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(54) SIGNALING ENHANCEMENT FOR BEAM CHANGE PREDICTIONS VIA MODELING

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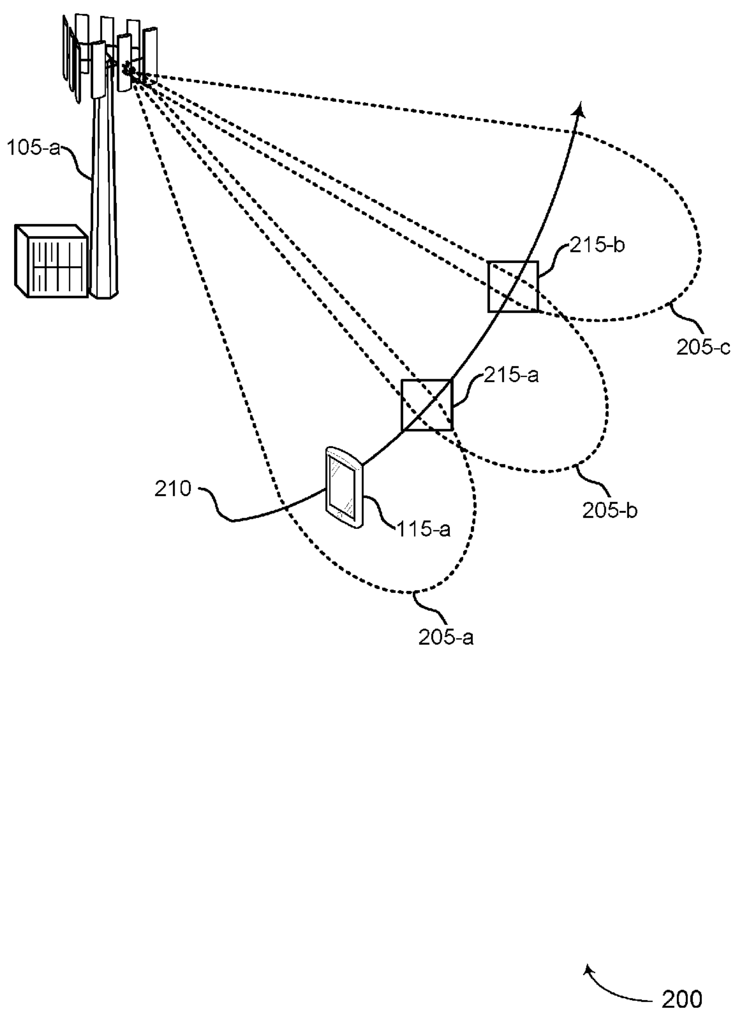
(57) ABSTRACT

Methods, systems, and devices for wireless communications are described. A user equipment (UE) may receive a reference signal from a network node. The reference signal may be associated with a beam, of a set of beams. Each beam of the set of beams may be associated with a respective beam index. The UE may determine a probability associated with an adjustment of the beam. The probability may indicate whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The UE may transmit an indication of the probability associated with the adjustment of the beam to the network node.



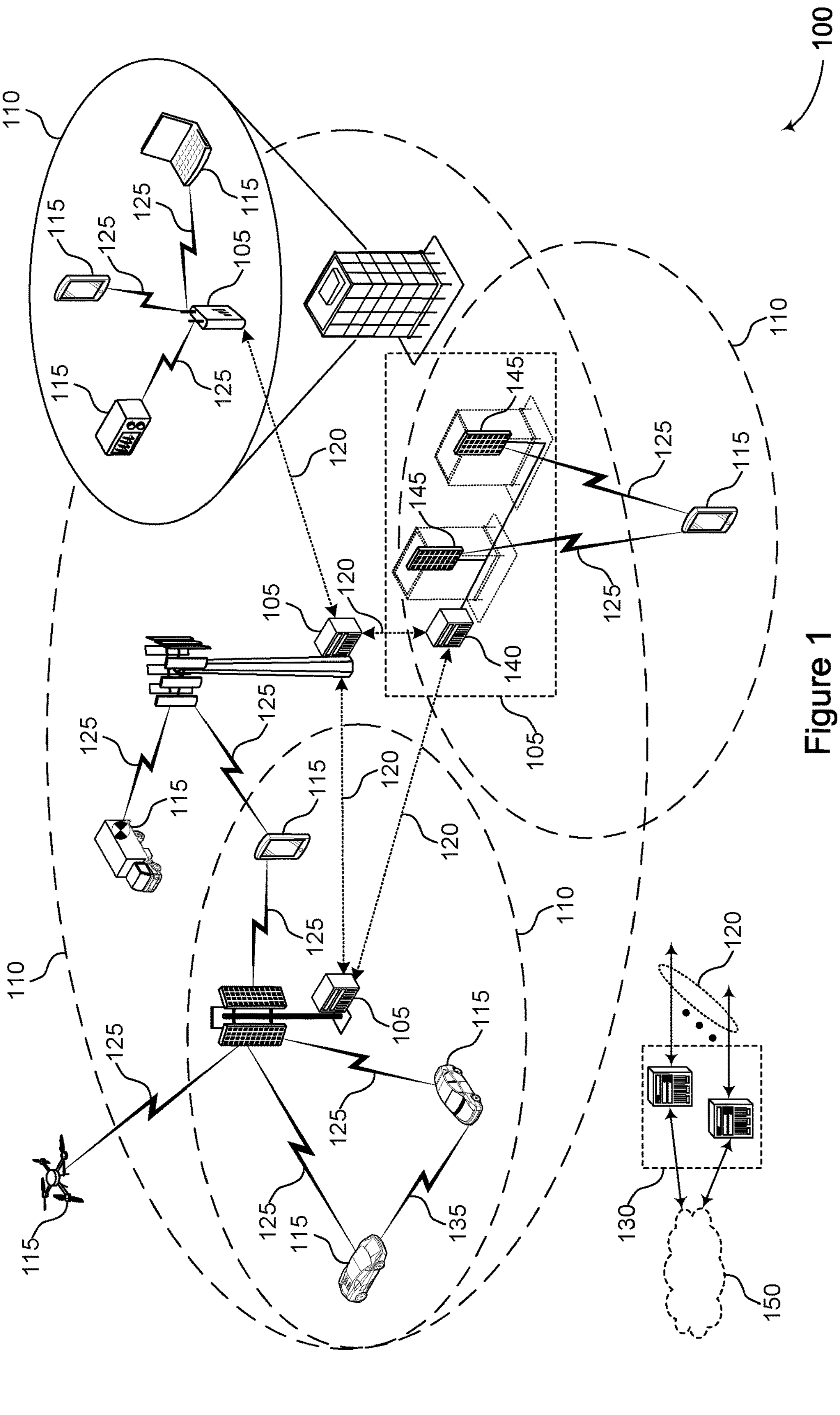


Figure 1

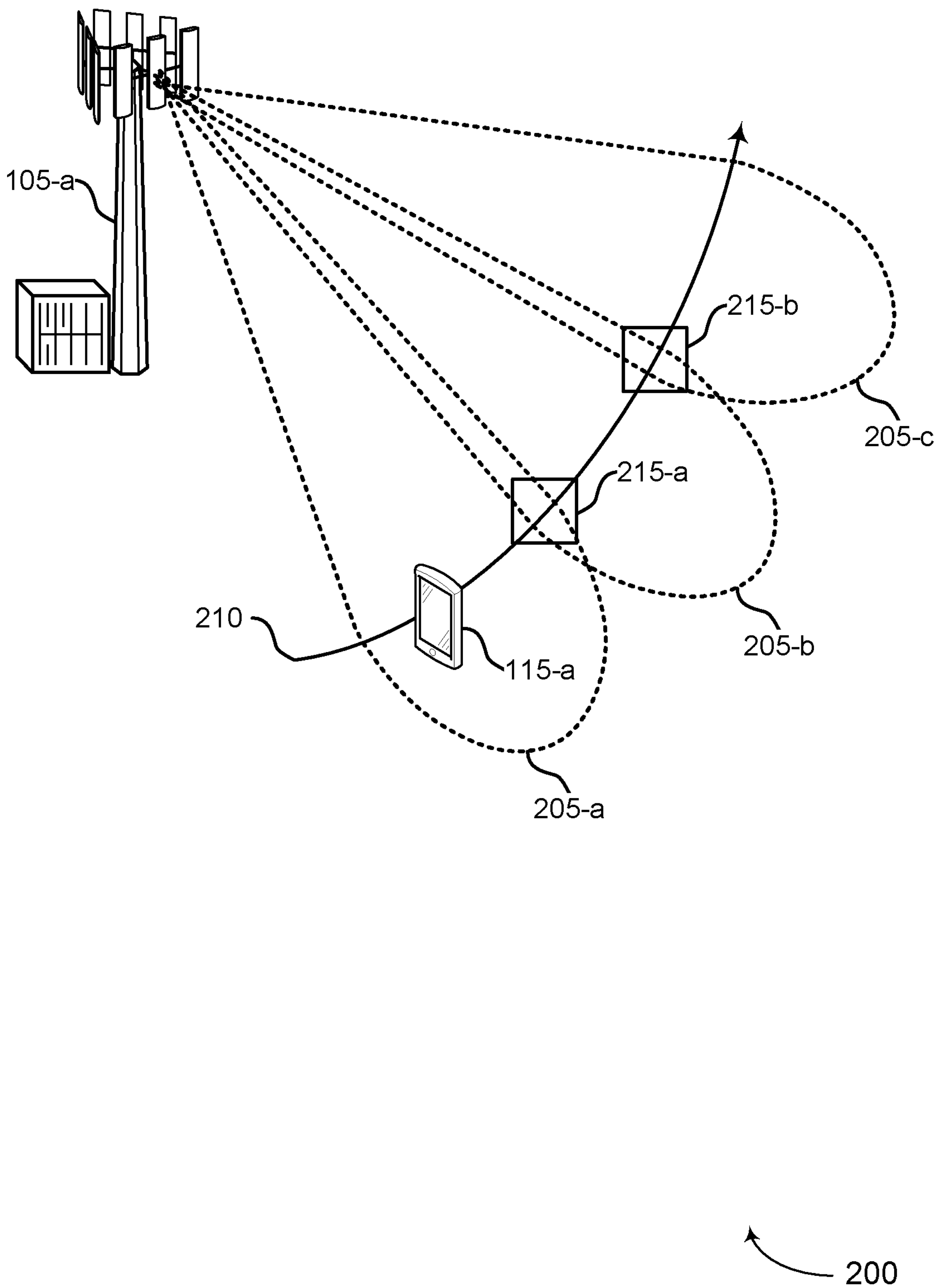
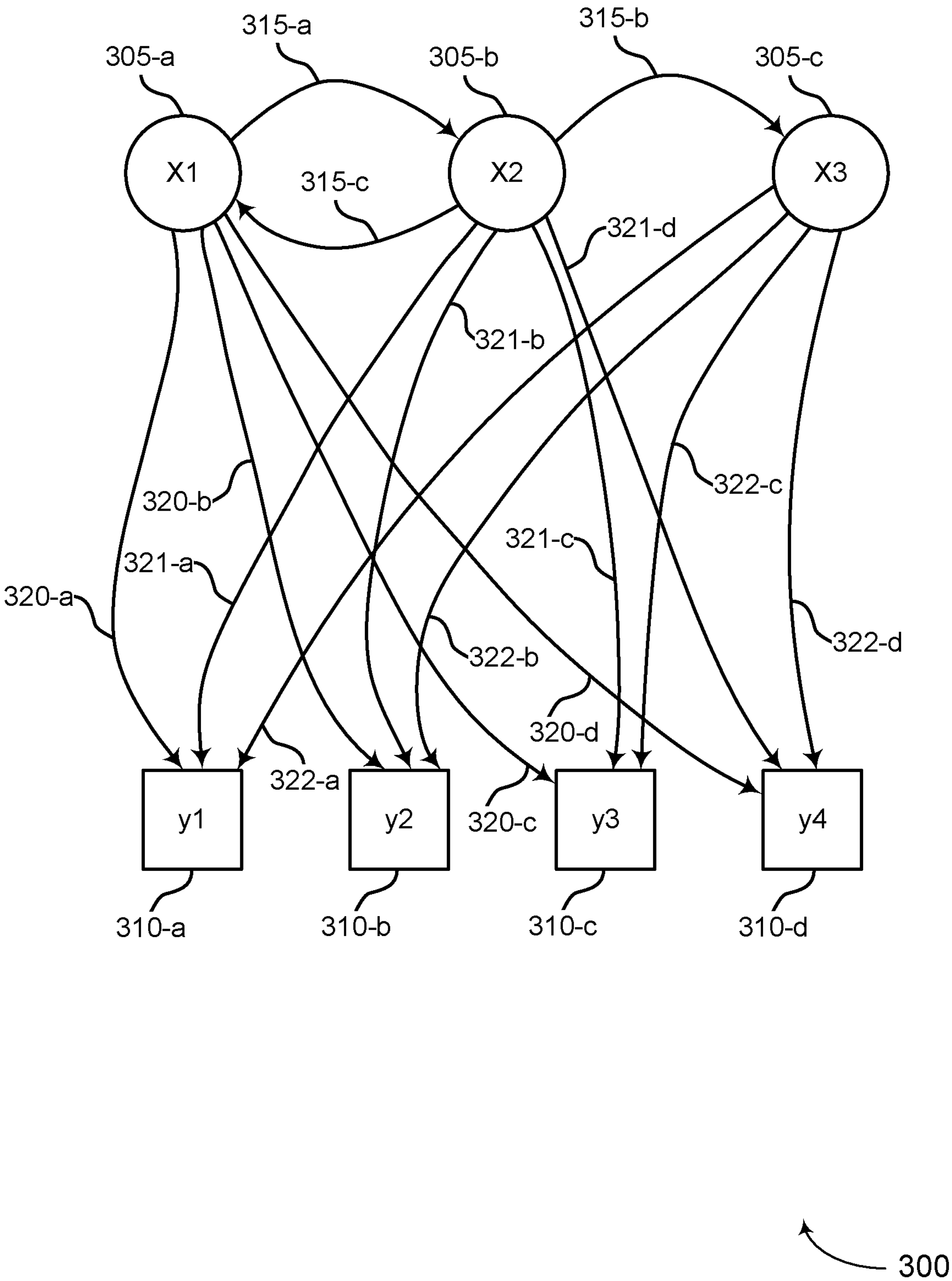


Figure 2


315-a
315-b
305-a
305-b
305-c
X1
X2
X3
315-c
321-d
321-b
320-b
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321-c
321-a
320-a
322-d
322-b
320-d
322-a
320-c
y1
y2
y3
y4
310-a
310-b
310-c
310-d
300

Figure 3

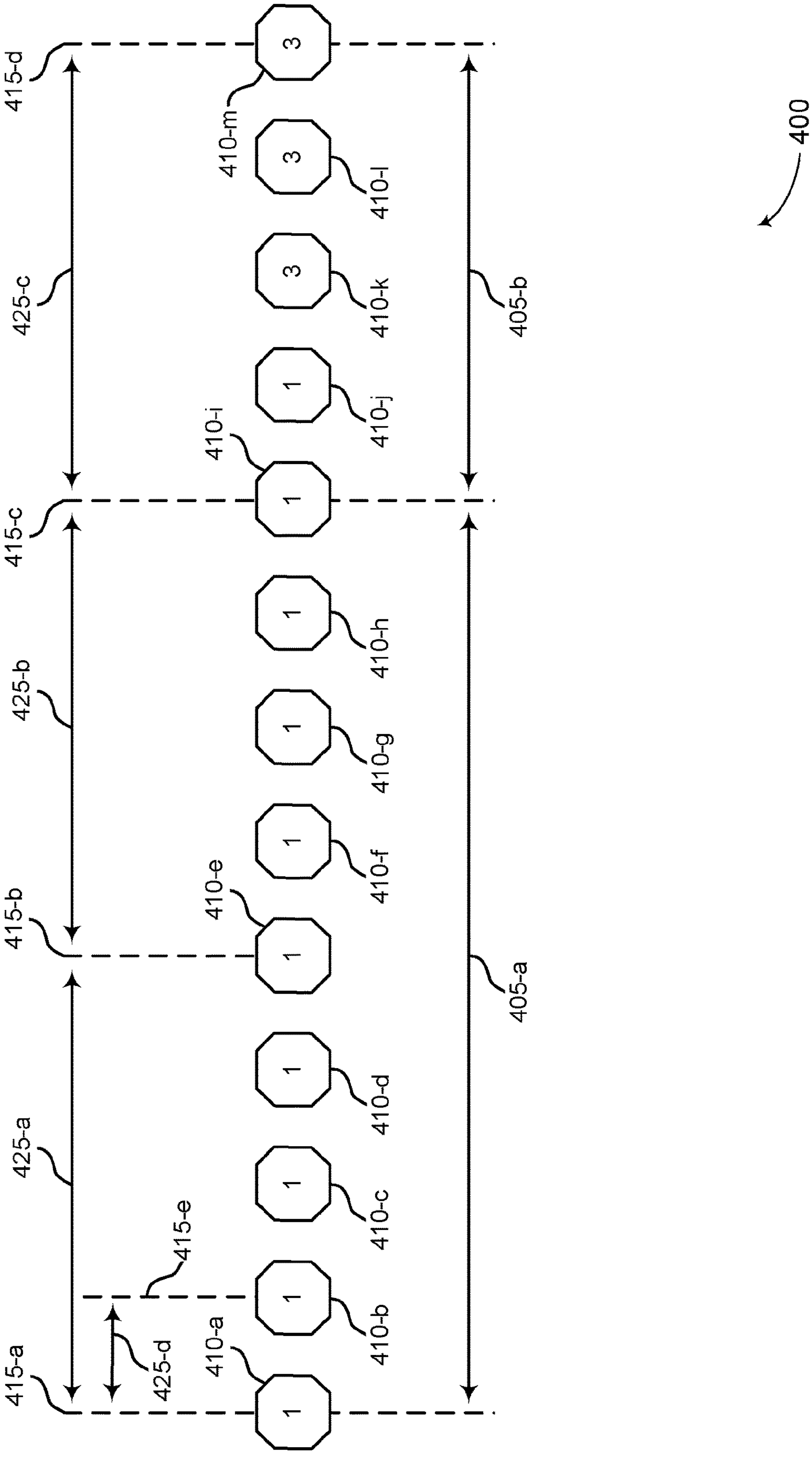
400
415-a
415-b
415-c
415-d
415-e
425-a
425-b
425-c
425-d
405-a
405-b
410-a
410-b
410-c
410-d
410-e
410-f
410-g
410-h
410-i
410-j
410-k
410-l
410-m
1
3

Figure 4

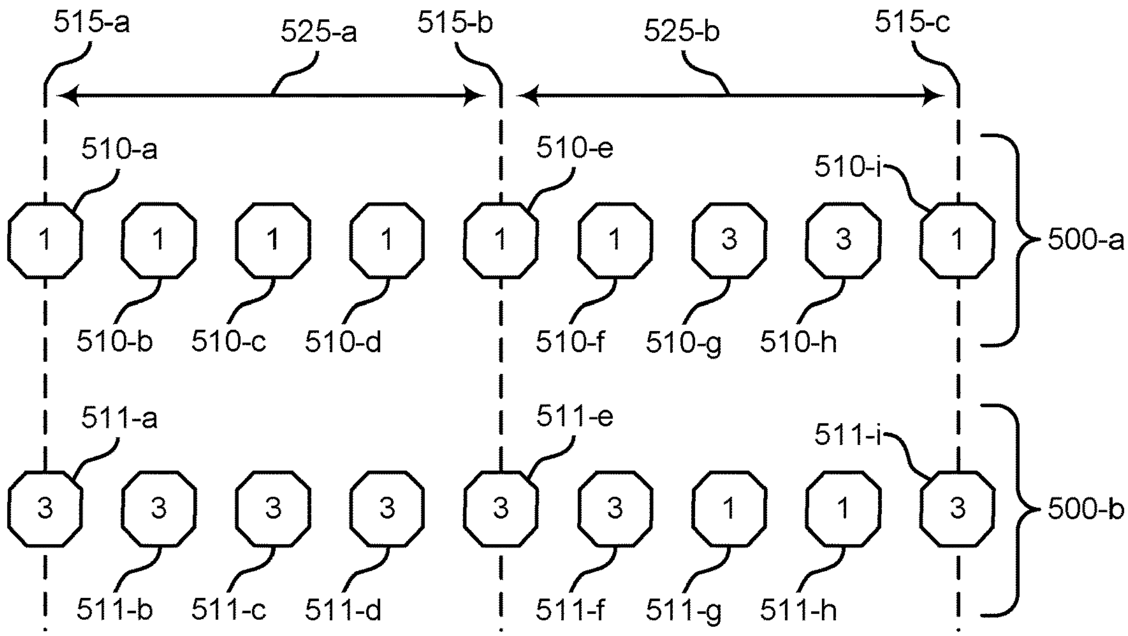

Figure 5A

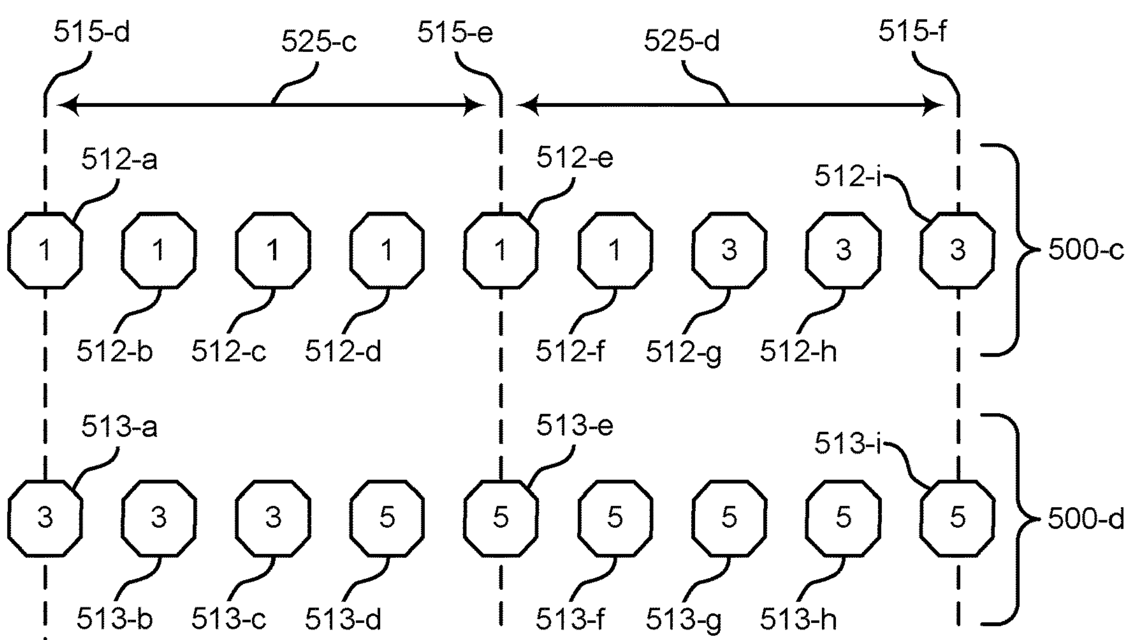

Figure 5B

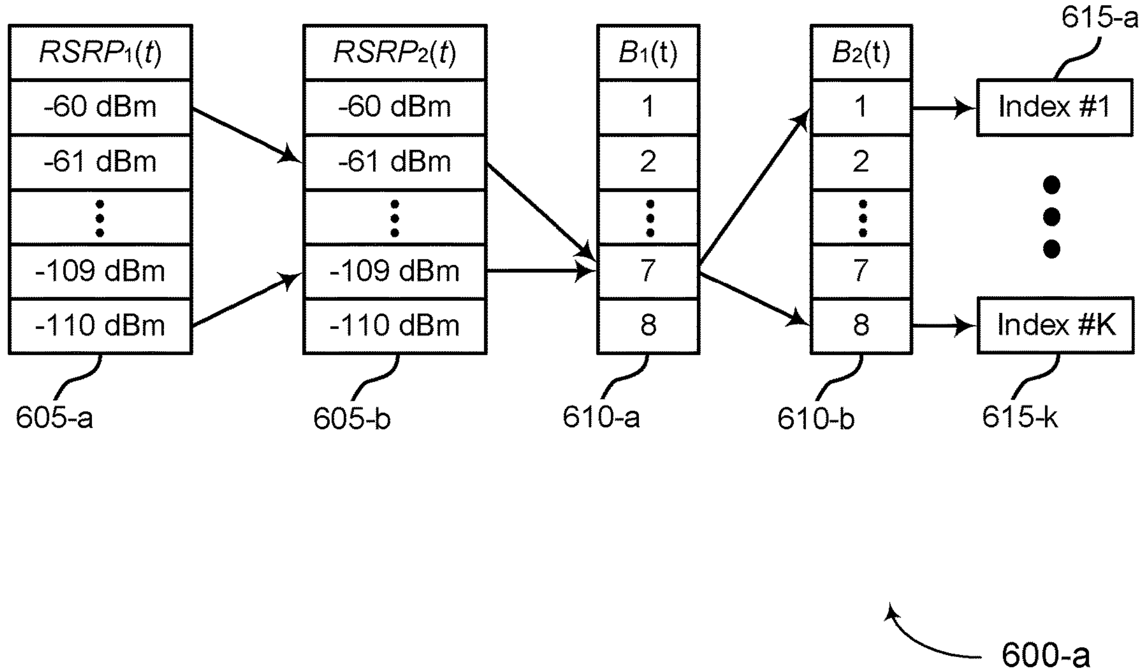

Figure 6A

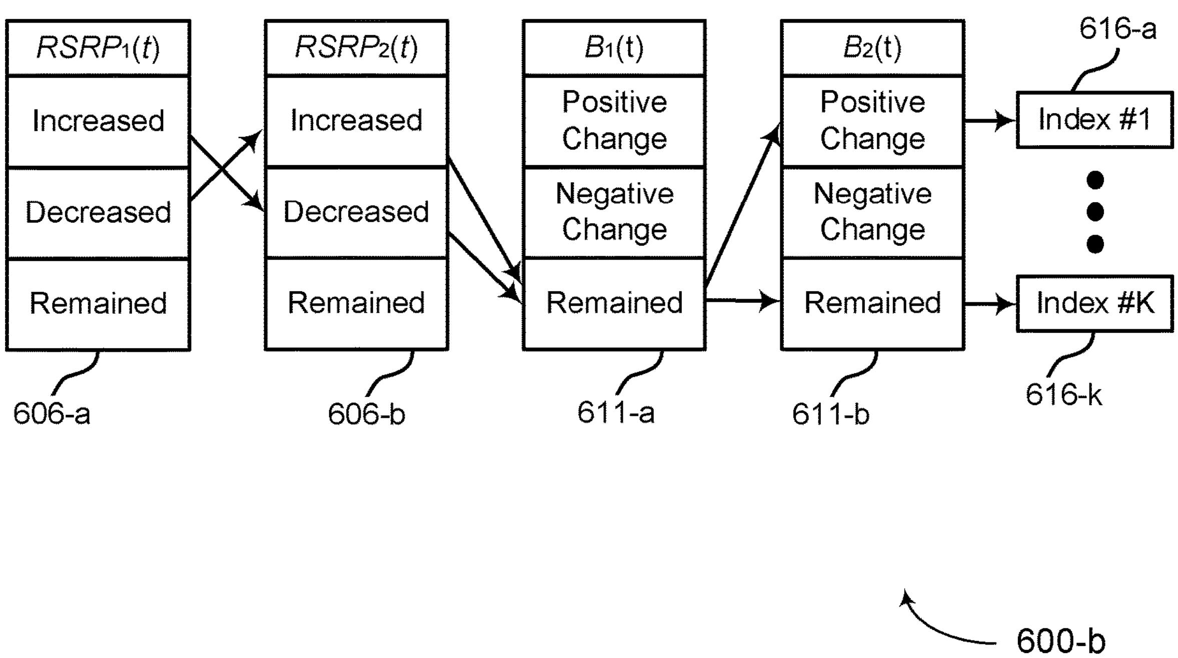

Figure 6B

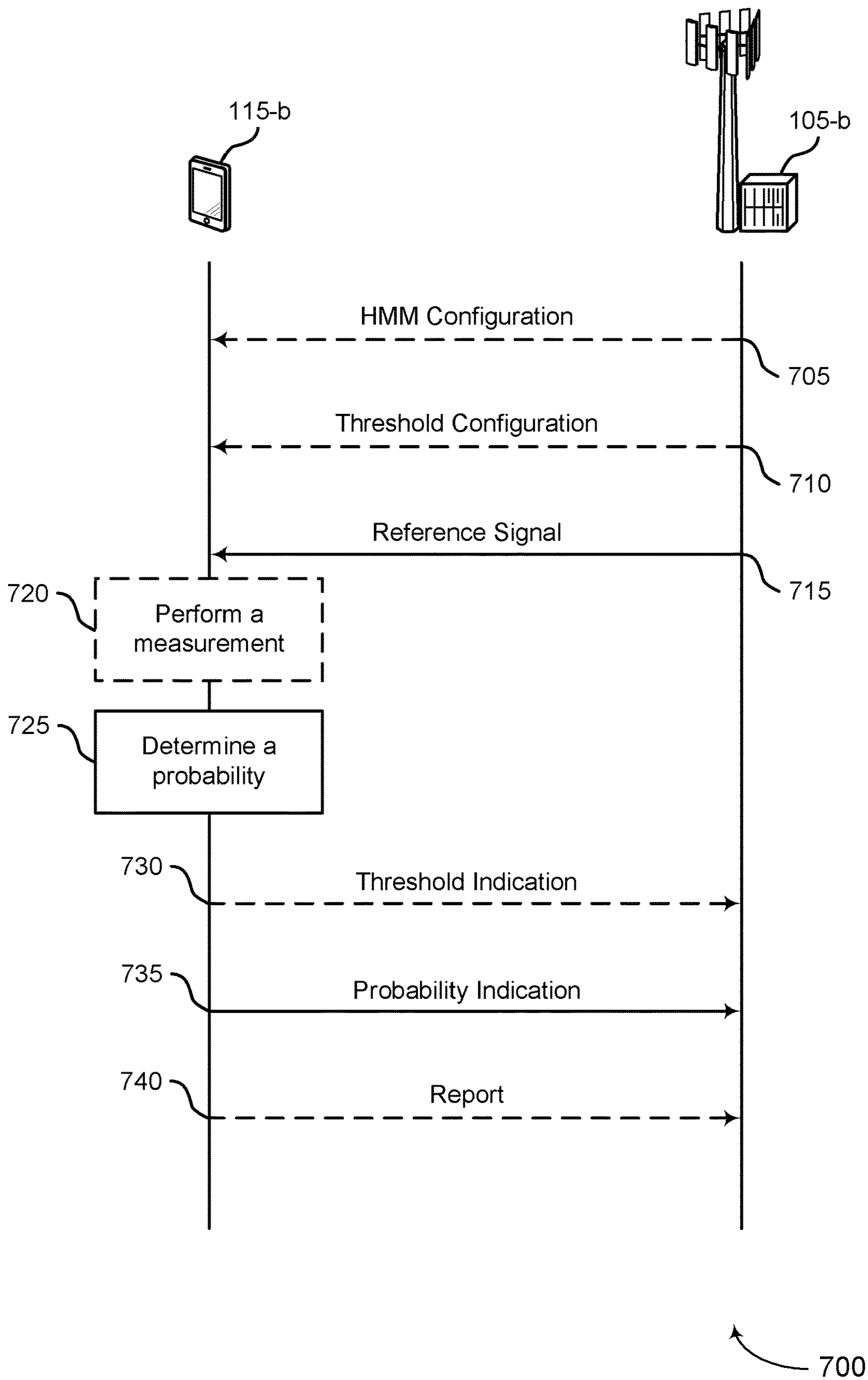
115-b
105-b
HMM Configuration
705
Threshold Configuration
710
Reference Signal
715
720
Perform a measurement
725
Determine a probability
730
Threshold Indication
735
Probability Indication
740
Report
700

Figure 7

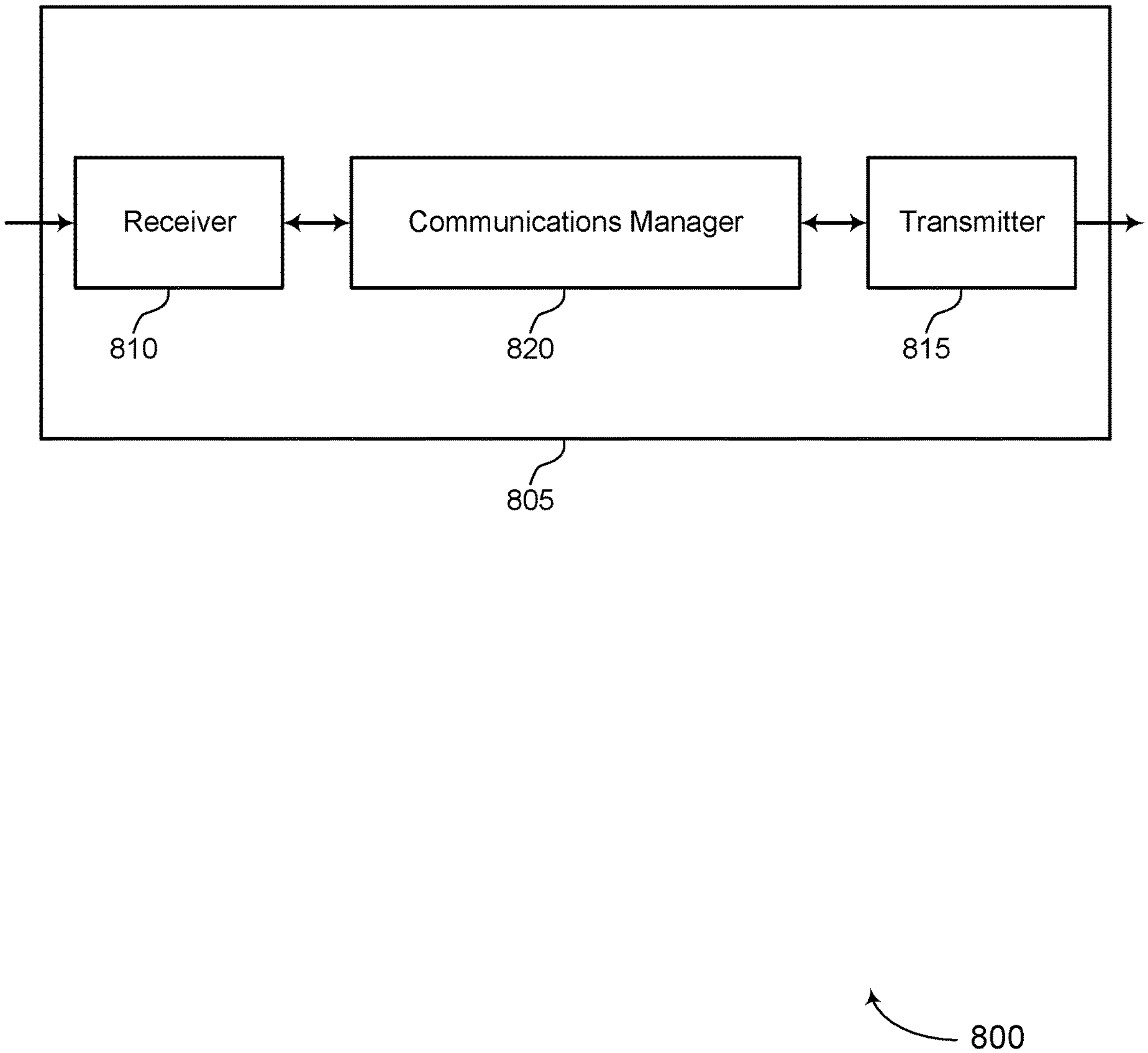
Receiver
Communications Manager
Transmitter
810
820
815
805
800

Figure 8

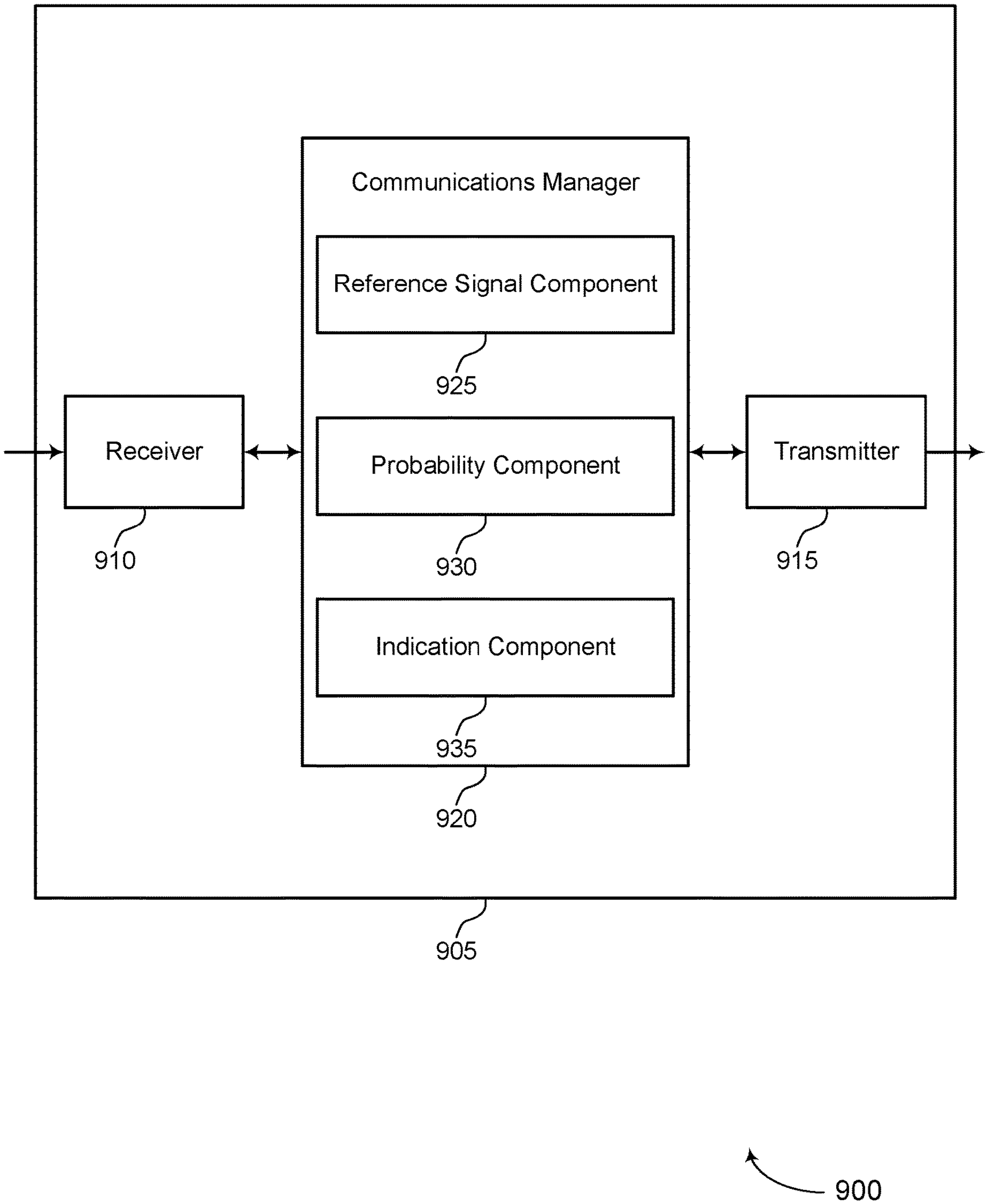
Communications Manager
Reference Signal Component
925
Receiver
Probability Component
Transmitter
910
930
915
Indication Component
935
920
905
900

Figure 9

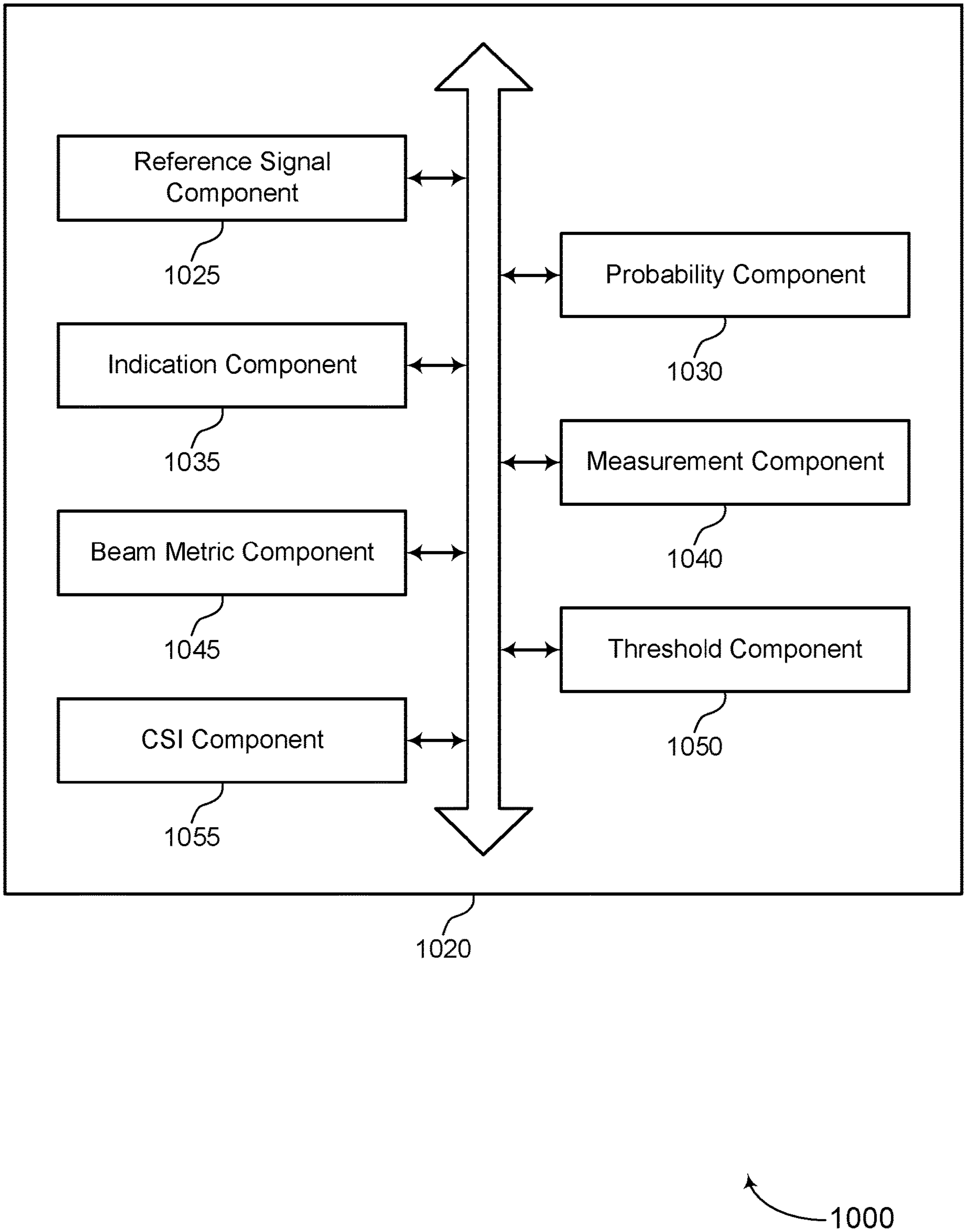
Reference Signal Component
1025
Indication Component
1035
Beam Metric Component
1045
CSI Component
1055
Probability Component
1030
Measurement Component
1040
Threshold Component
1050
1020
1000

Figure 10

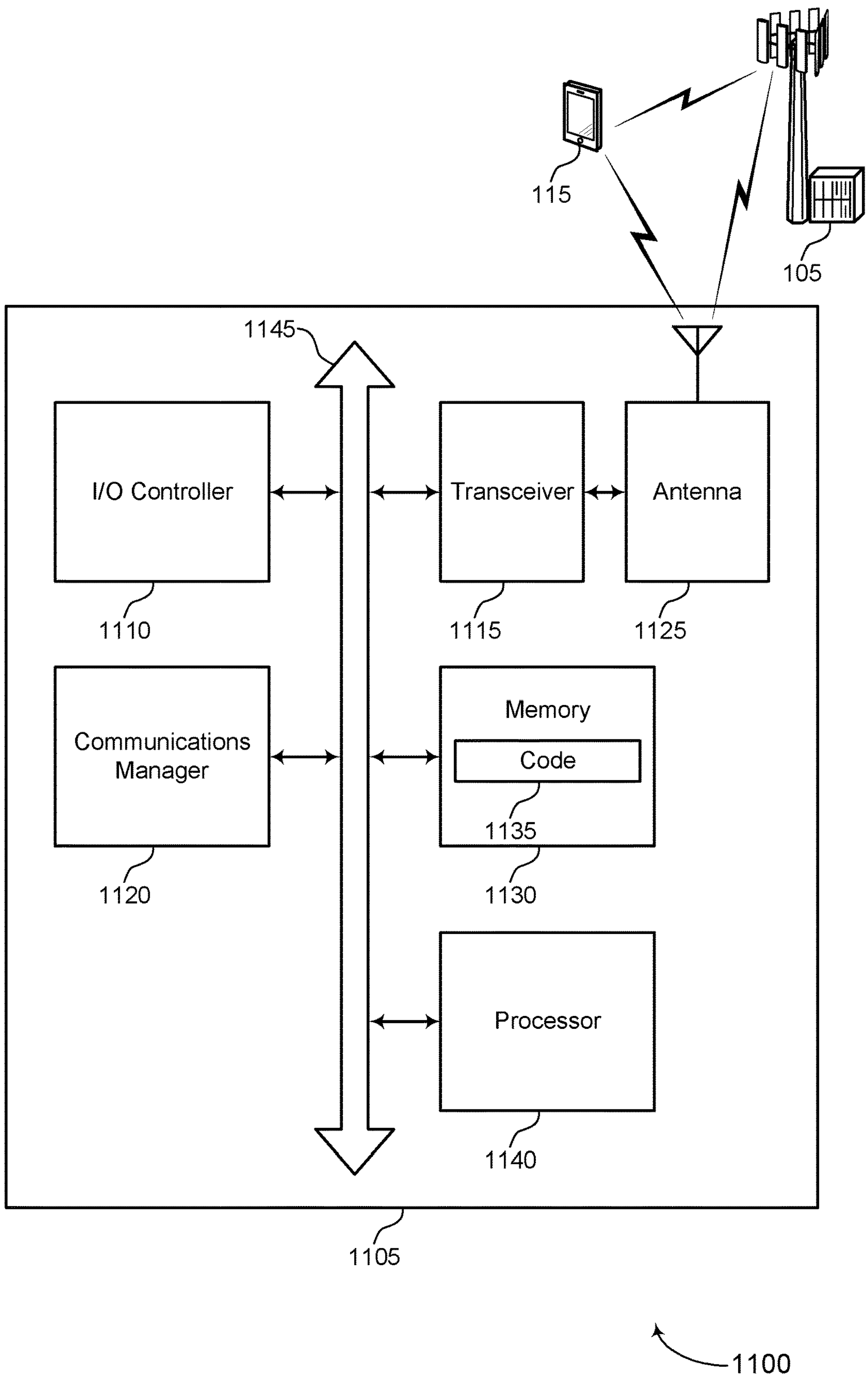
115
105
1145
I/O Controller
Transceiver
Antenna
1110
1115
1125
Memory
Code
Communications Manager
1135
1120
1130
Processor
1140
1105
1100

Figure 11

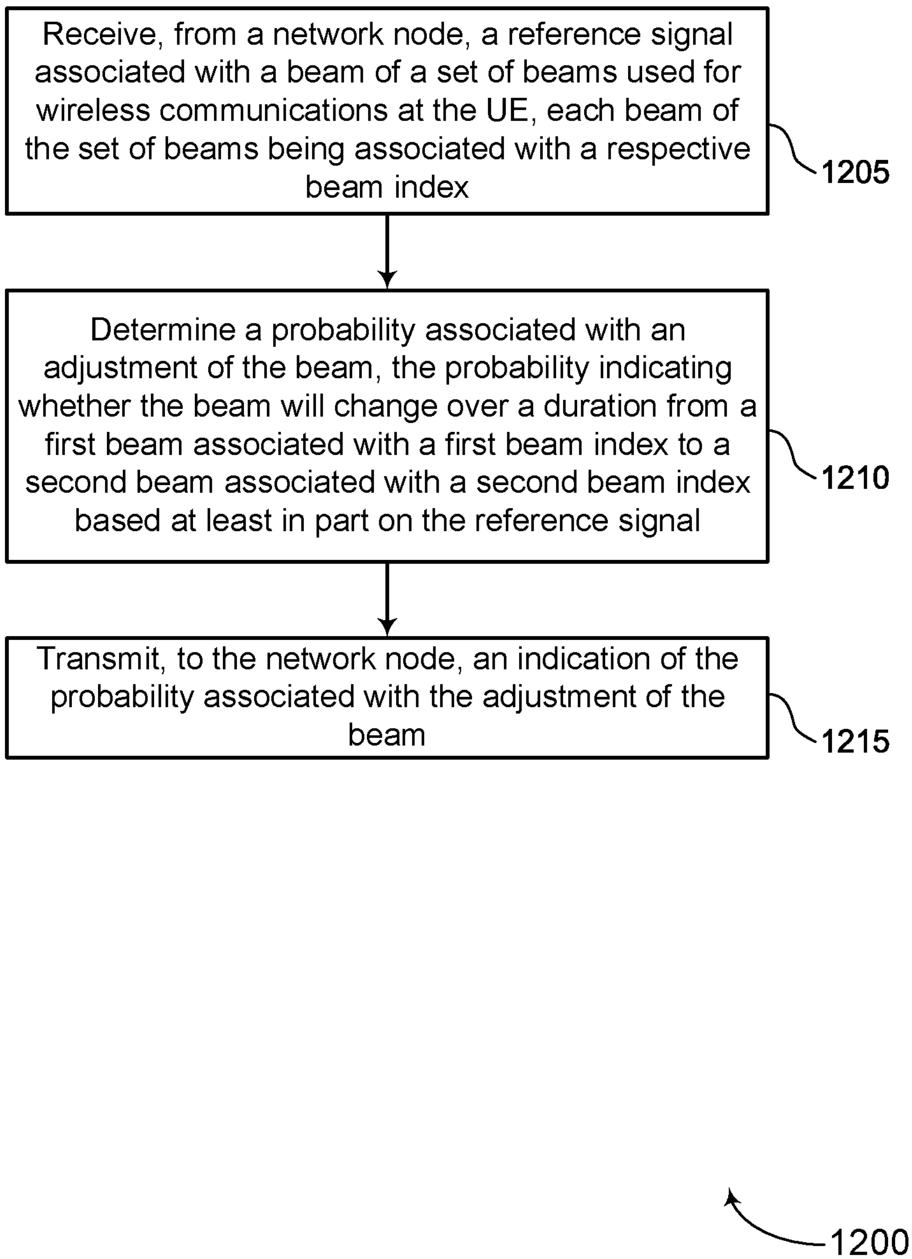
Receive, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index
1205
Determine a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal
1210
Transmit, to the network node, an indication of the probability associated with the adjustment of the beam
1215
1200

Figure 12

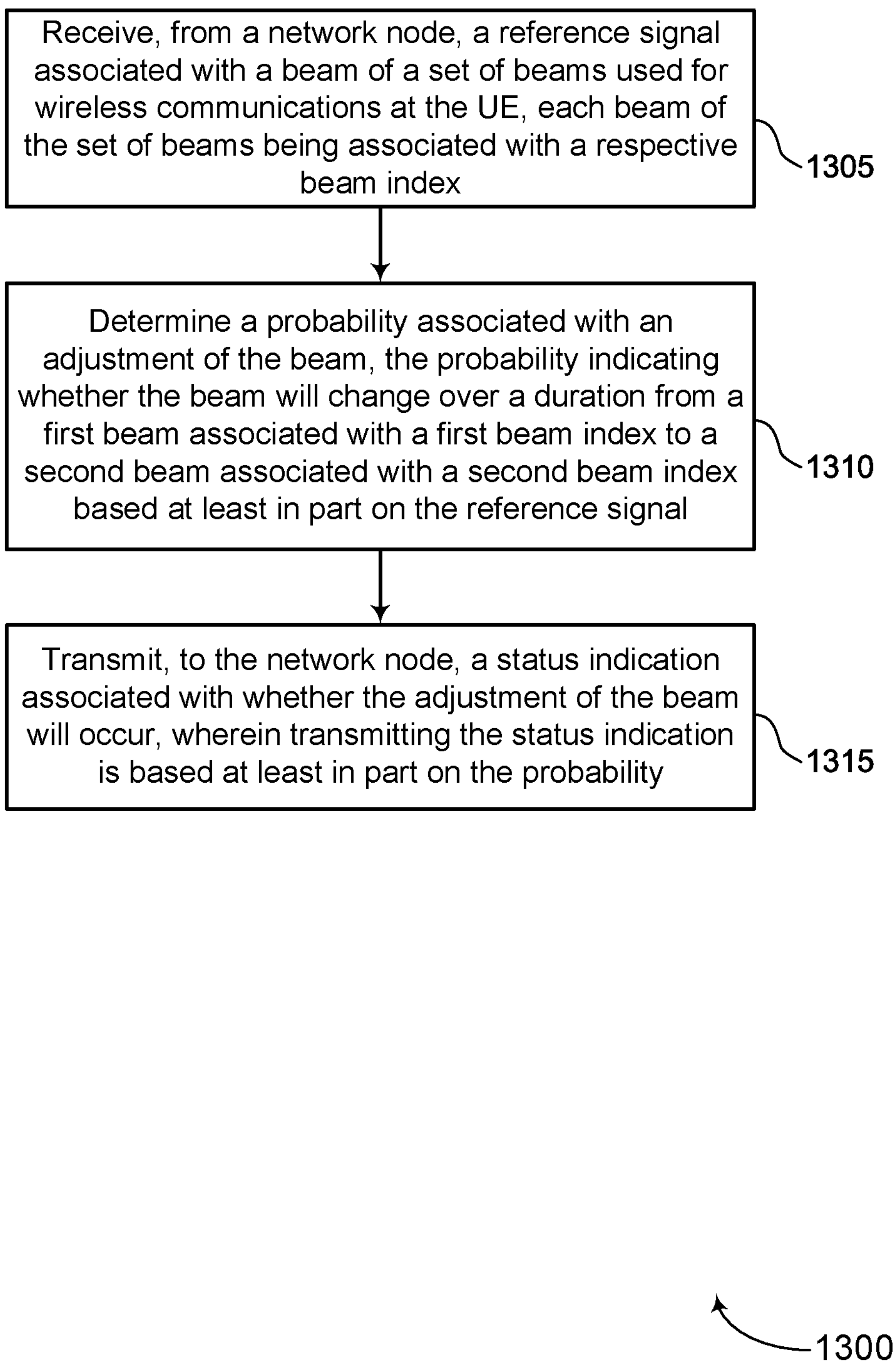
Receive, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index
1305
Determine a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal
1310
Transmit, to the network node, a status indication associated with whether the adjustment of the beam will occur, wherein transmitting the status indication is based at least in part on the probability
1315
1300

Figure 13

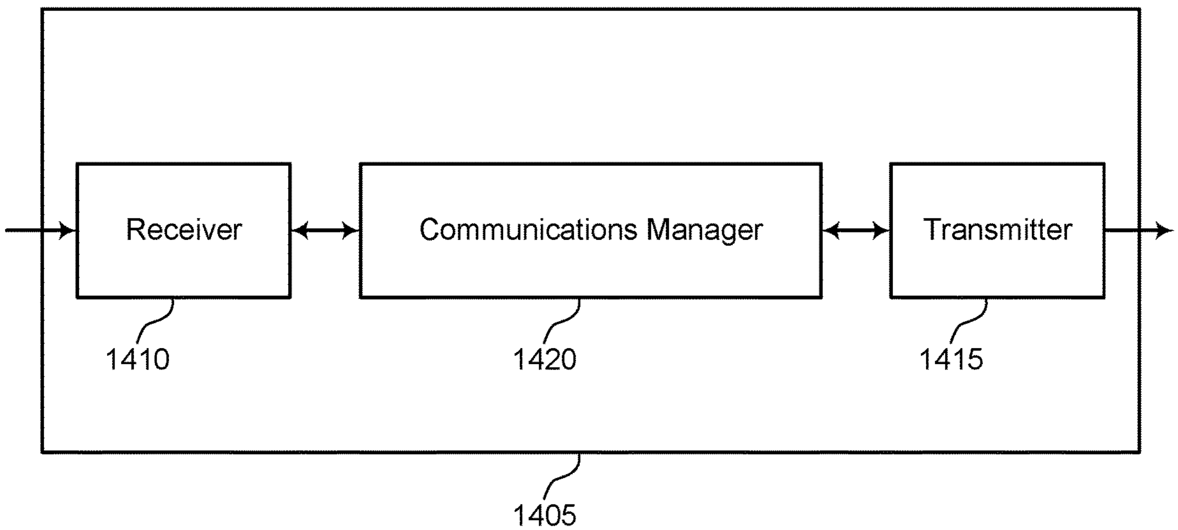
Receiver
Communications Manager
Transmitter
1410
1420
1415
1405

Figure 14

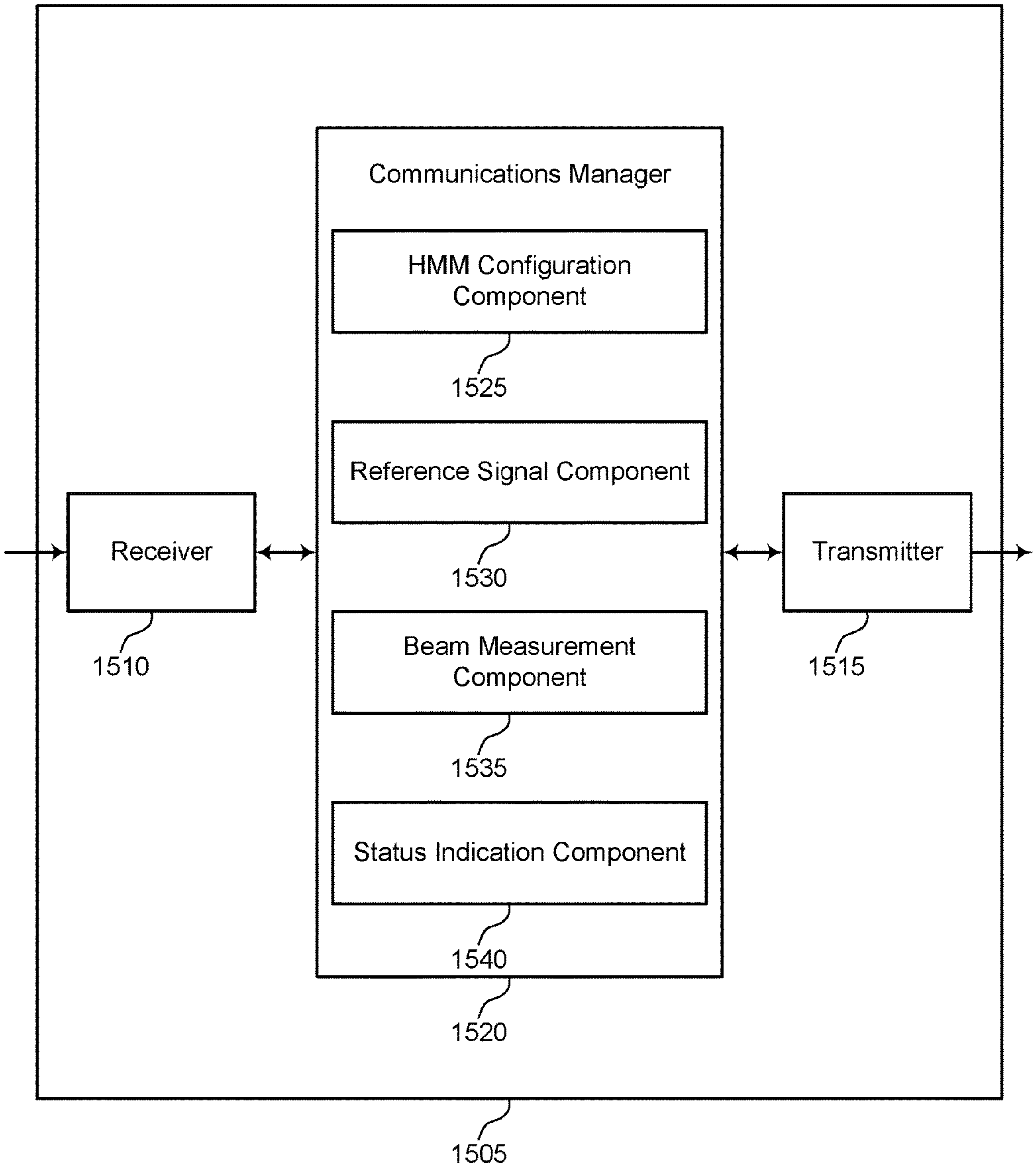
Communications Manager
HMM Configuration Component
1525
Reference Signal Component
1530
Receiver
1510
Transmitter
1515
Beam Measurement Component
1535
Status Indication Component
1540
1520
1505

Figure 15

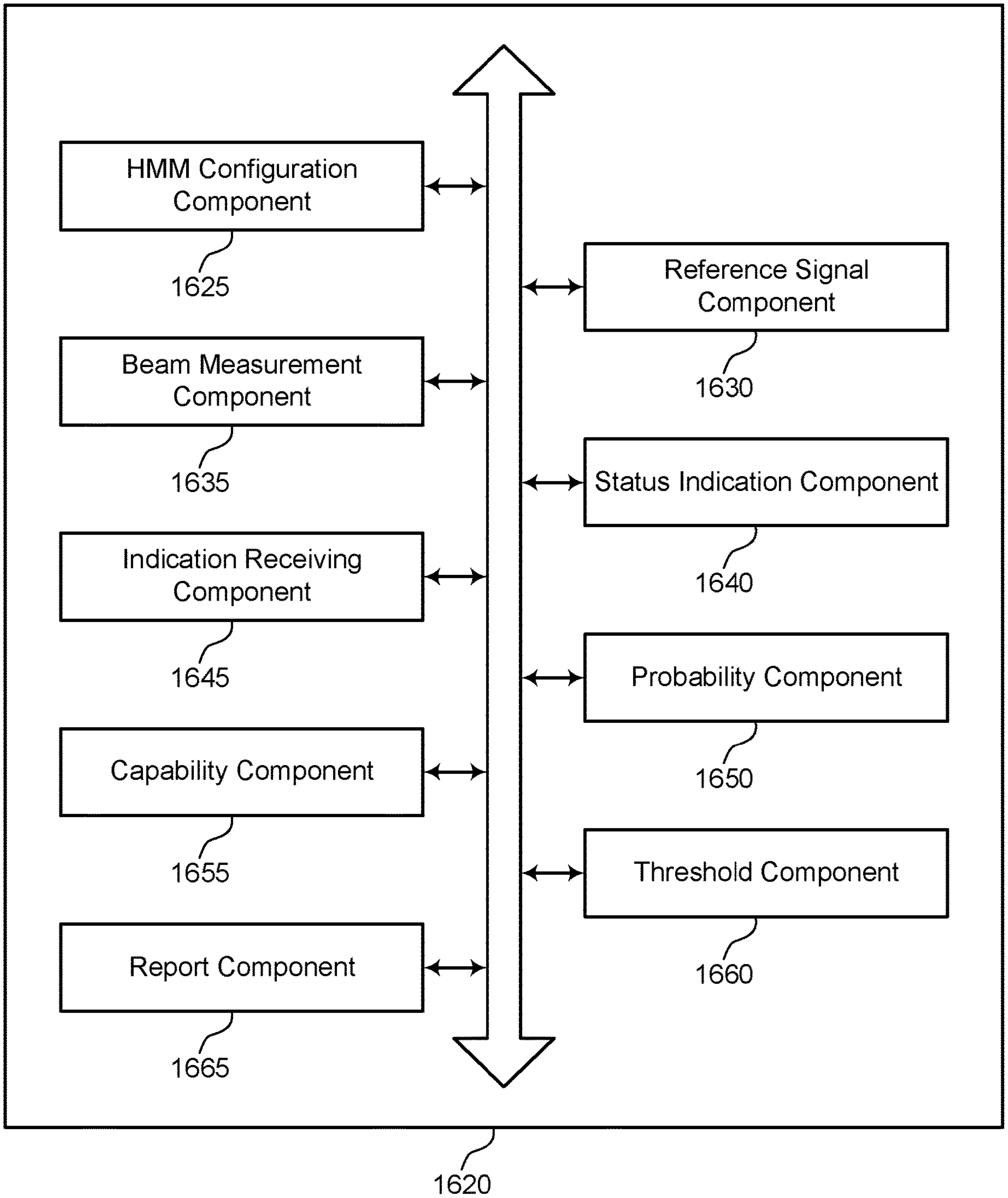
HMM Configuration Component
1625
Beam Measurement Component
1635
Indication Receiving Component
1645
Capability Component
1655
Report Component
1665
Reference Signal Component
1630
Status Indication Component
1640
Probability Component
1650
Threshold Component
1660
1620

Figure 16

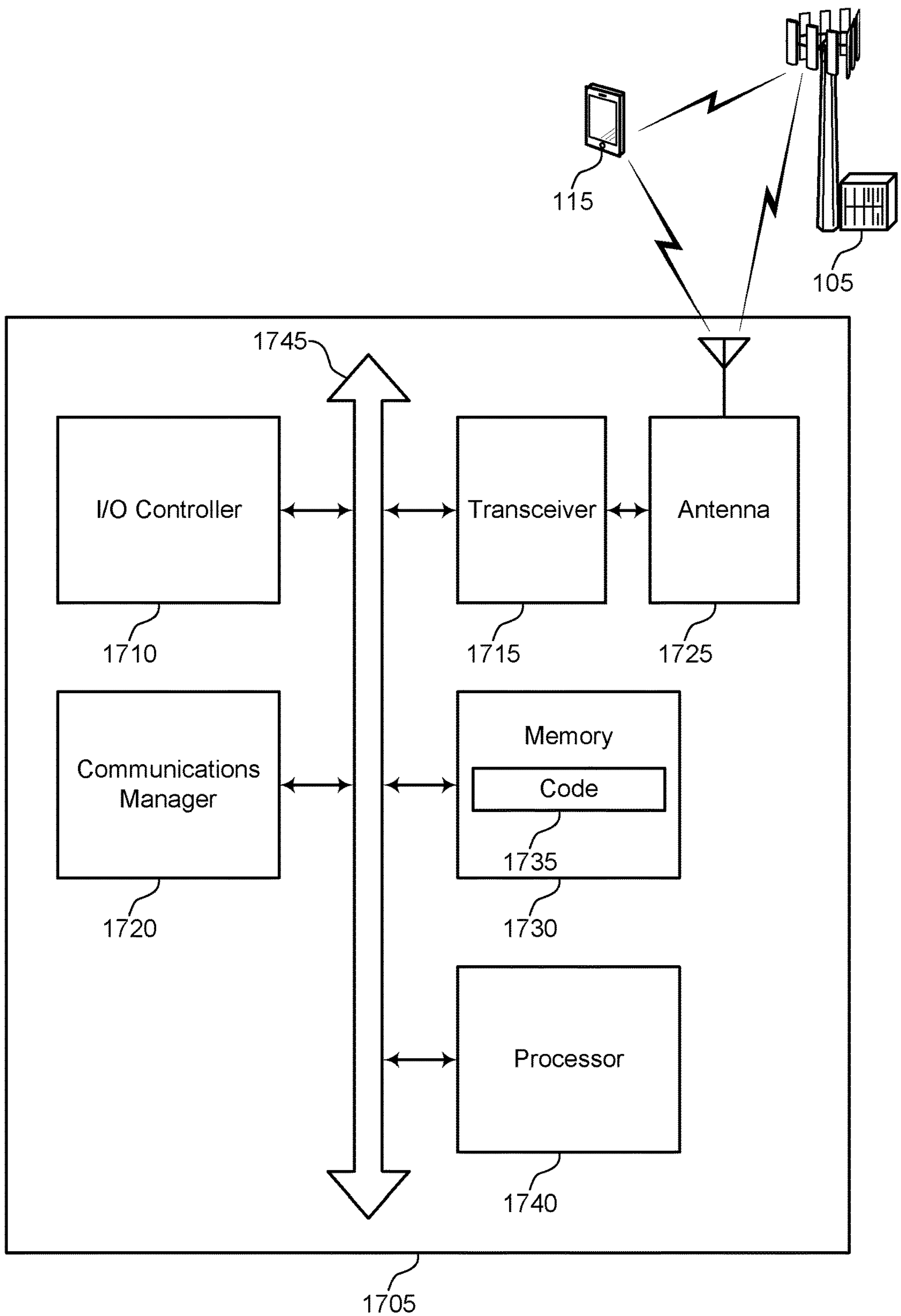
115
105
1745
I/O Controller
Transceiver
Antenna
1710
1715
1725
Communications Manager
Memory
Code
1735
1720
1730
Processor
1740
1705

Figure 17

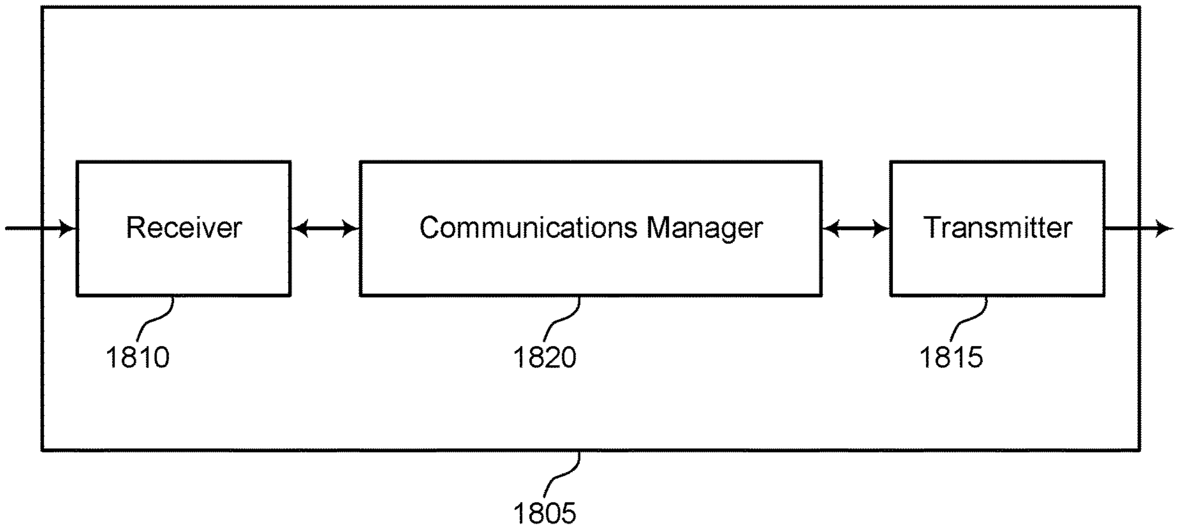
Receiver
Communications Manager
Transmitter
1810
1820
1815
1805

Figure 18

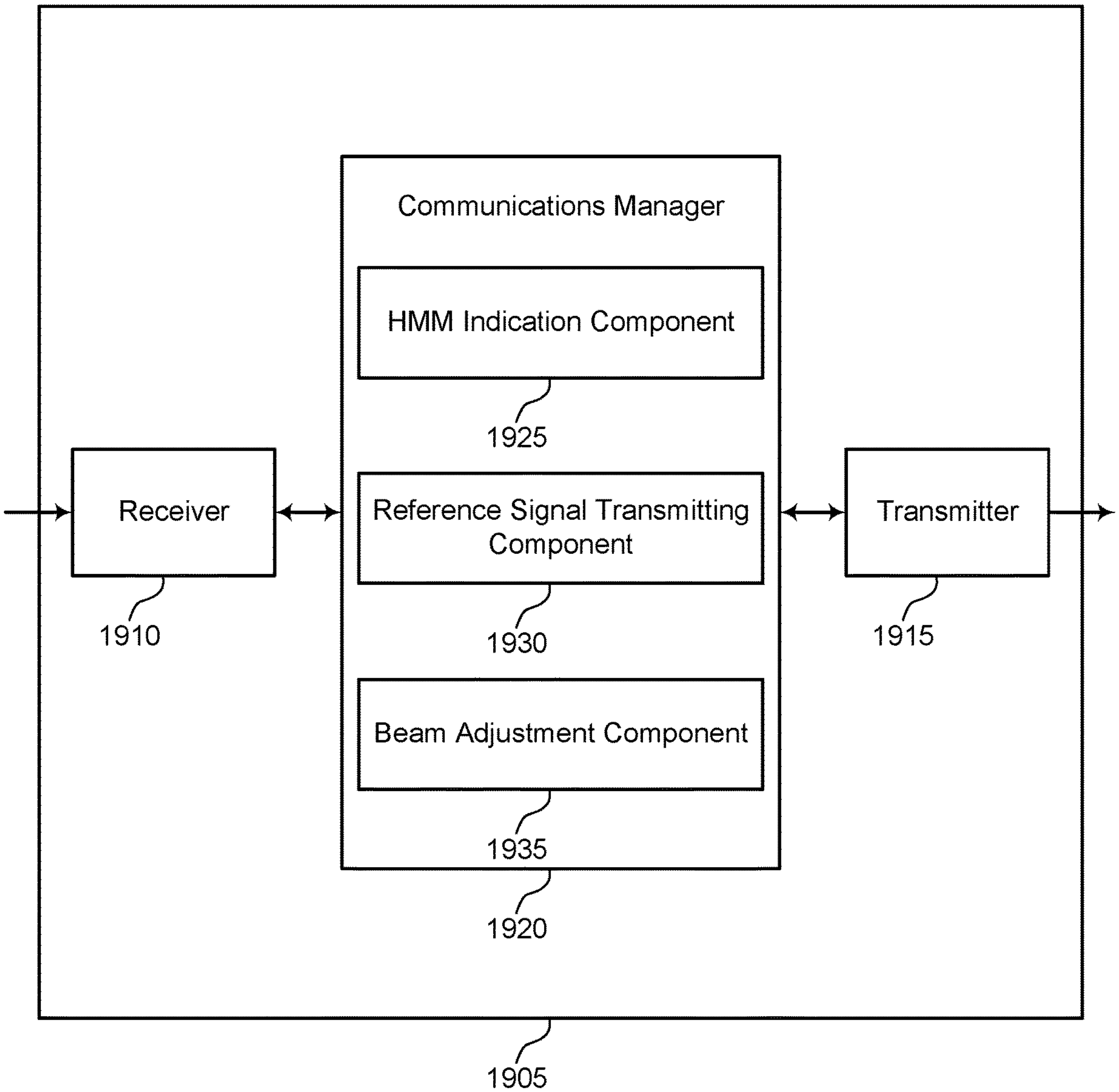
Communications Manager
HMM Indication Component
1925
Receiver
Reference Signal Transmitting Component
Transmitter
1910
1930
1915
Beam Adjustment Component
1935
1920
1905

Figure 19

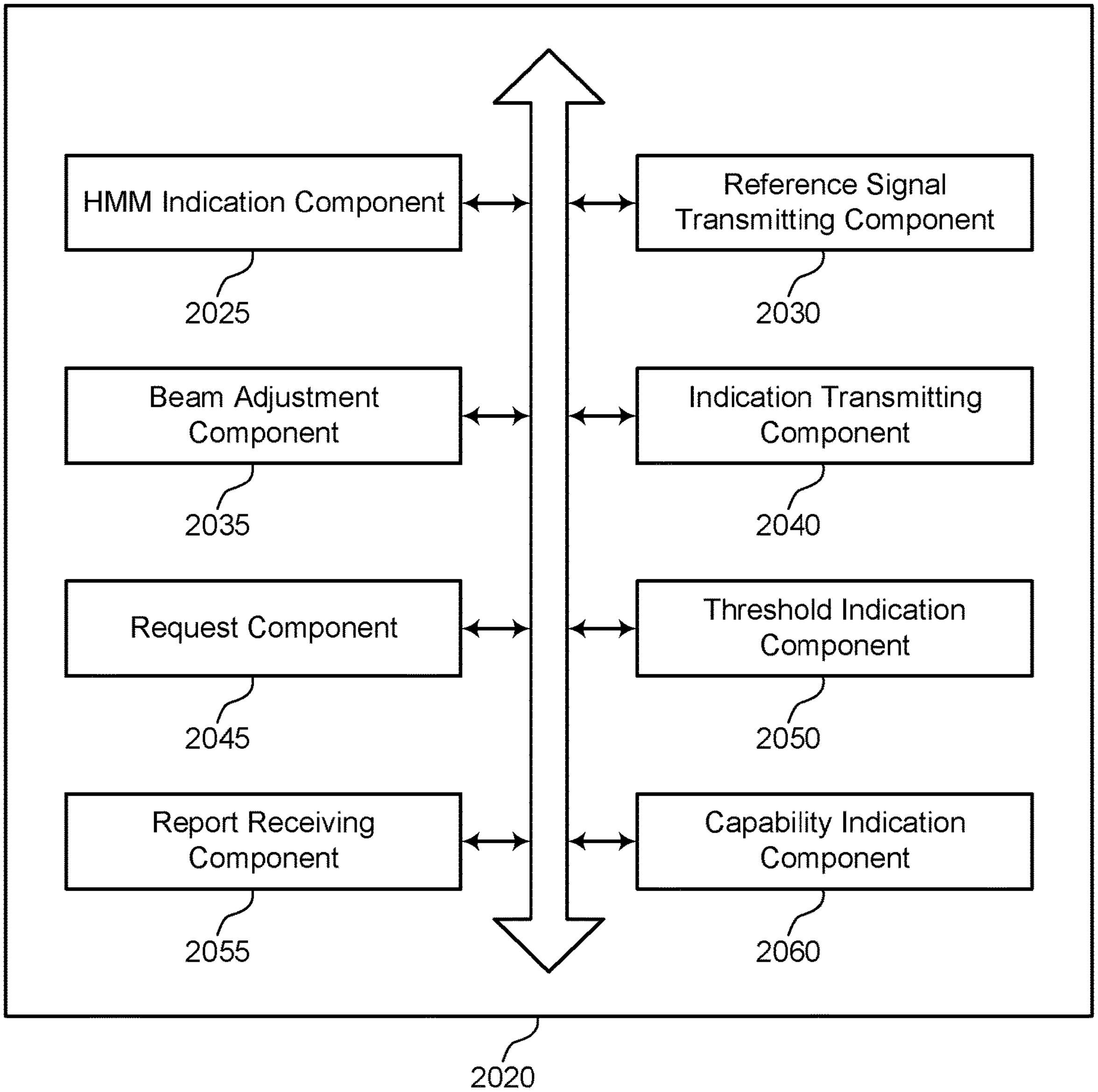
HMM Indication Component
2025
Reference Signal Transmitting Component
2030
Beam Adjustment Component
2035
Indication Transmitting Component
2040
Request Component
2045
Threshold Indication Component
2050
Report Receiving Component
2055
Capability Indication Component
2060
2020

Figure 20

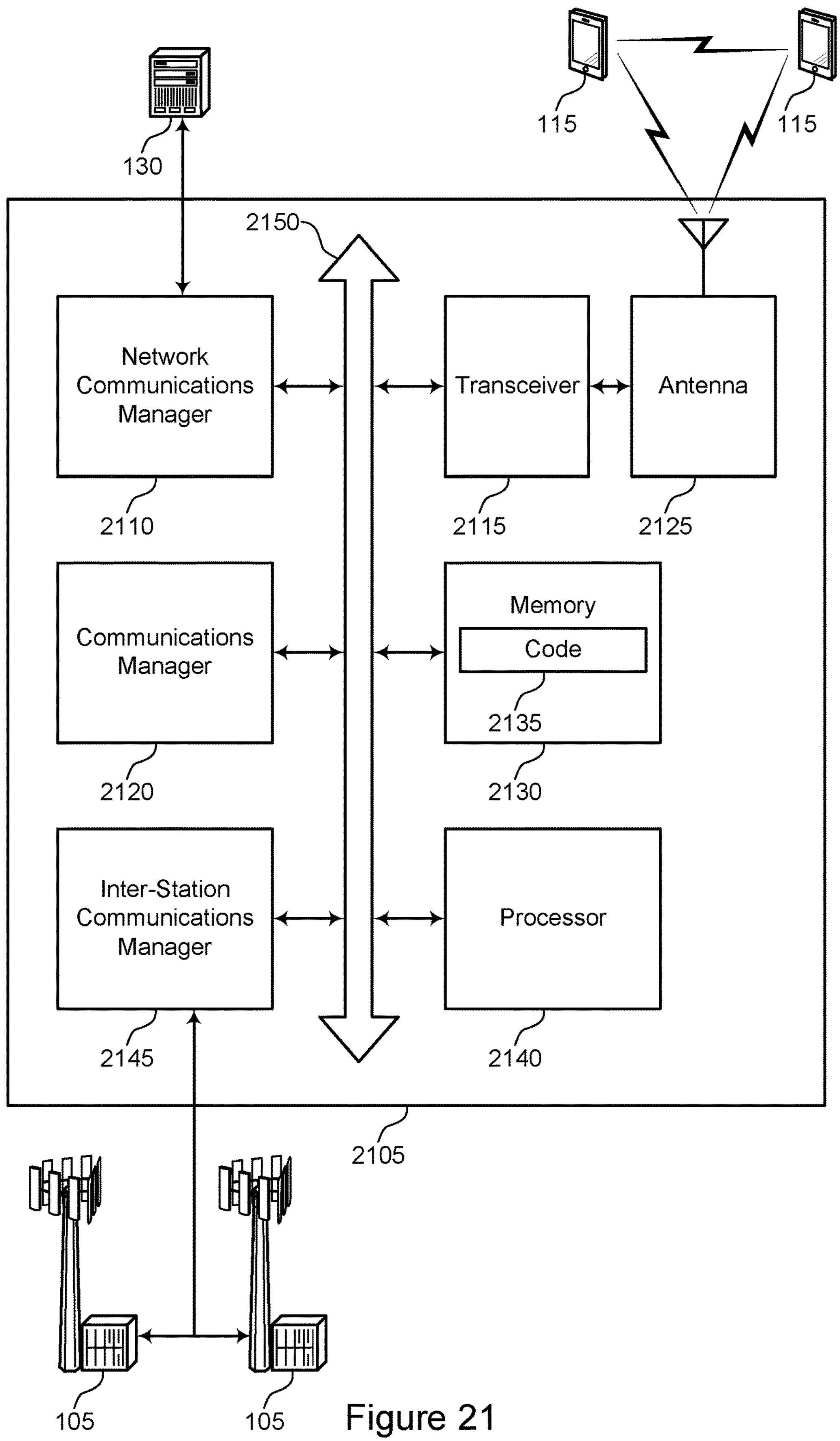
130
115
115
2150
Network Communications Manager
Transceiver
Antenna
2110
2115
2125
Communications Manager
Memory
Code
2135
2120
2130
Inter-Station Communications Manager
Processor
2145
2140
2105
105
105

Figure 21

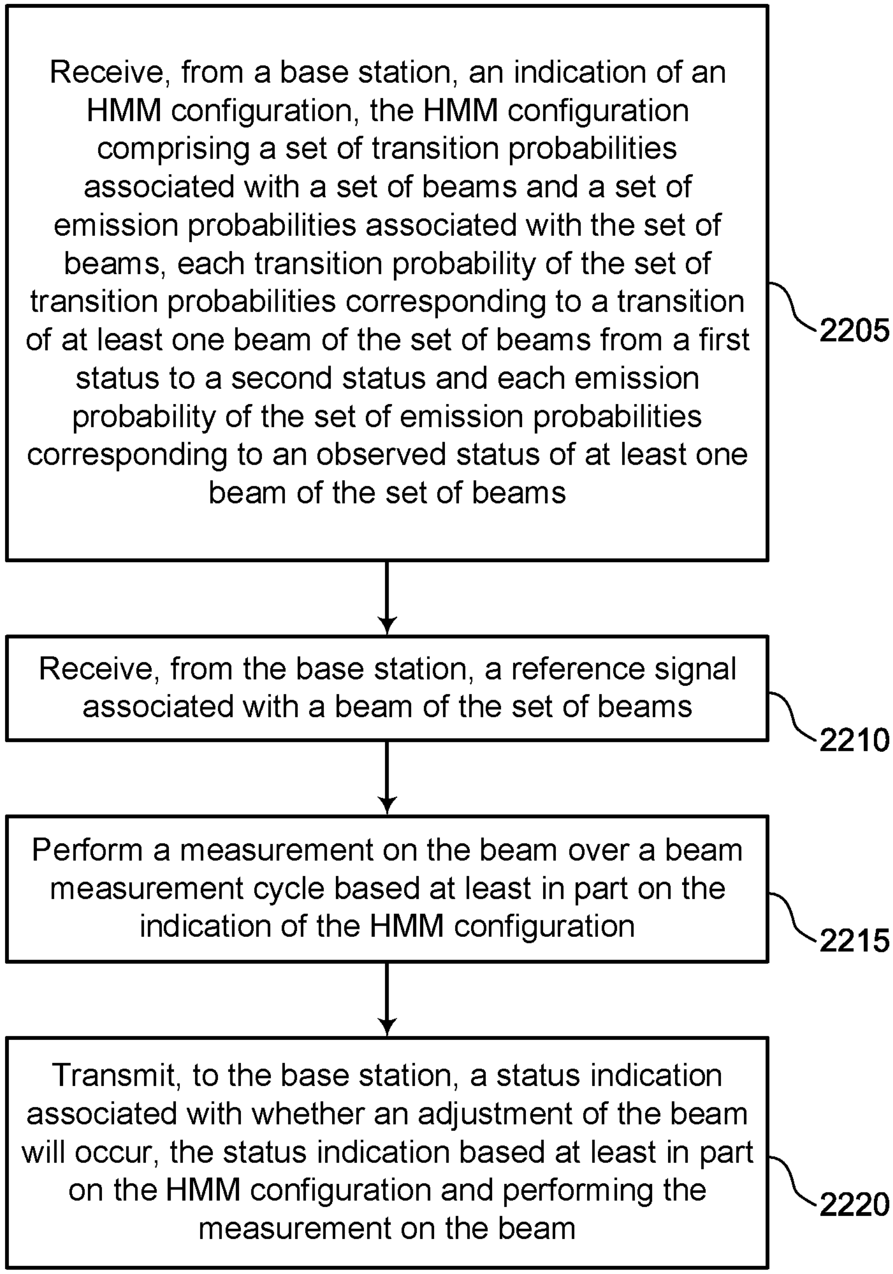
Receive, from a base station, an indication of an HMM configuration, the HMM configuration comprising a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams
2205
Receive, from the base station, a reference signal associated with a beam of the set of beams
2210
Perform a measurement on the beam over a beam measurement cycle based at least in part on the indication of the HMM configuration
2215
Transmit, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based at least in part on the HMM configuration and performing the measurement on the beam
2220

Figure 22

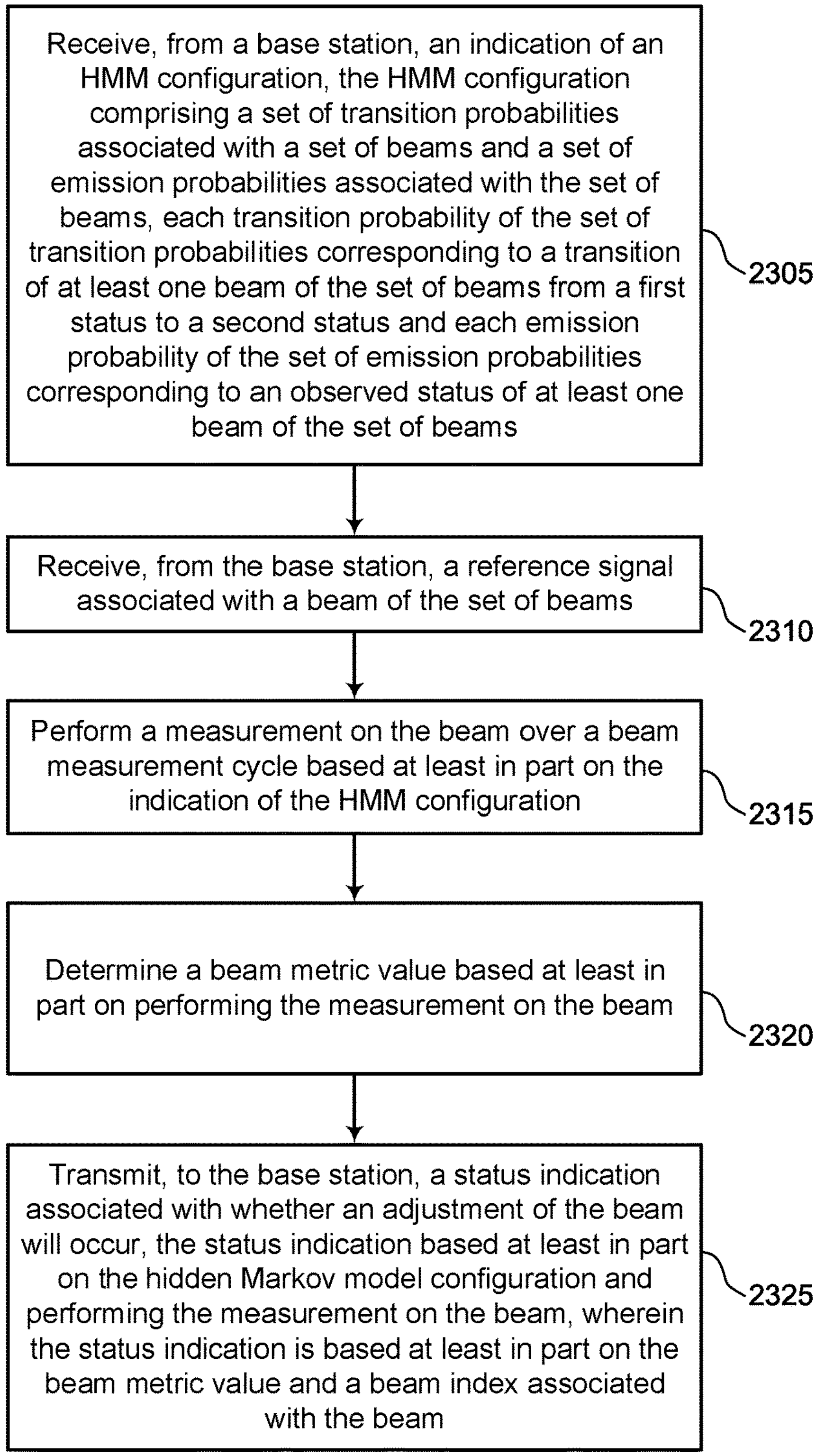
Receive, from a base station, an indication of an HMM configuration, the HMM configuration comprising a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams
2305
Receive, from the base station, a reference signal associated with a beam of the set of beams
2310
Perform a measurement on the beam over a beam measurement cycle based at least in part on the indication of the HMM configuration
2315
Determine a beam metric value based at least in part on performing the measurement on the beam
2320
Transmit, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based at least in part on the hidden Markov model configuration and performing the measurement on the beam, wherein the status indication is based at least in part on the beam metric value and a beam index associated with the beam
2325

Figure 23

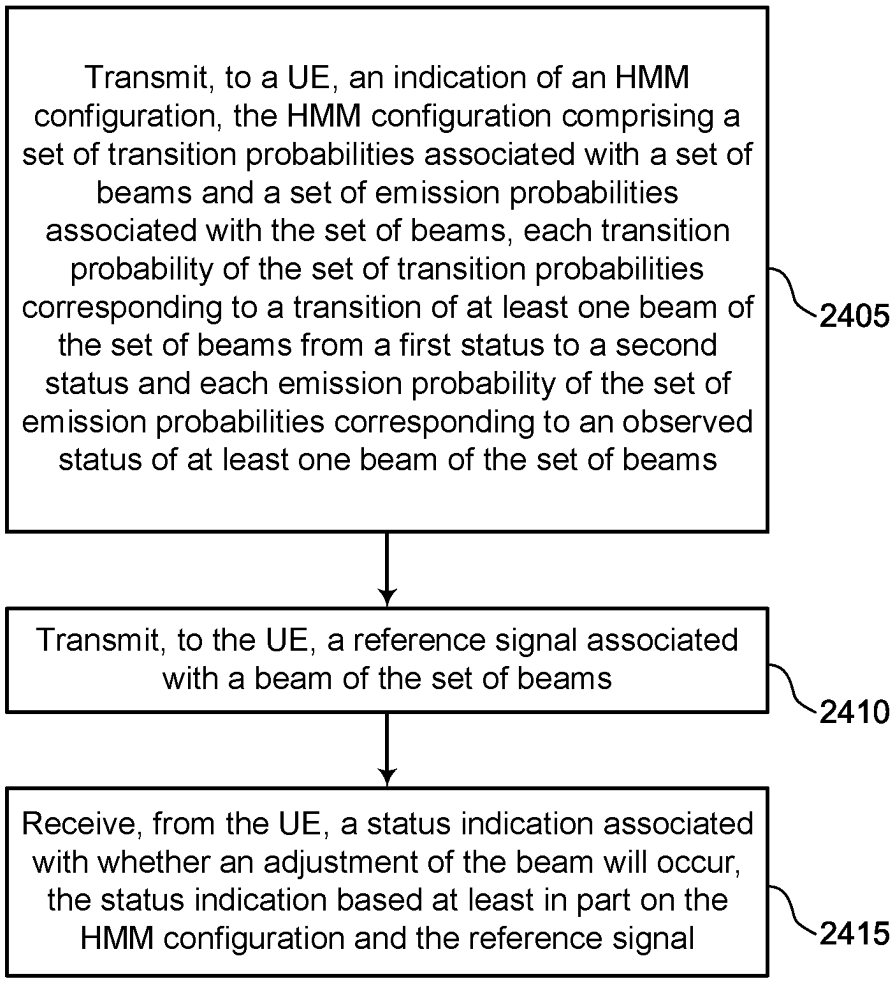
Transmit, to a UE, an indication of an HMM configuration, the HMM configuration comprising a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams
2405
Transmit, to the UE, a reference signal associated with a beam of the set of beams
2410
Receive, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based at least in part on the HMM configuration and the reference signal
2415

Figure 24

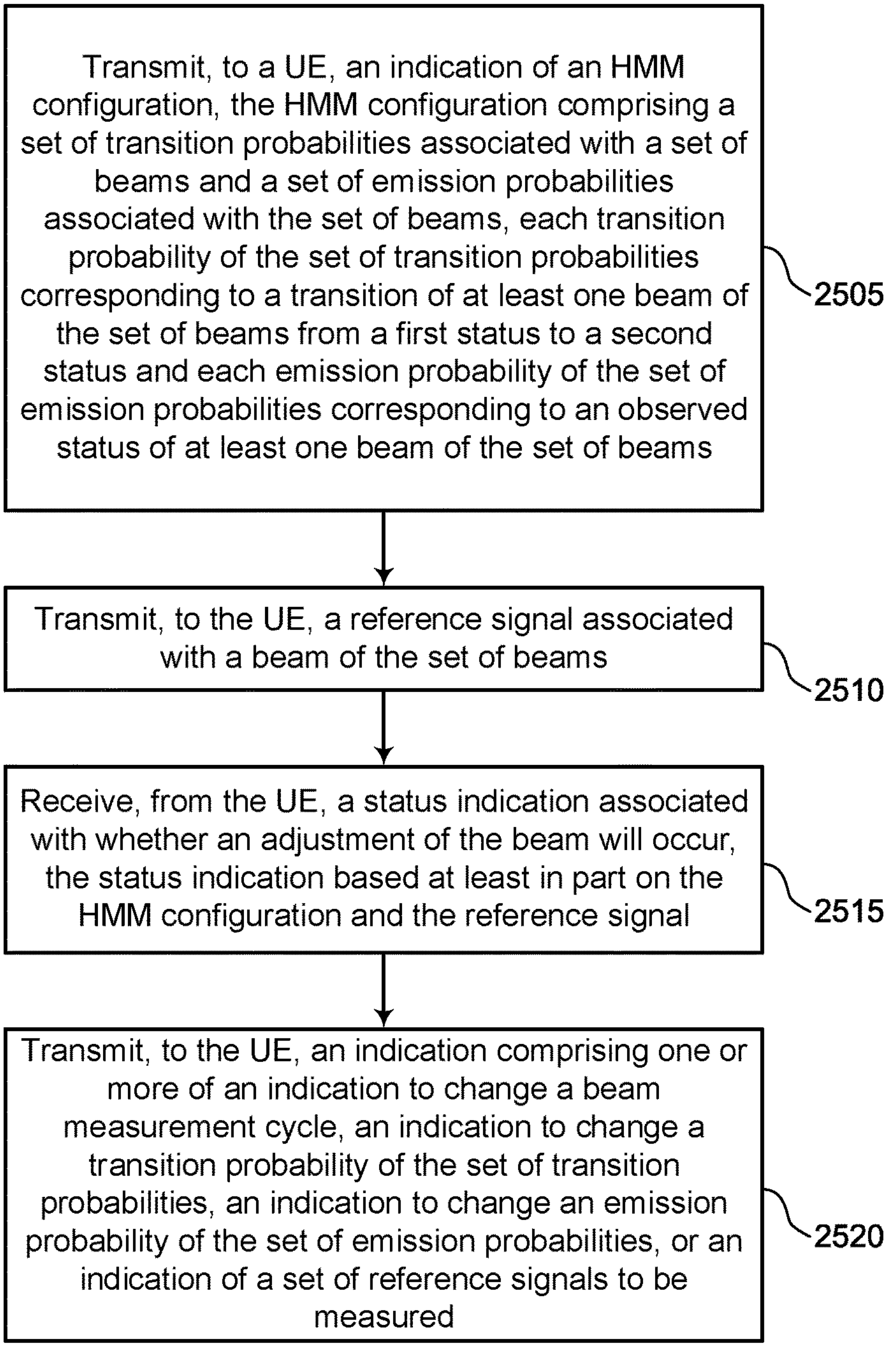
Transmit, to a UE, an indication of an HMM configuration, the HMM configuration comprising a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams
2505
Transmit, to the UE, a reference signal associated with a beam of the set of beams
2510
Receive, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based at least in part on the HMM configuration and the reference signal
2515
Transmit, to the UE, an indication comprising one or more of an indication to change a beam measurement cycle, an indication to change a transition probability of the set of transition probabilities, an indication to change an emission probability of the set of emission probabilities, or an indication of a set of reference signals to be measured
2520

Figure 25

SIGNALING ENHANCEMENT FOR BEAM CHANGE PREDICTIONS VIA MODELING

CROSS REFERENCES

[0001] The present Application is a 371 national stage filing of International PCT Application No. PCT/CN2022/086787 by Li et al. entitled "SIGNALING ENHANCEMENT FOR BEAM CHANGE PREDICTIONS VIA MODELING," filed Apr. 14, 2022; and claims priority to International Patent Application No. PCT/CN2021/138235 by Li et al. entitled "SIGNALING ENHANCEMENT FOR BEAM CHANGE PREDICTIONS VIA MODELING," filed Dec. 15, 2021, each of which is assigned to the assignee hereof, and each of which is expressly incorporated by reference in its entirety herein.

TECHNICAL FIELD

[0002] The following relates to wireless communications, including signaling enhancement for beam change predictions via modeling.

DESCRIPTION OF THE RELATED TECHNOLOGY

[0003] Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (for example, time, frequency, and power). Examples of such multiple-access systems include fourth generation (4G) systems such as Long Term Evolution (LTE) systems, LTE-Advanced (LTE-A) systems, or LTE-A Pro systems, and fifth generation (5G) systems which may be referred to as New Radio (NR) systems. These systems may employ technologies such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), or discrete Fourier transform spread orthogonal frequency division multiplexing (DFT-S-OFDM). A wireless multiple-access communications system may include one or more base stations or one or more network access nodes, or one or more access network entities, each simultaneously supporting communication for multiple communication devices, which may be otherwise known as user equipment (UE).

[0004] Some wireless communications systems may support beamforming operations for directional communications. Beamforming involves a signal processing technique in which a transmitting communication device, or a receiving communication device, or both, select, shape, or steer an antenna beam (for example, a directional beam) along a spatial path between the two communication devices (for example, between a base station and a UE). Some communication devices (for example, base stations) may use beamforming to simultaneously support wireless communications (for example, downlink communications) in multiple directions. For example, a base station may support simultaneous downlink communications for multiple UEs in different locations or for a single UE moving from a first location to a second location. In some examples, a directional beam that may be suitable for transmitting downlink communications to a UE at the first location may not be suitable for transmitting downlink communications to the UE (or another UE, or both the UE and another UE) at the second location. In such examples, the base station may select a first beam to transmit downlink communications to the UE at the first location, and select a second beam to transmit downlink communications to the UE (or another UE, or both the UE and another UE) at the second location. In some cases, however, the UE may not be aware that the change will occur and, as a result, may lose a connection with the base station. Or, alternatively, the UE may predict whether a beam change may occur at a future time, but in some cases conditions or parameters (for example, a beam index) may not change over a duration, and the UE may incorrectly predict that a beam change will occur and unnecessarily alter the behavior of the UE or unnecessarily expend power determining that no change will occur. In some cases, unnecessary changes in the behavior of the UE may result in increased power consumption and reduced link performance, and some methods of the UE trying to predict the beam change may be complex, prohibitive, and rigid.

SUMMARY

[0005] The systems, methods, and devices of this disclosure each have several innovative aspects, no single one of which is solely responsible for the desirable attributes disclosed herein.

[0006] One innovative aspect of the subject matter described in this disclosure can be implemented in a method for wireless communication at a user equipment (UE). The method includes receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index, determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal, and transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0007] Another innovative aspect of the subject matter described in this disclosure can be implemented in an apparatus for wireless communication at a UE. The apparatus includes a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to receive, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index, determine a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal, and transmit, to the network node, an indication of the probability associated with the adjustment of the beam.

[0008] Another innovative aspect of the subject matter described in this disclosure can be implemented in an apparatus for wireless communication at a UE. The apparatus includes means for receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index, means for determining a probability associated with

an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal, and means for transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0009] Another innovative aspect of the subject matter described in this disclosure can be implemented in a non-transitory computer-readable medium storing code for wireless communication at a UE. The code includes instructions executable by a processor to receive, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index, determine a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal, and transmit, to the network node, an indication of the probability associated with the adjustment of the beam.

[0010] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, transmitting an indication of the probability may include operations, features, means, or instructions for transmitting, to the network node, a status indication associated with whether the adjustment of the beam will occur, where transmitting the status indication may be based on the probability.

[0011] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, from the network node, an indication of a threshold and determining whether the probability satisfies the threshold, where transmitting the status indication may be based on the probability satisfying the threshold.

[0012] Another innovative aspect of the subject matter described in this disclosure can be implemented in a method for wireless communication at a user equipment (UE). The method includes receiving, from a base station, an indication of a hidden Markov model (HMM) configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, receiving, from the base station, a reference signal associated with a beam of the set of beams, performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration, and transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0013] Another innovative aspect of the subject matter described in this disclosure can be implemented in an apparatus for wireless communication at a UE. The apparatus includes a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to receive, from a base station, an indication of an HMM configuration, the HMM including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, receive, from the base station, a reference signal associated with a beam of the set of beams, perform a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration, and transmit, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0014] Another innovative aspect of the subject matter described in this disclosure can be implemented in an apparatus for wireless communication at a UE. The apparatus includes means for receiving, from a base station, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, means for receiving, from the base station, a reference signal associated with a beam of the set of beams, means for performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration, and means for transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0015] Another innovative aspect of the subject matter described in this disclosure can be implemented in a non-transitory computer-readable medium storing code for wireless communication at a UE. The code includes instructions executable by a processor to receive, from a base station, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, receive, from the base station, a reference signal associated with a beam of the set of beams, perform a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration, and transmit, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0016] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the set of transition probabilities and the set of emission probabilities of the HMM configuration may be associated with whether a beam metric changed from a second beam measurement cycle to the beam measurement cycle, the beam metric based on performing the measurement on the beam.

[0017] Another innovative aspect of the subject matter described in this disclosure can be implemented in a method for wireless communication at a base station. The method includes transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, transmitting, to the UE, a reference signal associated with a beam of the set of beams, and receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal.

[0018] Another innovative aspect of the subject matter described in this disclosure can be implemented in an apparatus for wireless communication at a base station. The apparatus includes a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to transmit, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, transmit, to the UE, a reference signal associated with a beam of the set of beams, and receive, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal.

[0019] Another innovative aspect of the subject matter described in this disclosure can be implemented in an apparatus for wireless communication at a base station. The apparatus includes means for transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, means for transmitting, to the UE, a reference signal associated with a beam of the set of beams, and means for receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal.

[0020] Another innovative aspect of the subject matter described in this disclosure can be implemented in a non-transitory computer-readable medium storing code for wireless communication at a base station. The code includes instructions executable by a processor to transmit, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, transmit, to the UE, a reference signal associated with a beam of the set of beams, and receive, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal.

[0021] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the set of transition probabilities and the set of emission probabilities of the HMM configuration may be associated with whether a beam metric changed from a second beam measurement cycle to a beam measurement cycle, the beam metric corresponding to a measurement of the beam.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIGS. **1** and **2** each illustrate an example of a wireless communications system that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0023] FIG. **3** illustrates an example of a hidden Markov model (HMM) that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0024] FIGS. **4**, **5**A, and **5**B each illustrate an example of a beam change prediction procedure that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0025] FIGS. **6**A and **6**B each illustrate an example of a sequence that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0026] FIG. **7** illustrates an example of a process flow that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0027] FIGS. **8** and **9** show block diagrams of devices that support signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0028] FIG. **10** shows a block diagram of a communications manager that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0029] FIG. **11** shows a diagram of a system including a device that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0030] FIGS. **12** and **13** show flowcharts illustrating methods that support signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure.

[0031] FIGS. **14** and **15** show block diagrams of devices that support signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

[0032] FIG. **16** shows a block diagram of a communications manager that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

[0033] FIG. **17** shows a diagram of a system including a device that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

[0034] FIGS. **18** and **19** show block diagrams of devices that support signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

[0035] FIG. **20** shows a block diagram of a communications manager that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

[0036] FIG. **21** shows a diagram of a system including a device that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

[0037] FIGS. **22** through **25** show flowcharts illustrating methods that support signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0038] A first communication device (for example, a base station) may use multiple beams (for example, directional beams) to support communication with a second communication device (for example, a user equipment (UE)) as the second communication device moves throughout a geographic coverage area supported by the first communication device. However, the second communication device may not be aware that a beam change will occur as the second communication device moves and, as a result, the second communication device may lose a connection with the first communication device (for example, a downlink connection may be lost). To reduce the likelihood of losing the connection, the second communication device may predict whether the beam change may occur based on signal measurements by the second communication device. In some cases, however, beam conditions or parameters may not change over a duration (for example, hundreds of milliseconds (ms)) and the second communication device may unnecessarily expend power performing the signal measurements. Additionally or alternatively, the second communication device may incorrectly predict the beam change will occur and unnecessarily alter the behavior of the second communication device. These unnecessary changes in the behavior of the second communication device may result in increased power consumption and reduce link performance, among other disadvantages.

[0039] Various aspects generally relate to techniques for signaling enhancement for beam change predictions, and more specifically, for beam change predictions based on probabilities determined at a second communication device. In some examples, the second communication device may predict a beam change using a machine learning model, such as a hidden Markov model (HMM), a long short-term memory (LSTM) neural network, a gated recurrent unit (GRU) neural network, a convolution neural network (CNN), a recurrent neural network (RNN), or a deep neural network (DNN), among other examples. For example, the second communication device (for example, a UE) may use a machine learning model to predict a state (for example, whether a beam change at a first communication device will occur at a future time or over a future duration) based on one or both of information (for example, included in a machine learning model such as an HMM configuration) and observations (for example, signal measurements) made by the second communication device. The information, may include probabilities associated with the likelihood of a transition between a number of states and probabilities associated with the likelihood that an observation will occur given a state. The second communication device may signal a beam change prediction (for example, whether the beam will change, a probability that the beam will change) to the first communication device (for example, a network node). For example, the second communication device may use the machine learning model (for example, a machine learning model determined at the second communication device or configured for the second communication device by the first communication device) to estimate a probability of the beam change occurring at the future time or over the future duration, and in some examples, the second communication device may compare the estimated probability to a threshold to determine whether the beam change will occur. The second communication device may transmit an indication of the estimated probability (or the beam change prediction) to the first communication device, such that the first communication device may account for or use the beam change prediction indication in signaling to the second communication device or for adjustments for the second communication device.

[0040] Particular aspects of the subject matter described herein may be implemented to realize one or more of the following potential advantages. The techniques employed by the described communication devices may enable a flexible tradeoff between power consumption and link performance by predicting whether a beam change will occur at a future time or over a future duration. The first communication device (for example, the base station) may provide (for example, indicate) a machine learning model, such as via a machine learning model configuration (for example an HMM configuration), to improve procedures for predicting beam changes by increasing the reliability of beam change predictions, such as at the second communication device (for example, the UE). In some implementations, using a machine learning model to predict the probability that the beam change will occur will reduce a miss detection error rate and a false alarm rate associated with beam change predictions and avoid unnecessary changes or operations. In some implementations, operations performed by the described communication devices via modeling, such as via the machine learning model, support improvements to power consumption, reliability for downlink communications, and spectral efficiency, among other benefits.

[0041] Aspects of the disclosure are initially described in the context of wireless communications systems. Aspects of the disclosure are also described in the context of an HMM, beam change prediction procedures, a result sequence, and a process flow. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to signaling enhancement for beam change predictions via modeling.

[0042] FIG. **1** illustrates an example of a wireless communications system **100** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The wireless communications system **100** may include one or more base stations **105**, one or more UEs **115**, and a core network **130**. In some examples, the wireless communications system **100** may be a Long Term Evolution (LTE) network, an LTE-Advanced (LTE-A) network, an LTE-A Pro network, or a New Radio (NR) network. In some examples, the wireless communications system **100** may support enhanced broadband communications, ultra-reliable communications, low latency communications, communications with low-cost and low-complexity devices, or any combination thereof.

[0043] The base stations **105** may be dispersed throughout a geographic area to form the wireless communications system **100** and may be devices in different forms or having different capabilities. The base stations **105** and the UEs **115** may wirelessly communicate via one or more communication links **125**. Each base station **105** may provide a coverage area **110** over which the UEs **115** and the base station **105** may establish one or more communication links **125**. The coverage area **110** may be an example of a geographic area over which a base station **105** and a UE **115** may support the communication of signals according to one or more radio access technologies.

[0044] The UEs **115** may be dispersed throughout a coverage area **110** of the wireless communications system **100**, and each UE **115** may be stationary, or mobile, or both at different times. The UEs **115** may be devices in different forms or having different capabilities. Some example UEs **115** are illustrated in FIG. **1**. The UEs **115** described herein may be able to communicate with various types of devices, such as other UEs **115**, the base stations **105**, or network equipment (for example, core network nodes, relay devices, integrated access and backhaul (IAB) nodes, or other network equipment), as shown in FIG. **1**.

[0045] In some examples, one or more components of the wireless communications system **100** may operate as or be referred to as a network node. As used herein, a network node may refer to any UE **115**, base station **105**, entity of a core network **130**, apparatus, device, or computing system configured to perform any techniques described herein. For example, a network node may be a UE **115**. As another example, a network node may be a base station **105**. As another example, a first network node may be configured to communicate with a second network node or a third network node. In one aspect of this example, the first network node may be a UE **115**, the second network node may be a base station **105**, and the third network node may be a UE **115**. In another aspect of this example, the first network node may be a UE **115**, the second network node may be a base station **105**, and the third network node may be a base station **105**. In yet other aspects of this example, the first, second, and third network nodes may be different. Similarly, reference to a UE **115**, a base station **105**, an apparatus, a device, or a computing system may include disclosure of the UE **115**, base station **105**, apparatus, device, or computing system being a network node. For example, disclosure that a UE **115** is configured to receive information from a base station **105** also discloses that a first network node is configured to receive information from a second network node. In this example, consistent with this disclosure, the first network node may refer to a first UE **115**, a first base station **105**, a first apparatus, a first device, or a first computing system configured to receive the information; and the second network node may refer to a second UE **115**, a second base station **105**, a second apparatus, a second device, or a second computing system.

[0046] The base stations **105** may communicate with the core network **130**, or with one another, or both. For example, the base stations **105** may interface with the core network **130** through one or more backhaul links **120** (for example, via an S1, N2, N3, or other interface). The base stations **105** may communicate with one another over the backhaul links **120** (for example, via an X2, Xn, or other interface) either directly (for example, directly between base stations **105**), or indirectly (for example, via core network **130**), or both. In some examples, the backhaul links **120** may be or include one or more wireless links.

[0047] One or more of the base stations **105** described herein may include or may be referred to by a person having ordinary skill in the art as a base transceiver station, a radio base station, an access point, a radio transceiver, a NodeB, an eNodeB (eNB), a next-generation NodeB or a giga-NodeB (either of which may be referred to as a gNB), a Home NodeB, a Home eNodeB, or other suitable terminology.

[0048] A UE **115** may include or may be referred to as a mobile device, a wireless device, a remote device, a handheld device, or a subscriber device, or some other suitable terminology, in which the "device" may also be referred to as a unit, a station, a terminal, or a client, among other examples. A UE **115** may also include or may be referred to as a personal electronic device such as a cellular phone, a personal digital assistant (PDA), a tablet computer, a laptop computer, or a personal computer. In some examples, a UE **115** may include or be referred to as a wireless local loop (WLL) station, an Internet of Things (IoT) device, an Internet of Everything (IoE) device, or a machine type communications (MTC) device, among other examples, which may be implemented in various objects such as appliances, or vehicles, meters, among other examples. The UEs **115** described herein may be able to communicate with various types of devices, such as other UEs **115** that may sometimes act as relays as well as the base stations **105** and the network equipment including macro eNBs or gNBs, small cell eNBs or gNBs, or relay base stations, among other examples, as shown in FIG. **1**.

[0049] The UEs **115** and the base stations **105** may wirelessly communicate with one another via one or more communication links **125** over one or more carriers. The term "carrier" may refer to a set of radio frequency spectrum resources having a defined physical layer structure for supporting the communication links **125**. For example, a carrier used for a communication link **125** may include a portion of a radio frequency spectrum band (for example, a bandwidth part (BWP)) that is operated according to one or more physical layer channels for a given radio access technology (for example, LTE, LTE-A, LTE-A Pro, NR). Each physical layer channel may carry acquisition signaling (for example, synchronization signals, system information), control signaling that coordinates operation for the carrier, user data, or other signaling. The wireless communications system **100** may support communication with a UE **115**

using carrier aggregation or multi-carrier operation. A UE **115** may be configured with multiple downlink component carriers and one or more uplink component carriers according to a carrier aggregation configuration. Carrier aggregation may be used with both frequency division duplexing (FDD) and time division duplexing (TDD) component carriers.

[0050] Signal waveforms transmitted over a carrier may be made up of multiple subcarriers (for example, using multi-carrier modulation (MCM) techniques such as orthogonal frequency division multiplexing (OFDM) or discrete Fourier transform spread OFDM (DFT-S-OFDM)). In a system employing MCM techniques, a resource element may consist of one symbol period (for example, a duration of one modulation symbol) and one subcarrier, in which the symbol period and subcarrier spacing are inversely related. The number of bits carried by each resource element may depend on the modulation scheme (for example, the order of the modulation scheme, the coding rate of the modulation scheme, or both). The more resource elements that a UE **115** receives and the higher the order of the modulation scheme, the higher the data rate may be for the UE **115**. A wireless communications resource may refer to a combination of a radio frequency spectrum resource, a time resource, and a spatial resource (for example, spatial layers or beams), and the use of multiple spatial layers may further increase the data rate or data integrity for communications with a UE **115**.

[0051] The time intervals for the base stations **105** or the UEs **115** may be expressed in multiples of a basic time unit which may, for example, refer to a sampling period of $T_s=1/(\Delta f_{max}-N_f)$ seconds, in which Δf_{max} may represent the maximum supported subcarrier spacing, and N_f may represent the maximum supported discrete Fourier transform (DFT) size. Time intervals of a communications resource may be organized according to radio frames each having a specified duration (for example, 10 ms). Each radio frame may be identified by a system frame number (SFN) (for example, ranging from 0 to 1023).

[0052] Each frame may include multiple consecutively numbered subframes or slots, and each subframe or slot may have the same duration. In some examples, a frame may be divided (for example, in the time domain) into subframes, and each subframe may be further divided into a number of slots. Alternatively, each frame may include a variable number of slots, and the number of slots may depend on subcarrier spacing. Each slot may include a number of symbol periods (for example, depending on the length of the cyclic prefix prepended to each symbol period). In some wireless communications systems **100**, a slot may further be divided into multiple mini-slots containing one or more symbols. Excluding the cyclic prefix, each symbol period may contain one or more (for example, N_f) sampling periods. The duration of a symbol period may depend on the subcarrier spacing or frequency band of operation.

[0053] A subframe, a slot, a mini-slot, or a symbol may be the smallest scheduling unit (for example, in the time domain) of the wireless communications system **100** and may be referred to as a transmission time interval (TTI). In some examples, the TTI duration (for example, the number of symbol periods in a TTI) may be variable. Additionally or alternatively, the smallest scheduling unit of the wireless communications system **100** may be dynamically selected (for example, in bursts of shortened TTIs (sTTIs)).

[0054] Physical channels may be multiplexed on a carrier according to various techniques. A physical control channel and a physical data channel may be multiplexed on a downlink carrier, for example, using one or more of time division multiplexing (TDM) techniques, frequency division multiplexing (FDM) techniques, or hybrid TDM-FDM techniques. A control region (for example, a control resource set (CORESET)) for a physical control channel may be defined by a number of symbol periods and may extend across the system bandwidth or a subset of the system bandwidth of the carrier. One or more control regions (for example, CORESETs) may be configured for a set of the UEs **115**. For example, one or more of the UEs **115** may monitor or search control regions for control information according to one or more search space sets, and each search space set may include one or multiple control channel candidates in one or more aggregation levels arranged in a cascaded manner. An aggregation level for a control channel candidate may refer to a number of control channel resources (for example, control channel elements (CCEs)) associated with encoded information for a control information format having a given payload size. Search space sets may include common search space sets configured for sending control information to multiple UEs **115** and UE-specific search space sets for sending control information to a specific UE **115**.

[0055] In some examples, a base station **105** may be movable and therefore provide communication coverage for a moving geographic coverage area **110**. In some examples, different geographic coverage areas **110** associated with different technologies may overlap, but the different geographic coverage areas **110** may be supported by the same base station **105**. In other examples, the overlapping geographic coverage areas **110** associated with different technologies may be supported by different base stations **105**. The wireless communications system **100** may include, for example, a heterogeneous network in which different types of the base stations **105** provide coverage for various geographic coverage areas **110** using the same or different radio access technologies.

[0056] The wireless communications system **100** may be configured to support ultra-reliable communications or low-latency communications, or various combinations thereof. For example, the wireless communications system **100** may be configured to support ultra-reliable low-latency communications (URLLC). The UEs **115** may be designed to support ultra-reliable, low-latency, or critical functions. Ultra-reliable communications may include private communication or group communication and may be supported by one or more services such as push-to-talk, video, or data. Support for ultra-reliable, low-latency functions may include prioritization of services, and such services may be used for public safety or general commercial applications. The terms ultra-reliable, low-latency, and ultra-reliable low-latency may be used interchangeably herein.

[0057] In some examples, a UE **115** may also be able to communicate directly with other UEs **115** over a device-to-device (D2D) communication link **135** (for example, using a peer-to-peer (P2P) or D2D protocol). One or more UEs **115** utilizing D2D communications may be within the geographic coverage area **110** of a base station **105**. Other UEs **115** in such a group may be outside the geographic coverage area **110** of a base station **105** or be otherwise unable to receive transmissions from a base station **105**. In some examples, groups of the UEs **115** communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE **115** transmits to every other UE **115** in the group. In some examples, a base station **105** facilitates the scheduling of resources for D2D communications. In other cases, D2D communications are carried out between the UEs **115** without the involvement of a base station **105**.

[0058] The core network **130** may provide user authentication, access authorization, tracking, Internet Protocol (IP) connectivity, and other access, routing, or mobility functions. The core network **130** may be an evolved packet core (EPC) or 5G core (5GC), which may include at least one control plane entity that manages access and mobility (for example, a mobility management entity (MME), an access and mobility management function (AMF)) and at least one user plane entity that routes packets or interconnects to external networks (for example, a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). The control plane entity may manage non-access stratum (NAS) functions such as mobility, authentication, and bearer management for the UEs **115** served by the base stations **105** associated with the core network **130**. User IP packets may be transferred through the user plane entity, which may provide IP address allocation as well as other functions. The user plane entity may be connected to IP services **150** for one or more network operators. The IP services **150** may include access to the Internet, Intranet(s), an IP Multimedia Subsystem (IMS), or a Packet-Switched Streaming Service.

[0059] Some of the network devices, such as a base station **105**, may include subcomponents such as an access network entity **140**, which may be an example of an access node controller (ANC). Each access network entity **140** may communicate with the UEs **115** through one or more other access network transmission entities **145**, which may be referred to as radio heads, smart radio heads, or transmission/reception points (TRPs). Each access network transmission entity **145** may include one or more antenna panels. In some configurations, various functions of each access network entity **140** or base station **105** may be distributed across various network devices (for example, radio heads and ANCs) or consolidated into a single network device (for example, a base station **105**).

[0060] The wireless communications system **100** may operate using one or more frequency bands, typically in the range of 300 megahertz (MHz) to 300 gigahertz (GHz). Generally, the region from 300 MHz to 3 GHz is known as the ultra-high frequency (UHF) region or decimeter band because the wavelengths range from approximately one decimeter to one meter in length. The UHF waves may be blocked or redirected by buildings and environmental features, but the waves may penetrate structures sufficiently for a macro cell to provide service to the UEs **115** located indoors. The transmission of UHF waves may be associated with smaller antennas and shorter ranges (for example, less than 100 kilometers) compared to transmission using the smaller frequencies and longer waves of the high frequency (HF) or very high frequency (VHF) portion of the spectrum below 300 MHz.

[0061] The wireless communications system **100** may utilize both licensed and unlicensed radio frequency spectrum bands. For example, the wireless communications system **100** may employ License Assisted Access (LAA), LTE-Unlicensed (LTE-U) radio access technology, or NR technology in an unlicensed band such as the 5 GHz industrial, scientific, and medical (ISM) band. In some examples of operating in unlicensed radio frequency spectrum bands, devices such as the base stations **105** and the UEs **115** may employ carrier sensing for collision detection and avoidance. In some examples, operations in unlicensed bands may be based on a carrier aggregation configuration in conjunction with component carriers operating in a licensed band (for example, LAA). Operations in unlicensed spectrum may include downlink transmissions, uplink transmissions, P2P transmissions, or D2D transmissions, among other examples.

[0062] A base station **105** or a UE **115** may be equipped with multiple antennas, which may be used to employ techniques such as transmit diversity, receive diversity, multiple-input multiple-output (MIMO) communications, or beamforming. The antennas of a base station **105** or a UE **115** may be located within one or more antenna arrays or antenna panels, which may support MIMO operations or transmit or receive beamforming. For example, one or more base station antennas or antenna arrays may be co-located at an antenna assembly, such as an antenna tower. In some examples, antennas or antenna arrays associated with a base station **105** may be located in diverse geographic locations. A base station **105** may have an antenna array with a number of rows and columns of antenna ports that the base station **105** may use to support beamforming of communications with a UE **115**. Likewise, a UE **115** may have one or more antenna arrays that may support various MIMO or beamforming operations. Additionally or alternatively, an antenna panel may support radio frequency beamforming for a signal transmitted via an antenna port.

[0063] Beamforming, which may also be referred to as spatial filtering, directional transmission, or directional reception, is a signal processing technique that may be used at a transmitting device or a receiving device (for example, a base station **105**, a UE **115**) to shape or steer an antenna beam (for example, a transmit beam, a receive beam) along a spatial path between the transmitting device and the receiving device. Beamforming may be achieved by combining the signals communicated via antenna elements of an antenna array such that some signals propagating at particular orientations with respect to an antenna array experience constructive interference while others experience destructive interference. The adjustment of signals communicated via the antenna elements may include a transmitting device or a receiving device applying amplitude offsets, phase offsets, or both to signals carried via the antenna elements associated with the device. The adjustments associated with each of the antenna elements may be defined by a beamforming weight set associated with a particular orientation (for example, with respect to the antenna array of the transmitting device or receiving device, or with respect to some other orientation).

[0064] A base station **105** or a UE **115** may use beam sweeping techniques as part of beam forming operations. For example, a base station **105** may use multiple antennas or antenna arrays (for example, antenna panels) to conduct beamforming operations for directional communications with a UE **115**. Some signals (for example, synchronization signals, reference signals, beam selection signals, or other control signals) may be transmitted by a base station **105** multiple times in different directions. For example, the base station **105** may transmit a signal according to different beamforming weight sets associated with different directions of transmission. Transmissions in different beam directions may be used to determine (for example, by a transmitting device, such as a base station **105**, or by a receiving device, such as a UE **115**) a beam direction for later transmission or reception by the base station **105**.

[0065] Some signals, such as data signals associated with a particular receiving device, may be transmitted by a base station **105** in a single beam direction (for example, a direction associated with the receiving device, such as a UE **115**). In some examples, the beam direction associated with transmissions along a single beam direction may be determined based on a signal that was transmitted in one or more beam directions. For example, a UE **115** may receive one or more of the signals transmitted by the base station **105** in different directions and may report to the base station **105** an indication of the signal that the UE **115** received with a highest signal quality or an otherwise acceptable signal quality compared to other measured beams.

[0066] In some examples, transmissions by a device (for example, by a base station **105** or a UE **115**) may be performed using multiple beam directions, and the device may use a combination of digital precoding or radio frequency beamforming to generate a combined beam for transmission (for example, from a base station **105** to a UE **115**). The UE **115** may report feedback that indicates precoding weights for one or more beam directions, and the feedback may correspond to a configured number of beams across a system bandwidth or one or more sub-bands. The base station **105** may transmit a reference signal (for example, a cell-specific reference signal (CRS), a channel state information reference signal (CSI-RS)), which may be precoded or unprecoded. The UE **115** may provide feedback for beam selection, which may be a precoding matrix indicator (PMI) or codebook-based feedback (for example, a multi-panel type codebook, a linear combination type codebook, a port selection type codebook). Although these techniques are described with reference to signals transmitted in one or more directions by a base station **105**, a UE **115** may employ similar techniques for transmitting signals multiple times in different directions (for example, for determining a beam direction for subsequent transmission or reception by the UE **115**) or for transmitting a signal in a single direction (for example, for transmitting data to a receiving device).

[0067] A receiving device (for example, a UE **115**) may try multiple receive configurations (for example, directional listening) for receiving various signals from the base station **105**, such as synchronization signals, reference signals, beam selection signals, or other control signals. For example, a receiving device may try multiple receive directions by receiving via different antenna subarrays, by processing received signals according to different antenna subarrays, by receiving according to different receive beamforming weight sets (for example, different directional listening weight sets) applied to signals received at multiple antenna elements of an antenna array, or by processing received signals according to different receive beamforming weight sets applied to signals received at multiple antenna elements of an antenna array, any of which may be referred to as "listening" according to different receive configurations or receive directions. In some examples, a receiving device may use a single receive configuration to receive along a single beam direction (for example, for receiving a data signal). The single receive configuration may be aligned in a beam direction determined based on listening according to different receive configuration directions (for example, a beam direction determined to have a highest signal strength, highest signal-to-noise ratio (SNR), or otherwise acceptable signal quality based on listening according to multiple beam directions).

[0068] In the wireless communications system **100**, a communication device (for example, a UE **115**) may be a mobile communication device, such that the UE **115** may be able to move (for example, travel) throughout the geographic coverage area **110**. A base station **105** may use different beams to support communications, such as downlink communications, with the UE **115** as the UE **115** travels through the geographic coverage area **110**. In some examples, however, the UE **115** may not be aware that a beam change will occur and as such, may lose a connection with the base station **105** due to the beam change. To reduce the likelihood of disruptions in wireless communications between the UE **115** and the base station **105**, the UE **115** may perform one or more beam change predictions using a machine learning model, such as an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, among other examples.

[0069] For example, a UE **115** may receive, from a network node (for example, a base station or an access network entity), a reference signal associated with a beam of a set of beams used for wireless communications at the UE **115**. Each beam of the set of beams may be associated with a respective beam index. The UE **115** may determine a probability associated with an adjustment of the beam. In some examples, the probability may indicate whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal. The UE **115** may transmit, to the network node, an indication of the probability associated with the adjustment of the beam.

[0070] In some examples, the UE **115** may use a machine learning model, such as an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, among other examples, to predict whether a beam change (for example, a beam adjustment) will occur at a future time or over a future duration. For example, the UE **115** may use the HMM to predict whether a beam change will occur (for example, over the future duration). In such an example, the beam change prediction may be based on information included in a model configuration, such as an HMM configuration, and measurements (for example, beam quality measurements) performed by the UE **115**. The UE **115** may perform the measurements on signals (for example, reference signals) received from the base station **105** over one or more beam measurement cycle and use the measurement results as input for the model, such as an HMM (for example, with information included in the configuration such as an HMM configuration) to predict whether a beam change will occur at the future time or over the future duration. The UE **115** may indicate a beam change prediction (for example, an indication based on the output of the model) to the base station **105**, and the base station **105** may use the beam change prediction in signaling to the UE **115** or for adjustments of the UE **115** (along with signaling to one or more other UEs **115** or for one or more adjustments of one or more other UEs **115**).

[0071] In some examples, to increase the reliability of beam change predictions, the UE **115** may use the machine learning model, such as the HMM, the LSTM neural network, the GRU neural network, the CNN, the RNN, or the DNN, to estimate a probability (for example, a soft decision) of a beam change occurring at the future time or over the duration. The UE **115** may compare the estimated probability to a threshold to determine whether the beam change will occur (for example, a rigid decision). The UE **115** may indicate whether the beam change will occur (for example, the rigid decision) or the estimated probability (for example, the soft decision) to the base station **105**. Predicting whether a beam change will occur at the future time may increase the reliability of communications between the UE **115** and the base station **105**, as well as improve throughput and reduce latency for the UE **115**.

[0072] FIG. **2** illustrates an example of a wireless communications system **200** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The wireless communications system **200** may implement or be implemented by one or more aspects of the wireless communications system **100**. For example, the wireless communications system **200** may include a UE **115**-*a* and a base station **105**-*a*, which may be examples of the corresponding devices as described in the present disclosure including with reference to FIG. **1**.

[0073] The UE **115**-*a* may be a mobile UE that can travel along a path **210**. The UE **115**-*a* may perform an initial access procedure to establish a connection with the base station **105**-*a*. For example, while in a connected mode, the UE **115**-*a* may receive downlink communications from the base station **105**-*a* via a directional beam (for example, a beam **205**-*a*, a beam **205**-*b*, or a beam **205**-*c*). As the UE **115**-*a* travels along the path **210**, the established connection (for example, a communication link that may also referred to as a radio link or a link) may be susceptible to blockages and degradation, which may cause interruptions in the radio link or a radio link failure (for example, downlink communications may be lost). To reduce the likelihood of radio link failures occurring or to recover after a radio link failure, the UE **115**-*a* may perform beam management procedures, such as a beam failure prevention procedure or a beam failure recovery procedure.

[0074] For example, the UE **115**-*a* may perform the beam failure recovery procedure to reestablish a connection with the base station **105**-*a* and select another (for example, different) beam pair for communications with the base station **105**-*a*. In some examples, the UE **115**-*a* may perform beam management procedures, such as synchronization signal block (SSB) or CSI-RS beam sweeping, SSB and random access channel (RACH) occasion association (for example, with relatively wide beams, such as layer one (L1) beams), hierarchical beam refinement procedures (for example, P1/P2/P3 procedures for downlink beam management or UT/U2/U3 procedures for uplink beam management), and L1 reporting. In examples in which the UE **115**-*a* detects interruptions in the radio link or a radio link failure, the UE **115**-*a* may perform a recovery procedure (for example, a fast master cell group (MCG) link recovery procedure) to reduce a link interruption time or a link failure time. However, in some examples, the UE **115** may resort to (for example, determine to) perform a handover procedure.

[0075] To reduce the likelihood of interruptions in the radio link as the UE **115**-*a* changes location (for example, as the UE **115**-*a* travels along the path **210**), the base station **105**-*a* may switch (for example, change) the beam used for downlink communications with the UE **115**-*a*. For example, the base station **105**-*a* may use different beams to transmit downlink communications to the UE **115**-*a* based on the location of the UE **115**-*a*. The base station **105**-*a* may use the beam **205**-*a* to transmit downlink communications to the UE **115**-*a* while the UE **115**-*a* is located in a first region and a beam **205**-*b* to transmit downlink communications to the UE **115**-*a* while the UE **115**-*a* is located in a second region (for example, an adjacent region).

[0076] In examples in which the UE **115**-*a* travels to a location in which multiple beams overlap (for example, a location **215**-*a* or a location **215**-*b*), the base station **105**-*a* may change a beam used to transmit downlink communications to the UE **115**-*a*. For example, the base station **105**-*a* may transmit downlink communications to the UE **115**-*a* via the beam **205**-*a* and the UE **115**-*a* may travel along the path **210** to the location **215**-*a*. In such an example, the base station **105**-*a* may change beams (for example, from the beam **205**-*a* to the beam **205**-*b*) and transmit downlink communications to the UE **115**-*a* via the beam **205**-*b*. In some examples, the beam **205**-*a*, the beam **205**-*b*, and a beam **205**-*c* may each be associated with a different beam index, also referred to as a beam indicator.

[0077] In some examples, the UE **115**-*a* may not be aware that a beam change (for example, by the base station **105**-*a*) may occur. As such, the UE **115**-*a* may perform beam change predictions, for example with increased beam measurement cycles, reduced measurements, or artificial intelligence (AI) methods to predict the beam change. For example, as discussed above, the UE **115**-*a* may perform beam management procedures to reduce the likelihood of link interruptions. In some examples, however, performing beam management procedures with reporting may unnecessarily consume overhead (for example, UE-specific overhead) and power at the UE **115**-*a*. For example, the UE **115**-*a* may perform beam management procedures with relatively frequent reporting (for example, at 20 ms or 40 ms time increments or durations). In some examples, the UE **115**-*a* may report beam measurements (for example, as part of a beam management procedure) via fields of an information element (IE). For example, the UE **115**-*a* may be configured (for example, via a CSI-ReportConfig IE) with a higher layer reporting parameter (for example, a reportQuantity IE) that may be used to report beam measurements. In some examples, the UE **115**-*a* may set the higher layer reporting parameter to different values, such as with a ssb-Index-RSRP field to indicate a reference signal received power (RSRP) measurement of an SSB and a cri-RSRP field to indicate an RSRP measurement of a CSI-RS. In some examples, the UE **115**-*a* may report (for example, in a channel state information (CSI) report) a resource indicator (RI), such as an SSB resource indicator (SSBRI) or a CSI-RS resource indicator (CRI), based on the value in which the higher layer reporting parameter is set to.

[0078] Additionally or alternatively, in stationary or low-speed scenarios where the UE **115**-*a* is moving relatively slowly (for example, with a low speed walk), the beam index associated with a beam with a highest beam quality, a highest signal strength, or an otherwise acceptable signal quality (for example, relative to other detectable beams) may not change over a duration (for example, hundreds of ms). A beam with a highest beam quality, a highest signal strength, or an otherwise acceptable signal quality relative to other detectable beams may be referred to as a top beam. Additionally or alternatively, an index associated with a top beam may be referred to as a top beam index. In some examples, in relatively low speed scenarios, base station beams may be relatively stationary (for example, beams may be 90% unchanged over 20 ms beam measurement cycles) and beam management procedures may not need to be used. As such, it may be beneficial to reduce overhead or power consumption (for example, at the UE **115**-*a*) by enabling the UE **115**-*a* to predict whether a beam change will occur.

[0079] In some examples, the UE **115**-*a* may predict whether the top beam may change (for example, may change from one beam to another beam, or additionally or alternatively may change dynamically at an increased rate) at a future time or over a future duration with increased beam measurement periodicity (for example, hundreds of ms rather than tens of ms) or with a reduced number of reference signal resources (for example, CSI-RS resources or SSB resources). For example, the UE **115**-*a* may use 4 measured beams to predict a top beam out of 32 potential (for example, detectable) beams. Further, in examples in which the top beam is predicted to change or the rate of dynamic beam changes shifts (for example, increases), the UE **115**-*a* may transmit requests to the base station **105**-*a* for decreased beam measurement periodicity or increased reference signal resources. In examples in which the UE **115**-*a* determines a stationary condition or a stationary state (for example, a state in which a beam change does not occur), beam management procedures (for example, beam management procedures with reporting via the ssb-Index-RSRP field or the cri-RSRP field) may be suspended.

[0080] In some examples, the UE **115**-*a* may perform beam change predictions via a machine learning model, such as an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, among other examples. For example, the UE **115**-*a* may estimate a probability that a beam change will occur based on a machine learning model that may be determined at the UE **115**-*a* or may be indicated to the UE **115**-*a* by the network. In some examples, the probability associated with the beam change may be reported by the UE **115**-*a*, independent of whether a machine learning model is configured for the UE **115**-*a* by the network. For example, the UE **115**-*a* may determine a machine learning model and use the determined machine learning model to predict whether a beam change will occur (for example, estimate a probability that a beam change will occur). In some examples, the UE **115**-*a* may be configured with one or more machine learning models that the UE **115**-*a* may train, for example using federated learning. In such examples, the UE **115**-*a* may determine (for example, select) a machine learning model (for example, the UE may determine an HMM) to use for estimating the probability associated with the beam change by or based on measurements performed at the UE **115**-*a*. Additionally or alternatively, the UE **115**-*a* may estimate the probability associated with the beam change (or predict whether a beam change will occur based on the estimated probability) independent of a machine learning model.

[0081] In some examples, the network may configure the UE **115**-*a* with a machine learning model to be used by the UE **115**-*a* for predicting whether a beam change will occur. For example, the network may train one or more machine learning models and configure (for example, transmit an indication for) the UE **115**-*a* to use one or more of the trained models for beam change predictions. In some examples, the network may train, such as through federated learning, a global HMM for beam change predictions or problems associated with beam changes. The global HMM, which may also be referred to as the HMM, may be a statistical model in which unobservable states of a system (for example, hidden states) may be predicted based on probabilities associated with the likelihood of a transition between states (for example, from one state to another), probabilities associated with the likelihood that an observation will occur given a state of the system (for example, a current hidden state) and observations (for example, measurements performed by the UE **115**-*a*). In some examples, a state of the system may refer to whether a beam change will occur. For example, a state in which a beam change will not occur may be referred to as a static state and a state in which a beam change will occur may be referred to as a dynamic state. In some examples, probabilities associated with the likelihood of a transition between states may be referred to as transition probabilities and probabilities associated with the likelihood that an observation will occur given a state may be referred to as emission probabilities.

[0082] The machine learning model (for example, the HMM) may be updated for a UE, such as UE **115**-*a*, depending on the trajectory of the UE **115**-*a* (for example, the path **210**) or locations of the UE **115**-*a* while served by a particular base station (for example, the base station **105**-*a*). In other words, different machine learning parameters or parameters included in a configuration of the machine learning model (for example, transition probabilities and emission probabilities that may be included in an HMM configuration) may be suitable for different trajectories of the UE **115**-*a* or different positions of the UE **115**-*a*. In some examples, configuration of (for example, preconfiguration) or dynamic updating of parameters associated with the machine learning model (for example, the HMM parameters or other parameters associated with other machine learning models) may be enabled to support beam change predictions at the UE **115**-*a*. For example, techniques that support signaling enhancement for beam change predictions via modeling, as described in the present disclosure, may enable beam change predictions at the UE **115**-*a* with reduced complexity and increased flexibility for model generalization.

[0083] In some examples, determinations of whether a beam change may occur (for example, a rigid decision) may be insufficient. For example, the UE **115**-*a* may incorrectly predict that a beam change will occur and alter the behavior of the UE **115**-*a* unnecessarily or the UE **115**-*a* may unnecessarily expend power determining that no beam change will occur. In some examples, unnecessary changes in the behavior of the UE **115**-*a* may result in increased power consumption and reduce link performance (for example, reduced throughput). Further, some methods for beam change predictions may be too rigid. For example, techniques which generate rigid decisions on the estimated hidden state (for example, whether the state is dynamic or static) may have a reduced flexibility relative to techniques which generate a soft decision (for example, a probability that a beam change will occur). As such, miss detection rates and false alarm rates for techniques which generate rigid decision based beam change predictions may be fixed, such that both power consumption and link performance may not be alterable. However, soft decision based beam change prediction via the machine learning model may enable an increased flexibility in the trade-off between power consumption for beam management and link performance.

[0084] FIG. **3** illustrates an example of an HMM **300** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The HMM **300** may implement aspects of the wireless communications system **100** and the wireless communications system **200**. For example, aspects of the HMM **300** may be implemented at, or implemented by, one or both of a base station **105** or a UE **115**, which may be examples of the corresponding devices described with reference to FIGS. **1** and **2**. The HMM **300** illustrates an example of a model (for example, an HMM of beam change prediction problems) which may be used by a communication device (for example, the base station **105** or the UE **115**) to predict beam changes. The HMM **300** may be an example of an HMM described in the present disclosure, including with reference to FIG. **2**.

[0085] The communication device may predict whether a beam change will occur via a machine learning model, such as via the HMM **300**. In the example of FIG. **3**, the HMM **300** illustrates components of an HMM which may include hidden states (for example, a hidden state **305**-*a*, a hidden state **305**-*b*, or a hidden state **305**-*c*) and transition probabilities (for example, a transition probability **315**-*a*, a transition probability **315**-*b*, and a transition probability **315**-*c*) that may control, or determine, the way a hidden state (X(t)) is chosen given a previous hidden state (X(t)−1). For example, the transition probability **315**-*a* may be associated with the likelihood that the hidden state **305**-*b* may be chosen given a previous hidden state of the hidden state **305**-*a*. The HMM **300** may include observations (Y(t)) and emission probabilities (for example, or output probabilities) that may determine, or govern, the distribution of the observed variable (Y(t)) given a state of the hidden variable (X(t)), for example at a particular time. In some examples, a number of emission probabilities (for example, an emission probability **320**-*a*, an emission probability **320**-*b*, an emission probability **320**-*c*, and an emission probability **320**-*d*) may be associated with an observation **310**-*a*, a number of emission probabilities (for example, an emission probability **321**-*a*, an emission probability **321**-*b*, an emission probability **321**-*c*, and an emission probability **321**-*d*) may be associated with an observation **310**-*b*, and a number of emission probabilities (for example, an emission probability **322**-*a*, an emission probability **322**-*b*, an emission probability **322**-*c*, and an emission probability **322**-*d*) may be associated with an observation **310**-*c*.

[0086] In some examples, to reduce overhead and power consumption, a communication device (for example, the UE **115**) may use the HMM **300** to predict whether a beam change will occur at a future time or over a future duration. For example, the HMM **300** may be used for beam change predictions by defining a hidden state (for example, a value of the hidden state variable (X(t)), for the case in which the beam change will not occur (for example, a static state) and a hidden state for the case in which the beam change will occur (for example, a dynamic state). For example, given an observation, which may be an input, of a number of measured reference signals, the state X(t)=1 may represent a case in which a top beam change will not occur over a duration (for example, t to t+N) and the state X(t)=2 may represent a case in which the top beam change will occur over the duration. In some examples, the top beam change may refer to a change in the beam index of a top beam. For example, a top beam may change from a first beam with a first beam index to a second beam with a second beam index. In some examples, the input for the HMM may include a beam quality measurement value, such as an RSRP value (for example, an L1-RSRP value) or a signal-to-interference-plus-noise ratio (SINR) value (for example, an L1-SINR value), for each of the measured reference signals.

[0087] In some examples, an observation (for example, an observation **310**-*a*, an observation **310**-*b*, an observation **310**-*c*, or an observation **310**-*d*) may be defined for a set of K beams used to transmit the measured reference signals (for example, K SSB beams) and observation (Y(t)) may be defined according to Equation (1):

$$Y(t)\{B_1(t), \ldots, B_K(t), RSRP(t), \ldots, RSRP(t)\}, \tag{1}$$

in which $B_k(t) \in \{1, 2, \ldots, K\}$ may represent an index associated with a kth top beam, for example the kth beam with a highest beam quality measurement value (for example, a strongest RSRP value or SINR value) compared to beam quality measurement values of a number (K) of other measured beams. Additionally or alternatively, transition probabilities may be defined according to Equation (2):

$$Pr(X(t) = i \mid X(t-1) = j), \tag{2}$$

in which $i,j \in \{1,2\}$ and emission probabilities may be defined according to Equation (3):

$$Pr(Y(t) = Y_C \mid X(t) = i) \tag{3}$$

in which $Y_c \in C$ and C may be a measurable set associated with the observations and $i \in \{1,2\}$.

[0088] In some examples, using estimated or base station signaled transition probabilities and emission probabilities, the UE **115** may obtain, or estimate, the hidden states X(t) based on observation Y(t). In other words, the UE **115** may estimate whether the top beam change will occur at the future time or over the future duration, based on transition probabilities, emission probabilities, and observations Y(t). In some examples, transition probabilities and emission probabilities may be estimated via samples of observations and related ground truth hidden state labels (for example, measurements) using an expectation-maximization (EM) algorithm, such as a Baum-Welch algorithm. In some examples, a hidden state estimation may be obtained via dynamic programming algorithms, such as a Viterbi algorithm.

[0089] In some examples, the number (M) of hidden states may be more than 2. In such examples, the number of transition probabilities may be determined according to Equation (4) and the number of emission probabilities may be determined according to Equation (5):

$$M \times M \tag{4}$$

$$M \times |Y_C| \tag{5}$$

[0090] The number of hidden states beyond 2 (for example, the additional M-2 hidden states), may include transitional states. In some examples, the transitional hidden states may include a transitional state which suggests a status (for example, associated with the top beam change) between a stationary state and a dynamic state. In some examples, the transitional states may include states (for example, different states) which indicate beams (for example, other top beams) in which the top beams may switch to. In some examples, the indicated beams may be associated with SSBRIs or CRIs of the top beams. In some examples, the UE **115** may report an estimated state (for example, an estimated (m) state of M hidden states) to the base station **105**. In such examples, decisions regarding the adjustment of beam management procedures at the base station **105** may be improved.

[0091] Although the example of FIG. **3** has been described in the context of an HMM, it is to be understood that the communication device may predict whether a beam change will occur via other machine learning models, such as via an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, among other examples.

[0092] FIG. **4** illustrates an example of a beam change prediction procedure **400** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The beam change prediction procedure **400** may implement aspects of the wireless communications system **100** and the wireless communications system **200**. For example, aspects of the beam change prediction procedure **400** may be implemented at, or implemented by, one or both of a base station **105** or a UE **115**, which may be examples of the corresponding devices described with reference to FIGS. **1** and **2**.

[0093] For example, a communication device (for examples, the base station **105** or the UE **115**) may implement the beam change prediction procedure **400** using a machine learning model for beam change predictions. The machine learning model may be an example of an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, among other examples. The HMM may be an example of the HMM **300** described with reference to FIG. **3**. In some examples (for example, if the machine learning model used by the UE is the HMM), the UE **115** may be configured, via the HMM configuration, with transition probabilities and emission probabilities associated with, or regarding, an HMM to predict a top beam change. The beam change predictions may be based on beam measurements (for example, RSRP measurements or SINR measurements) associated with a number of reference signal resources (for example, CSI-RS resources or SSB resources) measured in a beam measurement cycle (for example, a first beam measurement cycle).

[0094] For example, the UE **115** may use information (for example, the transition probabilities and the emission probabilities or other information that may be used at input for a machine learning model) to determine whether the top beam change will occur at a future time or over a future duration based on measurements preformed over the first beam measurement cycle and whether the top beam change occurred over a second duration. In some examples, the top beam change may be defined as whether a beam indicator (for example, a beam index) associated with a highest measured beam quality metric value (for example, a strongest measured beam quality metric value, a highest signal strength, or an otherwise acceptable signal quality) compared to other measured beams will change in a duration (for example, over the future duration) compared to the beam index associated with a highest beam quality metric value in a beam measurement cycle prior to the duration (for example, a current beam measurement cycle). A beam index may refer to an SSBRI or a CRI and a beam quality metric value may refer to an RSRP value or an SINR value. In other words, using the information, together with the observation including the top beam index (for example, $B_1(t)$=SSBRI) and the associated measured beam quality metric (for example, $RSRP_1(t)$), the UE **115** may estimate whether the top beam change will occur (for example, a state X(t)) over the future duration.

[0095] In some examples, at a beam measurement occasion (for example, a beam measurement occasion **415**-*c*) the UE **115** may determine whether the top beam change (for example, a change in the beam index associated with the top beam) will occur over the future duration (for example, the duration **405**-*b*) or at a future beam measurement occasions (for example, a beam measurement occasion **415**-*d*) based on the information, the beam measurement results (for example, a beam index of 1 as illustrated by a beam measurement result **410**-*i*), and (for example, optionally) one or more previous measurement results (for example, one or more of a beam measurement result **410**-*a*, a beam measurement result **410**-*b*, a beam measurement result **410**-*c*, a beam measurement result **410**-*d*, a beam measurement result **410**-*e*, a beam measurement result **410**-*f*, a beam measurement result **410**-*g*, or a beam measurement result **410**-*h*). The UE **115** may predict whether future beam measurement results (for example, a beam measurement result **410**-*j*, a beam measurement result **410**-*k*, a beam measurement result **410**-*l*, or a beam measurement result **410**-*m*) may be different relative to the measured (for example, current) beam measurement results (for example, the beam measurement result **410**-*i*).

[0096] In some examples, a duration associated with a beam measurement cycle may be variable (for example, 20 ms, 40 ms, 80 ms, or 160 ms). In other words, beam measurement occasions (for example, a beam measurement occasion **415**-*a*, a beam measurement occasion **415**-*b*, the beam measurement occasion **415**-*c*, a beam measurement occasion **415**-*d*, or a beam measurement occasion **415**-*e*) may occur at different periodicities. In some examples, beam measurements (for example, performed at the beam measurement occasion **415**-*e* with a periodicity of 20 ms) may be used to determine a ground truth for predicting whether a beam change may occur (for example, may be used as input for the machine learning model). Additionally or alternatively, a duration associated with a duration (for example, over which a beam change may or may not occur) may be variable (for example, 20 ms, 40 ms, 80 ms, or 160 ms).

[0097] In some examples, the duration associated with the beam measurement cycle may be equal to or different than the duration associated with the duration. For example, a duration associated with the first beam measurement cycle (for example, the beam measurement cycle **425**-*b*) may be equal to a duration associated with a second beam measurement cycle (for example, the beam measurement cycle **425**-*a*), a duration associated with another beam measurement cycle (for example, a beam measurement cycle **425**-*c*), and a duration associated with the second duration (for example, the duration **405**-*b*). In another example, the duration (for example, 80 ms) associated with the second beam measurement cycle (for example, the beam measurement cycle **425**-*b*) may be different than the duration (for example, 20 ms) associated with another beam measurement cycle (for example, a beam measurement cycle **425**-*d*). Additionally or alternatively, the duration (for example, 160 ms) associated with the second duration (for example, the duration **405**-*a*) may be different than a duration (for example, 80 ms) associated with a first duration (for example, the duration **405**-*b*).

[0098] The timing relationships among (for example, or between) the first beam measurement cycle, the second beam measurement cycle, the first duration, and the second duration may be predefined (for example, in an industry standard or other regulation), preconfigured (for example, in one or more of the communication devices such as the **115** or the base station **105**), configured (for example, via signaling from a base station **105**), dynamically indicated (for example, via signaling from the base station **105**), or based on an indication, such as a recommendation, transmitted by the UE **115** to the base station **105** and then the base station **105** may indicate or otherwise provide a configuration to the UE **115**. Additionally or alternatively, the timing relationships may include the durations, durations of the beam measurement cycles, time intervals between components (for example, two different components) of the beam measurement cycles or time intervals between components of the durations.

[0099] In some examples, the UE **115** may be configured to update (or alter) one or more aspects of the beam change prediction procedure **400**. For example, the UE **115** may be configured or indicated (for example, via application layer signaling, radio resource control (RRC) signaling, downlink control information (DCI) signaling, or medium access control control element (MAC-CE) signaling) to alter information used as input for a machine learning model (for example, one or multiple probabilities of the transition probabilities, one or multiple probabilities of the emission probabilities), the timing relationships among (for example, or between) the beam measurement cycles and the durations, the number of considered (for example, measured) reference signal beams (for example, SSB beams or CSI-RS beams), or the particular reference signal beams to be accounted for (for example, measured). Additionally or alternatively, the indication (for example, dynamic indication) or configurations (for example, or pre-configurations) may be based on a position or a trajectory of the UE **115**. In some examples, the position or the trajectory of the UE **115** may be based on position information or trajectory information reported by the UE **115**. In some examples, the position or the trajectory of the UE **115** may be based on determinations made by the base station **105**.

[0100] For scenarios in which the UE **115** may perform beam change predictions via an HMM, the emission probabilities and the transition probabilities may be examples of the respective probabilities described in the present disclosure, including with reference to FIG. **3**. In some examples, the transition probabilities and the emission probabilities may each be associated with the first beam measurement cycle (for example, a beam measurement cycle **425**-*b*), the future duration (for example, the first duration, a duration **405**-*b*) after or subsequent to the first beam measurement cycle, the second beam measurement cycle (for example, a beam measurement cycle **425**-*a*) preceding the first beam measurement cycle and the second duration (for example, a duration **405**-*a*) subsequent to, or overlapping with, the second beam measurement cycle. In some examples, the first duration may occur after, or subsequent to, the first beam measurement cycle.

[0101] For example, the transition probabilities may be defined according to one or multiple of Equations 6-9:

$$Pr(X(t)=1 \mid X(t-1)=1), \tag{6}$$

$$Pr(X(t)=2 \mid X(t-1)=1), \tag{7}$$

$$Pr(X(t)=1 \mid X(t-1)=2), \tag{8}$$

$$Pr(X(t)=2 \mid X(t-1)=2), \tag{9}$$

in which Equation 6 may represent a probability that a beam index associated with a highest measured beam quality metric value (for example, a strongest measured beam quality metric value, a highest signal strength, or an otherwise acceptable signal quality) compared to other measured beams in the first beam measurement cycle will not change, while the beam index associated with the highest measured beam quality metric value in the second duration did not change compared to the beam index associated with the highest measured beam quality metric value measured in the second beam measurement cycle.

[0102] Equation 7 may represent a probability that a beam index associated with a highest measured beam quality metric value (for example, a strongest RSRP value or SINR value compared to other measured RSRP values or other measured SINR values) in the first beam measurement cycle will change, while the beam index associated with the highest measured beam quality metric value in the second duration did not change compared to the beam index associated with the highest measured beam quality metric value measured in the second beam measurement cycle. Equation 8 may represent a probability that a beam index associated with a highest measured beam quality metric value in the first beam measurement cycle will not change, while the beam index associated with the highest measured beam quality metric value in the second duration did change compared to the beam index associated with the highest measured beam quality metric value measured in the second beam measurement cycle. Equation 9 may represent a probability that a beam index associated with a highest measured beam quality metric value in the first beam measurement cycle will change, while the beam index associated with the highest measured beam quality metric value in the second duration did change compared to the beam index associated with the highest measured beam quality metric value measured in the second beam measurement cycle.

[0103] Additionally or alternatively, the emission probabilities may be associated with the results (for example, the beam quality metric values) measured over the first beam measurement cycle. For examples, the results may be regarding (for example, correspond to) the beam indices associated with the highest measured beam quality metric values (for example, of a number of measured beams) and the respective beam quality metric values. For example, the emission probabilities may be defined according to one or both of Equations 10 and 11:

$$Pr(X(t)=1 \mid X(t-1)=2), \tag{10}$$

$$Pr(X(t)=2 \mid X(t-1)=2), \tag{11}$$

in which Equation 10 may represent a probability that the results measured over the first beam measurement cycle, given that the beam index associated with the highest measured beam quality metric values in the first duration will not change compared to the beam index associated with the highest measured beam quality metric values measured in the first beam measurement cycle. Equation 11 may represent a probability that the results measured over the first beam measurement cycle, given that the beam index associated with the highest measured beam quality metric values in the first duration will change compared to the beam index associated with the highest measured beam quality metric values measured in the first beam measurement cycle.

[0104] The UE **115** may report beam change predictions (or probabilities that a beam change will occur) to the network. For example, the UE **115** may report the probability that a beam change will occur based on one or more methods. In some examples, the UE **115** may report the probability that a beam change will occur within a same CSI report as may be used to indicate channel characteristics (for example, measured by the UE **115**) to the network. For example, the UE **115** may report the probability in a CSI report that may carry L1-RSRP or L1-SINR measurements (for example, performed on network configured reference signals). In such an example, a periodicity associated with reporting the probability may match the beam management periodicity (for example, a periodicity associated with a beam management procedure performed by the network).

[0105] Additionally, or alternatively, the UE **115** may report the probability via a separate CSI report. For example, the UE **115** and the network may implement multiple CSI report settings, such as separate CSI report settings for reporting measured channel characteristics and predicted channel characteristics, such as beam change predictions (for example, estimated probabilities that a beam change will occur). For example, the network may configure the UE **115** with the multiple CSI reporting settings and the UE **115** may transmit separate CSI reports for measured channel characteristics and beam change predictions to the network based on separate CSI report settings for measured and predicted channel characteristics. In some examples, by using the multiple CSI report settings, CSI reports for measured channel characteristics and CSI reports for predicted beam changes may each have relatively lower overhead and relatively smaller payloads, for example compared to a CSI report that may be used to report both predicted beam changes and measured channel characteristics. As an illustrative example, the UE **115** may transmit a first CSI report that indicates one or more measured channel characteristics (for example, of a channel used for the wireless communications between the UE **115** and the network) and a second CSI report that indicates a probability that a beam change will occur.

[0106] In some examples, the UE **115** may determine whether requests to refine channel state reporting parameters (for example, parameters configured via a CSI-ReportConfig **1**E) may be sent based on the beam change prediction. For example, the UE **115** may request to increase or decrease the report periodicity (for example, associated with the CSI-ReportConfig **1**E) or trigger one or multiple additional reports (for example, dynamic, persistent, or semi-persistent CSI reports). In some examples, the UE **115** may request to increase or decrease the number of reference signal resources (for example, CSI-RS resources or SSB resources) associated with the report configuration, such as indicate via the CSI-ReportConfig **1**E. In some examples, the UE **115** may report a predicted beam change incident or suggest (for example, indicate) that the rate at which a top beam index is predicted to change may increase (for example, more dynamically compared to the previously reported top beam indices).

[0107] FIGS. **5**A and **5**B illustrate examples of beam change prediction procedures **500** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The beam change prediction procedures **500** (for example, a beam change prediction procedure **500**-*a*, a beam change prediction procedure **500**-*b*, a beam change prediction procedure **500**-*c*, and a beam change prediction procedure **500**-*d*) may implement aspects of the wireless communications system **100** and the wireless communications system **200**. For example, aspects of the beam change prediction procedures **500** may be implemented at, or implemented by, one or both of a base station **105** or a UE **115**, which may be examples of the corresponding devices described with reference to FIGS. **1** and **2**.

[0108] In some examples, techniques which generate a rigid decision based beam change prediction (for example, whether a beam change will occur) may have a reduced flexibility relative to techniques which generate a soft decision (for example, a posteriori probability that a beam change will occur). That is, soft decision based beam change predictions via a machine learning model (for example, an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, a DNN) may enable an increased flexibility in the trade-off between power consumption for beam management and link performance. For example, a communication device (for example, the UE **115**) may be configured to predict, via the machine learning model (for example, based on machine learning model configuration, such as an HMM configuration), a probability (for example, the posteriori probability) that a beam index associated with a highest measured beam quality metric value (for example, a strongest measured beam quality metric value, a highest signal strength, or an otherwise acceptable signal quality) compared to other measured beams will change in a duration compared to the measured beam index associated with the highest measured beam quality metric value measured in a beam measurement cycle which occurs prior to the duration.

[0109] In some examples, the beam index may refer to a SSBRI or a CRI and a highest measured beam quality metric value may refer to a strongest RSRP value or a strongest SINR value compared to other measured RSRP values or other measured SINR values. For example, beams associated with the highest measured beam quality metric value, or values, may be referred to as top beams which may be examples of the top beams described in the present disclosure including with reference to FIGS. **3** and **4**. That is, the UE **115** may predict the probability that a top beam change may occur at a future time or over a future duration based on the machine learning model (for example, the machine learning model configuration) and measurements performed over a beam measurement cycle. In some examples, the machine learning model may be an HMM. In such examples, the UE **115** may predict the probability that a top beam change may occur based on an HMM configuration that may include transmission probabilities and emission probabilities. The transmission probabilities and the emission probabilities may be examples of the respective probabilities described in the present disclosure, including with reference to FIG. **3**.

[0110] In some examples, determining whether the top beam change will occur may be based on a capability of the UE **115** to estimate the probability of the predicted top beam changes. In some examples, the UE **115** may report the capability to base station **105**. For example, the UE **115** may indicate to the base station **105**, whether the UE **115** may determine (for example, calculate) the probability that the top beam change will occur at the future time or in the future duration.

[0111] In some examples, the UE **115**-*a* may predict the probability that the top beam change may occur for multiple beams. As illustrated in the example of FIG. **5**A, the UE **115**-*a* may predict (for example, at a beam measurement occasion **515**-*b*) the probability that the top beam change for a first beam (for example, illustrated by the beam change prediction procedure **500**-*a*) and a second beam (for example, illustrated by the beam change prediction procedure **500**-*b*) will occur over the future duration (for example, associated with a beam measurement cycle **525**-*b*) or at future beam measurement occasions (for example, a beam measurement occasion **515**-*c*) based on the machine learning model and the beam measurement results measured at the beam measurement occasion **515**-*b* (for example, current beam measurement results). In some examples, the predicted probability may depend on one or more beam measurement results measured over a beam measurement cycle **525**-*a* or at a beam measurement occasion **515**-*a* (for example, one or more previous beam measurement results). For example, the predicted probability of the top beam change associated with the first beam may depend on a beam measurement result **510**-*a*, a beam measurement result **510**-*b*, a beam measurement result **510**-*c*, and a beam measurement result **510**-*d*. Additionally or alternatively, the predicted probability of the top beam change associated with the second beam may depend on one or more of a beam measurement result **511**-*a*, a beam measurement result **511**-*b*, a beam measurement result **511**-*c*, or a beam measurement result **511**-*d*.

[0112] For example, the UE **115** may predict, for the first beam, a probability that future beam measurement results (for example, a beam measurement result **510**-*f*, a beam measurement result **510**-*g*, a beam measurement result **510**-*h*, or a beam measurement result **510**-*i*) will be different relative to the measured (for example, current) beam measurement results (for example, the beam measurement result **510**-*e*). Additionally or alternatively, the UE **115** may predict, for the second beam, a probability that future beam measurement results (for example, a beam measurement result **511**-*f*, a beam measurement result **511**-*g*, a beam measurement result **511**-*h*, or a beam measurement result **511**-*i*) will be different relative to the beam measurement result **511**-*e*.

[0113] In some examples, the UE **115**-*a* may determine, based on the predicted probabilities, that a future top beam index associated with the first beam (for example, the value associated with the beam measurement result **510**-*i*) may be equal to a measured top beam index associated with the second beam (for example, the value associated with the beam measurement result **511**-*e*). Additionally or alternatively, the UE **115** may determine that a future top beam index associated with the second beam (for example, the value associated with the beam measurement result **511**-*i*) may be equal to a measured top beam index associated with the first beam (for example, the value associated with the beam measurement result **510**-*e*). In other words, the UE **115** may predict the top beam change in which the respective top beam index associated with two top beams (for example two beam with similar RSRP levels) will switch values.

[0114] As illustrated in the example of FIG. **5**B, the UE **115**-*a* may predict (for example, at a beam measurement occasion **515**-*e*) the probability that the top beam change for the first beam (for example, illustrated by the beam change prediction procedure **500**-*c*) and the second beam (for example, illustrated by the beam change prediction procedure **500**-*d*) will occur over the future duration (for example, associated with a beam measurement cycle **525**-*d*) or at future beam measurement occasions (for example, a beam measurement occasion **515**-*f*) based on the machine learning model and the beam measurement results measured at a beam measurement occasion **515**-*e* (for example, current beam measurement results). In some examples, the predicted probability may depend on one or more beam measurement results measured over a beam measurement cycle **525**-*c* or at a beam measurement occasion **515**-*d* (for example, previous beam measurement results). For example, the predicted probability of the top beam change associated with the first beam may depend on one or more of a beam measurement result **512**-*a*, a beam measurement result **512**-*b*, a beam measurement result **512**-*c*, or a beam measurement result **512**-*d*. Additionally or alternatively, the predicted probability of the top beam change associated with the second beam may depend on one or more of a beam measurement result **513**-*a*, a beam measurement result **513**-*b*, a beam measurement result **513**-*c*, or a beam measurement result **513**-*d*.

[0115] For example, the UE **115** may predict, for the first beam, a probability that future beam measurement results (for example, a beam measurement result **512**-*f*, a beam measurement result **512**-*g*, a beam measurement result **512**-*h*, or a beam measurement result **512**-*i*) will be different relative to the beam measurement result **512**-*e*. Additionally or alternatively, the UE **115** may predict, for the second beam, a probability that future beam measurement results (for example, a beam measurement result **513**-*f*, a beam measurement result **513**-*g*, a beam measurement result **513**-*h*, or a beam measurement result **513**-*i*) will be different relative to the beam measurement result **513**-*e*.

[0116] In some examples, the UE **115**-*a* may determine, based on the predicted probabilities, that a future top beam index associated with the first beam (for example, the value associated with the beam measurement result **511**-*i*) may be different than the measured top beam index associated with the second beam (for example, the value associated with the beam measurement result **513**-*e*). Additionally or alternatively, the UE **115** may determine that a future top beam index associated with the second beam (for example, the value associated with the beam measurement result **513**-*i*) may be different than the measured top beam index associated with the first beam (for example, the value associated with the beam measurement result **512**-*e*). In other words, the UE **115** may predict a top beam change in which the respective top beam index associated with two top beams will not switch. In some examples, a probability associated with the top beam change in which the respective top beam index associated with two top beams switch values may be smaller than a probability associated with a top beam change in which the respective top beam index associated with two top beams do not switch values.

[0117] In some examples, the UE **115** may compare the determined probability (for example, the soft decision) to a threshold to determine whether the top beam change will occur (for example, the rigid decision). That is, the UE **115** may use a threshold for determining a state, such as a static state or a dynamic state. The threshold may, in some examples, be configured for the UE by the network. For example, the network may configure the UE **115** with one or more thresholds may be associated with one or more machine learning models (for example, each threshold may be associated with a respective machine learning model or a threshold may be associated with multiple machine learning models).

[0118] In examples in which the determined probability satisfies the threshold, the UE **115** may determine that the top beam will change at the future time (for example, the state is dynamic). In some examples, the UE **115** may be configured (for example, pre-configured) or dynamically updated with the threshold to determine whether the top beam will change. In some examples, the UE **115** may recommend (for example indicated) the threshold to the base station **105** prior to being configured or updated with the threshold (for example, or prior to receiving an indication of a machine learning model, or a configuration for a machine learning model, such as an HMM configuration). The threshold may be a value between 0 and 1.

[0119] In some examples, the UE **115** may use the threshold to increase the flexibility of the trade-off between power consumption and throughput performance (for example, link performance). For example, the UE **115** may be configured (for example, pre-configured) with multiple (for example, different) thresholds. In such an example, the UE **115** may select a threshold based on a desired performance. In examples in which the UE **115** increases the value of the threshold, the likelihood that the UE **115** will predict a top beam change may decrease and the frequency in which the UE **115** performs beam measurements may also decrease. As a result, the power consumed by the UE **115** (for example, to perform beam measurements) may be reduced. However, in examples in which the UE **115** decreases the value of the threshold, the likelihood that the UE **115** will predict a top beam changes may increase and the frequency in which the UE **115** performs beam measurements may also increase. As a result, the link performance at the UE **115** may increase. As such, the UE **115** may increase the flexibility of the trade-off between power consumption and link performance by changing the value of the threshold.

[0120] In some examples, the UE may be configured with multiple thresholds associated with different hidden states (for example, different hidden states in which the UE **115** may predict a probability). For example, the UE may be configured with a first threshold associated with a first respective state, such as the stationary state (for example, or a static state), a second threshold associated with a second respective state, such as the dynamic state, and a third threshold associated with a third respective state, such as a transitional state. In such an example, the UE **115** may determine a state with a probability (for example, a maximum probability or a highest probability compared to other configured probabilities) and whether the determined state may be determined by comparing the estimated probability to the respective threshold. For example, the UE **115** may determine whether the dynamic state may be determined by comparing the estimated probability to the first threshold. In other words, for examples in which the estimated probability (for example, the output from the machine learning model) satisfies the first threshold, the UE **115** may determine whether a beam change will occur (for example, the dynamic state). In examples in which the estimated probability does not satisfy the first threshold, the UE **115** may proceed to (for example, determine) a next state (for example, until the UE **115** determines a state with a lowest probability compared to the other configured probabilities).

[0121] In some examples, the UE **115** may report a soft decision (for example, the estimated probability that the top beam change will occur) or a rigid decision (for example, whether the top beam change will occur) to the base station **105**. For example, the UE **115** may report the soft decision or the rigid decision (for example, based on the soft decision or otherwise) in a CSI report (for example, via the ssb-Index-RSRP field, the ssb-Index-SINR field, the cri-RSRP field, or the cri-SINR field of the reportQuantity IE). In some examples, the number of measured reference signals (for example, SSBs) to be reported to the base station **105** may be indicated to the UE **115** (for example, via an RRC message through the nrofReportedRS field). That is, for examples in which the nrofReportedRS field is set equal to a number (R), the UE **115** may report a measurement (for example, through the ssb-Index-RSRP field via the reportQuantity IE) for R measured reference signals. Additionally or alternatively, the UE **115** may report the threshold used to determine whether the top beam change will occur (for example, whether the state is dynamic or static). For example, the UE **115** may report the threshold prior to, at the time of, or after determining the top beam change. In some examples, the UE **115** may report the threshold via the RRC message (for example through the reportQuantity IE).

[0122] In some examples, the UE **115** may report the probability based on multiple hidden states (for example, the UE **115** may report probabilities associated with one or multiple of the dynamic state, the static state, or other transitional states). In such examples, the UE **115** may report an identifier associated with the state (for example, a state ID) and the respective probability of the state (for example, a maximum probability or a highest probability compared to other configured probabilities).

[0123] FIGS. **6**A and **6**B illustrate examples of result sequences **600** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The result sequences **600** (for example, a result sequence **600**-*a* and a result sequence **600**-*b*) may implement aspects of the wireless communications system **100** and the wireless communications system

200. For example, aspects of the result sequences 600 may be implemented at, or implemented by, one or both of a base station 105 or a UE 115, which may be examples of the corresponding devices described with reference to FIGS. 1 and 2.

[0124] In some examples, a communication device (for example, the UE 115) may use a machine learning model, such as an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, among other examples, to predict whether a top beam change will occur (for example, a rigid decision) or a probability that the top beam change will occur (for example, a soft decision) based on the machine learning model (for example, a configuration of the machine learning model, such as an HMM configuration) and results measured over a first beam measurement cycle. The first beam measurement cycle may be an example of a first beam measurement cycle described in the present disclosure including with reference to FIGS. 3, 4, 5A, and 5B. For example, the results measured over the first beam measurement cycle may include a number of beam indicators (for example, beam indices), each corresponding to a top beam. The beam indices may include SSBRIs or CRIs. For examples in which the machine learning model is an HMM, the HMM configuration may be an example of an HMM configuration described in the present disclosure including with reference to FIG. 3.

[0125] Additionally or alternatively, the results measured over the first beam measurement cycle may include a beam quality metric value (for example, the measured RSRP value or the measured SINR value for each top beam) corresponding to each beam index. In some examples, the corresponding beam quality metric value may be rounded to an integer value (for example, a 5th dBm or a 10th dBm). In other words, the results measured over the first beam measurement cycle may include the beam index associated with each top beam and the corresponding beam quality metric value. For example, as illustrated in the example of FIG. 6A, the results (for example, or results sequence) may include measured beam quality metric values 605 (for example, a measured beam quality metric value 605-*a* and a measured beam quality metric value 605-*b*) and beam indices 610 (for example, a beam index 610-*a* and a beam index 610-*b*) for each top beam of a number (K) of top beams. In some examples, each results sequence may be identified by combinatorial indices 615 (for example, a combinatorial 615-*a* through a combinatorial 615-*k*).

[0126] In examples, the results may include an indication of whether the beam index associated with each top beam changed or remained the same over the first beam measurement cycle compared to the beam index associated with the top beams over the second beam measurement cycle. In examples in which the beam index associated with one or multiple of the top beams changed, the results may indicate how many beam indices (for example, SSB beam indices or CSI-RS beam indices) each top beam changed by. That is, the results may indicate a difference in the top beam index of the top beams in which the beam changed from the second beam measurement cycle and the first beam measurement cycle. In some examples, the input (for example, for the machine learning model) may be labelled to indicate the difference (for example, a first top beam changed with an SSB beam index of +4). Additionally or alternatively, the results may indicate whether the corresponding beam quality metric values increase, decreased, or remained the same over the first beam measurement cycle compared to the beam quality metric values measured over the second beam measurement cycle. In some examples, the indication of whether the measured beam quality metric value changed (for example, the increased indication, the decrease indication, or the remained indication) may be based on a comparison of the filtered (for example, averaged) beam quality metric value measured over multiple (for example, instantaneous) beam measurement cycles.

[0127] In some examples, as illustrated in the example of FIG. 6B, each results sequence (for example, identified by a combinatorial index 616-*a* through a combinatorial index 616-*k*) may include an indication of whether the measured beam quality metric value changed (for example, a beam quality metric indication 606-*a* or a beam quality metric indication 606-*b*). Additionally or alternatively, each results sequence may include an indication of whether the beam index associated with each top beam changed (for example, a beam change indication 611-*a* or a beam change indication 611-*b*) for each top beam of the number (K) of top beams.

[0128] FIG. 7 illustrates an example of a process flow 700 that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The process flow 700 may implement aspects of the wireless communications system 100 and the wireless communications system 200. For example, the process flow 700 may be implemented by a base station 105-*b* or a UE 115-*b*, which may be examples of the corresponding devices described with reference to FIGS. 1 and 2. In some examples, the base station 105-*b* and the UE 115-*b* may implement the process flow 700 to promote network efficiencies by supporting beam change predictions via an HMM, as described in the present disclosure. The process flow 700 may also be implemented by the base station 105-*b* and the UE 115-*b* to promote high reliability and low latency operations, among other benefits. In the following description of the process flow 700, the operations between the UE 115-*b* and the base station 105-*b* may be transmitted in a different order than the example order shown, or the operations performed by the UE 115-*b* and the base station 105-*b* may be performed in different orders or at different times. Some operations may also be omitted.

[0129] A communication device (for example, the UE 115-*b*) may use a machine learning model, such as an HMM, an LSTM neural network, a GRU neural network, a CNN, an RNN, or a DNN, to predict whether a top beam change will occur (for example, a rigid decision) or a probability that a top bam change will occur (for example, a soft decision). In some examples, the UE 115-*b* may use the HMM. In such examples, the top beam change prediction (or the probability of a top beam change occurring) may be based on an HMM configuration and results measured over a beam measurement cycle. For example, at 705 the UE 115-*b* may receive an indication of an HMM configuration from a network node (for example, the base station 105-*b*). In some examples, the HMM configuration may be an HMM configuration described in the present disclosure, including with reference to FIG. 3. For example, the HMM configuration may include a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams. Each transition probability of the set may correspond to a transition of a beam (for example, of the set of beams) from a first status to a second status and each emission probability of the set may correspond to an observed status of a beam (for example, of the set of beams). The transmission probabilities and the emission probabilities may be examples of the respective probabilities described with reference to FIG. **3**.

[0130] In some examples, at **710**, the UE **115**-*b* may receive a threshold configuration. The threshold configuration may indicate one or multiple thresholds, which may each be an example of a threshold described in the present disclosure, including with reference to FIGS. **5**A and **5**B. At **715**, the UE **115**-*b* may receive a reference signal (for example an SSB or a CSI-RS) associated with a beam of the set of beams. In some examples, the UE **115**-*b* may perform one or more measurements on the reference signal received at **715**. For example, at **720**, the UE **115**-*b* may perform a measurement (for example, an RSRP measurement or an SINR measurement) on the beam over a beam measurement cycle. The beam measurement cycle may be an example of a first beam measurement cycle described in the present disclosure including with reference to FIGS. **3**, **4**, **5**A, and **5**B. The UE **115**-*b* may perform the beam measurement based on the indication of the HMM configuration.

[0131] At **725**, the UE **115**-*b* may determine a probability associated with the adjustment of the beam (for example, whether the top beam change will occur). That is, the UE **115**-*b* may determine a probability associated with an adjustment of the beam. For example, the probability may indicate whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal (for example, received by the UE **115**-*b* at **715**). In some examples, the probability may be determined by the UE **115**-*b* based on the machine learning model and performing one or more measurements on the beam. For example, if the UE **115**-*b* uses the HMM, the probability may be based on the HMM configuration and performing the measurement on the beam at **720**. In some examples, the UE **115**-*b* may determine whether the probability satisfies a threshold of the one or multiple thresholds indicated by the threshold configuration received from the base station **105**-*b* at **710**. In some examples, at **730**, the UE **115**-*b* may transmit an indication of the threshold (for example, a threshold indication) to the base station **105**-*b*.

[0132] At **735**, the UE **115**-*b* may transmit an indication of the probability associated with the adjustment of the beam to the base station **105**-*b* (for example, a network node). In some examples, transmitting the indication of the probability may include transmitting a status indication associated with whether an adjustment of the beam to the base station **105**-*b*. The status indication may be based on the HMM configuration and performing the measurement on the beam at **720**. In some examples, the UE **115**-*b* may transmit the status indication based on the probability satisfying the threshold. In some examples, at **740**, the UE **115**-*b* may transmit a report to the base station **105**-*b*. The report may include the status indication and an indication of the threshold.

[0133] FIG. **8** shows a block diagram **800** of a device **805** that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure. The device **805** may be an example of aspects of a UE **115** as described in the present disclosure. The device **805** may include a receiver **810**, a transmitter **815**, and a communications manager **820**. The device **805** may also include a processor. Each of these components may be in communication with one another (for example, via one or more buses).

[0134] The receiver **810** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). Information may be passed on to other components of the device **805**. The receiver **810** may utilize a single antenna or a set of multiple antennas.

[0135] The transmitter **815** may provide a means for transmitting signals generated by other components of the device **805**. For example, the transmitter **815** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). In some examples, the transmitter **815** may be co-located with a receiver **810** in a transceiver module. The transmitter **815** may utilize a single antenna or a set of multiple antennas.

[0136] The communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

[0137] In some examples, the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may be implemented in hardware (for example, in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), a central processing unit (CPU), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a microcontroller, discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some examples, a processor and memory coupled with the processor may be configured to perform one or more of the functions described herein (for example, by executing, by the processor, instructions stored in the memory).

[0138] Additionally, or alternatively, in some examples, the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may be implemented in code (for example, as communications management software or firmware) executed by a processor. If implemented in code executed by a processor, the functions of the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may be performed by a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, a microcontroller, or any combination of these or other programmable logic devices (for example, configured as or otherwise supporting a means for performing the functions described in the present disclosure).

[0139] In some examples, the communications manager **820** may be configured to perform various operations (for example, receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **810**, the transmitter **815**, or both. For example, the communications manager **820** may receive information from the receiver **810**, send information to the transmitter **815**, or be integrated in combination with the receiver **810**, the transmitter **815**, or both to obtain information, output information, or perform various other operations as described in the present disclosure.

[0140] The communications manager **820** may support wireless communication at a UE (for example, the device **805**) in accordance with examples as disclosed herein. For example, the communications manager **820** may be configured as or otherwise support a means for receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index. The communications manager **820** may be configured as or otherwise support a means for determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The communications manager **820** may be configured as or otherwise support a means for transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0141] By including or configuring the communications manager **820** in accordance with examples as described in the present disclosure, the device **805** (for example, a processor controlling or otherwise coupled with the receiver **810**, the transmitter **815**, the communications manager **820**, or a combination thereof) may support techniques for beam change predictions. For example, the device **805** may predict beam changes via a machine learning model at a UE **115**, which may result in reduced power consumption and more efficient utilization of communication resources.

[0142] FIG. **9** shows a block diagram **900** of a device **905** that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure. The device **905** may be an example of aspects of a device **805** or a UE **115** as described in the present disclosure. The device **905** may include a receiver **910**, a transmitter **915**, and a communications manager **920**. The device **905** may also include a processor. Each of these components may be in communication with one another (for example, via one or more buses).

[0143] The receiver **910** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). Information may be passed on to other components of the device **905**. The receiver **910** may utilize a single antenna or a set of multiple antennas.

[0144] The transmitter **915** may provide a means for transmitting signals generated by other components of the device **905**. For example, the transmitter **915** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). In some examples, the transmitter **915** may be co-located with a receiver **910** in a transceiver module. The transmitter **915** may utilize a single antenna or a set of multiple antennas.

[0145] The device **905**, or various components thereof, may be an example of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **920** may include a reference signal component **925**, a probability component **930**, an indication component **935**, or any combination thereof. The communications manager **920** may be an example of aspects of a communications manager **820** as described in the present disclosure. In some examples, the communications manager **920**, or various components thereof, may be configured to perform various operations (for example, receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **910**, the transmitter **915**, or both. For example, the communications manager **920** may receive information from the receiver **910**, send information to the transmitter **915**, or be integrated in combination with the receiver **910**, the transmitter **915**, or both to obtain information, output information, or perform various other operations as described in the present disclosure.

[0146] The communications manager **920** may support wireless communication at a UE (for example, the device **905**) in accordance with examples as disclosed herein. The reference signal component **925** may be configured as or otherwise support a means for receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index. The probability component **930** may be configured as or otherwise support a means for determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The indication component **935** may be configured as or otherwise support a means for transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0147] FIG. **10** shows a block diagram **1000** of a communications manager **1020** that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure. The communications manager **1020** may be an example of aspects of a communications manager **820**, a communications manager **920**, or both, as described in the present disclosure. The communications manager **1020**, or various components thereof, may be an example of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **1020** may include a reference signal component **1025**, a probability component **1030**, an indication component **1035**, a measurement component **1040**, a beam metric component **1045**, a threshold component **1050**, a CSI component **1055**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (for example, via one or more buses).

[0148] The communications manager **1020** may support wireless communication at a UE in accordance with examples as disclosed herein. The reference signal component **1025** may be configured as or otherwise support a means for receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index. The probability component **1030** may be configured as or otherwise support a means for determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The indication component **1035** may be configured as or otherwise support a means for transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0149] In some examples, to support transmitting an indication of the probability, the indication component **1035** may be configured as or otherwise support a means for transmitting, to the network node, a status indication associated with whether the adjustment of the beam will occur, where transmitting the status indication is based on the probability. In some examples, the threshold component **1050** may be configured as or otherwise support a means for receiving, from the network node, an indication of a threshold. In some examples, the probability component **1030** may be configured as or otherwise support a means for determining whether the probability satisfies the threshold, where transmitting the status indication is based on the probability satisfying the threshold.

[0150] In some examples, the threshold component **1050** may be configured as or otherwise support a means for transmitting, to the network node, an indication of a threshold. In some examples, the probability component **1030** may be configured as or otherwise support a means for determining whether the probability satisfies the threshold, where transmitting the status indication is based on the probability satisfying the threshold. In some examples, the probability component **1030** may be configured as or otherwise support a means for determining whether the probability satisfies a threshold, where transmitting the status indication includes. In some examples, the indication component **1035** may be configured as or otherwise support a means for transmitting, to the network node, a report including the status indication and an indication of the threshold.

[0151] In some examples, the threshold component **1050** may be configured as or otherwise support a means for receiving, from the network node, an indication of a set of thresholds. In some examples, the threshold component **1050** may be configured as or otherwise support a means for selecting a threshold of the set of thresholds based on a performance metric associated with performing a measurement on the beam. In some examples, the probability component **1030** may be configured as or otherwise support a means for determining whether the probability satisfies the threshold, where transmitting the status indication is based on the probability satisfying the threshold.

[0152] In some examples, determining the probability is based on a machine learning model. In some examples, the machine learning model includes one or more of a long short-term memory neural network, a gated recurrent unit neural network, a convolution neural network, a recurrent neural network, or a deep neural network.

[0153] In some examples, the probability component **1030** may be configured as or otherwise support a means for determining the probability is based on receiving the indication. In some examples, the probability component **1030** may be configured as or otherwise support a means for determining the probability is based on determining the machine learning model. In some examples, the machine learning model includes a hidden Markov Model.

[0154] In some examples, the probability component **1030** may be configured as or otherwise support a means for determining the probability is based on receiving the indication of the hidden Markov model configuration. In some examples, transmitting the indication of the probability includes transmitting, to the network node, a report including the indication of the probability.

[0155] In some examples, to support transmitting the report including the indication of the probability, the CSI component **1055** may be configured as or otherwise support a means for transmit a first channel state information report that indicates one or more measured channel characteristics of a channel used for the wireless communications between the UE and the network node. In some examples, to support transmitting the report including the indication of the probability, the CSI component **1055** may be configured as or otherwise support a means for transmit a second channel state information report that indicates the probability.

[0156] In some examples, the measurement component **1040** may be configured as or otherwise support a means for performing a measurement on the beam over a beam measurement cycle. In some examples, the beam metric component **1045** may be configured as or otherwise support a means for determining a beam metric value based on performing the measurement on the beam, where the probability is based on the beam metric value and a beam index associated with the beam. In some examples, the beam index associated with the beam includes the first beam index or the second beam index.

[0157] In some examples, the indication component **1035** may be configured as or otherwise support a means for transmitting the indication of the probability is based on determining one or both of whether the beam metric value changed relative to the second beam metric value associated with the second beam measurement cycle or whether the beam index changed relative to the second beam index associated with the second beam measurement cycle. In some examples, the indication is received via an RRC message, a downlink control information, or a MAC-CE. In some examples, the indication is based on one or both of a position of the UE or a trajectory of the UE.

[0158] FIG. **11** shows a diagram of a system **1100** including a device **1105** that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure. The device **1105** may be an example of or include the components of a device **805**, a device **905**, or a UE **115** as described in the present disclosure. The device **1105** may communicate (for example, wirelessly) with one or more base stations **105**, one or more UEs **115**, or any combination thereof. The device **1105** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **1120**, an input/output (I/O) controller **1110**, a transceiver **1115**, an antenna **1125**, a memory **1130**, code **1135**, and a processor **1140**. These components may be in electronic communication or otherwise coupled (for example, operatively, communicatively, functionally, electronically, electrically) via one or more buses (for example, a bus **1145**).

[0159] The I/O controller **1110** may manage input and output signals for the device **1105**. The I/O controller **1110** may also manage peripherals not integrated into the device **1105**. In some cases, the I/O controller **1110** may represent a physical connection or port to an external peripheral. In some cases, the I/O controller **1110** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. Additionally or alternatively, the I/O controller **1110** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **1110** may be implemented as part of a processor, such as the processor **1140**. In some cases, a user may interact with the device **1105** via the I/O controller **1110** or via hardware components controlled by the I/O controller **1110**.

[0160] In some cases, the device **1105** may include a single antenna **1125**. However, in some other cases, the device **1105** may have more than one antenna **1125**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **1115** may communicate bi-directionally, via the one or more antennas **1125**, wired, or wireless links as described in the present disclosure. For example, the transceiver **1115** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1115** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **1125** for transmission, and to demodulate packets received from the one or more antennas **1125**. The transceiver **1115**, or the transceiver **1115** and one or more antennas **1125**, may be an example of a transmitter **815**, a transmitter **915**, a receiver **810**, a receiver **910**, or any combination thereof or component thereof, as described in the present disclosure.

[0161] The memory **1130** may include random access memory (RAM) and read-only memory (ROM). The memory **1130** may store computer-readable, computer-executable code **1135** including instructions that, when executed by the processor **1140**, cause the device **1105** to perform various functions described herein. The code **1135** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **1135** may not be directly executable by the processor **1140** but may cause a computer (for example, when compiled and executed) to perform functions described herein. In some cases, the memory **1130** may contain, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0162] The processor **1140** may include an intelligent hardware device (for example, a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **1140** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **1140**. The processor **1140** may be configured to execute computer-readable instructions stored in a memory (for example, the memory **1130**) to cause the device **1105** to perform various functions (for example, functions or tasks supporting signaling enhancement for beam change predictions via modeling). For example, the device **1105** or a component of the device **1105** may include a processor **1140** and memory **1130** coupled to the processor **1140**, the processor **1140** and memory **1130** configured to perform various functions described herein.

[0163] The communications manager **1120** may support wireless communication at a UE (for example, the device **1105**) in accordance with examples as disclosed herein. For example, the communications manager **1120** may be configured as or otherwise support a means for receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index. The communications manager **1120** may be configured as or otherwise support a means for determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The communications manager **1120** may be configured as or otherwise support a means for transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0164] By including or configuring the communications manager **1120** in accordance with examples as described in the present disclosure, the device **1105** may support techniques for beam change predictions. For example, the device **1105** may predict beam changes via a machine learning model at a UE **115**, which may result in communication reliability, reduced power consumption, more efficient utilization of communication resources, and longer battery life.

[0165] In some examples, the communications manager **1120** may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the transceiver **1115**, the one or more antennas **1125**, or any combination thereof. Although the communications manager **1120** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **1120** may be supported by or performed by the processor **1140**, the memory **1130**, the code **1135**, or any combination thereof. For example, the code **1135** may include instructions executable by the processor **1140** to cause the device **1105** to perform various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure, or the processor **1140** and the memory **1130** may be otherwise configured to perform or support such operations.

[0166] FIG. **12** shows a flowchart illustrating a method **1200** that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure. The operations of the method **1200** may be implemented by a UE or its components as described in the present disclosure. For example, the operations of the method **1200** may be performed by a UE **115** as described with reference to FIGS. **1** through **11**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally, or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0167] At **1205**, the method may include receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index. The operations of **1205** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1205** may be performed by a reference signal component **1025** as described with reference to FIG. **10**.

[0168] At **1210**, the method may include determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The operations of **1210** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1210** may be performed by a probability component **1030** as described with reference to FIG. **10**.

[0169] At **1215**, the method may include transmitting, to the network node, an indication of the probability associated with the adjustment of the beam. The operations of **1215** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1215** may be performed by an indication component **1035** as described with reference to FIG. **10**.

[0170] FIG. **13** shows a flowchart illustrating a method **1300** that supports signaling enhancement for beam change predictions via modeling in accordance with one or more aspects of the present disclosure. The operations of the method **1300** may be implemented by a UE or its components as described in the present disclosure. For example, the operations of the method **1300** may be performed by a UE **115** as described with reference to FIGS. **1** through **11**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally, or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0171] At **1305**, the method may include receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index. The operations of **1305** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1305** may be performed by a reference signal component **1025** as described with reference to FIG. **10**.

[0172] At **1310**, the method may include determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based on the reference signal. The operations of **1310** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1310** may be performed by a probability component **1030** as described with reference to FIG. **10**.

[0173] At **1315**, the method may include transmitting, to the network node, a status indication associated with whether the adjustment of the beam will occur, where transmitting the status indication is based on the probability. The operations of **1315** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1315** may be performed by an indication component **1035** as described with reference to FIG. **10**.

[0174] FIG. **14** shows a block diagram of a device **1405** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The device **1405** may be an example of aspects of a UE **115** as described in the present disclosure. The device **1405** may include a receiver **1410**, a transmitter **1415**, and a communications manager **1420**. The communications manager **1420** can be implemented, at least in part, by one or both of a modem and a processor. Each of these components may be in communication with one another (for example, via one or more buses).

[0175] The receiver **1410** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). Information may be passed on to other components of the device **1405**. The receiver **1410** may utilize a single antenna or a set of multiple antennas.

[0176] The transmitter **1415** may provide a means for transmitting signals generated by other components of the device **1405**. For example, the transmitter **1415** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). In some examples, the transmitter **1415** may be co-located with a receiver **1410** in a transceiver component. The transmitter **1415** may utilize a single antenna or a set of multiple antennas.

[0177] The communications manager **1420**, the receiver **1410**, the transmitter **1415**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **1420**, the receiver **1410**, the transmitter **1415**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

[0178] In some examples, the communications manager **1420** may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the receiver **1410**, the transmitter **1415**, or both. For example, the communications manager **1420** may receive information from the receiver **1410**, send information to the transmitter **1415**, or be integrated in combination with the receiver **1410**, the transmitter **1415**, or both to receive information, transmit information, or perform various other operations as described in the present disclosure.

[0179] The communications manager **1420** may support wireless communication at a UE (for example, the device **1405**) in accordance with examples as disclosed herein. For example, the communications manager **1420** may be configured as or otherwise support a means for receiving, from a base station, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The communications manager **1420** may be configured as or otherwise support a means for receiving, from the base station, a reference signal associated with a beam of the set of beams. The communications manager **1420** may be configured as or otherwise support a means for performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration. The communications manager **1420** may be configured as or otherwise support a means for transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0180] By including or configuring the communications manager **1420** in accordance with examples as described in the present disclosure, the device **1405** (for example, a processor controlling or otherwise coupled with the receiver **1410**, the transmitter **1415**, the communications manager **1420**, or a combination thereof) may support techniques for beam change predictions. For example, the device **1405** may predict beam changes via an HMM at a UE **115**, which may result in reduced power consumption and more efficient utilization of communication resources.

[0181] FIG. **15** shows a block diagram of a device **1505** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The device **1505** may be an example of aspects of a device **1405** or a UE **115** as described in the present disclosure. The device **1505** may include a receiver **1510**, a transmitter **1515**, and a communications manager **1520**. The communications manager **1520** can be implemented, at least in part, by one or both of a modem and a processor. Each of these components may be in communication with one another (for example, via one or more buses).

[0182] The receiver **1510** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). Information may be passed on to other components of the device **1505**. The receiver **1510** may utilize a single antenna or a set of multiple antennas.

[0183] The transmitter **1515** may provide a means for transmitting signals generated by other components of the device **1505**. For example, the transmitter **1515** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). In some examples, the transmitter **1515** may be co-located with a receiver **1510** in a transceiver component. The transmitter **1515** may utilize a single antenna or a set of multiple antennas.

[0184] The device **1505**, or various components thereof, may be an example of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **1520** may include an HMM configuration component **1525**, a reference signal component **1530**, a beam measurement component **1535**, a status indication component **1540**, or any combination thereof. The communications manager **1520** may be an example of aspects of a communications manager **1420** as described in the present disclosure. In some examples, the communications manager **1520**, or various components thereof, may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the receiver **1510**, the transmitter **1515**, or both. For example, the communications manager **1520** may receive information from the receiver **1510**, send information to the transmitter **1515**, or be integrated in combination with the receiver **1510**, the transmitter **1515**, or both to receive information, transmit information, or perform various other operations as described in the present disclosure.

[0185] The communications manager **1520** may support wireless communication at a UE (for example, the device **1505**) in accordance with examples as disclosed in the present disclosure. The HMM configuration component **1525** may be configured as or otherwise support a means for receiving, from a base station, an indication of a HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The reference signal component **1530** may be configured as or otherwise support a means for receiving, from the base station, a reference signal associated with a beam of the set of beams. The beam measurement component **1535** may be configured as or otherwise support a means for performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration. The status indication component **1540** may be configured as or otherwise support a means for transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0186] FIG. **16** shows a block diagram of a communications manager **1620** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The communications manager **1620** may be an example of aspects of a communications manager **1420**, a communications manager **1520**, or both, as described in the present disclosure. The communications manager **1620**, or various components thereof, may be an example of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **1620** may include an

HMM configuration component **1625**, a reference signal component **1630**, a beam measurement component **1635**, a status indication component **1640**, an indication receiving component **1645**, a probability component **1650**, a capability component **1655**, a threshold component **1660**, a report component **1665**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (for example, via one or more buses).

[0187] The communications manager **1620** may support wireless communication at a UE **115** in accordance with examples as disclosed in the present disclosure. The HMM configuration component **1625** may be configured as or otherwise support a means for receiving, from a base station, an indication of a HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The reference signal component **1630** may be configured as or otherwise support a means for receiving, from the base station, a reference signal associated with a beam of the set of beams. The beam measurement component **1635** may be configured as or otherwise support a means for performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration. The status indication component **1640** may be configured as or otherwise support a means for transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0188] In some examples, the set of transition probabilities and the set of emission probabilities of the HMM configuration are associated with whether a beam metric changed from a second beam measurement cycle to the beam measurement cycle, the beam metric based on performing the measurement on the beam. In some examples, the beam measurement component **1635** may be configured as or otherwise support a means for determining a beam metric value based on performing the measurement on the beam. In some examples, the status indication is based on the beam metric value and a beam index associated with the beam.

[0189] In some examples, the beam measurement component **1635** may be configured as or otherwise support a means for determining one or both of whether the beam metric value changed relative to a second beam metric value associated with a second beam measurement cycle or whether the beam index changed relative to a second beam index associated with the second beam measurement cycle. In some examples, transmitting the status indication is based on the determination.

[0190] In some examples, the indication receiving component **1645** may be configured as or otherwise support a means for receiving, from the base station, an indication including one or more of an indication to change the beam measurement cycle, an indication to change a transition probability of the set of transition probabilities, an indication to change an emission probability of the set of emission probabilities, or an indication of a set of reference signals to be measured. In some examples, the indication is received via an RRC message, a DCI, or a MAC-CE. In some examples, the indication is based on one or both of a position of the UE or a trajectory of the UE.

[0191] In some examples, the status indication component **1640** may be configured as or otherwise support a means for transmitting, to the base station, a request based on the status indication, the request including one or more of a request to decrease a report periodicity, a request to trigger one or more reports, a request to change a number of resources associated with a report, a predicted change in the beam, or a predicted change from the beam to a second beam different from the beam. In some examples, the probability component **1650** may be configured as or otherwise support a means for determining, based on the HMM configuration and performing the measurement on the beam, a probability associated with the adjustment of the beam. In some examples, transmitting the status indication is based on the probability.

[0192] In some examples, the threshold component **1660** may be configured as or otherwise support a means for receiving, from the base station, an indication of a threshold. In some examples, the threshold component **1660** may be configured as or otherwise support a means for determining whether the probability satisfies the threshold, where transmitting the status indication is based on the probability satisfying the threshold.

[0193] In some examples, the threshold component **1660** may be configured as or otherwise support a means for transmitting, to the base station, an indication of a threshold. In some examples, receiving the HMM configuration is based on transmitting the indication of the threshold. In some examples, the threshold component **1660** may be configured as or otherwise support a means for determining whether the probability satisfies the threshold. In some examples, transmitting the status indication is based on the probability satisfying the threshold.

[0194] In some examples, the threshold component **1660** may be configured as or otherwise support a means for determining whether the probability satisfies a threshold. In some examples, transmitting the status indication includes. In some examples, the report component **1665** may be configured as or otherwise support a means for transmitting, to the base station, a report including the status indication and an indication of the threshold.

[0195] In some examples, the threshold component **1660** may be configured as or otherwise support a means for receiving, from the base station, an indication of a set of thresholds. In some examples, the threshold component **1660** may be configured as or otherwise support a means for selecting a threshold of the set of thresholds based on a performance metric associated with performing the measurement. In some examples, the threshold component **1660** may be configured as or otherwise support a means for determining whether the probability satisfies the selected threshold, where transmitting the status indication is based on the selected probability satisfying the threshold. In some examples, the report component **1665** may be configured as or otherwise support a means for transmitting, to the base station, a report including the status indication and an indication of the selected threshold.

[0196] In some examples, the capability component **1655** may be configured as or otherwise support a means for transmitting, to the base station, an indication of a capability of the UE to determine a probability associated with the adjustment of the beam based on an HMM corresponding to the HMM configuration. In some examples, the status indication indicates whether the beam will change from a first beam associated with a first beam index to a second beam associated with a second beam index over a duration.

[0197] FIG. **17** shows a diagram of a system including a device **1705** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The device **1705** may be an example of or include the components of a device **1405**, a device **1505**, or a UE **115** as described in the present disclosure. The device **1705** may communicate wirelessly with one or more base stations **105**, UEs **115**, or any combination thereof. The device **1705** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **1720**, an input/output (I/O) controller **1710**, a transceiver **1715**, an antenna **1725**, a memory **1730**, code **1735**, and a processor **1740**. These components may be in electronic communication or otherwise coupled (for example, operatively, communicatively, functionally, electronically, electrically) via one or more buses (for example, a bus **1745**).

[0198] The I/O controller **1710** may manage input and output signals for the device **1705**. The I/O controller **1710** may also manage peripherals not integrated into the device **1705**. In some examples, the I/O controller **1710** may represent a physical connection or port to an external peripheral. In some examples, the I/O controller **1710** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. Additionally or alternatively, the I/O controller **1710** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some examples, the I/O controller **1710** may be implemented as part of a processor, such as the processor **1740**. In some examples, a user may interact with the device **1705** via the I/O controller **1710** or via hardware components controlled by the I/O controller **1710**.

[0199] In some examples, the device **1705** may include a single antenna **1725**. However, in some other cases, the device **1705** may have more than one antenna **1725**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **1715** may communicate bi-directionally, via the one or more antennas **1725**, wired, or wireless links as described in the present disclosure. For example, the transceiver **1715** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1715** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **1725** for transmission, and to demodulate packets received from the one or more antennas **1725**. The transceiver **1715**, or the transceiver **1715** and one or more antennas **1725**, may be an example of a transmitter **1415**, a transmitter **1515**, a receiver **1410**, a receiver **1510**, or any combination thereof or component thereof, as described in the present disclosure.

[0200] The memory **1730** may include random access memory (RAM) and read-only memory (ROM). The memory **1730** may store computer-readable, computer-executable code **1735** including instructions that, in examples in which the instructions are executed by the processor **1740**, cause the device **1705** to perform various functions described in the present disclosure. The code **1735** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some examples, the code **1735** may not be directly executable by the processor **1740** but may cause a computer (for example, in which the code is compiled and executed) to perform functions described in the present disclosure. In some examples, the memory **1730** may contain, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0201] The processor **1740** may include an intelligent hardware device (for example, a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, a field programmable gate array (FPGA), a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some examples, the processor **1740** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **1740**. The processor **1740** may be configured to execute computer-readable instructions stored in a memory (for example, the memory **1730**) to cause the device **1705** to perform various functions (for example, functions or tasks supporting signaling enhancement for beam change predictions via modeling). For example, the device **1705** or a component of the device **1705** may include a processor **1740** and memory **1730** coupled with the processor **1740**, the processor **1740** and memory **1730** configured to perform various functions described in the present disclosure.

[0202] The communications manager **1720** may support wireless communication at a UE (for example, the device **1705**) in accordance with examples as disclosed in the present disclosure. For example, the communications manager **1720** may be configured as or otherwise support a means for receiving, from a base station, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The communications manager **1720** may be configured as or otherwise support a means for receiving, from the base station, a reference signal associated with a beam of the set of beams.

[0203] The communications manager **1720** may be configured as or otherwise support a means for performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration. The communications manager **1720** may be configured as or otherwise support a means for transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam.

[0204] By including or configuring the communications manager **1720** in accordance with examples as described in the present disclosure, the device **1705** may support techniques for beam change predictions. For example, the device **1705** may predict beam changes via an HMM at a UE **115**, which may result in communication reliability, reduced power consumption, more efficient utilization of communication resources, and longer battery life.

[0205] In some examples, the communications manager **1720** may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the transceiver **1715**, the one or more antennas **1725**, or any combination thereof. Although the communications manager **1720** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **1720** may be supported by or performed by the processor **1740**, the memory **1730**, the code **1735**, or any combination thereof. For example, the code **1735** may include instructions executable by the processor **1740** to cause the device **1705** to perform various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure, or the processor **1740** and the memory **1730** may be otherwise configured to perform or support such operations.

[0206] FIG. **18** shows a block diagram of a device **1805** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The device **1805** may be an example of aspects of a base station **105** as described in the present disclosure. The device **1805** may include a receiver **1810**, a transmitter **1815**, and a communications manager **1820**. The communications manager **1820** can be implemented, at least in part, by one or both of a modem and a processor. Each of these components may be in communication with one another (for example, via one or more buses).

[0207] The receiver **1810** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). Information may be passed on to other components of the device **1805**. The receiver **1810** may utilize a single antenna or a set of multiple antennas.

[0208] The transmitter **1815** may provide a means for transmitting signals generated by other components of the device **1805**. For example, the transmitter **1815** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). In some examples, the transmitter **1815** may be co-located with a receiver **1810** in a transceiver component. The transmitter **1815** may utilize a single antenna or a set of multiple antennas.

[0209] The communications manager **1820**, the receiver **1810**, the transmitter **1815**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **1820**, the receiver **1810**, the transmitter **1815**, or various combinations or components thereof may support a method for performing one or more of the functions described in the present disclosure.

[0210] In some examples, the communications manager **1820** may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the receiver **1810**, the transmitter **1815**, or both. For example, the communications manager **1820** may receive information from the receiver **1810**, send information to the transmitter **1815**, or be integrated in combination with the receiver **1810**, the transmitter **1815**, or both to receive information, transmit information, or perform various other operations as described in the present disclosure.

[0211] The communications manager **1820** may support wireless communication at a base station (for example, the device **1805**) in accordance with examples as disclosed in the present disclosure. For example, the communications manager **1820** may be configured as or otherwise support a means for transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The communications manager **1820** may be configured as or otherwise support a means for transmitting, to the UE, a reference signal associated with a beam of the set of beams. The communications manager **1820** may be configured as or otherwise support a means for receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication on the HMM configuration and the reference signal.

[0212] By including or configuring the communications manager **1820** in accordance with examples as described in the present disclosure, the device **1805** (for example, a processor controlling or otherwise coupled with the receiver **1810**, the transmitter **1815**, the communications manager **1820**, or a combination thereof) may support techniques for beam change predictions. For example, the device **1805** may support beam change predictions via an HMM at a UE **115**, which may result in reduced power consumption and more efficient utilization of communication resources.

[0213] FIG. **19** shows a block diagram of a device **1905** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The device **1905** may be an example of aspects of a device **1805** or a base station **105** as described in the present disclosure. The device **1905** may include a receiver **1910**, a transmitter **1915**, and a communications manager **1920**. The communications manager **1920** can be implemented, at least in part, by one or both of a modem and a processor. Each of these components may be in communication with one another (for example, via one or more buses).

[0214] The receiver **1910** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). Information may be passed on to other components of the device **1905**. The receiver **1910** may utilize a single antenna or a set of multiple antennas.

[0215] The transmitter **1915** may provide a means for transmitting signals generated by other components of the device **1905**. For example, the transmitter **1915** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (for example, control channels, data channels, information channels related to signaling enhancement for beam change predictions via modeling). In some examples, the transmitter **1915** may be co-located with a receiver **1910** in a transceiver component. The transmitter **1915** may utilize a single antenna or a set of multiple antennas.

[0216] The device **1905**, or various components thereof, may be an example of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **1920** may include an HMM indication component **1925**, a reference signal transmitting component **1930**, a beam adjustment component **1935**, or any combination thereof. The communications manager **1920** may be an example of aspects of a communications manager **1820** as described in the present disclosure. In some examples, the communications manager **1920**, or various components thereof, may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the receiver **1910**, the transmitter **1915**, or both. For example, the communications manager **1920** may receive information from the receiver **1910**, send information to the transmitter **1915**, or be integrated in combination with the receiver **1910**, the transmitter **1915**, or both to receive information, transmit information, or perform various other operations as described in the present disclosure.

[0217] The communications manager **1920** may support wireless communication at a base station (for example, the device **1905**) in accordance with examples as disclosed in the present disclosure. The HMM indication component **1925** may be configured as or otherwise support a means for transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The reference signal transmitting component **1930** may be configured as or otherwise support a means for transmitting, to the UE, a reference signal associated with a beam of the set of beams. The beam adjustment component **1935** may be configured as or otherwise support a means for receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal.

[0218] FIG. **20** shows a block diagram of a communications manager **2020** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The communications manager **2020** may be an example of aspects of a communications manager **1820**, a communications manager **1920**, or both, as described in the present disclosure. The communications manager **2020**, or various components thereof, may be an example of means for performing various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure. For example, the communications manager **2020** may include an HMM indication component **2025**, a reference signal transmitting component **2030**, a beam adjustment component **2035**, an indication transmitting component **2040**, a request component **2045**, a threshold indication component **2050**, a report receiving component **2055**, a capability indication component **2060**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (for example, via one or more buses).

[0219] The communications manager **2020** may support wireless communication at a base station **105** in accordance with examples as disclosed in the present disclosure. The HMM indication component **2025** may be configured as or otherwise support a means for transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The reference signal transmitting component **2030** may be configured as or otherwise support a means for transmitting, to the UE, a reference signal associated with a beam of the set of beams. The beam adjustment component **2035** may be configured as or otherwise support a means for receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal. In some examples, the set of transition probabilities and the set of emission probabilities of the HMM configuration are associated with whether a beam metric changed from a second beam measurement cycle to a beam measurement cycle, the beam metric corresponding to a measurement of the beam.

[0220] In some examples, the indication transmitting component **2040** may be configured as or otherwise support a means for transmitting, to the UE, an indication including one or more of an indication to change a beam measurement cycle, an indication to change a transition probability of the set of transition probabilities, an indication to change an emission probability of the set of emission probabilities, or an indication of a set of reference signals to be measured.

[0221] In some examples, the indication is transmitted via an RRC message, a DCI, or a MAC-CE. In some examples, the indication transmitting component **2040** may be configured as or otherwise support a means for determining one or both of a position of the UE or a trajectory of the UE. In some examples, the indication is based on one or both of the position of the UE or the trajectory of the UE.

[0222] In some examples, the request component **2045** may be configured as or otherwise support a means for receiving, from the UE, a request based on the status indication, the request including one or more of a request to decrease a report periodicity, a request to trigger one or more reports, a request to change a number of resources associated with a report, a predicted change in the beam, or a predicted change from the beam to a second beam different from the beam. In some examples, the threshold indication component **2050** may be configured as or otherwise support a means for transmitting, to the UE, an indication of a threshold. In some examples, the status indication is based on a probability associated with the adjustment of the beam satisfying the threshold.

[0223] In some examples, the threshold indication component **2050** may be configured as or otherwise support a means for receiving, from the UE, an indication of a threshold. In some examples, transmitting the HMM configuration is based on receiving the indication of the threshold. In some examples, the report receiving component **2055** may be configured as or otherwise support a means for receiving, from the UE, a report including the status indication and an indication of a threshold. In some examples, the status indication is based on a probability associated with the adjustment of the beam satisfying the threshold.

[0224] In some examples, the capability indication component **2060** may be configured as or otherwise support a means for receiving, from the UE, an indication of a capability of the UE to determine a probability associated with the adjustment of the beam based on an HMM corresponding to the HMM configuration. In some examples, the status indication indicates whether the beam will change from a first beam associated with a first beam index to a second beam associated with a second beam index over a duration.

[0225] FIG. **21** shows a diagram of a system including a device **2105** that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The device **2105** may be an example of or include the components of a device **1805**, a device **1905**, or a base station **105** as described in the present disclosure. The device **2105** may communicate wirelessly with one or more base stations **105**, UEs **115**, or any combination thereof. The device **2105** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **2120**, a network communications manager **2110**, a transceiver **2115**, an antenna **2125**, a memory **2130**, code **2135**, a processor **2140**, and an inter-station communications manager **2145**. These components may be in electronic communication or otherwise coupled (for example, operatively, communicatively, functionally, electronically, electrically) via one or more buses (for example, a bus **2150**).

[0226] The network communications manager **2110** may manage communications with a core network **130** (for example, via one or more wired backhaul links). For example, the network communications manager **2110** may manage the transfer of data communications for client devices, such as one or more UEs **115**.

[0227] In some examples, the device **2105** may include a single antenna **2125**. However, in some other cases the device **2105** may have more than one antenna **2125**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **2115** may communicate bi-directionally, via the one or more antennas **2125**, wired, or wireless links as described in the present disclosure. For example, the transceiver **2115** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **2115** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **2125** for transmission, and to demodulate packets received from the one or more antennas **2125**. The transceiver **2115**, or the transceiver **2115** and one or more antennas **2125**, may be an example of a transmitter **1815**, a transmitter **1915**, a receiver **1810**, a receiver **1910**, or any combination thereof or component thereof, as described in the present disclosure.

[0228] The memory **2130** may include RAM and ROM. The memory **2130** may store computer-readable, computer-executable code **2135** including instructions that, in examples in which the instructions are executed by the processor **2140**, cause the device **2105** to perform various functions described in the present disclosure. The code **2135** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some examples, the code **2135** may not be directly executable by the processor **2140** but may cause a computer (for example, in which the code is compiled and executed) to perform functions described in the present disclosure. In some examples, the memory **2130** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0229] The processor **2140** may include an intelligent hardware device (for example, a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some examples, the processor **2140** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **2140**. The processor **2140** may be configured to execute computer-readable instructions stored in a memory (for example, the memory **2130**) to cause the device **2105** to perform various functions (for example, functions or tasks supporting signaling enhancement for beam change predictions via modeling). For example, the device **2105** or a component of the device **2105** may include a processor **2140** and memory **2130** coupled with the processor **2140**, the processor **2140** and memory **2130** configured to perform various functions described in the present disclosure.

[0230] The inter-station communications manager **2145** may manage communications with other base stations **105**, and may include a controller or scheduler for controlling communications with UEs **115** in cooperation with other base stations **105**. For example, the inter-station communications manager **2145** may coordinate scheduling for transmissions to UEs **115** for various interference mitigation techniques such as beamforming or joint transmission. In some examples, the inter-station communications manager **2145** may provide an X2 interface within an LTE/LTE-A wireless communications network technology to provide communication between base stations **105**.

[0231] The communications manager **2120** may support wireless communication at a base station (for example, the device **2105**) in accordance with examples as disclosed in the present disclosure. For example, the communications manager **2120** may be configured as or otherwise support a means for transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The communications manager **2120** may be configured as or otherwise support a means for transmitting, to the UE, a reference signal associated with a beam of the set of beams. The communications manager **2120** may be configured as or otherwise support a means for receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal.

[0232] By including or configuring the communications manager **2120** in accordance with examples as described in the present disclosure, the device **2105** may support techniques for beam change predictions via an HMM at a UE **115**, which may result in communication reliability, reduced power consumption, more efficient utilization of communication resources, and longer battery life.

[0233] In some examples, the communications manager **2120** may be configured to perform various operations (for example, receiving, monitoring, transmitting) using or otherwise in cooperation with the transceiver **2115**, the one or more antennas **2125**, or any combination thereof. Although the communications manager **2120** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **2120** may be supported by or performed by the processor **2140**, the memory **2130**, the code **2135**, or any combination thereof. For example, the code **2135** may include instructions executable by the processor **2140** to cause the device **2105** to perform various aspects of signaling enhancement for beam change predictions via modeling as described in the present disclosure, or the processor **2140** and the memory **2130** may be otherwise configured to perform or support such operations.

[0234] FIG. **22** shows a flowchart illustrating a method that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE or its components as described in the present disclosure. For example, the operations of the method may be performed by a UE **115** as described with reference to FIGS. **1-25**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0235] At **2205**, the method may include receiving, from a base station, an indication of an HMM configuration, the HMM including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The operations of **2205** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2205** may be performed by an HMM configuration component **1625** as described with reference to FIG. **16**.

[0236] At **2210**, the method may include receiving, from the base station, a reference signal associated with a beam of the set of beams. The operations of **2210** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2210** may be performed by a reference signal component **1630** as described with reference to FIG. **16**.

[0237] At **2215**, the method may include performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration. The operations of **2215** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2215** may be performed by a beam measurement component **1635** as described with reference to FIG. **16**.

[0238] At **2220**, the method may include transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam. The operations of **2220** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2220** may be performed by a status indication component **1640** as described with reference to FIG. **16**.

[0239] FIG. **23** shows a flowchart illustrating a method that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE or its components as described in the present disclosure. For example, the operations of the method may be performed by a UE **115** as described with reference to FIGS. **1-25**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0240] At **2305**, the method may include receiving, from a base station, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The operations of **2305** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2305** may be performed by an HMM configuration component **1625** as described with reference to FIG. **16**.

[0241] At **2310**, the method may include receiving, from the base station, a reference signal associated with a beam of the set of beams. The operations of **2310** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2310** may be performed by a reference signal component **1630** as described with reference to FIG. **16**.

[0242] At **2315**, the method may include performing a measurement on the beam over a beam measurement cycle based on the indication of the HMM configuration. The operations of **2315** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2315** may be performed by a beam measurement component **1635** as described with reference to FIG. **16**.

[0243] At **2320**, the method may include determining a beam metric value based on performing the measurement on the beam. The operations of **2320** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2320**

may be performed by a beam measurement component **1635** as described with reference to FIG. **16**.

[0244] At **2325**, the method may include transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and performing the measurement on the beam. In some examples, the status indication is based on the beam metric value and a beam index associated with the beam. The operations of **2325** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2325** may be performed by a status indication component **1640** as described with reference to FIG. **16**.

[0245] FIG. **24** shows a flowchart illustrating a method that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The operations of the method may be implemented by a base station or its components as described in the present disclosure. For example, the operations of the method may be performed by a base station **105** as described with reference to FIGS. **1-7** and **22-25**. In some examples, a base station may execute a set of instructions to control the functional elements of the base station to perform the described functions. Additionally or alternatively, the base station may perform aspects of the described functions using special-purpose hardware.

[0246] At **2405**, the method may include transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The operations of **2405** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2405** may be performed by an HMM indication component **2025** as described with reference to FIG. **20**.

[0247] At **2410**, the method may include transmitting, to the UE, a reference signal associated with a beam of the set of beams. The operations of **2410** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2410** may be performed by a reference signal transmitting component **2030** as described with reference to FIG. **20**.

[0248] At **2415**, the method may include receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal. The operations of **2415** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2415** may be performed by a beam adjustment component **2035** as described with reference to FIG. **20**.

[0249] FIG. **25** shows a flowchart illustrating a method that supports signaling enhancement for beam change predictions via modeling in accordance with aspects of the present disclosure. The operations of the method may be implemented by a base station or its components as described in the present disclosure. For example, the operations of the method may be performed by a base station **105** as described with reference to FIGS. **1-7** and **22-25**. In some examples, a base station may execute a set of instructions to control the functional elements of the base station to perform the described functions. Additionally or alternatively, the base station may perform aspects of the described functions using special-purpose hardware.

[0250] At **2505**, the method may include transmitting, to a UE, an indication of an HMM configuration, the HMM configuration including a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams. The operations of **2505** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2505** may be performed by an HMM indication component **2025** as described with reference to FIG. **20**.

[0251] At **2510**, the method may include transmitting, to the UE, a reference signal associated with a beam of the set of beams. The operations of **2510** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2510** may be performed by a reference signal transmitting component **2030** as described with reference to FIG. **20**.

[0252] At **2515**, the method may include receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based on the HMM configuration and the reference signal. The operations of **2515** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2515** may be performed by a beam adjustment component **2035** as described with reference to FIG. **20**.

[0253] At **2520**, the method may include transmitting, to the UE, an indication including one or more of an indication to change a beam measurement cycle, an indication to change a transition probability of the set of transition probabilities, an indication to change an emission probability of the set of emission probabilities, or an indication of a set of reference signals to be measured. The operations of **2520** may be performed in accordance with examples as disclosed in the present disclosure. In some examples, aspects of the operations of **2520** may be performed by an indication transmitting component **2040** as described with reference to FIG. **20**.

[0254] The following provides an overview of aspects of the present disclosure:

[0255] Aspect 1: A method for wireless communication at a UE, comprising: receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index; determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal; and transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

[0256] Aspect 2: The method of aspect 1, wherein transmitting an indication of the probability comprises: transmitting, to the network node, a status indication associated with whether the adjustment of the beam will occur, wherein transmitting the status indication is based at least in part on the probability.

[0257] Aspect 3: The method of aspect 2, further comprising: receiving, from the network node, an indication of a threshold; and determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

[0258] Aspect 4: The method of any of aspects 2 through 3, further comprising: transmitting, to the network node, an indication of a threshold; and determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

[0259] Aspect 5: The method of any of aspects 2 through 4, further comprising: determining whether the probability satisfies a threshold, wherein transmitting the status indication comprises: transmitting, to the network node, a report comprising the status indication and an indication of the threshold.

[0260] Aspect 6: The method of any of aspects 2 through 5, further comprising: receiving, from the network node, an indication of a set of thresholds; selecting a threshold of the set of thresholds based at least in part on a performance metric associated with performing a measurement on the beam; and determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

[0261] Aspect 7: The method of any of aspects 1 through 6, further comprising transmitting, to the network node, an indication of a capability of the UE to determine the probability associated with the adjustment of the beam.

[0262] Aspect 8: The method of any of aspects 1 through 7, wherein determining the probability is based at least in part on a machine learning model.

[0263] Aspect 9: The method of aspect 8, wherein the machine learning model comprises one or more of a long short-term memory neural network, a gated recurrent unit neural network, a convolution neural network, a recurrent neural network, or a deep neural network.

[0264] Aspect 10: The method of aspect 9, further comprising receiving, from the network node, an indication of the machine learning model, wherein determining the probability is based at least in part on receiving the indication.

[0265] Aspect 11: The method of any of aspects 9 through 10, further comprising determining the machine learning model at the UE, wherein determining the probability is based at least in part on determining the machine learning model.

[0266] Aspect 12: The method of aspect 8, wherein the machine learning model comprises a hidden Markov Model.

[0267] Aspect 13: The method of aspect 12, further comprising receiving, from the network node, an indication of a hidden Markov model configuration, the hidden Markov model configuration comprising a set of transition probabilities associated with the set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, wherein determining the probability is based at least in part on receiving the indication of the hidden Markov model configuration.

[0268] Aspect 14: The method of any of aspects 1 through 13, wherein transmitting the indication of the probability comprises transmitting, to the network node, a report comprising the indication of the probability.

[0269] Aspect 15: The method of aspect 14, wherein transmitting the report comprising the indication of the probability comprises: transmit a first channel state information report that indicates one or more measured channel characteristics of a channel used for the wireless communications between the UE and the network node; and transmit a second channel state information report that indicates the probability.

[0270] Aspect 16: The method of any of aspects 1 through 15, further comprising: performing a measurement on the beam over a beam measurement cycle; and determining a beam metric value based at least in part on performing the measurement on the beam, wherein the probability is based at least in part on the beam metric value and a beam index associated with the beam.

[0271] Aspect 17: The method of aspect 16, wherein the beam index associated with the beam comprises the first beam index or the second beam index.

[0272] Aspect 18: The method of any of aspects 16 through 17, further comprising determining one or both of whether the beam metric value changed relative to a second beam metric value associated with a second beam measurement cycle or whether the beam index changed relative to the second beam index associated with the second beam measurement cycle, wherein transmitting the indication of the probability is based at least in part on determining one or both of whether the beam metric value changed relative to the second beam metric value associated with the second beam measurement cycle or whether the beam index changed relative to the second beam index associated with the second beam measurement cycle.

[0273] Aspect 19: The method of any of aspects 16 through 18, further comprising receiving, from the network node, an indication comprising one or both of an indication to change the beam measurement cycle or an indication of a set of reference signals to be measured.

[0274] Aspect 20: The method of aspect 19, wherein the indication is received via an RRC message, a downlink control information, or a MAC-CE.

[0275] Aspect 21: The method of any of aspects 19 through 20, wherein the indication is based at least in part on one or both of a position of the UE or a trajectory of the UE.

[0276] Aspect 22: The method of any of aspects 1 through 21, further comprising transmitting, to the network node, a request based at least in part on the probability, the request comprising one or more of a request to decrease a report periodicity, a request to trigger one or more reports, a request to change a number of resources associated with a report, a predicted change in the beam, or a predicted change of the beam from the first beam to the second beam different from the beam.

[0277] Aspect 23: The method of any of aspects 1 through 22, wherein the beam of the set of beams used for the wireless communications at the UE is a top beam.

[0278] Aspect 24: An apparatus for wireless communication at a UE, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 1 through 22.

[0279] Aspect 25: An apparatus for wireless communication at a UE, comprising at least one means for performing a method of any of aspects 1 through 23.

[0280] Aspect 26: A non-transitory computer-readable medium storing code for wireless communication at a UE, the code comprising instructions executable by a processor to perform a method of any of aspects 1 through 23.

[0281] Aspect 27: A method for wireless communication at a UE, comprising: receiving, from a base station, an indication of an HMM configuration, the HMM configuration comprising a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams; receiving, from the base station, a reference signal associated with a beam of the set of beams; performing a measurement on the beam over a beam measurement cycle based at least in part on the indication of the HMM configuration; and transmitting, to the base station, a status indication associated with whether an adjustment of the beam will occur, the status indication based at least in part on the HMM configuration and performing the measurement on the beam.

[0282] Aspect 28: The method of aspect 27, wherein the set of transition probabilities and the set of emission probabilities of the HMM configuration are associated with whether a beam metric changed from a second beam measurement cycle to the beam measurement cycle, the beam metric based at least in part on performing the measurement on the beam.

[0283] Aspect 29: The method of any of aspects 27 through 28, further comprising: determining a beam metric value based at least in part on performing the measurement on the beam, wherein the status indication is based at least in part on the beam metric value and a beam index associated with the beam.

[0284] Aspect 30: The method of aspect 29, further comprising: determining one or both of whether the beam metric value changed relative to a second beam metric value associated with a second beam measurement cycle or whether the beam index changed relative to a second beam index associated with the second beam measurement cycle, wherein transmitting the status indication is based at least in part on the determination.

[0285] Aspect 31: The method of any of aspects 27 through 20, further comprising: receiving, from the base station, an indication comprising one or more of an indication to change the beam measurement cycle, an indication to change a transition probability of the set of transition probabilities, an indication to change an emission probability of the set of emission probabilities, or an indication of a set of reference signals to be measured.

[0286] Aspect 32: The method of aspect 31, wherein the indication is received via an RRC message, a DCI, or a MAC-CE.

[0287] Aspect 33: The method of any of aspects 31 through 32, wherein the indication is based at least in part on one or both of a position of the UE or a trajectory of the UE.

[0288] Aspect 34: The method of any of aspects 27 through 33, further comprising: transmitting, to the base station, a request based at least in part on the status indication, the request comprising one or more of a request to decrease a report periodicity, a request to trigger one or more reports, a request to change a number of resources associated with a report, a predicted change in the beam, or a predicted change from the beam to a second beam different from the beam.

[0289] Aspect 35: The method of any of aspects 27 through 34, further comprising: determining, based at least in part on the HMM configuration and performing the measurement on the beam, a probability associated with the adjustment of the beam, wherein transmitting the status indication is based at least in part on the probability.

[0290] Aspect 36: The method of aspect 35, further comprising: receiving, from the base station, an indication of a threshold; determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

[0291] Aspect 37: The method of aspect 35, further comprising: transmitting, to the base station, an indication of a threshold, wherein receiving the HMM configuration is based at least in part on transmitting the indication of the threshold; and determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

[0292] Aspect 38: The method of aspect 35, further comprising: determining whether the probability satisfies a threshold, wherein transmitting the status indication comprises: transmitting, to the base station, a report comprising the status indication and an indication of the threshold.

[0293] Aspect 39: The method of aspect 35, further comprising: receiving, from the base station, an indication of a set of thresholds; selecting a threshold of the set of thresholds based at least in part on a performance metric associated with performing the measurement; determining whether the probability satisfies the selected threshold, wherein transmitting the status indication is based at least in part on the selected probability satisfying the threshold.

[0294] Aspect 40: The method of any of aspects 27 through 39, further comprising: transmitting, to the base station, an indication of a capability of the UE to determine a probability associated with the adjustment of the beam based at least in part on an HMM corresponding to the HMM configuration.

[0295] Aspect 41: The method of any of aspects 27 through 40, wherein the status indication indicates whether the beam will change from a first beam associated with a first beam index to a second beam associated with a second beam index over a duration.

[0296] Aspect 42: A method for wireless communication at a base station, comprising: transmitting, to a UE, an indication of an HMM configuration, the HMM configuration comprising a set of transition probabilities associated with a set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams; transmitting, to the UE, a reference signal associated with a beam of the set of beams; and receiving, from the UE, a status indication associated with whether an adjustment of the beam will occur, the status indication based at least in part on the HMM configuration and the reference signal.

[0297] Aspect 43: The method of aspect 42, wherein the set of transition probabilities and the set of emission probabilities of the HMM configuration are associated with whether a beam metric changed from a second beam measurement cycle to a beam measurement cycle, the beam metric corresponding to a measurement of the beam.

[0298] Aspect 44: The method of any of aspects 42 through 43, further comprising: transmitting, to the UE, an indication comprising one or more of an indication to change a beam measurement cycle, an indication to change a transition probability of the set of transition probabilities, an indication to change an emission probability of the set of emission probabilities, or an indication of a set of reference signals to be measured.

[0299] Aspect 45: The method of aspect 44, wherein the indication is transmitted via an RRC message, a DCI, or a MAC-CE.

[0300] Aspect 46: The method of any of aspects 44 through 45, further comprising: determining one or both of a position of the UE or a trajectory of the UE, wherein the indication is based at least in part on one or both of the position of the UE or the trajectory of the UE.

[0301] Aspect 47: The method of any of aspects 42 through 46, further comprising: receiving, from the UE, a request based at least in part on the status indication, the request comprising one or more of a request to decrease a report periodicity, a request to trigger one or more reports, a request to change a number of resources associated with a report, a predicted change in the beam, or a predicted change from the beam to a second beam different from the beam.

[0302] Aspect 48: The method of any of aspects 42 through 47, further comprising: transmitting, to the UE, an indication of a threshold, wherein the status indication is based at least in part on a probability associated with the adjustment of the beam satisfying the threshold.

[0303] Aspect 49: The method of any of aspects 42 through 47, further comprising: receiving, from the UE, an indication of a threshold, wherein transmitting the HMM configuration is based at least in part on receiving the indication of the threshold.

[0304] Aspect 50: The method of any of aspects 42 through 47, further comprising: receiving, from the UE, a report comprising the status indication and an indication of a threshold, wherein the status indication is based at least in part on a probability associated with the adjustment of the beam satisfying the threshold.

[0305] Aspect 51: The method of any of aspects 42 through 47, further comprising: receiving, from the UE, an indication of a capability of the UE to determine a probability associated with the adjustment of the beam based at least in part on an HMM corresponding to the HMM configuration.

[0306] Aspect 52: The method of any of aspects 42 through 47, wherein the status indication indicates whether the beam will change from a first beam associated with a first beam index to a second beam associated with a second beam index over a duration.

[0307] Aspect 53: An apparatus for wireless communication at a UE, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 27 through 41.

[0308] Aspect 54: An apparatus for wireless communication at a UE, comprising at least one means for performing a method of any of aspects 27 through 41.

[0309] Aspect 55: A non-transitory computer-readable medium storing code for wireless communication at a UE, the code comprising instructions executable by a processor to perform a method of any of aspects 27 through 41.

[0310] Aspect 56: An apparatus for wireless communication at a base station, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 42 through 47.

[0311] Aspect 57: An apparatus for wireless communication at a base station, comprising at least one means for performing a method of any of aspects 42 through 47.

[0312] Aspect 58: A non-transitory computer-readable medium storing code for wireless communication at a base station, the code comprising instructions executable by a processor to perform a method of any of aspects 42 through 47.

[0313] It should be noted that the methods described herein describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0314] Although aspects of an LTE, LTE-A, LTE-A Pro, or NR system may be described for purposes of example, and LTE, LTE-A, LTE-A Pro, or NR terminology may be used in much of the description, the techniques described herein are applicable beyond LTE, LTE-A, LTE-A Pro, or NR networks. For example, the described techniques may be applicable to various other wireless communications systems such as Ultra Mobile Broadband (UMB), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, as well as other systems and radio technologies not explicitly mentioned herein.

[0315] Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0316] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (for example, a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

[0317] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0318] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, and not limitation, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of computer-readable medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[0319] As used herein, including in the claims, "or" as used in a list of items (for example, a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on."

[0320] The term "determine" or "determining" encompasses a wide variety of actions and, therefore, "determining" can include calculating, computing, processing, deriving, investigating, looking up (such as via looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" can include receiving (such as receiving information), accessing (such as accessing data in a memory) and the like. Also, "determining" can include resolving, selecting, choosing, establishing and other such similar actions.

[0321] In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label, or other subsequent reference label.

[0322] The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "example" used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

[0323] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

1. A method for wireless communication at a user equipment (UE), comprising:

receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index;

determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal; and

transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

2. The method of claim **1**, wherein transmitting an indication of the probability comprises:

transmitting, to the network node, a status indication associated with whether the adjustment of the beam will occur, wherein transmitting the status indication is based at least in part on the probability.

3. The method of claim **2**, further comprising:

receiving, from the network node, an indication of a threshold; and determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

4. The method of claim **2**, further comprising:

transmitting, to the network node, an indication of a threshold; and

determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

5. The method of claim **2**, further comprising:

determining whether the probability satisfies a threshold, wherein transmitting the status indication comprises:

transmitting, to the network node, a report comprising the status indication and an indication of the threshold.

6. The method of claim **2**, further comprising:

receiving, from the network node, an indication of a set of thresholds;

selecting a threshold of the set of thresholds based at least in part on a performance metric associated with performing a measurement on the beam; and

determining whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

7. The method of claim **1**, further comprising transmitting, to the network node, an indication of a capability of the UE to determine the probability associated with the adjustment of the beam.

8. The method of claim **1**, wherein determining the probability is based at least in part on a machine learning model.

9. The method of claim **8**, wherein the machine learning model comprises one or more of a long short-term memory neural network, a gated recurrent unit neural network, a convolution neural network, a recurrent neural network, or a deep neural network.

10. The method of claim **9**, further comprising receiving, from the network node, an indication of the machine learning model, wherein determining the probability is based at least in part on receiving the indication.

11. The method of claim **9**, further comprising determining the machine learning model at the UE, wherein determining the probability is based at least in part on determining the machine learning model.

12. The method of claim **8**, wherein the machine learning model comprises a hidden Markov Model.

13. The method of claim **12**, further comprising receiving, from the network node, an indication of a hidden Markov model configuration, the hidden Markov model configuration comprising a set of transition probabilities associated with the set of beams and a set of emission probabilities associated with the set of beams, each transition probability of the set of transition probabilities corresponding to a transition of at least one beam of the set of beams from a first status to a second status and each emission probability of the set of emission probabilities corresponding to an observed status of at least one beam of the set of beams, wherein determining the probability is based at least in part on receiving the indication of the hidden Markov model configuration.

14. The method of claim **1**, wherein transmitting the indication of the probability comprises transmitting, to the network node, a report comprising the indication of the probability.

15. The method of claim **14**, wherein transmitting the report comprising the indication of the probability comprises:

transmit a first channel state information report that indicates one or more measured channel characteristics of a channel used for the wireless communications between the UE and the network node; and

transmit a second channel state information report that indicates the probability.

16. The method of claim **1**, further comprising:

performing a measurement on the beam over a beam measurement cycle; and

determining a beam metric value based at least in part on performing the measurement on the beam, wherein the probability is based at least in part on the beam metric value and a beam index associated with the beam.

17. The method of claim **16**, wherein the beam index associated with the beam comprises the first beam index or the second beam index.

18. The method of claim **16**, further comprising determining one or both of whether the beam metric value changed relative to a second beam metric value associated with a second beam measurement cycle or whether the beam index changed relative to the second beam index associated with the second beam measurement cycle, wherein transmitting the indication of the probability is based at least in part on determining one or both of whether the beam metric value changed relative to the second beam metric value associated with the second beam measurement cycle or whether the beam index changed relative to the second beam index associated with the second beam measurement cycle.

19. The method of claim **16**, further comprising receiving, from the network node, an indication comprising one or both of an indication to change the beam measurement cycle or an indication of a set of reference signals to be measured.

20. The method of claim **19**, wherein the indication is received via a radio resource control message, a downlink control information, or a medium access control control element.

21. method of claim **19**, wherein the indication is based at least in part on one or both of a position of the UE or a trajectory of the UE.

22. method of claim **1**, further comprising transmitting, to the network node, a request based at least in part on the probability, the request comprising one or more of a request to decrease a report periodicity, a request to trigger one or more reports, a request to change a number of resources associated with a report, a predicted change in the beam, or a predicted change of the beam from the first beam to the second beam different from the beam.

23. The method of claim **1**, wherein the beam of the set of beams used for the wireless communications at the UE is a top beam.

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

a processor; and

memory coupled with the processor and storing instructions executable by the processor to cause the apparatus to:

receive, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index;

determine a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal; and

transmit, to the network node, an indication of the probability associated with the adjustment of the beam.

25. The apparatus of claim **24**, wherein the instructions to transmit an indication of the probability are executable by the processor to cause the apparatus to:

transmit, to the network node, a status indication associated with whether the adjustment of the beam will occur, wherein transmitting the status indication is based at least in part on the probability.

26. The apparatus of claim **25**, wherein the instructions are further executable by the processor to cause the apparatus to:

receive, from the network node, an indication of a threshold; and

determine whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

27. The apparatus of claim **25**, wherein the instructions are further executable by the processor to cause the apparatus to:

transmit, to the network node, an indication of a threshold; and

determine whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

28. The apparatus of claim **25**, wherein the instructions are further executable by the processor to cause the apparatus to:

determine whether the probability satisfies a threshold, wherein transmitting the status indication comprises:

transmit, to the network node, a report comprising the status indication and an indication of the threshold.

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62. The apparatus of claim **25**, wherein the instructions are further executable by the processor to cause the apparatus to:

receive, from the network node, an indication of a set of thresholds;

select a threshold of the set of thresholds based at least in part on a performance metric associated with performing a measurement on the beam; and

determine whether the probability satisfies the threshold, wherein transmitting the status indication is based at least in part on the probability satisfying the threshold.

63. A user equipment (UE) for wireless communications, comprising:

means for receiving, from a network node, a reference signal associated with a beam of a set of beams used for wireless communications at the UE, each beam of the set of beams being associated with a respective beam index;

means for determining a probability associated with an adjustment of the beam, the probability indicating whether the beam will change over a duration from a first beam associated with a first beam index to a second beam associated with a second beam index based at least in part on the reference signal; and

means for transmitting, to the network node, an indication of the probability associated with the adjustment of the beam.

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