United States Patent Application Publication	20250254600
Kind Code	A1
Publication Date	August 07, 2025
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CONTROL OF DISCOVERY SIGNAL TRANSMISSION BETWEEN USER EQUIPMENT

Abstract

Aspects of the disclosure relate to control of discovery signal transmissions for D2D communication. A first UE may transmit a discovery signal initiation message to at least a second UE to control transmission of a discovery signal from the second UE to a third UE. The second UE may identify a discovery signal monitoring duration of the second UE during which the second UE monitors for transmitted discovery signals transmitted from other UEs to the third UE. At expiration of the discovery signal monitoring duration, the second UE may transmit a discovery signal to the third UE when the number of transmitted discovery signals transmitted from the other UEs during the discovery signal monitoring duration is less than a discovery signal transmission number threshold.

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Family ID: **76478149**

Appl. No.: **19/186369**

Filed: **April 22, 2025**

Related U.S. Application Data

parent US continuation 17785388 20220614 parent-grant-document US 12323899 WO continuation PCT/CN2019/126864 20191220 child US 19186369

Publication Classification

Int. Cl.: **H04W40/24** (20090101); **H04W76/14** (20180101); **H04W88/04** (20090101)

U.S. Cl.:

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION(S) [0001] This application is a Continuation of application Ser. No. 17/785,388, filed on Jun. 14, 2022. Application Ser. No. 17/785,388 is a 371 National Stage of PCT Application No. PCT/CN 2019/126864, filed on Dec. 20, 2019, and assigned to the assignee hereof. The disclosure of the prior Applications is considered part of and is incorporated by reference into this Patent Application.

TECHNICAL FIELD
[0002] The technology discussed below relates generally to wireless communication networks, and more particularly, to control of discovery signal transmissions between user equipment (UEs) for device-to-device (D2D) communication.
INTRODUCTION
[0003] Communication networks have used relays in varying capacities. Relaying in cellular networks seeks to extend base station coverage, improve transmission reliability, and recover failed links due to, for example, blockage or fading. A relaying node may be a fixed node or a mobile device (e.g., a user equipment (UE)). Relaying between mobile devices may be achieved using D2D technology. D2D allows UEs to communicate over direct links, referred to herein as sidelinks, instead of through cellular network infrastructure.
[0004] D2D communications may use various frequency bands. In fifth-generation wireless technology, or 5G, D2D relaying may employ millimeter wave (mmWave) frequency transmissions in the range of 24 to 52.6 gigahertz (GHz) or more. In addition, due to the high propagation loss experienced by mmWaves, wireless devices may utilize highly directional antenna beams to facilitate mmWave communication.
[0005] As the demand for 5G wireless communication increases, research and development continue to advance 5G technologies not only to meet the growing demand for 5G wireless communication, but also to advance and enhance the user experience.
BRIEF SUMMARY OF SOME EXAMPLES
[0006] The following presents a summary of one or more aspects of the present disclosure, in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated features of the disclosure and is intended neither to identify key or critical elements of all aspects of the disclosure nor to delineate the scope of any or all aspects of the disclosure. Its sole purpose is to present some concepts of one or more aspects of the disclosure in a form as a prelude to the more detailed description that is presented later.
[0007] In one example, a method for wireless communication at a first user equipment (UE) in a wireless communication network is disclosed. The method includes identifying a discovery signal monitoring duration and a discovery signal transmission number threshold, receiving a discovery signal initiation message from a second UE, and initiating discovery signal monitoring for the discovery signal monitoring duration upon receiving the discovery signal initiation message from the second UE. The method further includes, upon expiration of the discovery signal monitoring duration, determining whether a number of transmitted discovery signals transmitted from other UEs is less than the discovery signal transmission number threshold, and when the number of transmitted discovery signals transmitted from the other UEs is less than the discovery signal transmission number threshold, transmitting a discovery signal to a third UE.
[0008] Another example provides a first user equipment (UE) configured for wireless communication. The first UE includes a processor, a memory communicatively coupled to the processor, and a transceiver communicatively coupled to the processor. The processor and the

memory are configured to identify a discovery signal monitoring duration and a discovery signal transmission number threshold, receive a discovery signal initiation message from a second UE, and initiate discovery signal monitoring for the discovery signal monitoring duration upon receiving the discovery signal initiation message from the second UE. The processor and the memory are further configured to, upon expiration of the discovery signal monitoring duration, determine whether a number of transmitted discovery signals transmitted from other UEs is less than the discovery signal transmission number threshold, and when the number of transmitted discovery signals transmitted from the other UEs is less than the discovery signal transmission number threshold, transmit a discovery signal to a third UE.

[0009] Another example provides a first user equipment (UE) configured for wireless communication. The first UE includes means for identifying a discovery signal monitoring duration and a discovery signal transmission number threshold, means for receiving a discovery signal initiation message from a second UE, and means for initiating discovery signal monitoring for the discovery signal monitoring duration upon receiving the discovery signal initiation message from the second UE. The first UE further includes, means for determining whether a number of transmitted discovery signals transmitted from other UEs is less than the discovery signal transmission number threshold upon expiration of the discovery signal monitoring duration, and means for transmitting a discovery signal to a third UE when the number of transmitted discovery signals transmitted from the other UEs is less than the discovery signal transmission number threshold.

[0010] Another example provides a computer readable medium storing computer executable code including instructions for causing a first user equipment (UE) to identify a discovery signal monitoring duration and a discovery signal transmission number threshold, receive a discovery signal initiation message from a second UE, and initiate discovery signal monitoring for the discovery signal monitoring duration upon receiving the discovery signal initiation message from the second UE. The computer readable medium further includes instruction for causing the first UE to, upon expiration of the discovery signal monitoring duration, determine whether a number of transmitted discovery signals transmitted from other UEs is less than the discovery signal transmission number threshold, and when the number of transmitted discovery signals transmitted from the other UEs is less than the discovery signal transmission number threshold, transmit a discovery signal to a third UE.

[0011] Another example provides method of wireless communication at a first user equipment (UE) in a wireless communication network. The method includes communicating with a second UE via a sidelink, and transmitting a discovery signal initiation message to at least a third UE to control transmission of a discovery signal from the third UE to the second UE based on a discovery signal monitoring duration during which the third UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0012] Another example provides a first user equipment (UE) configured for wireless communication. The first UE includes a processor, a memory communicatively coupled to the processor, and a transceiver communicatively coupled to the processor. The processor and the memory are configured to communicate with a second UE via a sidelink, and transmit a discovery signal initiation message to at least a third UE to control transmission of a discovery signal from the third UE to the second UE based on a discovery signal monitoring duration during which the third UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0013] Another example provides a first user equipment (UE) configured for wireless communication. The first UE includes means for communicating with a second UE via a sidelink, and means for transmitting a discovery signal initiation message to at least a third UE to control transmission of a discovery signal from the third UE to the second UE based on a discovery signal monitoring duration during which the third UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0014] Another example provides a computer readable medium storing computer executable code including instructions for causing a first user equipment (UE) to communicate with a second UE via a sidelink, and transmit a discovery signal initiation message to at least a third UE to control transmission of a discovery signal from the third UE to the second UE based on a discovery signal monitoring duration during which the third UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0015] Another example provides method of wireless communication at a base station in a wireless communication network. The method includes communicating with at least a first user equipment (UE) in the wireless communication network, and transmitting at least one of a discovery signal transmission number threshold or a discovery signal monitoring parameter to at least the first UE to control transmission of a discovery signal from the first UE to a second UE based on a discovery signal monitoring duration during which the first UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0016] Another example provides a base station configured for wireless communication. The base station includes a processor, a memory communicatively coupled to the processor, and a transceiver communicatively coupled to the processor. The processor and the memory are configured to communicate with at least a first user equipment (UE) in the wireless communication network, and transmit at least one of a discovery signal transmission number threshold or a discovery signal monitoring parameter to at least the first UE to control transmission of a discovery signal from the first UE to a second UE based on a discovery signal monitoring duration during which the first UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0017] Another example provides a base station configured for wireless communication. The base station includes means for communicating with at least a first user equipment (UE) in the wireless communication network, and means for transmitting at least one of a discovery signal transmission number threshold or a discovery signal monitoring parameter to at least the first UE to control transmission of a discovery signal from the first UE to a second UE based on a discovery signal monitoring duration during which the first UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0018] Another example provides a computer readable medium storing computer executable code including instructions for causing a base station to communicate with at least a first user equipment (UE) in the wireless communication network, and transmit at least one of a discovery signal transmission number threshold or a discovery signal monitoring parameter to at least the first UE to control transmission of a discovery signal from the first UE to a second UE based on a discovery signal monitoring duration during which the first UE monitors for transmitted discovery signals transmitted from other UEs to the second UE.

[0019] These and other aspects will become more fully understood upon a review of the detailed description, which follows. Other aspects, features, and embodiments will become apparent to those of ordinary skill in the art, upon reviewing the following description of specific, exemplary embodiments of in conjunction with the accompanying figures. While features may be discussed relative to certain embodiments and figures below, all embodiments can include one or more of the advantageous features discussed herein. In other words, while one or more embodiments may be discussed as having certain advantageous features, one or more of such features may also be used in accordance with the various embodiments discussed herein. In similar fashion, while exemplary embodiments may be discussed below as device, system, or method embodiments such exemplary embodiments can be implemented in various devices, systems, and methods.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a conceptual illustration of an example of a radio access network according to some aspects.

[0021] FIG. **2** is a diagram illustrating an example of a frame structure for use in a radio access network according to some aspects.

[0022] FIG. **3** is a diagram illustrating an exemplary wireless network employing D2D relaying according to some aspects.

[0023] FIG. **4** is a diagram illustrating an exemplary implementation of discovery signal transmission control according to some aspects.

[0024] FIG. **5** is a diagram illustrating another exemplary implementation of discovery signal transmission control according to some aspects.

[0025] FIG. **6** is a signaling diagram illustrating exemplary signaling to facilitate relay node switching according to some aspects.

[0026] FIG. **7** is a signaling diagram illustrating other exemplary signaling to facilitate relay node switching according to some aspects.

[0027] FIG. **8** is a block diagram illustrating an example of a hardware implementation for a base station employing a processing system according to some aspects.

[0028] FIG. **9** is a block diagram illustrating an example of a hardware implementation for a UE employing a processing system according to some aspects.

[0029] FIG. **10** is a flow chart of an exemplary method for a UE to facilitate discovery signal transmission according to some aspects.

[0030] FIG. **11** is a flow chart of another exemplary method for a UE to facilitate discovery signal transmission according to some aspects.

[0031] FIG. **12** is a flow chart of another exemplary method for a base station to facilitate discovery signal transmission between UEs according to some aspects.

DETAILED DESCRIPTION

[0032] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0033] Various aspects of the disclosure relate to control of discovery signal transmissions for D2D communication. A first UE may transmit a discovery signal initiation message to at least a second UE to control transmission of a discovery signal from the second UE to a third UE. The second UE may identify a discovery signal monitoring duration of the second UE during which the second UE monitors for transmitted discovery signals transmitted from other UEs to the third UE. At expiration of the discovery signal monitoring duration, the second UE may transmit a discovery signal to the third UE when the number of transmitted discovery signals transmitted from the other UEs during the discovery signal monitoring duration is less than a discovery signal transmission number threshold.

[0034] In one example, the discovery signal control mechanism may be implemented within a wireless network to facilitate switching of a relay node relaying communication between a UE and a base station. However, it should be understood that the discovery signal control mechanism is not limited to relay node switching processes and may be utilized in other D2D discovery processes. In the relay node switching example, the first UE may be a source relay UE that operates as a relay node to relay communication between the third UE (e.g., a remote UE) and a base station. The source relay UE may initiate a relay node switch of the remote UE to the second UE (e.g., a

neighbor relay UE) due to various factors, such as the movement of the first UE and/or third UE, channel variance, a battery status change, and/or a load status change.

[0035] To facilitate relay node switching, the source relay UE may transmit the discovery signal initiation message to one or more neighbor relay UEs. For example, the discovery signal initiation message may be broadcast or multicast to the neighbor relay UEs. The discovery signal initiation message initiates a respective discovery signal monitoring duration on each of the neighbor relay UEs. The respective discovery signal monitoring duration may be calculated on each of the neighbor relay UEs based on a discovery signal monitoring parameter. For example, the discovery signal monitoring parameter may include at least one probability distribution parameter associated with a probability distribution.

[0036] Each neighbor relay UE monitors the number of discovery signals transmitted by other neighbor relay UEs during their respective discovery signal monitoring duration. At expiration of the monitoring signal duration on a particular neighbor relay UE, the particular neighbor relay UE compares the number of transmitted discovery signals with the discovery signal transmission number threshold. When the number of transmitted discovery signals is less than the discovery signal transmission number threshold, the particular neighbor relay UE transmits a discovery signal to the remote UE. However, when the number of transmitted discovery signals is greater than or equal to the discovery signal transmission number threshold, the particular neighbor relay UE is precluded from transmitting the discovery signal and returns to a stand-by (non-relay) mode.

[0037] In some examples, the discovery signal monitoring parameter and discovery signal transmission number threshold are broadcast or multicast by the source relay UE to the neighbor relay UEs. In other examples, the discovery signal monitoring parameter and discovery signal transmission number threshold are broadcast, multicast, or unicast by the base station to the neighbor relay UEs. In still other examples, the discovery signal monitoring parameter and discovery signal transmission number threshold are hard-coded within the neighbor relay UEs.

[0038] While aspects and embodiments are described in this application by illustration to some examples, those skilled in the art will understand that additional implementations and use cases may come about in many different arrangements and scenarios. Innovations described herein may be implemented across many differing platform types, devices, systems, shapes, sizes, packaging arrangements. For example, embodiments and/or uses may come about via integrated chip embodiments and other non-module-component based devices (e.g., end-user devices, vehicles, communication devices, computing devices, industrial equipment, retail/purchasing devices, medical devices, AI-enabled devices, etc.). While some examples may or may not be specifically directed to use cases or applications, a wide assortment of applicability of described innovations may occur. Implementations may range a spectrum from chip-level or modular components to non-modular, non-chip-level implementations and further to aggregate, distributed, or OEM devices or systems incorporating one or more aspects of the described innovations. In some practical settings, devices incorporating described aspects and features may also necessarily include additional components and features for implementation and practice of claimed and described embodiments. For example, transmission and reception of wireless signals necessarily includes a number of components for analog and digital purposes (e.g., hardware components including antenna, RF-chains, power amplifiers, modulators, buffer, processor(s), interleaver, adders/summers, etc.). It is intended that innovations described herein may be practiced in a wide variety of devices, chip-level components, systems, distributed arrangements, end-user devices, etc. of varying sizes, shapes and constitution.

[0039] The various concepts presented throughout this disclosure may be implemented across a broad variety of telecommunication systems, network architectures, and communication standards. Referring now to FIG. **1**, as an illustrative example without limitation, a schematic illustration of a radio access network **100** is provided. The RAN **100** may implement any suitable wireless communication technology or technologies to provide radio access. As one example, the RAN **100**

may operate according to 3.sup.rd Generation Partnership Project (3GPP) New Radio (NR) specifications, often referred to as 5G. As another example, the RAN **100** may operate under a hybrid of 5G NR and Evolved Universal Terrestrial Radio Access Network (eUTRAN) standards, often referred to as LTE. The 3GPP refers to this hybrid RAN as a next-generation RAN, or NG-RAN. Of course, many other examples may be utilized within the scope of the present disclosure.

[0040] The geographic region covered by the radio access network **100** may be divided into a number of cellular regions (cells) that can be uniquely identified by a user equipment (UE) based on an identification broadcasted over a geographical area from one access point or base station. FIG. **1** illustrates macrocells **102**, **104**, and **106**, **144** and a small cell **108**, each of which may include one or more sectors (not shown). A sector is a sub-area of a cell. All sectors within one cell are served by the same base station. A radio link within a sector can be identified by a single logical identification belonging to that sector. In a cell that is divided into sectors, the multiple sectors within a cell can be formed by groups of antennas with each antenna responsible for communication with UEs in a portion of the cell.

[0041] In general, a respective base station (BS) serves each cell. Broadly, a base station is a network element in a radio access network responsible for radio transmission and reception in one or more cells to or from a UE. A BS may also be referred to by those skilled in the art as a base transceiver station (BTS), a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), an access point (AP), a Node B (NB), an eNode B (eNB), a gNode B (gNB) or some other suitable terminology.

[0042] In FIG. **1**, three base stations **110**, **112**, and **146** are shown in cells **102**, **104**, and **144**, respectively; and a third base station **114** is shown controlling a remote radio head (RRH) **116** in cell **106**. That is, a base station can have an integrated antenna or can be connected to an antenna or RRH by feeder cables. In the illustrated example, the cells **102**, **104**, **106**, and **144** may be referred to as macrocells, as the base stations **110**, **112**, **114**, and **146** support cells having a large size. Further, a base station **118** is shown in the small cell **108** (e.g., a microcell, picocell, femtocell, home base station, home Node B, home eNode B, etc.) which may overlap with one or more macrocells. In this example, the cell **108** may be referred to as a small cell, as the base station **118** supports a cell having a relatively small size. Cell sizing can be done according to system design as well as component constraints. It is to be understood that the radio access network **100** may include any number of wireless base stations and cells. Further, a relay node may be deployed to extend the size or coverage area of a given cell. The base stations **110**, **112**, **114**, **118**, **146** provide wireless access points to a core network for any number of mobile apparatuses.

[0043] FIG. **1** further includes a quadcopter or drone **120**, which may be configured to function as a base station. That is, in some examples, a cell may not necessarily be stationary, and the geographic area of the cell may move according to the location of a mobile base station such as the quadcopter **120**.

[0044] In general, base stations may include a backhaul interface for communication with a backhaul portion (not shown) of the network. The backhaul may provide a link between a base station and a core network (not shown), and in some examples, the backhaul may provide interconnection between the respective base stations. The core network may be a part of a wireless communication system and may be independent of the radio access technology used in the radio access network. Various types of backhaul interfaces may be employed, such as a direct physical connection, a virtual network, or the like using any suitable transport network.

[0045] The RAN **100** is illustrated supporting wireless communication for multiple mobile apparatuses. A mobile apparatus is commonly referred to as user equipment (UE) in standards and specifications promulgated by the 3rd Generation Partnership Project (3GPP), but may also be referred to by those skilled in the art as a mobile station (MS), a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal (AT), a

mobile terminal, a wireless terminal, a remote terminal, a handset, a terminal, a user agent, a mobile client, a client, or some other suitable terminology. A UE may be an apparatus that provides a user with access to network services.

[0046] Within the present document, a "mobile" apparatus need not necessarily have a capability to move, and may be stationary. The term mobile apparatus or mobile device broadly refers to a diverse array of devices and technologies. For example, some non-limiting examples of a mobile apparatus include a mobile, a cellular (cell) phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal computer (PC), a notebook, a netbook, a smartbook, a tablet, a personal digital assistant (PDA), and a broad array of embedded systems, e.g., corresponding to an "Internet of things" (IT). A mobile apparatus may additionally be an automotive or other transportation vehicle, a remote sensor or actuator, a robot or robotics device, a satellite radio, a global positioning system (GPS) device, an object tracking device, a drone, a multi-copter, a quad-copter, a remote control device, a consumer and/or wearable device, such as eyewear, a wearable camera, a virtual reality device, a smart watch, a health or fitness tracker, a digital audio player (e.g., MP3 player), a camera, a game console, etc. A mobile apparatus may additionally be a digital home or smart home device such as a home audio, video, and/or multimedia device, an appliance, a vending machine, intelligent lighting, a home security system, a smart meter, etc. A mobile apparatus may additionally be a smart energy device, a security device, a solar panel or solar array, a municipal infrastructure device controlling electric power (e.g., a smart grid), lighting, water, etc.; an industrial automation and enterprise device; a logistics controller; agricultural equipment; military defense equipment, vehicles, aircraft, ships, and weaponry, etc. Still further, a mobile apparatus may provide for connected medicine or telemedicine support, i.e., health care at a distance. Telehealth devices may include telehealth monitoring devices and telehealth administration devices, whose communication may be prioritized access over other types of information, e.g., in terms of prioritized access for transport of critical service data, and/or relevant QoS for transport of critical service data.

[0047] Within the RAN **100**, the cells may include UEs that may be in communication with one or more sectors of each cell. For example, UEs **122** and **124** may be in communication with base station **110**; UEs **126** and **128** may be in communication with base station **112**; UEs **130** and **132** may be in communication with base station **114** by way of RRH **116**; UE **134** may be in communication with base station **118**; UEs **138**, **140**, and **142** may be in communication with base station **146**; and UE **136** may be in communication with mobile base station **120**. Here, each base station **110**, **112**, **114**, **118**, **120**, and **146** may be configured to provide an access point to a core network (not shown) for all the UEs in the respective cells. In another example, a mobile network node (e.g., quadcopter **120**) may be configured to function as a UE. For example, the quadcopter **120** may operate within cell **102** by communicating with base station **110**.

[0048] Wireless communication between a RAN **100** and a UE (e.g., UE **122** or **124**) may be described as utilizing an air interface. Transmissions over the air interface from a base station (e.g., base station **110**) to one or more UEs (e.g., UE **122** and **124**) may be referred to as downlink (DL) transmission. In accordance with certain aspects of the present disclosure, the term downlink may refer to a point-to-multipoint transmission originating at a scheduling entity (described further below; e.g., base station **110**). Another way to describe this scheme may be to use the term broadcast channel multiplexing. Transmissions from a UE (e.g., UE **122**) to a base station (e.g., base station **110**) may be referred to as uplink (UL) transmissions. In accordance with further aspects of the present disclosure, the term uplink may refer to a point-to-point transmission originating at a scheduled entity (described further below; e.g., UE **122**).

[0049] For example, DL transmissions may include unicast or broadcast transmissions of control information and/or data (e.g., user data traffic or other type of traffic) from a base station (e.g., base station **110**) to one or more UEs (e.g., UEs **122** and **124**), while UL transmissions may include transmissions of control information and/or traffic information originating at a UE (e.g., UE **122**).

In addition, the uplink and/or downlink control information and/or traffic information may be time-divided into frames, subframes, slots, and/or symbols. As used herein, a symbol may refer to a unit of time that, in an orthogonal frequency division multiplexed (OFDM) waveform, carries one resource element (RE) per sub-carrier. A slot may carry 7 or 14 OFDM symbols. A subframe may refer to a duration of 1 ms. Multiple subframes or slots may be grouped together to form a single frame or radio frame. Of course, these definitions are not required, and any suitable scheme for organizing waveforms may be utilized, and various time divisions of the waveform may have any suitable duration.

[0050] The air interface in the RAN **100** may utilize one or more multiplexing and multiple access algorithms to enable simultaneous communication of the various devices. For example, 5G NR specifications provide multiple access for UL or reverse link transmissions from UEs **122** and **124** to base station **110**, and for multiplexing DL or forward link transmissions from the base station **110** to UEs **122** and **124** utilizing orthogonal frequency division multiplexing (OFDM) with a cyclic prefix (CP). In addition, for UL transmissions, 5G NR specifications provide support for discrete Fourier transform-spread-OFDM (DFT-s-OFDM) with a CP (also referred to as single-carrier FDMA (SC-FDMA)). However, within the scope of the present disclosure, multiplexing and multiple access are not limited to the above schemes, and may be provided utilizing time division multiple access (TDMA), code division multiple access (CDMA), frequency division multiple access (FDMA), sparse code multiple access (SCMA), resource spread multiple access (RSMA), or other suitable multiple access schemes. Further, multiplexing DL transmissions from the base station **110** to UEs **122** and **124** may be provided utilizing time division multiplexing (TDM), code division multiplexing (CDM), frequency division multiplexing (FDM), orthogonal frequency division multiplexing (OFDM), sparse code multiplexing (SCM), or other suitable multiplexing schemes.

[0051] Further, the air interface in the RAN **100** may utilize one or more duplexing algorithms. Duplex refers to a point-to-point communication link where both endpoints can communicate with one another in both directions. Full duplex means both endpoints can simultaneously communicate with one another. Half duplex means only one endpoint can send information to the other at a time. In a wireless link, a full duplex channel generally relies on physical isolation of a transmitter and receiver, and suitable interference cancellation technologies. Full duplex emulation is frequently implemented for wireless links by utilizing frequency division duplex (FDD) or time division duplex (TDD). In FDD, transmissions in different directions operate at different carrier frequencies. In TDD, transmissions in different directions on a given channel are separated from one another using time division multiplexing. That is, at some times the channel is dedicated for transmissions in one direction, while at other times the channel is dedicated for transmissions in the other direction, where the direction may change very rapidly, e.g., several times per slot.

[0052] In the RAN **100**, the ability for a UE to communicate while moving, independent of their location, is referred to as mobility. The various physical channels between the UE and the RAN are generally set up, maintained, and released under the control of an access and mobility management function (AMF), which may include a security context management function (SCM F) that manages the security context for both the control plane and the user plane functionality and a security anchor function (SEAF) that performs authentication. In various aspects of the disclosure, a RAN **100** may utilize DL-based mobility or UL-based mobility to enable mobility and handovers (i.e., the transfer of a UE's connection from one radio channel to another). In a network configured for DL-based mobility, during a call with a scheduling entity, or at any other time, a UE may monitor various parameters of the signal from its serving cell as well as various parameters of neighboring cells. Depending on the quality of these parameters, the UE may maintain communication with one or more of the neighboring cells. During this time, if the UE moves from one cell to another, or if signal quality from a neighboring cell exceeds that from the serving cell for a given amount of time, the UE may undertake a handoff or handover from the serving cell to

the neighboring (target) cell. For example, UE **124** may move from the geographic area corresponding to its serving cell **102** to the geographic area corresponding to a neighbor cell **106**. When the signal strength or quality from the neighbor cell **106** exceeds that of its serving cell **102** for a given amount of time, the UE **124** may transmit a reporting message to its serving base station **110** indicating this condition. In response, the UE **124** may receive a handover command, and the UE may undergo a handover to the cell **106**.

[0053] In a network configured for UL-based mobility, UL reference signals from each UE may be utilized by the network to select a serving cell for each UE. In some examples, the base stations **110**, **112**, **146**, and **114**/**116** may broadcast unified synchronization signals (e.g., unified Primary Synchronization Signals (PSSs), unified Secondary Synchronization Signals (SSSs) and unified Physical Broadcast Channels (PBCH)). The UEs **122**, **124**, **126**, **128**, **130**, **132**, **138**, **140**, and **142** may receive the unified synchronization signals, derive the carrier frequency and radio frame timing from the synchronization signals, and in response to deriving timing, transmit an uplink pilot or reference signal. The uplink pilot signal transmitted by a UE (e.g., UE **124**) may be concurrently received by two or more cells (e.g., base stations **110** and **114**/**116**) within the RAN **100**. Each of the cells may measure a strength of the pilot signal, and the RAN (e.g., one or more of the base stations **110** and **114**/**116** and/or a central node within the core network) may determine a serving cell for the UE **124**. As the UE **124** moves through the RAN **100**, the network may continue to monitor the uplink pilot signal transmitted by the UE **124**. When the signal strength or quality of the pilot signal measured by a neighboring cell exceeds that of the signal strength or quality measured by the serving cell, the RAN **100** may handover the UE **124** from the serving cell to the neighboring cell, with or without informing the UE **124**.

[0054] Although the synchronization signal transmitted by the base stations **110**, **112**, and **114**/**116** may be unified, the synchronization signal may not identify a particular cell, but rather may identify a zone of multiple cells operating on the same frequency and/or with the same timing. The use of zones in 5G networks or other next generation communication networks enables the uplink-based mobility framework and improves the efficiency of both the UE and the network, since the number of mobility messages that need to be exchanged between the UE and the network may be reduced.

[0055] In various implementations, the air interface in the RAN **100** may utilize licensed spectrum, unlicensed spectrum, or shared spectrum. Licensed spectrum provides for exclusive use of a portion of the spectrum, generally by virtue of a mobile network operator purchasing a license from a government regulatory body. Unlicensed spectrum provides for shared use of a portion of the spectrum without need for a government-granted license. While compliance with some technical rules is generally still required to access unlicensed spectrum, generally, any operator or device may gain access. Shared spectrum may fall between licensed and unlicensed spectrum, wherein technical rules or limitations may be required to access the spectrum, but the spectrum may still be shared by multiple operators and/or multiple RATs. For example, the holder of a license for a portion of licensed spectrum may provide licensed shared access (LSA) to share that spectrum with other parties, e.g., with suitable licensee-determined conditions to gain access.

[0056] In order for transmissions over the RAN **100** to obtain a low block error rate (BLER) while still achieving very high data rates, channel coding may be used. That is, wireless communication may generally utilize a suitable error correcting block code. In a typical block code, an information message or sequence is split up into code blocks (CBs), and an encoder (e.g., a CODEC) at the transmitting device then mathematically adds redundancy to the information message. Exploitation of this redundancy in the encoded information message can improve the reliability of the message, enabling correction for any bit errors that may occur due to the noise.

[0057] In early 5G NR specifications, data is coded using quasi-cyclic low-density parity check (LDPC) with two different base graphs: one base graph is used for large code blocks and/or high code rates, while the other base graph is used otherwise. Control information and the physical

broadcast channel (PBCH) are coded using Polar coding, based on nested sequences. For these channels, puncturing, shortening, and repetition are used for rate matching.

[0058] However, those of ordinary skill in the art will understand that aspects of the present disclosure may be implemented utilizing any suitable channel code. Various implementations of base stations and UEs may include suitable hardware and capabilities (e.g., an encoder, a decoder, and/or a CODEC) to utilize one or more of these channel codes for wireless communication.

[0059] In some examples, access to the air interface may be scheduled, wherein a scheduling entity (e.g., a base station) allocates resources (e.g., time-frequency resources) for communication among some or all devices and equipment within its service area or cell. Within the present disclosure, as discussed further below, the scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more scheduled entities. That is, for scheduled communication, UEs or scheduled entities utilize resources allocated by the scheduling entity.

[0060] Base stations are not the only entities that may function as a scheduling entity. That is, in some examples, a UE may function as a scheduling entity, scheduling resources for one or more scheduled entities (e.g., one or more other UEs). In other examples, two or more UEs (e.g., UEs **138** and **140**) may communicate with each other using sidelink signals **137** without conveying that communication through a base station (e.g., base station **146**) and without necessarily relying on scheduling or control information from a base station. In some examples, the UE **138** is functioning as a scheduling entity or an initiating (e.g., transmitting) sidelink device, and UE **140** may function as a scheduled entity or a receiving sidelink device. For example, the UE **138** may function as a scheduling entity in a device-to-device (D2D) system, peer-to-peer (P2P) system, vehicle-to-vehicle (V2V) network, a vehicle-to-everything (V2X) network, and/or in a mesh network.

[0061] For example, in D2D systems, two or more UEs (e.g., UEs **138** and **140**) may communicate over a direct link with one other without traversing a base station (e.g., base station **146**). For example, the UEs **138** and **140** may communicate using narrow directional beams over a mmWave carrier frequency. Here, D2D communication may refer to sidelink communication or relaying communication utilizing sidelink signals. In various aspects of the disclosure, a D2D relay framework may be included within a cellular network to facilitate relaying of communication to/from the base station **146** via D2D links (referred to herein as sidelinks **137**). For example, one or more UEs (e.g., UE **138**) within the coverage area of the base station **146** may operate as relaying UEs to extend the coverage of the base station **146**, improve the transmission reliability to one or more UEs (e.g., UE **140**), and/or to allow the base station to recover from a failed UE link due to, for example, blockage or fading.

[0062] To facilitate D2D communication between UEs **138** and **140** over the sidelink **137**, UE **138** may include a discovery signal (DS) manager **148** configured to control transmission of a discovery signal to UE **140**. In some examples, the discovery signal may include a synchronization signal, such as a primary synchronization signal (PSS) and/or a secondary synchronization signal (SSS) that facilitates device discovery and enables synchronization of communication on the sidelink **137**. The discovery signal may be utilized by the UE **140** to measure the signal strength and channel status of a potential sidelink (e.g., sidelink **137**) with another UE (e.g., UE **138**). The UE **140** may utilize the measurement results to select a UE (e.g., UE **138**) for sidelink communication or relay communication.

[0063] In some examples, the sidelink **137** between UE **138** and UE **140** may be established as part of a relay node switching process. For example, the UE **140** may have a relay connection to the base station **146** via another UE (e.g., UE **142**). The UE **140** may then select UE **138** as a relay node switch target to switch relaying communication with the base station **146** from UE **142** to UE **138**. Relay node switching may be performed, for example, due to one or more factors, such as movement of the UE **140** and/or UE **142**, channel variance, a battery status change, and/or a load status change.

[0064] The DS manager **148** within UE **138** may be configured, for example, to receive a discovery

signal initiation message from UE **142** to control transmission of a discovery signal from UE **138** to UE **140** based on a discovery signal monitoring duration of the UE **138**. The discovery signal monitoring duration defines a period of time during which the UE **138** monitors for transmitted discovery signals transmitted from other UEs to the UE **140**. In some examples, the discovery signal monitoring duration may be calculated from a discovery signal monitoring parameter that is hard-coded into the UE **138** or received from the UE **142** or the base station **146**. For example, the discovery signal monitoring parameter may include at least one probability distribution parameter associated with a probability distribution.

[0065] At expiration of the discovery signal monitoring duration, the DS manager **148** enables the UE **138** to transmit a discovery signal to the UE **140** when the number of transmitted discovery signals transmitted from the other UEs during the discovery signal monitoring duration is less than a discovery signal transmission number threshold. The discovery signal transmission number threshold may be hard-coded into the UE **138** or received from the UE **142** or the base station **146**.

[0066] In some examples, after establishing the sidelink **137** between UE **138** and UE **140** for relay communication, the DS manager **148** within the UE **138** may further be configured to facilitate a relay node switch from the UE **138** to another UE (e.g., UE **142**). In this example, the DS manager **148** may be configured to transmit the discovery signal initiation message to one or more neighbor UEs (e.g., UE **142**) to control transmission of a discovery signal from the neighbor UE(s) **142** to UE **140** for relay node switching from the UE **138** to, for example, the UE **142**. The DS manager **148** may further be configured to transmit the discovery signal monitoring parameter to the one or more neighbor UE(s) **142** via, for example, broadcast or multicast signaling for use in calculating respective discovery signal monitoring durations on the neighbor UE(s) **142**. In addition, the DS manager **148** may further be configured to transmit the discovery signal transmission number threshold to the one or more neighbor UE(s) **142** to allow transmission of the discovery signal from the neighbor UE **142** to the UE **140** when the number of transmitted discovery signal transmitted from other UEs to the UE **140** is less than the discovery signal transmission number threshold during the computed discovery signal monitoring duration of the neighbor UE **142**.

[0067] In some examples, as shown in FIG. **1**, the base station **146** may also include a DS parameter manager **150**. In this example, the DS parameter manager **150** of the base station **146** may be configured to transmit at least one of the discovery signal monitoring parameter or the discovery signal transmission number threshold to one or more UEs (e.g., UEs **138** and **142**). For example, the DS parameter manager **150** may be configured to broadcast, multicast, or unicast the discovery signal monitoring parameter and/or discovery signal transmission number threshold to the UEs **138** and **142**.

[0068] Various aspects of the present disclosure will be described with reference to an OFDM waveform, schematically illustrated in FIG. **2**. It should be understood by those of ordinary skill in the art that the various aspects of the present disclosure may be applied to an SC-FDMA waveform in substantially the same way as described herein below. That is, while some examples of the present disclosure may focus on an OFDM link for clarity, it should be understood that the same principles may be applied as well to SC-FDMA waveforms.

[0069] Referring now to FIG. **2**, an expanded view of an exemplary DL subframe **202** is illustrated, showing an OFDM resource grid. However, as those skilled in the art will readily appreciate, the PHY transmission structure for any particular application may vary from the example described here, depending on any number of factors. Here, time is in the horizontal direction with units of OFDM symbols; and frequency is in the vertical direction with units of subcarriers.

[0070] The resource grid **204** may be used to schematically represent time-frequency resources for a given antenna port. That is, in a multiple-input-multiple-output (MIMO) implementation with multiple antenna ports available, a corresponding multiple number of resource grids **204** may be available for communication. The resource grid **204** is divided into multiple resource elements (REs) **206**. An RE, which is 1 subcarrier×1 symbol, is the smallest discrete part of the time-

frequency grid, and contains a single complex value representing data from a physical channel or signal. Depending on the modulation utilized in a particular implementation, each RE may represent one or more bits of information. In some examples, a block of REs may be referred to as a physical resource block (PR B) or a resource block (RB) **208**, which contains any suitable number of consecutive subcarriers in the frequency domain. In one example, an RB may include 12 subcarriers, a number independent of the numerology used. In some examples, depending on the numerology, an RB may include any suitable number of consecutive OFDM symbols in the time domain. Within the present disclosure, it is assumed that a single RB such as the RB **208** entirely corresponds to a single direction of communication (either transmission or reception for a given device).

[0071] Scheduling of UEs (e.g., scheduled entities) for downlink, uplink, or sidelink transmissions typically involves scheduling one or more resource elements **206** within one or more sub-bands. Thus, a UE generally utilizes only a subset of the resource grid **204**. In some examples, an RB may be the smallest unit of resources that can be allocated to a UE. Thus, the more RBs scheduled for a UE, and the higher the modulation scheme chosen for the air interface, the higher the data rate for the UE. The RBs may be scheduled by a base station or may be self-scheduled by a UE implementing D2D sidelink communication.

[0072] In this illustration, the RB **208** is shown as occupying less than the entire bandwidth of the subframe **202**, with some subcarriers illustrated above and below the RB **208**. In a given implementation, the subframe **202** may have a bandwidth corresponding to any number of one or more RBs **208**. Further, in this illustration, the RB **208** is shown as occupying less than the entire duration of the subframe **202**, although this is merely one possible example.

[0073] Each 1 ms subframe **202** may consist of one or multiple adjacent slots. In the example shown in FIG. **2**, one subframe **202** includes four slots **210**, as an illustrative example. In some examples, a slot may be defined according to a specified number of OFDM symbols with a given cyclic prefix (CP) length. For example, a slot may include 7 or 14 OFDM symbols with a nominal CP. Additional examples may include mini-slots, sometimes referred to as shortened transmission time intervals (TTIs), having a shorter duration (e.g., one to three OFDM symbols). These mini-slots or shortened transmission time intervals (TTIs) may in some cases be transmitted occupying resources scheduled for ongoing slot transmissions for the same or for different UEs. Any number of resource blocks may be utilized within a subframe or slot.

[0074] An expanded view of one of the slots **210** illustrates the slot **210** including a control region **212** and a data region **214**. In general, the control region **212** may carry control channels, and the data region **214** may carry data channels. Of course, a slot may contain all DL, all UL, or at least one DL portion and at least one UL portion. The structure illustrated in FIG. **2** is merely exemplary in nature, and different slot structures may be utilized, and may include one or more of each of the control region(s) and data region(s).

[0075] Although not illustrated in FIG. **2**, the various REs **206** within a RB **208** may be scheduled to carry one or more physical channels, including control channels, shared channels, data channels, etc. Other REs **206** within the RB **208** may also carry pilots or reference signals, including but not limited to a demodulation reference signal (DMRS) a control reference signal (CRS), or a sounding reference signal (SRS). These pilots or reference signals may provide for a receiving device to perform channel estimation of the corresponding channel, which may enable coherent demodulation/detection of the control and/or data channels within the RB **208**.

[0076] In some examples, the slot **210** may be utilized for broadcast, multicast or unicast communication. For example, a broadcast or multicast communication may refer to a point-to-multipoint transmission by one device (e.g., a base station, UE, or other similar device) to other devices. Here, a broadcast communication is delivered to all devices, whereas a multicast communication is delivered to multiple intended recipient devices. A unicast communication may refer to a point-to-point transmission by a one device to a single other device.

[0077] In a DL transmission, the transmitting device may allocate one or more REs **206** (e.g., within a control region **212**) to carry DL control information including one or more DL control channels, such as a PBCH; a PSS; a SSS; a physical control format indicator channel (PCFICH); a physical hybrid automatic repeat request (HAR Q) indicator channel (PHICH); and/or a physical downlink control channel (PDCCH), etc., to one or more scheduled entities. The PCFICH provides information to assist a receiving device in receiving and decoding the PDCCH. The PDCCH carries downlink control information (DCI) including but not limited to power control commands, scheduling information, a grant, and/or an assignment of REs for DL and UL transmissions. The PHICH carries HARQ feedback transmissions such as an acknowledgment (ACK) or negative acknowledgment (NACK). HARQ is a technique well-known to those of ordinary skill in the art, wherein the integrity of packet transmissions may be checked at the receiving side for accuracy, e.g., utilizing any suitable integrity checking mechanism, such as a checksum or a cyclic redundancy check (CRC). If the integrity of the transmission confirmed, an ACK may be transmitted, whereas if not confirmed, a NACK may be transmitted. In response to a NACK, the transmitting device may send a HARQ retransmission, which may implement chase combining, incremental redundancy, etc.

[0078] In an UL transmission, the transmitting device may utilize one or more REs **206** to carry UL control information including one or more UL control channels, such as a physical uplink control channel (PUCCH), to the scheduling entity. UL control information may include a variety of packet types and categories, including pilots, reference signals, and information configured to enable or assist in decoding uplink data transmissions. In some examples, the control information may include a scheduling request (SR), i.e., request for the scheduling entity to schedule uplink transmissions. Here, in response to the SR transmitted on the control channel, the scheduling entity may transmit downlink control information that may schedule resources for uplink packet transmissions. UL control information may also include HARQ feedback, channel state feedback (CSF), or any other suitable UL control information.

[0079] In addition to control information, one or more REs **206** (e.g., within the data region **214**) may be allocated for user data traffic. Such traffic may be carried on one or more traffic channels, such as, for a DL transmission, a physical downlink shared channel (PDSCH); or for an UL transmission, a physical uplink shared channel (PUSCH). In some examples, one or more REs **206** within the data region **214** may be configured to carry system information blocks (SIBs), carrying information that may enable access to a given cell.

[0080] In an example of sidelink communication, the control region **212** of the slot **210** may include a physical sidelink control channel (PSCCH) including downlink control information (DCI) transmitted by a UE (e.g., D2D device) towards a set of one or more other UEs (e.g., other D2D devices). In some examples, the DCI may include synchronization information to synchronize communication between sidelink devices on the sidelink channel. In addition, the DCI may include scheduling information indicating one or more resource blocks within the data region **214** reserved by an initiating (or transmitting) sidelink device (e.g., the "scheduling entity") for sidelink communication. The data region **214** of the slot **210** may include a physical sidelink shared channel (PSSCH) including the data transmitted by the initiating sidelink device within the reserved resources over the sidelink channel.

[0081] These physical channels described above are generally multiplexed and mapped to transport channels for handling at the medium access control (MAC) layer. Transport channels carry blocks of information called transport blocks (TB). The transport block size (TBS), which may correspond to a number of bits of information, may be a controlled parameter, based on the modulation and coding scheme (MCS) and the number of RBs in a given transmission.

[0082] The channels or carriers described above in connection with FIGS. **1** and **2** are not necessarily all of the channels or carriers that may be utilized between a scheduling entity and scheduled entities, and those of ordinary skill in the art will recognize that other channels or

carriers may be utilized in addition to those illustrated, such as other traffic, control, and feedback channels.

[0083] FIG. **3** is a diagram illustrating an exemplary wireless network **300** employing D2D relaying. The wireless network **300** may correspond, for example, to the RAN **100** illustrated in FIG. **1**. The wireless network **300** may include a fifth generation base station (e.g., a gNB) **304** in wireless communication one or more UEs **302***a*, **302***b*, **302***c*, **302***d*, and **302***e*. In the example shown in FIG. **3**, the base station **304** may communicate with each of the UEs **302***a*, **302***b*, **302***c*, **302***d*, and **302***e* via a respective wireless communication link **306***a*, **306***b*, **306***c*, **306***d*, and **306***e*. Each of the wireless communication links **306***a*, **306***b*, **306***c*, **306***d*, and **306***e* may utilize a sub-6 GHz carrier frequency or a mmWave carrier frequency.

[0084] In addition, a D2D relay link (sidelink) **308***a* may be established between UE **302***a* and another UE **302***f* to enable relaying of information between the base station **304** and the UE **302***f*. In this example, the relay link (sidelink) **308***a* may be established between the UE **302***a* and UE **302***f* due to distance or signal blocking between the base station **304** and UE **302***f*, weak receiving capability of the UE **302***f*, low transmission power of the UE **302***f*, and/or limited battery capacity of UE **302***f*. The relay link **308***a* between UEs **302***a* and **302***f* may enable communication between the base station **304** and UE **302***f* to be relayed via UE **302***a* over wireless communication link (e.g., the Uu interface) **306***a* and relay link (e.g., sidelink) **308***a*.

[0085] In the example shown in FIG. **3**, the UE **302***a* may be referred to as a source relay UE, UEs **302***b*-**302***e* may be referred to as neighbor relay UEs, and the UE **302***f* may be referred to as a remote UE. When the source relay UE **302***a* initiates a relay node switch of the remote UE **302***f* from the source relay UE **302***a* to one of the neighbor relay UEs **302***b*-**302***e* (e.g., due to movement of UE **302***a* or **302***f*, channel variance of the channel between UE **302***a* and **302***f*, a battery status change of UE **302***a* or **302***f*, and/or a load status change associated with UE **302***a*), the source relay UE **302***a* may instruct the remote UE **302***f* to perform the relay node switch.

[0086] In some examples, the remote UE **302***f* may perform the relay node switch operation without assistance from the source relay UE **302***a*. For example, the remote UE **302***f* may detect one or more neighbor relay UEs **302***b*-**302***e*, awaken the one or more of the neighbor relay UEs **302***b*-**302***e*, and receive and process discovery signals from the one or more neighbor relay UEs **302***b*-**302***e*. In this example, a large amount of signaling and processing is involved in performing the relay node switch operation, which may impact the battery life of the remote UE **302***f*. Moreover, if the device bandwidth of the remote UE **302***f* is smaller than the device bandwidth of one or more of the neighbor UEs **302***b*-**302***e*, the remote UE **302***f* may perform inter-frequency measurements, which may result in data transfer interruptions.

[0087] In some examples, the source relay UE **302***a* may assist the remote UE **302***f* in discovering and activating neighbor relay UEs **302***b*-**302***e* for relay node switching. For example, the source relay UE **302***a* may monitor a scope of possible frequency spectrums to identify the device bandwidth of each of the neighbor relay UEs **302***b*-**302***e*, exchange messages with each of the neighbor relay UEs **302***b*-**302***e* to determine the availability of each of the neighbor relay UEs **302***b*-**302***e* to relay to the remote UE **302***f*, and then indicate to the available neighbor relay UEs **302***b*-**302***e* to transmit a discovery signal to the remote UE **302***f*. In this example, when there are a large number of neighbor relay UEs **302***b*-**302***e*, individually communicating with each neighbor relay UE **302***b*-**302***e* may increase the latency in completing the relay node switch process and may further result in high power consumption at the source relay UE **302***a*. In addition, the mutual interference among the discovery signals increases as the number of neighbor relay UEs **302***b*-**302***e* increases.

[0088] In various aspects of the disclosure, to reduce the latency in performing relay node switching, reduce the mutual interference among transmitted discovery signals, and minimize power consumption in the source relay UE **302***a* and remote UE **302***f*, a limited number of neighbor relay UEs **302***b*-**302***e* may be activated to transmit discovery signals to the remote UE **302***f*. To

control the activation of neighbor relay UEs **302***b*-**302***e* to transmit discovery signals to the remote UE **302***f*, the source relay UE **302***a* and neighbor relay UEs **302***b*-**302***e* may each include a respective discovery signal (DS) manager **310***a*-**310***e*. Each DS manager **310***a*-**310***e* may correspond, for example, to the DS manager **148** shown in FIG. **1**.

[0089] In some examples, the source relay UE **302***a* may activate the neighbor relay UEs **302***b*-**302***e* to transmit respective discovery signals. For example, the DS manager **310***a* within the source relay UE **302***a* may be configured to generate and transmit a discovery signal initiation message to the neighbor relay UEs **302***b*-**302***e*. In one example, the source relay UE **302***a* may broadcast the discovery signal initiation message to the neighbor relay UEs **302***a*-**302***e*. In another example, the source relay UE **302***a* may multicast the discovery signal initiation message to the neighbor relay UEs **302***a*-**302***e*. By broadcasting or multicasting the discovery signal initiation message, the power consumption on the source relay UE **302***a* and neighbor relay UEs **302***b*-**302***e* may be reduced.

[0090] Upon receiving the discovery signal initiation message, the respective DS managers **310***b*-**310***e* within the neighbor relay UEs **302***b*-**302***e* may initiate discovery signal monitoring for respective discovery signal monitoring durations. Each discovery signal monitoring duration may include at least one of a number of slots, a duration of time (e.g., a number of mini-seconds), or a number of discovery signal resources (e.g., time-frequency resources or code-division sequences) via which discovery signals are transmitted. For example, the discovery signal monitoring duration may indicate a number of discovery signal occasions, where each discovery signal occasion corresponds to a particular discovery signal resource (e.g., a time-frequency resource of a code-division sequence) that may be utilized or has been allocated for the transmission of discovery signals via D2D (sidelink) communication. In some examples, the discovery signal monitoring durations differ between the neighbor relay UEs **302***b*-**302***e* to alleviate or eliminate interference among transmitted discovery signals.

[0091] In some examples, the discovery signal monitoring duration on a particular neighbor relay UE (e.g., neighbor relay UE **302***b*) may be calculated based on a discovery signal monitoring parameter hard-coded in the neighbor relay UE **302***b* or received from the source relay UE **302***a* or the base station **304**. For example, the DS manager **310***a* within the source relay UE **302***a* may further be configured to generate and transmit the discovery signal monitoring parameter to the neighbor relay UEs **302***b* **302***e*. Each neighbor relay UE **302***b*-**302***e* may receive the discovery signal monitoring parameter from the source relay UE **302***a* via a broadcast signal or a multicast signal. In some examples, the discovery signal monitoring parameter may be transmitted substantially concurrently with the discovery signal initiation message in the same or different broadcast or multicast resources. For example, the discovery signal monitoring parameter and the discovery signal initiation message may be transmitted within the same time-frequency resources, slot, or mini-slot.

[0092] As another example, the base station **304** may be configured to transmit the discovery signal monitoring parameter to the neighbor relay UEs **302***b*-**302***e*. In this example, the base station **304** includes a DS parameter manager **312**, which may correspond, for example, to the DS parameter manager **150** shown in FIG. **1**. The DS parameter manager **312** may be configured to broadcast the discovery signal monitoring parameter to the neighbor relay UEs **302***b*-**302***e*, multicast the discovery signal monitoring parameter to the neighbor relay UEs **302***b*-**302***e*, or transmit the discovery signal monitoring parameter to the neighbor relay UEs **302***b*-**302***e* via respective unicast signals. For example, the DS parameter manager **312** within the base station **304** may include the discovery signal monitoring parameter within radio resource control (RRC) signaling, a medium access control-control element (MAC-CE), or downlink control information (DCI).

[0093] In some examples, the discovery signal monitoring parameter includes at least one probability distribution parameter associated with a probability distribution. The DS managers **310***b*-**310***e* within each of the neighbor relay UEs **302***b*-**302***e* may each be configured to generate a respective random value that satisfies the probability distribution based on the at least one

probability distribution factor. The DS managers **310***b*-**310***e* may each be then configured to set the respective discovery signal monitoring duration to the respective random value. For example, the at least one probability distribution parameter may include a Poisson distribution factor of a Poisson distribution. The DS managers **310***b*-**310***e* within each of the neighbor relay UEs **302***b*-**302***e* may each be configured to randomly generate a respective random value based on the Poisson distribution factor, and set the respective discovery signal monitoring duration to the respectively generated random value.

[0094] As another example, the at least one probability distribution factor may include a maximum value and a minimum value of an even probability distribution. In some examples, the DS managers **310***b*-**310***e* within each of the neighbor relay UEs **302***b*-**302***e* may each be configured to randomly select a respective random value between the maximum and minimum values and set the respective discovery signal monitoring duration to the respectively selected random value. In some examples, the DS managers **310***b*-**310***e* within each of the neighbor relay UEs **302***b*-**302***e* may each be configured to calculate the respective discovery signal monitoring duration based on an identifier of the respective neighbor relay UE **302***b*-**302***e* and the maximum and minimum values of the even probability distribution. For example, each DS manager **310***b*-**310***e* may be configured to calculate the respective discovery signal monitoring duration as follows:

[00001] $DSMonitor_{duration} = UEIDmod(MaxVal - MinVal) + MinVal,$ (Equation1)

where the UEID is the unique identifier of the neighbor relay UE, MaxVal is the maximum value of the even probability distribution, MinVal is the minimum value of the even probability distribution, and mod refers to the module operation.

[0095] During the respective discovery signal monitoring duration on each of the neighbor relay UEs **302***b*-**302***e*, the respective DS managers **310***b*-**310***e* may monitor the number of transmitted discovery signals transmitted by other neighbor relay UEs to the remote UE **302***f*. The respective DS managers **310***b*-**310***e* may then generate and transmit a respective discovery signal to the remote UE **302***f* at the end of the respective discovery signal monitoring durations when the number of transmitted discovery signals is less than a discovery signal transmission number threshold. In some examples, the discovery signal transmission number threshold is a positive integer, such as one, two, three, etc.

[0096] For example, the DS manager **310***b* of neighbor relay UE **302***b* may count the number of transmitted discovery signals transmitted by other neighbor relay UEs **302***c*-**302***e* over the discovery signal monitoring duration of the neighbor relay UE **302***b*. Upon expiration of the discovery signal monitoring duration of neighbor relay UE **302***b*, the DS manager **310***b* may then compare the counted number of transmitted discovery signals to the discovery signal transmission number threshold. When the number of transmitted discovery signals transmitted from other neighbor relay UEs is less than the discovery signal transmission number threshold, the DS manager **310***b* may generate and transmit a discovery signal to the remote UE **302***f*. However, if the number of transmitted discovery signals is greater than or equal to the discovery signal transmission number threshold, the DS manager **310***b* of neighbor relay UE **302***b* is precluded from transmitting the discovery signal to the remote UE **302***f* and returns to a stand-by (non-relay) mode. As a result, the number of neighbor relay UEs **302***b*-**302***e* transmitting discovery signals to the remote UE **302***f* may be limited, thus saving power on the remote UE **302***f* and the neighbor relay UEs **302***b*-**302***e* as a whole, while further reducing mutual interference between transmitted discovery signals.

[0097] In some examples, the discovery signal transmission number threshold may be hard-coded in each neighbor relay UE **302***b*-**302***e* or received from the source relay UE **302***a* or the base station **304**. For example, the DS manager **310***a* within the source relay UE **302***a* may further be configured to generate and transmit the discovery signal transmission number threshold to the neighbor relay UEs **302***b*-**302***e*. In this example, each neighbor relay UE **302***b*-**302***e* may receive

the discovery signal transmission number threshold from the source relay UE **302**a via a broadcast signal or a multicast signal. In some examples, the discovery signal transmission number threshold may be transmitted substantially concurrently with one or more of the discovery signal monitoring parameter or the discovery signal initiation message in the same or different broadcast or multicast resources (e.g., within the same time-frequency resources, the same slot, or the same mini-slot).

[0098] As another example, the base station **304** may be configured to transmit the discovery signal transmission number threshold to the neighbor relay UEs **302**b-**302**e. In this example, the DS parameter manager **312** of the base station **304** may be configured to broadcast the discovery signal transmission number threshold to the neighbor relay UEs **302**b-**302**e, multicast the discovery signal transmission number threshold to the neighbor relay UEs **302**b-**302**e, or transmit the discovery signal transmission number threshold to the neighbor relay UEs **302**b-**302**e via respective unicast signals. For example, the DS parameter manager **312** within the base station **304** may include the discovery signal transmission number threshold within RRC signaling, a MAC-CE, or DCI. In some examples, the DS parameter manager **312** may transmit the discovery signal transmission number threshold substantially concurrently with the discovery signal monitoring parameter in the same or different resources (e.g., within the same time-frequency resources, the same slot, or the same mini-slot).

[0099] In some examples, the discovery signal monitoring parameter may be determined by the DS manager **310**a or the DS parameter manager **312** based on a latency requirement associated with performing the relay node switch of the remote UE **312**f from the source relay UE **302**a to another neighbor relay UE **302**b-**302**e. In examples in which the latency requirement is small (e.g., there is minimal time to complete the relay node switch), the DS manager **310**a or DS parameter manager **312** may select a small maximum value for an even probability distribution or a large Poisson distribution factor to result in a shorter discovery signal monitoring duration on each of the neighbor relay UEs **302**b-**302**e. In addition, the discovery signal transmission number threshold may be determined by the DS manager **310**a or the DS parameter manager **312** based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs, not shown) to be relay node switched from the source relay UE **302**a to another neighbor relay UE **302**b-**302**e. In examples in which the latency requirement is small or there are a large number of candidate UEs to be relay node switched, the DS manager **310**a or the DS parameter manager **312** may select a higher discovery signal transmission number threshold to increase the number of discovery signals transmitted to the remote UE **310**f.

[0100] The remote UE **302**f may then receive one or more discovery signals from one or more respective neighbor relay UEs **302**b-**302**f and select one of the neighbor relay UEs (e.g., neighbor relay UE **302**d) as a relay node switch target to switch relaying communication with the base station **304**. To establish a new relay link (sidelink) **308**b with the target neighbor relay UE **302**d, the remote UE **302**f may initiate a random access procedure with the target neighbor relay UE **302**d. In an exemplary random access procedure, the remote UE **302**f may randomly select a preamble from an available set of preambles within a cell associated with the target neighbor relay UE **302**d, and transmit the selected preamble to the target neighbor relay UE **302**d in a random access channel (RACH) preamble message. Upon receipt of the RACH preamble message, the target neighbor relay UE **302**d may then transmit a random access response (RAR) message to the remote UE **302**f to establish the new relay link **308**b between the target neighbor relay UE **302**d and the remote UE **302**f.

[0101] FIG. **4** is a diagram illustrating an exemplary implementation of controlling the transmission of discovery signals by neighbor relay UEs (NRUs) to a remote UE. In the example shown in FIG. **4**, two NRUs (NRU1 and NRU2) are illustrated. The discovery signal monitoring durations on each of the NRUs are defined in terms of discovery signal (DS) occasions (e.g., time-frequency resources or code-division sequences on which discovery signals may be transmitted). The calculated discovery signal monitoring duration for NRU1 is one DS occasion, whereas the

calculated discovery signal monitoring duration for NRU2 is three DS occasions. In the example shown in FIG. **4**, the discovery signal transmission number threshold is equal to one.

[0102] Each NRU (NRU1 and NRU2) initiates their respective discovery signal monitoring duration at the beginning of the first DS occasion (e.g., DS Occasion 1). The discovery signal monitoring duration for NRU1 expires at the end of DS Occasion 1. Since no discovery signals were transmitted during DS Occasion 1, NRU1 transmits a discovery signal at DS Occasion 2. NRU2 detects the transmission of the discovery signal by NRU1 at DS Occasion 2. Since the discovery signal transmission number threshold is one, the number of transmitted discovery signals (e.g., one discovery signal transmitted by NRU1) is not less than the discovery signal transmission number threshold. Therefore, NRU2 does not transmit a discovery signal at the expiration of the discovery signal monitoring duration of NRU2. In some examples, NRU2 may return to stand-by (non-relay) mode upon detecting the discovery signal transmission from NRU1. In other examples, NRU2 may return to stand-by (non-relay) mode at the end of DS Occasion 3 (e.g., at the end of the discovery signal monitoring duration of NRU2).

[0103] FIG. **5** is a diagram illustrating another exemplary implementation of discovery signal transmission control according to some aspects. In the example shown in FIG. **5**, two NRUs (NRU1 and NRU2) are again illustrated. The calculated discovery signal monitoring duration for NRU1 is one DS occasion, whereas the calculated discovery signal monitoring duration for NRU2 is three DS occasions. In the example shown in FIG. **5**, the discovery signal transmission number threshold is equal to two.

[0104] Each NRU (NRU1 and NRU2) initiates their respective discovery signal monitoring duration at the beginning of the first DS occasion (e.g., DS Occasion 1). The discovery signal monitoring duration for NRU1 expires at the end of DS Occasion 1. Since no discovery signals were transmitted during DS Occasion 1, NRU1 transmits a discovery signal at DS Occasion 2. NRU2 detects the transmission of the discovery signal by NRU1 at DS Occasion 2. The discovery signal monitoring duration for NRU2 expires at the end of DS Occasion 3. Since the discovery signal transmission number threshold is two, the number of transmitted discovery signals (e.g., one discovery signal transmitted by NRU1) is less than the discovery signal transmission number threshold. Therefore, NRU2 transmits a discovery signal at DS Occasion 4.

[0105] FIG. **6** is a signaling diagram illustrating exemplary signaling to facilitate relay node switching from a source relay UE **604** to a target neighbor relay UE of a plurality of neighbor relay UEs **608***a* . . . **608**N to relay communication between a remote UE **602** and a base station **606**. The source relay UE **604** may correspond, for example, to the source relay UE **302***a* shown in FIG. **3** and/or the UE **138** shown in FIG. **1**. The neighbor relay UEs **608***a* . . . **608**N may correspond, for example, to the neighbor relay UEs **302***b*-**302***e* shown in FIG. **3** and/or the UE **142** shown in FIG. **1**. The remote UE **602** may correspond, for example, to the remote UE **302***f* shown in FIG. **3** and/or the UE **140** shown in FIG. **1**. The base station **606** may correspond, for example, to the base station **304** shown in FIG. **3** and/or the base station **146** shown in FIG. **1**.

[0106] At **610**, a relay link (sidelink) is established between the remote UE **602** and the source relay UE **604** to relay information between the remote UE **602** and the base station **606** via the source relay UE **604**. For example, the remote UE **602** may transmit information to and/or receive information from the base station **606** via the relay link and a Uu link between the source relay UE **604** and the base station **606**.

[0107] At **612**, the source relay UE **604** may initiate a relay node switch. For example, the source relay UE **604** may initiate a relay node switch due to movement of the remote UE **602** or source relay UE **604**, channel variance of the channel between the remote UE **602** and the source relay UE **604**, a battery status change of the remote UE **602** or source relay UE **604**, and/or a load status change associated with the source relay UE **604**. In some examples, the remote UE **602** may request the relay node switch. Upon initiating a relay node switch, at **614**, the source relay UE **604** may transmit a relay node switch message to the remote UE **602** instructing the remote UE **602** to

perform a relay node switch.

[0108] At **616***a* . . . **616**N, the source relay UE **604** may generate and transmit discovery signal (DS) parameters to the neighbor relay UEs **608***a* . . . **608**N. The DS parameters may include, for example, at least one of a discovery signal monitoring parameter or a discovery signal transmission number threshold. In an example, the source relay UE **604** may broadcast or multicast the DS parameters to the neighbor relay UEs **608***a* . . . **608**N. In some examples, the source relay UE may transmit the DS parameters prior to initiating the relay node switch. In some examples, one or more of the DS parameters are hard-coded into the neighbor relay UEs **608***a* . . . **608**N. In some examples, the discovery signal monitoring parameter may be determined by the source relay UE **604** based on a latency requirement associated with performing the relay node switch from the source relay UE **604** to a neighbor relay UE **608***a* . . . **608**N. In addition, the discovery signal transmission number threshold may be determined by the source relay UE **604** based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs, not shown) to be relay node switched from the source relay UE **604** to a neighbor relay UE **608***a* . . . **608**N.

[0109] At **618***a* . . . **618**N, the neighbor relay UEs **608***a* . . . **608**N may each calculate a respective DS monitoring duration based on the DS parameters. The discovery signal monitoring duration may include, for example, a number of slots, a duration of time, or a number of discovery signal resources (e.g., DS occasions) via which discovery signals are transmitted. For example, each neighbor relay UE **608***a* . . . **608**N may calculate the respective DS monitoring duration based on at least the discovery signal monitoring parameter. Here, the discovery signal monitoring parameter may include at least one probability distribution parameter associated with a probability distribution. For example, the at least one probability distribution parameter may include maximum and minimum values of an even probability distribution or a Poisson distribution factor of a Poisson distribution. In some examples, one or more of the neighbor relay UEs **608***a* . . . **608**N may calculate their respective discovery signal monitoring duration based further on an identifier of the respective neighbor relay UE.

[0110] At **620***a* . . . **620**N, the source relay UE **604** may generate and transmit a DS initiation message to initiate discovery signal monitoring on the neighbor relay UEs **608***a* . . . **608**N for the respective discovery signal monitoring durations of the neighbor relay UEs **608***a* . . . **608**N. In some examples, the source relay UE **604** may broadcast or multicast the DS initiation message to the neighbor relay UEs **608***a* . . . **608**N. In some examples, the source relay UE **604** may transmit the DS parameters concurrently with the DS initiation message.

[0111] At **622***a* . . . **622**N, each of the neighbor relay UEs **608***a* . . . **608**N may monitor DS transmissions by other neighbor relay UEs **608***a* . . . **608**N. For example, each neighbor relay UE **608***a* . . . **608**N may count the number of discovery signals transmitted from other neighbor relay UEs to the remote UE **602** during their respective discovery signal duration. Upon expiration of their respective discovery signal duration, each neighbor relay UE **608***a* . . . **608**N may determine whether the number of transmitted discovery signals transmitted from other neighbor relay UEs to the remote UE **602** is less than the discovery signal transmission number threshold. When the number of transmitted discovery signals counted by one or more of the neighbor relay UEs **608***a* . . . **608**N during their respective discovery signal monitoring durations is less than the discovery signal transmission number threshold, at **624***a* . . . **624**N, those one or more neighbor relay UEs **608***a* . . . **608**N each transmit a respective discovery signal to the remote UE **602**.

[0112] FIG. **7** is a signaling diagram illustrating other exemplary signaling to facilitate relay node switching from a source relay UE **604** to a target neighbor relay UE of a plurality of neighbor relay UEs **708***a* . . . **708**N to relay communication between a remote UE **702** and a base station **706**. The source relay UE **704** may correspond, for example, to the source relay **604** shown in FIG. **6**, the source relay UE **302***a* shown in FIG. **3**, the UE **138** shown in FIG. **1**. The neighbor relay UEs **708***a* . . . **708**N may correspond, for example, to the neighbor relay UEs **608** . . . **608**N shown in FIG. **6**,

the neighbor relay UEs **302***b*-**302***e* shown in FIG. **3** and/or the UE **142** shown in FIG. **1**. The remote UE **702** may correspond, for example, to the remote UE **602** shown in FIG. **6**, the remote UE **302***f* shown in FIG. **3** and/or the UE **140** shown in FIG. **1**. The base station **706** may correspond, for example, to the base station **606** shown in FIG. **6**, the base station **304** shown in FIG. **3** and/or the base station **146** shown in FIG. **1**.

[0113] At **710**, a relay link (sidelink) is established between the remote UE **702** and the source relay UE **704** to relay information between the remote UE **702** and the base station **706** via the source relay UE **704**. For example, the remote UE **702** may transmit information to and/or receive information from the base station **706** via the relay link and a Uu link between the source relay UE **704** and the base station **706**.

[0114] At **712**, the source relay UE **704** may initiate a relay node switch. For example, the source relay UE **704** may initiate a relay node switch due to movement of the remote UE **702** or source relay UE **704**, channel variance of the channel between the remote UE **702** and the source relay UE **704**, a battery status change of the remote UE **702** or source relay UE **704**, and/or a load status change associated with the source relay UE **704**. In some examples, the remote UE **702** may request the relay node switch. Upon initiating a relay node switch, at **714***a*, the source relay UE **704** may transmit a relay node switch message to the remote UE **702** instructing the remote UE **702** to perform a relay node switch. In addition, at **714***b*, the source relay UE **704** may generate and transmit a relay node switch message to the base station **706** informing the base station that the remote UE **702** is performing a relay node switch. The relay node switch message transmitted to the base station **706** may further indicate a latency requirement associated with performing the relay node switch. For example, the latency requirement may indicate a duration of time within which the relay node switch should be completed based on, for example, one or more of the factors utilized in determining to initiate the relay node switch.

[0115] At **716***a* . . . **716**N, the base station **706** may generate and transmit discovery signal (DS) parameters to the neighbor relay UEs **708***a* . . . **708**N. The DS parameters may include, for example, at least one of a discovery signal monitoring parameter or a discovery signal transmission number threshold. In an example, the base station **706** may broadcast, multicast, or unicast the DS parameters to the neighbor relay UEs **708***a* . . . **708**N. In some examples, the base station **706** may transmit the DS parameters prior to receiving the indication of the relay node switch. In some examples, one or more of the DS parameters are hard-coded into the neighbor relay UEs **708***a* . . . **708**N. In some examples, the discovery signal monitoring parameter may be determined by the base station **706** based on a latency requirement associated with performing the relay node switch from the source relay UE **704** to a neighbor relay UE **708***a* . . . **708**N. In addition, the discovery signal transmission number threshold may be determined by the base station **706** based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs, not shown) to be relay node switched from the source relay UE **704** to a neighbor relay UE **708***a* . . . **708**N.

[0116] At **718***a* . . . **718**N, the neighbor relay UEs **708***a* . . . **708**N may each calculate a respective DS monitoring duration based on the DS parameters. The discovery signal monitoring duration may include, for example, a number of slots, a duration of time, or a number of discovery signal resources (e.g., DS occasions) via which discovery signals are transmitted. For example, each neighbor relay UE **708***a* . . . **708**N may calculate the respective DS monitoring duration based on at least the discovery signal monitoring parameter. Here, the discovery signal monitoring parameter may include at least one probability distribution parameter associated with a probability distribution. For example, the at least one probability distribution parameter may include maximum and minimum values of an even probability distribution or a Poisson distribution factor of a Poisson distribution. In some examples, one or more of the neighbor relay UEs **708***a* . . . **708**N may calculate their respective discovery signal monitoring duration based further on an identifier of the respective neighbor relay UE.

[0117] At **720***a* . . . **720**N, the source relay UE **704** may generate and transmit a DS initiation message to initiate discovery signal monitoring on the neighbor relay UEs **708***a* . . . **708**N for the respective discovery signal monitoring durations of the neighbor relay UEs **708***a* . . . **708**N. In some examples, the source relay UE **704** may broadcast or multicast the DS initiation message to the neighbor relay UEs **708***a* . . . **708**N. In some examples, the source relay UE **704** may transmit the DS parameters concurrently with the DS initiation message.

[0118] At **722***a* . . . **722**N, each of the neighbor relay UEs **708***a* . . . **708**N may monitor DS transmissions by other neighbor relay UEs **708***a* . . . **708**N. For example, each neighbor relay UE **708***a* . . . **708**N may count the number of discovery signals transmitted from other neighbor relay UEs to the remote UE **702** during their respective discovery signal duration. Upon expiration of their respective discovery signal duration, each neighbor relay UE **708***a* . . . **708**N may determine whether the number of transmitted discovery signals transmitted from other neighbor relay UEs to the remote UE **702** is less than the discovery signal transmission number threshold. When the number of transmitted discovery signals counted by one or more of the neighbor relay UEs **708***a* . . . **708**N during their respective discovery signal monitoring durations is less than the discovery signal transmission number threshold, at **724***a* . . . **724**N, those one or more neighbor relay UEs **708***a* . . . **708**N each transmit a respective discovery signal to the remote UE **702**.

[0119] FIG. **8** is a conceptual diagram illustrating an example of a hardware implementation for an exemplary base station **800** employing a processing system **814**. For example, the base station **800** may be a base station as illustrated in any one or more of FIGS. **1**, **3**, **6**, and **7**.

[0120] The base station **800** may be implemented with a processing system **814** that includes one or more processors **804**. Examples of processors **804** include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGA s), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. In various examples, the base station **800** may be configured to perform any one or more of the functions described herein. That is, the processor **804**, as utilized in a base station **800**, may be used to implement any one or more of the processes described below. The processor **804** may in some instances be implemented via a baseband or modem chip and in other implementations, the processor **804** may itself comprise a number of devices distinct and different from a baseband or modem chip (e.g., in such scenarios is may work in concert to achieve embodiments discussed herein). And as mentioned above, various hardware arrangements and components outside of a baseband modem processor can be used in implementations, including RF-chains, power amplifiers, modulators, buffers, interleavers, adders/summers, etc.

[0121] In this example, the processing system **814** may be implemented with a bus architecture, represented generally by the bus **802**. The bus **802** may include any number of interconnecting buses and bridges depending on the specific application of the processing system **814** and the overall design constraints. The bus **802** communicatively couples together various circuits including one or more processors (represented generally by the processor **804**), a memory **805**, and computer-readable media (represented generally by the computer-readable medium **806**). The bus **802** may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further. A bus interface **808** provides an interface between the bus **802** and a transceiver **88**. The transceiver **88** provides a means for communicating with various other apparatus over a transmission medium (e.g., air interface). Depending upon the nature of the apparatus, a user interface **812** (e.g., keypad, display, speaker, microphone, joystick) may also be provided. Of course, such a user interface **812** is optional, and may be omitted in some examples.

[0122] The processor **804** is responsible for managing the bus **802** and general processing, including the execution of software stored on the computer-readable medium **806**. The software, when executed by the processor **804**, causes the processing system **814** to perform the various

functions described below for any particular apparatus. The computer-readable medium **806** and the memory **805** may also be used for storing data that is manipulated by the processor **804** when executing software.

[0123] One or more processors **804** in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. The software may reside on a computer-readable medium **806**.

[0124] The computer-readable medium **806** may be a non-transitory computer-readable medium. A non-transitory computer-readable medium includes, by way of example, a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., a compact disc (CD) or a digital versatile disc (DVD)), a smart card, a flash memory device (e.g., a card, a stick, or a key drive), a random access memory (RAM), a read only memory (ROM), a programmable ROM (PROM), an erasable PROM (EPROM), an electrically erasable PROM (EEPROM), a register, a removable disk, and any other suitable medium for storing software and/or instructions that may be accessed and read by a computer. The computer-readable medium may also include, by way of example, a carrier wave, a transmission line, and any other suitable medium for transmitting software and/or instructions that may be accessed and read by a computer. The computer-readable medium **806** may reside in the processing system **814**, external to the processing system **814**, or distributed across multiple entities including the processing system **814**. The computer-readable medium **806** may be embodied in a computer program product. In some examples, the computer-readable medium **806** may be part of the memory **805**. By way of example, a computer program product may include a computer-readable medium in packaging materials. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

[0125] In some aspects of the disclosure, the processor **804** may include circuitry configured for various functions. For example, the processor **804** may include resource assignment and scheduling circuitry **842**, configured to generate, schedule, and modify a resource assignment or grant of time-frequency resources (e.g., a set of one or more resource elements). For example, the resource assignment and scheduling circuitry **842** may schedule time-frequency resources within a plurality of time division duplex (TDD) and/or frequency division duplex (FDD) subframes, slots, and/or mini-slots to carry user data traffic and/or control information to and/or from multiple UEs.

[0126] In some examples, the resource assignment and scheduling circuitry **842** may be configured to allocate/schedule resources for the transmission of information to and reception of information from a source relay UE configured to relay the information to and from a remote UE via a sidelink. In addition, the resource assignment and scheduling circuitry **843** may further be configured to allocate resources for sidelink communication between UEs (e.g., between the source relay UE and the remote UE and/or neighbor relay UEs). In some examples, the sidelink resources may include mmWave resources.

[0127] The resource assignment and scheduling circuitry **842** may further be configured to schedule resources for the transmission of discovery signal parameters from the base station **800** to one or more UEs (e.g., neighbor relay UEs). In some examples, the resource assignment and scheduling circuitry **842** may schedule resources for broadcasting, multicasting, or unicasting the discovery signal parameters to the one or more UEs. The resource assignment and scheduling circuitry **842** may further be configured to execute resource assignment and scheduling software **852** stored in the computer-readable medium **806** to implement one or more of the functions described herein.

[0128] The processor **804** may further include downlink (DL) traffic and control channel generation and transmission circuitry **844**, configured to generate and transmit downlink user data

traffic and control channels within one or more subframes, slots, and/or mini-slots. The DL traffic and control channel generation and transmission circuitry **844** may operate in coordination with the resource assignment and scheduling circuitry **842** to place the DL user data traffic and/or control information onto a time division duplex (TDD) or frequency division duplex (FDD) carrier by including the DL user data traffic and/or control information within one or more subframes, slots, and/or mini-slots in accordance with the resources assigned to the DL user data traffic and/or control information by the resource assignment and scheduling circuitry **842**.

[0129] For example, the DL traffic and control channel generation and transmission circuitry **844** may be configured to transmit discovery signal parameters to one or more UEs (e.g., neighbor relay UEs). The discovery signal parameters may include at least one of a discovery signal monitoring parameter or a discovery signal transmission number threshold. In some examples, the DL traffic and control channel generation and transmission circuitry **844** may broadcast, multicast, or unicast the discovery signal parameters to the one or more UEs. The DL traffic and control channel generation and transmission circuitry **844** may further be configured to transmit information (control and/or data) destined for a remote UE to a source relay UE. The DL traffic and control channel generation and transmission circuitry **844** may further be configured to execute DL traffic and control channel generation and transmission software **854** stored in the computer-readable medium **806** to implement one or more of the functions described herein.

[0130] The processor **804** may further include uplink (UL) traffic and control channel reception and processing circuitry **846**, configured to receive and process uplink control channels and uplink traffic channels from one or more UEs. For example, the UL traffic and control channel reception and processing circuitry **846** may be configured to receive uplink control information (UCI) or uplink user data traffic from one or more UEs. In addition, the UL traffic and control channel reception and processing circuitry **846** may operate in coordination with the resource assignment and scheduling circuitry **842** to schedule UL user data traffic transmissions, DL user data traffic transmissions and/or DL user data traffic retransmissions in accordance with the received UCI.

[0131] In some examples, the UL traffic and control channel reception and processing circuitry **846** may be configured to receive a relay node switch message from a source relay UE indicating that a remote UE served by the source relay UE is switching from the source relay UE to another neighbor relay UE to relay information between the remote UE and the base station **800**. In some examples, the relay node switch message may further include the latency requirement for performing the relay node switch. The UL traffic and control channel reception and processing circuitry **846** may further be configured to receive information (control and/or data) originated by the remote UE from the source relay UE. The UL traffic and control channel reception and processing circuitry **846** may further be configured to execute UL traffic and control channel reception and processing software **856** stored in the computer-readable medium **806** to implement one or more of the functions described herein.

[0132] The processor **804** may further include relay link management circuitry **848** configured to manage relay links between source relay UEs and remote UEs. For example, the relay link management circuitry **848** may be configured to operate in coordination with the resource assignment and scheduling circuitry **842** to schedule resources for communication over the relay links (sidelinks). In addition, the relay link management circuitry **848** may maintain a list **818** of source relay UEs and the corresponding remote UEs served by each source relay UE.

[0133] The relay link management circuitry **848** may further be configured to generate and/or maintain discovery signal parameters **815**, such as a discovery signal monitoring parameter and/or a discovery signal transmission number threshold. In some examples, the relay link management circuitry **848** may generate the discovery signal monitoring parameter for a particular remote UE based on the latency requirement associated with the remote UE performing the relay node switch from the source relay UE to a neighbor relay UE. In addition, the relay link management circuitry **848** may generate the discovery signal transmission number threshold for a particular remote UE

based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs, not shown) that are currently switching from the source relay UE to another neighbor relay UE. For example, the relay link management circuitry **848** may maintain within the list **818** of remote UEs served by the source relay UE, a respective status of each relay link (e.g., in-use, idle, switching, etc.). In some examples, the relay link management circuitry **848** may include the DS parameter manager **150** and/or **312** shown in FIGS. **1** and **3**. The relay link management circuitry **848** may further be configured to execute relay link management software **858** stored in the computer-readable medium **806** to implement one or more of the functions described herein.

[0134] FIG. **9** is a conceptual diagram illustrating an example of a hardware implementation for an exemplary user equipment (e.g., UE **900**) employing a processing system **914**. For example, the UE **900** may be a UE as illustrated in any one or more of FIGS. **1**, **3**, **6** and/or **7**.

[0135] The processing system **914** may be substantially the same as the processing system **814** illustrated in FIG. **8**, including a bus interface **908**, a bus **902**, memory **905**, a processor **904**, and a computer-readable medium **906**. Furthermore, the UE **900** may include a user interface **912** and a transceiver **910** substantially similar to those described above in FIG. **8**. In addition, the UE may further include one or more antenna array modules **920**. In accordance with various aspects of the disclosure, an element, or any portion of an element, or any combination of elements may be implemented with the processing system **914** that includes one or more processors **904**. That is, the processor **904**, as utilized in a UE **900**, may be used to implement any one or more of the processes described below.

[0136] In some aspects of the disclosure, the processor **904** may include circuitry configured for various functions. For example, the processor **904** may include communication and processing circuitry **942** configured to transmit and receive signals to and from a base station via a Uu interface. The communication and processing circuitry **942** may further be configured to transmit and receive to and from other UEs via respective sidelinks. In some examples, the communication and processing circuitry **942** may be configured to relay communication between the base station and one or more remote UEs via the Uu interface and respective sidelinks.

[0137] In some examples, the communication and processing circuitry **941** may include one or more hardware components that provide the physical structure that performs processes related to wireless communication (e.g., signal reception and/or signal transmission) and signal processing (e.g., processing a received signal and/or processing a signal for transmission). For example, the communication and processing circuitry **942** may be configured to generate and transmit an uplink signal, a downlink signal, or a sidelnk signal at a mmWave frequency or a sub-6 GHz frequency via the transceiver **910**. The communication and processing circuitry **942** may further be configured to execute communication and processing software **952** stored on the computer-readable medium **906** to implement one or more functions described herein.

[0138] The processor **904** may further include sidelink discovery and establishment circuitry **944**. The sidelink discovery and establishment circuitry **944** may be configured to operate in coordination with the communication and processing circuitry **942** to generate and transmit discovery signals to one or more remote UEs to initiate establishment of a relay link (sidelink) therebetween. The sidelink discovery and establishment circuitry **944** may further be configured to operate in coordination with the communication and processing circuitry **942** to receive one or more discovery signals from potential source relay UEs. In addition, the sidelink discovery and establishment circuitry **944** may further utilize the received discovery signal to select a source relay UE for relaying of communication between the remote UE and the base station. For example, the sidelink discovery and establishment circuitry **944** may be configured to perform a random access procedure with the selected source relay UE to establish a relay link (sidelink) therebetween. The sidelink discovery and establishment circuitry **944** may further be configured to execute relay link discovery software **954** stored on the computer-readable medium **906** to implement one or more

functions described herein.

[0139] The processor **904** may further include relay switch management circuitry **946** configured to manage a relay node switch of a remote UE from a source relay UE to a neighbor relay UE. For example, the relay switch management circuitry **946** may be configured to receive a relay node switch message from a source relay UE instructing the UE **900** (e.g., the remote UE) to initiate a relay node switch to a neighbor relay UE. The relay switch management circuitry **946** may further be configured to initiate a relay node switch of a remote UE from the UE (e.g., the source relay UE) to a neighbor UE based on one or more factors. The relay switch management circuitry **946** may then be configured to transmit the relay node switch message to the remote UE instructing the remote UE to initiate the relay node switch. The relay switch management circuitry **946** may further be configured to execute relay switch management software **956** stored on the computer-readable medium **906** to implement one or more of the functions described herein.

[0140] The processor **904** may further include discovery signal (DS) management circuitry **948** configured to manage transmission of one or more discovery signals to a remote UE. In some examples, the discovery signal(s) may be transmitted during a relay node switch procedure. However, it should be understood that the discovery signal management procedure is not limited to relay node switching processes and may be utilized in other D2D discovery processes. In some examples, the DS management circuitry **948** may correspond to the DS manager **148** shown in FIG. **1** and/or DS managers **310***a*-**310***e* shown in FIG. **3**.

[0141] The DS management circuitry **948** may be configured to receive a discovery signal initiation message from another UE (e.g., a source relay UE) to control transmission of a discovery signal from the UE **900** to yet another UE (e.g., a remote UE). The DS management circuitry **948** may further be configured to monitor for transmitted discovery signals transmitted from other UEs to the remote UE during a DS monitoring duration **917** that may be calculated by the DS management circuitry **948** from a DS monitoring parameter **915**. For example, the DS monitoring parameter **915** may include at least one probability distribution parameter associated with a probability distribution. The DS management circuitry **948** may then be configured to generate a random value that satisfies the probability distribution based on the at least one probability distribution factor. The DS management circuitry **948** may then be configured to set the DS monitoring duration **917** to the calculated random value and store the DS monitoring duration **917** within, for example, memory **905**.

[0142] For example, the at least one probability distribution parameter may include a Poisson distribution factor of a Poisson distribution. The DS management circuitry **948** may be configured to randomly generate the random value corresponding to the DS monitoring duration **917** based on the Poisson distribution factor. As another example, the at least one probability distribution factor may include a maximum value and a minimum value of an even probability distribution. In some examples, the DS management circuitry **948** may be configured to randomly select a random value corresponding to the DS monitoring duration **917** between the maximum and minimum values. In some examples, the DS management circuitry **948** may be configured to calculate the DS monitoring duration **917** based on an identifier of the UE **900** and the maximum and minimum values of the even probability distribution.

[0143] In some examples, the DS monitoring parameter **915** may be hard-coded into the memory **905** of the UE **900**. In other examples, the DS monitoring parameter **915** may be received from the source relay UE or the base station and stored in the memory **905**. For example, the DS monitoring parameter **915** may be received via a broadcast or multicast signal from the source relay UE. As another example, the DS monitoring parameter **915** may be received via a broadcast, multicast, or unicast signal from the base station.

[0144] At expiration of the DS monitoring duration **917**, the DS management circuitry **948** may further be configured to operate together with the communication and processing circuitry **942** and sidelink discovery and establishment circuitry **944** to transmit a discovery signal to the remote UE

when the number of transmitted discovery signals transmitted from other UEs to the remote UE during the discovery signal monitoring duration **917** is less than a DS transmission number threshold **916**. However, when the number of transmitted discovery signals transmitted by other UEs to the remote UE during the DS monitoring duration **917** is greater than or equal to the DS transmission number threshold **916**, the DS management circuitry **948** is precluded from transmitting the discovery signal to the remote UE and returns to a stand-by (non-relay) mode.

[0145] The DS transmission number threshold **916** may be hard-coded into the memory **905** of the UE **900** or received from the source relay UE or the base station. For example, the DS transmission number threshold **916** may be received via a broadcast or multicast signal from the source relay UE. As another example, the DS transmission number threshold **916** may be received via a broadcast, multicast, or unicast signal from the base station. In some examples, the DS transmission number threshold **916** may be broadcast, multicast, or unicast together with the DS monitoring parameter **915**. In some examples, the DS transmission number threshold **916** and/or DS monitoring parameter **915** may be transmitted concurrently with the discovery signal initiation message.

[0146] The DS management circuitry **948** may further be configured to transmit the discovery signal initiation message to one or more neighbor UEs to control transmission of a respective discovery signal from each of the neighbor UE(s) to a remote UE. The DS management circuitry **948** may further be configured to transmit the DS monitoring parameter **915** to the one or more neighbor UE(s) via, for example, broadcast or multicast signaling for use in calculating respective DS monitoring durations **917** on the neighbor UE(s). In addition, the DS management circuitry **948** may further be configured to transmit the DS transmission number threshold **916** to the one or more neighbor UE(s) to allow transmission of the respective discovery signal(s) from the neighbor UE(s) to the remote UE when the number of transmitted discovery signal transmitted from other UEs to the remote UE during the respective DS monitoring duration(s) **917** is less than the DS transmission number threshold **916**.

[0147] In some examples, the DS management circuitry **948** may generate the DS monitoring parameter **915** associated with discovery signals to be transmitted to the remote UE based on the latency requirement associated with the remote UE performing the relay node switch from the UE **900** to a neighbor relay UE. In addition, the DS management circuitry **948** may generate the DS transmission number threshold associated with the remote UE based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs) that are currently relay node switching from the UE **900** to another neighbor relay UE. The DS management circuitry **948** may further be configured to execute DS management software **958** stored on the computer-readable medium **906** to implement one or more of the functions described herein.

[0148] FIG. **10** is a flow chart of a method **1000** for a UE to facilitate discovery signal transmission. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all embodiments. In some examples, the method **1000** may be performed by the UE **900**, as described above and illustrated in FIG. **9**, by a processor or processing system, or by any suitable means for carrying out the described functions.

[0149] At block **1002**, the UE (e.g., a first UE) may identify a discovery signal monitoring duration and a discovery signal transmission number threshold. In some examples, the discovery signal monitoring duration may be calculated from a discovery signal monitoring parameter. The discovery signal monitoring parameter may include, for example, at least one probability distribution parameter associated with a probability distribution. The first UE may generate a random value corresponding to the discovery signal monitoring duration that satisfies the probability distribution based on the at least one probability distribution parameter. The discovery signal monitoring parameter and discovery signal transmission number threshold may be hard-

coded in memory within the first UE or received from a second UE (e.g., a source relay UE) or a base station. For example, the DS management circuitry **948**, shown and described above in connection with FIG. **9** may identify the discovery signal monitoring duration and discovery signal transmission number threshold.

[0150] At block **1004**, the first UE may receive a discovery signal initiation message from a second UE (e.g., a source relay UE). In some examples, the discovery signal initiation message may be transmitted concurrently with at least one of the discovery signal monitoring parameter or the discovery signal transmission number threshold. For example, the communication and processing circuitry **942** and transceiver **910**, shown and described above in connection with FIG. **9**, may receive the discovery signal initiation message from the second UE.

[0151] At block **1006**, the first UE may initiate discovery signal monitoring for the discovery signal monitoring duration upon receiving the discovery signal initiation message from the second UE. During discovery signal monitoring, the first UE may monitor transmitted discovery signals transmitted from other UEs to a third UE (e.g., a remote UE). For example, the first UE may count the number of transmitted discovery signals transmitted from other UEs to the third UE during the discovery signal monitoring duration. For example, the DS management circuitry **948**, shown and described above in connection with FIG. **9**, may initiate discovery signal monitoring for the discovery signal monitoring duration on the first UE.

[0152] At block **1008**, the first UE may determine whether the discovery signal monitoring duration has expired (e.g., the end of the discovery signal monitoring duration is reached). If the discovery signal monitoring duration has expired (Y branch of block **1008**), at block **1010**, the first UE may determine whether the number transmitted discovery signals transmitted from other UEs to the third UE is less than the discovery signal transmission number threshold. For example, the DS management circuitry **948**, shown and described above in connection with FIG. **9** may determine whether the discovery signal monitoring duration has expired and whether the number of transmitted discovery signals transmitted by other UEs to the third UE during the discovery signal monitoring duration is less than the discovery signal transmission number threshold.

[0153] If the number of transmitted discovery signals transmitted by other UEs to the third UE during the discovery signal monitoring duration is less than the discovery signal transmission number threshold (Y branch of block **1010**), at block **1012**, the first UE may transmit a discovery signal to the third UE. For example, the DS management circuitry **948** together with the communication and processing circuitry **942**, sidelink discovery and establishment circuitry **944** and transceiver **910**, shown and described above in connection with FIG. **9** may generate and transmit a discovery signal to the third UE.

[0154] If the number of transmitted discovery signals transmitted by other UEs to the third UE during the discovery signal monitoring duration is greater than or equal to the discovery signal transmission number threshold (N branch of block **1010**), at block **1014**, the first UE may be precluded from transmitting the discovery signal to the third UE. In some examples, the first UE may discontinue monitoring for transmitted discovery signals and be precluded from transmitting the discovery signal prior to expiration of the discovery signal monitoring duration at the time when the number of transmitted discovery signals transmitted from other UEs to the third UE becomes equal to or greater than the transmission number threshold. For example, the DS management circuitry **948**, shown and described above in connection with FIG. **9**, may preclude the first UE from transmitting a discovery signal to the third UE.

[0155] FIG. **11** is a flow chart of another method **1100** for a UE to facilitate discovery signal transmission. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all embodiments. In some examples, the method **1100** may be performed by the UE **900**, as described above and illustrated in FIG. **9**, by a processor or processing system, or by any suitable means for carrying out the described functions.

[0156] At block **1102**, the UE (e.g., a first UE) may communicate with a second UE (e.g., a remote UE) via a sidelink. In some examples, the first UE may communicate with the second UE over the sidelink utilizing a millimeter wave carrier frequency. For example, the communication and processing circuitry **942** together with the sidelink discovery and establishment circuitry **944** and transceiver **910**, shown and described above in connection with FIG. **9** may communicate with the second UE via the sidelink.

[0157] At block **1104**, the first UE may transmit a discovery signal initiation message to at least a third UE to control transmission of a discovery signal from the third UE to the second UE based on a discovery signal monitoring duration during which the third UE monitors for transmitted discovery signals transmitted from other UEs to the second UE. In some examples, the first UE may broadcast or multicast the discovery signal initiation message to at least the third UE.

[0158] In some examples, the first UE may further transmit a discovery signal monitoring parameter to the third UE to facilitate calculation of the discovery signal monitoring duration by the third UE. For example, the discovery signal monitoring parameter may include at least one probability distribution parameter associated with a probability distribution. In addition, the first UE may further transmit a discovery signal transmission number threshold to the third UE to allow transmission of the discovery signal from the third UE to the second UE when the number of transmitted discovery signals transmitted from the other UEs is less than the discovery signal transmission number threshold during the discovery signal monitoring duration of the third UE. In some examples, the discovery signal monitoring parameter and/or discovery signal transmission number threshold may be transmitted concurrently with the discovery signal initiation message.

[0159] In some examples, the first UE may determine the discovery signal monitoring parameter based on the latency requirement associated with the second UE performing a relay node switch from the first UE to a neighbor relay UE (e.g., the third UE). In addition, the first UE may determine the DS transmission number threshold associated with the second UE based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs) that are currently relay node switching from the first UE to another neighbor relay UE. For example, the DS management circuitry **948**, together with the communication and processing circuitry **942** and transceiver **910**, shown and described above in connection with FIG. **9** may transmit the discovery signal initiation message to at least the third UE.

[0160] FIG. **12** is a flow chart of a method **1200** for a base station to facilitate discovery signal transmission between UEs. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all embodiments. In some examples, the method **1000** may be performed by the base station **800**, as described above and illustrated in FIG. **8**, by a processor or processing system, or by any suitable means for carrying out the described functions.

[0161] At bock **1202**, the base station may communicate with at least a first user equipment (UE) in a wireless communication network. For example, the base station may communicate with at least the first UE over a Uu interface. For example, the resource assignment and scheduling circuitry **842**, together with the DL traffic and control channel generation and transmission circuitry **844** and UL traffic and control channel generation and transmission circuitry **846**, as shown and described above in connection with FIG. **8** may communicate with at least the first UE.

[0162] At block **1204**, the base station may transmit at least one of a discovery signal transmission number threshold or a discovery signal monitoring parameter to at least the first UE to control transmission of a discovery signal from the first UE to a second UE based on a discovery signal monitoring duration during which the first UE monitors for transmitted discovery signals transmitted from other UEs to the second UE. In some examples, the discovery signal monitoring parameter may include at least one probability distribution parameter associated with a probability distribution. In some examples, the base station may broadcast, multicast, or unicast the discovery

signal monitoring parameter and/or the discovery signal transmission number threshold to at least the first UE.

[0163] In some examples, the base station may determine the discovery signal monitoring parameter based on a latency requirement associated the second UE performing a relay node switch. In addition, the base station may determine the DS transmission number threshold associated with the second UE based on the latency requirement associated with performing the relay node switch or a number of candidate UEs (e.g., other remote UEs) that are currently relay node switching from a third UE to another neighbor relay UE (e.g., the first UE). For example, the relay link management circuitry **848**, together with the DL traffic and control channel generation and transmission circuitry **844** and transceiver **810**, shown and described above in connection with FIG. **8**, may transmit the discovery signal transmission number threshold and/or the discovery signal monitoring parameter to at least the first UE.

[0164] Several aspects of a wireless communication network have been presented with reference to an exemplary implementation. As those skilled in the art will readily appreciate, various aspects described throughout this disclosure may be extended to other telecommunication systems, network architectures and communication standards.

[0165] By way of example, various aspects may be implemented within other systems defined by 3GPP, such as Long-Term Evolution (LTE), the Evolved Packet System (EPS), the Universal Mobile Telecommunication System (UMTS), and/or the Global System for Mobile (GSM). Various aspects may also be extended to systems defined by the 3rd Generation Partnership Project 2 (3GPP2), such as CDMA 2000 and/or Evolution-Data Optimized (EV-DO). Other examples may be implemented within systems employing IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Ultra-Wideband (UWB), Bluetooth, and/or other suitable systems. The actual telecommunication standard, network architecture, and/or communication standard employed will depend on the specific application and the overall design constraints imposed on the system.

[0166] Within the present disclosure, the word "exemplary" is used to mean "serving as an example, instance, or illustration." Any implementation or aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects of the disclosure. Likewise, the term "aspects" does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation. The term "coupled" is used herein to refer to the direct or indirect coupling between two objects. For example, if object A physically touches object B, and object B touches object C, then objects A and C may still be considered coupled to one another- even if they do not directly physically touch each other. For instance, a first object may be coupled to a second object even though the first object is never directly physically in contact with the second object. The terms "circuit" and "circuitry" are used broadly, and intended to include both hardware implementations of electrical devices and conductors that, when connected and configured, enable the performance of the functions described in the present disclosure, without limitation as to the type of electronic circuits, as well as software implementations of information and instructions that, when executed by a processor, enable the performance of the functions described in the present disclosure.

[0167] One or more of the components, steps, features and/or functions illustrated in FIGS. **1-12** may be rearranged and/or combined into a single component, step, feature or function or embodied in several components, steps, or functions. Additional elements, components, steps, and/or functions may also be added without departing from novel features disclosed herein. The apparatus, devices, and/or components illustrated in FIGS. **1**, **3**, and **6-9** may be configured to perform one or more of the methods, features, or steps described herein. The novel algorithms described herein may also be efficiently implemented in software and/or embedded in hardware.

[0168] It is to be understood that the specific order or hierarchy of steps in the methods disclosed is an illustration of exemplary processes. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the methods may be rearranged. The accompanying method

claims present elements of the various steps in a sample order and are not meant to be limited to the specific order or hierarchy presented unless specifically recited therein.

[0169] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but are to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. A phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a; b; c; a and b; a and c; b and c; and a, b, and c. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims.

Claims

1. A first user equipment (UE) configured for wireless communication, comprising: one or more processors; one or more memories coupled to the one or more processors, wherein the one or more processors are configured to cause the first UE to: communicate with a second UE via a sidelink; transmit a discovery signal initiation message to at least a third UE, the discovery signal initiation message comprising at least one parameter indicating a discovery signal monitoring duration to monitor for other discovery signals from other UEs to the second UE; and transmit a discovery signal transmission number threshold to the third UE, wherein the discovery signal transmission number threshold indicates a number of other discovery signals from the other UEs during the discovery signal monitoring duration.