BEAM MANAGEMENT FOR NEW RADIO VEHICLE COMMUNICATIONS

Abstract

A user equipment (UE) determines sidelink resources for use in vehicle wireless communications. Initial beam establishment uses a Sidelink Synchronization Signal (SLSS), a Sidelink Channel State Information Reference Signal (SL-CSI-RS), or a Sidelink Demodulation Reference Signal (SL-DMRS). Beam refinement may then be conducted either by UEs in communication with each other, or by just one of the UEs. A base station such as a gNB may assign resources for a dedicated sidelink carrier or a shared licensed sidelink carrier, e.g., dynamically, as pre-configured by RRC, or based on activation and deactivation. In such cases, initial beam establishment and refinement may include gNB controlled beam forming at a connectionless stage, gNB controlled beam forming at connection stage with scheduling DCI transmitted to Tx UE only, or gNB controlled beam forming at connection stage with scheduling DCI transmitted to both Tx UE and Rx UE.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This Application is a Continuation of U.S. patent application Ser. No. 17/632,360, filed Feb. 2, 2022, which is the National Stage Application of International Patent Application No. PCT/US2020/045972, filed Aug. 12, 2020, which claims the benefit of U.S. Provisional Patent Application No. 62/888,0002, filed 16 Aug. 2019, entitled "BEAM MANAGEMENT FOR NEW RADIO VEHICLE COMMUNICATIONS", the contents of which are hereby incorporated by reference herein.

BACKGROUND
[0002] This disclosure pertains to beam forming in vehicle wireless communications, e.g., for new radio, and as described in 3GPP TR 22.886 Study on enhancement of 3GPP Support for 5G V2X Services, Release 15, V15.2.0, and 3GPP TS 22.186 Enhancement of 3GPP support for V2X scenarios (Stage 1), Release 15, V15.3.0.
SUMMARY
[0003] In new radio, where a user equipment (UE) determines sidelink resources for use in vehicle wireless communications, initial beam establishment may be achieved using a Sidelink Synchronization Signal (SLSS), a Sidelink Channel State Information Reference Signal (SL-CSI-RS), or a Sidelink Demodulation Reference Signal (SL-DMRS), for example. Beam refinement may then be conducted either by two user equipment (UEs) in communication with each other, or by just one of the UEs.
[0004] A base station such as a gNB may assign resources for a dedicated sidelink carrier or a shared licensed sidelink carrier, e.g., dynamically, as pre-configured by RRC, or based on activation and deactivation. In such cases, initial beam establishment and refinement may include gNB controlled beam forming at a connectionless stage, gNB controlled beam forming at connection stage with scheduling DCI transmitted to Tx UE only, or gNB controlled beam forming at connection stage with scheduling DCI transmitted to both Tx UE and Rx UE.
[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to limitations that solve any or all disadvantages noted in any part of this disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings.

[0007] FIG. **1**A is a flow diagram of an example beam forming procedure with beam refinement by one UE.

[0008] FIG. **1**B is a flow diagram of an example beam forming procedure with beam refinement by two UEs.

[0009] FIG. **2** is a call flow of an example initial beam establishment procedure at connectionless stage.

[0010] FIG. **3**A shows an example of SL-DMRS based initial beam sweeping with slot level sweeping.

[0011] FIG. **3**B shows an example of SL-DMRS based initial beam sweeping with mini-slot level sweeping.

[0012] FIG. **4** illustrates an example of SL-CSI-RS based initial beam sweeping.

[0013] FIG. **5**A illustrates an example of a beam index indicated by the RS with SL-DMRS indicating the beam index for SL-DMRS based beam measurement.

[0014] FIG. **5**B illustrates an example of a beam index indicated by the RS with SL-CSI-RS indicating the beam index for SL-CSI-RS based beam measurement.

[0015] FIG. **5**C illustrates an example of a beam index indicated by the RS with SL-DMRS indicating the beam index for SL-CSI-RS based beam measurement.

[0016] FIG. **6** is a call flow of an example procedure for UE initiated initial beam establishment at connection stage.

[0017] FIG. **7**A shows an example of initiating the beam pair establishment and scheduling the beam sweeping with sending the initiating indication in FR**1** and schedule the beam sweeping in FR2.

[0018] FIG. **7**B shows an example of initiating the beam pair establishment and scheduling the beam sweeping with sending the initiating indication and schedule the beam sweeping in FR1.

[0019] FIG. **7**C shows an example of initiating the beam pair establishment and scheduling the beam sweeping with sending the initiating indication and schedule the beam sweeping in FR2.

[0020] FIG. **8**A shows an example where UE**1** sends the reserve signaling in FR1 and UE**2** sends the response in FR**1** with separate reserve signalings for beam sweeping and responding,

[0021] FIG. **8**B shows an example where UE**1** sends the reserve signaling in FR**1** and UE**2** sends the response in FR**1** with same reserve signaling for beam sweeping and responding.

[0022] FIG. **9** shows an example where UE**1** sends the reserve signaling in FR**1** and UE**2** sends the response in FR2.

[0023] FIG. **10** shows an example where UE**1** sends the reserve signaling in FR2 and UE**2** send the response in FR2.

[0024] FIG. **11** shows an example where UE**1** sends the reserve signaling in FR2 and UE**2** send the response in FR1.

[0025] FIG. **12**A shows an example where UE**2** sends the reserve signaling and sends the response in FR1.

[0026] FIG. **12**B shows an example where UE**2** sends the reserve signaling and sends the response in FR2.

[0027] FIG. **13** is a call flow of an example procedure of beam refinement at both UE sides.

[0028] FIG. **14**A illustrates an example of beam repeating for beam refinement at Rx UE side where one SCI schedules multiple RS transmissions.

[0029] FIG. **14**B illustrates an example of beam repeating for beam refinement at Rx UE side where one SCI schedules one RS transmission.

[0030] FIG. **15** is a call flow of an example procedure for beam refinement at the Rx UE side only.

[0031] FIG. **16** is a call flow of an example procedure for gNB controlled beam forming at connectionless stage procedure with joint scheduling of initial beam establishment and fine tuning.

[0032] FIG. **17**A is a call flow of an example procedure for gNB controlled beam forming at connectionless stage procedure with separate scheduling of initial beam establishment and fine tuning.

[0033] FIG. **17**B is a call flow of an example procedure for gNB controlled beam forming at connectionless stage procedure with separate scheduling of initial beam establishment and fine tuning.

[0034] FIG. **18** is a call flow of an example procedure for gNB controlled beam forming procedure at connection stage with scheduling DCI transmitted to Tx UE only.

[0035] FIG. **19** is a call flow of an example procedure for gNB controlled beam forming procedure at connection stage with scheduling DCI transmitted to both Tx UE and Rx UE.

[0036] FIG. **20**A illustrates an example communications system.

[0037] FIGS. **20**B, **20**C, and **20**D are system diagrams of example RANs and core networks.

[0038] FIG. **20**E illustrates another example communications system.

[0039] FIG. **20**F is a block diagram of an example apparatus or device, such as a WTRU.

[0040] FIG. **20**G is a block diagram of an exemplary computing system.

DETAILED DESCRIPTION

[0041] Table 1 includes many abbreviations used herein.

TABLE-US-00001 TABLE 1 Abbreviations BSR Buffer Status Report DCI Downlink Control Information FR1 Frequency Range 1 GNSS Global Navigation Satellite System L1-SINR Layer-1 Signal to Interference Noise Ratio LTE Long Term Evolution MAC Medium Access Control MAC-CE MAC Control Element MSB Most Significant Bit NR New Radio PSCCH Physical Sidelink Control Channel PSSCH Physical Sidelink Shared Channel QCL Quasi Co-Locate QoS Quality of Service RAN Radio Access Network RRC Radio Resource Control RS Reference Signal RSRP Reference Signal Received Power RSRQ Reference Signal Received Quality SCI Sidelink Control Information SL-CSI-RS Sidelink Channel State Information Reference Signal SL-DMRS Sidelink Demodulation Reference Signal SLSS Sidelink Synchronization Signal SR Scheduling Request TCI Transmission Configuration Indicator UE User Equipment V2V Vehicle-to-Vehicle V2X Vehicle-to-everything

LTE V2X

[0042] Vehicular communication services, represented by LTE V2X services, can consist of the following four different types: V2V, V2I, V2N and V2P.

[0043] V2X services can be provided by PC5 interface and/or Uu interface. Support of V2X services via PC5 interface is provided by V2X sidelink communication, which is a mode of communication whereby UEs can communicate with each other directly over the PC5 interface. This communication mode is supported when the UE is served by E-UTRAN and when the UE is outside of E-UTRA coverage. Only the UEs authorized to be used for V2X services can perform V2X sidelink communication.

[0044] LTE-Uu can be unicast and/or MBMS. These two operation modes may be used by a UE independently for transmission and reception, e.g. a UE can use MBMS for reception without using LTE-Uu for transmission. A UE may also receive V2X messages via LTE-Uu unicast downlink.

USE CASES AND REQUIREMENTS FOR NR V2X

[0045] As Vehicle-to-everything (V2X) applications make significant progress, transmission of short messages about vehicles' own status data for basic safety needs to be extended with transmission of larger messages containing raw sensor data, vehicles' intention data, coordination, confirmation of future man oeuvre, etc. For these advanced applications, the expected requirements to meet the needed data rate, latency, reliability, communication range and speed are made more stringent.

[0046] For enhanced V2X (eV2X) services, 3GPP has identified 25 use cases and the related

requirements in 3GPP TR 22.886 Study on enhancement of 3GPP Support for 5G V2X Services, Release 15, V15.2.0.

[0047] A set of the normative requirements are specified in 3GPP TS 22.186 Enhancement of 3GPP support for V2X scenarios (Stage 1), Release 15, V15.3.0, where the use cases are categorized into four groups: vehicle platooning, extended sensors, advanced driving, and remote driving.

[0048] Among the 25 identified use cases, high data rate and/or long communication range is required by the following use cases: sensor and state map sharing, information sharing for high/full automated driving, information sharing for high/full automated platooning, and video data sharing for assisted and improved automated driving.

[0049] The detailed description of performance requirements for each use case group is specified in TS 22.186.

RESOURCE ALLOCATION MODE IN NR V2X

[0050] In NR V2X, sidelink resource allocation mode **1** and mode **2** are supported. In mode **1**, the base station schedules the sidelink resources used by the UE for sidelink transmission. In mode **2**, a UE determines the sidelink resources used for sidelink transmission within the sidelink resources configured by the base station or pre-configured sidelink resources.

[0051] Mode **1** supports the gNB to assign the sidelink resources for both dedicated sidelink carrier and shared licensed carrier between Uu and sidelink through the Uu interface. The resources used for sidelink transmission may be dynamically allocated, or pre-configured by the RRC, or based on activation and deactivation.

[0052] In mode **2**, the resources used for sidelink transmission may be determined by following resource allocation sub-modes: UE autonomously selects sidelink resource for transmission, UE assists sidelink resource selection for other UE(s), UE is configured with NR configured grant (type-1 like) for sidelink transmission, and UE schedules sidelink transmissions of other UEs.

EXAMPLE CHALLENGES

[0053] In NR beam management P**1**, gNB sweeps the beams and sends different SSBs on each beam. A UE measures the SSBs and indicates the preferred beam for initial beam establishment by performing the random-access transmission associated with the selected SSB. In NR V2X, a UE may try to establish beam pair link with a synchronization source V2X UE or a non-synchronization source V2X UE, where only synchronization source V2X UE will send SSB, and non-synchronization source will not send SSB. Also, PRACH is not supported in NR V2X. The mechanism UEs establish their beam pair link in NR V2X needs to be addressed.

EXAMPLE SOLUTIONS

[0054] Beam management in NR V2X may be managed in several ways. For example, initial beam establishment in NR V2X mode **2** may include initial beam establishment using SLSS, SL-CSI-RS, or SL-DMRS, for example, as well as a mechanism for reporting the preferred beam. Procedures for beam refinement in NR V2X mode **2** may include refinement at both UE, for example, or only at the Rx UE side.

[0055] Similarly, there are options for procedures of gNB controlled initial beam establishment and beam refinement in NR V2X mode **1**. These include, for example: gNB controlled beam forming at connectionless stage; gNB controlled beam forming at connection stage with scheduling DCI transmitted to Tx UE only; and gNB controlled beam forming at connection stage with scheduling DCI transmitted to both Tx UE and Rx UE. BEAM FORMING AND MANAGEMENT IN NR V2X MODE **2**

[0056] In NR V2X mode **2**, two UEs (UE**1** and UE**2**), e.g., two vehicular UEs, or one vehicular UE and one non-vehicular UE, etc., may form beam pair link to conduct sidelink communication. High-level overviews of the beam forming procedures are depicted in FIG. **1**A and FIG. **1**B.

[0057] Step **1** of FIG. **1**A and FIG. **1**B is initial beam establishment at connectionless or at connection stage. One vehicular UE, e.g., UE**1**, may sweep the beams and transmit reference signal (RS) on each beam. The other UE, e.g., UE**2**, may monitor and measure the transmitted RS. Based

on the measurement result, UE**2** may identify the preferred beam and establish the initial beam pair with UE**1**.

[0058] Step **2** is beam refinement at connection stage, wherein, after establishing the initial beam pair, UE**1** and UE**2** may further refine the beam pair to improve the beam condition. This may be done in different ways, as illustrated in the FIGS. **1**A and **1**B. In step **2**A of FIG. **1**A, beam refinement occurs at the UE**2** side only. UE**1** may use the beam identified in the initial beam establishment as the Tx beam for the sidelink communication. Or UE**1** may form a narrow beam that is quasi co-located (QCL-ed) with the beam identified in the initial beam establishment, e.g., pointing to the same direction with narrower beam width, as the Tx beam. The UE**2** may further refine its beam to have a better alignment with the beam used by UE**1**.

[0059] In step **2**B of FIG. **1**B, beam refinement first occurs at the at UE**1** side. With the knowledge of the identified beam in the initial beam establishment, UE**1** may further refine its beam, e.g., UE**1** may perform another beam sweeping with narrower beams. UE**2** may measure and identify the preferred beam among the refined UE**1** beams. In step **2**C of FIG. **1**B, beam refinement then occurs at the UE**2** side, whereby. UE**2** may further refine its beam to have a better alignment with the refined beam used by UE**1**.

INITIAL BEAM ESTABLISHMENT AT CONNECTIONLESS STAGE

[0060] In an example Case **1**, before UE**1** and UE**2** can communicate on the sidelink, the two UEs need to get synchronized. UE**1** may be the synchronization source and send sidelink synchronization signal (SLSS). UE**2** monitors and detects the SLSS to get synchronized with UE**1**, and vice versa.

[0061] In another example Case **2**, UE**1** and UE**2** may be synchronized with another synchronization source, where it can be the Global Navigation Satellite System (GNSS), a NR gNB, an LTE eNB, a NR V2X RSU, a NR V2X synchronization UE, or an LTE V2X synchronization UE. After UE**1** and UE**2** get synchronized, discovery procedure is performed and then they can communicate on the sidelink.

[0062] When UE**1** and UE**2** want to communicate on the sidelink through beam pair, a high-level overview of an example initial beam establishment procedure is depicted in FIG. **2**.

[0063] Step **1** of FIG. **2** is initial beam sweeping. One vehicular UE, e.g., UE**1**, may sweep the beams and transmit reference signal (RS) on each beam, where the RS may be an SLSS for Case **1**, a sidelink channel state information reference signal (SL-CSI-RS), or a sidelink demodulation reference signal (SL-DMRS) for Case **1** and/or **2**.

[0064] The RS may be transmitted standalone, e.g., SLSS for Case **1**, standalone SL-CSI-RS for Case **1** and/or **2**, where the RS does not need to be transmitted together with a data.

[0065] The RS may be transmitted with data or sidelink control information, e.g., SL-CSI-RS with PSSCH, SL-DMRS of PSCCH, or PSSCH. In another word, when UE**1** does not have data or sidelink control information to transmit, it cannot transmit the RS. For example, the RS may be transmitted together with discovery message, regular data, or dummy data, on the physical sidelink shared channel (PSSCH). The RS may also be transmitted with the sidelink control information (SCI) on the PSCCH, e.g., SL-DMRS for physical sidelink control channel (PSCCH).

[0066] Step **2** is measuring and identifying the preferred beam or beams. UE**2** monitors and measures the received RS. UE**2** identifies the preferred beam(s) based on the measurement results.

[0067] For example, UE**2** may measure the reference signal received power (RSRP), or the reference signal received quality (RSRQ), or the layer-**1** signal to interference noise ratio (L**1**-SINR) of the received RS.

[0068] UE**2** may identify one preferred beam, e.g., the beam on which the RS having the best measurement result is transmitted. Or UE**2** may identify multiple preferred beams and form a preferred beam list. The measurement result of the identified beam(s) should be higher than a threshold, e.g., Q.sub.thresh, otherwise, UE**2** may claim no preferred beam is identified.

[0069] Step **3** is indicating the identified beam(s). UE**2** indicates the identified preferred beam or

beam list to UE**1**. Based on the response provided by UE**2**, UE**1** may form one or multiple initial beam pair links with UE**2**.

INITIAL BEAM SWEEPING USING SLSS

[0070] The initial beam pair link may be established based on the SLSS transmitted by UE**1**. This may be applicable to the case when UE**1** is a synchronization source, and when UE**2** is synchronized with UE**1** and UE**2** wants to establish the beam pair with UE**1**.

[0071] As a synchronization source, UE**1** may periodically sweep the beams to different directions with each beam associated with one SLSS.

[0072] When UE**2** determines UE**1** is the synchronization source within the proximity by detecting the SLSS transmitted from UE**1**, and if there is no other higher priority synchronization source available, e.g., GNSS, or NR gNB, or LTE eNB, UE**2** will get synchronized with UE**1**. As UE**1** is sweeping its SLSS, UE**2** may detect multiple SLSSs from UE**1** with different measurement results. Based on the measurement results, UE**2** may identity one or multiple beam(s) as the preferred beam. The measurement result of the identified beam(s) should be higher than a threshold, e.g., Q.sub.thresh, SLSS, otherwise, UE**2** may claim no preferred beam is identified.

[0073] UE**2** may periodically monitor and measure the SLSS transmitted by UE**1** before establishing initial beam pair link with UE**1**. There may be two scenarios that UE**1** and UE**2** may establish beam pair link with each other.

[0074] In one scenario, UE**2** may be triggered by UE**1**, e.g., UE**2** may receive an indication from UE**1**, to establish beam pair link. In another scenario, UE**2** may be triggered by its higher layer, UE**2** has data to be transmitted to UE**1**, to establish beam pair link.

[0075] When UE**2** is triggered to establish beam pair link with UE**1**, UE**2** may determine the preferred beam(s) using the latest measurement or k most recent measurements and report the preferred beam(s) to UE**1**.

INITIAL BEAM SWEEPING USING SL-DMRS OR SL-CSI-RS PIGGYBACKED WITH PSSCH

[0076] Initial beam sweeping may use SL-DMRS or SL-CSI-RS piggybacked with PSSCH. When a vehicular UE, e.g., UE**1**, initiates a first PSSCH transmission, for example a discovery procedure, in one case, it may transmit the discovery message e.g., 'I am here.', or 'who is there?' on the PSSCH using omni-direction antenna. Or, in another case, UE**1** may sweep the discovery message on the PSSCH to different directions or certain direction(s) for discovery based on the potential discoverees' directions or locations using different beams.

SL-DMRS BASED INITIAL BEAM SWEEPING

[0077] When UE**1** sweeps the discovery message on PSSCH, UE**1** may transmit SL-DMRS with the PSSCH to assist other UEs to estimate the channel and decode the data as shown in FIG. **3**A and FIG. **3**B.

[0078] UE**1** may transmit one discovery massage in one slot and sweep the beams in slot level as shown in FIG. **3**A. Or, UE**1** may transmit multiple discovery massages in one slot and sweep the beams in mini-lot level, where a mini-slot may contain 2-13 symbols, as shown in FIG. **3**B.

[0079] The SL-DMRS for PSSCH which carries the discovery massage may be also used by other UEs to measure and identify the preferred beam(s).

[0080] For example, UE**1** may transmit the PSSCH carrying the discovery massage on k beams, e.g., beam **1**, beam **2**, . . . , beam k. When UE**2** monitors and detects the discovery massage, it may measure the received SL-DMRS on the PSSCH. Based on the measurement results, UE**2** may identify one or multiple preferred beam(s). The measurement result of the identified beam(s) should be higher than a threshold, e.g., Q.sub.thresh,DMRS, otherwise, UE**2** may claim no preferred beam is identified.

[0081] The SL-DMRS configuration used in the PSSCH carrying the discovery massage may be associated with the beam and varies with the different beams. For example, the SL-DMRS for beam **1** and beam **2** may have different ports (e.g., RE mapping in the time domain and/or

frequency domain) and/or sequences.

SL-CSI-RS BASED INITIAL BEAM SWEEPING

[0082] When a UE sends the PSSCH carrying the discovery massage, it may transmit SL-CSI-RS on the PSSCH for other UEs to measure and identify the preferred beam(s) as shown in FIG. **4**.

[0083] The example in FIG. **4** shows an example of slot level SL-CSI-RS based beam sweeping. Like SL-DMRS based beam sweeping, the SL-CSI-RS based beam sweeping may be also swept in mini-slot level.

[0084] For a UE receiving the discovery massage, e.g., UE**2**, it may use the SL-DMRS on the PSSCH to estimate the channel and decode the data. UE**2** may use the transmitted SL-CSI-RS on the PSSCH to measure the beam condition and identify the preferred beam(s). The measurement result of the identified beam(s) should be higher than a threshold, e.g., Q.sub.thresh,CSI-RS, otherwise, UE**2** may claim no preferred beam is identified.

[0085] The SL-CSI-RS configuration used in the PSSCH carrying the discovery massage may be associated with the beam and varies with the different beams. For example, the SL-CSI-RS for beam **1** and beam **2** may have different ports (e.g., RE mapping in the time domain and/or frequency domain) and/or sequences.

BEAM INDEX INDICATING

[0086] Each PSSCH carrying the discovery massage is associated with one beam index. To allow other UE to figure out the beam index of the beam transmitting the PSSCH, there are at least five alternatives.

[0087] First, the beam index information may be indicated by the SCI scheduling the PSSCH carrying the discovery massage. Before UE**1** sends the PSSCH carrying the discovery massage, UE**1** will first send the SCI scheduling the PSSCH. In the scheduling SCI, a SCI field may be used to carry the beam index of the beam used for transmitting the scheduled PSSCH. For example, assume the maximum number of the supported beams is 32, a 5-bits field, e.g., beam index indicator field, may be used to explicit indicate the beam index. When 2-stage SCI is used to schedule the PSSCH carrying the discovery massage, this field may be carried by the 2nd stage SCI. After UE**2** decode this SCI field, it can figure out the beam index of the transmission.

[0088] Second, beam index information may be carried by the data payload. The beam index information may be carried by the data channel, e.g., PSSCH. The beam index information may be carried by the data transmitted on the PSSCH. After UE**2** decodes the data transmitted on the PSSCH, it can figure out the beam index of the transmission.

[0089] Third, the beam index information may be carried by the RS port. The beam index information may be carried by the RS port used in the PSSCH carrying the discovery massage or the RS port used in the PSCCH carrying the SCI. For example, the RS used in beam **1** and beam **2** may have different ports, e.g., RE mapping in the time domain and/or frequency domain. When SL-DMRS is used for beam measurement, such information may be carried by the SL-DMRS port as shown in FIG. **5**A. When SL-CSI-RS is used for beam measurement, such information may be carried by the SL-CSI-RS port as shown in FIG. **5**B; or may be carried by the SL-DMRS port as shown in FIG. **5**C. UE**1** may indicate the RS port information in the SCI associated with the PSSCH, e.g., using the SCI field 'CSI-RS port indicator field' or 'DMRS port indicator field'. UE**2** determines the RS port information and the beam index information by decoding such SCI field. Or, UE**1** may not indicate the RS port information in the SCI. UE**2** determines the RS port information and the beam index information by blindly detecting the DMRS or CSI-RS transmitted in the PSSCH.

[0090] Fourth, the beam index information may be carried by the RS sequence. The beam index information may be carried by the RS sequence used in the PSSCH carrying the discovery massage or the RS port used in the PSCCH carrying the SCI. For example, the RS used in beam **1** and beam **2** may use different initialization sequences. When SL-DMRS is used for beam measurement, such information may be carried by the SL-DMRS sequence. When SL-CSI-RS is used for beam

measurement, such information may be carried by the SL-CSI-RS sequence; or may be carried by the SL-DMRS sequence.

[0091] Fifth, the beam index information may be carried by a combination of the RS sequence and the RS port. For example, assume N total bits of information need to transmit to indicate the beam index. The k most significant bits (MSBs) may be carried by the RS port and the rest N-k bits may be carried by the RS sequence, and vice versa.

[0092] The PHY layer may need to know the V2X communication state to determine the corresponding procedure needed to be conducted, e.g., to start the initial beam establishment procedure, or to start the beam refinement procedure, etc. For example, if a UE (e.g., UE**1**) determines it is in the state of discovering with another UE (e.g., UE**2**), UE**1** may conduct the initial beam establishment procedure to establish beam pair link with UE**2**.

[0093] A UE may be explicitly indicated with the V2X communication state. For example, when a UE receives a massage from the higher layer to be transmitted on the sidelink, the higher layer may send an indication to let the UE know if the massage is a discovery message or other massage. If the massage is a discovery message, the UE determines it is in the V2X discovery state. Or, in another alternative, a UE may be implicitly indicated with the V2X communication state. For example, a UE may implicitly derive the current V2X communication state from some known information.

[0094] When the UE transmits the discovery message on the sidelink using PSSCH, it may send an indication to notify other UEs if the data transmitted on the PSSCH is a discovery message or other data. Such information may be indicated in at least three ways.

[0095] First, a field in the scheduling SCI may be used to indicate if the scheduled PSSCH is carrying the discovery message or other data. For example, a 1-bit field, discovery massage indicator field, may be used. When the discovery massage indicator field is set to '0', it indicates the PSSCH is carrying other data; when the discovery massage indicator field is set to '1', it indicates the PSSCH is carrying the discovery massage.

[0096] Second, the SL-DMRS in the PSSCH or PSCCH may be used to indicate if the scheduled PSSCH is carrying the discovery message or other data by using different ports and/or different sequences. For example, the SL-DMRS in PSSCH carrying the discovery message and the SL-DMRS in PSSCH carrying other data may have different frequency offsets, e.g., one starts from REO and the other one starts from RE**1**. Or they may have different initialization sequences, e.g., they may have different c.sub.init values.

[0097] Third, the PSSCH that carries a discovery message may be transmitted on pre-configured resources, e.g., on the resource or resource pool dedicated for discovery only. Then, by detecting it, the UE knows it is a discovery message.

INITIAL BEAM ESTABLISHMENT AT CONNECTION STAGE

[0098] In some scenarios, the initial beam pair may not be automatically established during the synchronization procedure and the discovery procedure, which may apply to the case when the discovery procedure is not beam based, e.g., when two UEs use omni-direction antenna to do the discovery.

[0099] After two UEs finish the discovery procedure and set up the connection, one of the UE may initiate to establish beam pair link. A high-level overview of initiating the initial beam establishment procedure is depicted in FIG. **6**, which may contain the following steps:

[0100] Step **0** of FIG. **6** is discovery. Two UEs (UE**1** and UE**2**) perform discovery procedure on the sidelink and set up connection.

[0101] Step **1** is the triggering of beam establishment. A UE, e.g., UE**1**, may receive a trigger of establishing beam pair link with the other UE, e.g., UE**2**. The trigger may be an indication sent by the higher layer based on certain quality of service (QOS) requirement.

[0102] Step **2** is initiate beam establishment. UE**1** may initiate the initial beam pair link establishment procedure with UE**2**. For example, UE**1** may send an initial beam pair link

establishment indicator to UE**2** to initiate the procedure.

[0103] Such indication may be a reference signal, e.g., SL-DMRS for SCI transmitted on the PSCCH; or may be a sidelink control information; or may be the data transmitted on the PSSCH, e.g., MAC-CE. The indication may also contain other information related to the beam sweeping such as: time domain and frequency domain resources used for the beam sweeping, RS configuration, etc.

[0104] Since UE**1** may already have established other connection with UE**2**, e.g., this connection may be a connection in frequency range **1** (FR**1**) using omnidirectional antenna or using very wide beam; or this connection may be a connection in frequency range **2** (FR**2**) using very wide beam, etc., UE**1** may send the indication and schedule, for example, in one of three ways.

[0105] First is indication on FR**1** and scheduling on FR**2**, whereby UE**1** may send the indication on the established connection, e.g., in FR**1**, and may send the schedule of the beam sweeping in FR**2**. Then UE**1** sweeps the beams as scheduled. An example is shown in FIG. **7**A. In this case, UE**1** may use different signaling to transmit such indication and the scheduling for beam sweeping.

[0106] Second is indication and scheduling on FR**1**, whereby UE**1** may send the indication and the schedule of the beam sweeping on the established connection e.g., in FR**1**. Then UE**1** sweeps the beams as scheduled. An example is shown in FIG. **7**B. For example, such indication may be transmitted together with the SCI scheduling the beam sweeping. Such indication may be carried by the SCI or may be carried by the DMRS for the SCI.

[0107] Third is indication and scheduling on FR**2**, whereby UE**1** may send the indication and the schedule of the beam sweeping in FR**2**. Then UE**1** sweeps the beams as scheduled. An example is shown in FIG. **7**C. For example, such indication may be transmitted together with the SCI scheduling the beam sweeping. Such indication may be carried by the SCI or may be carried by the DMRS for the SCI.

[0108] Step **3** is initial beam sweeping. UE**1**, may sweep the beams and transmit RS on each beam, where the RS may be a SL-CSI-RS, or a SL-DMRS.

[0109] The RS may be transmitted standalone, e.g., standalone SL-CSI-RS, where the RS does not need to be transmitted together with a data.

[0110] The RS may be transmitted with data or sidelink control information, e.g., SL-CSI-RS, SL-DMRS. In another word, when UE**1** does not have data or sidelink control information to transmit, it cannot transmit the RS. For example, the RS may be transmitted together with regular data or dummy data, etc., on the physical sidelink shared channel (PSSCH). The RS may also be transmitted with the SCI on the PSCCH, e.g., SL-DMRS for PSCCH.

[0111] Different from the synchronization procedure and the discovery procedure, where the UE may sweep the beams to all the directions, UE**1** may only sweep the beams within a range. UE**1** may determine such range using the information of UE**2** from the higher layer, e.g., location, direction, angle, relative speed, etc., extracted from the sensor, camera, etc.

[0112] Step **4** is measuring and identifying the preferred beam(s). UE**2** monitors and measures the received RS. UE**2** identify the preferred beam(s) based on the measurement results. For example, UE**2** may measure the RSRP, or the RSRQ, or the L**1**-SINR of the received RS. UE**2** may identify one preferred beam, e.g., the beam on which the RS having the best measurement result is transmitted. Or UE**2** may identify multiple preferred beams and form a preferred beam list. The measurement result of the identified beam(s) should be higher than a threshold, e.g., Q.sub.thresh, otherwise, UE**2** may claim no preferred beam is identified.

[0113] Step **5** is indicating the identified beam(s), whereby UE**2** indicates the identified preferred beam or beam list to UE**1**. Based on the response provided by UE**2**, UE**1** may form one or multiple initial beam pair links with UE**2**.

REPORTING THE PREFERRED BEAM

[0114] After UE**2** measures the RS on each beam, UE**2** may identify the preferred beam and notify UE**1**, reporting at connection stage or connectionless stage.

[0115] For reporting at connection stage, when UE**1** and UE**2** try to establish beam pair link, they may already have established other connection, e.g., connection in FR**1** communicating through omni direction or wide beams. In this case, UE**2** may send the response to UE**1** using the existing connection. For example, UE**1** may sweep the beam with RS in FR**2** and UE**2** may indicate the preferred beam to UE**1** through connection in FR**1**.

[0116] For reporting at connectionless stage, UE**2** may indicate the preferred beam to UE**1** through FR**2**. This may applicable to the case when there is no other available connection between UE**1** and UE**2**. In this case, UE**1** may sweep the beam with RS in FR**2** and UE**2** may indicate the preferred beam to UE**1** in FR**2** as well.

[0117] In the beam sweeping, UE**2** may identify one or multiple preferred beam(s).

[0118] The contents of the response sent from UE**2** to UE**1** may indicate preferred beam(s) only. For example, UE**2** may indicate the beam ID/index, or the RS port number, or the RS configuration ID/index, or the transmission configuration indicator (TCI) state of the prefer beam to UE**1**. UE**2** may only indicate one preferred beam in the response sent to UE**1**, e.g., indicate the beam with the best measurement result. Or UE**2** may indicate multiple preferred beams in the response sent to UE**1**, e.g., UE**2** may indicate k beam indexes to UE**1** with a decrement order of the beam condition.

[0119] The contents of the response sent from UE**2** to UE**1** may indicate preferred beam(s) and the corresponding measurement result. For example, UE**2** may indicate the beam index of the prefer beam and the corresponding RSRP or RSRQ value to UE**1**. UE**2** may indicate one or multiple preferred beam(s) to UE**1**. When UE**2** reports multiple preferred beams, UE**2** may indicate the absolute value of the measurement results for each beam in the reporting. Or UE**2** may indicate the absolute value of the measurement result for the best beam and the difference from a beam to the best beam for the rest beams in the reporting.

[0120] UE**2** may indicate the preferred beam to UE**1** explicitly by sending the response carrying the preferred beam information. UE**2** may also indicate the preferred beam to UE**1** implicitly by performing sidelink transmission to UE**1** using the selected beam.

[0121] The UE**2** may indicate the preferred beam to UE**1** using physical sidelink feedback channel (PSFCH), PSSCH, or PSCCH.

[0122] For reporting on PSFCH, the response carrying the preferred beam(s) may be transmitted on the PSFCH. For example, through the sidelink feedback control information (SFCI); or the DMRS for the SFCI, e.g., the preferred beam information may be carried by the DMRS port and/or DMRS sequence of the DMRS transmitted on the PSFCH.

[0123] For reporting on PSSCH, the response carrying the preferred beam(s) may be transmitted on the PSSCH. For example, through MAC PDU; or the DMRS for PSSCH, e.g., the preferred beam information may be carried by the DMRS port and/or DMRS sequence of the DMRS transmitted on the PSSCH.

[0124] For reporting on PSCCH, the response carrying the preferred beam(s) may be transmitted on the PSCCH. For example, through the field in the SCI; or the DMRS for SCI, e.g., the preferred beam information may be carried by the DMRS port and/or DMRS sequence of the DMRS transmitted on the PSCCH.

PREFERRED BEAM REPORTING USING UEI RESERVED RESOURCES

[0125] In NR V2X mode **2**, a UE need to sense the channel and reserve the resources before the transmission. In one approach, the resources used by UE**2** to transmit the response to UE**1** may be reserved by UE**1**. When UE**1** reserve the resource for beam sweeping, it may also reserve the resources for UE**2** to send the response.

[0126] UE**1** may reserve the resources through reserve signaling on FR**1** and the reporting is sent on FR**1** by UE**2**, whereby UE**1** may send the reserve signaling, e.g., scheduling SCI, on the existing connection, e.g., in FR**1**, and reserved the resources for sending the response on the existing connection, e.g., in FR**1**, as shown in FIGS. **8**A and **8**B. UE**1** may use different signalings to reserve the recourses used for beam sweeping and the resources used for sending the response as

shown in FIG. **8**A. UE**1** may use one signaling to reserve the resources used for beam sweeping and the resources used for sending the response as shown in FIG. **8**B. UE**2** may indicate the preferred beam index or the RS port number associate with the preferred beam in the response to allow UE**1** to figure out the preferred beam.

[0127] Alternatively, UE**1** may reserve the resources through reserve signaling sent on FR**1** and the reporting is sent on FR**2** by UE**2**. UE**1** may send the reserve signaling, e.g., scheduling SCI, on the existing connection, e.g., in FR**1**, and reserved the resources for sending the response in FR**2** as shown in FIG. **9**. UE**1** may reserve multiple resources where each resource may be associated with one beam. When UE**2** identifies the preferred beam, it may send response on the resource associated with the preferred beam. UE**1** may figure out the preferred beam by detecting response on the associated reserved resource.

[0128] Further, UE**1** may alternatively reserve the resources through reserve signaling on FR**2** and the reporting is sent on FR**2** by UE**2**. UE**1** may send the reserve signaling, e.g., scheduling SCI, in FR**2**, and reserved the resources for sending the response in FR**2** as shown in FIG. **10**. UE**1** may reserve multiple resources where each resource may be associated with one beam. When UE**2** identifies the preferred beam, it may send response on the resource associated with the preferred beam. UE**1** may figure out the preferred beam by detecting response on the associated reserved resource.

[0129] Also, UE**1** may alternatively reserve the resources through reserve signaling sent on FR**2** and the reporting is sent on FR**1** by UE**2**. UE**1** may send the reserve signaling, e.g., scheduling SCI, in FR**2**, and reserved the resources for sending the response on the existing connection, e.g., in FR**1**, as shown in FIG. **11**. For example, the same resource may be associated with different beam sweeping in the FR**2**. UE**2** may indicate the preferred beam index or the RS port number associate with the preferred beam in the response to allow UE**1** to figure out the preferred beam.

PREFERRED BEAM REPORTING SCHEDULED BY UE**2**

[0130] In another approach, the resources used by UE**2** to transmit the response to UE**1** may be reserved by UE**2**. For example, UE**1** may only reserve the resources for beam sweeping. After UE**2** measures the RS and identifies the preferred beam, UE**2** may reserve a transmission, e.g., using SCI, to send the response to UE**1** as shown in FIG. **12**. The UE**2** may reserve the transmission of the response in several ways.

[0131] First, UE**2** may schedule the reporting on FR**1**. UE**2** may reserve the resource and transmit the response on the existing connection, e.g., in FR**1**, as shown in FIG. **12**A. UE**2** may indicate the preferred beam index or the RS port number associate with the preferred beam in the response to allow UE**1** to figure out the preferred beam.

[0132] Second, UE**2** may schedule the reporting on FR**2**, whereby UE**2** reserves the resource and transmit the response on the preferred beam as shown in FIG. **12**B. For example, assume UE**2** identifies beam **2** is the best beam, then UE**2** may reserve the resource and transmit the response on beam **2**. UE**1** may figure out beam **2** is the preferred beam by detecting response.

BEAM REFINEMENT IN NR V2X MODE **2**

[0133] After UE**1** and UE**2** establish the initial beam pair link, they may perform beam refinement procedure to further improve the beam condition, e.g., fine tune the beams to make them better aligned. In this section, two schemes on the beam refinement procedure are elaborated.

BEAM REFINEMENT AT BOTH UE SIDES

[0134] In one approach, the beam refinement procedure may happen at both UE sides. A high-level overview of the beam refinement procedure at both UE sides is depicted in FIG. **13**.

[0135] Step **0** of FIG. **13** is initial beam establishment. UE**1** and UE**2** perform initial beam establishment. After this procedure, UE**1** receives indication from UE**2** with one or multiple preferred beam(s). For example, UE**1** may be indicated with beam k as the preferred beam.

[0136] Step **1** is finer beam sweeping at UE**1** side. With the information of the initial beam sweeping, e.g., the beam width, the angle rotated between each beam, etc.; and the information of

the preferred beam indicated by UE**2**, e.g., beam k in this example, UE**1** may perform another round of finer beam sweeping around beam k with one or more of the following alternatives.

[0137] First is finer beam sweeping with narrower beams. UE**1** may form beams with narrower beam width comparing to the one used in the initial beam sweeping and sweep them.

[0138] Second is finer beam sweeping with smaller rotation angle. Assume in initial beam sweeping, the beam is rotated by $\theta.\text{sub.init}$ degree each time. In the finer beam sweeping, UE**1** may rotate the beam by $\theta.\text{sub.finer}$ degree, where $\theta.\text{sub.finer} < \theta.\text{sub.init}$, between each beam transmission.

[0139] Third is finer beam sweeping with a smaller sweeping range. In the initial beam sweeping, UE**1** may sweep the beam in $\alpha.\text{sub.init}$ degree range, e.g., $\alpha.\text{sub.init} = 360$. In the finer beam sweeping, UE**1** may sweep the beam with a smaller range. For example, UE**1** may sweep the beam in $\alpha.\text{sub.finer}$ degree range around the direction of the preferred beam k, where $\alpha.\text{sub.finer} < \alpha.\text{sub.init}$.

[0140] Fourth is finer beam sweeping with a smaller number of swept beams. Assume UE**1** sweeps the beam in K directions in the initial beam sweeping, in the finer beam sweeping, UE**1** may only sweep the beam in N directions, where N<K.

[0141] The ideas proposed for the RS used for initial beam sweeping may be also applied here. For example, the RS may be SL-CSI-RS or may be SL-DMRS. The RS may be transmitted standalone, or the RS may be transmitted with data or sidelink control information.

[0142] Step **2** of FIG. **13** is measuring and identifying the preferred beam(s). UE**2** monitors and measures the received RS. UE**2** identifies the preferred beam(s) based on the measurement results. The ideas proposed for measuring the RS in initial beam establishment may be also applied here. For example, UE**2** may measure the RSRP, RSRQ, or the L**1**-SINR of the received RS. UE**2** may identify one or multiple beam(s) as the preferred beam(s). The measurement result of the identified beam(s) should be higher than a threshold, e.g., Q.sub.thresh, otherwise, UE**2** may claim no preferred beam is identified.

[0143] Step **3** is indicating the identified beam(s). UE**2** indicates the identified preferred beam or beam list to UE**1**. The ideas proposed for reporting the preferred beam in initial beam establishment may be also applied here. For example. UE**2** may explicit indicate the preferred beam or UE**2** may implicit indicate the preferred beam. UE**2** may indicate the preferred beam to UE**1** using PSFCH, using PSSCH or using PSCCH. UE**2** may indicate the preferred beam to UE**1** through an existing connection, e.g., connection in FR**1**; or through the identify beam.

[0144] Step **4** is repeating the beam at UE**1** side. UE**1** may fix the beam as the preferred beam indicated by UE**2** and transmit the RS multiple times on it. When UE**1** is indicated with multiple preferred beams, UE**1** may autonomously select one and transmit the RS multiple times on it. Like the beam sweeping, the RS may be SL-CSI-RS or may be SL-DMRS. The RS may be transmitted standalone, or the RS may be transmitted with data or sidelink control information. UE **1** may schedule one sidelink transmission which contains multiple RS transmission as shown in FIG. **14**A; or UE **1** may schedule multiple sidelink transmissions where each one may contain one RS transmission as shown in FIG. **14**B. In the figure, SL-CSI-RS is used as the example to be transmitted for beam refinement. The RS may also be the SL-DMRS as another option.

[0145] Step **5** is beam refinement at UE**2** side. UE**2** may sweep its beam and measure the RS transmitted by UE**1** using the same beam. UE**2** may determine the beam having the best measurement result as the beam having alignment with UE**1**. UE**2** may use the determined best beam to communicate with UE**1**, e.g., receiving data from UE**1** and/or transmitting data to UE**1**.

BEAM REFINEMENT AT UE**2** SIDE ONLY

[0146] In another approach, to reduce the complexity of the beam refinement procedure, thereby reducing the latency, the beam refinement procedure may happen only at UE**2** side. A high-level overview of the beam refinement procedure at UE**2** side only is depicted in FIG. **15**.

[0147] Step **0** of FIG. **15** is initial beam establishment. UE**1** and UE**2** perform initial beam

establishment. After this procedure, UE**1** is indicated by UE**2** with one or multiple preferred beam(s). For example, UE**1** may be indicated with beam k as the preferred beam.

[0148] Step **1** is repeating the beam at UE**1** side. UE**1** may fix k beam as the Tx beam and transmit the RS multiple times on it. When UE**1** is indicated with multiple preferred beams, UE**1** may autonomously select one and transmit the RS multiple times on it. Like the beam sweeping, the RS may be SL-CSI-RS or may be SL-DMRS. The RS may be transmitted standalone, or the RS may be transmitted with data or sidelink control information.

[0149] Step **2** is beam refinement at UE**2** side. UE**2** may sweep its beam and measure the RS transmitted by UE**1** using the same beam. UE**2** may determine the beam having the best measurement result as the beam having alignment with UE**1**. UE**2** may use the determined best beam to communicate with UE**1**, e.g., receiving data from UE**1** and/or transmitting data to UE**1**.

BEAM FORMING AND MANAGEMENT IN NR V2X MODE **1**

[0150] In NR V2X mode **1**, sidelink communication is controlled by the gNB. When two UEs (UE**1** and UE**2**), e.g., two vehicular UEs, or one vehicular UE and one non-vehicular UE etc., want to form beam pair to conduct sidelink communication, gNB controlled beam forming procedure may be conducted.

[0151] When a UE, e.g., UE**1** wants to establish beam pair link with other UE within the proximity, the beam forming may be conducted at either connectionless stage or connection stage. For example, UE**1** may form the beam with a known UE, e.g., UE**2**, which may have already established some connection with UE**1**. In this case, the beamforming may be conducted at connection stage. For another example, UE**1** may form the beam with an unknown UE, e.g., any UE x within the proximity, which may have not established any connection with UE**1**. In this case, the beamforming may be conducted at connection stage.

GNB CONTROLLED BEAM FORMING AT CONNECTIONLESS STAGE WITH JOINT SCHEDULING OF INITIAL BEAM ESTABLISHMENT AND FINE TUNING

[0152] A high-level overview of the gNB controlled beam forming procedure at connectionless stage is depicted in FIG. **16**.

[0153] Step **1** of FIG. **16** is the triggering of beam establishment. A UE, e.g., UE**1**, may receive a trigger to, or may want to establish beam pair link with an unknown UE. The trigger may be an indication sent by the higher layer based on certain quality of service (QoS) requirement.

[0154] Step **2** is requesting a resource from a gNB. UE**1** may send a signaling to gNB to request the resources, e.g., PSCCH, PSSCH, and/or PSFCH, for establishing the beam pair with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BRS), etc.

[0155] In step **3**, the gNB schedules the resources for initial beam establishing and beam refinement. gNB may schedule the resources on sidelink used by UE**1** and UE**2** to establish the initial beam and further refine the beam through DCI. The DCI may schedule multiple transmissions on the sidelink, where are used for establishing the initial beam and further refining the beam separately. Since UE**1** is in connectionless stage, gNB may only send the scheduling DCI to the Tx UE (UE**1**). Then UE**1** may forward the scheduled sidelink transmission to another UE using SCI.

[0156] Step **4** is initial beam establishment at connectionless stage. UE**1** may conduct the initial beam establishment procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for establishing the initial beam in V2X mode **2** at connectionless stage may be also applied here.

[0157] Step **5** is beam refinement. UE**1** may conduct the beam refinement procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for refining beam in V2X mode **2** may be also applied here.

GNB CONTROLLED BEAM FORMING AT CONNECTIONLESS STAGE WITH SEPARATE SCHEDULING OF INITIAL BEAM ESTABLISHMENT AND FINE TUNING

[0158] In another approach, another set of gNB controlled beam forming procedures at connectionless stage is depicted in FIG. **17**A and **17**B. The examples of FIG. **17**A and FIG. **17**B vary at step **6**.

[0159] In both FIG. **17**A and FIG. **17**B, step **1** is the triggering of beam establishment. A UE, e.g., UE**1**, may receive a trigger to or may want to establish beam pair link with an unknown UE, e.g., UE**2**. The trigger may be an indication sent by the higher layer based on certain quality of service (QOS) requirement.

[0160] Step **2** is a request for a resource from the gNB for initial beam establishment. UE**1** may send a signaling to gNB to request the resources, e.g., PSCCH, PSSCH, and/or PSFCH, for establishing the initial beam pair with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BRS), etc.

[0161] In step **3**, the gNB schedules the resources for initial beam establishment. The gNB may schedule the resources on sidelink used by UE**1** and UE**2** to establish the initial beam through DCI. Since UE**1** is in connectionless stage, gNB may only send the scheduling DCI to the Tx UE (UE**1**). Then UE**1** may forward the scheduled sidelink transmission to other UE(s) using SCI.

[0162] Step **4** is initial beam establishment. UE**1** may conduct the initial beam establishment procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for establishing the initial beam in V2X mode **2** (at connection stage and/or at connectionless stage) may be also applied here.

[0163] Step **5** is requesting a resource for beam refinement from the gNB. After establishing the initial beam pair link, UE**1** may send a signaling to gNB to request the resources for further refining the beam with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BRS), etc.

[0164] The examples of FIG. **17**A and FIG. **17**B differ at step **6**. In step **6***a* of FIG. **17**A, the gNB schedules the resources for beam refinement and sends scheduling DCI to Tx UE only. gNB may schedule the resources on sidelink used by UE**1** and UE**2** to further refine the beam through DCI. gNB may only send the scheduling DCI to the Tx UE (UE**1**).

[0165] In step **6***b* of FIG. **17**A, the Tx UE forward the scheduled sidelink transmission to Rx UE using SCI. UE**1** may forward the scheduled sidelink transmission to the Rx UE using SCI.

[0166] In steps **6***c* and **6***d* of FIG. **17**B, the gNB schedules the resources for beam refinement and sends scheduling DCI to both Tx UE and Rx UE. gNB may schedule the resources on sidelink used by UE**1** and UE**2** to further refine the beam through DCI. gNB may send the scheduling DCI to both the Tx UE (UE**1**) and the Rx UE (e.g., UE**2**). Note: step **6***c* and step **6***d* may be conducted simultaneously, or step **6***c* may be conducted before step **6***d*, and vice versa.

[0167] Step **7** is beam refinement. Step **7** is the same in FIG. **17**A and FIG. **17**B. UE**1** may conduct the beam refinement procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for refining beam in V2X mode **2** may be also applied here.

GNB CONTROLLED BEAM FORMING AT CONNECTION STAGE WITH SCHEDULING DCI TRANSMITTED TO TX UE ONLY

[0168] A high-level overview of the gNB controlled beam forming procedure at connection stage with scheduling DCI transmitted to Tx UE only is depicted in FIG. **18**.

[0169] Step **1** of FIG. **18** is the triggering of beam establishment. A UE, e.g., UE**1**, may receive a trigger to or may want to establish beam pair link with a known UE, e.g., UE**2**. The trigger may be an indication sent by the higher layer based on certain quality of service (QOS) requirement.

[0170] Step **2** is requesting a resource for initial beam establishment from the gNB. UE**1** may send a signaling to gNB to request the resources, e.g., PSCCH, PSSCH, and/or PSFCH, for establishing the initial beam pair with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BRS), etc.

[0171] In step **3**, the gNB schedules the resources for initial beam establishing and sends scheduling DCI to Tx UE only. The gNB may schedule the resources on sidelink used by UE**1** and

UE**2** to establish the initial beam through DCI. gNB may send the scheduling DCI to the Tx UE (UE**1**) only.

[0172] Step **4** is the initiation of the beam establishment. Step **4** is optional. UE**1** may initiate the initial beam pair link establishment procedure with UE**2**. For example, UE**1** may send an initial beam pair link establishment indicator to UE**2** to initiate the procedure.

[0173] In step **5**, the Tx UE forwards the scheduled sidelink transmission for initial beam establishment to Rx UE using SCI. El may forward the scheduled sidelink transmission for initial beam establishment to the Rx UE using SCI.

[0174] Step **6** is initial beam establishment at connection stage. UE**1** may conduct the initial beam establishment procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for establishing the initial beam in V2X mode **2** at connection stage may be also applied here.

[0175] Step **7** is a request resource for beam refinement from gNB. After establishing the initial beam pair link, UE**1** may send a signaling to gNB to request the resources for further refining the beam with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BRS), etc.

[0176] In step **8**, the gNB schedules the resources for beam refinement and sends scheduling DCI to Tx UE only. The gNB may schedule the resources on sidelink used by UE**1** and UE**2** to further refine the beam through DCI. gNB may send the scheduling DCI to the Tx UE (UE**1**) only.

[0177] In step **9**, the Tx UE forwards the scheduled sidelink transmission for beam refinement to the Rx UE using SCI. UE**1** may forward the scheduled sidelink transmission for beam refinement to the Rx UE using SCI.

[0178] Step **10** is beam refinement. UE**1** may conduct the beam refinement procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for refining beam in V2X mode **2** may be also applied here.

[0179] The Proposed procedures here may be applied to the case when UE**1** is under gNB's coverage while UE**1** is out of gNB's coverage. The Proposed procedures here may be also applied to the case when both UE**1** and UE**2** are under gNB's coverage.

[0180] The procedure in FIG. **18** shows an example where the resources used for initial beam sweeping and for further fine tuning are separately scheduled by gNB using different DCIs. In another example, like FIG. **16**, the resources used for initial beam sweeping and for further fine tuning may be jointly scheduled by gNB using one DCI.

GNB CONTROLLED BEAM FORMING AT CONNECTION STAGE WITH SCHEDULING DCI TRANSMITTED TO BOTH TX UE AND RX UE

[0181] A high-level overview of the gNB controlled beam forming procedure at connection stage with scheduling DCI transmitted to both Tx UE and Rx UE is depicted in FIG. **19**.

[0182] Step **1** of FIG. **19** is the triggering of beam establishment. A UE, e.g., UE**1**, may receive a trigger to or may want to establish beam pair link with a known UE, e.g., UE**2**. The trigger may be an indication sent by the higher layer based on certain quality of service (QOS) requirement.

[0183] Step **2** is a request resource for initial beam establishment from gNB. UE**1** may send a signaling to gNB to request the resources, e.g., PSCCH, PSSCH, and/or PSFCH, for establishing the initial beam pair with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BRS), etc.

[0184] In step **3***a* and step **3***b*, the gNB schedules the resources for initial beam establishing and sends scheduling DCI to both Tx UE and Rx UE. The gNB may schedule the resources on sidelink used by UE**1** and UE**2** to establish the initial beam through DCI. gNB may send the scheduling DCI to both the Tx UE (UE**1**) and the Rx UE (e.g., UE**2**). Note: step **3***a* and step **3***b* may be conducted simultaneously, or step **3***a* may be conducted before step **3***b*, and vice versa.

[0185] Step **4** is initial beam establishment at connection stage. UE**1** may conduct the initial beam establishment procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for establishing the initial beam in V2X mode **2** at connection stage may be also applied here.

[0186] Step **5** is requesting a resource for beam refinement from the gNB. After establishing the initial beam pair link, UE**1** may send a signaling to gNB to request the resources for further refining the beam with UE**2**. For example, the signaling may be a scheduling request (SR) or may be a buffer status report (BSR), etc.

[0187] In steps **6***a* and **6***b*, the NB schedules the resources for beam refinement and sends scheduling DCI to both Tx UE and Rx UE. The gNB may schedule the resources on sidelink used by UE**1** and UE**2** to further refine the beam through DCI. gNB may send the scheduling DCI to both the Tx UE (UE**1**) and the Rx UE (e.g., UE**2**). Note: step **6***a* and step **6***b* may be conducted simultaneously, or step **6***a* may be conducted before step **6***b*, and vice versa.

[0188] Step **7** is beam refinement. UE**1** may conduct the beam refinement procedure with UE**2** using the resources scheduled by the gNB. The ideas proposed for refining beam in V2X mode **2** may be also applied here.

[0189] The procedure in the example of FIG. **19** may be applied to the case when both UE**1** and UE**2** are under gNB's coverage.

[0190] The procedure in FIG. **19** shows an example where the resources used for initial beam sweeping and for further fine tuning are separately scheduled by gNB using different DCIs. In another example, like the example of FIG. **16**, the resources used for initial beam sweeping and for further fine tuning may be jointly scheduled by gNB using one DCI.

EXAMPLE SYSTEMS

[0191] The 3rd Generation Partnership Project (3GPP) develops technical standards for cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities-including work on codecs, security, and quality of service. Recent radio access technology (RAT) standards include WCDMA (commonly referred as 3G), LTE (commonly referred as 4G), LTE-Advanced standards, and New Radio (NR), which is also referred to as "5G". 3GPP NR standards development is expected to continue and include the definition of next generation radio access technology (new RAT), which is expected to include the provision of new flexible radio access below 7 GHz, and the provision of new ultra-mobile broadband radio access above 7 GHz. The flexible radio access is expected to consist of a new, non-backwards compatible radio access in new spectrum below 7 GHZ, and it is expected to include different operating modes that may be multiplexed together in the same spectrum to address a broad set of 3GPP NR use cases with diverging requirements. The ultra-mobile broadband is expected to include cmWave and mmWave spectrum that will provide the opportunity for ultra-mobile broadband access for, e.g., indoor applications and hotspots. In particular, the ultra-mobile broadband is expected to share a common design framework with the flexible radio access below 7 GHz, with cmWave and mmWave specific design optimizations.

[0192] 3GPP has identified a variety of use cases that NR is expected to support, resulting in a wide variety of user experience requirements for data rate, latency, and mobility. The use cases include the following general categories: enhanced mobile broadband (eMBB) ultra-reliable low-latency Communication (URLLC), massive machine type communications (mMTC), network operation (e.g., network slicing, routing, migration and interworking, energy savings), and enhanced vehicle-to-everything (eV2X) communications, which may include any of Vehicle-to-Vehicle Communication (V2V), Vehicle-to-Infrastructure Communication (V2I), Vehicle-to-Network Communication (V2N), Vehicle-to-Pedestrian Communication (V2P), and vehicle communications with other entities. Specific service and applications in these categories include, e.g., monitoring and sensor networks, device remote controlling, bi-directional remote controlling, personal cloud computing, video streaming, wireless cloud-based office, first responder connectivity, automotive eCall, disaster alerts, real-time gaming, multi-person video calls, autonomous driving, augmented reality, tactile internet, virtual reality, home automation, robotics, and aerial drones to name a few. All of these use cases and others are contemplated herein.

[0193] FIG. **20**A illustrates an example communications system **100** in which the systems,

methods, and apparatuses described and claimed herein may be used. The communications system **100** may include wireless transmit/receive units (WTRUs) **102***a*, **102***b*, **102***c*, **102***d*, **102***e*, **102***f*, and/or **102***g*, which generally or collectively may be referred to as WTRU **102** or WTRUs **102**. The communications system **100** may include, a radio access network (RAN) **103/104/105/103***b***/104***b***/105***b*, a core network **106/107/109**, a public switched telephone network (PSTN) **108**, the Internet **110**, other networks **112**, and Network Services **113**. Network Services **113** may include, for example, a V2X server, V2X functions, a ProSe server, ProSe functions, IoT services, video streaming, and/or edge computing, etc.

[0194] It will be appreciated that the concepts disclosed herein may be used with any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs **102** may be any type of apparatus or device configured to operate and/or communicate in a wireless environment. In the example of FIG. **20**A, each of the WTRUs **102** is depicted in FIGS. **20**A-**20**E as a hand-held wireless communications apparatus. It is understood that with the wide variety of use cases contemplated for wireless communications, each WTRU may comprise or be included in any type of apparatus or device configured to transmit and/or receive wireless signals, including, by way of example only, user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a tablet, a netbook, a notebook computer, a personal computer, a wireless sensor, consumer electronics, a wearable device such as a smart watch or smart clothing, a medical or eHealth device, a robot, industrial equipment, a drone, a vehicle such as a car, bus or truck, a train, or an airplane, and the like.

[0195] The communications system **100** may also include a base station **114***a* and a base station **114***b*. In the example of FIG. **20**A, each base stations **114***a* and **114***b* is depicted as a single element. In practice, the base stations **114***a* and **114***b* may include any number of interconnected base stations and/or network elements. Base stations **114***a* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102***a*, **102***b*, and **102***c* to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, Network Services **113**, and/or the other networks **112**. Similarly, base station **114***b* may be any type of device configured to wiredly and/or wirelessly interface with at least one of the Remote Radio Heads (RRHs) **118***a*, **118***b*, Transmission and Reception Points (TRPs) **119***a*, **119***b*, and/or Roadside Units (RSUs) **120***a* and **120***b* to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, other networks **112**, and/or Network Services **113**. RRHs **118***a*, **118***b* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102**, e.g., WTRU **102***c*, to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, Network Services **113**, and/or other networks **112**.

[0196] TRPs **119***a*, **119***b* may be any type of device configured to wirelessly interface with at least one of the WTRU **102***d*, to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, Network Services **113**, and/or other networks **112**. RSUs **120***a* and **120***b* may be any type of device configured to wirelessly interface with at least one of the WTRU **102***e* or **102***f*, to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, other networks **112**, and/or Network Services **113**. By way of example, the base stations **114***a*, **114***b* may be a Base Transceiver Station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a Next Generation Node-B (gNode B), a satellite, a site controller, an access point (AP), a wireless router, and the like.

[0197] The base station **114***a* may be part of the RAN **103/104/105**, which may also include other base stations and/or network elements (not shown), such as a Base Station Controller (BSC), a Radio Network Controller (RNC), relay nodes, etc. Similarly, the base station **114***b* may be part of the RAN **103***b***/104***b***/105***b*, which may also include other base stations and/or network elements (not shown), such as a BSC, a RNC, relay nodes, etc. The base station **114***a* may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be

referred to as a cell (not shown). Similarly, the base station **114***b* may be configured to transmit and/or receive wired and/or wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station **114***a* may be divided into three sectors. Thus, for example, the base station **114***a* may include three transceivers, e.g., one for each sector of the cell. The base station **114***a* may employ Multiple-Input Multiple Output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell, for instance.

[0198] The base station **114***a* may communicate with one or more of the WTRUs **102***a*, **102***b*, **102***c*, and **102***g* over an air interface **115/116/117**, which may be any suitable wireless communication link (e.g., Radio Frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface **115/116/117** may be established using any suitable Radio Access Technology (RAT).

[0199] The base station **114***b* may communicate with one or more of the RRHs **118***a* and **118***b*, TRPs **119***a* and **119***b*, and/or RSUs **120***a* and **120***b*, over a wired or air interface **115***b*/**116***b*/**117***b*, which may be any suitable wired (e.g., cable, optical fiber, etc.) or wireless communication link (e.g., RF, microwave, IR, UV, visible light, cmWave, mmWave, etc.). The air interface **115***b*/**116***b*/**117***b* may be established using any suitable RAT.

[0200] The RRHs **118***a*, **118***b*, TRPs **119***a*, **119***b*, and/or RSUs **120***a*, **120***b*, may communicate with one or more of the WTRUs **102***c*, **102***d*, **102***e*, **102***f* over an air interface **115***c*/**116***c*/**117***c*, which may be any suitable wireless communication link (e.g., RF, microwave, IR, ultraviolet UV, visible light, cmWave, mmWave, etc.) The air interface **115***c*/**116***c*/**117***c* may be established using any suitable RAT.

[0201] The WTRUs **102** may communicate with one another over a direct air interface **115***d*/**116***d*/**117***d*, such as Sidelink communication which may be any suitable wireless communication link (e.g., RF, microwave, IR, ultraviolet UV, visible light, cmWave, mmWave, etc.) The air interface **115***d*/**116***d*/**117***d* may be established using any suitable RAT.

[0202] The communications system **100** may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station **114***a* in the RAN **103/104/105** and the WTRUs **102***a*, **102***b*, **102***c*, or RRHs **118***a*, **118***b*, TRPs **119***a*, **119***b*, and/or RSUs **120***a* and **120***b* in the RAN **103***b*/**104***b*/**105***b* and the WTRUs **102***c*, **102***d*, **102***e*, and **102***f,* may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface **115/116/117** and/or **115***c*/**116***c*/**117***c* respectively using Wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0203] The base station **114***a* in the RAN **103/104/105** and the WTRUs **102***a*, **102***b*, **102***c*, and **102***g*, or RRHs **118***a* and **118***b*, TRPs **119***a* and **119***b*, and/or RSUs **120***a* and **120***b* in the RAN **103***b*/**104***b*/**105***b* and the WTRUs **102***c*, **102***d*, may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface **115/116/117** or **115***c*/**116***c*/**117***c* respectively using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A), for example. The air interface **115/116/117** or **115***c*/**116***c*/**117***c* may implement 3GPP NR technology. The LTE and LTE-A technology may include LTE D2D and/or V2X technologies and interfaces (such as Sidelink communications, etc.) Similarly, the 3GPP NR technology may include NR V2X technologies and interfaces (such as Sidelink communications, etc.)

[0204] The base station **114***a* in the RAN **103/104/105** and the WTRUs **102***a*, **102***b*, **102***c*, and **102***g* or RRHs **118***a* and **118***b*, TRPs **119***a* and **119***b*, and/or RSUs **120***a* and **120***b* in the RAN **103***b*/**104***b*/**105***b* and the WTRUs **102***c*, **102***d*, **102***e*, and **102***f* may implement radio technologies such as IEEE 802.16 (e.g., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim

Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0205] The base station **114***c* in FIG. **20**A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a train, an aerial, a satellite, a manufactory, a campus, and the like. The base station **114***c* and the WTRUs **102**, e.g., WTRU **102***e*, may implement a radio technology such as IEEE 802.11 to establish a Wireless Local Area Network (WLAN). Similarly, the base station **114***c* and the WTRUs **102**, e.g., WTRU **102***d*, may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). The base station **114***c* and the WTRUs **102**, e.g., WRTU **102***e*, may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, NR, etc.) to establish a picocell or femtocell. As shown in FIG. **20**A, the base station **114***c* may have a direct connection to the Internet **110**. Thus, the base station **114***c* may not be required to access the Internet **110** via the core network **106/107/109**.

[0206] The RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* may be in communication with the core network **106/107/109**, which may be any type of network configured to provide voice, data, messaging, authorization and authentication, applications, and/or Voice Over Internet Protocol (VOIP) services to one or more of the WTRUs **102**. For example, the core network **106/107/109** may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, packet data network connectivity, Ethernet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication.

[0207] Although not shown in FIG. **20**A, it will be appreciated that the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* and/or the core network **106/107/109** may be in direct or indirect communication with other RANs that employ the same RAT as the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* or a different RAT. For example, in addition to being connected to the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b*, which may be utilizing an E-UTRA radio technology, the core network **106/107/109** may also be in communication with another RAN (not shown) employing a GSM or NR radio technology.

[0208] The core network **106/107/109** may also serve as a gateway for the WTRUs **102** to access the PSTN **108**, the Internet **110**, and/or other networks **112**. The PSTN **108** may include circuit-switched telephone networks that provide Plain Old Telephone Service (POTS). The Internet **110** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and the internet protocol (IP) in the TCP/IP internet protocol suite. The other networks **112** may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks **112** may include any type of packet data network (e.g., an IEEE 802.3 Ethernet network) or another core network connected to one or more RANs, which may employ the same RAT as the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* or a different RAT.

[0209] Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, **102***e*, and **102***f* in the communications system **100** may include multi-mode capabilities, e.g., the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, **102***e*, and **102***f* may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU **102***g* shown in FIG. **20**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***c*, which may employ an IEEE **802** radio technology.

[0210] Although not shown in FIG. **20**A, it will be appreciated that a User Equipment may make a wired connection to a gateway. The gateway maybe a Residential Gateway (RG). The RG may provide connectivity to a Core Network **106/107/109**. It will be appreciated that many of the ideas contained herein may equally apply to UEs that are WTRUs and UEs that use a wired connection to connect to a network. For example, the ideas that apply to the wireless interfaces **115**, **116**, **117**

and **115***c*/**116***c*/**117***c* may equally apply to a wired connection.

[0211] FIG. **20**B is a system diagram of an example RAN **103** and core network **106**. As noted above, the RAN **103** may employ a UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **115**. The RAN **103** may also be in communication with the core network **106**. As shown in FIG. **20**B, the RAN **103** may include Node-Bs **140***a*, **140***b*, and **140***c*, which may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **115**. The Node-Bs **140***a*, **140***b*, and **140***c* may each be associated with a particular cell (not shown) within the RAN **103**. The RAN **103** may also include RNCs **142***a* and **142***b*. It will be appreciated that the RAN **103** may include any number of Node-Bs and Radio Network Controllers (RNCs.)

[0212] As shown in FIG. **20**B, the Node-Bs **140***a*, **140***b* may be in communication with the RNC **142***a*. Additionally, the Node-B **140***c* may be in communication with the RNC **142***b*. The Node-Bs **140***a*, **140***b*, and **140***c* may communicate with the respective RNCs **142***a* and **142***b* via an Iub interface. The RNCs **142***a* and **142***b* may be in communication with one another via an Iur interface. Each of the RNCs **142***a* and **142***b* may be configured to control the respective Node-Bs **140***a*, **140***b*, and **140***c* to which it is connected. In addition, each of the RNCs **142***a* and **142***b* may be configured to carry out or support other functionality, such as outer loop power control, load control, admission control, packet scheduling, handover control, macro-diversity, security functions, data encryption, and the like.

[0213] The core network **106** shown in FIG. **20**B may include a media gateway (MGW) **144**, a Mobile Switching Center (MSC) **146**, a Serving GPRS Support Node (SGSN) **148**, and/or a Gateway GPRS Support Node (GGSN) **150**. While each of the foregoing elements are depicted as part of the core network **106**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0214] The RNC **142***a* in the RAN **103** may be connected to the MSC **146** in the core network **106** via an IuCS interface. The MSC **146** may be connected to the MGW **144**. The MSC **146** and the MGW **144** may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, and **102***c*, and traditional land-line communications devices.

[0215] The RNC **142***a* in the RAN **103** may also be connected to the SGSN **148** in the core network **106** via an IuPS interface. The SGSN **148** may be connected to the GGSN **150**. The SGSN **148** and the GGSN **150** may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between and the WTRUs **102***a*, **102***b*, and **102***c*, and IP-enabled devices.

[0216] The core network **106** may also be connected to the other networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0217] FIG. **20**C is a system diagram of an example RAN **104** and core network **107**. As noted above, the RAN **104** may employ an E-UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **116**. The RAN **104** may also be in communication with the core network **107**.

[0218] The RAN **104** may include eNode-Bs **160***a*, **160***b*, and **160***c*, though it will be appreciated that the RAN **104** may include any number of eNode-Bs. The eNode-Bs **160***a*, **160***b*, and **160***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **116**. For example, the eNode-Bs **160***a*, **160***b*, and **160***c* may implement MIMO technology. Thus, the eNode-B **160***a*, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU **102***a*.

[0219] Each of the eNode-Bs **160***a*, **160***b*, and **160***c* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in FIG. **20**C, the eNode-Bs **160***a*, **160***b*, and **160***c* may communicate with one another over an X2 interface.

[0220] The core network **107** shown in FIG. **20**C may include a Mobility Management Gateway (MME) **162**, a serving gateway **164**, and a Packet Data Network (PDN) gateway **166**. While each of the foregoing elements are depicted as part of the core network **107**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0221] The MME **162** may be connected to each of the eNode-Bs **160***a*, **160***b*, and **160***c* in the RAN **104** via an SI interface and may serve as a control node. For example, the MME **162** may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, and **102***c*, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs **102***a*, **102***b*, and **102***c*, and the like. The MME **162** may also provide a control plane function for switching between the RAN **104** and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

[0222] The serving gateway **164** may be connected to each of the eNode-Bs **160***a*, **160***b*, and **160***c* in the RAN **104** via the S**1** interface. The serving gateway **164** may generally route and forward user data packets to/from the WTRUs **102***a*, **102***b*, and **102***c*. The serving gateway **164** may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs **102***a*, **102***b*, and **102***c*, managing and storing contexts of the WTRUs **102***a*, **102***b*, and **102***c*, and the like.

[0223] The serving gateway **164** may also be connected to the PDN gateway **166**, which may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, and **102***c*, and IP-enabled devices.

[0224] The core network **107** may facilitate communications with other networks. For example, the core network **107** may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, and **102***c* and traditional land-line communications devices. For example, the core network **107** may include, or may communicate with, an IP gateway (e.g., an IP Multimedia Subsystem (IMS) server) that serves as an interface between the core network **107** and the PSTN **108**. In addition, the core network **107** may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0225] FIG. **20**D is a system diagram of an example RAN **105** and core network **109**. The RAN **105** may employ an NR radio technology to communicate with the WTRUs **102***a* and **102***b* over the air interface **117**. The RAN **105** may also be in communication with the core network **109**. A Non-3GPP Interworking Function (N3IWF) **199** may employ a non-3GPP radio technology to communicate with the WTRU **102***c* over the air interface **198**. The N3IWF **199** may also be in communication with the core network **109**.

[0226] The RAN **105** may include gNode-Bs **180***a* and **180***b*. It will be appreciated that the RAN **105** may include any number of gNode-Bs. The gNode-Bs **180***a* and **180***b* may each include one or more transceivers for communicating with the WTRUs **102***a* and **102***b* over the air interface **117**. When integrated access and backhaul connection are used, the same air interface may be used between the WTRUs and gNode-Bs, which may be the core network **109** via one or multiple gNBs. The gNode-Bs **180***a* and **180***b* may implement MIMO, MU-MIMO, and/or digital beamforming technology. Thus, the gNode-B **180***a*, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU **102***a*. It should be appreciated that the RAN **105** may employ of other types of base stations such as an eNode-B. It will also be appreciated the RAN **105** may employ more than one type of base station. For example, the RAN may employ eNode-Bs and gNode-Bs.

[0227] The N3IWF **199** may include a non-3GPP Access Point **180***c*. It will be appreciated that the N3IWF **199** may include any number of non-3GPP Access Points. The non-3GPP Access Point

180*c* may include one or more transceivers for communicating with the WTRUs **102***c* over the air interface **198**. The non-3GPP Access Point **180***c* may use the 802.11 protocol to communicate with the WTRU **102***c* over the air interface **198**.

[0228] Each of the gNode-Bs **180***a* and **180***b* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in FIG. **20**D, the gNode-Bs **180***a* and **180***b* may communicate with one another over an Xn interface, for example.

[0229] The core network **109** shown in FIG. **20**D may be a 5G core network (5GC). The core network **109** may offer numerous communication services to customers who are interconnected by the radio access network. The core network **109** comprises a number of entities that perform the functionality of the core network. As used herein, the term "core network entity" or "network function" refers to any entity that performs one or more functionalities of a core network. It is understood that such core network entities may be logical entities that are implemented in the form of computer-executable instructions (software) stored in a memory of, and executing on a processor of, an apparatus configured for wireless and/or network communications or a computer system, such as system **90** illustrated in FIG. **20**G.

[0230] In the example of FIG. **20**D, the 5G Core Network **109** may include an access and mobility management function (AMF) **172**, a Session Management Function (SMF) **174**, User Plane Functions (UPFs) **176***a* and **176***b*, a User Data Management Function (UDM) **197**, an Authentication Server Function (AUSF) **190**, a Network Exposure Function (NEF) **196**, a Policy Control Function (PCF) **184**, a Non-3GPP Interworking Function (N3IWF) **199**, and/or a User Data Repository (UDR) **178**. While each of the foregoing elements are depicted as part of the 5G core network **109**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator. It will also be appreciated that a 5G core network may not consist of all of these elements, may consist of additional elements, and may consist of multiple instances of each of these elements. FIG. **20**D shows that network functions directly connect to one another, however, it should be appreciated that they may communicate via routing agents such as a diameter routing agent or message buses.

[0231] In the example of FIG. **20**D, connectivity between network functions is achieved via a set of interfaces, or reference points. It will be appreciated that network functions could be modeled, described, or implemented as a set of services that are invoked, or called, by other network functions or services. Invocation of a Network Function service may be achieved via a direct connection between network functions, an exchange of messaging on a message bus, calling a software function, etc.

[0232] The AMF **172** may be connected to the RAN **105** via an N**2** interface and may serve as a control node. For example, the AMF **172** may be responsible for registration management, connection management, reachability management, access authentication, and/or access authorization. The AMF may be responsible for forwarding user plane tunnel configuration information to the RAN **105** via the N**2** interface. The AMF **172** may receive the user plane tunnel configuration information from the SMF via an N**11** interface. The AMF **172** may generally route and forward NAS packets to/from the WTRUs **102***a*, **102***b*, and **102***c* via an N**1** interface. The N**1** interface is not shown in FIG. **20**D.

[0233] The SMF **174** may be connected to the AMF **172** via an N**11** interface. Similarly, the SMF may be connected to the PCF **184** via an N**7** interface, and to the UPFs **176***a* and **176***b* via an N**4** interface. The SMF **174** may serve as a control node. For example, the SMF **174** may be responsible for Session Management, IP address allocation for the WTRUs **102***a*, **102***b*, and **102***c*, management and configuration of traffic steering rules in the UPF **176***a* and UPF **176***b*, and generation of downlink data notifications to the AMF **172**.

[0234] The UPF **176***a* and UPF **176***b* may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to a Packet Data Network (PDN), such as the Internet **110**, to facilitate communications between the

WTRUs **102***a*, **102***b*, and **102***c*, and other devices. The UPF **176***a* and UPF **176***b* may also provide the WTRUs **102***a*, **102***b*, and **102***c* with access to other types of packet data networks. For example, Other Networks **112** may be Ethernet Networks or any type of network that exchanges packets of data. The UPF **176***a* and UPF **176***b* may receive traffic steering rules from the SMF **174** via the N**4** interface. The UPF **176***a* and UPF **176***b* may provide access to a packet data network by connecting a packet data network with an N**6** interface or by connecting to each other and to other UPFs via an N**9** interface. In addition to providing access to packet data networks, the UPF **176** may be responsible packet routing and forwarding, policy rule enforcement, quality of service handling for user plane traffic, and downlink packet buffering.

[0235] The AMF **172** may also be connected to the N3IWF **199**, for example, via an N**2** interface. The N3IWF facilitates a connection between the WTRU **102***c* and the 5G core network **170**, for example, via radio interface technologies that are not defined by 3GPP. The AMF may interact with the N3IWF **199** in the same, or similar, manner that it interacts with the RAN **105**.

[0236] The PCF **184** may be connected to the SMF **174** via an N**7** interface, connected to the AMF **172** via an N**15** interface, and to an Application Function (AF) **188** via an N**5** interface. The N**15** and N**5** interfaces are not shown in FIG. **20**D. The PCF **184** may provide policy rules to control plane nodes such as the AMF **172** and SMF **174**, allowing the control plane nodes to enforce these rules. The PCF **184** may send policies to the AMF **172** for the WTRUs **102***a*, **102***b*, and **102***c* so that the AMF may deliver the policies to the WTRUs **102***a*, **102***b*, and **102***c* via an N**1** interface. Policies may then be enforced, or applied, at the WTRUs **102***a*, **102***b*, and **102***c*.

[0237] The UDR **178** may act as a repository for authentication credentials and subscription information. The UDR may connect to network functions, so that network function can add to, read from, and modify the data that is in the repository. For example, the UDR **178** may connect to the PCF **184** via an N**36** interface. Similarly, the UDR **178** may connect to the NEF **196** via an N**37** interface, and the UDR **178** may connect to the UDM **197** via an N**35** interface.

[0238] The UDM **197** may serve as an interface between the UDR **178** and other network functions. The UDM **197** may authorize network functions to access of the UDR **178**. For example, the UDM **197** may connect to the AMF **172** via an N**8** interface, the UDM **197** may connect to the SMF **174** via an N**10** interface. Similarly, the UDM **197** may connect to the AUSF **190** via an N**13** interface. The UDR **178** and UDM **197** may be tightly integrated.

[0239] The AUSF **190** performs authentication related operations and connects to the UDM **178** via an N**13** interface and to the AMF **172** via an N**12** interface.

[0240] The NEF **196** exposes capabilities and services in the 5G core network **109** to Application Functions (AF) **188**. Exposure may occur on the N33 API interface. The NEF may connect to an AF **188** via an N33 interface and it may connect to other network functions in order to expose the capabilities and services of the 5G core network **109**.

[0241] Application Functions **188** may interact with network functions in the 5G Core Network **109**. Interaction between the Application Functions **188** and network functions may be via a direct interface or may occur via the NEF **196**. The Application Functions **188** may be considered part of the 5G Core Network **109** or may be external to the 5G Core Network **109** and deployed by enterprises that have a business relationship with the mobile network operator.

[0242] Network Slicing is a mechanism that could be used by mobile network operators to support one or more 'virtual' core networks behind the operator's air interface. This involves 'slicing' the core network into one or more virtual networks to support different RANs or different service types running across a single RAN. Network slicing enables the operator to create networks customized to provide optimized solutions for different market scenarios which demands diverse requirements, e.g. in the areas of functionality, performance, and isolation.

[0243] 3GPP has designed the 5G core network to support Network Slicing. Network Slicing is a good tool that network operators can use to support the diverse set of 5G use cases (e.g., massive IoT, critical communications, V2X, and enhanced mobile broadband) which demand very diverse

and sometimes extreme requirements. Without the use of network slicing techniques, it is likely that the network architecture would not be flexible and scalable enough to efficiently support a wider range of use cases need when each use case has its own specific set of performance, scalability, and availability requirements. Furthermore, introduction of new network services should be made more efficient.

[0244] Referring again to FIG. **20**D, in a network slicing scenario, a WTRU **102***a*, **102***b*, or **102***c* may connect to an AMF **172**, via an N**1** interface. The AMF may be logically part of one or more slices. The AMF may coordinate the connection or communication of WTRU **102***a*, **102***b*, or **102***c* with one or more UPF **176***a* and **176***b*, SMF **174**, and other network functions. Each of the UPFs **176***a* and **176***b*, SMF **174**, and other network functions may be part of the same slice or different slices. When they are part of different slices, they may be isolated from each other in the sense that they may utilize different computing resources, security credentials, etc.

[0245] The core network **109** may facilitate communications with other networks. For example, the core network **109** may include, or may communicate with, an IP gateway, such as an IP Multimedia Subsystem (IMS) server, that serves as an interface between the 5G core network **109** and a PSTN **108**. For example, the core network **109** may include, or communicate with a short message service (SMS) service center that facilities communication via the short message service. For example, the 5G core network **109** may facilitate the exchange of non-IP data packets between the WTRUs **102***a*, **102***b*, and **102***c* and servers or applications functions **188**. In addition, the core network **170** may provide the WTRUs **102***a*, **102***b*, and **102***c* with access to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0246] The core network entities described herein and illustrated in FIGS. **20**A, **20**C, **20**D, and **20**E are identified by the names given to those entities in certain existing 3GPP specifications, but it is understood that in the future those entities and functionalities may be identified by other names and certain entities or functions may be combined in future specifications published by 3GPP, including future 3GPP NR specifications. Thus, the particular network entities and functionalities described and illustrated in FIGS. **20**A, **20**B, **20**C, **20**D, and **20**E are provided by way of example only, and it is understood that the subject matter disclosed and claimed herein may be embodied or implemented in any similar communication system, whether presently defined or defined in the future.

[0247] FIG. **20**E illustrates an example communications system **111** in which the systems, methods, and apparatuses described herein may be used. Communications system **111** may include Wireless Transmit/Receive Units (WTRUs) A, B, C, D, E, F, a base station gNB **121**, a V2X server **124**, and Road-Side Units (RSUs) **123***a* and **123***b*. In practice, the concepts presented herein may be applied to any number of WTRUs, base station gNBs, V2X networks, and/or other network elements. One or several or all WTRUs A, B, C, D, E, and F may be out of range of the access network coverage **131**. WTRUs A, B, and C form a V2X group, among which WTRU A is the group lead and WTRUs B and C are group members.

[0248] WTRUs A, B, C, D, E, and F may communicate with each other over a Uu interface **129** via the gNB **121** if they are within the access network coverage **131**. In the example of FIG. **20**E, WTRUs B and F are shown within access network coverage **131**. WTRUs A, B, C, D, E, and F may communicate with each other directly via a Sidelink interface (e.g., PC5 or NR PC5) such as interface **125***a*, **125***b*, or **128**, whether they are under the access network coverage **131** or out of the access network coverage **131**. For instance, in the example of FIG. **20**E, WRTU D, which is outside of the access network coverage **131**, communicates with WTRU F, which is inside the coverage **131**.

[0249] WTRUs A, B, C, D, E, and F may communicate with RSU **123***a* or **123***b* via a Vehicle-to-Network (V2N) **133** or Sidelink interface **125***b*. WTRUs A, B, C, D, E, and F may communicate to a V2X Server **124** via a Vehicle-to-Infrastructure (V2I) interface **127**. WTRUs A, B, C, D, E, and F may communicate to another UE via a Vehicle-to-Person (V2P) interface **128**.

[0250] FIG. **20**F is a block diagram of an example apparatus or device WTRU **102** that may be configured for wireless communications and operations in accordance with the systems, methods, and apparatuses described herein, such as a WTRU **102** of FIG. **20**A, **20**B, **20**C, **20**D, or **20**E. As shown in FIG. **20**F, the example WTRU **102** may include a processor **118**, a transceiver **120**, a transmit/receive element **122**, a speaker/microphone **124**, a keypad **126**, a display/touchpad/indicators **128**, non-removable memory **130**, removable memory **132**, a power source **134**, a global positioning system (GPS) chipset **136**, and other peripherals **138**. It will be appreciated that the WTRU **102** may include any sub-combination of the foregoing elements. Also, the base stations **114***a* and **114***b*, and/or the nodes that base stations **114***a* and **114***b* may represent, such as but not limited to transceiver station (BTS), a Node-B, a site controller, an access point (AP), a home node-B, an evolved home node-B (eNodeB), a home evolved node-B (HeNB), a home evolved node-B gateway, a next generation node-B (gNode-B), and proxy nodes, among others, may include some or all of the elements depicted in FIG. **20**F and described herein.

[0251] The processor **118** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **118** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU **102** to operate in a wireless environment. The processor **118** may be coupled to the transceiver **120**, which may be coupled to the transmit/receive element **122**. While FIG. **20**F depicts the processor **118** and the transceiver **120** as separate components, it will be appreciated that the processor **118** and the transceiver **120** may be integrated together in an electronic package or chip.

[0252] The transmit/receive element **122** of a UE may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a* of FIG. **20**A) over the air interface **115**/**116**/**117** or another UE over the air interface **115***d*/**116***d*/**117***d*. For example, the transmit/receive element **122** may be an antenna configured to transmit and/or receive RF signals. The transmit/receive element **122** may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. The transmit/receive element **122** may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element **122** may be configured to transmit and/or receive any combination of wireless or wired signals.

[0253] In addition, although the transmit/receive element **122** is depicted in FIG. **20**F as a single element, the WTRU **102** may include any number of transmit/receive elements **122**. More specifically, the WTRU **102** may employ MIMO technology. Thus, the WTRU **102** may include two or more transmit/receive elements **122** (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface **115**/**116**/**117**.

[0254] The transceiver **120** may be configured to modulate the signals that are to be transmitted by the transmit/receive element **122** and to demodulate the signals that are received by the transmit/receive element **122**. As noted above, the WTRU **102** may have multi-mode capabilities. Thus, the transceiver **120** may include multiple transceivers for enabling the WTRU **102** to communicate via multiple RATs, for example NR and IEEE **802**.11 or NR and E-UTRA, or to communicate with the same RAT via multiple beams to different RRHs, TRPs, RSUs, or nodes.

[0255] The processor **118** of the WTRU **102** may be coupled to, and may receive user input data from, the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad/indicators **128** (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit. The processor **118** may also output user data to the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad/indicators **128**. In addition, the processor **118** may access information from, and store data in, any type of suitable memory, such as the non-removable memory **130**

and/or the removable memory **132**. The non-removable memory **130** may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory **132** may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. The processor **118** may access information from, and store data in, memory that is not physically located on the WTRU **102**, such as on a server that is hosted in the cloud or in an edge computing platform or in a home computer (not shown).

[0256] The processor **118** may receive power from the power source **134**, and may be configured to distribute and/or control the power to the other components in the WTRU **102**. The power source **134** may be any suitable device for powering the WTRU **102**. For example, the power source **134** may include one or more dry cell batteries, solar cells, fuel cells, and the like.

[0257] The processor **118** may also be coupled to the GPS chipset **136**, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU **102**. In addition to, or in lieu of, the information from the GPS chipset **136**, the WTRU **102** may receive location information over the air interface **115/116/117** from a base station (e.g., base stations **114***a*, **114***b*) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU **102** may acquire location information by way of any suitable location-determination method.

[0258] The processor **118** may further be coupled to other peripherals **138**, which may include one or more software and/or hardware modules that provide additional features, functionality, and/or wired or wireless connectivity. For example, the peripherals **138** may include various sensors such as an accelerometer, biometrics (e.g., finger print) sensors, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port or other interconnect interfaces, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

[0259] The WTRU **102** may be included in other apparatuses or devices, such as a sensor, consumer electronics, a wearable device such as a smart watch or smart clothing, a medical or eHealth device, a robot, industrial equipment, a drone, a vehicle such as a car, truck, train, or an airplane. The WTRU **102** may connect to other components, modules, or systems of such apparatuses or devices via one or more interconnect interfaces, such as an interconnect interface that may comprise one of the peripherals **138**.

[0260] FIG. **20**G is a block diagram of an exemplary computing system **90** in which one or more apparatuses of the communications networks illustrated in FIGS. **20**A, **20**C, **20**D, and **20**E may be embodied, such as certain nodes or functional entities in the RAN **103/104/105**, Core Network **106/107/109**, PSTN **108**, Internet **110**, Other Networks **112**, or Network Services **113**. Computing system **90** may comprise a computer or server and may be controlled primarily by computer readable instructions, which may be in the form of software, wherever, or by whatever means such software is stored or accessed. Such computer readable instructions may be executed within a processor **91**, to cause computing system **90** to do work. The processor **91** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **91** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the computing system **90** to operate in a communications network. Coprocessor **81** is an optional processor, distinct from main processor **91**, that may perform additional functions or assist processor **91**. Processor **91** and/or coprocessor **81** may receive, generate, and process data related to the methods and apparatuses disclosed herein.

[0261] In operation, processor **91** fetches, decodes, and executes instructions, and transfers information to and from other resources via the computing system's main data-transfer path, system bus **80**. Such a system bus connects the components in computing system **90** and defines the medium for data exchange. System bus **80** typically includes data lines for sending data, address lines for sending addresses, and control lines for sending interrupts and for operating the system bus. An example of such a system bus **80** is the PCI (Peripheral Component Interconnect) bus.

[0262] Memories coupled to system bus **80** include random access memory (RAM) **82** and read only memory (ROM) **93**. Such memories include circuitry that allows information to be stored and retrieved. ROMs **93** generally contain stored data that cannot easily be modified. Data stored in RAM **82** may be read or changed by processor **91** or other hardware devices. Access to RAM **82** and/or ROM **93** may be controlled by memory controller **92**. Memory controller **92** may provide an address translation function that translates virtual addresses into physical addresses as instructions are executed. Memory controller **92** may also provide a memory protection function that isolates processes within the system and isolates system processes from user processes. Thus, a program running in a first mode may access only memory mapped by its own process virtual address space; it cannot access memory within another process's virtual address space unless memory sharing between the processes has been set up.

[0263] In addition, computing system **90** may contain peripherals controller **83** responsible for communicating instructions from processor **91** to peripherals, such as printer **94**, keyboard **84**, mouse **95**, and disk drive **85**.

[0264] Display **86**, which is controlled by display controller **96**, is used to display visual output generated by computing system **90**. Such visual output may include text, graphics, animated graphics, and video. The visual output may be provided in the form of a graphical user interface (GUI). Display **86** may be implemented with a CRT-based video display, an LCD-based flat-panel display, gas plasma-based flat-panel display, or a touch-panel. Display controller **96** includes electronic components required to generate a video signal that is sent to display **86**.

[0265] Further, computing system **90** may contain communication circuitry, such as for example a wireless or wired network adapter **97**, that may be used to connect computing system **90** to an external communications network or devices, such as the RAN **103**/**104**/**105**, Core Network **106**/**107**/**109**, PSTN **108**, Internet **110**, WTRUs **102**, or Other Networks **112** of FIGS. **20**A, **20**B, **20**C, **20**D, and **20**E, to enable the computing system **90** to communicate with other nodes or functional entities of those networks. The communication circuitry, alone or in combination with the processor **91**, may be used to perform the transmitting and receiving steps of certain apparatuses, nodes, or functional entities described herein.

[0266] It is understood that any or all of the apparatuses, systems, methods, and processes described herein may be embodied in the form of computer executable instructions (e.g., program code) stored on a computer-readable storage medium which instructions, when executed by a processor, such as processors **118** or **91**, cause the processor to perform and/or implement the systems, methods, and processes described herein. Specifically, any of the steps, operations, or functions described herein may be implemented in the form of such computer executable instructions, executing on the processor of an apparatus or computing system configured for wireless and/or wired network communications. Computer readable storage media includes volatile and nonvolatile, removable and non-removable media implemented in any non-transitory (e.g., tangible or physical) method or technology for storage of information, but such computer readable storage media do not include signals. Computer readable storage media include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other tangible or physical medium which may be used to store the desired information and which may be accessed by a computing system.

Claims

1. A first wireless transmit/receive unit (WTRU) comprising: a processor configured to: receive configuration information, wherein the configuration information comprises beam sweep information to determine a set of beams to perform a beam pair link establishment with a second WTRU; determine the set of beams based on the beam sweep information; send an indication of the set of beams to the second WTRU; and based on configuration information and the determined set of beams, perform the beam pair link establishment with the second WTRU.

2. The WTRU of claim 1, wherein the set of beams is a first set of beams, wherein the processor is further configured to receive an indication of a second set of beams from the second WTRU, and wherein the processor is configured to perform the beam pair link establishment based on the indication of the second set of beams.

3. The WTRU of claim 1, wherein the configuration information comprises reporting configuration information, and wherein the processor is configured to receive the indication of the second set of beams based on the reporting configuration information.

4. The WTRU of claim 1, wherein the processor is configured to receive an indication from a network node to establish the beam pair link with the second WTRU, and wherein the processor is configured to determine the set of beams based on the indication.

5. The WTRU of claim 4, wherein the indication comprises a quality of service (QOS) requirement, and wherein the processor is configured to perform the beam pair link establishment based on the QoS requirement.

6. The WTRU of claim 1, wherein the processor is configured to determine one or more frequency resources or one or more time domain resources, based on the configuration information, to determine the set of beams.

7. The WTRU of claim 1, wherein the processor is configured to send an indicator to the second WTRU, wherein the processor is configured to perform the beam pair link establishment based on the indicator.

8. The WTRU of claim 1, wherein the beam link establishment is performed based on one or more of: a reference signal received power (RSRP) value, a reference signal received quality (RSRQ) value, a quality of service (QOS) value, or a signal to interference noise ratio (SINR) value.

9. The WTRU of claim 1, wherein the processor is configured to send one or more reference signals via the set of beams.

10. The WTRU of claim 1, wherein the processor is configured to: receive information to perform a beam refinement procedure; and perform the beam refinement procedure based on the received information.

11. A method performed by a first wireless transmit/receive unit (WTRU), the method comprising: receiving configuration information, wherein the configuration information comprises beam sweep information to determine a set of beams to perform a beam pair link establishment with a second WTRU; determining the set of beams based on the beam sweep information; sending an indication of the set of beams to the second WTRU; and based on configuration information and the determined set of beams, performing the beam pair link establishment with the second WTRU.

12. The method of claim 11, wherein the set of beams is a first set of beams, wherein the method further comprising receiving an indication of a second set of beams from the second WTRU, and wherein the method further comprising performing the beam pair link establishment based on the indication of the second set of beams.

13. The method of claim 11, wherein the configuration information comprises reporting configuration information, and wherein the method further comprising receiving the indication of the second set of beams based on the reporting configuration information.

14. The method of claim 11, further comprising receiving an indication from a network node to

establish the beam pair link with the second WTRU, and wherein the method further comprising determining the set of beams based on the indication.

15. The method of claim 14, wherein the indication comprises a quality of service (QOS) requirement, and wherein the beam pair link establishment is performed based on the QoS requirement.

16. The method of claim 11, further comprising determining one or more frequency resources or one or more time domain resources, based on the configuration information, to determine the set of beams.

17. The method of claim 11, further comprising sending an indicator to the second WTRU, wherein the beam pair link establishment is performed based on the indicator.

18. The method of claim 11, wherein the beam link establishment is performed based on one or more of: a reference signal received power (RSRP) value, a reference signal received quality (RSRQ) value, a quality of service (QOS) value, or a signal to interference noise ratio (SINR) value.

19. The method of claim 11, further comprising sending one or more reference signals via the set of beams.

20. The method of claim 11, further comprising: receiving information to perform a beam refinement procedure; and performing the beam refinement procedure based on the received information.