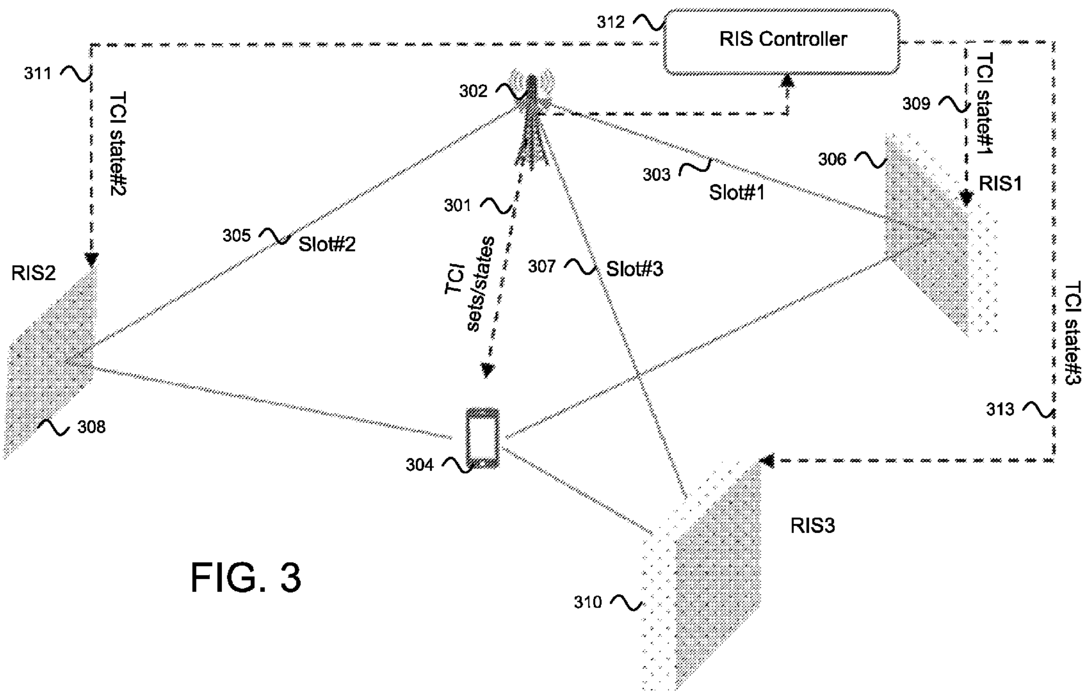

FIG. 3

(57) Abstract: Apparatuses, methods, and systems are disclosed for repetition using reconfigurable intelligent surfaces. An apparatus (800) includes a processor (805) and a memory (810) that is coupled to the processor (805). The memory (810) includes instructions that are executable by the processor (805) to cause the apparatus (800) to determine a first configuration for a repetition of a signal via at least one RIS, determine a second configuration for reflecting the repetition of the signal, determine a third configuration of a pattern of slot repetition for reflecting the signal, and transmit the first configuration to a UE) and the second and third configurations to the at least one RIS.

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TECHNIQUES FOR SIGNAL REPETITION USING RECONFIGURABLE INTELLIGENT SURFACES

FIELD

[0001] The subject matter disclosed herein relates generally to wireless communications and more particularly relates to techniques for signal repetition using reconfigurable intelligent surfaces ("RISs").

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB ("eNB"), a next-generation NodeB ("gNB"), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment ("UE"), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation ("3G") radio access technology, fourth generation ("4G") radio access technology, fifth generation ("5G") radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation ("6G")). In the wireless communications system, one or more of the network communication devices (e.g., base stations) or the user communication devices (e.g., UEs) may support one or multiple CG configurations for wireless communications (e.g., downlink communications, uplink communications).

BRIEF SUMMARY

[0003] Disclosed are procedures for repetition using RISs. Said procedures may be implemented by apparatus, systems, methods, or computer program products.

[0004] In one embodiment, a first apparatus includes a processor and a memory coupled to the processor. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to determine a first configuration for a repetition of a signal via at least one RIS, the signal comprising an uplink ("UL") signal or a downlink ("DL") signal, determine a second configuration for reflecting the repetition of the signal, determine a third configuration of a pattern of slot repetition for reflecting the signal, and transmit the first configuration to a UE and the second and third configurations to the at least one RIS.

[0005] In one embodiment, a first method determines a first configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, determines a second configuration for reflecting the repetition of the signal, determines a third configuration of a pattern of slot repetition for reflecting the signal, and transmits the first configuration to a UE and the second and third configurations to the at least one RIS.

[0006] In one embodiment, a second apparatus includes a processor and a memory coupled to the processor. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to receive, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to configure the apparatus with the received repetition configuration and receive, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition.

[0007] In one embodiment, a second method receives, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected. In one embodiment, the second method configures the apparatus with the received repetition configuration and receives, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition.

[0008] In one embodiment, a third apparatus includes a processor and a memory coupled to the processor. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to receive a first configuration for reflecting repetitions of a signal, the signal comprising an UL signal or a DL signal, receive a second configuration defining a pattern of slot repetition for reflecting the signal, configure the apparatus with the received first and second configurations, and transmit or receive reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations.

[0009] In one embodiment, a third method receives a first configuration for reflecting repetitions of a signal, the signal comprising an UL signal or a DL signal, receive a second configuration defining a pattern of slot repetition for reflecting the signal, configures the apparatus with the received first and second configurations, and transmits or receives reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A more particular description of the embodiments briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only some embodiments and are not therefore to be considered to be limiting of scope, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings, in which:

[0011] Figure 1 illustrates an example of a wireless communications system that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0012] Figure 2 illustrates an example of a new radio (“NR”) protocol stack that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0013] Figure 3 illustrates an example of configuring a RIS and a UE with multiple transmission configuration indicator (“TCI”) sets/states for UL repetition via multiple RISs that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0014] Figure 4 illustrates an example of configuring a UE with the same repetition configurations and the order of TCI states for the scheduled physical uplink shared channels (“PUSCHs”) that support techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0015] Figure 5 illustrates an example of configuring a UE with different repetition configurations for different scheduled PUSCHs that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0016] Figure 6 illustrates an example of configuring RISs with a pattern of spatial information based on the repetition configuration for each UE that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0017] Figure 7 illustrates an example of a UE apparatus that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0018] Figure 8 illustrates an example of a network equipment ("NE") apparatus that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0019] Figure 9 illustrates a flowchart of a method that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0020] Figure 10 illustrates a flowchart of a method that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0021] Figure 11 illustrates a flowchart of a method that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0022] Generally, the present disclosure describes systems, methods, and apparatus for repetition using RISs. In certain embodiments, the methods may be performed using computer code embedded on a computer-readable medium. In certain embodiments, an apparatus or system may include a computer-readable medium containing computer-readable code which, when executed by a processor, causes the apparatus or system to perform at least a portion of the below described solutions.

[0023] In one embodiment, a potential application of RISs is the coverage extension of DL and/or UL signals, e.g., in the case of signal blockage that causes drop of signal to noise ratio ("SNR") or beam failure of the DL/UL beams. RISs may be configured with the help of control information from the network for efficient reflection of the signal that makes use of time and spatial information of the Uu link provided by the network. This information may include time as well as common and UE dedicated spatial information for beamforming. The ability to control the surface to perform a specific beamforming of the reflected signal to a preferred direction with configurable beam gain/width opens the door for many applications.

[0024] In one embodiment, the coverage extension using RISs can be further enhanced by incorporating repetition of the signal using multiple RISs in the network. Because the RISs connected to the same network can reflect the signal from different angles to the UE, the coverage gain goes beyond repetition gain and further spatial diversity can be achieved. However, to perform this, both the UE and the RISs need to be simultaneously configured with corresponding spatial information for each repetition. In this disclosure, signaling for UL/DL repetition using RISs to enhance the UL and/or DL coverage is proposed.

[0025] In one embodiment, UE configuration with multiple TCI states/multiple quasi co-location ("QCL") assumptions for different repetitions of the same physical downlink shared channel ("PDSCH") and/or physical uplink shared channel ("PUSCH") transmission is disclosed. In one embodiment, configuring the UE with multiple TCI sets where each TCI set is associated with one RIS, is disclosed. In one embodiment, configuring RIS with spatial information corresponding to the configured TCI states of the UE is disclosed. In one embodiment, configuring the RIS with a pattern of spatial information where the pattern is associated with the configured repetition information of the UE is disclosed.

[0026] Figure 1 illustrates an example of a wireless communications system 100 that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure. In one embodiment, the wireless communication system 100 includes at least one remote unit 105, a radio access network ("RAN") 120, and a mobile core network 140. The RAN 120 and the mobile core network 140 form a mobile communication network. The RAN 120 may be composed of a base unit 121 with which the remote unit 105 communicates using wireless communication links 123. Even though a specific number of remote units 105, base units 121, wireless communication links 123, RANs 120, and mobile core networks 140 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 105, base units 121, wireless communication links 123, RANs 120, and mobile core networks 140 may be included in the wireless communication system 100.

[0027] In one implementation, the RAN 120 is compliant with the Fifth Generation ("5G") system specified in the Third Generation Partnership Project ("3GPP") specifications. For example, the RAN 120 may be a Next Generation Radio Access Network ("NG-RAN"), implementing NR Radio Access Technology ("RAT") and/or Long-Term Evolution ("LTE") RAT. In another example, the RAN 120 may include non-3GPP RAT (e.g., Wi-Fi® or Institute of Electrical and Electronics Engineers ("IEEE") 802.11-family compliant WLAN). In another implementation, the RAN 120 is compliant with the LTE system specified in the 3GPP specifications. More generally, however, the wireless communication system 100 may implement some other open or proprietary communication network, for example Worldwide Interoperability for Microwave Access ("WiMAX") or IEEE 802.16-family standards, among other networks. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0028] In one embodiment, the remote units 105 may include computing devices, such as desktop computers, laptop computers, personal digital assistants ("PDAs"), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet), smart appliances (e.g., appliances connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), or the like. In some embodiments, the remote units 105 include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units 105 may be referred to as the UEs, subscriber units, mobiles, mobile stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, user terminals, wireless transmit/receive unit ("WTRU"), a device, or by other terminology used in the art. In various embodiments, the remote unit 105 includes a subscriber identity and/or identification module ("SIM") and the mobile equipment ("ME") providing mobile termination functions (e.g., radio transmission, handover, speech encoding and decoding, error detection and correction, signaling and access to the SIM). In certain embodiments, the remote unit 105 may include a terminal equipment ("TE") and/or be embedded in an appliance or device (e.g., a computing device, as described above).

[0029] The remote units 105 may communicate directly with one or more of the base units 121 in the RAN 120 via UL and DL communication signals. Furthermore, the UL and DL communication signals may be carried over the wireless communication links 123. Here, the RAN 120 is an intermediate network that provides the remote units 105 with access to the mobile core network 140.

[0030] In various embodiments, the remote units 105 may communicate directly with each other (e.g., device-to-device communication) using sidelink communication 113. Here, sidelink transmissions may occur on sidelink resources. A remote unit 105 may be provided with different sidelink communication resources according to different allocation modes. Mode-1 corresponds to a NR-based network-scheduled sidelink communication mode, wherein the in-coverage RAN 120 indicates resources for use in sidelink operation, including resources of one or more resource pools. Mode-2 corresponds to a NR-based UE-scheduled sidelink communication mode (i.e., UE-autonomous selection), where the remote unit 105 select a resource pools and resources therein from a set of candidate pools. Mode-3 corresponds to an LTE-based network-scheduled sidelink communication mode. Mode-4 corresponds to an LTE-based UE-scheduled sidelink communication mode (i.e., UE-autonomous selection).

[0031] As used herein, a "resource pool" refers to a set of resources assigned for sidelink operation. A resource pool consists of a set of resource blocks (i.e., Physical Resource Blocks ("PRB")) over one or more time units (e.g., subframe, slots, Orthogonal Frequency Division Multiplexing ("OFDM") symbols). In some embodiments, the set of resource blocks comprises contiguous PRBs in the frequency domain. A PRB, as used herein, consists of twelve consecutive subcarriers in the frequency domain. In certain embodiments, a UE may be configured with separate transmission resource pools ("Tx RPs") and reception resource pools (“Rx RPs”), where the Tx RP of one UE is associated with an Rx RP of another UE to enable sidelink communication.

[0032] In various embodiments, the sidelink communication 113 relates to one or more services requiring sidelink connectivity, such as V2X services and ProSe services. A remote unit 105 may establish one or more sidelink connections with nearby remote units 105. A V2X application 107 running on a remote unit 105 may generate data relating to a V2X service and use a sidelink connection to transmit the V2X data to one or more nearby remote units 105. As described in greater detail below, a remote unit 105 may establish a multipath unicast link to support of service continuity (switch communication to a second path when a first path is lost) and/or redundant connectivity (duplication of packets in the two paths).

[0033] In some embodiments, the remote units 105 communicate with an application server 151 via a network connection with the mobile core network 140. For example, an application 107 (e.g., web browser, media client, telephone and/or Voice-over-Internet-Protocol (“VoIP”) application) in a remote unit 105 may trigger the remote unit 105 to establish a protocol data unit (“PDU”) session (or other data connection) with the mobile core network 140 via the RAN 120. The mobile core network 140 then relays traffic between the remote unit 105 and the application server 151 in the packet data network 150 using the PDU session. The PDU session represents a logical connection between the remote unit 105 and the User Plane Function (“UPF”) 141.

[0034] To establish the PDU session (or Packet Data Network (“PDN”) connection), the remote unit 105 must be registered with the mobile core network 140 (also referred to as “attached to the mobile core network” in the context of a Fourth Generation (“4G”) system). Note that the remote unit 105 may establish one or more PDU sessions (or other data connections) with the mobile core network 140. As such, the remote unit 105 may concurrently have at least one PDU session for communicating with the packet data network 150. The remote unit 105 may establish additional PDU sessions for communicating with other data networks and/or other communication peers.

[0035] In the context of a 5G system (“5GS”), the term “PDU Session” refers to a data connection that provides end-to-end (“E2E”) user plane (“UP”) connectivity between the remote unit 105 and a specific Data Network (“DN”) through the UPF 141. A PDU Session supports one or more Quality of Service (“QoS”) Flows. In certain embodiments, there may be a one-to-one mapping between a QoS Flow and a QoS profile, such that all packets belonging to a specific QoS Flow have the same 5G QoS Identifier (“5QI”).

[0036] In the context of a 4G/LTE system, such as the Evolved Packet System (“EPS”), a PDN connection (also referred to as EPS session) provides E2E UP connectivity between the remote unit and a PDN. The PDN connectivity procedure establishes an EPS Bearer, i.e., a tunnel between the remote unit 105 and a PDN Gateway (“PGW”, not shown) in the mobile core network 140. In certain embodiments, there is a one-to-one mapping between an EPS Bearer and a QoS profile, such that all packets belonging to a specific EPS Bearer have the same QoS Class Identifier (“QCI”).

[0037] The base units 121 may be distributed over a geographic region. In certain embodiments, a base unit 121 may also be referred to as an access terminal, an access point, a base, a base station, a Node-B (“NB”), an Evolved Node B (abbreviated as eNodeB or “eNB,” also known as Evolved Universal Terrestrial Radio Access Network (“E-UTRAN”) Node B), a 5G/NR gNB, a Home Node-B, a relay node, a RAN node, or by any other terminology used in the art. The base units 121 are generally part of a RAN, such as the RAN 120, that may include one or more controllers communicably coupled to one or more corresponding base units 121. These and other elements of radio access network are not illustrated but are well known generally by those having ordinary skill in the art. The base units 121 connect to the mobile core network 140 via the RAN 120.

[0038] The base units 121 may serve a number of remote units 105 within a serving area, for example, a cell or a cell sector, via a wireless communication link 123. The base units 121 may communicate directly with one or more of the remote units 105 via communication signals. Generally, the base units 121 transmit DL communication signals to serve the remote units 105 in the time, frequency, and/or spatial domain. Furthermore, the DL communication signals may be carried over the wireless communication links 123. The wireless communication links 123 may be any suitable carrier in licensed or unlicensed radio spectrum. The wireless communication links 123 facilitate communication between one or more of the remote units 105 and/or one or more of the base units 121. Note that during NR operation on unlicensed spectrum (referred to as “NR-U”), the base unit 121 and the remote unit 105 communicate over unlicensed (i.e., shared) radio spectrum.

[0039] In one embodiment, the mobile core network 140 is a 5G core (“5GC”) or an Evolved Packet Core (“EPC”), which may be coupled to a packet data network 150, like the Internet and private data networks, among other data networks. A remote unit 105 may have a subscription or other account with the mobile core network 140. In various embodiments, each mobile core network 140 belongs to a single mobile network operator (“MNO”) and/or Public Land Mobile Network (“PLMN”). The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0040] The mobile core network 140 includes several network functions ("NFs"). As depicted, the mobile core network 140 includes at least one UPF 141. The mobile core network 140 also includes multiple control plane ("CP") functions including, but not limited to, an Access and Mobility Management Function ("AMF") 143 that serves the RAN 120, a Session Management Function ("SMF") 145, a Policy Control Function ("PCF") 147, a Unified Data Management function ("UDM") and a User Data Repository ("UDR", also referred to as "Unified Data Repository"). Although specific numbers and types of network functions are depicted in Figure 1, one of skill in the art will recognize that any number and type of network functions may be included in the mobile core network 140.

[0041] The UPF(s) 141 is/are responsible for packet routing and forwarding, packet inspection, QoS handling, and external PDU session for interconnecting Data Network ("DN"), in the 5G architecture. The AMF 143 is responsible for termination of Non-Access Stratum ("NAS") signaling, NAS ciphering and integrity protection, registration management, connection management, mobility management, access authentication and authorization, security context management. The SMF 145 is responsible for session management (i.e., session establishment, modification, release), remote unit (i.e., UE) Internet Protocol ("IP") address allocation and management, DL data notification, and traffic steering configuration of the UPF 141 for proper traffic routing.

[0042] The PCF 147 is responsible for unified policy framework, providing policy rules to CP functions, access subscription information for policy decisions in UDR. The UDM is responsible for generation of Authentication and Key Agreement ("AKA") credentials, user identification handling, access authorization, subscription management. The UDR is a repository of subscriber information and may be used to service a number of network functions. For example, the UDR may store subscription data, policy-related data, subscriber-related data that is permitted to be exposed to third party applications, and the like. In some embodiments, the UDM is co-located with the UDR, depicted as combined entity "UDM/UDR" 149.

[0043] In various embodiments, the mobile core network 140 may also include a Network Repository Function ("NRF") (which provides Network Function ("NF") service registration and discovery, enabling NFs to identify appropriate services in one another and communicate with each other over Application Programming Interfaces ("APIs")), a Network Exposure Function ("NEF") (which is responsible for making network data and resources easily accessible to customers and network partners), an Authentication Server Function

("AUSF"), or other NFs defined for the 5GC. When present, the AUSF may act as an authentication server and/or authentication proxy, thereby allowing the AMF 143 to authenticate a remote unit 105. In certain embodiments, the mobile core network 140 may include an authentication, authorization, and accounting ("AAA") server.

[0044] In various embodiments, the mobile core network 140 supports different types of mobile data connections and different types of network slices, wherein each mobile data connection utilizes a specific network slice. Here, a "network slice" refers to a portion of the mobile core network 140 optimized for a certain traffic type or communication service. For example, one or more network slices may be optimized for enhanced mobile broadband ("eMBB") service. As another example, one or more network slices may be optimized for ultra-reliable low-latency communication ("URLLC") service. In other examples, a network slice may be optimized for machine-type communication ("MTC") service, massive MTC ("mMTC") service, Internet-of-Things ("IoT") service. In yet other examples, a network slice may be deployed for a specific application service, a vertical service, a specific use case, etc.

[0045] A network slice instance may be identified by a single-network slice selection assistance information ("S-NSSAI") while a set of network slices for which the remote unit 105 is authorized to use is identified by network slice selection assistance information ("NSSAI"). Here, "NSSAI" refers to a vector value including one or more S-NSSAI values. In certain embodiments, the various network slices may include separate instances of network functions, such as the SMF 145 and UPF 141. In some embodiments, the different network slices may share some common network functions, such as the AMF 143. The different network slices are not shown in Figure 1 for ease of illustration, but their support is assumed.

[0046] While Figure 1 depicts components of a 5G RAN and a 5G core network, the described embodiments for repetition using RISs apply to other types of communication networks and RATs, including IEEE 802.11 variants, Global System for Mobile Communications ("GSM"), i.e., a 2G digital cellular network), General Packet Radio Service ("GPRS"), Universal Mobile Telecommunications System ("UMTS"), LTE variants, CDMA 2000, Bluetooth, ZigBee, Sigfox, and the like.

[0047] Moreover, in an LTE variant where the mobile core network 140 is an EPC, the depicted network functions may be replaced with appropriate EPC entities, such as a Mobility Management Entity ("MME"), a Serving Gateway ("SGW"), a PGW, a Home Subscriber Server ("HSS"), and the like. For example, the AMF 143 may be mapped to an MME, the SMF 145 may be mapped to a control plane portion of a PGW and/or to an MME, the UPF 141 may be mapped to an SGW and a user plane portion of the PGW, the UDM/UDR 149 may be mapped to an HSS, etc.

[0048] In the following descriptions, the term “RAN node” is used for the base station/ base unit, but it is replaceable by any other radio access node, e.g., gNB, ng-eNB, eNB, Base Station (“BS”), Access Point (“AP”), etc. Additionally, the term “UE” is used for the mobile station/remote unit, but it is replaceable by any other remote device, e.g., remote unit, MS, ME, etc. Further, the operations are described mainly in the context of 5G NR. However, the below described solutions/methods are also equally applicable to other mobile communication systems for repetition using RISs.

[0049] Figure 2 illustrates an example of a NR protocol stack that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure. While Figure 2 shows the UE 205, the RAN node 210 and a 5G core network 220, these are representative of a set of remote units 105 interacting with a base unit 121 (or gNB) and a mobile core network 140. As depicted, the protocol stack 200 comprises a User Plane protocol stack 201 and a Control Plane protocol stack 203. The User Plane protocol stack 201 includes a physical (“PHY”) layer 207, a Medium Access Control (“MAC”) sublayer 209, the Radio Link Control (“RLC”) sublayer 211, a Packet Data Convergence Protocol (“PDCP”) sublayer 213, and a Service Data Adaptation Protocol (“SDAP”) sublayer 215. The Control Plane protocol stack 203 includes a physical layer 207, a MAC sublayer 209, a RLC sublayer 211, and a PDCP sublayer 213. The Control Plane protocol stack 203 also includes a Radio Resource Control (“RRC”) sublayer 217 and a Non-Access Stratum (“NAS”) layer 219.

[0050] The AS layer 221 (also referred to as “AS protocol stack”) for the User Plane protocol stack 201 consists of at least SDAP, PDCP, RLC and MAC sublayers, and the physical layer. The AS layer 223 for the Control Plane protocol stack 203 consists of at least RRC, PDCP, RLC and MAC sublayers, and the physical layer. The Layer-1 (“L1”) consists of the PHY layer 207. The Layer-2 (“L2”) is split into the SDAP, PDCP, RLC and MAC sublayers. The Layer-3 (“L3”) includes the RRC sublayer 217 and the NAS layer 219 for the control plane and includes, e.g., an Internet Protocol (“IP”) layer or PDU Layer (note depicted) for the user plane. L1 and L2 are referred to as “lower layers,” while L3 and above (e.g., transport layer, application layer) are referred to as “higher layers” or “upper layers.”

[0051] The physical layer 207 offers transport channels to the MAC sublayer 209. The MAC sublayer 209 offers logical channels to the RLC sublayer 211. The RLC sublayer 211 offers RLC channels to the PDCP sublayer 213. The PDCP sublayer 213 offers radio bearers to the SDAP sublayer 215 and/or RRC layer 217. The SDAP sublayer 215 offers QoS flows to the core network (e.g., 5GC 220). The RRC layer 217 provides for the addition, modification, and release of Carrier Aggregation and/or Dual Connectivity. The RRC layer 217 also manages the establishment, configuration, maintenance, and release of Signaling Radio Bearers ("SRBs") and Data Radio Bearers ("DRBs").

[0052] In general, RISs, also known as intelligent reflecting surfaces ("IRSs"), or large intelligent surfaces ("LISs"), have potential to enhance the capacity and coverage of wireless networks by intelligently reconfiguring the propagation environment by adjusting the phase and the amplitude of the RIS elements. It is considered as a promising technology for the sixth generation ("6G") wireless communication networks due to its cost effectiveness since RIS technology requires neither digital-to-analog converter ("DAC")/DAC converters nor power amplifiers, and hence meets the green communications requirements.

[0053] In one embodiment, RISs are made of large number of low-cost and passive elements that can modify the radio waves impinging upon them and can be easily coated on the existing infrastructures. However, RISs may potentially have a large impact on designing of the future wireless systems, especially when integrated with other emerging and advanced technologies such as Terahertz communication, massive multiple input/multiple output ("MIMO"), artificial intelligence ("AI")/machine learning ("ML") based systems, or the like, and can be used for different applications such as communication, sensing, positioning, or the like. To control the phases and amplitude of the RIS elements, in one embodiment, interface to the network is needed to adapt the reflection characteristics of the RIS based on the channel conditions and the transmission needs.

[0054] Regarding antenna ports quasi co-location, e.g., according to 3GPP TS 38.214 (incorporated herein by reference), a UE can be configured with a list of up to M TCI-State configurations within the higher layer parameter PDSCH-Config to decode PDSCH according to a detected physical downlink control channel ("PDCCH") with downlink control information ("DCI") intended for the UE and the given serving cell, where M depends on the UE capability *maxNumberConfiguredTCIstatesPerCC*. Each TCI-State contains parameters for configuring a quasi co-location relationship between one or two downlink reference signals and the demodulation reference signal ("DM-RS") ports of the PDSCH, the DM-RS port of PDCCH or the channel state information reference signal ("CSI-RS") port(s) of a CSI-RS resource. The quasi co-location relationship is configured by the higher layer parameter qcl-Type1 for the first DL RS, and qcl-Type2 for the second DL RS (if configured). For the case of two DL RSs, the QCL types shall not be the same, regardless of whether the references are to the same DL RS or different DL RSs. The quasi co-location types corresponding to each DL

RS are given by the higher layer parameter qcl-Type in QCL-Info and may take one of the following values - 'typeA': {Doppler shift, Doppler spread, average delay, delay spread}; 'typeB': {Doppler shift, Doppler spread}; 'typeC': {Doppler shift, average delay}; 'typeD': {Spatial Rx parameter}.

[0055] The UE receives an activation command, e.g., as described in clause 6.1.3.14 of TS 38.321 (incorporated herein by reference), used to map up to 8 TCI states to the codepoints of the DCI field 'Transmission Configuration Indication' in one component carrier ("CC")/DL bandwidth part ("BWP") or in a set of CCs/DL BWPs, respectively. When a set of TCI state IDs are activated for a set of CCs/DL BWPs, where the applicable list of CCs is determined by indicated CC in the activation command, the same set of TCI state IDs are applied for all DL BWPs in the indicated CCs.

[0056] When a UE supports two TCI states in a codepoint of the DCI field 'Transmission Configuration Indication' the UE may receive an activation command, e.g., as described in clause 6.1.3.24 of TS 38.321, the activation command is used to map up to 8 combinations of one or two TCI states to the codepoints of the DCI field 'Transmission Configuration Indication'. The UE is not expected to receive more than 8 TCI states in the activation command.

[0057] When the DCI field 'Transmission Configuration Indication' is present in DCI format 1_2 and when the number of codepoints S in the DCI field 'Transmission Configuration Indication' of DCI format 1_2 is smaller than the number of TCI codepoints that are activated by the activation command, e.g., as described in clauses 6.1.3.14 and 6.1.3.24 of TS3 8.321, only the first S activated codepoints are applied for DCI format 1_2.

[0058] When the UE would transmit a physical uplink control channel ("PUCCH") with HARQ-ACK information in slot n corresponding to the PDSCH carrying the activation command, the indicated mapping between TCI states and codepoints of the DCI field 'Transmission Configuration Indication' should be applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where m is the subcarrier spacing ("SCS") configuration for the PUCCH. If *tci-PresentInDCI* is set to 'enabled' or *tci-PresentDCI-1-2* is configured for the control resource set ("CORESET") scheduling the PDSCH, and the time offset between the reception of the DL DCI and the corresponding PDSCH is equal to or greater than *timeDurationForQCL* if applicable, after a UE receives an initial higher layer configuration of TCI states and before reception of the activation command, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the SS/PBCH block determined in the initial access procedure with respect to qcl-Type set to 'typeA', and when applicable, also with respect to qcl-Type set to 'typeD'.

[0059] If a UE is configured with the higher layer parameter *tci-PresentInDCI* that is set as 'enabled' for the CORESET scheduling the PDSCH, the UE assumes that the TCI field is present in the DCI format 1_1 of the PDCCH transmitted on the CORESET. If a UE is configured with the higher layer parameter *tci-PresentDCI-1-2* for the CORESET scheduling the PDSCH, the UE assumes that the TCI field with a DCI field size indicated by *tci-PresentDCI-1-2* is present in the DCI format 1_2 of the PDCCH transmitted on the CORESET. If the PDSCH is scheduled by a DCI format not having the TCI field present, and the time offset between the reception of the DL DCI and the corresponding PDSCH of a serving cell is equal to or greater than a threshold *timeDurationForQCL* if applicable, where the threshold is based on reported UE capability, e.g., according to TS 38.306 (incorporated herein by reference), for determining PDSCH antenna port quasi co-location, the UE assumes that the TCI state or the QCL assumption for the PDSCH is identical to the TCI state or QCL assumption whichever is applied for the CORESET used for the PDCCH transmission within the active BWP of the serving cell.

[0060] If the PDSCH is scheduled by a DCI format having the TCI field present, the TCI field in DCI in the scheduling component carrier points to the activated TCI states in the scheduled component carrier or DL BWP, the UE shall use the TCI-State according to the value of the 'Transmission Configuration Indication' field in the detected PDCCH with DCI for determining PDSCH antenna port quasi co-location. The UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL type parameter(s) given by the indicated TCI state if the time offset between the reception of the DL DCI and the corresponding PDSCH is equal to or greater than a threshold *timeDurationForQCL*, where the threshold is based on reported UE capability, e.g., according to TS 38.306.

[0061] When the UE is configured with a single slot PDSCH, the indicated TCI state should be based on the activated TCI states in the slot with the scheduled PDSCH. When the UE is configured with a multi-slot PDSCH, the indicated TCI state should be based on the activated TCI states in the first slot with the scheduled PDSCH, and UE shall expect the activated TCI states are the same across the slots with the scheduled PDSCH. When the UE is configured with CORESET associated with a search space set for cross-carrier scheduling and the UE is not configured with *enableDefaultBeamForCCS*, the UE expects *tci-PresentInDCI* is set as 'enabled' or *tci-PresentDCI-1-2* is configured for the CORESET, and if one or more of the TCI states configured for the serving cell scheduled by the search space set contains qcl-Type set to 'typeD', the UE expects the time offset between the reception of the detected PDCCH in the search space set and the corresponding PDSCH is larger than or equal to the threshold *timeDurationForQCL*.

[0062] Independent of the configuration of *tci-PresentInDCI* and *tci-PresentDCI-1-2* in RRC connected mode, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *timeDurationForQCL* and at least one configured TCI state for the serving cell of scheduled PDSCH contains qcl-Type set to 'typeD', the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the CORESET associated with a monitored search space with the lowest *controlResourceSetId* in the latest slot in which one or more CORESETs within the active BWP of the serving cell are monitored by the UE. In this case, if the qcl-Type is set to 'typeD' of the PDSCH DM-RS is different from that of the PDCCH DM-RS with which they overlap in at least one symbol, the UE is expected to prioritize the reception of PDCCH associated with that CORESET. This also applies to the intra-band carrier aggregation (“CA”) case (when PDSCH and the CORESET are in different component carriers).

[0063] If a UE is configured with *enableDefaultTCIStatePerCoresetPoolIndex* and the UE is configured by higher layer parameter PDCCH-Config that contains two different values of *coresetPoolIndex* in different *ControlResourceSets*, the UE may assume that the DM-RS ports of PDSCH associated with a value of *coresetPoolIndex* of a serving cell are quasi co-located with the RS(s) with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the CORESET associated with a monitored search space with the lowest *controlResourceSetId* among CORESETs, which are configured with the same value of *coresetPoolIndex* as the PDCCH scheduling that PDSCH, in the latest slot in which one or more CORESETs associated with the same value of *coresetPoolIndex* as the PDCCH scheduling that PDSCH within the active BWP of the serving cell are monitored by the UE. In this case, if the 'QCL-TypeD' of the PDSCH DM-RS is different from that of the PDCCH DM-RS with which they overlap in at least one symbol and they are associated with same *coresetPoolIndex*, the UE is expected to prioritize the reception of PDCCH associated with that CORESET. This also applies to the intra-band CA case (when PDSCH and the CORESET are in different component carriers).

[0064] If a UE is configured with *enableTwoDefaultTCI*-States, and at least one TCI codepoint indicates two TCI states, the UE may assume that the DM-RS ports of PDSCH or

PDSCH transmission occasions of a serving cell are quasi co-located with the RS(s) with respect to the QCL parameter(s) associated with the TCI states corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states. When the UE is configured by higher layer parameter *repetitionScheme* set to 'tdmSchemeA' or is configured with higher layer parameter *repetitionNumber*, the mapping of the TCI states to PDSCH transmission occasions is determined, e.g., according to clause 5.1.2.1, by replacing the indicated TCI states with the TCI states corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states based on the activated TCI states in the slot with the first PDSCH transmission occasion. In this case, if the 'QCL-TypeD' in both of the TCI states corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states is different from that of the PDCCH DM-RS with which they overlap in at least one symbol, the UE is expected to prioritize the reception of PDCCH associated with that CORESET. This also applies to the intra-band CA case (when PDSCH and the CORESET are in different component carriers).

[0065] In all cases above, if none of configured TCI states for the serving cell of scheduled PDSCH is configured with qcl-Type set to 'typeD', the UE shall obtain the other QCL assumptions from the indicated TCI states for its scheduled PDSCH irrespective of the time offset between the reception of the DL DCI and the corresponding PDSCH.

[0066] Figure 3 illustrates an example of configuring a RIS and a UE with multiple TCI sets/states for UL repetition via multiple RISs that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure According to a first embodiment, a network node 302, e.g., a base station with a local RIS control function, transmits a first configuration message 301 to a UE 304 for repetition of the DL and/or UL physical channels. The configuration contains information about the physical channel to be repeated in multiple slots, the number of repetitions associated with each physical channel, and TCI sets each with a TCI state for each repetition. The TCI states for different repetitions are associated with different RISs 306-310 connected to the network node 302 and each TCI set corresponds to one RIS 306-310. In one embodiment, the network node 302 transmits a second configuration 303-307 to the connected and synchronized RISs 306-310 involved in reflecting the repetitions of the signal towards and/or from the UE 304. In one embodiment, the second configuration contains information of the TCI states/spatial information that to be translated by the RIS controller 312 to phase/amplitude information of the elements of the surface for different time slots, and the TCI state of each RIS 306-310 is associated with the TCI state transmitted to the UE 304 in the first configuration of the given time slot.

[0067] As used herein, spatial information may refer to phase/amplitude values for RIS elements to be applied so that the signal is reflected towards a certain direction. For instance, the spatial information can be the absolute phases/amplitudes of RIS elements, can be an index to a matrix of phases/amplitudes, or can be an angle of reflection. In one embodiment, the RIS controller applies the suitable phases/amplitudes on the RIS elements so that the signal is reflected to the required angle.

[0068] In one embodiment, the UE 304 is preconfigured with multiple TCI sets (e.g., TCI set#1 – TCI set#N), each TCI set is associated with one RIS 306-310, and each TCI set contains multiple TCI states 309-313 (e.g., TCI state#1- TCI state#M) representing different spatial information of the reflected signal from a RIS 306-310. In one embodiment, the UE 304 is indicated in the DCI with the enabled TCI state for each TCI set.

[0069] In one embodiment, each TCI state 309-313 in a TCI set is associated with a TCI state/spatial information of one RIS 306-310 in a given time slot, as shown in Figure 4. Figure 4 illustrates an example of configuring a UE with the same repetition configurations and the order of TCI states for the scheduled PUSCHs that support techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0070] In one implementation, the UE 304 may assume that the TCI state or the QCL assumption of the first repetition is based on the TCI/QCL/beam (e.g., associated with the CORESET used for the PDCCH transmission within the active BWP of the serving cell). In one embodiment, the UE 304 receives PDCCH reflected from one RIS 306-310, e.g., RIS1 306 with TCI state#1 309. In another implementation, the UE 304 is indicated in the DCI 404 with TCI state 309-313 of the first repetition different than the one used for PDCCH if the offset between receiving the DCI 404 and the first repetition is less than *timeDurationForQCL*. In one embodiment, the UE 304 receives PDCCH carrying the TCI information reflected via one of the RISs 306-310 or directly from the network node 302 and receives different repetitions reflected from different RISs 306-310.

[0071] In one implementation, the UE 304 is configured with the repetition period (e.g., *numberofRepetitions*) for each scheduled DL/UL slot (e.g., new scheduled transport block ("TB") of the PDSCH/PUSCH), where the number of repetitions is the same for different scheduled DL slots and/or for different UL slots. In one embodiment, the UE 304 is indicated with an order of the TCI states from each TCI set, so that the same order is performed for the next scheduled DL and/or UL slot.

[0072] As illustrated in the example of Figure 4, a UE 304 is configured to transmit PUSCH repeated in 3 consecutive slots 402, each with different TCI state 309-313 (e.g., TCI state#1, TCI state#2, TCI state#3), where each TCI state 309-313 belongs to a different TCI set, and each TCI set is associated with one RIS 306-310. In one embodiment, the UE 304 is indicated to apply the same order of TCI states for the next scheduled PUSCH, e.g., for PUSCH#2 same TCI states 309-313 (e.g., TCI state#1, TCI state#2, TCI state#3) are used. In one embodiment, the UE 304 may receive an indication in the DCI to terminate/update the on-going repetition and the TCI states order. In another implementation the UE 304 is expected to receive a different repetition configuration for different scheduled DL/UL slots in the next DCI 502, 504, as shown in Figure 5. Figure 5 illustrates an example of configuring a UE with different repetition configurations for different scheduled PUSCHs that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure.

[0073] In some embodiments, the UE 304 is configured with DL/UL repetition configuration, where some of the consecutive repetitions are reflected from one RIS 306-310 with the same TCI set and same TCI state 309-313.

[0074] According to the first embodiment, a network node 302, e.g., a base station with a local RIS control function transmits a configuration message 303-307 to the connected and synchronized RIS 306-310 involved in reflecting the repetitions of the signal towards and/or from the UE(s) 304. In one embodiment, the configuration contains information about the TCI states/spatial information for different time slots, and each TCI state/spatial information is associated with a TCI state 309-313 indicated by the network node 302 to one UE 304. The network node 302 configures the RIS 306-310 to associate each TCI state/spatial information with multiple slots. In one embodiment, the multiple slots correspond to the number of scheduled PUSCH/PDCCH to be repeated towards the given UE 304. The distance between the slots with the same TCI state is associated with the number of repetitions of the given scheduled PDSCH/PUSCH for the given UE 304.

[0075] Figure 6 illustrates an example of configuring RISs with a pattern of spatial information based on the repetition configuration for each UE that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure. According to a second embodiment, the RISs 608-610 (e.g., RIS1 608) are configured with multiple TCI states for multiple slots of the reflected PDSCH towards multiple UEs 604-608. For example, RIS1 608 is configured with TCI state#1 to be applied for slot#1,4,7 to reflect the signal to UE1 604, which is configured by the network node 602 to receive PDSCH repeated, in addition to RIS1 608, from another two RISs 610, each using a different time slot. For example, from RIS1 608, UE1 604 receives slot#1 with TCI state#1, from RIS2 610, UE1 604 receives slot#2 with TCI state#2, and from RIS3 (not shown), UE1 604 receives slot#3 with TCI state#3, and so on. In one embodiment, the order of the TCIs is kept for slot#4,5, or the like. The configuration is valid until the RIS 608-610 receives an indication/update from the network node 602 with termination of the repetition of a given UE 604-608 or for a given scheduled DL/UL channel, or a change of the number of TCI states and/or the number of repetitions.

[0076] Figure 7 illustrates an example of a UE apparatus 700 that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure. In various embodiments, the UE apparatus 700 is used to implement one or more of the solutions described above. The UE apparatus 700 may be one embodiment of the remote unit 105 and/or the UE 205, described above. Furthermore, the UE apparatus 700 may include a processor 705, a memory 710, an input device 715, an output device 720, and a transceiver 725.

[0077] In some embodiments, the input device 715 and the output device 720 are combined into a single device, such as a touchscreen. In certain embodiments, the UE apparatus 700 may not include any input device 715 and/or output device 720. In various embodiments, the UE apparatus 700 may include one or more of: the processor 705, the memory 710, and the transceiver 725, and may not include the input device 715 and/or the output device 720.

[0078] As depicted, the transceiver 725 includes at least one transmitter 730 and at least one receiver 735. In some embodiments, the transceiver 725 communicates with one or more cells (or wireless coverage areas) supported by one or more base units 121. In various embodiments, the transceiver 725 is operable on unlicensed spectrum. Moreover, the transceiver 725 may include multiple UE panels supporting one or more beams. Additionally, the transceiver 725 may support at least one network interface 740 and/or application interface 745. The application interface(s) 745 may support one or more APIs. The network interface(s) 740 may support 3GPP reference points, such as Uu, N1, PC5, etc. Other network interfaces 740 may be supported, as understood by one of ordinary skill in the art.

[0079] The processor 705, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 705 may be a microcontroller, a microprocessor, a central processing unit (“CPU”), a graphics processing unit (“GPU”), an auxiliary processing unit, a field programmable gate array (“FPGA”), or similar programmable controller. In some embodiments, the processor 705 executes instructions stored in the memory 710 to perform the methods and routines described herein. The processor 705 is communicatively coupled to the memory 710, the input device 715, the output device 720, and the transceiver 725.

[0080] In various embodiments, the processor 705 controls the UE apparatus 700 to implement the above described UE behaviors. In certain embodiments, the processor 705 may include an application processor (also known as "main processor") which manages application-domain and operating system ("OS") functions and a baseband processor (also known as "baseband radio processor") which manages radio functions.

[0081] The memory 710, in one embodiment, is a computer readable storage medium. In some embodiments, the memory 710 includes volatile computer storage media. For example, the memory 710 may include a RAM, including dynamic RAM ("DRAM"), synchronous dynamic RAM ("SDRAM"), and/or static RAM ("SRAM"). In some embodiments, the memory 710 includes non-volatile computer storage media. For example, the memory 710 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory 710 includes both volatile and non-volatile computer storage media.

[0082] In some embodiments, the memory 710 stores data related to repetition using RISs and/or mobile operation. For example, the memory 710 may store various parameters, panel/beam configurations, resource assignments, policies, and the like as described above. In certain embodiments, the memory 710 also stores program code and related data, such as an operating system or other controller algorithms operating on the apparatus 700.

[0083] The input device 715, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 715 may be integrated with the output device 720, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device 715 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 715 includes two or more different devices, such as a keyboard and a touch panel.

[0084] The output device 720, in one embodiment, is designed to output visual, audible, and/or haptic signals. In some embodiments, the output device 720 includes an electronically controllable display or display device capable of outputting visual data to a user. For example, the output device 720 may include, but is not limited to, a Liquid Crystal Display ("LCD"), a Light-Emitting Diode ("LED") display, an Organic LED ("OLED") display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 720 may include a wearable display separate from, but communicatively coupled to, the rest of the UE apparatus 700, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 720 may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0085] In certain embodiments, the output device 720 includes one or more speakers for producing sound. For example, the output device 720 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the output device 720 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all or portions of the output device 720 may be integrated with the input device 715. For example, the input device 715 and output device 720 may form a touchscreen or similar touch-sensitive display. In other embodiments, the output device 720 may be located near the input device 715.

[0086] The transceiver 725 communicates with one or more network functions of a mobile communication network via one or more access networks. The transceiver 725 operates under the control of the processor 705 to transmit messages, data, and other signals and also to receive messages, data, and other signals. For example, the processor 705 may selectively activate the transceiver 725 (or portions thereof) at particular times in order to send and receive messages.

[0087] The transceiver 725 includes at least transmitter 730 and at least one receiver 735. One or more transmitters 730 may be used to provide UL communication signals to a base unit 121, such as the UL transmissions described herein. Similarly, one or more receivers 735 may be used to receive DL communication signals from the base unit 121, as described herein. Although only one transmitter 730 and one receiver 735 are illustrated, the UE apparatus 700 may have any suitable number of transmitters 730 and receivers 735. Further, the transmitter(s) 730 and the receiver(s) 735 may be any suitable type of transmitters and receivers. In one embodiment, the transceiver 725 includes a first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio spectrum and a second transmitter/receiver pair used to communicate with a mobile communication network over unlicensed radio spectrum.

[0088] In certain embodiments, the first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio spectrum and the second transmitter/receiver pair used to communicate with a mobile communication network over unlicensed radio spectrum may be combined into a single transceiver unit, for example a single chip performing functions for use with both licensed and unlicensed radio spectrum. In some embodiments, the first transmitter/receiver pair and the second transmitter/receiver pair may share one or more hardware components. For example, certain transceivers 725, transmitters 730, and receivers 735 may be implemented as physically separate components that access a shared hardware resource and/or software resource, such as for example, the network interface 740.

[0089] In various embodiments, one or more transmitters 730 and/or one or more receivers 735 may be implemented and/or integrated into a single hardware component, such as a multi-transceiver chip, a system-on-a-chip, an Application-Specific Integrated Circuit ("ASIC"), or other type of hardware component. In certain embodiments, one or more transmitters 730 and/or one or more receivers 735 may be implemented and/or integrated into a multi-chip module. In some embodiments, other components such as the network interface 740 or other hardware components/circuits may be integrated with any number of transmitters 730 and/or receivers 735 into a single chip. In such embodiment, the transmitters 730 and receivers 735 may be logically configured as a transceiver 725 that uses one more common control signals or as modular transmitters 730 and receivers 735 implemented in the same hardware chip or in a multi-chip module.

[0090] In one embodiment, the memory 710 includes instructions that are executable by the processor 705 to cause the apparatus 700 to receive, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected. In one embodiment, the memory 710 includes instructions that are executable by the processor 705 to cause the apparatus 700 to configure the apparatus with the received repetition configuration and receive, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition.

[0091] In one embodiment, the instructions are executable by the processor 705 to cause the apparatus 700 to receive a DCI comprising at least one of a new repetition configuration and an update of the existing repetition configuration.

[0092] In one embodiment, the instructions are executable by the processor 705 to cause the apparatus 700 to receive a first repetition with a TCI state corresponding to a QCL assumption used for receiving PDCCH.

[0093] In one embodiment, the instructions are executable by the processor 705 to cause the apparatus 700 to receive a DCI comprising an indication of a TCI state of a first repetition that is different than the TCI state or QCL assumption used to receive PDCCH.

[0094] Figure 8 illustrates an example of an NE apparatus 800 that supports techniques for signal repetition using RISs in accordance with aspects of the present disclosure. In one embodiment, network apparatus 800 may be one implementation of a RAN entity, such as the base unit 121 and/or the RAN node 210, as described above. Furthermore, the network apparatus 800 may include a processor 805, a memory 810, an input device 815, an output device 820, and a transceiver 825.

[0095] In some embodiments, the input device 815 and the output device 820 are combined into a single device, such as a touchscreen. In certain embodiments, the network apparatus 800 may not include any input device 815 and/or output device 820. In various embodiments, the network apparatus 800 may include one or more of: the processor 805, the memory 810, and the transceiver 825, and may not include the input device 815 and/or the output device 820.

[0096] As depicted, the transceiver 825 includes at least one transmitter 830 and at least one receiver 835. Here, the transceiver 825 communicates with one or more remote units 105. Additionally, the transceiver 825 may support at least one network interface 840 and/or application interface 845. The application interface(s) 845 may support one or more APIs. The network interface(s) 840 may support 3GPP reference points, such as Uu, N1, N2 and N3. Other network interfaces 840 may be supported, as understood by one of ordinary skill in the art.

[0097] The processor 805, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 805 may be a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or similar programmable controller. In some embodiments, the processor 805 executes instructions stored in the memory 810 to perform the methods and routines described herein. The processor 805 is communicatively coupled to the memory 810, the input device 815, the output device 820, and the transceiver 825.

[0098] In various embodiments, the network apparatus 800 is a RAN node (e.g., gNB) that communicates with one or more UEs, as described herein. In such embodiments, the processor 805 controls the network apparatus 800 to perform the above described RAN behaviors. When operating as a RAN node, the processor 805 may include an application processor (also known as “main processor”) which manages application-domain and operating system (“OS”) functions and a baseband processor (also known as “baseband radio processor”) which manages radio functions.

[0099] The memory 810, in one embodiment, is a computer readable storage medium. In some embodiments, the memory 810 includes volatile computer storage media. For example, the memory 810 may include a RAM, including DRAM, SDRAM, and/or SRAM. In some embodiments, the memory 810 includes non-volatile computer storage media. For example, the memory 810 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory 810 includes both volatile and non-volatile computer storage media.

[0100] In some embodiments, the memory 810 stores data related to repetition using RISs and/or mobile operation. For example, the memory 810 may store parameters, configurations, resource assignments, policies, and the like, as described above. In certain embodiments, the memory 810 also stores program code and related data, such as an operating system or other controller algorithms operating on the apparatus 800.

[0101] The input device 815, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 815 may be integrated with the output device 820, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device 815 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 815 includes two or more different devices, such as a keyboard and a touch panel.

[0102] The output device 820, in one embodiment, is designed to output visual, audible, and/or haptic signals. In some embodiments, the output device 820 includes an electronically controllable display or display device capable of outputting visual data to a user. For example, the output device 820 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 820 may include a wearable display separate from, but communicatively coupled to, the rest of the network apparatus 800, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 820 may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0103] In certain embodiments, the output device 820 includes one or more speakers for producing sound. For example, the output device 820 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the output device 820 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all or portions of the output device 820 may be integrated with the input device 815. For example, the input device 815 and output device 820 may form a touchscreen or similar touch-sensitive display. In other embodiments, the output device 820 may be located near the input device 815.

[0104] The transceiver 825 includes at least transmitter 830 and at least one receiver 835. One or more transmitters 830 may be used to communicate with the UE, as described herein. Similarly, one or more receivers 835 may be used to communicate with network functions in the PLMN and/or RAN, as described herein. Although only one transmitter 830 and one receiver 835 are illustrated, the network apparatus 800 may have any suitable number of transmitters 830 and receivers 835. Further, the transmitter(s) 830 and the receiver(s) 835 may be any suitable type of transmitters and receivers.

[0105] In one embodiment, the memory 810 includes instructions that are executable by the processor 805 to cause the apparatus 800 to determine a first configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, determine a second configuration for reflecting the repetition of the signal, determine a third configuration of a pattern of slot repetition for reflecting the signal, and transmit the first configuration to a UE and the second and third configurations to the at least one RIS.

[0106] In one embodiment, the first configuration comprises information for a physical channel to be repeated using of the at least one RIS and a number of repetitions to be reflected.

[0107] In one embodiment, the first configuration comprises at least one TCI set, each TCI set of the at least one TCI set corresponding to a respective RIS of the at least one RIS.

[0108] In one embodiment, each TCI set of the at least one TCI set corresponds to at least one TCI state for the repetition of the UL or DL signal, or both, via the respective RIS.

[0109] In one embodiment, each TCI set of the at least one TCI set corresponds to spatial information associated with a reflected signal via the respective RIS for a respective slot associated with the slot repetition, and wherein the reflected signal corresponds to the UL signal or the DL signal, or both.

[0110] In one embodiment, the instructions are executable by the processor 805 to cause the apparatus 800 to transmit, to the UE, a RIS configuration comprising a data structure that maps each of one or more TCI sets of the at least one TCI set to each of one or more RISs of the at least one RIS, each of the one or more TCI sets of the at least one TCI set corresponding to a set of TCI states.

[0111] In one embodiment, the instructions are executable by the processor 805 to cause the apparatus 800 to transmit, to the UE, a DCI that enables a respective TCI state for each of one or more TCI states of the set of TCI states associated with a respective TCI set of the at least one TCI set for a respective slot associated with the slot repetition based at least in part on an indication in the received DCI, the indication comprising a TCI state index value.

[0112] In one embodiment, the instructions are executable by the processor 805 to cause the apparatus 800 to transmit, to the UE, a DCI comprising an indication to apply a same order of TCI states corresponding to multiple repetitions used for a scheduled PDSCH/PUSCH, to another scheduled PDSCH/PUSCH.

[0113] In one embodiment, the instructions are executable by the processor 805 to cause the apparatus 800 to transmit, to a RIS of the at least one RIS, a fourth configuration comprising information for TCI states, or spatial information, or both, for each slot, the TCI states associated with configured TCI states of the UE for different repetitions.

[0114] In one embodiment, the instructions are executable by the processor 805 to cause the apparatus 800 to transmit, to a RIS of the at least one RIS, a fourth configuration indicating spatial information to be applied in different slots based on the pattern of slot repetition, the pattern corresponding to a number of UEs, a number of RISs involved in the repetition, and a number of repetitions for each UE.

[0115] In one embodiment, the memory 810 includes instructions that are executable by the processor 805 to cause the apparatus 800 to receive a first configuration for reflecting repetitions of a signal, the signal comprising an UL signal or a DL signal, receive a second configuration defining a pattern of slot repetition for reflecting the signal, configure the apparatus 800 with the received first and second configurations, and transmit or receive reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations.

[0116] Figure 9 depicts one embodiment of a method 900 for repetition using RISs, according to embodiments of the disclosure. In various embodiments, the method 900 is performed by a network entity, such as the base unit 121, the RAN node 210, and/or the network apparatus 800, as described above. In some embodiments, the method 900 is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0117] In one embodiment, the method 900 begins and determines 905 a first configuration for a repetition of a signal via at least one RIS, the signal comprising an uplink signal or a downlink signal. In one embodiment, the method 900 determines a second configuration for reflecting the repetition of the signal. In one embodiment, the method 900 determines 915 a third configuration of a pattern of slot repetition for reflecting the signal. In one embodiment, the method 900 transmits 920 the first configuration to a UE and the second and third configurations to the at least one RIS, and the method 900 ends.

[0118] Figure 10 depicts one embodiment of a method 1000 for repetition using RISs, according to embodiments of the disclosure. In various embodiments, the method 1000 is performed by a UE device, such as the remote unit 105, the UE 205, and/or the UE apparatus 700, as described above. In some embodiments, the method 1000 is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0119] In one embodiment, the method 1000 begins and receives 1005, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected. In one embodiment, the method 1000 configures 1010 an apparatus with the received repetition configuration. In one embodiment, the method 1000 receives 1015, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition, and the method 1000 ends.

[0120] Figure 11 depicts one embodiment of a method 1100 for repetition using RISs, according to embodiments of the disclosure. In various embodiments, the method 1100 is performed by a network device, such as a RIS, as described above. In some embodiments, the method 1100 is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0121] In one embodiment, the method 1100 begins and receives 1105 a first configuration for reflecting repetitions of a signal, the signal comprising an UL signal or a DL signal. In one embodiment, the method 1100 receives 1110 a second configuration defining a pattern of slot repetition for reflecting the signal. In one embodiment, the method 1100 configures 1115 an apparatus with the received first and second configurations. In one embodiment, the method 1100 transmits or receives 1120 reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations, and the method 1100 ends.

[0122] Disclosed herein is a first apparatus for repetition using RISs, according to embodiments of the disclosure. The first apparatus may be implemented by a network entity, such as the base unit 121, the RAN node 210, and/or the network apparatus 800, as described above. In some embodiments, the first apparatus includes a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0123] In one embodiment, the first apparatus includes a processor and a memory coupled to the processor. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to determine a first configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, determine a second configuration for reflecting the repetition of the signal, determine a third configuration of a pattern of slot repetition for reflecting the signal, and transmit the first configuration to a UE and the second and third configurations to the at least one RIS.

[0124] In one embodiment, the first configuration comprises information for a physical channel to be repeated using of the at least one RIS and a number of repetitions to be reflected.

[0125] In one embodiment, the first configuration comprises at least one TCI set, each TCI set of the at least one TCI set corresponding to a respective RIS of the at least one RIS.

[0126] In one embodiment, each TCI set of the at least one TCI set corresponds to at least one TCI state for the repetition of the UL or DL signal, or both, via the respective RIS.

[0127] In one embodiment, each TCI set of the at least one TCI set corresponds to spatial information associated with a reflected signal via the respective RIS for a respective slot associated with the slot repetition, and wherein the reflected signal corresponds to the UL signal or the DL signal, or both.

[0128] In one embodiment, the instructions are executable by the processor to cause the apparatus to transmit, to the UE, a RIS configuration comprising a data structure that maps each of one or more TCI sets of the at least one TCI set to each of one or more RISs of the at least one RIS, each of the one or more TCI sets of the at least one TCI set corresponding to a set of TCI states.

[0129] In one embodiment, the instructions are executable by the processor to cause the apparatus to transmit, to the UE, a DCI that enables a respective TCI state for each of one or more TCI states of the set of TCI states associated with a respective TCI set of the at least one TCI set for a respective slot associated with the slot repetition based at least in part on an indication in the received DCI, the indication comprising a TCI state index value.

[0130] In one embodiment, the instructions are executable by the processor to cause the apparatus to transmit, to the UE, a DCI comprising an indication to apply a same order of TCI states corresponding to multiple repetitions used for a scheduled PDSCH/PUSCH, to another scheduled PDSCH/PUSCH.

[0131] In one embodiment, the instructions are executable by the processor to cause the apparatus to transmit, to a RIS of the at least one RIS, a fourth configuration comprising information for TCI states, or spatial information, or both, for each slot, the TCI states associated with configured TCI states of the UE for different repetitions.

[0132] In one embodiment, the instructions are executable by the processor to cause the apparatus to transmit, to a RIS of the at least one RIS, a fourth configuration indicating spatial information to be applied in different slots based on the pattern of slot repetition, the pattern corresponding to a number of UEs, a number of RISs involved in the repetition, and a number of repetitions for each UE.

[0133] Disclosed herein is a first method for repetition using RISs, according to embodiments of the disclosure. The first method may be performed by a network entity, such as the base unit 121, the RAN node 210, and/or the network apparatus 800, as described above. In some embodiments, the method 900 is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0134] In one embodiment, the first method determines a first configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, determines a second configuration for reflecting the repetition of the signal, determines a third configuration of a pattern of slot repetition for reflecting the signal, and transmits the first configuration to a UE and the second and third configurations to the at least one RIS.

[0135] In one embodiment, the first configuration comprises information for a physical channel to be repeated using of the at least one RIS and a number of repetitions to be reflected.

[0136] In one embodiment, the first configuration comprises at least one TCI set, each TCI set of the at least one TCI set corresponding to a respective RIS of the at least one RIS.

[0137] In one embodiment, each TCI set of the at least one TCI set corresponds to at least one TCI state for the repetition of the UL or DL signal, or both, via the respective RIS.

[0138] In one embodiment, each TCI set of the at least one TCI set corresponds to spatial information associated with a reflected signal via the respective RIS for a respective slot associated with the slot repetition, and wherein the reflected signal corresponds to the UL signal or the DL signal, or both.

[0139] In one embodiment, the first method transmits, to the UE, a RIS configuration comprising a data structure that maps each of one or more TCI sets of the at least one TCI set to each of one or more RISs of the at least one RIS, each of the one or more TCI sets of the at least one TCI set corresponding to a set of TCI states.

[0140] In one embodiment, the first method transmits a DCI that enables a respective TCI state for each of one or more TCI states of the set of TCI states associated with a respective TCI set of the at least one TCI set for a respective slot associated with the slot repetition based at least in part on an indication in the received DCI, the indication comprising a TCI state index value.

[0141] In one embodiment, the first method transmits, to the UE, a DCI comprising an indication to apply a same order of TCI states corresponding to multiple repetitions used for a scheduled PDSCH/PUSCH, to another scheduled PDSCH/PUSCH.

[0142] In one embodiment, the first method transmits, to a RIS of the at least one RIS, a fourth configuration comprising information for TCI states, or spatial information, or both, for each slot, the TCI states associated with configured TCI states of the UE for different repetitions.

[0143] In one embodiment, the first method transmits, to a RIS of the at least one RIS, a fourth configuration indicating spatial information to be applied in different slots based on the pattern of slot repetition, the pattern corresponding to a number of UEs, a number of RISs involved in the repetition, and a number of repetitions for each UE.

[0144] Disclosed herein is a second apparatus for repetition using RISs, according to embodiments of the disclosure. The second apparatus may be implemented by a UE device, such as the remote unit 105, the UE 205, and/or the UE apparatus 700, as described above. In some embodiments, the second apparatus includes a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0145] In one embodiment, the second apparatus includes a processor and a memory coupled to the processor. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to receive, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to configure the apparatus with the received repetition configuration and receive, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition.

[0146] In one embodiment, the instructions are executable by the processor to cause the apparatus to receive a DCI comprising at least one of a new repetition configuration and an update of the existing repetition configuration.

[0147] In one embodiment, the instructions are executable by the processor to cause the apparatus to receive a first repetition with a TCI state corresponding to a QCL assumption used for receiving PDCCH.

[0148] In one embodiment, the instructions are executable by the processor to cause the apparatus to receive a DCI comprising an indication of a TCI state of a first repetition that is different than the TCI state or QCL assumption used to receive PDCCH.

[0149] Disclosed herein is a second method for repetition using RISs, according to embodiments of the disclosure. The second method may be performed by a UE device, such as the remote unit 105, the UE 205, and/or the UE apparatus 700, as described above. In some embodiments, the method 1000 is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0150] In one embodiment, the second method receives, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an UL signal or a DL signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected. In one embodiment, the second method configures the apparatus with the received repetition configuration and receives, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition.

[0151] In one embodiment, the second method receives a DCI comprising at least one of a new repetition configuration and an update of the existing repetition configuration.

[0152] In one embodiment, the second method receives a first repetition with a TCI state corresponding to a QCL assumption used for receiving PDCCH.

[0153] In one embodiment, the second method receives a DCI comprising an indication of a TCI state of a first repetition that is different than the TCI state or QCL assumption used to receive PDCCH.

[0154] Disclosed herein is a third apparatus for repetition using RISs, according to embodiments of the disclosure. The third apparatus may be implemented by a network device, such as a RIS, as described above. In some embodiments, the third apparatus includes a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0155] In one embodiment, the third apparatus includes a processor and a memory coupled to the processor. In one embodiment, the memory includes instructions that are executable by the processor to cause the apparatus to receive a first configuration for reflecting repetitions of a signal, the signal comprising an UL signal or a DL signal, receive a second configuration defining a pattern of slot repetition for reflecting the signal, configure the apparatus with the received first and second configurations, and transmit or receive reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations.

[0156] Disclosed herein is a third method for repetition using RISs, according to embodiments of the disclosure. The third method may be performed by a network device, such as a RIS, as described above. In some embodiments, the third method is performed by a processor, such as a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0157] In one embodiment, the third method receives a first configuration for reflecting repetitions of a signal, the signal comprising an UL signal or a DL signal, receive a second configuration defining a pattern of slot repetition for reflecting the signal, configures the apparatus with the received first and second configurations, and transmits or receives reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations.

[0158] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0159] As will be appreciated by one skilled in the art, aspects of the embodiments may be embodied as a system, apparatus, method, or program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects.

[0160] For example, the disclosed embodiments may be implemented as a hardware circuit comprising custom very-large-scale integration ("VLSI") circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. The disclosed embodiments may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. As another example, the disclosed embodiments may include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function.

[0161] Furthermore, embodiments may take the form of a program product embodied in one or more computer readable storage devices storing machine readable code, computer readable code, and/or program code, referred hereafter as code. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In a certain embodiment, the storage devices only employ signals for accessing code.

[0162] Any combination of one or more computer readable medium may be utilized. The computer readable medium may be a computer readable storage medium. The computer readable storage medium may be a storage device storing the code. The storage device may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0163] More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random-access memory ("RAM"), a read-only memory ("ROM"), an erasable programmable read-only memory ("EPROM" or Flash memory), a portable compact disc read-only memory ("CD-ROM"), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0164] Code for carrying out operations for embodiments may be any number of lines and may be written in any combination of one or more programming languages including an object-oriented programming language such as Python, Ruby, Java, Smalltalk, C++, or the like, and conventional procedural programming languages, such as the "C" programming language, or the like, and/or machine languages such as assembly languages. The code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network ("LAN"), wireless LAN ("WLAN"), or a wide area network ("WAN"), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider ("ISP")).

[0165] Furthermore, the described features, structures, or characteristics of the embodiments may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions, database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of an embodiment.

[0166] Reference throughout this specification to “one embodiment,” “an embodiment,” or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment,” “in an embodiment,” and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment, but mean “one or more but not all embodiments” unless expressly specified otherwise. The terms “including,” “comprising,” “having,” and variations thereof mean “including but not limited to,” unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise. The terms “a,” “an,” and “the” also refer to “one or more” unless expressly specified otherwise.

[0167] As used herein, a list with a conjunction of “and/or” includes any single item in the list or a combination of items in the list. For example, a list of A, B and/or C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology “one or more of” includes any single item in the list or a combination of items in the list. For example, one or more of A, B and C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology “one of” includes one and only one of any single item in the list. For example, “one of A, B and C” includes only A, only B or only C and excludes combinations of A, B and C. As used herein, “a member selected from the group consisting of A, B, and C,” includes one and only one of A, B, or C, and excludes combinations of A, B, and C. As used herein, “a member selected from the group consisting of A, B, and C and combinations thereof” includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C.

[0168] Aspects of the embodiments are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and program products according to embodiments. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams and/or schematic block diagrams, can be implemented by code. This code may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart diagrams and/or block diagrams.

[0169] The code may also be stored in a storage device that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function/act specified in the flowchart diagrams and/or block diagrams.

[0170] The code may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus, or other devices to produce a computer implemented process such that the code which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart diagrams and/or block diagrams.

[0171] The call-flow diagrams, flowchart diagrams and/or block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods, and program products according to various embodiments. In this regard, each block in the flowchart diagrams and/or block diagrams may represent a module, segment, or portion of code, which includes one or more executable instructions of the code for implementing the specified logical function(s).

[0172] It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, of the illustrated Figures.

[0173] Although various arrow types and line types may be employed in the call-flow, flowchart and/or block diagrams, they are understood not to limit the scope of the corresponding embodiments. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the depicted embodiment. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted embodiment. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and code.

[0174] The description of elements in each figure may refer to elements of proceeding figures. Like numbers refer to like elements in all figures, including alternate embodiments of like elements.

CLAIMS

1. An apparatus, comprising:
   a processor; and
   a memory coupled to the processor, the memory comprising instructions that are executable by the processor to:
   determine a first configuration for a repetition of a signal via at least one reconfigurable intelligent surface ("RIS"), the signal comprising an uplink ("UL") signal or a downlink ("DL") signal;
   determine a second configuration for reflecting the repetition of the signal;
   determine a third configuration of a pattern of slot repetition for reflecting the signal; and
   transmit the first configuration to a user equipment ("UE") and the second and third configurations to the at least one RIS.

2. The apparatus of claim 1, wherein the first configuration comprises information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected.

3. The apparatus of claim 1, wherein the first configuration comprises at least one transmission configuration indicator ("TCI") set, each TCI set of the at least one TCI set corresponding to a respective RIS of the at least one RIS.

4. The apparatus of claim 3, wherein each TCI set of the at least one TCI set corresponds to at least one TCI state for the repetition of the signal via the respective RIS of the at least one RIS.

5. The apparatus of claim 3, wherein each TCI set of the at least one TCI set corresponds to spatial information associated with a reflected signal via the respective RIS for a respective slot associated with the slot repetition, and wherein the reflected signal corresponds the UL signal, the DL signal, or both.

6. The apparatus of claim 3, wherein the instructions are executable by the processor to cause the apparatus to transmit, to the UE, a RIS configuration comprising a data structure that maps each of one or more TCI sets of the at least one TCI set to each of one or more RISs of the at least one RIS, each of the one or more TCI sets of the at least one TCI set corresponding to a set of TCI states.

7. The apparatus of claim 3, wherein the instructions are executable by the processor to cause the apparatus to transmit, to the UE, a downlink control information (“DCI”) that enables a respective TCI state for each of one or more TCI states of the set of TCI states associated with a respective TCI set of the at least one TCI set for a respective slot associated with the slot repetition based at least in part on an indication in the received DCI, the indication comprising a TCI state index value.

8. The apparatus of claim 1, wherein the instructions are executable by the processor to cause the apparatus to transmit, to the UE, a downlink control information (“DCI”) comprising an indication to apply a same order of TCI states corresponding to multiple repetitions used for a scheduled physical downlink shared channel (“PDSCH”)/physical uplink shared channel (“PUSCH”), to another scheduled PDSCH/PUSCH.

9. The apparatus of claim 1, wherein the instructions are executable by the processor to cause the apparatus to transmit, to a RIS of the at least one RIS, a fourth configuration comprising information for transmission configuration indicator (“TCI”) states, or spatial information, or both, for each slot, the TCI states associated with configured TCI states of the UE for different repetitions.

10. The apparatus of claim 1, wherein the instructions are executable by the processor to cause the apparatus to transmit, to a RIS of the at least one RIS, a fourth configuration indicating spatial information to be applied in different slots based on the pattern of slot repetition, the pattern corresponding to a number of UEs, a number of RISs involved in the repetition, and a number of repetitions for each UE.

11. An apparatus, comprising:

a processor; and

a memory coupled to the processor, the memory comprising instructions that are executable by the processor to cause the apparatus to:

receive, from a network node, a repetition configuration for a repetition of a signal via at least one reconfigurable intelligent surfaces (“RIS”), the signal comprising an uplink (“UL”) signal or a downlink (“DL”) signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected;

configure the apparatus with the received repetition configuration; and

receive, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition.

12. The apparatus of claim 11, wherein the instructions are executable by the processor to cause the apparatus to receive a downlink control information (“DCI”) comprising at least one of a new repetition configuration and an update of the existing repetition configuration.

13. The apparatus of claim 11, wherein the instructions are executable by the processor to cause the apparatus to receive a first repetition with a transmission configuration indicator (“TCI”) state corresponding to a quasi co-location (“QCL”) assumption used for receiving physical downlink control channel (“PDCCH”).

14. The apparatus of claim 11, wherein the instructions are executable by the processor to cause the apparatus to receive a downlink control information (“DCI”) comprising an indication of a transmission configuration indicator (“TCI”) state of a first repetition that is different than the TCI state or quasi co-location (“QCL”) assumption used to receive physical downlink control channel (“PDCCH”).

15. An apparatus, comprising:

a processor; and

a memory coupled to the processor, the memory comprising instructions that are executable by the processor to cause the apparatus to:

receive a first configuration for reflecting repetitions of a signal, the signal comprising an uplink ("UL") signal or a downlink ("DL") signal;

receive a second configuration defining a pattern of slot repetition for reflecting the signal;

configure the apparatus with the received first and second configurations; and

transmit or receive reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations.

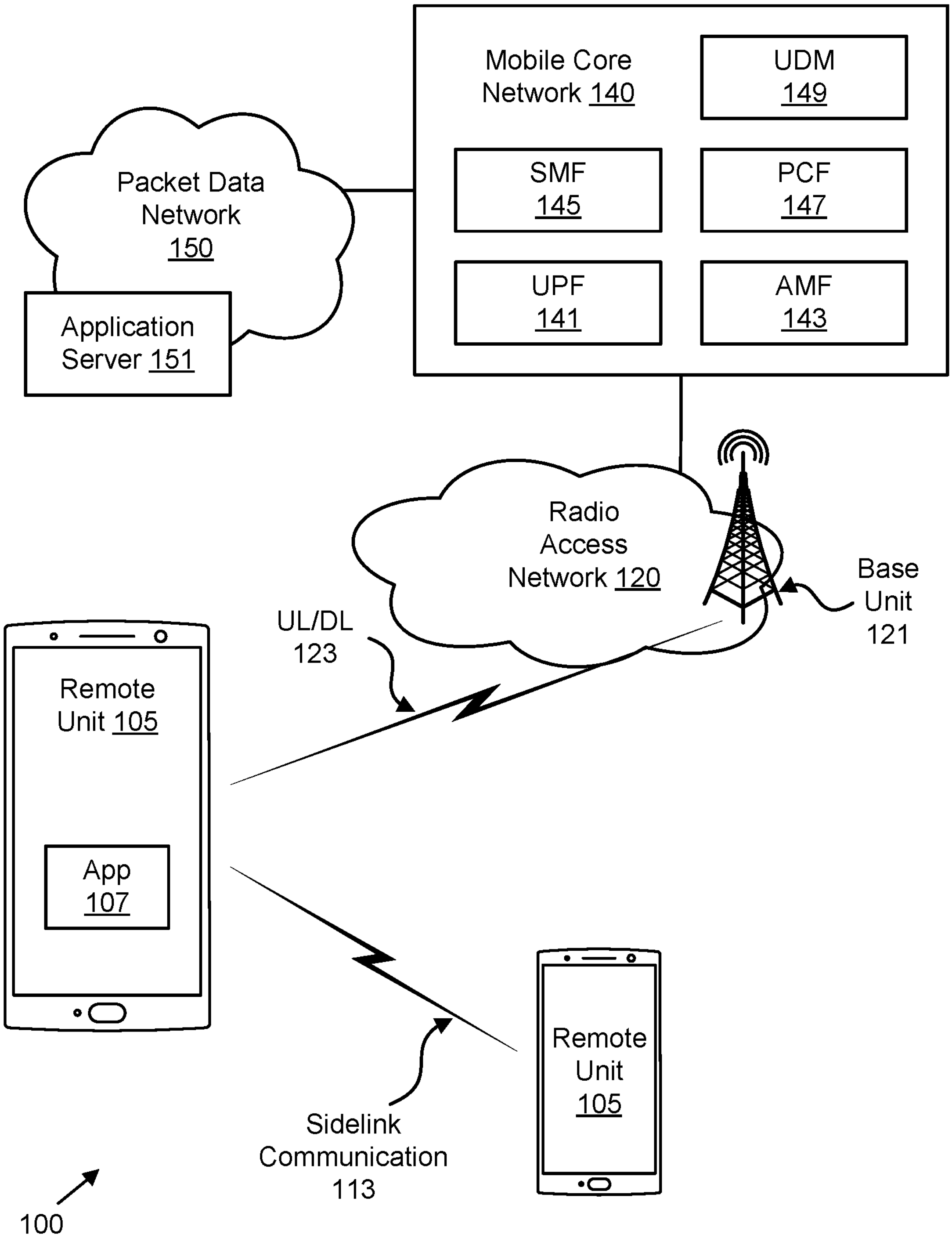
Mobile Core Network 140
UDM 149
SMF 145
PCF 147
UPF 141
AMF 143
Packet Data Network 150
Application Server 151
Radio Access Network 120
Base Unit 121
UL/DL 123
Remote Unit 105
App 107
Remote Unit 105
Sidelink Communication 113
100

FIG. 1

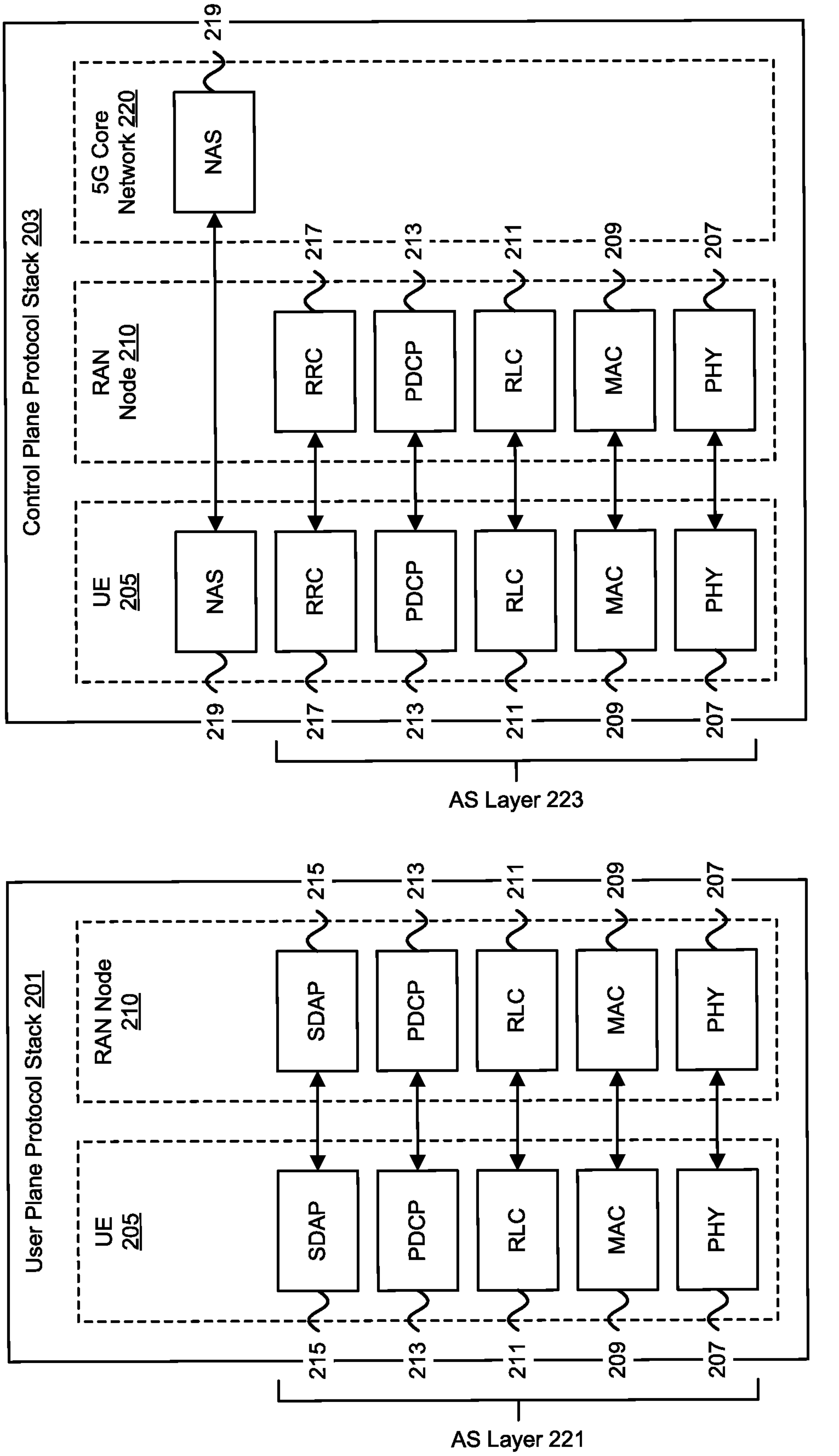
Control Plane Protocol Stack 203
UE 205
RAN Node 210
5G Core Network 220
NAS
RRC
PDCP
RLC
MAC
PHY
219
217
213
211
209
207
AS Layer 223
User Plane Protocol Stack 201
SDAP
215
AS Layer 221
200

FIG. 2

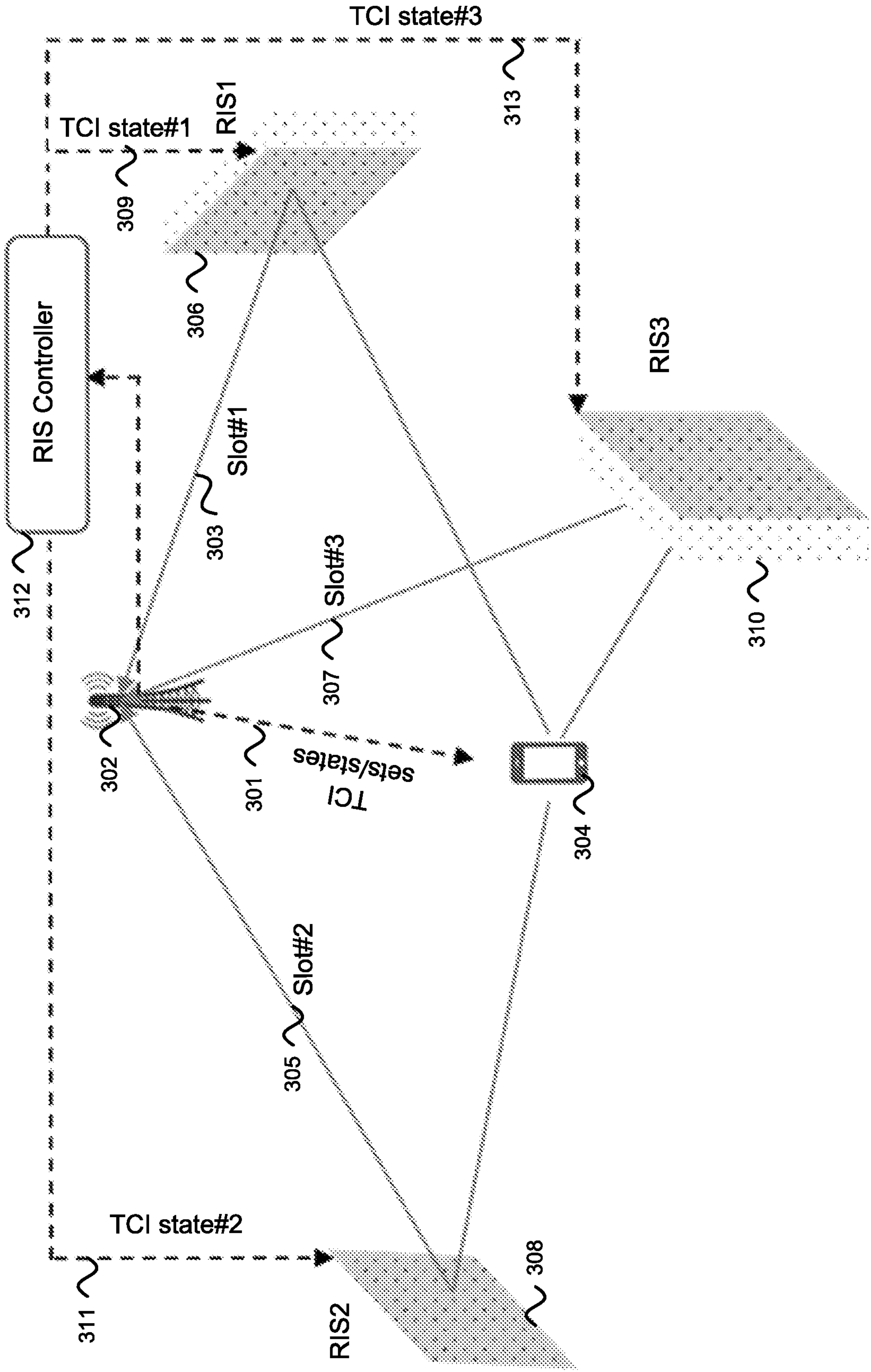
TCI state#3
313
TCI state#1
RIS1
309
306
RIS Controller
RIS3
Slot#1
303
312
Slot#3
307
310
302
TCI sets/states
301
304
Slot#2
305
TCI state#2
308
311
RIS2

FIG. 3

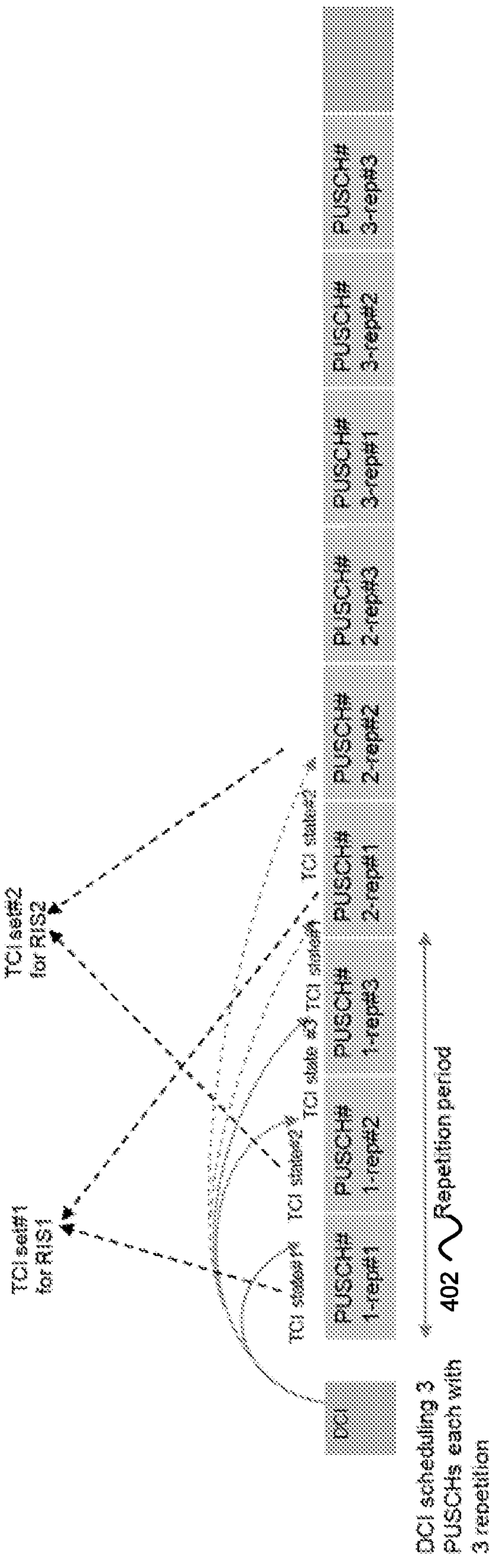
TCI set#1 for RIS1
TCI set#2 for RIS2
TCI state#1
TCI state#2
TCI state #3
TCI state#1
TCI state#2
DCI
PUSCH# 1-rep#1
PUSCH# 1-rep#2
PUSCH# 1-rep#3
PUSCH# 2-rep#1
PUSCH# 2-rep#2
PUSCH# 2-rep#3
PUSCH# 3-rep#1
PUSCH# 3-rep#2
PUSCH# 3-rep#3
Repetition period
402
DCI scheduling 3 PUSCHs each with 3 repetition reflected by 3 RISs
404

FIG. 4

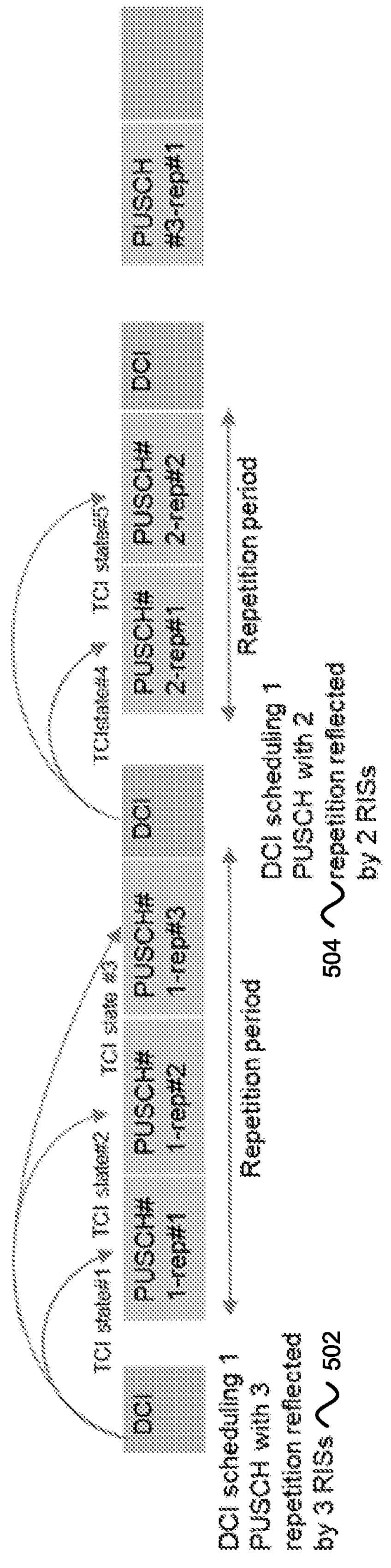
TCI state#1
TCI state#2
TCI state #3
TCI state#4
TCI state#5
DCI
PUSCH# 1-rep#1
PUSCH# 1-rep#2
PUSCH# 1-rep#3
DCI
PUSCH# 2-rep#1
PUSCH# 2-rep#2
DCI
PUSCH #3-rep#1
Repetition period
Repetition period
DCI scheduling 1 PUSCH with 3 repetition reflected by 3 RISs
502
DCI scheduling 1 PUSCH with 2 repetition reflected by 2 RISs
504

FIG. 5

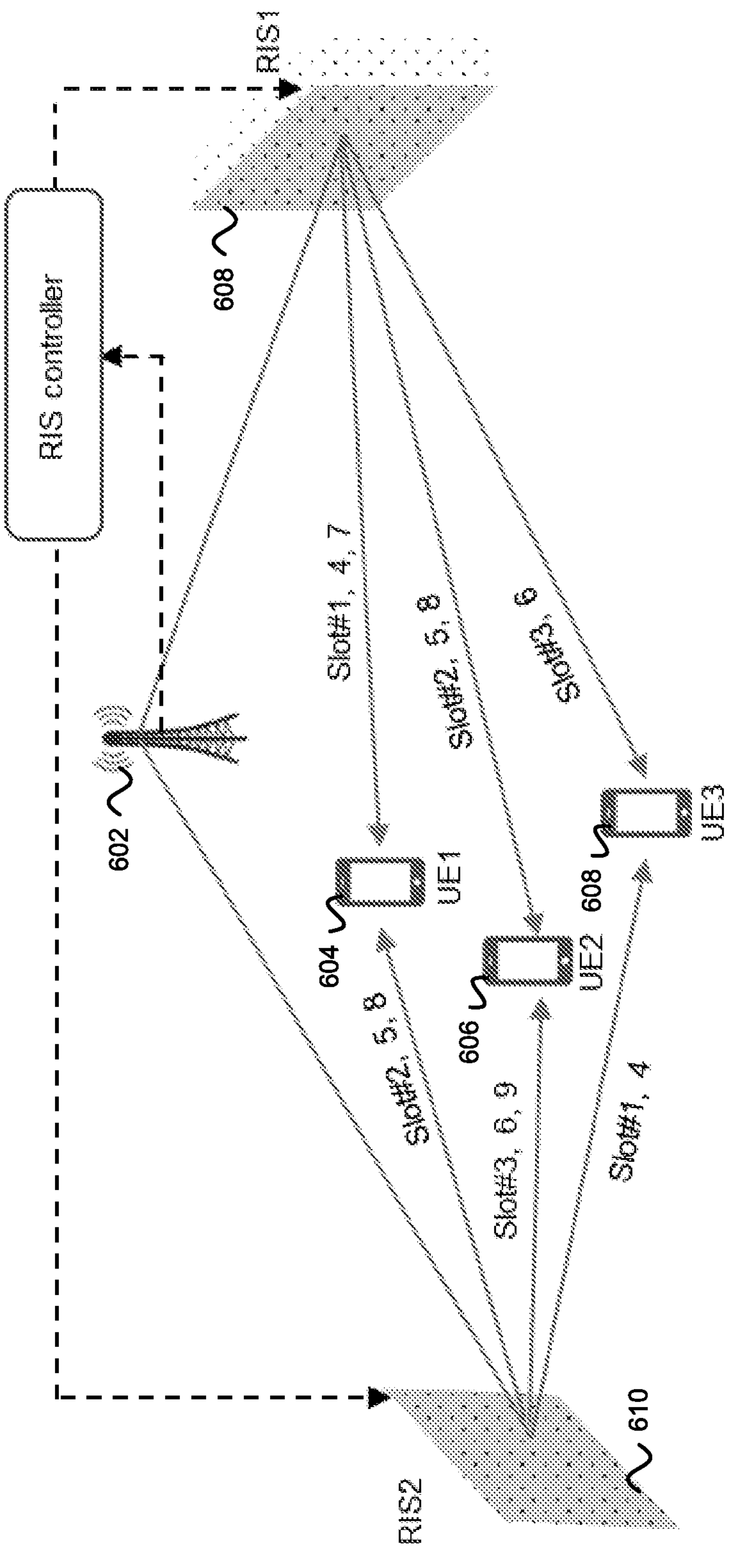
RIS controller
RIS1
608
602
Slot#1, 4, 7
Slot#2, 5, 8
Slot#3, 6
UE1
604
UE2
606
UE3
608
Slot#2, 5, 8
Slot#3, 6, 9
Slot#1, 4
RIS2
610

FIG. 6

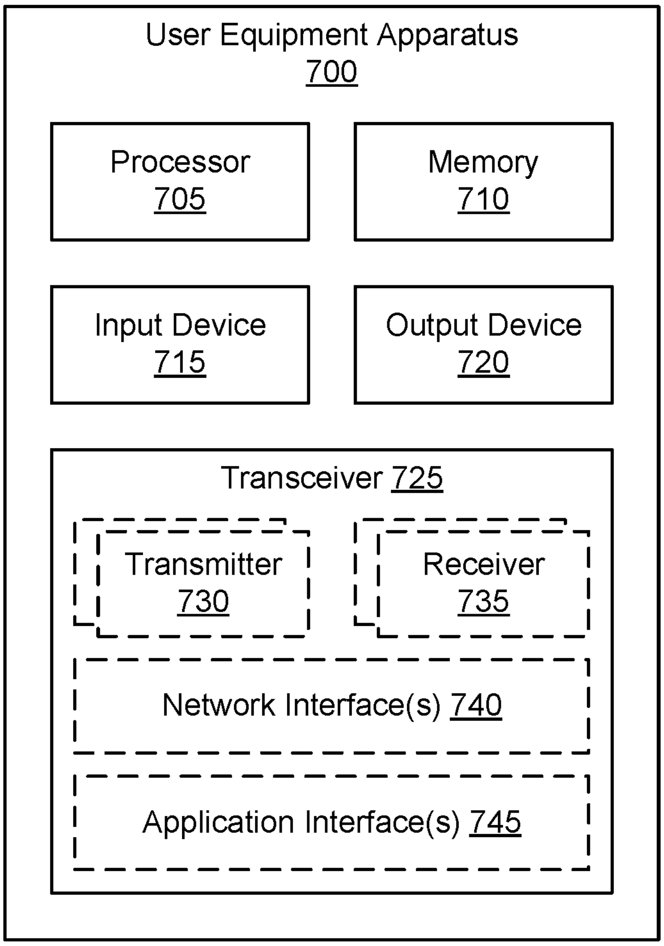
User Equipment Apparatus
700
Processor
705
Memory
710
Input Device
715
Output Device
720
Transceiver 725
Transmitter
730
Receiver
735
Network Interface(s) 740
Application Interface(s) 745

FIG. 7

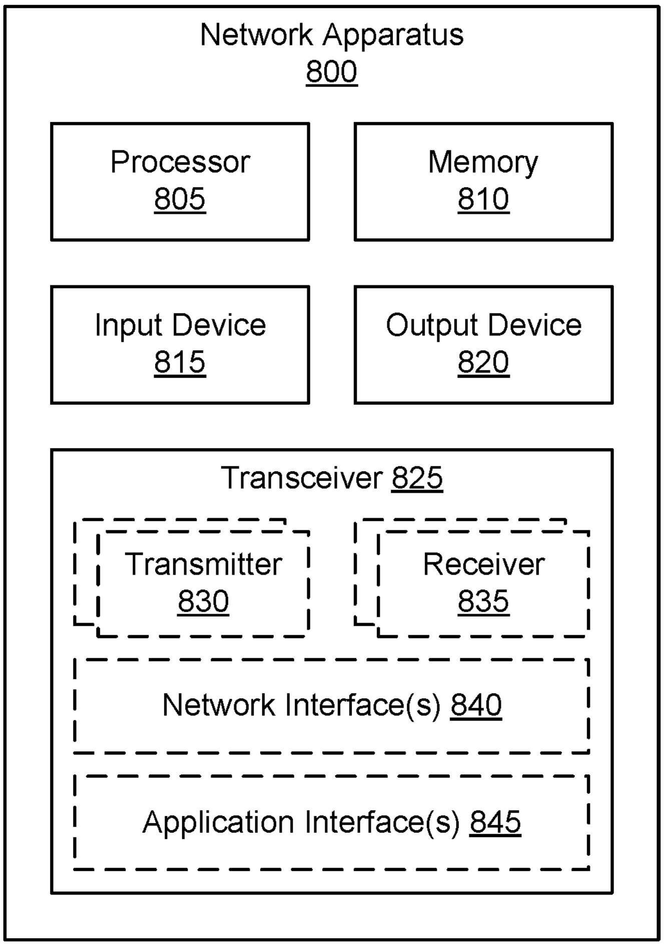
Network Apparatus
800
Processor
805
Memory
810
Input Device
815
Output Device
820
Transceiver 825
Transmitter
830
Receiver
835
Network Interface(s) 840
Application Interface(s) 845

FIG. 8

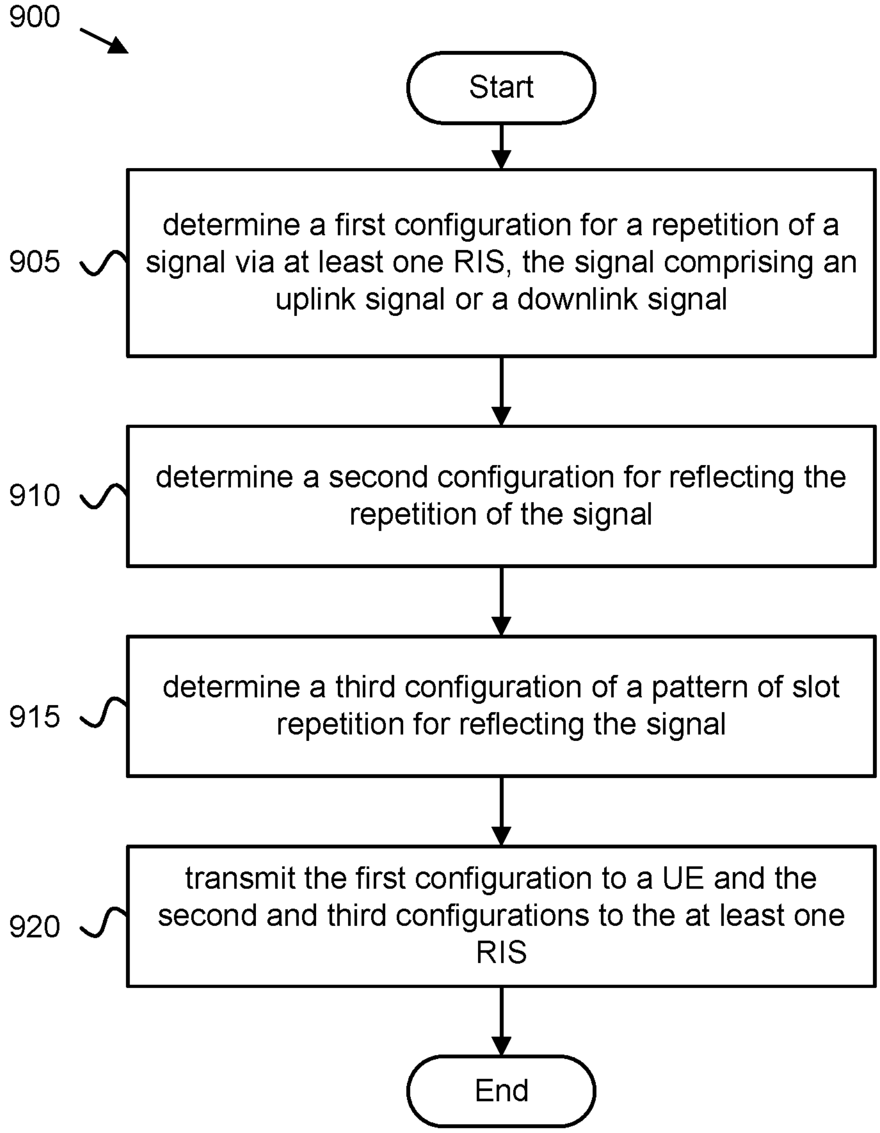
900
Start
905
determine a first configuration for a repetition of a signal via at least one RIS, the signal comprising an uplink signal or a downlink signal
910
determine a second configuration for reflecting the repetition of the signal
915
determine a third configuration of a pattern of slot repetition for reflecting the signal
920
transmit the first configuration to a UE and the second and third configurations to the at least one RIS
End

FIG. 9

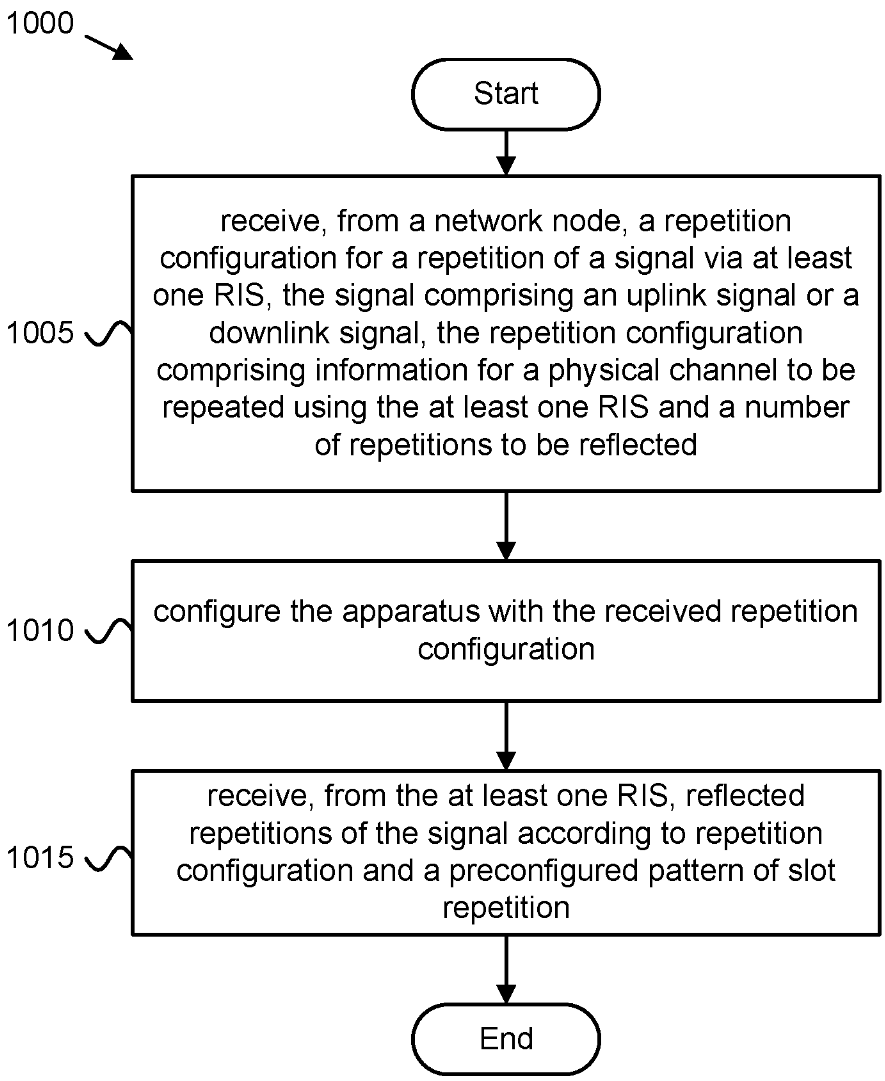
1000
Start
1005
receive, from a network node, a repetition configuration for a repetition of a signal via at least one RIS, the signal comprising an uplink signal or a downlink signal, the repetition configuration comprising information for a physical channel to be repeated using the at least one RIS and a number of repetitions to be reflected
1010
configure the apparatus with the received repetition configuration
1015
receive, from the at least one RIS, reflected repetitions of the signal according to repetition configuration and a preconfigured pattern of slot repetition
End

FIG. 10

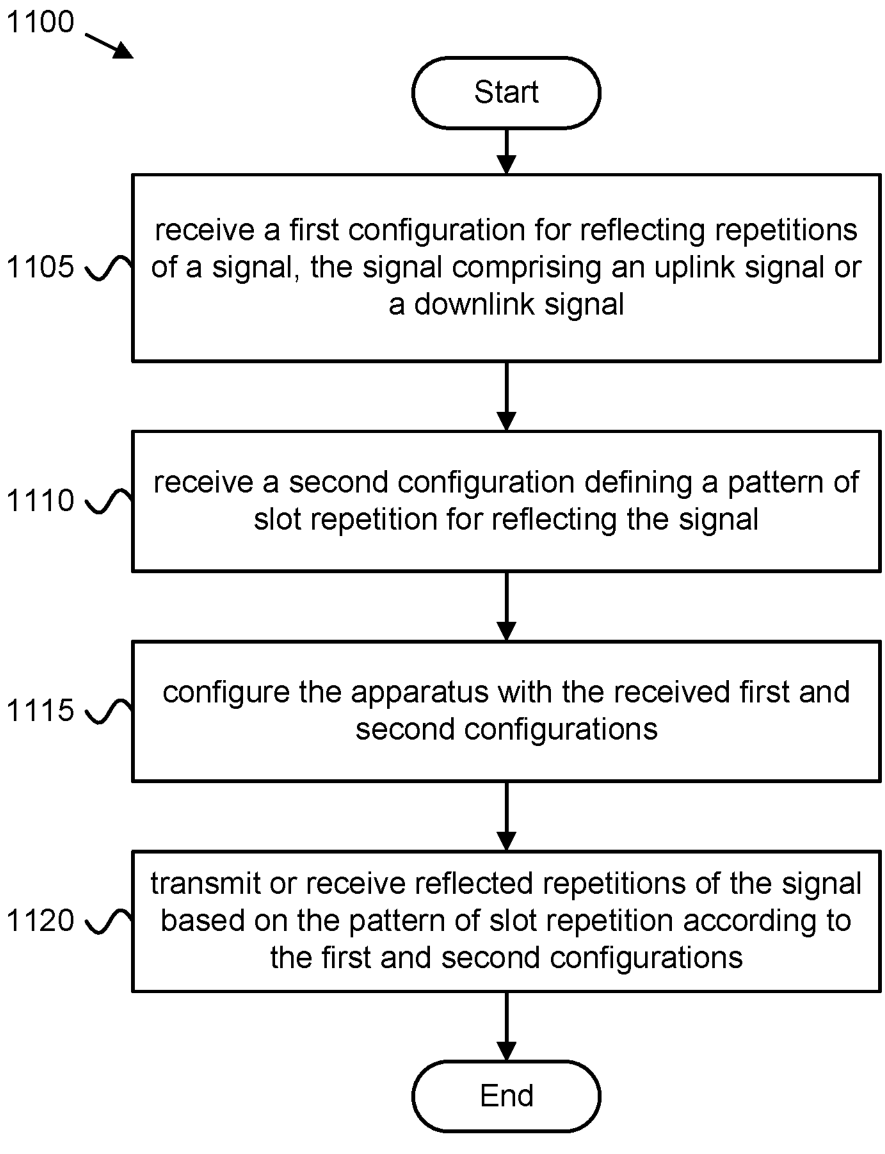
1100
Start
1105
receive a first configuration for reflecting repetitions of a signal, the signal comprising an uplink signal or a downlink signal
1110
receive a second configuration defining a pattern of slot repetition for reflecting the signal
1115
configure the apparatus with the received first and second configurations
1120
transmit or receive reflected repetitions of the signal based on the pattern of slot repetition according to the first and second configurations
End

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2023/053931

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/384958 A1 (DENIS BENOÎT [FR] ET AL) 9 December 2021 (2021-12-09) paragraph [0060] - paragraph [0069] paragraph [0078] - paragraph [0103] paragraph [0152] - paragraph [0153] figures 1-5 claim 1 -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 July 2023	17/07/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Spinnler, Florian

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2023/053931

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2021384958 A1	09-12-2021	EP 3919929 A1	08-12-2021
		US 2021384958 A1	09-12-2021