US012388561B2

(12) **United States Patent**
Landis et al.

(10) **Patent No.: US 12,388,561 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **CHANNEL ORIENTED MODULATION SELECTION FOR IMPROVED SPECTRAL EFFICIENCY**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventors: **Shay Landis**, Hod Hasharon (IL); **Idan Michael Horn**, Hod Hasharon (IL); **Yehonatan Dallal**, Kfar Saba (IL)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 523 days.

(21) Appl. No.: **17/804,279**

(22) Filed: **May 26, 2022**

(65) **Prior Publication Data**

US 2023/0388043 A1 Nov. 30, 2023

(51) **Int. Cl.**

H04L 1/00 (2006.01)
H04L 27/34 (2006.01)
H04W 24/08 (2009.01)

(52) **U.S. Cl.**

CPC ***H04L 1/0003*** (2013.01); ***H04L 27/3488*** (2013.01); ***H04W 24/08*** (2013.01)

(58) **Field of Classification Search**

CPC ... H04L 1/0003; H04L 27/3488; H04W 24/08
USPC 370/329
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,869,308 B2 * 12/2020 Park H04W 72/044
11,876,747 B2 * 1/2024 Lee H04L 1/1864
12,156,229 B2 * 11/2024 Yi H04L 5/0053
2011/0216723 A1 9/2011 Sartori et al.
2015/0382328 A1 * 12/2015 Jiang H04W 72/51 370/329
2018/0092092 A1 3/2018 Cariou et al.
2018/0205488 A1 * 7/2018 Rico Alvarino H04L 27/00
2018/0375630 A1 * 12/2018 Kim H04L 5/0053
2020/0412431 A1 * 12/2020 Park H04B 7/0469
2021/0050938 A1 * 2/2021 Sarkis H04L 1/0009
2021/0195565 A1 * 6/2021 Venugopal H04L 5/0096
2021/0320747 A1 * 10/2021 Yoshioka H04L 1/0009
2021/0345374 A1 11/2021 Abotabl et al.

FOREIGN PATENT DOCUMENTS

WO 2017140344 A1 8/2017

OTHER PUBLICATIONS

International Search Report and Written Opinion—PCT/US2023/020578—ISA/EPO—Aug. 8, 2023.

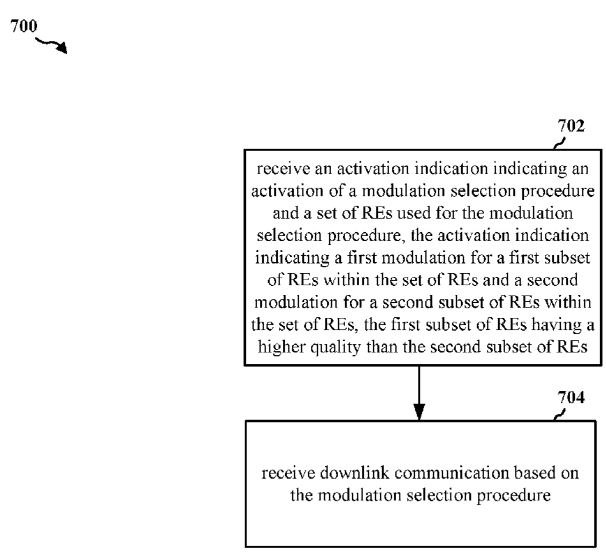
* cited by examiner

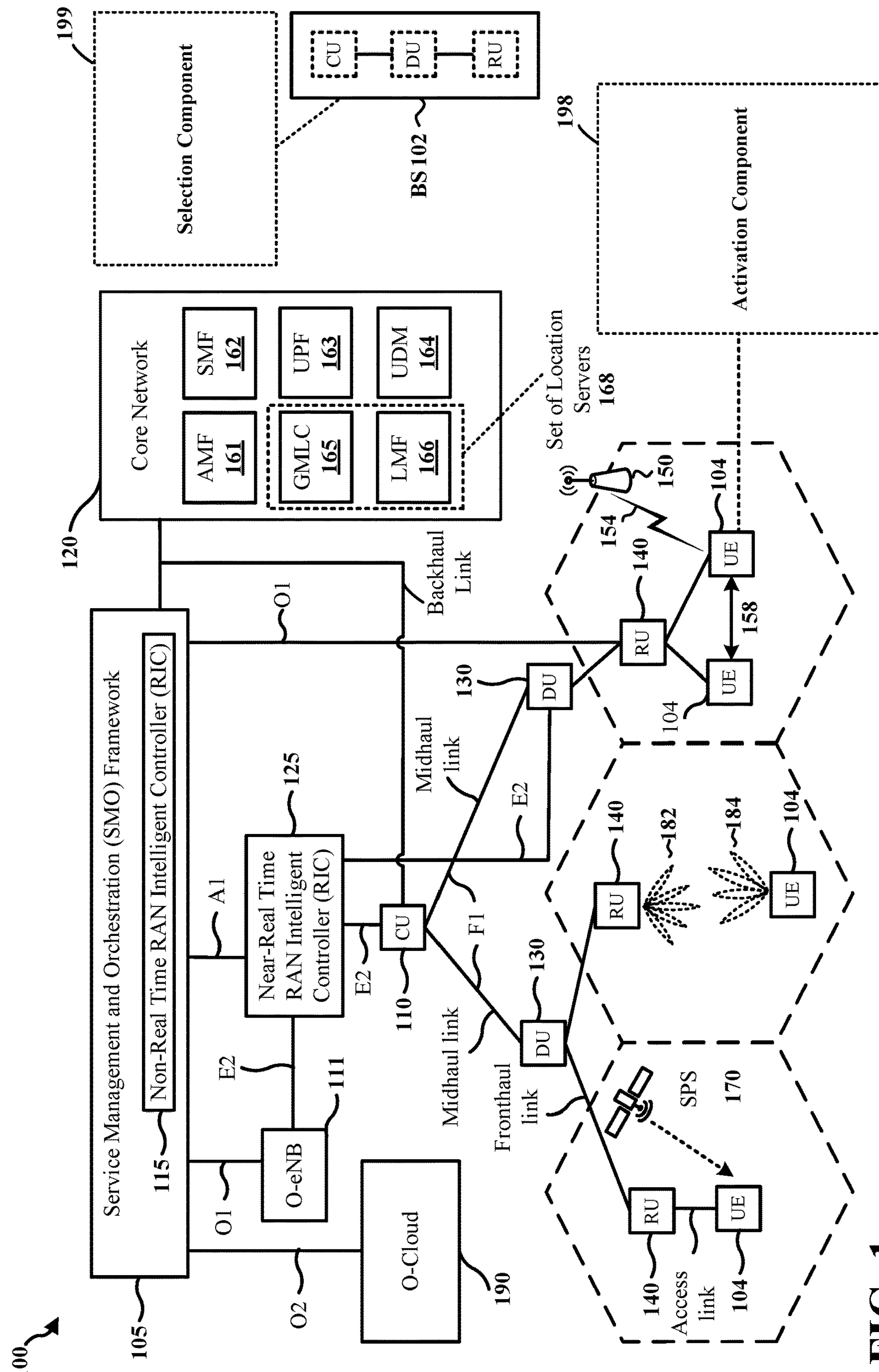
Primary Examiner — Mong-Thuy T Tran
(74) *Attorney, Agent, or Firm* — Procopio, Cory, Hargreaves & Savitch LLP

(57) **ABSTRACT**

Method and apparatus for channel oriented modulation selection for improved spectral efficiency. The apparatus receives an activation indication indicating an activation of a modulation selection procedure and a set of REs used for the modulation selection procedure. The activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs. The apparatus receives downlink communication based on the modulation selection procedure.

28 Claims, 12 Drawing Sheets




100
Service Management and Orchestration (SMO) Framework
Non-Real Time RAN Intelligent Controller (RIC)
105
115
Near-Real Time RAN Intelligent Controller (RIC)
125
A1
E2
O1
O2
O-eNB
111
O-Cloud
190
CU
110
F1
Midhaul link
DU
130
RU
140
Fronthaul link
Access link
UE
104
SPS
170
182
184
158
154
150
Backhaul Link
Core Network
120
AMF 161
SMF 162
UPF 163
UDM 164
GMLC 165
LMF 166
Set of Location Servers 168
Selection Component
199
BS 102
Activation Component
198
FIG. 1

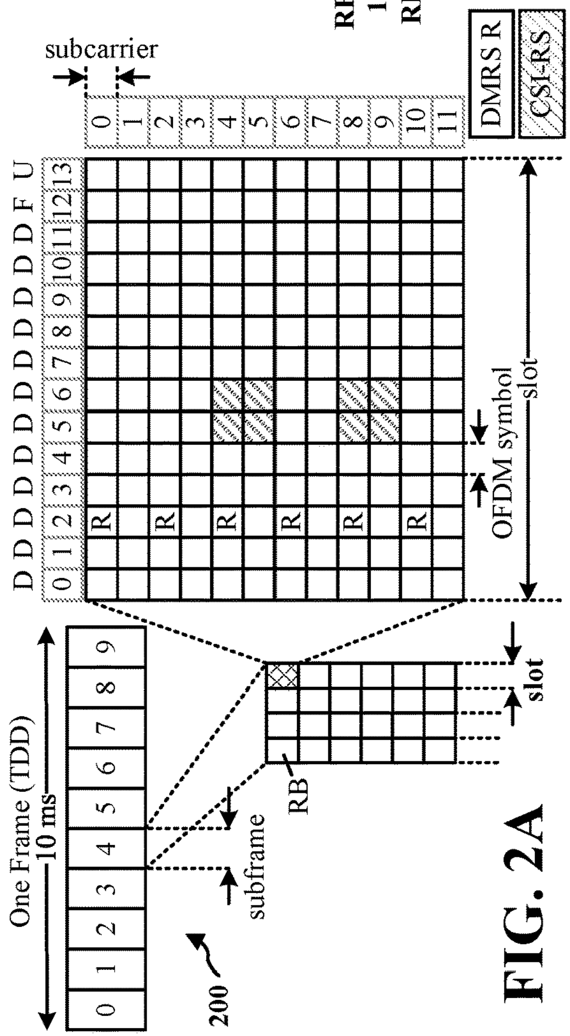


FIG. 2A

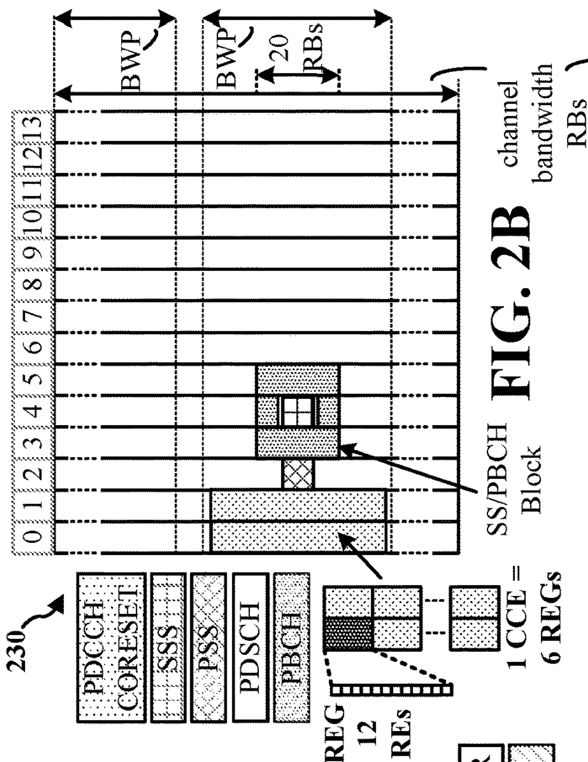


FIG. 2B

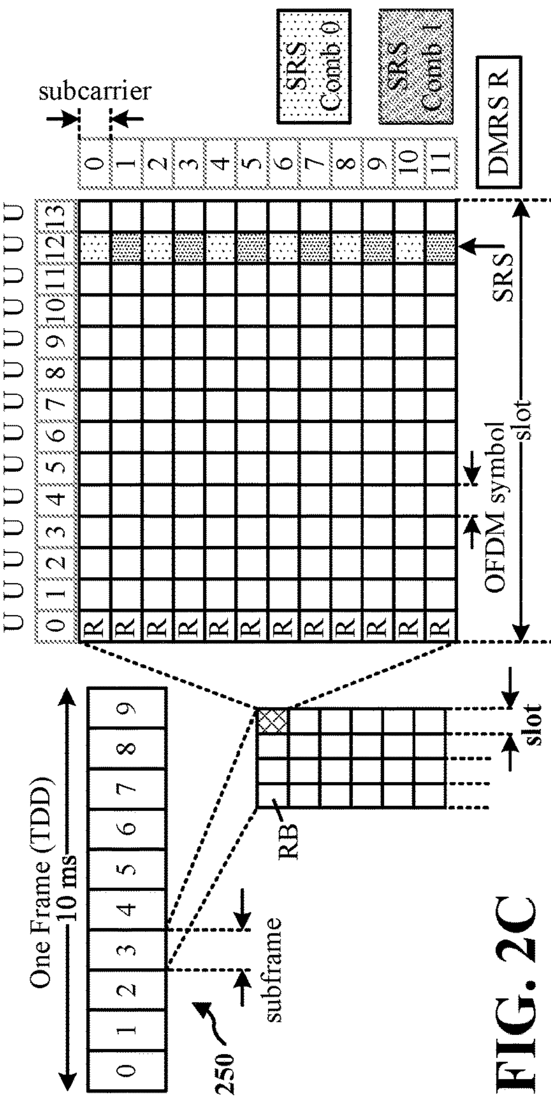


FIG. 2C

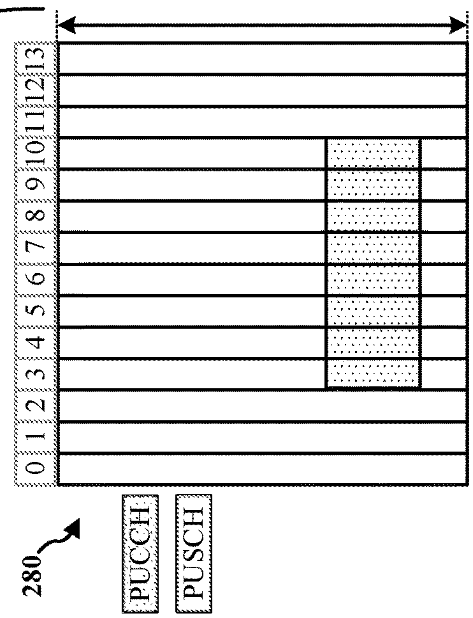


FIG. 2D

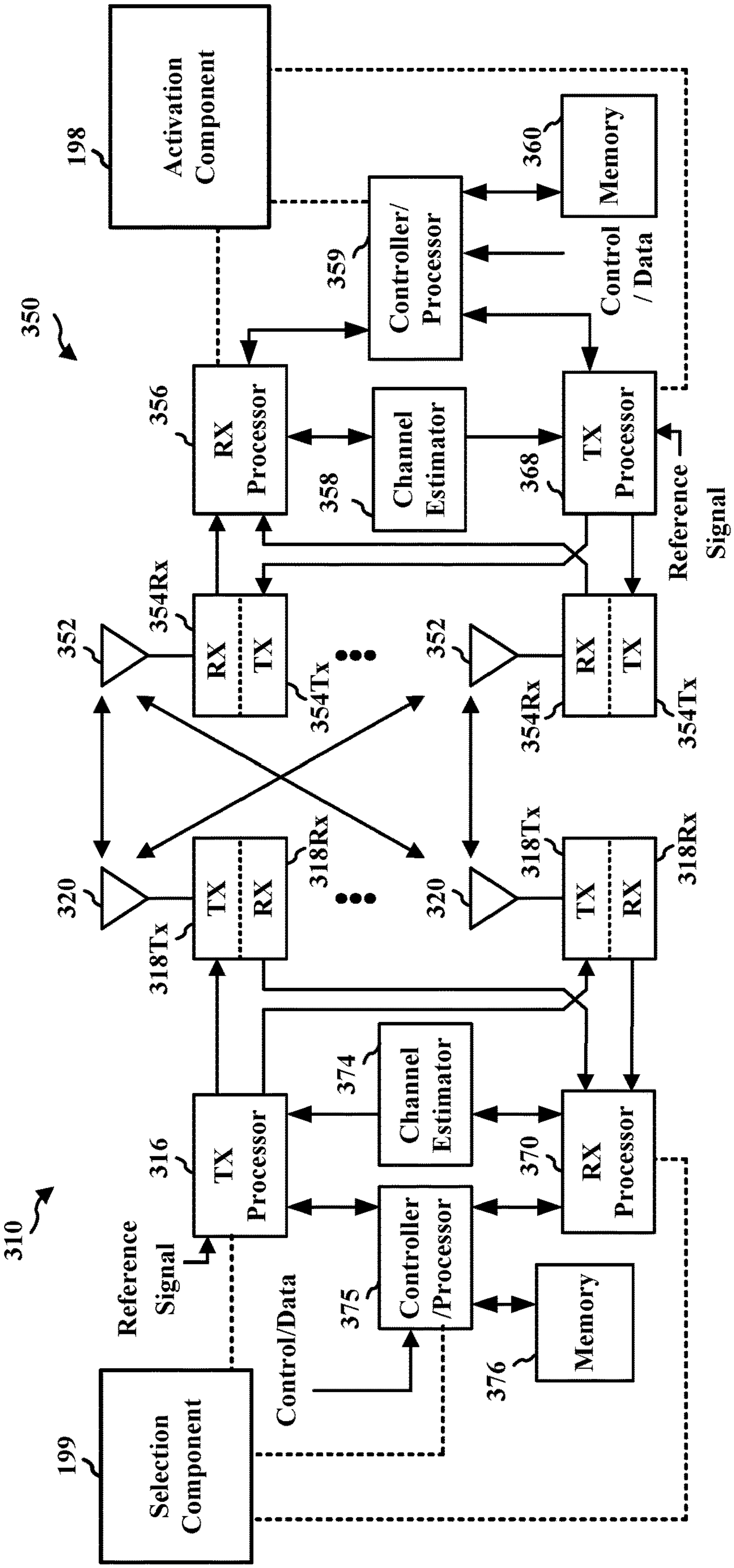

198
Activation Component
350
360
Memory
359
Controller/ Processor
Control / Data
356
RX Processor
358
Channel Estimator
368
TX Processor
Reference Signal
352
354Rx
RX
TX
354Tx
320
318Tx
318Rx
310
316
TX Processor
374
Channel Estimator
370
RX Processor
375
Controller /Processor
376
Memory
Reference Signal
Control/Data
199
Selection Component

FIG. 3

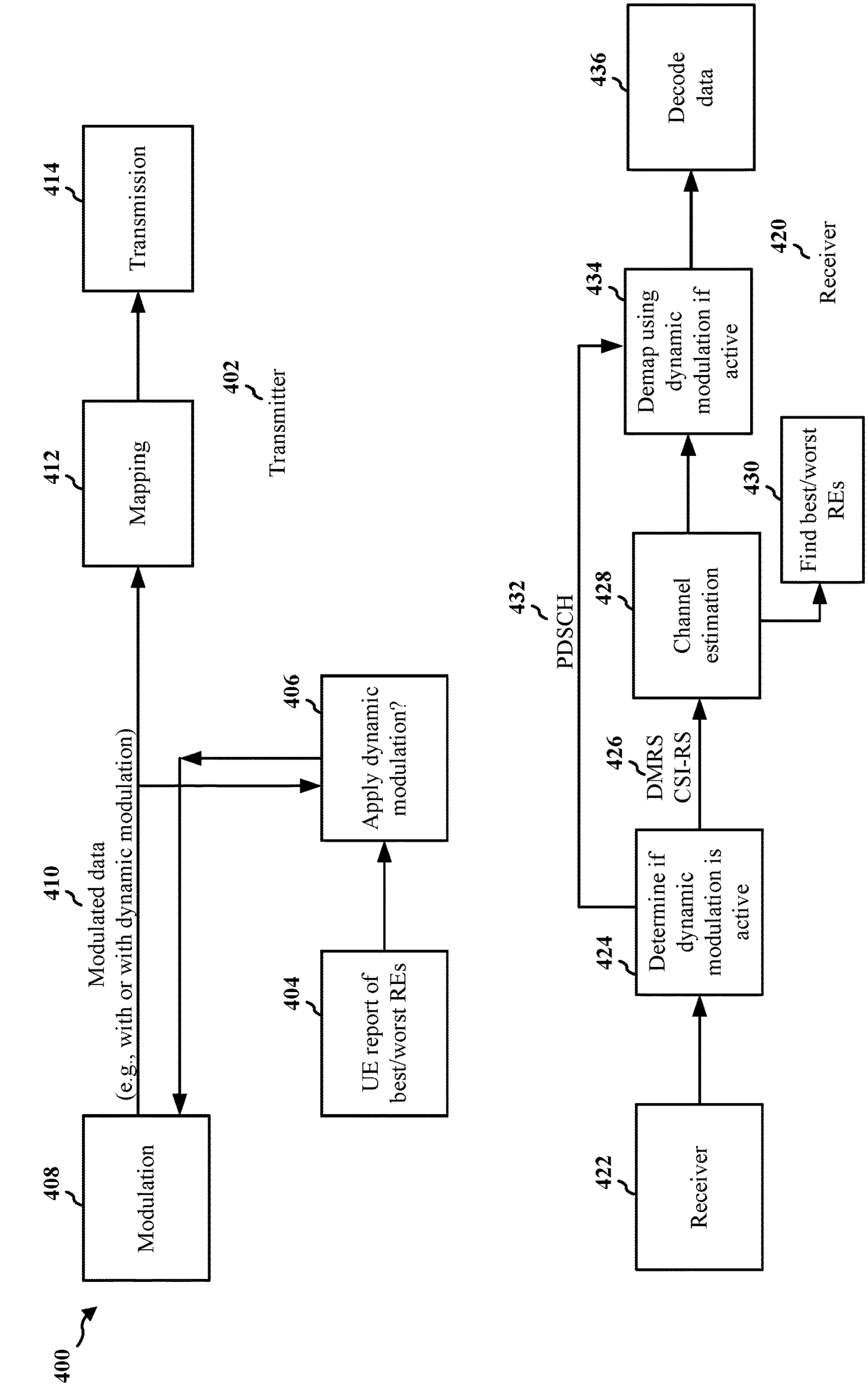

400
408
Modulation
410
Modulated data
(e.g., with or with dynamic modulation)
412
Mapping
414
Transmission
402
Transmitter
404
UE report of best/worst REs
406
Apply dynamic modulation?
422
Receiver
424
Determine if dynamic modulation is active
426
DMRS
CSI-RS
428
Channel estimation
430
Find best/worst REs
432
PDSCH
434
Demap using dynamic modulation if active
436
Decode data
420
Receiver

FIG. 4

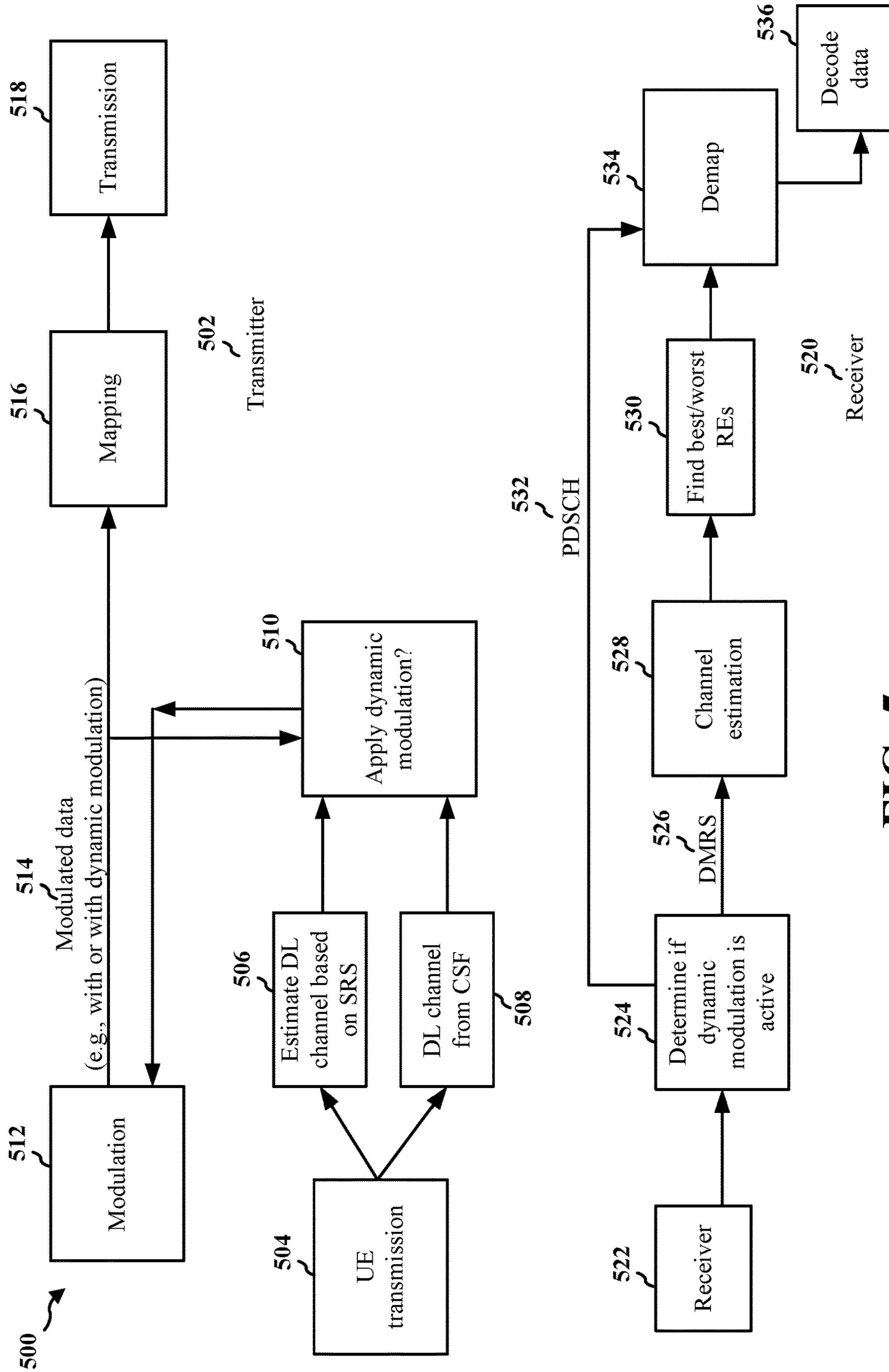

500
512
Modulation
514
Modulated data
(e.g., with or with dynamic modulation)
516
Mapping
518
Transmission
502
Transmitter
504
UE transmission
506
Estimate DL channel based on SRS
508
DL channel from CSF
510
Apply dynamic modulation?
522
Receiver
524
Determine if dynamic modulation is active
526
DMRS
528
Channel estimation
530
Find best/worst REs
532
PDSCH
534
Demap
536
Decode data
520
Receiver

FIG. 5

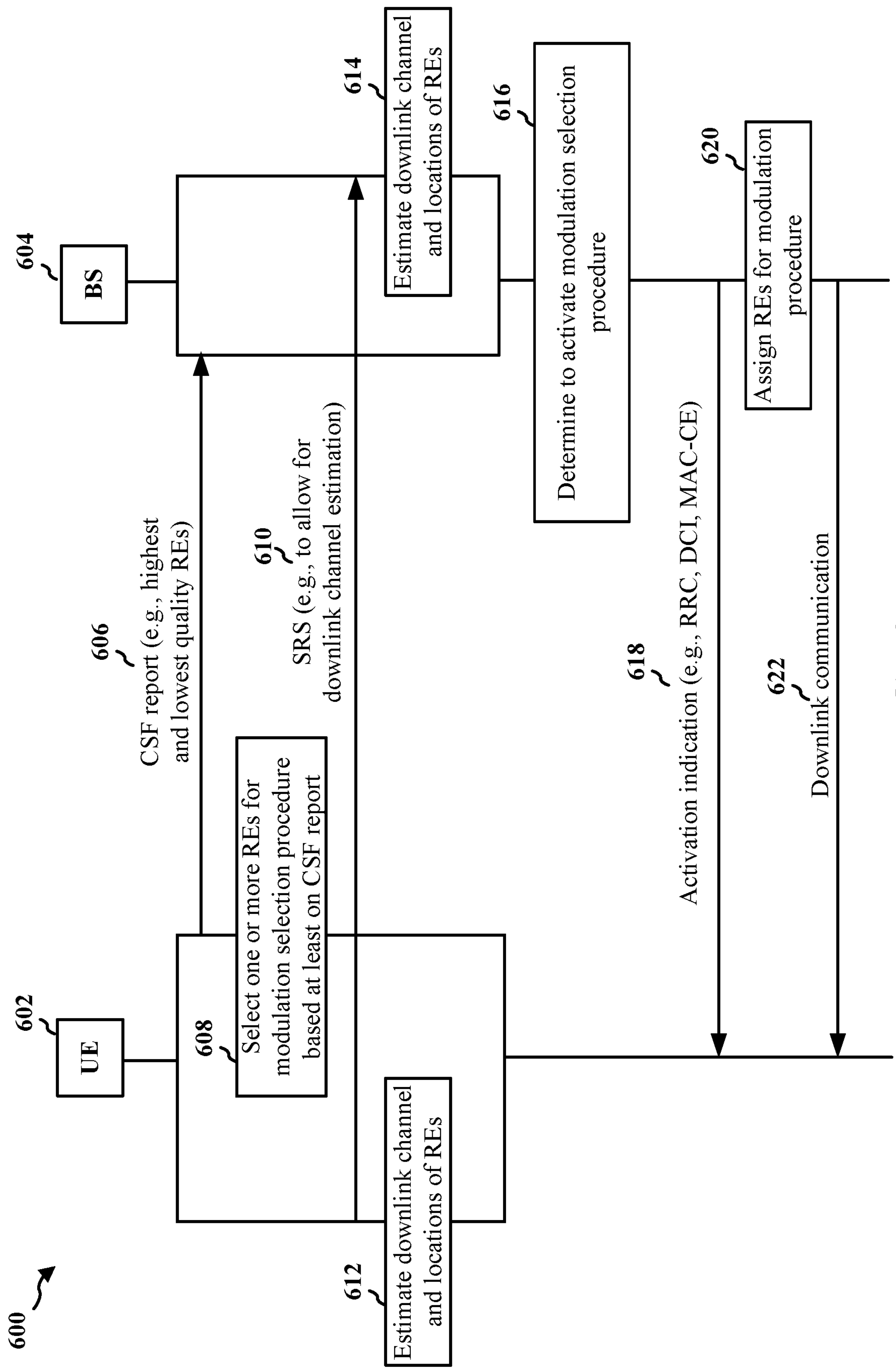

600
602
UE
604
BS
606
CSF report (e.g., highest and lowest quality REs)
608
Select one or more REs for modulation selection procedure based at least on CSF report
610
SRS (e.g., to allow for downlink channel estimation)
612
Estimate downlink channel and locations of REs
614
Estimate downlink channel and locations of REs
616
Determine to activate modulation selection procedure
618
Activation indication (e.g., RRC, DCI, MAC-CE)
620
Assign REs for modulation procedure
622
Downlink communication

FIG. 6

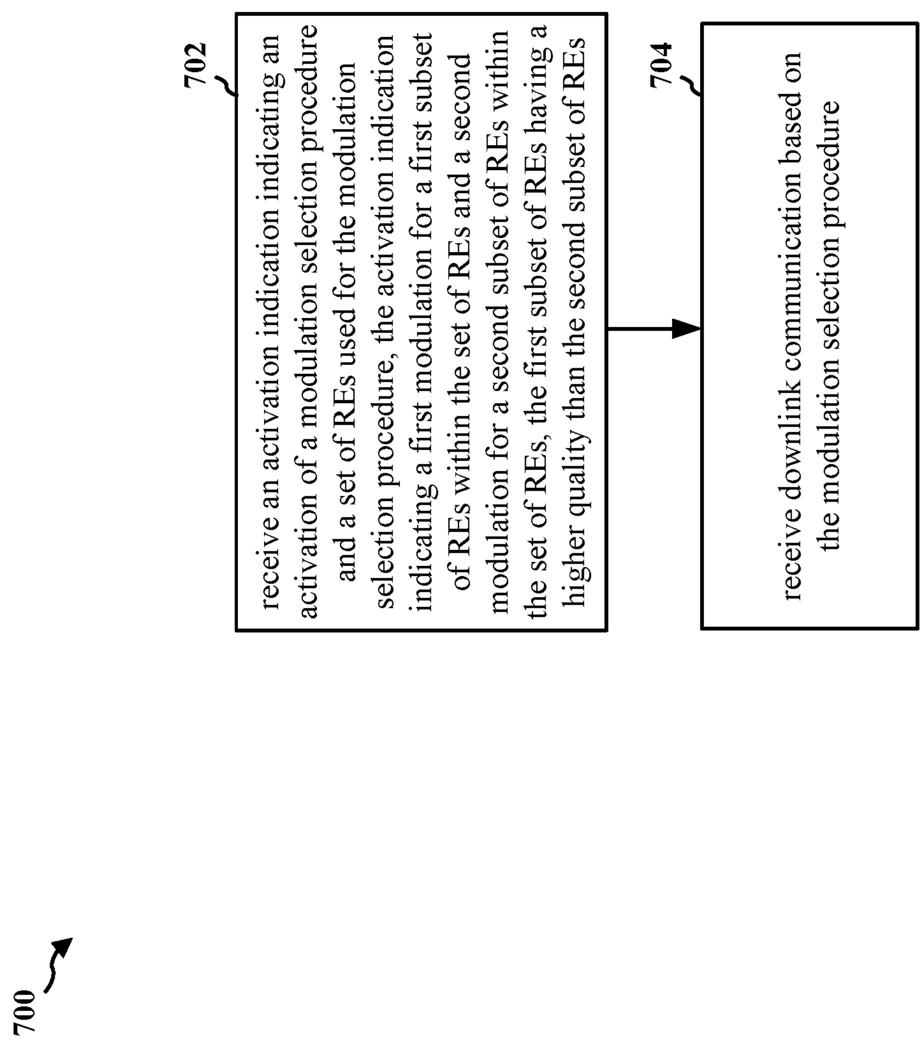

700
702
receive an activation indication indicating an activation of a modulation selection procedure and a set of REs used for the modulation selection procedure, the activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs
704
receive downlink communication based on the modulation selection procedure

FIG. 7

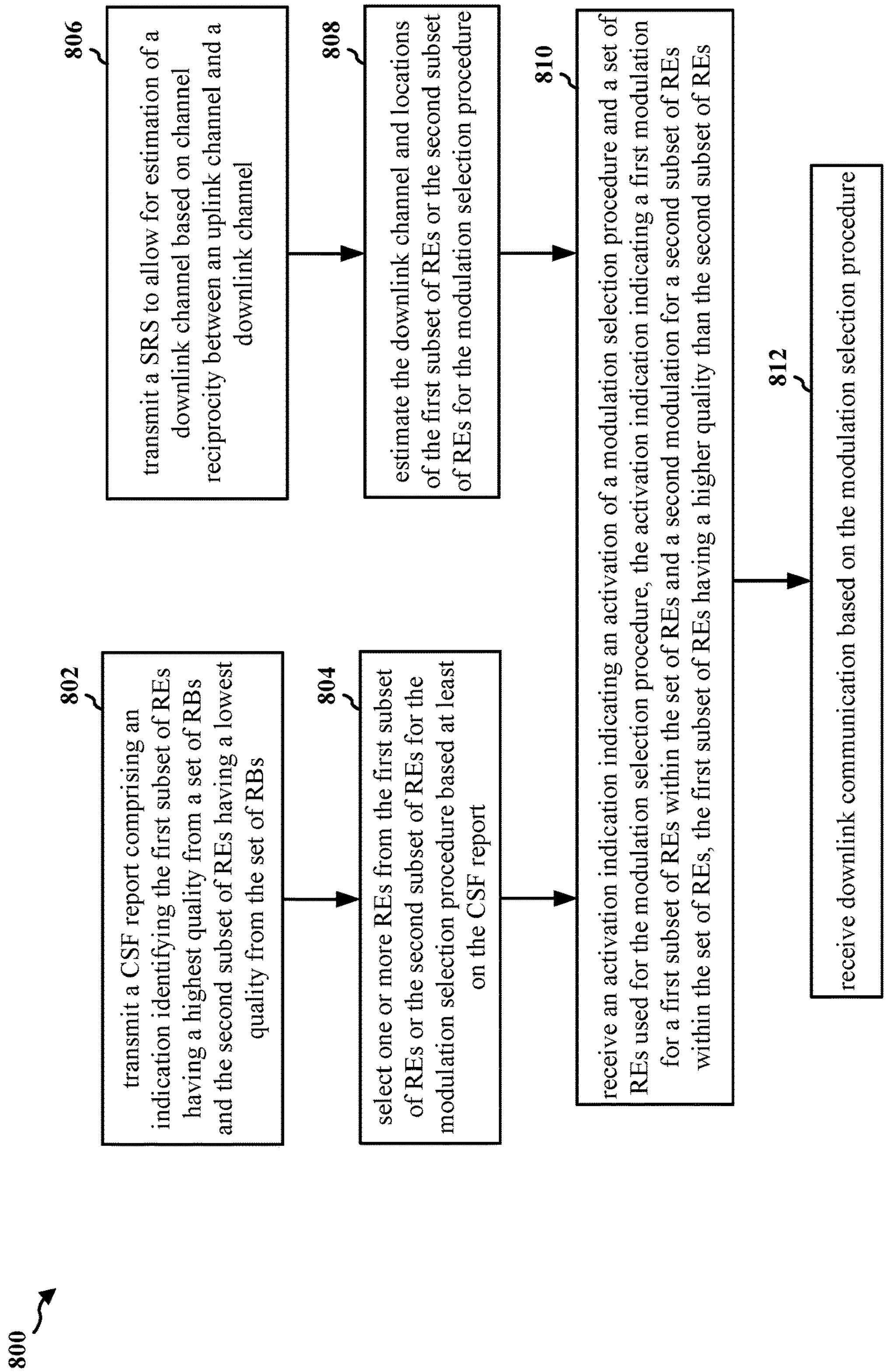
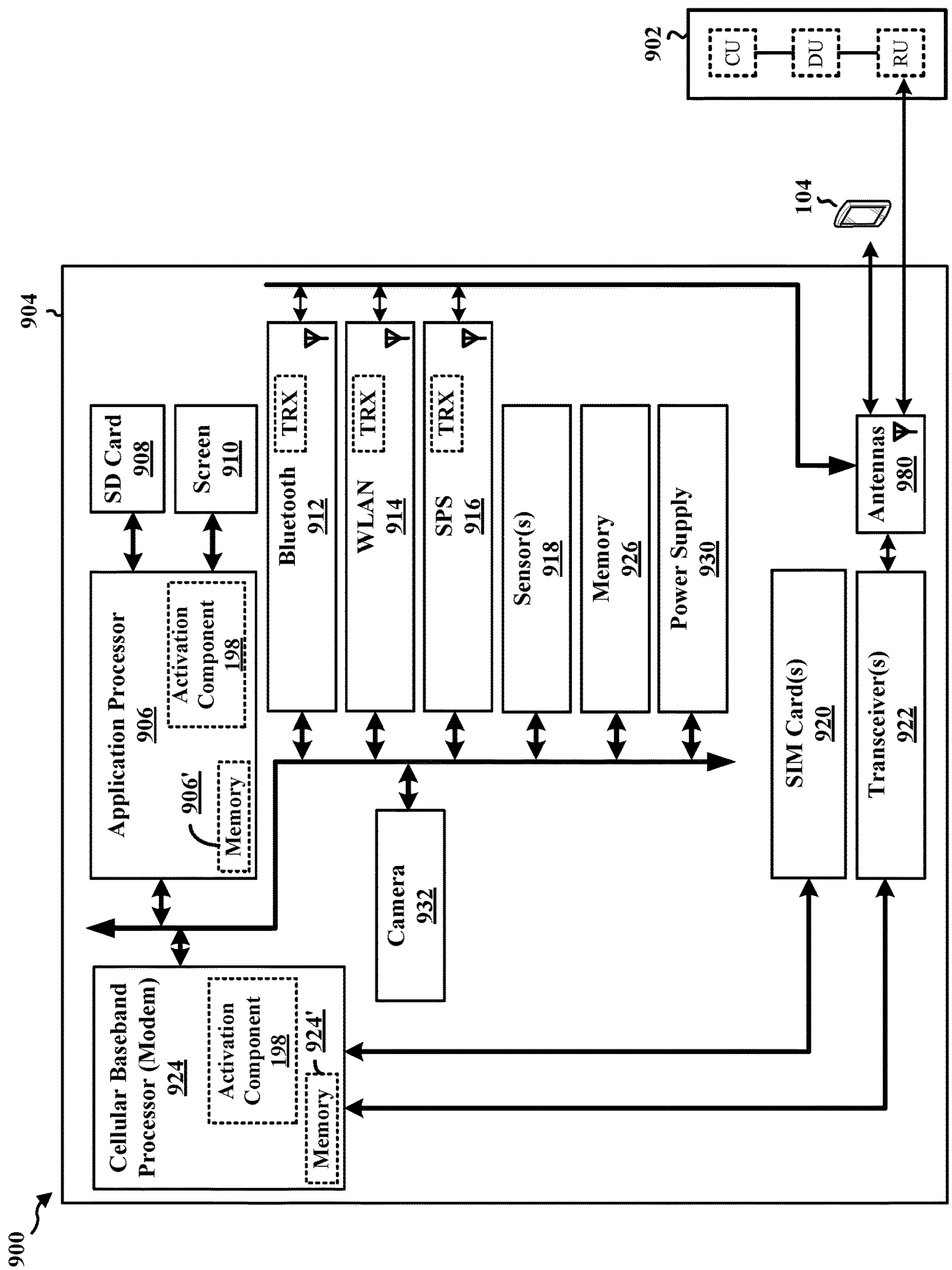

800
802
transmit a CSF report comprising an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs
804
select one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report
806
transmit a SRS to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and a downlink channel
808
estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure
810
receive an activation indication indicating an activation of a modulation selection procedure and a set of REs used for the modulation selection procedure, the activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs
812
receive downlink communication based on the modulation selection procedure

FIG. 8



900
904
902
CU
DU
RU
104
SD Card 908
Screen 910
Application Processor 906
Activation Component 198
906'
Memory
Bluetooth 912
TRX
WLAN 914
TRX
SPS 916
TRX
Sensor(s) 918
Memory 926
Power Supply 930
Antennas 980
Camera 932
SIM Card(s) 920
Transceiver(s) 922
Cellular Baseband Processor (Modem) 924
Activation Component 198
924'
Memory

FIG. 9

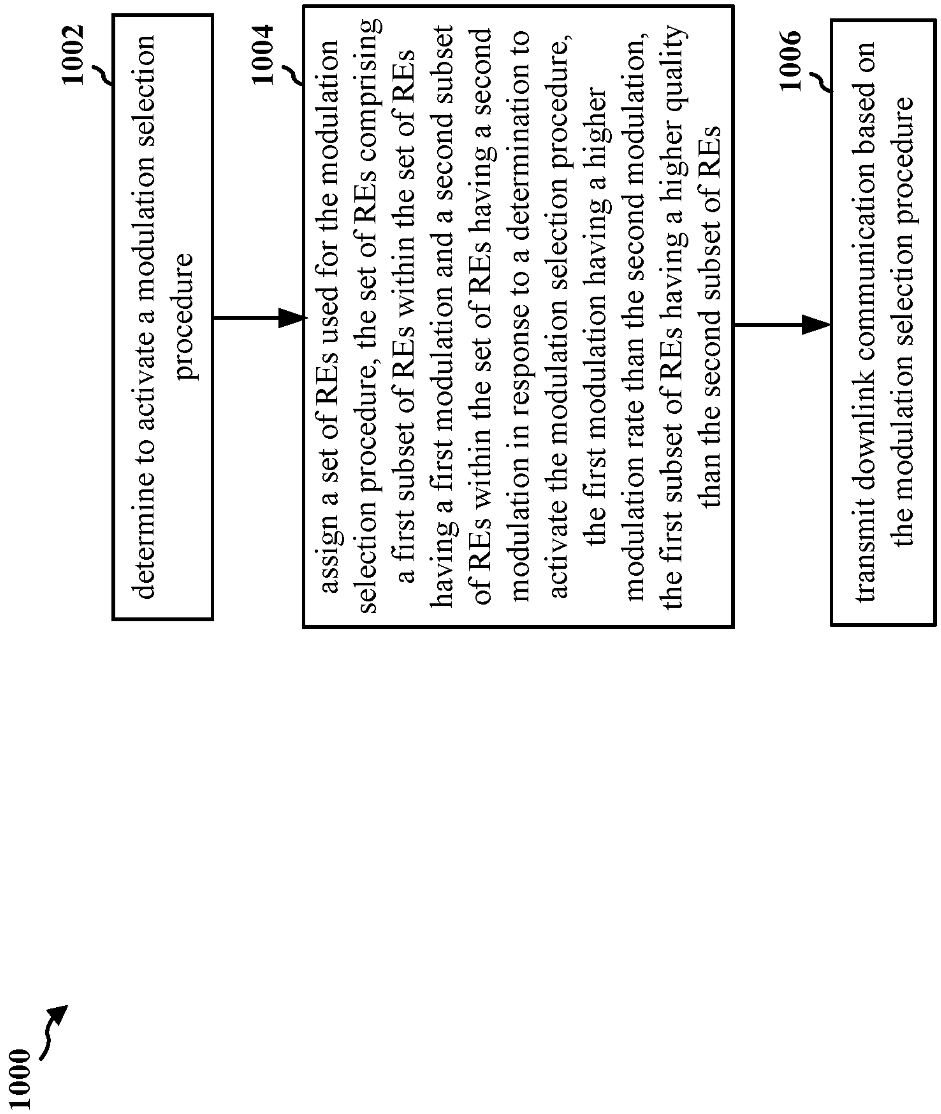

1000
1002
determine to activate a modulation selection procedure
1004
assign a set of REs used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs
1006
transmit downlink communication based on the modulation selection procedure

FIG. 10

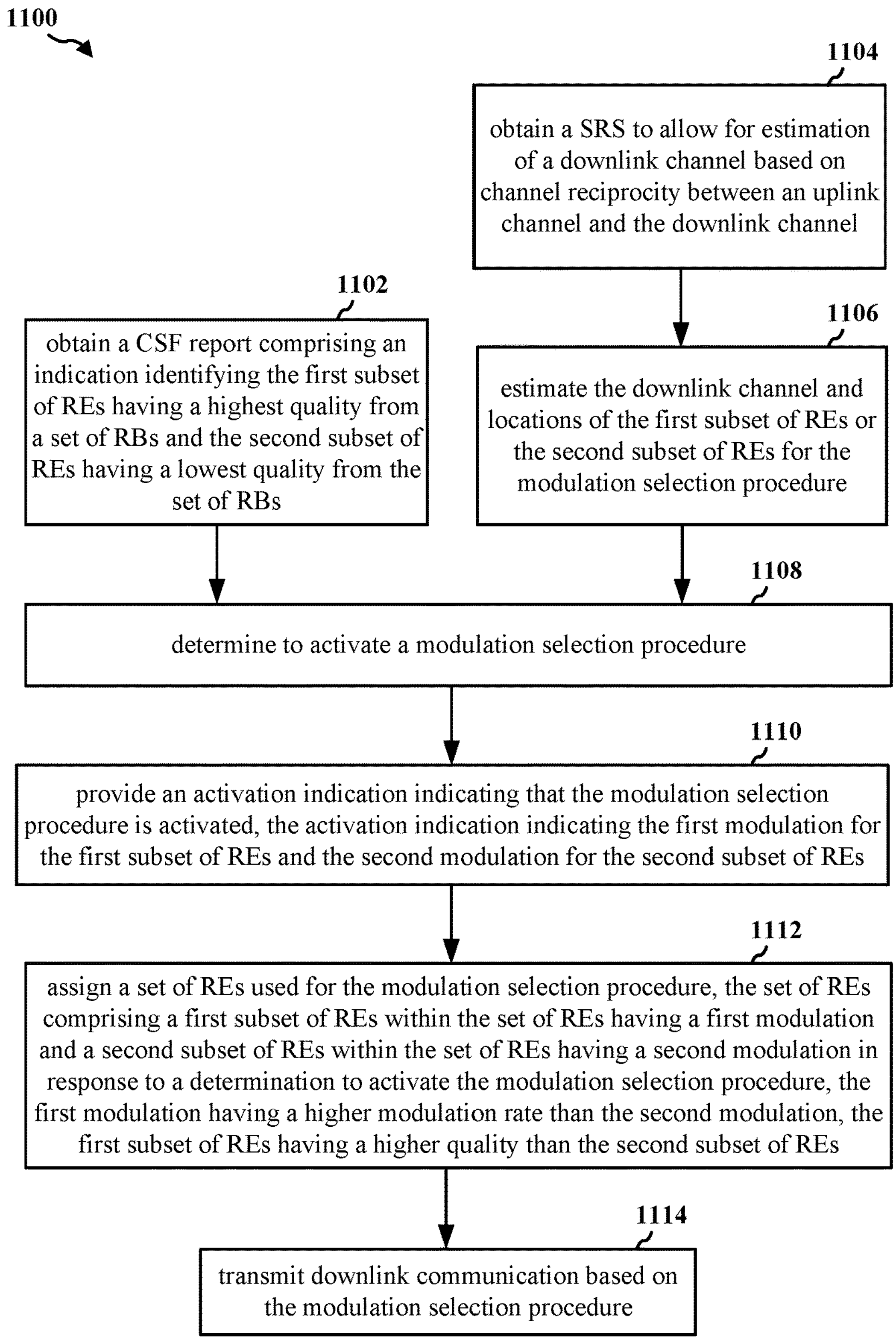

1100
1104
obtain a SRS to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel
1102
obtain a CSF report comprising an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs
1106
estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure
1108
determine to activate a modulation selection procedure
1110
provide an activation indication indicating that the modulation selection procedure is activated, the activation indication indicating the first modulation for the first subset of REs and the second modulation for the second subset of REs
1112
assign a set of REs used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs
1114
transmit downlink communication based on the modulation selection procedure

FIG. 11

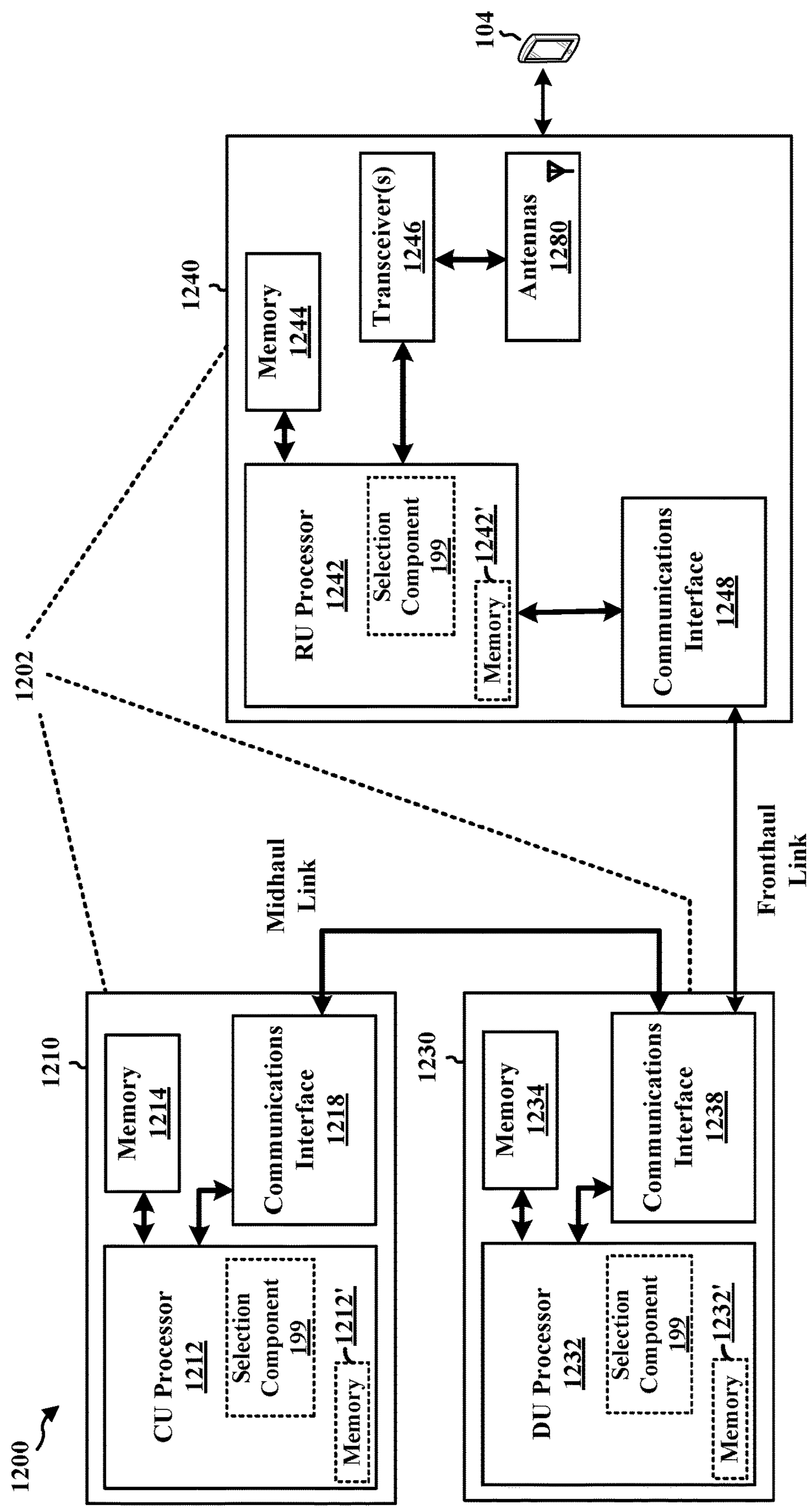

1200
1210
Memory 1214
Communications Interface 1218
CU Processor 1212
Selection Component 199
Memory
1212'
1230
Memory 1234
Communications Interface 1238
DU Processor 1232
Selection Component 199
Memory
1232'
Midhaul Link
Fronthaul Link
1202
1240
Memory 1244
Transceiver(s) 1246
Antennas 1280
RU Processor 1242
Selection Component 199
Memory
1242'
Communications Interface 1248
104

FIG. 12

CHANNEL ORIENTED MODULATION SELECTION FOR IMPROVED SPECTRAL EFFICIENCY

TECHNICAL FIELD

The present disclosure relates generally to communication systems, and more particularly, to a configuration for channel oriented modulation selection.

INTRODUCTION

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

These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability (e.g., with Internet of Things (IoT)), and other requirements. 5G NR includes services associated with enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable low latency communications (URLLC). Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

BRIEF SUMMARY

The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects. This summary neither identifies key or critical elements of all aspects nor delineates the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus may be a device at a UE. The device may be a processor and/or a modem at a UE or the UE itself. The apparatus receives an activation indication indicating an activation of a modulation selection procedure and a set of resource elements (REs) used for the modulation selection procedure, the activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs. The apparatus receives downlink communication based on the modulation selection procedure.

In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus may be a device at a network entity. The device may be a processor and/or a modem at a network entity or the network entity itself. The apparatus determines to activate a modulation selection procedure. The apparatus assigns a set of resource elements (REs) used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs. The apparatus transmits downlink communication based on the modulation selection procedure.

To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating an example of a wireless communications system and an access network.

FIG. **2A** is a diagram illustrating an example of a first frame, in accordance with various aspects of the present disclosure.

FIG. **2B** is a diagram illustrating an example of DL channels within a subframe, in accordance with various aspects of the present disclosure.

FIG. **2C** is a diagram illustrating an example of a second frame, in accordance with various aspects of the present disclosure.

FIG. **2D** is a diagram illustrating an example of UL channels within a subframe, in accordance with various aspects of the present disclosure.

FIG. **3** is a diagram illustrating an example of a base station and user equipment (UE) in an access network.

FIG. **4** is a diagram illustrating an example of a transmitter and a receiver, in accordance with aspects presented herein.

FIG. **5** is a diagram illustrating an example of a transmitter and a receiver, in accordance with aspects presented herein.

FIG. **6** is a call flow diagram of signaling between a UE and a base station.

FIG. **7** is a flowchart of a method of wireless communication.

FIG. **8** is a flowchart of a method of wireless communication.

FIG. **9** is a diagram illustrating an example of a hardware implementation for an example apparatus and/or network entity.

FIG. **10**. is a flowchart of a method of wireless communication.

FIG. **11** is a flowchart of a method of wireless communication.

FIG. **12** is a diagram illustrating an example of a hardware implementation for an example network entity.

DETAILED DESCRIPTION

In wireless communications, a UE may report channel state information (CSI) to a base station so that the base station may maximize throughput. The UE may also report to the base station the RB having the highest quality for downlink. In wireless communications, such as NR, high bands may be time division duplexed (TDD) for FR1 and FR2. A common assumption for TDD is a high reciprocity between the uplink and the downlink channels. In instances where high reciprocity is obtained, the base station may estimate the UE downlink channel response by estimating the UE uplink channel response seen on the SRS. Algorithm optimizations may be achieved in instances where the UE has a high signal to noise ratio (SNR) and a quality downlink channel estimation.

Aspects presented herein provide for algorithm optimizations between the UE and the base station. The UE may be configured to report to the base station the lowest quality REs and the highest quality REs, such that the base station may use the lowest and highest quality REs at different modulations. In addition, a modulation selection procedure may identify REs with the lowest/highest channel at the UE based on a channel response without the UE reporting the lowest/highest quality REs.

The detailed description set forth below in connection with the drawings describes various configurations and does not represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

Several aspects of telecommunication systems are presented with reference to various apparatus and methods. These apparatus and methods are described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as "elements"). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise, shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, or any combination thereof.

Accordingly, in one or more example aspects, implementations, and/or use cases, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

While aspects, implementations, and/or use cases are described in this application by illustration to some examples, additional or different aspects, implementations and/or use cases may come about in many different arrangements and scenarios. Aspects, implementations, and/or use cases described herein may be implemented across many differing platform types, devices, systems, shapes, sizes, and packaging arrangements. For example, aspects, implementations, and/or use cases may come about via integrated chip implementations and other non-module-component based devices (e.g., end-user devices, vehicles, communication devices, computing devices, industrial equipment, retail/purchasing devices, medical devices, artificial intelligence (AI)-enabled devices, etc.). While some examples may or may not be specifically directed to use cases or applications, a wide assortment of applicability of described examples may occur. Aspects, implementations, and/or use cases may range a spectrum from chip-level or modular components to non-modular, non-chip-level implementations and further to aggregate, distributed, or original equipment manufacturer (OEM) devices or systems incorporating one or more techniques herein. In some practical settings, devices incorporating described aspects and features may also include additional components and features for implementation and practice of claimed and described aspect. For example, transmission and reception of wireless signals necessarily includes a number of components for analog and digital purposes (e.g., hardware components including antenna, RF-chains, power amplifiers, modulators, buffer, processor(s), interleaver, adders/summers, etc.). Techniques described herein may be practiced in a wide variety of devices, chip-level components, systems, distributed arrangements, aggregated or disaggregated components, end-user devices, etc. of varying sizes, shapes, and constitution.

Deployment of communication systems, such as 5G NR systems, may be arranged in multiple manners with various components or constituent parts. In a 5G NR system, or network, a network node, a network entity, a mobility element of a network, a radio access network (RAN) node, a core network node, a network element, or a network equipment, such as a base station (BS), or one or more units (or one or more components) performing base station functionality, may be implemented in an aggregated or disaggregated architecture. For example, a BS (such as a Node B (NB), evolved NB (eNB), NR BS, 5G NB, access point

(AP), a transmit receive point (TRP), or a cell, etc.) may be implemented as an aggregated base station (also known as a standalone BS or a monolithic BS) or a disaggregated base station.

An aggregated base station may be configured to utilize a radio protocol stack that is physically or logically integrated within a single RAN node. A disaggregated base station may be configured to utilize a protocol stack that is physically or logically distributed among two or more units (such as one or more central or centralized units (CUs), one or more distributed units (DUs), or one or more radio units (RUs)). In some aspects, a CU may be implemented within a RAN node, and one or more DUs may be co-located with the CU, or alternatively, may be geographically or virtually distributed throughout one or multiple other RAN nodes. The DUs may be implemented to communicate with one or more RUs. Each of the CU, DU and RU can be implemented as virtual units, i.e., a virtual central unit (VCU), a virtual distributed unit (VDU), or a virtual radio unit (VRU).

Base station operation or network design may consider aggregation characteristics of base station functionality. For example, disaggregated base stations may be utilized in an integrated access backhaul (IAB) network, an open radio access network (O-RAN (such as the network configuration sponsored by the O-RAN Alliance)), or a virtualized radio access network (vRAN, also known as a cloud radio access network (C-RAN)). Disaggregation may include distributing functionality across two or more units at various physical locations, as well as distributing functionality for at least one unit virtually, which can enable flexibility in network design. The various units of the disaggregated base station, or disaggregated RAN architecture, can be configured for wired or wireless communication with at least one other unit.

FIG. **1** is a diagram **100** illustrating an example of a wireless communications system and an access network. The illustrated wireless communications system includes a disaggregated base station architecture. The disaggregated base station architecture may include one or more CUs **110** that can communicate directly with a core network **120** via a backhaul link, or indirectly with the core network **120** through one or more disaggregated base station units (such as a Near-Real Time (Near-RT) RAN Intelligent Controller (RIC) **125** via an E2 link, or a Non-Real Time (Non-RT) RIC **115** associated with a Service Management and Orchestration (SMO) Framework **105**, or both). A CU **110** may communicate with one or more DUs **130** via respective midhaul links, such as an F1 interface. The DUs **130** may communicate with one or more RUs **140** via respective fronthaul links. The RUs **140** may communicate with respective UEs **104** via one or more radio frequency (RF) access links. In some implementations, the UE **104** may be simultaneously served by multiple RUs **140**.

Each of the units, i.e., the CUs **110**, the DUs **130**, the RUs **140**, as well as the Near-RT RICs **125**, the Non-RT RICs **115**, and the SMO Framework **105**, may include one or more interfaces or be coupled to one or more interfaces configured to receive or to transmit signals, data, or information (collectively, signals) via a wired or wireless transmission medium. Each of the units, or an associated processor or controller providing instructions to the communication interfaces of the units, can be configured to communicate with one or more of the other units via the transmission medium. For example, the units can include a wired interface configured to receive or to transmit signals over a wired transmission medium to one or more of the other units. Additionally, the units can include a wireless interface, which may include a receiver, a transmitter, or a transceiver (such as an RF transceiver), configured to receive or to transmit signals, or both, over a wireless transmission medium to one or more of the other units.

In some aspects, the CU **110** may host one or more higher layer control functions. Such control functions can include radio resource control (RRC), packet data convergence protocol (PDCP), service data adaptation protocol (SDAP), or the like. Each control function can be implemented with an interface configured to communicate signals with other control functions hosted by the CU **110**. The CU **110** may be configured to handle user plane functionality (i.e., Central Unit-User Plane (CU-UP)), control plane functionality (i.e., Central Unit-Control Plane (CU-CP)), or a combination thereof. In some implementations, the CU **110** can be logically split into one or more CU-UP units and one or more CU-CP units. The CU-UP unit can communicate bidirectionally with the CU-CP unit via an interface, such as an E1 interface when implemented in an O-RAN configuration. The CU **110** can be implemented to communicate with the DU **130**, as necessary, for network control and signaling.

The DU **130** may correspond to a logical unit that includes one or more base station functions to control the operation of one or more RUs **140**. In some aspects, the DU **130** may host one or more of a radio link control (RLC) layer, a medium access control (MAC) layer, and one or more high physical (PHY) layers (such as modules for forward error correction (FEC) encoding and decoding, scrambling, modulation, demodulation, or the like) depending, at least in part, on a functional split, such as those defined by 3GPP. In some aspects, the DU **130** may further host one or more low PHY layers. Each layer (or module) can be implemented with an interface configured to communicate signals with other layers (and modules) hosted by the DU **130**, or with the control functions hosted by the CU **110**.

Lower-layer functionality can be implemented by one or more RUs **140**. In some deployments, an RU **140**, controlled by a DU **130**, may correspond to a logical node that hosts RF processing functions, or low-PHY layer functions (such as performing fast Fourier transform (FFT), inverse FFT (iFFT), digital beamforming, physical random access channel (PRACH) extraction and filtering, or the like), or both, based at least in part on the functional split, such as a lower layer functional split. In such an architecture, the RU(s) **140** can be implemented to handle over the air (OTA) communication with one or more UEs **104**. In some implementations, real-time and non-real-time aspects of control and user plane communication with the RU(s) **140** can be controlled by the corresponding DU **130**. In some scenarios, this configuration can enable the DU(s) **130** and the CU **110** to be implemented in a cloud-based RAN architecture, such as a vRAN architecture.

The SMO Framework **105** may be configured to support RAN deployment and provisioning of non-virtualized and virtualized network elements. For non-virtualized network elements, the SMO Framework **105** may be configured to support the deployment of dedicated physical resources for RAN coverage requirements that may be managed via an operations and maintenance interface (such as an O1 interface). For virtualized network elements, the SMO Framework **105** may be configured to interact with a cloud computing platform (such as an open cloud (O-Cloud) **190**) to perform network element life cycle management (such as to instantiate virtualized network elements) via a cloud computing platform interface (such as an O2 interface). Such virtualized network elements can include, but are not limited to, CUs **110**, DUs **130**, RUs **140** and Near-RT RICs

125. In some implementations, the SMO Framework 105 can communicate with a hardware aspect of a 4G RAN, such as an open eNB (O-eNB) 111, via an O1 interface. Additionally, in some implementations, the SMO Framework 105 can communicate directly with one or more RUs 140 via an O1 interface. The SMO Framework 105 also may include a Non-RT RIC 115 configured to support functionality of the SMO Framework 105.

The Non-RT RIC 115 may be configured to include a logical function that enables non-real-time control and optimization of RAN elements and resources, artificial intelligence (AI)/machine learning (ML) (AI/ML) workflows including model training and updates, or policy-based guidance of applications/features in the Near-RT RIC 125. The Non-RT RIC 115 may be coupled to or communicate with (such as via an AI interface) the Near-RT RIC 125. The Near-RT RIC 125 may be configured to include a logical function that enables near-real-time control and optimization of RAN elements and resources via data collection and actions over an interface (such as via an E2 interface) connecting one or more CUs 110, one or more DUs 130, or both, as well as an O-eNB, with the Near-RT RIC 125.

In some implementations, to generate AI/ML models to be deployed in the Near-RT RIC 125, the Non-RT RIC 115 may receive parameters or external enrichment information from external servers. Such information may be utilized by the Near-RT RIC 125 and may be received at the SMO Framework 105 or the Non-RT RIC 115 from non-network data sources or from network functions. In some examples, the Non-RT RIC 115 or the Near-RT RIC 125 may be configured to tune RAN behavior or performance. For example, the Non-RT RIC 115 may monitor long-term trends and patterns for performance and employ AI/ML models to perform corrective actions through the SMO Framework 105 (such as reconfiguration via O1) or via creation of RAN management policies (such as A1 policies).

At least one of the CU 110, the DU 130, and the RU 140 may be referred to as a base station 102. Accordingly, a base station 102 may include one or more of the CU 110, the DU 130, and the RU 140 (each component indicated with dotted lines to signify that each component may or may not be included in the base station 102). The base station 102 provides an access point to the core network 120 for a UE 104. The base stations 102 may include macrocells (high power cellular base station) and/or small cells (low power cellular base station). The small cells include femtocells, picocells, and microcells. A network that includes both small cell and macrocells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links between the RUs 140 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to an RU 140 and/or downlink (DL) (also referred to as forward link) transmissions from an RU 140 to a UE 104. The communication links may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more carriers. The base stations 102/UEs 104 may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 100, 400, etc. MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or fewer carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

Certain UEs 104 may communicate with each other using device-to-device (D2D) communication link 158. The D2D communication link 158 may use the DL/UL wireless wide area network (WWAN) spectrum. The D2D communication link 158 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, Bluetooth, Wi-Fi based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard, LTE, or NR.

The wireless communications system may further include a Wi-Fi AP 150 in communication with UEs 104 (also referred to as Wi-Fi stations (STAs)) via communication link 154, e.g., in a 5 GHz unlicensed frequency spectrum or the like. When communicating in an unlicensed frequency spectrum, the UEs 104/AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.

The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR, two initial operating bands have been identified as frequency range designations FR1 (410 MHz-7.125 GHz) and FR2 (24.25 GHz-52.6 GHz). Although a portion of FR1 is greater than 6 GHz, FR1 is often referred to (interchangeably) as a "sub-6 GHz" band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a "millimeter wave" band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHz-300 GHz) which is identified by the International Telecommunications Union (ITU) as a "millimeter wave" band.

The frequencies between FR1 and FR2 are often referred to as mid-band frequencies. Recent 5G NR studies have identified an operating band for these mid-band frequencies as frequency range designation FR3 (7.125 GHz-24.25 GHz). Frequency bands falling within FR3 may inherit FR1 characteristics and/or FR2 characteristics, and thus may effectively extend features of FR1 and/or FR2 into mid-band frequencies. In addition, higher frequency bands are currently being explored to extend 5G NR operation beyond 52.6 GHz. For example, three higher operating bands have been identified as frequency range designations FR2-2 (52.6 GHz-71 GHz), FR4 (71 GHz-114.25 GHz), and FR5 (114.25 GHz-300 GHz). Each of these higher frequency bands falls within the EHF band.

With the above aspects in mind, unless specifically stated otherwise, the term "sub-6 GHz" or the like if used herein may broadly represent frequencies that may be less than 6 GHz, may be within FR1, or may include mid-band frequencies. Further, unless specifically stated otherwise, the term "millimeter wave" or the like if used herein may broadly represent frequencies that may include mid-band frequencies, may be within FR2, FR4, FR2-2, and/or FR5, or may be within the EHF band.

The base station 102 and the UE 104 may each include a plurality of antennas, such as antenna elements, antenna panels, and/or antenna arrays to facilitate beamforming. The base station 102 may transmit a beamformed signal 182 to the UE **104** in one or more transmit directions. The UE **104** may receive the beamformed signal from the base station **102** in one or more receive directions. The UE **104** may also transmit a beamformed signal **184** to the base station **102** in one or more transmit directions. The base station **102** may receive the beamformed signal from the UE **104** in one or more receive directions. The base station **102**/UE **104** may perform beam training to determine the best receive and transmit directions for each of the base station **102**/UE **104**. The transmit and receive directions for the base station **102** may or may not be the same. The transmit and receive directions for the UE **104** may or may not be the same.

The base station **102** may include and/or be referred to as a gNB, Node B, eNB, an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), a transmit reception point (TRP), network node, network entity, network equipment, or some other suitable terminology. The base station **102** can be implemented as an integrated access and backhaul (IAB) node, a relay node, a sidelink node, an aggregated (monolithic) base station with a baseband unit (BBU) (including a CU and a DU) and an RU, or as a disaggregated base station including one or more of a CU, a DU, and/or an RU. The set of base stations, which may include disaggregated base stations and/or aggregated base stations, may be referred to as next generation (NG) RAN (NG-RAN).

The core network **120** may include an Access and Mobility Management Function (AMF) **161**, a Session Management Function (SMF) **162**, a User Plane Function (UPF) **163**, a Unified Data Management (UDM) **164**, one or more location servers **168**, and other functional entities. The AMF **161** is the control node that processes the signaling between the UEs **104** and the core network **120**. The AMF **161** supports registration management, connection management, mobility management, and other functions. The SMF **162** supports session management and other functions. The UPF **163** supports packet routing, packet forwarding, and other functions. The UDM **164** supports the generation of authentication and key agreement (AKA) credentials, user identification handling, access authorization, and subscription management. The one or more location servers **168** are illustrated as including a Gateway Mobile Location Center (GMLC) **165** and a Location Management Function (LMF) **166**. However, generally, the one or more location servers **168** may include one or more location/positioning servers, which may include one or more of the GMLC **165**, the LMF **166**, a position determination entity (PDE), a serving mobile location center (SMLC), a mobile positioning center (MPC), or the like. The GMLC **165** and the LMF **166** support UE location services. The GMLC **165** provides an interface for clients/applications (e.g., emergency services) for accessing UE positioning information. The LMF **166** receives measurements and assistance information from the NG-RAN and the UE **104** via the AMF **161** to compute the position of the UE **104**. The NG-RAN may utilize one or more positioning methods in order to determine the position of the UE **104**. Positioning the UE **104** may involve signal measurements, a position estimate, and an optional velocity computation based on the measurements. The signal measurements may be made by the UE **104** and/or the serving base station **102**. The signals measured may be based on one or more of a satellite positioning system (SPS) **170** (e.g., one or more of a Global Navigation Satellite System (GNSS), global position system (GPS), non-terrestrial network (NTN), or other satellite position/location system), LTE signals, wireless local area network (WLAN) signals, Bluetooth signals, a terrestrial beacon system (TBS), sensor-based information (e.g., barometric pressure sensor, motion sensor), NR enhanced cell ID (NR E-CID) methods, NR signals (e.g., multi-round trip time (Multi-RTT), DL angle-of-departure (DL-AoD), DL time difference of arrival (DL-TDOA), UL time difference of arrival (UL-TDOA), and UL angle-of-arrival (UL-AoA) positioning), and/or other systems/signals/sensors.

Examples of UEs **104** include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a sensor/actuator, a display, or any other similar functioning device. Some of the UEs **104** may be referred to as IoT devices (e.g., parking meter, gas pump, toaster, vehicles, heart monitor, etc.). The UE **104** may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology. In some scenarios, the term UE may also apply to one or more companion devices such as in a device constellation arrangement. One or more of these devices may collectively access the network and/or individually access the network.

Referring again to FIG. **1**, in certain aspects, the UE **104** may comprise an activation component **198** configured to receive an activation indication indicating an activation of a modulation selection procedure and a set of REs used for the modulation selection procedure, the activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs; and receive downlink communication based on the modulation selection procedure.

Referring again to FIG. **1**, in certain aspects, the base station **102** may comprise a selection component **199** configured to determine to activate a modulation selection procedure; assign a set of REs used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs; and transmit downlink communication based on the modulation selection procedure.

Although the following description may be focused on 5G NR, the concepts described herein may be applicable to other similar areas, such as LTE, LTE-A, CDMA, GSM, and other wireless technologies.

FIG. **2**A is a diagram **200** illustrating an example of a first subframe within a 5G NR frame structure. FIG. **2**B is a diagram **230** illustrating an example of DL channels within a 5G NR subframe. FIG. **2**C is a diagram **250** illustrating an example of a second subframe within a 5G NR frame structure. FIG. **2**D is a diagram **280** illustrating an example of UL channels within a 5G NR subframe. The 5G NR frame structure may be frequency division duplexed (FDD) in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for either DL or UL, or may be time division duplexed (TDD) in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for both DL and UL. In the examples provided by FIGS. **2**A, **2**C, the 5G NR frame structure is assumed to be TDD, with subframe 4 being configured with slot format 28 (with mostly DL), where D is DL, U is UL, and F is flexible for use between DL/UL, and subframe 3 being configured with slot format 1 (with all UL). While subframes 3, 4 are shown with slot formats 1, 28, respectively, any particular subframe may be configured with any of the various available slot formats 0-61. Slot formats 0, 1 are all DL, UL, respectively. Other slot formats 2-61 include a mix of DL, UL, and flexible symbols. UEs are configured with the slot format (dynamically through DL control information (DCI), or semi-statically/statically through radio resource control (RRC) signaling) through a received slot format indicator (SFI). Note that the description infra applies also to a 5G NR frame structure that is TDD.

FIGS. **2**A-**2**D illustrate a frame structure, and the aspects of the present disclosure may be applicable to other wireless communication technologies, which may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized subframes (1 ms). Each subframe may include one or more time slots. Subframes may also include mini-slots, which may include 7, 4, or 2 symbols. Each slot may include 14 or 12 symbols, depending on whether the cyclic prefix (CP) is normal or extended. For normal CP, each slot may include 14 symbols, and for extended CP, each slot may include 12 symbols. The symbols on DL may be CP orthogonal frequency division multiplexing (OFDM) (CP-OFDM) symbols. The symbols on UL may be CP-OFDM symbols (for high throughput scenarios) or discrete Fourier transform (DFT) spread OFDM (DFT-s-OFDM) symbols (also referred to as single carrier frequency-division multiple access (SC-FDMA) symbols) (for power limited scenarios; limited to a single stream transmission). The number of slots within a subframe is based on the CP and the numerology. The numerology defines the subcarrier spacing (SCS) and, effectively, the symbol length/duration, which is equal to 1/SCS.

μ	SCS $\Delta f = 2^{\mu} \cdot 15$[kHz]	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal

For normal CP (14 symbols/slot), different numerologies μ 0 to 4 allow for 1, 2, 4, 8, and 16 slots, respectively, per subframe. For extended CP, the numerology 2 allows for 4 slots per subframe. Accordingly, for normal CP and numerology μ, there are 14 symbols/slot and 2^{μ} slots/subframe. The subcarrier spacing may be equal to $2^{\mu}*15$ kHz, where μ is the numerology 0 to 4. As such, the numerology $\mu=0$ has a subcarrier spacing of 15 kHz and the numerology $\mu=4$ has a subcarrier spacing of 240 kHz. The symbol length/duration is inversely related to the subcarrier spacing. FIGS. **2**A-**2**D provide an example of normal CP with 14 symbols per slot and numerology $\mu=2$ with 4 slots per subframe. The slot duration is 0.25 ms, the subcarrier spacing is 60 kHz, and the symbol duration is approximately 16.67 μs. Within a set of frames, there may be one or more different bandwidth parts (BWPs) (see FIG. **2**B) that are frequency division multiplexed. Each BWP may have a particular numerology and CP (normal or extended).

A resource grid may be used to represent the frame structure. Each time slot includes a resource block (RB) (also referred to as physical RBs (PRBs)) that extends 12 consecutive subcarriers. The resource grid is divided into multiple resource elements (REs). The number of bits carried by each RE depends on the modulation scheme.

As illustrated in FIG. **2**A, some of the REs carry reference (pilot) signals (RS) for the UE. The RS may include demodulation RS (DM-RS) (indicated as R for one particular configuration, but other DM-RS configurations are possible) and channel state information reference signals (CSI-RS) for channel estimation at the UE. The RS may also include beam measurement RS (BRS), beam refinement RS (BRRS), and phase tracking RS (PT-RS).

FIG. **2**B illustrates an example of various DL channels within a subframe of a frame. The physical downlink control channel (PDCCH) carries DCI within one or more control channel elements (CCEs) (e.g., 1, 2, 4, 8, or 16 CCEs), each CCE including six RE groups (REGs), each REG including 12 consecutive REs in an OFDM symbol of an RB. A PDCCH within one BWP may be referred to as a control resource set (CORESET). A UE is configured to monitor PDCCH candidates in a PDCCH search space (e.g., common search space, UE-specific search space) during PDCCH monitoring occasions on the CORESET, where the PDCCH candidates have different DCI formats and different aggregation levels. Additional BWPs may be located at greater and/or lower frequencies across the channel bandwidth. A primary synchronization signal (PSS) may be within symbol 2 of particular subframes of a frame. The PSS is used by a UE **104** to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) may be within symbol 4 of particular subframes of a frame. The SSS is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the DM-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSS and SSS to form a synchronization signal (SS)/PBCH block (also referred to as SS block (SSB)). The MIB provides a number of RBs in the system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

As illustrated in FIG. **2**C, some of the REs carry DM-RS (indicated as R for one particular configuration, but other DM-RS configurations are possible) for channel estimation at the base station. The UE may transmit DM-RS for the physical uplink control channel (PUCCH) and DM-RS for the physical uplink shared channel (PUSCH). The PUSCH DM-RS may be transmitted in the first one or two symbols of the PUSCH. The PUCCH DM-RS may be transmitted in different configurations depending on whether short or long PUCCHs are transmitted and depending on the particular PUCCH format used. The UE may transmit sounding reference signals (SRS). The SRS may be transmitted in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

FIG. 2D illustrates an example of various UL channels within a subframe of a frame. The PUCCH may be located as indicated in one configuration. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and hybrid automatic repeat request (HARQ) acknowledgment (ACK) (HARQ-ACK) feedback (i.e., one or more HARQ ACK bits indicating one or more ACK and/or negative ACK (NACK)). The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

FIG. **3** is a block diagram of a base station **310** in communication with a UE **350** in an access network. In the DL, Internet protocol (IP) packets may be provided to a controller/processor **375**. The controller/processor **375** implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a service data adaptation protocol (SDAP) layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor **375** provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression/decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

The transmit (TX) processor **316** and the receive (RX) processor **370** implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor **316** handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator **374** may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE **350**. Each spatial stream may then be provided to a different antenna **320** via a separate transmitter **318**Tx. Each transmitter **318**Tx may modulate a radio frequency (RF) carrier with a respective spatial stream for transmission.

At the UE **350**, each receiver **354**Rx receives a signal through its respective antenna **352**. Each receiver **354**Rx recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor **356**. The TX processor **368** and the RX processor **356** implement layer 1 functionality associated with various signal processing functions. The RX processor **356** may perform spatial processing on the information to recover any spatial streams destined for the UE **350**. If multiple spatial streams are destined for the UE **350**, they may be combined by the RX processor **356** into a single OFDM symbol stream. The RX processor **356** then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station **310**. These soft decisions may be based on channel estimates computed by the channel estimator **358**. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station **310** on the physical channel. The data and control signals are then provided to the controller/processor **359**, which implements layer 3 and layer 2 functionality.

The controller/processor **359** can be associated with a memory **360** that stores program codes and data. The memory **360** may be referred to as a computer-readable medium. In the UL, the controller/processor **359** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets. The controller/processor **359** is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

Similar to the functionality described in connection with the DL transmission by the base station **310**, the controller/processor **359** provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

Channel estimates derived by a channel estimator **358** from a reference signal or feedback transmitted by the base station **310** may be used by the TX processor **368** to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor **368** may be provided to different antenna **352** via separate transmitters **354**Tx. Each transmitter 354Tx may modulate an RF carrier with a respective spatial stream for transmission.

The UL transmission is processed at the base station **310** in a manner similar to that described in connection with the receiver function at the UE **350**. Each receiver **318**Rx receives a signal through its respective antenna **320**. Each receiver **318**Rx recovers information modulated onto an RF carrier and provides the information to a RX processor **370**.

The controller/processor **375** can be associated with a memory **376** that stores program codes and data. The memory **376** may be referred to as a computer-readable medium. In the UL, the controller/processor **375** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets. The controller/processor **375** is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

At least one of the TX processor **368**, the RX processor **356**, and the controller/processor **359** may be configured to perform aspects in connection with the activation component **198** of FIG. **1**.

At least one of the TX processor **316**, the RX processor **370**, and the controller/processor **375** may be configured to perform aspects in connection with the selection component **199** of FIG. **1**.

In wireless communications, a UE may report CSI to a base station so that the base station may maximize throughput. The CSI may be wideband or narrowband with a common MCS per transport block. The UE may also report to the base station the RB having the highest quality for downlink.

In wireless communications, such as NR, high bands may be TDD for FR1 and FR2. A common assumption for TDD is a high reciprocity between the uplink and the downlink channels. In instances where high reciprocity is obtained, the base station may estimate the UE downlink channel response by estimating the UE uplink channel response seen on the SRS. In instances where channel reciprocity is not present, the downlink channel may be sent by the UE via a CSF report. Algorithm optimizations may be achieved in instances where the UE has a high signal to noise ratio (SNR) and a quality downlink channel estimation.

Aspects presented herein provide a configuration for channel oriented modulation selection. The aspects presented herein may provide for algorithm optimizations between the UE and the base station. The UE may be configured to report to the base station the lowest quality REs and the highest quality REs, such that the base station may use the lowest and highest quality REs at different modulations. For example, the lowest/highest quality REs may have a lower/higher modulation than the modulation indicated in a DCI for the current PDSCH. In addition, a modulation selection procedure may identify REs with the lowest/highest channel at the UE based on a channel response without the UE reporting the lowest/highest quality REs. At least one advantage of the disclosure is that channel oriented modulation selection may enhance spectral efficiency by handling spurs or other impairments within a PDSCH allocation.

FIG. **4** is a diagram **400** illustrating an example of a transmitted and a receiver, in accordance with aspects presented herein. The diagram includes an example of a transmitter **402** and a receiver **420**. The transmitter **402** may receive a report **404** from the UE, where the report indicates the best and worst REs from a set of REs. The transmitter **402** may determine whether to apply a dynamic modulation procedure **406** in response to the report (e.g., CSF) **404**. The transmitter may perform modulation **408** to generate modulated data **410**. The modulated data **410** may be modulated based on the dynamic modulation. The transmitter may then perform a mapping **412** of the data, and prepare the data for transmission **414** to the receiver **420**.

The receiver **420**, may receive data at receiver **422**. The receiver **420** may receive a reference signal **426** (e.g., DMRS, CSI-RS) to perform a channel estimation **428**. The receiver may, at **430**, find the best and worst REs from a set of REs based on the reference signal **426**. The receiver may report (e.g., **404**) the best and worst REs to the transmitter **402**. The receiver **420**, at **424**, may determine if dynamic modulation is active. In some instances, the receiver **420** may receive an indication from the transmitter indicating that the dynamic modulation is active. The dynamic modulation may be activated based on the report (e.g., **404**) indicating the best and worst REs. At **434**, the receiver may demap the received data using dynamic modulation, if active. In instances where the dynamic modulation is active, the best/worst REs may have a higher/lower modulation than that indicated within a DCI of PDSCH **432**. The receiver, at **436**, may than decode the data based on the dynamic modulation.

FIG. **5** is a diagram **500** illustrating an example of a transmitted and a receiver, in accordance with aspects presented herein. The diagram includes an example of a transmitter **502** and a receiver **520**. The transmitter **502** may receive a UE transmission **504**. Based on the transmission **504**, the transmitter **502** may, at **506** or **508**, estimate a downlink channel. The transmitter, at **506**, may estimate the downlink channel based on a SRS. The transmitter, at **508**, may estimate the downlink channel based on a CSF report from the receiver **520**. The transmitter, at **510**, may determine to apply dynamic modulation. Dynamic modulation may be applied based on the SRS or the CSF. The transmitter may perform modulation **512** to generate modulated data **514**. The modulated data **514** may be modulated based on the dynamic modulation. The transmitter may then perform a mapping **516** of the data, and prepare the data for transmission **518** to the receiver **520**.

The receiver **520**, may receive data at receiver **522**. The receiver **520**, at **524**, may determine if dynamic modulation is active. The receiver **520** may receive a reference signal from the transmitter **502**. The receiver may transmit, to the transmitter, a CSF report based on the reference signal. In some instances, the receiver may transmit an SRS, to the transmitter, to allow the transmitter to perform channel estimation of the downlink channel. The receiver **520** may receive an indication from the transmitter **502** indicating that the dynamic modulation is active. Receipt of the indication may be based on the CSF or the SRS transmitted by the receiver. The receiver may receive a DMRS **526** in order to perform channel estimation **528**. The receiver may estimate the downlink channel based on the DMRS **526**. The receiver, at **530**, may determine the locations of the best/worst REs. At **534**, the receiver may demap the received data using dynamic modulation, if active. In instances where the dynamic modulation is active, the best/worst REs may have a higher/lower modulation than that indicated within a DCI of PDSCH **532**. The receiver, at **536**, may than decode the data based on the dynamic modulation.

FIG. **6** is a call flow diagram **600** of signaling between a UE **602** and a base station **604**. The base station **604** may be configured to provide at least one cell. The UE **602** may be configured to communicate with the base station **604**. For example, in the context of FIG. **1**, the base station **604** may correspond to base station **102** and. Further, a UE **602** may correspond to at least UE **104**. In another example, in the context of FIG. **3**, the base station **604** may correspond to base station **310** and the UE **602** may correspond to UE **350**.

At **606**, the UE **602** may transmit a CSF report to the base station **604**. The base station **604** may receive the CSF report from the UE **602**. The CSF report may comprise an indication identifying a first subset of REs having a highest quality from a set of RBs and a second subset of REs having a lowest quality from the set of RBs. In some aspects, the CSF report may be based on at least one of channel state information reference signal (CSI-RS) or demodulation reference signal (DMRS) measured at the UE.

At **608**, the UE **602** may select one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report. In some aspects, a number of REs selected for the modulation selection procedure may be relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs.

At **610**, the UE **602** may the UE may transmit an SRS. The UE may transmit the SRS to the base station **604**. The UE may transmit the SRS to allow for estimation of a downlink channel. The UE may transmit the SRS to allow for the estimation of the downlink channel based on a channel reciprocity between an uplink channel and a downlink channel between the UE and the network entity.

At **612**, the UE **602** may estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure. For example, **808** may be performed by activation component **198** of apparatus **904**. In some aspects, estimation of the downlink channel may be based on a demodulation reference signal (DMRS) or a channel state information reference signal (CSI-RS) measured at the UE.

At **614**, the base station **604** may estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure. In some aspects, the estimation of the downlink channel is based on SRS received at the base station.

At **616**, the base station **604** may determine to activate a modulation selection procedure. In some aspects, the determination to activate the modulation selection procedure may be based on a CSF report from the UE.

At **618**, the base station **604** may provide an activation indication indicating that the modulation selection procedure is activated. The base station may provide the activation indication to the UE **602**. The UE **602** may receive the activation indication from the base station **604**. The activation indication may indicate the first modulation for the first subset of REs and the second modulation for the second subset of REs. In some aspects, the activation indication is provided via RRC, DCI, or MAC-CE.

At **620**, the base station **604** may assign a set of REs used for the modulation selection procedure. The set of REs may comprise a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure. The first modulation may have a higher modulation rate than the second modulation. In some aspects, a number of REs selected for the modulation selection procedure may be relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs. In some aspects, the first modulation may be greater than an MCS indicated for a current slot. For example, the first modulation may comprise 64 QAM or 32 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the second modulation may be less than the MCS indicated for the current slot. For example, the second modulation may comprise 8 QAM or 4 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the first modulation and the second modulation may be different than a modulation indicated in the DCI associated with the downlink communication. In some aspects, the first subset of REs may have a higher quality than the second subset of REs. In some aspects, the first subset of REs may have the higher quality in comparison to other REs within the set of REs. In some aspects, the second subset of REs may have the lowest quality in comparison to the other REs within the set of REs. In some aspects, the first subset of REs having the highest or higher quality or the second subset of REs having the lowest or lower quality may be based on an average quality of all the REs within one or more RBs. The lowest or lower quality or the highest or higher quality may be based on a threshold. In some aspects, the highest or higher quality may be greater than the average quality by the threshold. In some aspects, the lowest or lower quality may be less than the average quality by the threshold.

At **622**, the base station **604** may transmit the downlink communication based on the modulation selection procedure. The base station may transmit the downlink communication to the UE **602**. The UE **602** may receive the downlink communication from the base station **604**. The base station may transmit the downlink communication based on the modulation selection procedure. In some aspects, the downlink communication may be demodulated, by the UE, based at least on the first modulation and the second modulation.

FIG. **7** is a flowchart **700** of a method of wireless communication. The method may be performed by a UE (e.g., the UE **104**; the apparatus **904**). One or more of the illustrated operations may be omitted, transposed, or contemporaneous. The method may allow a UE to receive downlink communication based on a modulation selection procedure.

At **702**, the UE may receive an activation indication of a modulation selection procedure and a set of REs used for the modulation selection procedure. For example, **702** may be performed by activation component **198** of apparatus **904**. The UE may receive the activation indication from a network entity. The activation indication may indicate a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs. The first subset of REs may have a higher quality than the second subset of REs. In some aspects, the first subset of REs may have the higher quality in comparison to other REs within the set of REs. In some aspects, the second subset of REs may have the lowest quality in comparison to the other REs within the set of REs. In some aspects, the activation indication indicating the activation of the modulation selection procedure may be received via radio resource control (RRC), downlink control information (DCI), or media access control (MAC) control element (CE) (MAC-CE). In some aspects, the first modulation may be greater than an MCS indicated for a current slot. For example, the first modulation may comprise 64 QAM or 32 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the second modulation may be less than the MCS indicated for the current slot. For example, the second modulation may comprise 8 QAM or 4 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the first modulation and the second modulation may be different than a modulation indicated in the DCI associated with the downlink communication. In some aspects, the first subset of REs having the highest or higher quality or the second subset of REs having the lowest or lower quality may be based on an average quality of all the REs within one or more RBs. The lowest or lower quality or the highest or higher quality may be based on a threshold. In some aspects, the highest or higher quality may be greater than the average quality by the threshold. In some aspects, the lowest or lower quality may be less than the average quality by the threshold.

At **704**, the UE may receive downlink communication based on the modulation selection procedure. For example, **704** may be performed by activation component **198** of apparatus **904**. The UE may receive the downlink communication based on the modulation selection procedure from the network entity. In some aspects, the downlink communication may be demodulated based at least on the first modulation and the second modulation.

FIG. **8** is a flowchart **800** of a method of wireless communication. The method may be performed by a UE (e.g., the UE **104**; the apparatus **904**). The method may allow a UE to receive downlink communication based on a modulation selection procedure.

At **802**, the UE may transmit a CSF report. For example, **802** may be performed by activation component **198** of apparatus **904**. The UE may transmit the CSF report to the network entity. The CSF report may comprise an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs. In some aspects, the CSF report may be based on at least one of CSI-RS or DMRS measured at the UE.

At **804**, the UE may select one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure. For example, **804** may be performed by activation component **198** of apparatus **904**. The UE may select one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report. In some aspects, a number of REs selected for the modulation selection procedure may be relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs.

At **806**, the UE may transmit an SRS. For example, **806** may be performed by activation component **198** of apparatus **904**. The UE may transmit the SRS to the network entity. The UE may transmit the SRS to allow for estimation of a downlink channel. The UE may transmit the SRS to allow for the estimation of the downlink channel based on a channel reciprocity between an uplink channel and a downlink channel between the UE and the network entity.

At **808**, the UE may estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure. For example, **808** may be performed by activation component **198** of apparatus **904**. In some aspects, estimation of the downlink channel may be based on a DMRS or a CSI-RS measured at the UE.

At **810**, the UE may receive an activation indication of a modulation selection procedure and a set of REs used for the modulation selection procedure. For example, **810** may be performed by activation component **198** of apparatus **904**. The UE may receive the activation indication from a network entity. The activation indication may indicate a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs. The first subset of REs may have a higher quality than the second subset of REs. In some aspects, the first subset of REs may have the higher quality in comparison to other REs within the set of REs. In some aspects, the second subset of REs may have the lowest quality in comparison to the other REs within the set of REs. In some aspects, the activation indication indicating the activation of the modulation selection procedure may be received via radio resource control (RRC), downlink control information (DCI), or media access control (MAC) control element (CE) (MAC-CE). In some aspects, the first modulation may be greater than an MCS indicated for a current slot. For example, the first modulation may comprise 64 QAM or 32 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the second modulation may be less than the MCS indicated for the current slot. For example, the second modulation may comprise 8 QAM or 4 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the first modulation and the second modulation may be different than a modulation indicated in the DCI associated with the downlink communication. In some aspects, the first subset of REs having the highest or higher quality or the second subset of REs having the lowest or lower quality may be based on an average quality of all the REs within one or more RBs. The lowest or lower quality or the highest or higher quality may be based on a threshold. In some aspects, the highest or higher quality may be greater than the average quality by the threshold. In some aspects, the lowest or lower quality may be less than the average quality by the threshold.

At **812**, the UE may receive downlink communication based on the modulation selection procedure. For example, **812** may be performed by activation component **198** of apparatus **904**. The UE may receive the downlink communication based on the modulation selection procedure from the network entity. In some aspects, the downlink communication may be demodulated based at least on the first modulation and the second modulation.

FIG. **9** is a diagram **900** illustrating an example of a hardware implementation for an apparatus **904**. The apparatus **904** may be a UE, a component of a UE, or may implement UE functionality. In some aspects, the apparatus **904** may include a cellular baseband processor **924** (also referred to as a modem) coupled to one or more transceivers **922** (e.g., cellular RF transceiver). The cellular baseband processor **924** may include on-chip memory **924'**. In some aspects, the apparatus **904** may further include one or more subscriber identity modules (SIM) cards **920** and an application processor **906** coupled to a secure digital (SD) card **908** and a screen **910**. The application processor **906** may include on-chip memory **906'**. In some aspects, the apparatus **904** may further include a Bluetooth module **912**, a WLAN module **914**, an SPS module **916** (e.g., GNSS module), one or more sensor modules **918** (e.g., barometric pressure sensor/altimeter; motion sensor such as inertial management unit (IMU), gyroscope, and/or accelerometer(s); light detection and ranging (LIDAR), radio assisted detection and ranging (RADAR), sound navigation and ranging (SONAR), magnetometer, audio and/or other technologies used for positioning), additional memory modules **926**, a power supply **930**, and/or a camera **932**. The Bluetooth module **912**, the WLAN module **914**, and the SPS module **916** may include an on-chip transceiver (TRX) (or in some cases, just a receiver (RX)). The Bluetooth module **912**, the WLAN module **914**, and the SPS module **916** may include their own dedicated antennas and/or utilize the antennas **980** for communication. The cellular baseband processor **924** communicates through the transceiver(s) **922** via one or more antennas **980** with the UE **104** and/or with an RU associated with a network entity **902**. The cellular baseband processor

924 and the application processor 906 may each include a computer-readable medium/memory 924', 906', respectively. The additional memory modules 926 may also be considered a computer-readable medium/memory. Each computer-readable medium/memory 924', 906', 926 may be non-transitory. The cellular baseband processor 924 and the application processor 906 are each responsible for general processing, including the execution of software stored on the computer-readable medium/memory. The software, when executed by the cellular baseband processor 924/application processor 906, causes the cellular baseband processor 924/application processor 906 to perform the various functions described supra. The computer-readable medium/memory may also be used for storing data that is manipulated by the cellular baseband processor 924/application processor 906 when executing software. The cellular baseband processor 924/application processor 906 may be a component of the UE 350 and may include the memory 360 and/or at least one of the TX processor 368, the RX processor 356, and the controller/processor 359. In one configuration, the apparatus 904 may be a processor chip (modem and/or application) and include just the cellular baseband processor 924 and/or the application processor 906, and in another configuration, the apparatus 904 may be the entire UE (e.g., see 350 of FIG. 3) and include the additional modules of the apparatus 904.

As discussed supra, the component 198 is configured to receive an activation indication indicating an activation of a modulation selection procedure and a set of resource elements (REs) used for the modulation selection procedure, the activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs; and receive downlink communication based on the modulation selection procedure. The component 198 may be within the cellular baseband processor 924, the application processor 906, or both the cellular baseband processor 924 and the application processor 906. The component 198 may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by one or more processors configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by one or more processors, or some combination thereof. As shown, the apparatus 904 may include a variety of components configured for various functions. In one configuration, the apparatus 904, and in particular the cellular baseband processor 924 and/or the application processor 906, includes means for receiving an activation indication indicating an activation of a modulation selection procedure and a set of REs used for the modulation selection procedure. The activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs. The first subset of REs having a higher quality than the second subset of REs. The apparatus includes means for receiving downlink communication based on the modulation selection procedure. The apparatus further includes means for transmitting a channel state feedback (CSF) report comprising an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs. The apparatus further includes means for selecting one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report. The apparatus further includes means for transmitting a SRS to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and a downlink channel. The apparatus further includes means for estimating the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure. The means may be the component 198 of the apparatus 904 configured to perform the functions recited by the means. As described supra, the apparatus 904 may include the TX processor 368, the RX processor 356, and the controller/processor 359. As such, in one configuration, the means may be the TX processor 368, the RX processor 356, and/or the controller/processor 359 configured to perform the functions recited by the means.

FIG. 10 is a flowchart 1000 of a method of wireless communication. The method may be performed by a base station (e.g., the base station 102; the network entity 1202. One or more of the illustrated operations may be omitted, transposed, or contemporaneous. The method may allow a network entity to transmit downlink communication utilizing a modulation selection procedure.

At 1002, the network entity may determine to activate a modulation selection procedure. For example, 1002 may be performed by selection component 199 of network entity 1202. In some aspects, the determination to activate the modulation selection procedure is based on a CSF report from the UE.

At 1004, the network entity may assign a set of REs used for the modulation selection procedure. For example, 1004 may be performed by selection component 199 of network entity 1202. The set of REs may comprise a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure. The first modulation may have a higher modulation rate than the second modulation. The first subset of REs may have a higher quality than the second subset of REs. In some aspects, the first subset of REs may have the higher quality in comparison to other REs within the set of REs. In some aspects, the second subset of REs may have the lowest quality in comparison to the other REs within the set of REs. In some aspects, a number of REs selected for the modulation selection procedure may be relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs. In some aspects, the first modulation may be greater than an MCS indicated for a current slot. For example, the first modulation may comprise 64 QAM or 32 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the second modulation may be less than the MCS indicated for the current slot. For example, the second modulation may comprise 8 QAM or 4 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the first modulation and the second modulation may be different than a modulation indicated in the DCI associated with the downlink communication.

At 1006, the network entity may transmit the downlink communication based on the modulation selection procedure. For example, 1006 may be performed by selection component 199 of network entity 1202. The network entity may transmit the downlink communication, to the UE, based on the modulation selection procedure.

FIG. 11 is a flowchart 1100 of a method of wireless communication. The method may be performed by a base station (e.g., the base station 102; the network entity 1202. One or more of the illustrated operations may be omitted, transposed, or contemporaneous. The method may allow a network entity to transmit downlink communication utilizing a modulation selection procedure.

At **1102**, the network entity may obtain a CSF report. For example, **1102** may be performed by selection component **199** of network entity **1202**. The network entity may obtain the CSF report from the UE. The CSF report may comprise an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs. In some aspects, the CSF report may be based on at least one of CSI-RS or DMRS measured at the UE. In some aspects, the set of REs used for the modulation selection procedure may be based on the CSF report.

At **1104**, the network entity may obtain an SRS. For example, **1104** may be performed by selection component **199** of network entity **1202**. The network entity may obtain the SRS from the UE. The network entity obtaining the SRS may allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel between the UE and the network entity.

At **1106**, the network entity may estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure. For example, **1106** may be performed by selection component **199** of network entity **1202**. In some aspects, the estimation of the downlink channel is based on SRS received at the network entity.

At **1108**, the network entity may determine to activate a modulation selection procedure. For example, **1108** may be performed by selection component **199** of network entity **1202**. In some aspects, the determination to activate the modulation selection procedure is based on a CSF report from the UE.

At **1110**, the network entity may provide an activation indication indicating that the modulation selection procedure is activated. For example, **1110** may be performed by selection component **199** of network entity **1202**. The activation indication may indicate the first modulation for the first subset of REs and the second modulation for the second subset of REs. In some aspects, the activation indication is provided via RRC, DCI, or MAC-CE.

At **1112**, the network entity may assign a set of REs used for the modulation selection procedure. For example, **1112** may be performed by selection component **199** of network entity **1202**. The set of REs may comprise a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure. The first modulation may have a higher modulation rate than the second modulation. The first subset of REs may have a higher quality than the second subset of REs. In some aspects, the first subset of REs may have the higher quality in comparison to other REs within the set of REs. In some aspects, the second subset of REs may have the lowest quality in comparison to the other REs within the set of REs. In some aspects, a number of REs selected for the modulation selection procedure may be relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs. In some aspects, the first modulation may be greater than an MCS indicated for a current slot. For example, the first modulation may comprise 64 QAM or 32 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the second modulation may be less than the MCS indicated for the current slot. For example, the second modulation may comprise 8 QAM or 4 QAM, while the MCS indicated in the DCI may comprise 16 QAM. In some aspects, the first modulation and the second modulation may be different than a modulation indicated in the DCI associated with the downlink communication.

At **1114**, the network entity may transmit the downlink communication based on the modulation selection procedure. For example, **1114** may be performed by selection component **199** of network entity **1202**. The network entity may transmit the downlink communication, to the UE, based on the modulation selection procedure.

FIG. **12** is a diagram **1200** illustrating an example of a hardware implementation for a network entity **1202**. The network entity **1202** may be a BS, a component of a BS, or may implement BS functionality. The network entity **1202** may include at least one of a CU **1210**, a DU **1230**, or an RU **1240**. For example, depending on the layer functionality handled by the component **199**, the network entity **1202** may include the CU **1210**; both the CU **1210** and the DU **1230**; each of the CU **1210**, the DU **1230**, and the RU **1240**; the DU **1230**; both the DU **1230** and the RU **1240**; or the RU **1240**. The CU **1210** may include a CU processor **1212**. The CU processor **1212** may include on-chip memory **1212'**. In some aspects, the CU **1210** may further include additional memory modules **1214** and a communications interface **1218**. The CU **1210** communicates with the DU **1230** through a midhaul link, such as an F1 interface. The DU **1230** may include a DU processor **1232**. The DU processor **1232** may include on-chip memory **1232'**. In some aspects, the DU **1230** may further include additional memory modules **1234** and a communications interface **1238**. The DU **1230** communicates with the RU **1240** through a fronthaul link. The RU **1240** may include an RU processor **1242**. The RU processor **1242** may include on-chip memory **1242'**. In some aspects, the RU **1240** may further include additional memory modules **1244**, one or more transceivers **1246**, antennas **1280**, and a communications interface **1248**. The RU **1240** communicates with the UE **104**. The on-chip memory **1212'**, **1232'**, **1242'** and the additional memory modules **1214**, **1234**, **1244** may each be considered a computer-readable medium/memory. Each computer-readable medium/memory may be non-transitory. Each of the processors **1212**, **1232**, **1242** is responsible for general processing, including the execution of software stored on the computer-readable medium/memory. The software, when executed by the corresponding processor(s) causes the processor(s) to perform the various functions described supra. The computer-readable medium/memory may also be used for storing data that is manipulated by the processor(s) when executing software.

As discussed supra, the component **199** is configured to determine to activate a modulation selection procedure; assign a set of resource elements (REs) used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs; and transmit downlink communication based on the modulation selection procedure. The component **199** may be within one or more processors of one or more of the CU **1210**, DU **1230**, and the RU **1240**. The component **199** may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by one or more processors configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by one or more processors, or some combination thereof. The network entity **1202** may include a variety of components configured for various functions. In one configuration, the network entity **1202** includes means for determining to activate a modulation selection procedure. The network entity includes means for assigning a set of REs used for the modulation selection procedure. The set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs. The network entity includes means for transmitting downlink communication based on the modulation selection procedure. The network entity further includes means for providing an activation indication indicating that the modulation selection procedure is activated. The activation indication indicating the first modulation for the first subset of REs and the second modulation for the second subset of REs. The network entity further includes means for obtaining a CSF report comprising an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs. The network entity further includes means for obtaining a SRS to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel. The network entity further includes means for estimating the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure. The means may be the component **199** of the network entity **1202** configured to perform the functions recited by the means. As described supra, the network entity **1202** may include the TX processor **316**, the RX processor **370**, and the controller/processor **375**. As such, in one configuration, the means may be the TX processor **316**, the RX processor **370**, and/or the controller/processor **375** configured to perform the functions recited by the means.

It is understood that the specific order or hierarchy of blocks in the processes/flowcharts disclosed is an illustration of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes/flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not limited to the specific order or hierarchy presented.

The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not limited to the aspects described herein, but are to be accorded the full scope consistent with the language claims. Reference to an element in the singular does not mean "one and only one" unless specifically so stated, but rather "one or more." Terms such as "if," "when," and "while" do not imply an immediate temporal relationship or reaction. That is, these phrases, e.g., "when," do not imply an immediate action in response to or during the occurrence of an action, but simply imply that if a condition is met then an action will occur, but without requiring a specific or immediate time constraint for the action to occur. The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term "some" refers to one or more. Combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. Sets should be interpreted as a set of elements where the elements number one or more. Accordingly, for a set of X, X would include one or more elements. If a first apparatus receives data from or transmits data to a second apparatus, the data may be received/transmitted directly between the first and second apparatuses, or indirectly between the first and second apparatuses through a set of apparatuses. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are encompassed by the claims. Moreover, nothing disclosed herein is dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words "module," "mechanism," "element," "device," and the like may not be a substitute for the word "means." As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase "means for."

As used herein, the phrase "based on" shall not be construed as a reference to a closed set of information, one or more conditions, one or more factors, or the like. In other words, the phrase "based on A" (where "A" may be information, a condition, a factor, or the like) shall be construed as "based at least on A" unless specifically recited differently.

The following aspects are illustrative only and may be combined with other aspects or teachings described herein, without limitation.

Aspect 1 is a method of wireless communication at a UE comprising receiving an activation indication indicating an activation of a modulation selection procedure and a set of REs used for the modulation selection procedure, the activation indication indicating a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs; and receiving downlink communication based on the modulation selection procedure.

Aspect 2 is the method of aspect 1, further including transmitting a CSF report comprising an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs; and selecting one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report.

Aspect 3 is the method of any of aspects 1 and 2, further includes that a number of REs selected for the modulation selection procedure are relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs.

Aspect 4 is the method of any of aspects 1-3, further includes that the CSF report is based on at least one of CSI-RS or DMRS measured at the UE.

Aspect 5 is the method of any of aspects 1-4, further including transmitting a sounding reference signal (SRS) to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel; and estimating the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure.

Aspect 6 is the method of any of aspects 1-5, further includes that the estimation of the downlink channel is based on a DMRS or a CSI-RS measured at the UE.

Aspect 7 is the method of any of aspects 1-6, further includes that the activation indication indicating the activation of the modulation selection procedure is RRC, DCI, or MAC-CE.

Aspect 8 is the method of any of aspects 1-7, further includes that the first modulation is greater than an MCS indicated for a current slot, wherein the second modulation is less than the MCS indicated for the current slot.

Aspect 9 is the method of any of aspects 1-8, further includes that the first modulation and the second modulation are different than a modulation indicated in DCI associated with the downlink communication.

Aspect 10 is the method of any of aspects 1-9, further includes that the first subset of REs having the higher quality or the second subset of REs having the lower quality are based on an average quality of all the REs within one or more RBs.

Aspect 11 is the method of any of aspects 1-10, further includes that the lower quality or the higher quality is based on a threshold, wherein the higher quality is greater than the average quality by the threshold, and the lower quality is less than the average quality by the threshold.

Aspect 12 is the method of any of aspects 1-11, further includes that the downlink communication is demodulated based on the first modulation and the second modulation.

Aspect 13 is an apparatus for wireless communication at a UE including at least one processor coupled to a memory and at least one transceiver, the at least one processor configured to implement any of Aspects 1-12.

Aspect 14 is an apparatus for wireless communication at a UE including means for implementing any of Aspects 1-12.

Aspect 15 is a computer-readable medium storing computer executable code, where the code when executed by a processor causes the processor to implement any of Aspects 1-12.

Aspect 16 is a method of wireless of wireless communication at a network entity comprising determining to activate a modulation selection procedure; assigning a set of REs used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs; and transmitting downlink communication based on the modulation selection procedure.

Aspect 17 is the method of aspect 16, further including providing an activation indication indicating that the modulation selection procedure is activated, the activation indication indicating the first modulation for the first subset of REs and the second modulation for the second subset of REs.

Aspect 18 is the method of any of aspects 16 and 17, further includes that the activation indication is provided via RRC, DCI, or MAC-CE.

Aspect 19 is the method of any of aspects 16-18, further including obtaining a CSF report comprising an indication identifying the first subset of REs having a highest quality from a set of RBs and the second subset of REs having a lowest quality from the set of RBs.

Aspect 20 is the method of any of aspects 16-19, further includes that the determination to activate the modulation selection procedure is based on the CSF report.

Aspect 21 is the method of any of aspects 16-20, further includes that the CSF report is based on at least one of CSI-RS or DMRS measured at a UE.

Aspect 22 is the method of any of aspects 16-21, further includes that the set of REs used for the modulation selection procedure is based on the CSF report.

Aspect 23 is the method of any of aspects 16-22, further including obtaining a SRS to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel; and estimating the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure.

Aspect 24 is the method of any of aspects 16-23, further includes that the estimation of the downlink channel is based on SRS received at the network entity.

Aspect 25 is the method of any of aspects 16-24, further includes that a number of REs selected for the modulation selection procedure are relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs.

Aspect 26 is the method of any of aspects 16-25, further includes that the first modulation is greater than an MCS indicated for a current slot, wherein the second modulation is less than the MCS indicated for the current slot.

Aspect 27 is the method of any of aspects 16-26, further includes that the first modulation and the second modulation are different than a modulation indicated in a DCI associated with the downlink communication.

Aspect 28 is an apparatus for wireless communication at a network entity including at least one processor coupled to a memory and at least one transceiver, the at least one processor configured to implement any of Aspects 16-27.

Aspect 29 is an apparatus for wireless communication at a UE including means for implementing any of Aspects 16-27.

Aspect 30 is a computer-readable medium storing computer executable code, where the code when executed by a processor causes the processor to implement any of Aspects 16-27.

What is claimed is:

1. An apparatus for wireless communication at a user equipment (UE), comprising:

memory; and

at least one processor coupled to the memory and, based at least in part on information stored in the memory, the at least one processor is configured to:

receive an activation indication indicating an activation of a modulation selection procedure and a set of resource elements (REs) used for the modulation selection procedure, the activation indication identifying a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs; and receive a downlink communication based on the modulation selection procedure.

2. The apparatus of claim **1**, further comprising a transceiver coupled to the at least one processor.

3. The apparatus of claim **1**, wherein the at least one processor is further configured to:

transmit a channel state feedback (CSF) report comprising an indication identifying the first subset of REs having a highest quality from a set of resource blocks (RBs) and the second subset of REs having a lowest quality from the set of RBs; and

select one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report.

4. The apparatus of claim **3**, wherein a number of REs selected for the modulation selection procedure are relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs.

5. The apparatus of claim **3**, wherein the CSF report is based on at least one of channel state information reference signal (CSI-RS) or demodulation reference signal (DMRS) measured at the UE.

6. The apparatus of claim **1**, wherein the at least one processor is further configured to:

transmit a sounding reference signal (SRS) to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel; and

estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure.

7. The apparatus of claim **6**, wherein to estimate the downlink channel, the at least one processor is configured to estimate the downlink channel is-based on a demodulation reference signal (DMRS) or a channel state information reference signal (CSI-RS) measured at the UE.

8. The apparatus of claim **1**, wherein to receive the activation indication, the at least one processor is configured to receive the activation indication indicating the activation of the modulation selection procedure via radio resource control (RRC), downlink control information (DCI), or media access control (MAC) control element (CE) (MAC-CE).

9. The apparatus of claim **1**, wherein the first modulation is greater than an MCS indicated for a current slot, wherein the second modulation is less than the MCS indicated for the current slot.

10. The apparatus of claim **1**, wherein the first modulation and the second modulation are different than a modulation indicated in a downlink control information (DCI) associated with the downlink communication.

11. The apparatus of claim **1**, wherein the first subset of REs having the higher quality or the second subset of REs having a lower quality are based on an average quality of all the REs within one or more RBs.

12. The apparatus of claim **11**, wherein the lower quality or the higher quality is based on a threshold, wherein the higher quality is greater than the average quality by the threshold, and the lower quality is less than the average quality by the threshold.

13. The apparatus of claim **1**, wherein the downlink communication is demodulated based on the first modulation and the second modulation.

14. A method of wireless communication at a user equipment (UE), comprising:

receiving an activation indication indicating an activation of a modulation selection procedure and a set of resource elements (REs) used for the modulation selection procedure, the activation indication identifying a first modulation for a first subset of REs within the set of REs and a second modulation for a second subset of REs within the set of REs, the first subset of REs having a higher quality than the second subset of REs; and

receiving a downlink communication based on the modulation selection procedure.

15. The method of claim **14**, further comprising:

transmitting a channel state feedback (CSF) report comprising an indication identifying the first subset of REs having a highest quality from a set of resource blocks (RBs) and the second subset of REs having a lowest quality from the set of RBs; and

selecting one or more REs from the first subset of REs or the second subset of REs for the modulation selection procedure based at least on the CSF report.

16. An apparatus for wireless communication at a network entity, comprising:

memory; and

at least one processor coupled to the memory and, based at least in part on information stored in the memory, the at least one processor is configured to:

determine to activate a modulation selection procedure;

assign a set of resource elements (REs) used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of RES;

provide an activation indication indicating that the modulation selection procedure is activated, the activation indication identifying the first modulation for the first subset of REs and the second modulation for the second subset of REs; and

transmit a downlink communication based on the modulation selection procedure.

17. The apparatus of claim **16**, further comprising a transceiver coupled to the at least one processor.

18. The apparatus of claim **16**, wherein to provide the activation indication, the at least one processor is configured to provide the activation indication via radio resource control (RRC), downlink control information (DCI), or media access control (MAC) control element (CE) (MAC-CE).

19. The apparatus of claim **16**, wherein the at least one processor is further configured to:

obtain a channel state feedback (CSF) report comprising an indication identifying the first subset of REs having a highest quality from a set of resource blocks (RBs) and the second subset of REs having a lowest quality from the set of RBs.

20. The apparatus of claim **19**, wherein the determination to activate the modulation selection procedure is based on the CSF report.

21. The apparatus of claim **19**, wherein the CSF report is based on at least one of channel state information reference signal (CSI-RS) or demodulation reference signal (DMRS) measured at a user equipment (UE).

22. The apparatus of claim **19**, wherein the set of REs used for the modulation selection procedure is based on the CSF report.

23. The apparatus of claim **16**, wherein the at least one processor is further configured to:

obtain a sounding reference signal (SRS) to allow for estimation of a downlink channel based on channel reciprocity between an uplink channel and the downlink channel; and

estimate the downlink channel and locations of the first subset of REs or the second subset of REs for the modulation selection procedure.

24. The apparatus of claim **23**, wherein to estimate the downlink channel, the at least one processor is configured to estimate the downlink channel is based on SRS received at the network entity.

25. The apparatus of claim **16**, wherein a number of REs selected for the modulation selection procedure are relative to an allocation of a total number of REs or based on a percentage amount of the total number of REs.

26. The apparatus of claim **16**, wherein the first modulation is greater than an MCS indicated for a current slot, wherein the second modulation is less than the MCS indicated for the current slot.

27. The apparatus of claim **16**, wherein the first modulation and the second modulation are different than a modulation indicated in a DCI associated with the downlink communication.

28. A method of wireless communication at a network node, comprising:

determining to activate a modulation selection procedure;

assigning a set of resource elements (REs) used for the modulation selection procedure, the set of REs comprising a first subset of REs within the set of REs having a first modulation and a second subset of REs within the set of REs having a second modulation in response to a determination to activate the modulation selection procedure, the first modulation having a higher modulation rate than the second modulation, the first subset of REs having a higher quality than the second subset of REs;

providing an activation indication indicating that the modulation selection procedure is activated, the activation indication identifying the first modulation for the first subset of REs and the second modulation for the second subset of REs; and

transmit downlink communication based on the modulation selection procedure.

* * * * *