



(51) International Patent Classification:

H04L 5/00 (2006.01) *H04W 84/00* (2009.01)
H04W 4/00 (2018.01) *H04W 84/18* (2009.01)
H04W 72/04 (2009.01) *H04W 88/04* (2009.01)

(21) International Application Number:

PCT/US2017/045862

(22) International Filing Date:

08 August 2017 (08.08.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/373,895 11 August 2016 (11.08.2016) US

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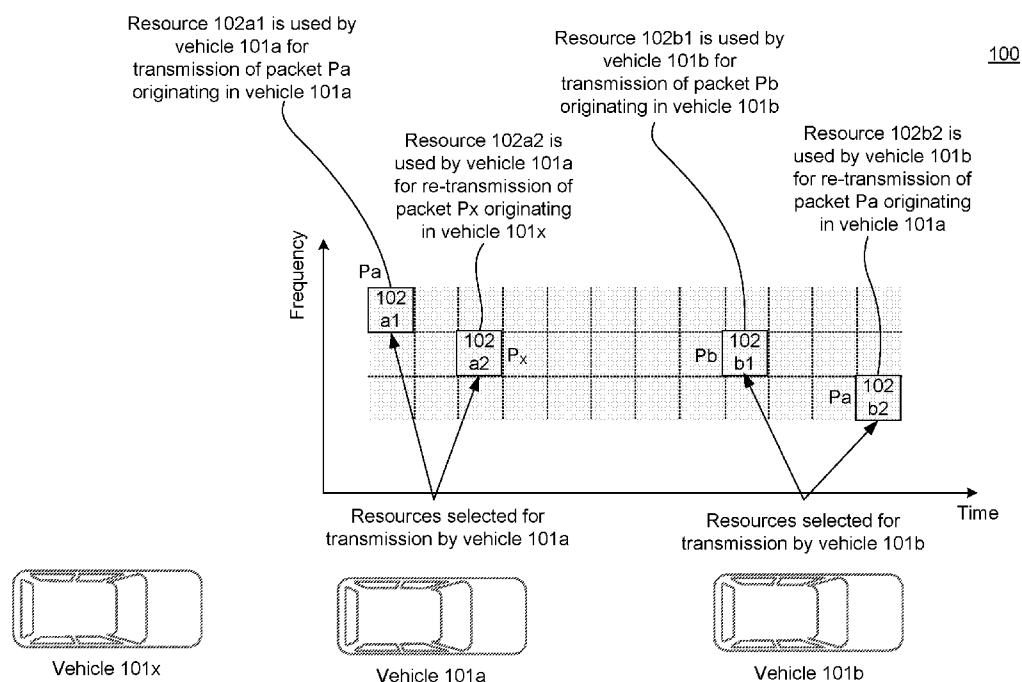
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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) Title: SELECTIVE PACKET RE-TRANSMISSION IN A VEHICLE-TO-VEHICLE (V2V) COMMUNICATION SYSTEM

**Fig. 1**

(57) **Abstract:** Described is an apparatus of a first User Equipment (UE) operable to communicate with on a wireless network. The apparatus may comprise a first circuitry, and a second circuitry. The first circuitry may be operable to identify a plurality of resources on a frequency-time spectrum. The second circuitry may be operable to select one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE, and select one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

SELECTIVE PACKET RE-TRANSMISSION IN A VEHICLE-TO-VEHICLE (V2V) COMMUNICATION SYSTEM

CLAIM OF PRIORITY

[0001] The present application claims priority under 35 U.S.C. § 119(e) to United States Provisional Patent Application Serial Number 62/373,895, filed August 11, 2016 and entitled “INCREASE RELIABILITY OF VEHICLE-TO-VEHICLE COMMUNICATION,” which is herein incorporated by reference in its entirety.

BACKGROUND

[0002] A variety of wireless cellular communication systems have been implemented, including a 3rd Generation Partnership Project (3GPP) Universal Mobile Telecommunications System, a 3GPP Long-Term Evolution (LTE) system, and a 3GPP LTE-Advanced (LTE-A) system. Next-generation wireless cellular communication systems based upon LTE and LTE-A systems are being developed, such as a fifth generation (5G) wireless system / 5G mobile networks system. Next-generation wireless cellular communication systems may provide support for higher bandwidths in part by supporting higher carrier frequencies, such as centimeter-wave and millimeter-wave frequencies.

[0003] Vehicular communication systems are networks in which vehicles are the communicating nodes, providing each other with information, such as safety warnings, traffic information, etc., thereby creating the “connected cars” concept. For example, LTE technology may provide vehicles with wireless connections among each other (e.g., vehicle to vehicle or V2V communication) and to the Internet. To address the strong interest of the automobile industry and the cellular network operators in the “connected cars” concept, LTE-based V2X services (vehicle-to-vehicle or V2V, vehicle-to-infrastructure/network or V2I/N, vehicle-to-pedestrian V2P, etc.) were recently introduced (e.g., in LTE Release 14). It may be useful to increase reliability of V2V communication.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. However, while the drawings are to aid in explanation and

understanding, they are only an aid, and should not be taken to limit the disclosure to the specific embodiments depicted therein.

[0005] **Fig. 1** illustrates a V2V system implementing proximate vehicle packet forwarding, according to some embodiments.

[0006] **Fig. 2** illustrates an example scenario employing vehicle packet forwarding, according to some embodiments.

[0007] **Fig. 3** illustrates a V2V system, in which a relay node XORs packets from multiple vehicles, and re-transmits the XORed packet, according to some embodiments.

[0008] **Fig. 4** illustrates a V2V system for implementing selective vehicle packet forwarding, based on factors such as vehicle geo-location information, radio-measurements, and/or the like, according to some embodiments.

[0009] **Fig. 5** illustrates a V2V system for implementing a filtering scheme to select one or more packets from one or more vehicles for relaying or forwarding, according to some embodiments.

[0010] **Fig. 6** illustrates a method for a UE for implementing dynamic and intelligent forwarding of packets from other vehicles, according to some embodiments.

[0011] **Fig. 7** illustrates an eNB and a UE, according to some embodiments.

[0012] **Fig. 8** illustrates hardware processing circuitries for a UE for implementing proximate vehicle packet forwarding, according to some embodiments.

[0013] **Fig. 9** illustrates a method for a UE for selecting resources for transmission of its own packets and for re-transmission of packets from other UEs, according to some embodiments.

[0014] **Fig. 10** illustrates a method for a UE for selecting one or more other UEs for re-transmission of packets, according to some embodiments.

[0015] **Fig. 11** illustrates an architecture of a system of a network, according to some embodiments.

[0016] **Fig. 12** illustrates example components of a device, according to some embodiments.

[0017] **Fig. 13** illustrates example interfaces of baseband circuitry, according to some embodiments.

DETAILED DESCRIPTION

[0018] Vehicle-to-vehicle (V2V) communication is a fast and emerging field in wireless communication. Future cars may be able to communicate with each other, e.g., to support various applications ranging from road-safety to autonomous driving.

[0019] In an example, V2V communication system may be expected to have a high reliability of packet delivery within predefined target communication range of a transmitter, e.g., subject to very low latency of packet delivery. For road-safety applications, an end-to-end latency requirement may be about 100 milliseconds (ms) and a target communication range may be about 320 meters (m) in freeway and highway scenarios. The larger the communication range, the more reliable system performance may be achieved. In an example, about 90% of receivers within this target range from transmitter may be expected to be able to reliably receive V2V packets.

[0020] Future autonomous driving applications may have even stricter requirements, e.g., in terms of communication range, latency, reliability of V2V packet delivery, etc. For example, it is foreseen that latency of less than 10-20 ms, or even as low as 1 ms, may be aimed with even higher reliability, e.g., measured as a success probability of transmitting V2V packet of length L with latency requirement TL at a certain communication range RT (target communication range). This requirement may have to be satisfied even for high-speed scenarios, e.g., where relative vehicle speed among two vehicles may be as high as 500 kilometers/hour.

[0021] In an example, current V2V requirements may be difficult to achieve, e.g., especially taking into account the ad-hoc nature of V2V communication. For example, in contrast to a cellular communication where a base station or an Evolved NodeB (eNB) may schedule communication of various UEs, in V2V system the eNB may not be a centralized authority to schedule communication between the vehicles.

[0022] In an example, one of the challenges of a V2V communication system may be associated with half-duplexing. For example, a vehicle terminal may not transmit and receive simultaneously, e.g., at the same time interval. Therefore, if several vehicles are to transmit at the same time, the vehicles may not hear each other. This may adversely affect reliability, if two vehicles are within target communication range

[0023] In an example, another challenge of a V2V communication system may be co-channel interference and collision in resource selection. For example, if two proximate vehicles select the same spectrum resource (e.g., the same frequency-time channel) for

transmission, co-channel interference may degrade the reception performance in the target communication range.

[0024] In an example, another challenge of a V2V communication system may be associated with hidden nodes. For example, in a V2V system (e.g., which may be an ad-hoc network), vehicles may select resources autonomously, aiming to avoid co-channel collision. However, if two vehicles are outside of communication range of each other, the two vehicles may select the same frequency-time spectrum resource. This may cause a problem for receivers that may suffer from co-channel interference.

[0025] In an example, another challenge of a V2V communication system may be associated with in-band emission and near far problems. For example, in order to increase the efficiency of spectrum resources, the frequency-time partitioning of system spectrum on frequency sub-channel and time slots may be applied. In this case, distant transmitters (e.g., UEs) may select different frequency sub-channels to avoid co-channel interference issue. However, due to non-ideal Radio Frequency (RF) and Baseband (BB) processing at the transmitter side, the in-band emissions may be injected on non-occupied sub-channels within system bandwidth. In addition, out-of-band (e.g., out of system bandwidth) emissions may be produced due to transceiver non-ideality (e.g., dynamic range, IQ imbalance, quantization, non-linearity, etc.). The in-band emissions from proximate transmitter may mask the weak useful signal from distant transmitter of interest, e.g., so that reception of packets from distant transmitter may fail.

[0026] In an example, another challenge of a V2V communication system may be associated with possibly high mobility of the vehicles. For example, vehicles may be moving at high speed, and thus the interference environment in V2V communication systems may be highly dynamic. The mobility effects may limit applicability of sensing based solutions for resource selection, e.g., which aim to analyze whether the particular spectrum resource is occupied or not.

[0027] All these challenges may have to be resolved at least in part, in order to ensure the reliable V2V communication. Moreover, it may be useful to resolve these challenges in a distributed manner, so that vehicles can autonomously select resources for transmission without requiring centralized scheduling from any network entity. At the same time, the reliability of V2V communication performance, latency of packet delivery, communication range, etc. may not be compromised.

[0028] In an example, V2V traffic may be typically periodical. For example, assume that the vehicles can generate N bytes packet every TG ms (e.g., which may be about 100ms)

and may deliver the packet within TL latency budget to the receivers within target V2V communication range R_{V2V} .

[0029] V2V communications may be based at least in part on PC5 interface, also referred to as sidelink at the physical layer (e.g., sidelink channels of UEs of the vehicles). The LTE PC5 based V2V communication may rely on autonomous sensing based resource selection procedure, that may take into account V2V traffic characteristics and requirements. The available spectrum resources may be partitioned into synchronous frequency-time sub-channels that may be used for direct V2V communication between vehicles. The UE may utilize semi-persistent resource allocation principles to transmit periodically generated packets. Before transmission, the UE of a vehicle may perform medium sensing procedure in order to determine the best spectrum resources (e.g. relatively less congested resources, optimal or near optimal, or least congested resources) for transmission within the transmission window, where the transmission window may be bounded by V2V packet latency budget. For that purpose, the UE may monitor ongoing transmissions from other vehicles by processing control physical sidelink control channel (PSCCH), physical sidelink shared channel (PSSCH), and/or another sidelink channel. By monitoring the sidelink channels, the UE may identify a set of non-occupied or relatively less congested resources (from its own receiver point of view), and may randomly select one for transmission of a packet of the UE within a transmission window. In an example, the set of less congested resources may be determined by the minimum received energy metric, and/or by another appropriate manner.

[0030] In an example, this approach may have some drawbacks, such as the inherited hidden node problem, half-duplex, limited communication range in interference and noise limited scenarios, etc., as discussed herein previously. In an example, in order to cope with half-duplex issues, the vehicle may select two resources in order to randomize its transmission with other vehicles. Although selecting two resources and transmitting packets over the two selected resources may help to reduce the half-duplex problem, other problems (e.g., such as in-band and co-channel interference, hidden node problem, etc.) may not be fully resolved. In an example, although the transmitter may optimize its resource selection decision based on its own receiver observations and power measurements, these may not reflect the environment at the target receivers. For example, the resource which seems optimal from the transmitter perspective may not reliably represent the best (e.g., less congested) resource at distant receivers.

[0031] Various embodiments of this disclosure propose modifications of the V2V system to address at least some of the above discussed issues. For example, various embodiments of this disclosure provide methods to improve reliability of V2V communication in distributed system with autonomous resource selection principles. The teachings of this disclosure may be applicable to both 3GPP LTE (4G) V2V communication systems, 3GPP NR (5G) V2V communication systems, or another appropriate V2V communication systems. The teachings of this disclosure may be based on distributed architecture for sidelink-based V2V communication.

[0032] As will be discussed in further details herein later, in some embodiments, a UE in a vehicle may implement autonomous sensing and resource selection procedures. In some embodiments, each transmitter may select multiple spectrum resources that optimize its own broadcast transmission. Various embodiments of this disclosure may propose geo-location aware packet relaying for V2V communication, intelligent packet forwarding concepts, listen-before talk procedure or filtering procedure to forward packets on least congested resources, control relaying decisions, and/or the like. In some examples, the teachings of this disclosure may aim to improve broadcast V2V communication performance by increasing the communication range in noise limited or interference limited scenarios, as well as improve reliability of the packet delivery within target V2V communication range.

[0033] In the following description, numerous details are discussed to provide a more thorough explanation of embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring embodiments of the present disclosure.

[0034] Note that in the corresponding drawings of the embodiments, signals are represented with lines. Some lines may be thicker, to indicate a greater number of constituent signal paths, and/or have arrows at one or more ends, to indicate a direction of information flow. Such indications are not intended to be limiting. Rather, the lines are used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit or a logical unit. Any represented signal, as dictated by design needs or preferences, may actually comprise one or more signals that may travel in either direction and may be implemented with any suitable type of signal scheme.

[0035] Throughout the specification, and in the claims, the term "connected" means a direct electrical, mechanical, or magnetic connection between the things that are connected,

without any intermediary devices. The term "coupled" means either a direct electrical, mechanical, or magnetic connection between the things that are connected or an indirect connection through one or more passive or active intermediary devices. The term "circuit" or "module" may refer to one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" may refer to at least one current signal, voltage signal, magnetic signal, or data/clock signal. The meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0036] The terms "substantially," "close," "approximately," "near," and "about" generally refer to being within +/- 10% of a target value. Unless otherwise specified the use of the ordinal adjectives "first," "second," and "third," etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0037] It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

[0038] The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions.

[0039] For the purposes of the present disclosure, the phrases "A and/or B" and "A or B" mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0040] In addition, the various elements of combinatorial logic and sequential logic discussed in the present disclosure may pertain both to physical structures (such as AND gates, OR gates, or XOR gates), or to synthesized or otherwise optimized collections of devices implementing the logical structures that are Boolean equivalents of the logic under discussion.

[0041] In addition, for purposes of the present disclosure, the term "eNB" may refer to a legacy eNB, a next-generation or NR gNB, a 5G eNB, an Access Point (AP), a Base Station or an eNB communicating on the unlicensed spectrum, and/or another base station for a wireless communication system. For purposes of the present disclosure, the term "UE" may refer to a legacy UE, a next-generation or NR UE, a 5G UE, an STA, and/or another mobile equipment for a wireless communication system.

[0042] Various embodiments of eNBs and/or UEs discussed below may process one or more transmissions of various types. Some processing of a transmission may comprise receiving, conducting, and/or otherwise handling a transmission that has been received. In some embodiments, an eNB or UE processing a transmission may determine or recognize the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE processing a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE processing a transmission may also recognize one or more values or fields of data carried by the transmission. Processing a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission that has been received by an eNB or a UE through one or more layers of a protocol stack.

[0043] Various embodiments of eNBs and/or UEs discussed below may also generate one or more transmissions of various types. Some generating of a transmission may comprise receiving, conducting, and/or otherwise handling a transmission that is to be transmitted. In some embodiments, an eNB or UE generating a transmission may establish the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE generating a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE generating a transmission may also determine one or more values or fields of data carried by the transmission. Generating a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission to be sent by an eNB or a UE through one or more layers of a protocol stack.

[0044] **Fig. 1** illustrates a V2V system 100 implementing proximate vehicle packet forwarding, according to some embodiments. In the system 100, three vehicles 101x, 101a, and 101b are illustrated, although the system 100 is likely to include other vehicles not illustrated in **Fig. 1**.

[0045] In some embodiments, each vehicle 101x, 101a, and 101b (generally referred to as vehicle 101 or UE 101) may include or embed communications equipment, such as a UE that may communicate in accordance with the V2V communication protocol. For example, a vehicle 101 may have an integrated, inbuilt, embedded, or an associated UE. As such, the terms "vehicle," "UE within a vehicle," "vehicle based UE," "communication nodes," "nodes," or simply "UE" may be used interchangeably. Thus, for example, a

reference to the vehicle 101a may refer to the physical vehicle 101a and/or to a UE embedded within (or otherwise associated with) the vehicle 101a. Accordingly, the vehicle 101a may also be referred to as UE 101a.

[0046] Also, illustrated in **Fig. 1** is a graph depicting frequency-time resources that may be used by a vehicle 101 for transmission of packets to other vehicles of the system 100. Such transmission of packets may be via PC5 channels or sidelink channels, e.g., PSCCH, PSSCH, Physical Sidelink Broadcast Channel (PSBCH), and/or the like.

[0047] For example, the frequency-time spectrum in the graph may be divided in multiple segments, where a vehicle may use one or more specific segments (e.g., one or more specific frequency-time channels) for transmission of packets to one or more other vehicles, e.g., for sidelink transmissions. Unless otherwise mentioned and for the purposes of this disclosure, a resource may indicate a corresponding segment or square in the graph depicting the frequency-time spectrum. Thus, a resource may indicate a corresponding frequency-time channel or a corresponding frequency-time spectrum for transmission of packets, e.g., possibly using sidelink transmissions.

[0048] In some embodiments, in the system 100, individual UEs may perform sensing procedure in order to identify a plurality of resources from the frequency-time spectrum. For example, M_{BEST} resources may be selected by individual UEs, e.g., from their own transceiver perspective. Thus, the UE 101a may select M_{BEST} resources from the perspective of the transceiver of the UE 101a. In some embodiments, M_{BEST} may be 1, 2, 3, ..., and so on. Thus, a UE may select multiple resources. In the example of **Fig. 1**, M_{BEST} may comprise two resources for a UE.

[0049] In an example, one or more appropriate criteria may be used to select the resources. In some embodiments, the set of selected M_{BEST} resources may be composed from relatively less congested resources, e.g., determined by minimum received energy in individual resources, although any other appropriate criteria may also be used for the selection. Thus, from the perspective of a UE, the corresponding M_{BEST} resources may be optimal or near optimal for transmission of packets from the UE.

[0050] In some embodiments, a UE may use some of the M_{BEST} resources for the transmission and/or re-transmission of its own packets (e.g., packets originating at the UE). In some embodiments, instead of utilizing all of the M_{BEST} resources for the transmission and/or re-transmission of its own packets, a UE may use at least part of the M_{BEST} resources for relaying or re-transmitting received packets from other vehicles. For example, the UE

may use N_{BEST} resources of the M_{BEST} resources for relaying or re-transmitting received packets from other vehicles, as illustrated in **Fig. 1**.

[0051] For example, in the example of **Fig. 1**, the M_{BEST} resources for the vehicle 101a are resources 102a1 and 102a2 in the frequency-time spectrum, and the M_{BEST} resources for the vehicle 101b are resources 102b1 and 102b2 in the frequency-time spectrum (the M_{BEST} resources for the vehicle 101x are not illustrated for purposes of illustrative clarity). Thus, each UE selects two resources in the example of **Fig. 1**, although in some other embodiments, a UE may select another appropriate number of M_{BEST} resources.

[0052] Although not illustrated in **Fig. 1**, the UE 101a is assumed to receive a packet Px from the vehicle 101x. Of the two resource 102a1 and 102a2 selected by the UE 101a, the UE 101a may use the resource 102a1 for transmission of a packet Pa that originates in the UE 101a (e.g., the UE 101a transmits its own packet Pa via the resource 102a1). Also, the UE 101a may use the resource 102a2 for transmission of the packet Px that originated in the UE 101x. Thus, using the resource 102a2, the UE 101a re-transmits the packet Px received from the UE 101x.

[0053] Similarly, the UE 101b may receive the packet Pa and the packet Px transmitted from the UE 101a. Of the two resource 102b1 and 102b2 selected by the UE 101b, the UE 101b may use the resource 102b1 for transmission of a packet Pb that originates in the UE 101b (e.g., the UE 101b transmits its own packet Pb via the resource 102b1). Also, the UE 101b may use the resource 102b2 for transmission of the packet Pa that originated in the UE 101a. Thus, using the resource 102b2, the UE 101b re-transmits the packet Pa received from the UE 101a.

[0054] Thus, in some embodiments, **Fig. 1** illustrates a two-hop V2V communication system for transmission of packets via sidelink channels. For example, the UE 101a acts as a relaying node, e.g., for transmission of the packet Px from the UE 101x to the UE 101b. It should be noted that the concept of re-transmission of packets can be extended beyond two hops. For example, the UE 101b can again re-transmit the packet Px (e.g., along with, or instead of packet Pa) received from the vehicle 101a. In such an example, the packet Px may be transmitted from UE 101x to UE 101a, from UE 101a to UE 101b, and from 101b to one or more other UEs.

[0055] For the purposes of this disclosure, a first vehicle “relaying” a packet originating in a second vehicle may be synonymous to the first vehicle “forwarding” or “re-transmitting” the packet originating in the second vehicle. Thus, the terms relaying,

forwarding, and/or re-transmitting may be used interchangeably in this disclosure, when used in the context of a first vehicle relaying a packet that originated in a second vehicle.

[0056] **Fig. 2** illustrates an example scenario 200 employing vehicle packet forwarding, according to some embodiments. For example, the scenario 200 comprises a road intersection and the vehicles 101x, 101a, and 101b of **Fig. 1** located in a specific example locations. The vehicle 101a may communicate with both the vehicles 101x and 101b. However, some blockage or relatively long distance may prevent direct communication between vehicles 101x and 101b.

[0057] **Fig. 2** illustrates transmission of the packet Px originating the vehicle 101x. As discussed with respect to **Fig. 1**, packet Px may be transmitted by the vehicle 101x, and may be received by the vehicle 101a (and may possibly be received by vehicle 101b, although the blockage in the intersection may prevent the vehicle 101b from receiving the packet Px directly from vehicle 101x). The first or initial transmission of the packet Px is illustrated using dotted lines. The vehicle 101a may re-transmit or relay the packet Px, where the re-transmission (e.g., the second transmission) is illustrated using dashed line. The vehicle 101b may receive the re-transmitted packet Px from the vehicle 101a. Thus, even if the vehicle 101b does not receive the direct or first transmission of the packet Px from vehicle 101x due to the blockage in the intersection, the vehicle 101b may receive the second or re-transmission of the packet Px from the vehicle 101a.

[0058] In some embodiments, relaying or retransmitting packets may have various advantages. As an example, each V2V packet may propagate over the air by using optimal or near optimal resource at each relaying node or hop. This may improve the overall radio propagation conditions towards distant target receivers, may increase robustness to interference, increase V2V communication range and reliability, etc.

[0059] In some embodiments, in order to relay packets in both road directions, at least three resources may have to be used by individual vehicles. As an example, a first vehicle may use one resource for its own transmission, and two remaining resources for packet forwarding from other two vehicles (e.g. packet forwarding from a second vehicle that is located in front of the first vehicle, and a third vehicle that is behind the first vehicle). Thus, the first vehicle may have to use at least three resources, e.g., in order to relay packets in both road directions.

[0060] In some embodiments, instead of, or in addition to, increasing the amount of resources for relaying, it may be possible to concatenate or combine packets from two or more vehicles, and transmit the concatenated packets in a single resource (e.g., a second

resource of the two selected resources). Concatenating or otherwise combining the packets and transmitting the concatenated packets in a single resource may keep the same number of resources (e.g., two) utilized by a vehicle, but may reduce the effective code rate for re-transmitted packets.

[0061] Instead of, or in addition to, concatenating packet from two or more vehicles, in some embodiments, packets from two or more vehicles may be processed with Network Coding principles (e.g. XORed) and transmitted in one or more resources. For example, a first packet from a first vehicle and a second packet from a second vehicle may be received by a third vehicle. The third vehicle may act as a relay node, and XOR the first packet and the second packet. The third vehicle may then transmit the XORed packet. When the first vehicle receives the XORed packet, the first vehicle can estimate the second packet from the second vehicle (e.g., as the first vehicle knows the first packet). Similarly, when the second vehicle receives the XORed packet, the second vehicle can estimate the first packet from the first vehicle (e.g., as the second vehicle knows the second packet).

[0062] **Fig. 3** illustrates a V2V system 300, in which a relay node XORs packets from multiple vehicles, and re-transmits the XORed packet, according to some embodiments. In the system 300, three vehicles 301a, 301b, and 301c are illustrated. A graph having X-Y coordinates illustrative example relative positions of the vehicles 301a, 301b, and 301c. Also, illustrated in **Fig. 3** is a graph depicting frequency-time resources that may be used by the vehicles 301 for transmission of packets to other vehicles of the system 300, e.g., similar to **Fig. 1**.

[0063] Similar to **Fig. 1**, in **Fig. 3** the UE 301a is assumed to receive a packet P_x from another vehicle (not illustrated in **Fig. 3**). Of two resource 302a1 and 302a2 selected by the UE 301a, the UE 301a may use the resource 302a1 for transmission of a packet P_a that originates in the UE 301a. Also, the UE 301a may use the resource 302a2 for transmission of the packet P_x that originated in another UE. Similarly, the UE 301c may receive a packet P_y from another vehicle (not illustrated in **Fig. 3**). Of the two resource 302c1 and 302c2 selected by the UE 301c, the UE 301c may use the resource 302c1 for transmission of a packet P_c that originates in the UE 301c (e.g., the UE 301c transmits its own packet P_c via the resource 302c1). Also, the UE 301c may use the resource 302c2 for re-transmission of the packet P_y that originated in another UE.

[0064] UE 301b may receive the packets P_a , P_b , P_x , and/or P_y from the UEs 301a and 301c. The UE 301c may decide to re-transmit the packets P_a and P_b received from the UEs 301a and 301c, respectively. In some embodiments, the UE 301b may XOR the packets

Pa and Pb to generate an XORed packet Pxor. Of two resource 302b1 and 302b2 selected by the UE 301b, the UE 301b may use the resource 302b1 for transmission of a packet Pb that originates in the UE 301b (e.g., the UE 301b transmits its own packet Pb via the resource 302b1). Also, the UE 301b may use the resource 302b2 for re-transmission of the XORed packet Pxor.

[0065] When the UE 301a receives the XORed packet Pxor, the UE 301a already has access to the packet Pa (e.g., as the UE 301a generated the packet Pa). Accordingly, the UE 301a can demodulate the XORed packet Pxor (e.g., based on the knowledge of the packet Pa) to identify the packet Pc.

[0066] Similarly, when the UE 301c receives the XORed packet Pxor, the UE 301c already has access to the packet Pc (e.g., as the UE 301c generated the packet Pc). Accordingly, the UE 301c can demodulate the XORed packet Pxor (e.g., based on the knowledge of the packet Pc) to identify the packet Pa.

[0067] Thus, due to the XOR operation, the vehicle 301b may transmit, in essence, the packet Pc to the UE 301a, and the packet Pa to the UE 301c, using a single resource 302b. Although **Fig. 3** illustrates only three vehicles and XORing of only two packets, the teachings of this disclosure may be extended for a larger number of vehicles and/or packets.

[0068] **Fig. 4** illustrates a V2V system 400 for implementing selective vehicle packet forwarding, based on factors such as vehicle geo-location information, vehicle distance, radio-measurements, and/or the like, according to some embodiments. For example, as discussed with respect to **Figs. 1-3**, a vehicle may forward or relay packets from one or more other vehicles. **Fig. 4** is directed to, for a first vehicle 401a, selecting other vehicles from which packets may be relayed by the first vehicle 401a.

[0069] **Fig. 4** illustrates the vehicle 401a, which may forward packets from one or more other vehicles. **Fig. 4** is from the perspective of packet forwarding decision of the vehicle 401a. The system 400 comprises other vehicles, e.g., vehicles 403a, 403b, ..., 403h (generally referred to as vehicles 403), where the vehicles 401a and 403 may be on a road 405.

[0070] For example, **Fig. 4** illustrates a distance D_{MIN} and a distance D_{MAX} , illustrated as dashed line in **Fig. 4**, from a radio transceiver of the vehicle 401a. Merely as an example, some of the vehicles 403 (e.g., vehicle 403a) may be relatively closely located to the vehicle 401a (e.g., located at a distance that may be less than distance D_{MIN}). Some of the vehicles 403 (e.g., vehicles 403b, 403c, 403d, and 403e) may be located at a moderate distance from the vehicle 401a (e.g., located at a distance that may be more than the distance D_{MIN} , but less

than the distance D_{MAX}). Some of the vehicles 403 (e.g., vehicles 403f, 403g, and 403h) may be located relatively far away from the vehicle 401a (e.g., located at a distance that may be more than the distance D_{MAX}).

[0071] In the V2V system 400, a geo-location aware resource selection principle may be used. According to this principle, individual vehicles may select resources for transmission, e.g., based on its own geo-location information (e.g. relative or absolute coordinate points of the vehicle). This idea may be extended for intelligent V2V packet forwarding or relaying. For instance, in order to improve V2V communication range and reduce sensitivity to interference, a distance between the vehicle 401a and a vehicle 403 may be estimated, and the distance may be used as a metric to decide on whether the vehicle 401a may relay a packet from the vehicle 403.

[0072] For example, in general, it may not make much sense for a first vehicle to relay packets from a nearby or proximate vehicle, since the broadcast environment the nearby vehicle is likely to experience may have similar radio conditions as the first vehicle. Thus, for example, the vehicle 401a may not relay a packet from the nearby or proximate vehicle 403a (e.g., from vehicles that are at less than the distance D_{MIN} from the vehicle 401a), since in broadcast environment the relayed packet from the vehicle 401a may likely experience similar radio conditions as the original transmission of the packet from the vehicle 403a. Put differently, as the broadcast environment of vehicles 401a and 403a are likely to have similar radio conditions (e.g., due to the proximity of the vehicles), the vehicle 401a may not relay packets from the proximally located vehicle 403a. Thus, in some embodiments, the vehicle 401a may not relay packets from vehicles (e.g., vehicle 403a) that may be located at a distance less than the distance D_{MIN} .

[0073] On the other hand, relaying packets from the relatively distant vehicles (e.g., vehicles 403f, 403g, 403h) may be possible - however the reception of packets from such distant vehicles may fail more frequently. Thus, in some embodiments, the vehicle 401a may not relay packets from distance vehicles 403f, 403g, and 403h, e.g., may not relay packets from vehicles that may be located more than the distance D_{MAX} .

[0074] In some embodiments, the vehicle 401a may relay packets from vehicles that are within a distance range of D_{MIN} and D_{MAX} . For example, vehicles 403b, 403c, 403d, and 403e may be candidate vehicles for packet forwarding by the vehicle 401a. For example, the vehicle 401a may forward packets from one or more of the vehicles 403b, 403c, 403d, and 403e. In some embodiments, using distance as a factor to select candidate vehicles for packet forwarding may also be referred to as geo-location aware packet relaying.

[0075] In some embodiments, as the vehicles 401a and 403 may move at a fast speed, the distance between the vehicles may vary with time. Accordingly, the candidate vehicles for packet forwarding may also change with time.

[0076] In some embodiments, in order to perform geo-location aware packet relaying, the vehicle 401a may have to estimate geo-location information or distance information between the vehicle 401a and other vehicles 403. In some embodiments, vehicles may extract this information from the V2V messages that may carry geo-location coordinates and/or vehicle kinematics information for V2V applications. Additionally, or alternatively, in some embodiments, vehicles may perform distance estimation based on time of arrival or roundtrip time measurements of radio signals. In some embodiments, a vehicle may use received power measurements to estimate a radio distance, and whether a packet from another vehicle may be considered as a candidate for relaying. In an example, these measurements may be conducted using reference signals of known V2V transmissions using, for example, PSCCH and/or PSSCH channels in 3GPP LTE systems, their alternatives in 3GPP NR systems, and/or the like.

[0077] **Fig. 5** illustrates a V2V system 500 for implementing a filtering scheme to select one or more packets 517 from one or more candidate vehicles for relaying or forwarding, according to some embodiments. The system 500 is at least in part similar to the system 400 of **Fig. 4**. For example, both the figures have vehicles 401a, and 403a, ..., 403h. Similar to **Fig. 4**, in **Fig. 5** the vehicle 401a may select vehicles 403b, 403c, 403d, and 403e for possible packet forwarding. As discussed with respect to **Fig. 4**, such selection of the candidate vehicles may be based on geo-location information of the vehicles 403 relative to the vehicle 401a, distance information between the vehicle 401a and other vehicles 403, time of arrival or roundtrip time measurements of radio signals received by vehicle 401a from other vehicles 403, received power measurements or radio-layer measurements, and/or the like.

[0078] In some embodiments, the candidate vehicles 403b, ..., 403e may have multiple packets 515 that may be possibly forwarded by the vehicle 401a. However, the vehicle 401a may not prefer to use resources to forward all possible candidate packets 515 from all the candidate vehicles 403b, ..., 403e.

[0079] In some embodiments, the vehicle 401a may comprise a filtering mechanism (e.g., a filter 507) to possibly prune the list of candidate packets 515 from the candidate vehicles (403b, ..., 403e) for forwarding. For example, of the possible multiple candidate packets 515 from the candidate vehicles (403b, ..., 403e), the vehicle 401 may use the filter

507 to select one or more packets 517 for forwarding. In some embodiments, such filtering may be applied if the number of candidate packets 515 from the candidate vehicles (403b, ..., 403e) are too large for the vehicle 401a to forward, e.g., using the limited resource available to the vehicle 401a for packet forwarding.

[0080] Thus, in some embodiments, the vehicle 401a may prioritize packets for forwarding, e.g., subject to latency budget requirements. For example, the filter 507 may comprise a mechanism to decide which messages/packets from the candidate vehicles (403b, ..., 403e) may be prioritized for relaying, and which messages/packets from the candidate vehicles (403b, ..., 403e) may be dropped.

[0081] Additionally or alternatively, in an example, for efficient usage of spectrum resources, re-transmission or relaying of the same packet by multiple vehicles may be avoided. For example, a packet from the vehicle 403c may be received by both vehicles 401a and 403a. For example, the vehicle 403c may be within the permissible distance range $\{D_{MIN}, D_{MAX}\}$ for both the vehicles 401a and 403a. Accordingly, the vehicle 403c may be a candidate vehicle for packet forwarding for both the vehicles 401a and 403a. However, if a packet from the vehicle 403c is re-transmitted by both the vehicles 401a and 403a, this may be an inefficient use of spectrum resources. Thus, in some embodiments, a vehicle 401a may try to avoid relaying a packet from another vehicle (e.g., vehicle 403c), which may be anyway relayed by yet another vehicle (e.g., vehicle 403a).

[0082] For example, in some embodiments, a vehicle, e.g., vehicle 401a, may detect whether one or more other vehicles already performed retransmission of a packet that is in the candidate packet list 515 for relaying. This may be achieved, for example, by decoding transmissions from all vehicles, and dropping the packets that were identified as being retransmitted by other vehicles. For example, assume a scenario in which a specific packet P0 is received by the vehicle 401a from the vehicle 403c (e.g., the packet P0 originated in the vehicle 403c) and the packet P0 is one of the candidate packets 515. Now, if the vehicle 401a determines that the vehicle 403a has already relayed the packet P0, the vehicle 401a may refrain from relaying this packet P0 (e.g., the filter 507 may drop the packet P0 from the list of candidate packets 515, and the packet P0 may not be selected as the selected packets 517). In some embodiments, such a decision to drop the packet may also be based on distance to the relay node that forwarded the packet.

[0083] Additionally, or alternatively, for prioritization of packet forwarding, the vehicle 401a may use a packet expiration time (e.g., remaining latency budget) as a metric to prioritize its relaying, e.g., for filtering the candidate packets 515 to select the packets 517 for

relaying. Merely as an example, packet(s) with the relatively low latency budget (e.g., one or more packets with the lowest latency budget) may be prioritized or selected for transmission. Thus, merely as an example, if packets P51, P52, and P53 are in the list of candidate packets 515 and the vehicle 401a is to relay two packets from other vehicles, two of the P51, P52, and P53 with relatively low latency budget (e.g., two of the packets P51, 52, 53 that were most recently generated) may be selected for relaying by the vehicle 401a.

[0084] In some embodiments, the vehicle 401a may use distance as the metric to prioritize packet transmission. For example, one or more packets from a vehicle that is within the distance range $\{D_{MIN}, D_{MAX}\}$ and that is farthest among the candidate vehicles 403b, ..., 403e may be selected for retransmission.

[0085] In some embodiments, the vehicle 401a may randomly select one or more packets (e.g., from the list of candidate packets 515) for re-transmission.

[0086] In some embodiments, if the list of candidate packets 515 is empty (e.g., if the vehicle 401a has no packets from other vehicles for re-transmission), the vehicle 401a may re-transmit its own V2V packet (e.g., transmit its own packet multiple times).

[0087] In some embodiments, a V2V packet transmitted by a vehicle may include various information about the packet. Such information may facilitate the filter 507 to effectively filter out packets from the list of candidate packets 515, and may facilitate the filter 507 to select a subset of the candidate packets 515 for relaying. In some embodiments, such information about the packet may comprise one or more of information about a source of the packet, a packet ID, a retransmission indicator (e.g., to indicate if the packet is a re-transmitted packet, or to provide relevant information for re-transmission), and/or the like. In some embodiments, such information may be added to the control signaling. In some embodiments, the information may be used to apply network coding or other re-transmission and combining concepts, as well as advanced receiver processing to detect relayed and original packet transmissions.

[0088] **Fig. 6** illustrates a method 600 for a UE (e.g., a UE in the vehicle 401a of **Figs. 4-5**, or a UE of one of **Figs. 1-3**) for implementing dynamic and intelligent forwarding of packets from other vehicles, according to some embodiments. Although the actions in the method 600 are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 6** may be optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various

actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[0089] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause a UE (e.g., a UE 730 and/or hardware processing circuitry 740 discussed with respect to **Fig. 7** herein later) to perform an operation comprising the method 600 of **Fig. 6**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[0090] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the method 600 of **Fig. 6**.

[0091] Returning to **Fig. 6**, the method 600 may comprise, at 604, performing, by a UE associated with a first vehicle (e.g., one of vehicles 101a, 301a, or 401a of **Figs. 1-5**), medium sensing to identify a plurality of resources. Selection of resource has been discussed with respect to **Figs. 1 and 3**. For example, as discussed with respect to **Fig. 1**, M_{BEST} resources may be selected by a UE. A resource may indicate a corresponding frequency-time channel for transmission of packets, e.g., possibly using sidelink transmission.

[0092] The method 600 may comprise, at 608, transmitting, using a first one or more resources of the plurality of resources, first one or more packets originating from the first vehicle. Merely as an example, with reference to **Fig. 1**, the vehicle 101a may select resources 102a1 and 102a2 at 604 of method 600. The vehicle 101a may transmit a packet Pa, originating from the vehicle 101a, using the resource 102a1 at 608 of method 600. The packet may be transmitted over sidelink channels of the vehicle 101a.

[0093] The method 600 may comprise, at 612, receiving packets from a plurality of vehicles, selecting candidate vehicles, and selecting candidate packets from the candidate vehicles for possible forwarding. For example, with reference to **Figs. 4-5**, the vehicle 401a may receive packets from one or more of vehicles 403a, ..., 403h. The vehicle 401a may select vehicles 403b, 403c, 403d, and 403e as candidate vehicles, and may select candidate packets 515 received from these vehicles, as discussed in further details with respect to **Figs. 4-5**.

[0094] The method 600 may comprise, at 616, filtering the candidate packets from the candidate vehicles, to select a subset of the candidate packets for re-transmission. For

example, the filter 507 of the vehicle 401a of **Fig. 5** may select packets 517 from the candidate packets 515 using one or more criteria, e.g., as discussed in further details in **Fig. 5**.

[0095] The method 600 may comprise, at 620, re-transmitting or relaying, using a second one or more resources of the plurality of resources, the selected subset of the candidate packets from other vehicles. For example, as discussed with respect to **Fig. 1**, the vehicle 101a uses the resource 102a2 to re-transmit a packet Px originating from the vehicle 101x.

[0096] In some embodiments, the method 600 may operate in a continuous basis. Thus, in an example, the method 600 may loop back from block 620 to block 604.

[0097] Although various blocks in **Fig. 6** are illustrated using a specific order, the order may be changed. Merely as an example, the transmission at 608 may occur at least in part simultaneously with, or subsequent to, the re-transmission at 620. In another example, the selection of the candidate packets at 612 and the filtering of the candidate packets at 616 may occur at a single step or as a part of a combined operation, where the UE selects one or more packets (e.g., from all the packets received by the UE from other vehicles) for re-transmission.

[0098] **Fig. 7** illustrates an eNB and a UE, according to some embodiments. **Fig. 7** includes block diagrams of an eNB 710 and a UE 730 which are operable to co-exist with each other and other elements of an LTE network. High-level, simplified architectures of eNB 710 and UE 730 are described so as not to obscure the embodiments. It should be noted that in some embodiments, eNB 710 may be a stationary non-mobile device.

[0099] eNB 710 is coupled to one or more antennas 705, and UE 730 is similarly coupled to one or more antennas 725. However, in some embodiments, eNB 710 may incorporate or comprise antennas 705, and UE 730 in various embodiments may incorporate or comprise antennas 725.

[00100] In some embodiments, antennas 705 and/or antennas 725 may comprise one or more directional or omni-directional antennas, including monopole antennas, dipole antennas, loop antennas, patch antennas, microstrip antennas, coplanar wave antennas, or other types of antennas suitable for transmission of RF signals. In some MIMO (multiple-input and multiple output) embodiments, antennas 705 are separated to take advantage of spatial diversity.

[00101] eNB 710 and UE 730 are operable to communicate with each other on a network, such as a wireless network. eNB 710 and UE 730 may be in communication with

each other over a wireless communication channel 750, which has both a downlink path from eNB 710 to UE 730 and an uplink path from UE 730 to eNB 710.

[00102] As illustrated in **Fig. 7**, in some embodiments, eNB 710 may include a physical layer circuitry 712, a MAC (media access control) circuitry 714, a processor 716, a memory 718, and a hardware processing circuitry 720. A person skilled in the art will appreciate that other components not shown may be used in addition to the components shown to form a complete eNB.

[00103] In some embodiments, physical layer circuitry 712 includes a transceiver 713 for providing signals to and from UE 730. Transceiver 713 provides signals to and from UEs or other devices using one or more antennas 705. In some embodiments, MAC circuitry 714 controls access to the wireless medium. Memory 718 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Hardware processing circuitry 720 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 716 and memory 718 are arranged to perform the operations of hardware processing circuitry 720, such as operations described herein with reference to logic devices and circuitry within eNB 710 and/or hardware processing circuitry 720.

[00104] Accordingly, in some embodiments, eNB 710 may be a device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device.

[00105] As is also illustrated in **Fig. 7**, in some embodiments, UE 730 may include a physical layer circuitry 732, a MAC circuitry 734, a processor 736, a memory 738, a hardware processing circuitry 740, a wireless interface 742, and a display 744. A person skilled in the art would appreciate that other components not shown may be used in addition to the components shown to form a complete UE.

[00106] In some embodiments, physical layer circuitry 732 includes a transceiver 733 for providing signals to and from eNB 710 (as well as other eNBs). Transceiver 733 provides signals to and from eNBs or other devices using one or more antennas 725. In some embodiments, MAC circuitry 734 controls access to the wireless medium. Memory 738 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based

storage media), or any tangible storage media or non-transitory storage media. Wireless interface 742 may be arranged to allow the processor to communicate with another device. Display 744 may provide a visual and/or tactile display for a user to interact with UE 730, such as a touch-screen display. Hardware processing circuitry 740 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 736 and memory 738 may be arranged to perform the operations of hardware processing circuitry 740, such as operations described herein with reference to logic devices and circuitry within UE 730 and/or hardware processing circuitry 740.

[00107] Accordingly, in some embodiments, UE 730 may be a device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display.

[00108] Elements of **Fig. 7**, and elements of other figures having the same names or reference numbers, can operate or function in the manner described herein with respect to any such figures (although the operation and function of such elements is not limited to such descriptions). For example, UEs, and/or hardware processing circuitry of UEs, and the embodiments described with respect to **Fig. 7** and **Figs. 1-5** can operate or function in the manner described herein with respect to any of the figures.

[00109] In addition, although eNB 710 and UE 730 are each described as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements and/or other hardware elements. In some embodiments of this disclosure, the functional elements can refer to one or more processes operating on one or more processing elements. Examples of software and/or hardware configured elements include Digital Signal Processors (DSPs), one or more microprocessors, DSPs, Field-Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), Radio-Frequency Integrated Circuits (RFICs), and so on.

[00110] **Fig. 8** illustrates hardware processing circuitries for a UE for implementing proximate vehicle packet forwarding, according to some embodiments. With reference to **Fig. 7**, a UE may include various hardware processing circuitries discussed below, which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 7**, UE 730 (or various elements or components therein, such as hardware processing circuitry 740, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00111] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 736 (and/or one or more other processors which UE 730 may comprise), memory 738, and/or other elements or components of UE 730 (which may include hardware processing circuitry 740) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 736 (and/or one or more other processors which UE 730 may comprise) may be a baseband processor.

[00112] Returning to **Fig. 8**, an apparatus of UE 730 (or another UE or mobile handset), which may be operable to communicate with one or more eNBs on a wireless network, may comprise hardware processing circuitry 800. In some embodiments, hardware processing circuitry 800 may comprise one or more antenna ports 805 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 750). Antenna ports 805 may be coupled to one or more antennas 807 (which may be antennas 725). In some embodiments, hardware processing circuitry 800 may incorporate antennas 807, while in other embodiments, hardware processing circuitry 800 may merely be coupled to antennas 807.

[00113] Antenna ports 805 and antennas 807 may be operable to provide signals from a UE to a wireless communications channel and/or an eNB, and may be operable to provide signals from an eNB and/or a wireless communications channel to a UE. For example, antenna ports 805 and antennas 807 may be operable to provide transmissions from UE 730 to wireless communication channel 750 (and from there to eNB 710, or to another eNB). Similarly, antennas 807 and antenna ports 805 may be operable to provide transmissions from a wireless communication channel 750 (and beyond that, from eNB 710, or another eNB) to UE 730.

[00114] Hardware processing circuitry 800 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 8**, hardware processing circuitry 800 may comprise a first circuitry 810 and/or a second circuitry 820.

[00115] In some embodiments, the UE comprising the hardware processing circuitry 800 may be a first UE. In some embodiments, the first circuitry 810 may be operable to identify a plurality of resources on a frequency-time spectrum. In some embodiments, the second circuitry 820 may be operable to select one or more first resources of the plurality of

resources for transmission of one or more first packets originating in the first UE, and select one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE. In some embodiments, the UE may comprise an interface to output the one or more first packets originating in the first UE to a transceiver circuitry, for transmission using the one or more first resources. In some embodiments, the hardware processing circuitry 800 may process a plurality of packets originating in the one or more UEs that are different from the first UE; and select the one or more second packets, for re-transmission, from the plurality of packets originating in the one or more UEs. In some embodiments, the plurality of packets may originate in a plurality of UEs that excludes the first UE, and wherein to select the one or more second packets from the plurality of packets, the hardware processing circuitry 800 may determine that a second UE of the plurality of UEs is outside a first distance range from the first UE; and exclude packets originating in the second UE from the selected one or more second packets. In some embodiments, to select the one or more second packets from the plurality of packets, the hardware processing circuitry 800 may determine that a third UE of the plurality of UEs is within the first distance range from the first UE; and consider packets originating in the third UE for selection in the one or more second packets. In some embodiments, to select the one or more second packets from the plurality of packets, the hardware processing circuitry 800 may process a third packet originating in the third UE and a fourth packet originating in the third or fourth UE; determine a latency budget associated with the third packet and a latency budget associated with the fourth packet; and select, as the one or more second packets, one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet. In some embodiments, to select the one or more second packets from the plurality of packets, the hardware processing circuitry 800 may process a third packet and a fourth packet originating in the third UE; determine that the third packet has been re-transmitted by another UE; and select, as the one or more second packets, the fourth packet. In some embodiments, to select the plurality of resources on the frequency-time spectrum, the hardware processing circuitry 800 may identify relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and select the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time spectrum. In some embodiments, the hardware processing circuitry 800 may select a third packet originating in a second UE and a fourth packet originating in a third UE for re-transmission; perform an XOR operation of the third packet

and the fourth packet to generate a combined packet, the combined packet being included in the one or more second packets; and initiate re-transmission of the combined packet using the one or more second resources. In some embodiments, the hardware processing circuitry 800 may initiate transmission of the one or more first packets and re-transmission of the one or more second packets over one or more sidelink channels of the UE. In some embodiments, the hardware processing circuitry 800 may initiate transmission of the one or more first packets and re-transmission of the one or more second packets using a Vehicle-to-Vehicle (V2V) communication protocol. In some embodiments, the first UE may be embedded in a vehicle.

[00116] In some embodiments, the UE comprising the hardware processing circuitry 800 may be a first UE. In some embodiments, the first circuitry 810 may be operable to process packets originating in a plurality of UEs that excludes the first UE, the plurality of UEs comprising a first subset of UEs and a second subset of UEs. In some embodiments, the second circuitry 820 may be operable to select the first subset of UEs for re-transmission of packets originating in the first subset of UEs, and refrain from selecting the second subset of UEs for re-transmission of packets originating in the second subset of UEs. In some embodiments, the UE may comprise an interface to input packets originating in the plurality of UEs from a transceiver circuitry. In some embodiments, to select the first subset of UEs, the hardware processing circuitry 800 may estimate that individual UEs in the first subset of UEs are within a first distance range from the first UE; and select the first subset of UEs, based on estimating that individual UEs in the first subset of UEs are within the first distance range from the first UE. In some embodiments, to refrain from selecting the second subset of UEs, the hardware processing circuitry 800 may estimate that no UE in the second subset of UEs is within the first distance range from the first UE; and refrain from selecting the second subset of UEs, based on estimating that no UE in the second subset of UEs is within the first distance range from the first UE. In some embodiments, to select the first subset of UEs, the hardware processing circuitry 800 may perform radio-layer measurements of transmissions received from the plurality of UEs; and select the first subset of UEs, based on the radio-layer measurements of transmissions received from the plurality of UEs. In some embodiments, the radio-layer measurements may comprise at least one of: timing measurements, received power measurements, or reference signal received power measurements. In some embodiments, the hardware processing circuitry 800 may process a first plurality of packets originating in the first subset of UEs, the first plurality of packets comprising a first subset of packets and a second subset of packets; select the first subset of packets for re-transmission;

and refrain from selecting the second subset of packets for re-transmission. In some embodiments, to select the first subset of packets for re-transmission, the hardware processing circuitry 800 may determine that the first subset of packets have not been previously re-transmitted; and select the first subset of packets for re-transmission, based on determining that the first subset of packets have not been previously re-transmitted. In some embodiments, the hardware processing circuitry 800 may select a first resource on a frequency-time spectrum for transmission of a packet originating in the first UE; and select a second resource on the frequency-time spectrum for transmission of a packet originating in one of the one or more first resources.

[00117] In some embodiments, first circuitry 810 and/or second circuitry 820 may be implemented as separate circuitries. In other embodiments, first circuitry 810 and second circuitry 820 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00118] **Fig. 9** illustrates a method 900 for a UE for selecting resources for transmission of its own packets and for re-transmission of packets from other UEs, according to some embodiments. **Fig. 10** illustrates a method 1000 for a UE for selecting one or more other UEs for re-transmission of packets, according to some embodiments. With reference to **Fig. 7**, each of methods 900 and 1000 that may relate to UE 730 and hardware processing circuitry 740 are discussed below. Although the actions in the methods 900 and 1000 are shown in a particular order, the order of the actions in any of these methods can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in any of **Figs. 9 and/or 10** may be optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00119] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause UE 730 and/or hardware processing circuitry 740 to perform an operation comprising any of the methods of **Figs. 9 or 10**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00120] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods of **Figs. 9 and/or 10**.

[00121] Returning to **Fig. 9**, the method 900 may be implemented by a first UE. The method 900 may comprise, at 904, identify a plurality of resources on a frequency-time spectrum. At 908, the method 900 may comprise selecting one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE; and selecting one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE. In some embodiments, a plurality of packets originating in the one or more UEs that are different from the first UE may be processed; and the one or more second packets may be selected, for re-transmission, from the plurality of packets originating in the one or more UEs. In some embodiments, the plurality of packets originates in a plurality of UEs that excludes the first UE, and wherein to select the one or more second packets from the plurality of packets, the method 900 may comprises: determining that a second UE of the plurality of UEs is outside a first distance range from the first UE; and excluding packets originating in the second UE from the selected one or more second packets. In some embodiments, to select the one or more second packets from the plurality of packets, the method 900 may comprises: determining that a third UE of the plurality of UEs is within the first distance range from the first UE; and considering packets originating in the third UE for selection in the one or more second packets. In some embodiments, to select the one or more second packets from the plurality of packets, the method 900 may comprises: processing a third packet originating in the third UE and a fourth packet originating in the third or fourth UE in the third UE; determining a latency budget associated with the third packet and a latency budget associated with the fourth packet; and selecting, as the one or more second packets, one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet. In some embodiments, to select the one or more second packets from the plurality of packets, the method may comprises: processing a third packet and a fourth packet originating in the third UE; determining that the third packet has been re-transmitted by another UE; and selecting, as the one or more second packets, the fourth packet. In some embodiments, to select the plurality of resources on the frequency-time spectrum, the method 900 may comprises: identifying relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and selecting the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time

spectrum. In some embodiments, the method 900 may comprise selecting a third packet originating in a second UE and a fourth packet originating in a third UE for re-transmission; performing an XOR operation of the third packet and the fourth packet to generate a combined packet, the combined packet being included in the one or more second packets; and initiating re-transmission of the combined packet using the one or more second resources. In some embodiments, the method 900 may comprises: initiating transmission of the one or more first packets and re-transmission of the one or more second packets over one or more sidelink channels of the UE. In some embodiments, the method 900 may comprises: initiating transmission of the one or more first packets and re-transmission of the one or more second packets using a Vehicle-to-Vehicle (V2V) communication protocol.

[00122] Returning to **Fig. 10**, the method 1000 may be implemented by a first UE. The method 1000 may comprise, at 1004, processing packets originating in a plurality of UEs that excludes the first UE, the plurality of UEs comprising a first subset of UEs and a second subset of UEs. The method 1000 may comprise, at 1008, selecting the first subset of UEs for re-transmission of packets originating in the first subset of UEs; and refraining from selecting the second subset of UEs for re-transmission of packets originating in the second subset of UEs. In some embodiments, to select the first subset of UEs, the method 1000 may comprise: estimating that individual UEs in the first subset of UEs are within a first distance range from the first UE; and selecting the first subset of UEs, based on estimating that individual UEs in the first subset of UEs are within the first distance range from the first UE. In some embodiments, to refrain from selecting the second subset of UEs, the method 1000 may comprise: estimating that no UE in the second subset of UEs is within the first distance range from the first UE; and refraining from selecting the second subset of UEs, based on estimating that no UE in the second subset of UEs is within the first distance range from the first UE. In some embodiments, to select the first subset of UEs, the method 1000 may comprise: performing radio-layer measurements of transmissions received from the plurality of UEs; and selecting the first subset of UEs, based on the radio-layer measurements of transmissions received from the plurality of UEs. In some embodiments, the radio-layer measurements comprise at least one of: timing measurements, received power measurements, or reference signal received power measurements. In some embodiments, the method 1000 may comprise processing a first plurality of packets originating in the first subset of UEs, the first plurality of packets comprising a first subset of packets and a second subset of packets; selecting the first subset of packets for re-transmission; and refraining from selecting the second subset of packets for re-transmission. In some embodiments, to select the first subset

of packets for re-transmission, the method 1000 may comprise determining that the first subset of packets have not been previously re-transmitted; and selecting the first subset of packets for re-transmission, based on determining that the first subset of packets have not been previously re-transmitted. In some embodiments, the method 1000 may comprise: selecting a first resource on a frequency-time spectrum for transmission of a packet originating in the first UE; and selecting a second resource on the frequency-time spectrum for transmission of a packet originating in one of the one or more first resources.

[00123] **Fig. 11** illustrates an architecture of a system 1100 of a network, according to some embodiments. The system 1100 is shown to include a user equipment (UE) 1101 and a UE 1102. The UEs 1101 and 1102 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks), but may also comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

[00124] In some embodiments, any of the UEs 1101 and 1102 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[00125] The UEs 1101 and 1102 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) — in this embodiment, an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN) 1110. The UEs 1101 and 1102 utilize connections 1103 and 1104, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 1103 and 1104 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT

over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

[00126] In this embodiment, the UEs 1101 and 1102 may further directly exchange communication data via a ProSe interface 1105. The ProSe interface 1105 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[00127] The UE 1102 is shown to be configured to access an access point (AP) 1106 via connection 1107. The connection 1107 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.11 protocol, wherein the AP 1106 would comprise a wireless fidelity (WiFi®) router. In this example, the AP 1106 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[00128] The E-UTRAN 1110 can include one or more access nodes that enable the connections 1103 and 1104. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The E-UTRAN 1110 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 1111, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 1112.

[00129] Any of the RAN nodes 1111 and 1112 can terminate the air interface protocol and can be the first point of contact for the UEs 1101 and 1102. In some embodiments, any of the RAN nodes 1111 and 1112 can fulfill various logical functions for the E-UTRAN 1110 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

[00130] In accordance with some embodiments, the UEs 1101 and 1102 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 1111 and 1112 over a multicarrier communication channel in accordance various communication techniques, such

as, but not limited to, an Orthogonal Frequency-Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[00131] In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 1111 and 1112 to the UEs 1101 and 1102, while uplink transmissions can utilize similar techniques. The grid can be a frequency-time grid, called a resource grid or frequency-time resource grid, which is the physical resource in the downlink in each slot. Such a frequency-time plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest frequency-time unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[00132] The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 1101 and 1102. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 1101 and 1102 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 102 within a cell) may be performed at any of the RAN nodes 1111 and 1112 based on channel quality information fed back from any of the UEs 1101 and 1102. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 1101 and 1102.

[00133] The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements

known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, $L=1, 2, 4$, or 8).

[00134] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[00135] The E-UTRAN 1110 is shown to be communicatively coupled to a core network — in this embodiment, an Evolved Packet Core (EPC) network 1120 via an S1 interface 1113. In this embodiment the S1 interface 1113 is split into two parts: the S1-U interface 1114, which carries traffic data between the RAN nodes 1111 and 1112 and the serving gateway (S-GW) 1122, and the S1-mobility management entity (MME) interface 1115, which is a signaling interface between the RAN nodes 1111 and 1112 and MMEs 1121.

[00136] In this embodiment, the EPC network 1120 comprises the MMEs 1121, the S-GW 1122, the Packet Data Network (PDN) Gateway (P-GW) 1123, and a home subscriber server (HSS) 1124. The MMEs 1121 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 1121 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 1124 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The EPC network 1120 may comprise one or several HSSs 1124, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 1124 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[00137] The S-GW 1122 may terminate the S1 interface 1113 towards the E-UTRAN 1110, and routes data packets between the E-UTRAN 1110 and the EPC network 1120. In addition, the S-GW 1122 may be a local mobility anchor point for inter-RAN node handovers

and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

[00138] The P-GW 1123 may terminate an SGi interface toward a PDN. The P-GW 1123 may route data packets between the EPC network 1123 and external networks such as a network including the application server 1130 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 1125. Generally, the application server 1130 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 1123 is shown to be communicatively coupled to an application server 1130 via an IP communications interface 1125. The application server 1130 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 1101 and 1102 via the EPC network 1120.

[00139] The P-GW 1123 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 1126 is the policy and charging control element of the EPC network 1120. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 1126 may be communicatively coupled to the application server 1130 via the P-GW 1123. The application server 1130 may signal the PCRF 1126 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 1126 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 1130.

[00140] **Fig. 12** illustrates example components of a device 1200, according to some embodiments. In some embodiments, the device 1200 may include application circuitry 1202, baseband circuitry 1204, Radio Frequency (RF) circuitry 1206, front-end module (FEM) circuitry 1208, one or more antennas 1210, and power management circuitry (PMC) 1212 coupled together at least as shown. The components of the illustrated device 1200 may be included in a UE or a RAN node. In some embodiments, the device 1200 may include less elements (e.g., a RAN node may not utilize application circuitry 1202, and instead include a

processor/controller to process IP data received from an EPC). In some embodiments, the device 1200 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[00141] The application circuitry 1202 may include one or more application processors. For example, the application circuitry 1202 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 1200. In some embodiments, processors of application circuitry 1202 may process IP data packets received from an EPC.

[00142] The baseband circuitry 1204 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1204 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 1206 and to generate baseband signals for a transmit signal path of the RF circuitry 1206. Baseband processing circuitry 1204 may interface with the application circuitry 1202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1206. For example, in some embodiments, the baseband circuitry 1204 may include a third generation (3G) baseband processor 1204A, a fourth generation (4G) baseband processor 1204B, a fifth generation (5G) baseband processor 1204C, or other baseband processor(s) 1204D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 1204 (e.g., one or more of baseband processors 1204A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1206. In other embodiments, some or all of the functionality of baseband processors 1204A-D may be included in modules stored in the memory 1204G and executed via a Central Processing Unit (CPU) 1204E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1204 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some

embodiments, encoding/decoding circuitry of the baseband circuitry 1204 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[00143] In some embodiments, the baseband circuitry 1204 may include one or more audio digital signal processor(s) (DSP) 1204F. The audio DSP(s) 1204F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1204 and the application circuitry 1202 may be implemented together such as, for example, on a system on a chip (SOC).

[00144] In some embodiments, the baseband circuitry 1204 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1204 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1204 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[00145] RF circuitry 1206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1206 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1206 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1208 and provide baseband signals to the baseband circuitry 1204. RF circuitry 1206 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1204 and provide RF output signals to the FEM circuitry 1208 for transmission.

[00146] In some embodiments, the receive signal path of the RF circuitry 1206 may include mixer circuitry 1206a, amplifier circuitry 1206b and filter circuitry 1206c. In some embodiments, the transmit signal path of the RF circuitry 1206 may include filter circuitry 1206c and mixer circuitry 1206a. RF circuitry 1206 may also include synthesizer circuitry

1206d for synthesizing a frequency for use by the mixer circuitry 1206a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1206a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1208 based on the synthesized frequency provided by synthesizer circuitry 1206d. The amplifier circuitry 1206b may be configured to amplify the down-converted signals and the filter circuitry 1206c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 1204 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1206a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00147] In some embodiments, the mixer circuitry 1206a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1206d to generate RF output signals for the FEM circuitry 1208. The baseband signals may be provided by the baseband circuitry 1204 and may be filtered by filter circuitry 1206c.

[00148] In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may be configured for super-heterodyne operation.

[00149] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1206 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1204 may include a digital baseband interface to communicate with the RF circuitry 1206.

[00150] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[00151] In some embodiments, the synthesizer circuitry 1206d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1206d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00152] The synthesizer circuitry 1206d may be configured to synthesize an output frequency for use by the mixer circuitry 1206a of the RF circuitry 1206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1206d may be a fractional $N/N+1$ synthesizer.

[00153] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1204 or the applications processor 1202 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1202.

[00154] Synthesizer circuitry 1206d of the RF circuitry 1206 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[00155] In some embodiments, synthesizer circuitry 1206d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO

frequency (fLO). In some embodiments, the RF circuitry 1206 may include an IQ/polar converter.

[00156] FEM circuitry 1208 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1206 for further processing. FEM circuitry 1208 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1206 for transmission by one or more of the one or more antennas 1210. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 1206, solely in the FEM 1208, or in both the RF circuitry 1206 and the FEM 1208.

[00157] In some embodiments, the FEM circuitry 1208 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1206). The transmit signal path of the FEM circuitry 1208 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1210).

[00158] In some embodiments, the PMC 1212 may manage power provided to the baseband circuitry 1204. In particular, the PMC 1212 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 1212 may often be included when the device 1200 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 1212 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[00159] While **Fig. 12** shows the PMC 1212 coupled only with the baseband circuitry 1204. However, in other embodiments, the PMC 1212 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 1202, RF circuitry 1206, or FEM 1208.

[00160] In some embodiments, the PMC 1212 may control, or otherwise be part of, various power saving mechanisms of the device 1200. For example, if the device 1200 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after

a period of inactivity. During this state, the device 1200 may power down for brief intervals of time and thus save power.

[00161] If there is no data traffic activity for an extended period of time, then the device 1200 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 1200 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 1200 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

[00162] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[00163] Processors of the application circuitry 1202 and processors of the baseband circuitry 1204 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 1204, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 1204 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[00164] **Fig. 13** illustrates example interfaces of baseband circuitry, according to some embodiments. As discussed above, the baseband circuitry 1204 of FIG. 12 may comprise processors 1204A-1204E and a memory 1204G utilized by said processors. Each of the processors 1204A-1204E may include a memory interface, 1304A-1304E, respectively, to send/receive data to/from the memory 1204G.

[00165] The baseband circuitry 1204 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 1312 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 1204), an

application circuitry interface 1314 (e.g., an interface to send/receive data to/from the application circuitry 1202 of FIG. 12), an RF circuitry interface 1316 (e.g., an interface to send/receive data to/from RF circuitry 1206 of FIG. 12), a wireless hardware connectivity interface 1318 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 1320 (e.g., an interface to send/receive power or control signals to/from the PMC 1212).

[00166] Reference in the specification to "an embodiment," "one embodiment," "some embodiments," or "other embodiments" means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least some embodiments, but not necessarily all embodiments. The various appearances of "an embodiment," "one embodiment," or "some embodiments" are not necessarily all referring to the same embodiments. If the specification states a component, feature, structure, or characteristic "may," "might," or "could" be included, that particular component, feature, structure, or characteristic is not required to be included. If the specification or claim refers to "a" or "an" element, that does not mean there is only one of the elements. If the specification or claims refer to "an additional" element, that does not preclude there being more than one of the additional element.

[00167] Furthermore, the particular features, structures, functions, or characteristics may be combined in any suitable manner in one or more embodiments. For example, a first embodiment may be combined with a second embodiment anywhere the particular features, structures, functions, or characteristics associated with the two embodiments are not mutually exclusive.

[00168] While the disclosure has been described in conjunction with specific embodiments thereof, many alternatives, modifications and variations of such embodiments will be apparent to those of ordinary skill in the art in light of the foregoing description. For example, other memory architectures e.g., Dynamic RAM (DRAM) may use the embodiments discussed. The embodiments of the disclosure are intended to embrace all such alternatives, modifications, and variations as to fall within the broad scope of the appended claims.

[00169] In addition, well known power/ground connections to integrated circuit (IC) chips and other components may or may not be shown within the presented figures, for simplicity of illustration and discussion, and so as not to obscure the disclosure. Further, arrangements may be shown in block diagram form in order to avoid obscuring the

disclosure, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the present disclosure is to be implemented (i.e., such specifics should be well within purview of one skilled in the art). Where specific details (e.g., circuits) are set forth in order to describe example embodiments of the disclosure, it should be apparent to one skilled in the art that the disclosure can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

[00170] The following examples pertain to further embodiments. Specifics in the examples may be used anywhere in one or more embodiments. All optional features of the apparatus described herein may also be implemented with respect to a method or process.

[00171] Example 1. An apparatus of a first User Equipment (UE) operable to communicate on a wireless network, comprising: one or more processors to: identify a plurality of resources on a frequency-time spectrum, select one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE, and select one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE; and an interface to output the one or more first packets originating in the first UE to a transceiver circuitry, for transmission using the one or more first resources.

[00172] Example 2. The apparatus of example 1 or any other example, wherein the one or more processors are to: process a plurality of packets originating in the one or more UEs that are different from the first UE; and select the one or more second packets, for re-transmission, from the plurality of packets originating in the one or more UEs.

[00173] Example 3. The apparatus of example 2 or any other example, wherein the one or more UEs that are different from the first UE comprises a plurality of UEs that excludes the first UE, and wherein to select the one or more second packets from the plurality of packets, the one or more processors are to: determine that a second UE of the plurality of UEs is outside a first distance range from the first UE; and exclude packets originating in the second UE from the selected one or more second packets.

[00174] Example 4. The apparatus of example 3 or any other example, wherein to select the one or more second packets from the plurality of packets, the one or more processors are to: determine that a third UE of the plurality of UEs is within the first distance range from the first UE; and consider packets originating in the third UE for selection in the one or more second packets.

[00175] Example 5. The apparatus of example 4 or any other example, wherein to select the one or more second packets from the plurality of packets, the one or more processors are to: process a third packet originating in the third UE, and a fourth packet originating in the third UE or a fourth UE; determine a latency budget associated with the third packet and a latency budget associated with the fourth packet; and select, as the one or more second packets, at least one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet.

[00176] Example 6. The apparatus of example 4 or any other example, wherein to select the one or more second packets from the plurality of packets, the one or more processors are to: process a third packet and a fourth packet originating in the third UE; determine that the third packet has been re-transmitted by another UE; and select, as the one or more second packets, the fourth packet.

[00177] Example 7. The apparatus of any of examples 1-6 or any other example, wherein to select the plurality of resources on the frequency-time spectrum, the one or more processors are to: identify relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and select the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time spectrum.

[00178] Example 8. The apparatus of any of examples 1-6 or any other example, wherein the one or more processors are to: select a third packet originating in a second UE and a fourth packet originating in a third UE for re-transmission; perform an XOR operation or a concatenation operation of the third packet and the fourth packet to generate a combined packet, the combined packet being included in the one or more second packets; and initiate re-transmission of the combined packet using the one or more second resources.

[00179] Example 9. The apparatus of any of examples 1-6 or any other example, wherein the one or more processors are to: initiate transmission of the one or more first packets and re-transmission of the one or more second packets over one or more sidelink channels of the first UE.

[00180] Example 10. The apparatus of any of examples 1-6 or any other example, wherein the one or more processors are to: initiate transmission of the one or more first packets and re-transmission of the one or more second packets using a Vehicle-to-Vehicle (V2V) communication protocol.

[00181] Example 11. The apparatus of any of examples 1-6 or any other example, wherein the first UE is embedded in a vehicle.

[00182] Example 12. The apparatus of any of examples 1-11 or any other example, further comprising: a transceiver circuitry for generating transmissions and processing transmissions.

[00183] Example 13. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of examples 1-12 or any other example.

[00184] Example 14. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a first User Equipment (UE) to perform an operation comprising: identify a plurality of resources on a frequency-time spectrum; select one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE; and select one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE.

[00185] Example 15. The machine readable storage media of example 14 or any other example, wherein the operation comprises: process a plurality of packets originating in the one or more UEs that are different from the first UE; and select the one or more second packets, for re-transmission, from the plurality of packets originating in the one or more UEs.

[00186] Example 16. The machine readable storage media of example 15 or any other example, wherein the one or more UEs that are different from the first UE comprises a plurality of UEs that excludes the first UE, and wherein to select the one or more second packets from the plurality of packets, the operation comprises: determine that a second UE of the plurality of UEs is outside a first distance range from the first UE; and exclude packets originating in the second UE from the selected one or more second packets.

[00187] Example 17. The machine readable storage media of example 16 or any other example, wherein to select the one or more second packets from the plurality of packets, the operation comprises: determine that a third UE of the plurality of UEs is within the first distance range from the first UE; and consider packets originating in the third UE for selection in the one or more second packets.

[00188] Example 18. The machine readable storage media of example 17 or any other example, wherein to select the one or more second packets from the plurality of packets, the operation comprises: process a third packet originating in the third UE, and a fourth packet originating in one of the third UE or a fourth UE; determine a latency budget associated with the third packet and a latency budget associated with the fourth packet; and select, as the one

or more second packets, at least one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet.

[00189] Example 19. The machine readable storage media of example 17 or any other example, wherein to select the one or more second packets from the plurality of packets, the operation comprises: process a third packet and a fourth packet originating in the third UE; determine that the third packet has been re-transmitted by another UE; and select, as the one or more second packets, the fourth packet.

[00190] Example 20. The machine readable storage media of any of examples 14-19 or any other example, wherein to select the plurality of resources on the frequency-time spectrum, the operation comprises: identify relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and select the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time spectrum.

[00191] Example 21. The machine readable storage media of any of examples 14-19 or any other example, wherein the operation comprises: select a third packet originating in a second UE and a fourth packet originating in a third UE for re-transmission; perform an XOR operation or a concatenation operation of the third packet and the fourth packet to generate a combined packet, the combined packet being included in the one or more second packets; and initiate re-transmission of the combined packet using the one or more second resources.

[00192] Example 22. The machine readable storage media of any of examples 14-19 or any other example, wherein the operation comprises: initiate transmission of the one or more first packets and re-transmission of the one or more second packets over one or more sidelink channels of the first UE.

[00193] Example 23. The machine readable storage media of any of examples 14-19 or any other example, wherein the operation comprises: initiate transmission of the one or more first packets and re-transmission of the one or more second packets using a Vehicle-to-Vehicle (V2V) communication protocol.

[00194] Example 24. An apparatus of a first User Equipment (UE) operable to communicate on a wireless network, comprising: one or more processors to: process packets originating in a plurality of UEs that excludes the first UE, the plurality of UEs comprising a first subset of UEs and a second subset of UEs, select the first subset of UEs for re-transmission of packets originating in the first subset of UEs, and refrain from selecting the second subset of UEs for re-transmission of packets originating in the second subset of UEs;

and an interface to input packets originating in the plurality of UEs from a transceiver circuitry.

[00195] Example 25. The apparatus of example 24 or any other example, wherein to select the first subset of UEs, the one or more processors are to: estimate that individual UEs in the first subset of UEs are within a first distance range from the first UE; and select the first subset of UEs, based on estimating that individual UEs in the first subset of UEs are within the first distance range from the first UE.

[00196] Example 26. The apparatus of example 25 or any other example, wherein to refrain from selecting the second subset of UEs, the one or more processors to: estimate that no UE in the second subset of UEs is within the first distance range from the first UE; and refrain from selecting the second subset of UEs, based on estimating that no UE in the second subset of UEs is within the first distance range from the first UE.

[00197] Example 27. The apparatus of example 24 or any other example, wherein to select the first subset of UEs, the one or more processors to: perform radio-layer measurements of transmissions received from the plurality of UEs; and select the first subset of UEs, based on the radio-layer measurements of transmissions received from the plurality of UEs.

[00198] Example 28. The apparatus of example 27 or any other example, wherein the radio-layer measurements comprise at least one of: timing measurements, received power measurements, or reference signal received power measurements.

[00199] Example 29. The apparatus of any of examples 24-28 or any other example, wherein the one or more processors to: process a first plurality of packets originating in the first subset of UEs, the first plurality of packets comprising a first subset of packets and a second subset of packets; select the first subset of packets for re-transmission; and refrain from selecting the second subset of packets for re-transmission.

[00200] Example 30. The apparatus example 29 or any other example, wherein to select the first subset of packets for re-transmission, the one or more processors to: determine that the first subset of packets have not been previously re-transmitted; and select the first subset of packets for re-transmission, based on determining that the first subset of packets have not been previously re-transmitted.

[00201] Example 31. The apparatus any of examples 24-30 or any other example, wherein the one or more processors are to: select a first resource on a frequency-time spectrum for transmission of a packet originating in the first UE; and select a second resource

on the frequency-time spectrum for transmission of a packet originating in one of the one or more first resources.

[00202] Example 32. The apparatus of any of examples 24-31 or any other example, further comprising: a transceiver circuitry for generating transmissions and processing transmissions.

[00203] Example 33. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of examples 24-32 or any other example.

[00204] Example 34. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a first User Equipment (UE) to perform an operation comprising: process packets originating in a plurality of UEs that excludes the first UE, the plurality of UEs comprising a first subset of UEs and a second subset of UEs; select the first subset of UEs for re-transmission of packets originating in the first subset of UEs; and refrain from selecting the second subset of UEs for re-transmission of packets originating in the second subset of UEs.

[00205] Example 35. The machine readable storage media of example 24 or any other example, wherein to select the first subset of UEs, wherein the operation comprises: estimate that individual UEs in the first subset of UEs are within a first distance range from the first UE; and select the first subset of UEs, based on estimating that individual UEs in the first subset of UEs are within the first distance range from the first UE.

[00206] Example 36. The machine readable storage media of example 35 or any other example, wherein to refrain from selecting the second subset of UEs, wherein the operation comprises: estimate that no UE in the second subset of UEs is within the first distance range from the first UE; and refrain from selecting the second subset of UEs, based on estimating that no UE in the second subset of UEs is within the first distance range from the first UE.

[00207] Example 37. The machine readable storage media of example 34 or any other example, wherein to select the first subset of UEs, wherein the operation comprises: perform radio-layer measurements of transmissions received from the plurality of UEs; and select the first subset of UEs, based on the radio-layer measurements of transmissions received from the plurality of UEs.

[00208] Example 38. The machine readable storage media of example 37 or any other example, wherein the radio-layer measurements comprise at least one of: timing

measurements, received power measurements, or reference signal received power measurements.

[00209] Example 39. The machine readable storage media of any of examples 34-38 or any other example, wherein the operation comprises: process a first plurality of packets originating in the first subset of UEs, the first plurality of packets comprising a first subset of packets and a second subset of packets; select the first subset of packets for re-transmission; and refrain from selecting the second subset of packets for re-transmission.

[00210] Example 40. The machine readable storage media of example 39 or any other example, wherein to select the first subset of packets for re-transmission, wherein the operation comprises: determine that the first subset of packets have not been previously re-transmitted; and select the first subset of packets for re-transmission, based on determining that the first subset of packets have not been previously re-transmitted.

[00211] Example 41. The machine readable storage media any of examples 34-40 or any other example, wherein the operation comprises: select a first resource on a frequency-time spectrum for transmission of a packet originating in the first UE; and select a second resource on the frequency-time spectrum for transmission of a packet originating in one of the one or more first resources.

[00212] Example 42. A method for operating a first User Equipment (UE), comprising: identifying a plurality of resources on a frequency-time spectrum; selecting one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE; and selecting one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE.

[00213] Example 43. The method of example 42 or any other example, further comprising: processing a plurality of packets originating in the one or more UEs that are different from the first UE; and selecting the one or more second packets, for re-transmission, from the plurality of packets originating in the one or more UEs.

[00214] Example 44. The method of example 43 or any other example, wherein the one or more UEs that are different from the first UE comprises a plurality of UEs that excludes the first UE, and selecting the one or more second packets from the plurality of packets comprises: determining that a second UE of the plurality of UEs is outside a first distance range from the first UE; and excluding packets originating in the second UE from the selected one or more second packets.

[00215] Example 45. The method of example 44 or any other example, wherein selecting the one or more second packets from the plurality of packets comprises: determining that a third UE of the plurality of UEs is within the first distance range from the first UE; and considering packets originating in the third UE for selection in the one or more second packets.

[00216] Example 46. The method of example 45 or any other example, wherein selecting the one or more second packets from the plurality of packets comprises: processing a third packet originating in the third UE, and a fourth packet originating in one of the third UE or a fourth UE; determining a latency budget associated with the third packet and a latency budget associated with the fourth packet; and selecting, as the one or more second packets, at least one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet.

[00217] Example 47. The method of example 45 or any other example, wherein selecting the one or more second packets from the plurality of packets comprises: processing a third packet and a fourth packet originating in the third UE; determining that the third packet has been re-transmitted by another UE; and selecting, as the one or more second packets, the fourth packet.

[00218] Example 48. The method of any of examples 42-47 or any other example, wherein selecting the plurality of resources on the frequency-time spectrum comprises: identifying relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and selecting the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time spectrum.

[00219] Example 49. One or more non-transitory computer-readable storage media to store instructions that, when executed by a processor, cause the processor to execute a method of any of the examples 42-48 or any other example.

[00220] Example 50. An apparatus comprising: means for performing the method of any of the examples 42-48 or any other example.

[00221] An abstract is provided that will allow the reader to ascertain the nature and gist of the technical disclosure. The abstract is submitted with the understanding that it will not be used to limit the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

We claim:

1. An apparatus of a first User Equipment (UE) operable to communicate on a wireless network, comprising:
 - one or more processors to:
 - identify a plurality of resources on a frequency-time spectrum,
 - select one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE, and
 - select one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE; and
 - an interface to output the one or more first packets originating in the first UE to a transceiver circuitry, for transmission using the one or more first resources.
2. The apparatus of claim 1, wherein the one or more processors are to:
 - process a plurality of packets originating in the one or more UEs that are different from the first UE; and
 - select the one or more second packets, for re-transmission, from the plurality of packets originating in the one or more UEs.
3. The apparatus of claim 2, wherein the one or more UEs that are different from the first UE comprises a plurality of UEs that excludes the first UE, and wherein to select the one or more second packets from the plurality of packets, the one or more processors are to:
 - determine that a second UE of the plurality of UEs is outside a first distance range from the first UE; and
 - exclude packets originating in the second UE from the selected one or more second packets.
4. The apparatus of claim 3, wherein to select the one or more second packets from the plurality of packets, the one or more processors are to:
 - determine that a third UE of the plurality of UEs is within the first distance range from the first UE; and
 - consider packets originating in the third UE for selection in the one or more second packets.

5. The apparatus of claim 4, wherein to select the one or more second packets from the plurality of packets, the one or more processors are to:
 - process a third packet originating in the third UE, and a fourth packet originating in the third UE or a fourth UE;
 - determine a latency budget associated with the third packet and a latency budget associated with the fourth packet; and
 - select, as the one or more second packets, at least one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet.
6. The apparatus of claim 4, wherein to select the one or more second packets from the plurality of packets, the one or more processors are to:
 - process a third packet and a fourth packet originating in the third UE;
 - determine that the third packet has been re-transmitted by another UE; and
 - select, as the one or more second packets, the fourth packet.
7. The apparatus of any of claims 1-6, wherein to select the plurality of resources on the frequency-time spectrum, the one or more processors are to:
 - identify relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and
 - select the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time spectrum.
8. The apparatus of any of claims 1-6, wherein the one or more processors are to:
 - select a third packet originating in a second UE and a fourth packet originating in a third UE for re-transmission;
 - perform an XOR operation or a concatenation operation of the third packet and the fourth packet to generate a combined packet, the combined packet being included in the one or more second packets; and
 - initiate re-transmission of the combined packet using the one or more second resources.
9. The apparatus of any of claims 1-6, wherein the one or more processors are to:

initiate transmission of the one or more first packets and re-transmission of the one or more second packets over one or more sidelink channels of the first UE.

10. The apparatus of any of claims 1-6, wherein the first UE is embedded in a vehicle.

11. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a first User Equipment (UE) to perform an operation comprising:

identify a plurality of resources on a frequency-time spectrum;

select one or more first resources of the plurality of resources for transmission of one or more first packets originating in the first UE; and

select one or more second resources of the plurality of resources for re-transmission of one or more second packets originating in one or more UEs that are different from the first UE.

12. The machine readable storage media of claim 11, wherein the operation comprises:

process a plurality of packets originating in the one or more UEs that are different from the first UE; and

select the one or more second packets, for re-transmission, from the plurality of packets originating in the one or more UEs.

13. The machine readable storage media of claim 12, wherein the one or more UEs that are different from the first UE comprises a plurality of UEs that excludes the first UE, and wherein to select the one or more second packets from the plurality of packets, the operation comprises:

determine that a second UE of the plurality of UEs is outside a first distance range from the first UE; and

exclude packets originating in the second UE from the selected one or more second packets.

14. The machine readable storage media of claim 13, wherein to select the one or more second packets from the plurality of packets, the operation comprises:

determine that a third UE of the plurality of UEs is within the first distance range from the first UE; and

consider packets originating in the third UE for selection in the one or more second packets.

15. The machine readable storage media of claim 14, wherein to select the one or more second packets from the plurality of packets, the operation comprises:

process a third packet originating in the third UE, and a fourth packet originating in one of the third UE or a fourth UE;

determine a latency budget associated with the third packet and a latency budget associated with the fourth packet; and

select, as the one or more second packets, at least one of the third packet or the fourth packet, based on the latency budgets associated with the third packet and the fourth packet.

16. The machine readable storage media of claim 14, wherein to select the one or more second packets from the plurality of packets, the operation comprises:

process a third packet and a fourth packet originating in the third UE;

determine that the third packet has been re-transmitted by another UE; and

select, as the one or more second packets, the fourth packet.

17. The machine readable storage media of any of claims 11-16, wherein to select the plurality of resources on the frequency-time spectrum, the operation comprises:

identify relatively less congested resources on the frequency-time spectrum, based on radio-layer measurements or decoding of control signaling information; and

select the plurality of resources on the frequency-time spectrum, based on identifying the relatively less congested resources on the frequency-time spectrum.

18. An apparatus of a first User Equipment (UE) operable to communicate on a wireless network, comprising:

one or more processors to:

process packets originating in a plurality of UEs that excludes the first UE, the plurality of UEs comprising a first subset of UEs and a second subset of UEs,

select the first subset of UEs for re-transmission of packets originating in the first subset of UEs, and

refrain from selecting the second subset of UEs for re-transmission of packets originating in the second subset of UEs; and

an interface to input packets originating in the plurality of UEs from a transceiver circuitry.

19. The apparatus of claim 18, wherein to select the first subset of UEs, the one or more processors are to:

estimate that individual UEs in the first subset of UEs are within a first distance range from the first UE; and

select the first subset of UEs, based on estimating that individual UEs in the first subset of UEs are within the first distance range from the first UE.

20. The apparatus of claim 19, wherein to refrain from selecting the second subset of UEs, the one or more processors to:

estimate that no UE in the second subset of UEs is within the first distance range from the first UE; and

refrain from selecting the second subset of UEs, based on estimating that no UE in the second subset of UEs is within the first distance range from the first UE.

21. The apparatus of claim 18, wherein to select the first subset of UEs, the one or more processors to:

perform radio-layer measurements of transmissions received from the plurality of UEs; and

select the first subset of UEs, based on the radio-layer measurements of transmissions received from the plurality of UEs.

22. The apparatus of claim 21, wherein the radio-layer measurements comprise at least one of: timing measurements, received power measurements, or reference signal received power measurements.

23. The apparatus of any of claims 18-22, wherein the one or more processors to:

process a first plurality of packets originating in the first subset of UEs, the first plurality of packets comprising a first subset of packets and a second subset of packets;

select the first subset of packets for re-transmission; and

refrain from selecting the second subset of packets for re-transmission.

24. The apparatus claim 23, wherein to select the first subset of packets for re-transmission, the one or more processors to:
- determine that the first subset of packets have not been previously re-transmitted; and
 - select the first subset of packets for re-transmission, based on determining that the first subset of packets have not been previously re-transmitted.
25. The apparatus any of claims 18-22, wherein the one or more processors are to:
- select a first resource on a frequency-time spectrum for transmission of a packet originating in the first UE; and
 - select a second resource on the frequency-time spectrum for transmission of a packet originating in one of the one or more first resources.

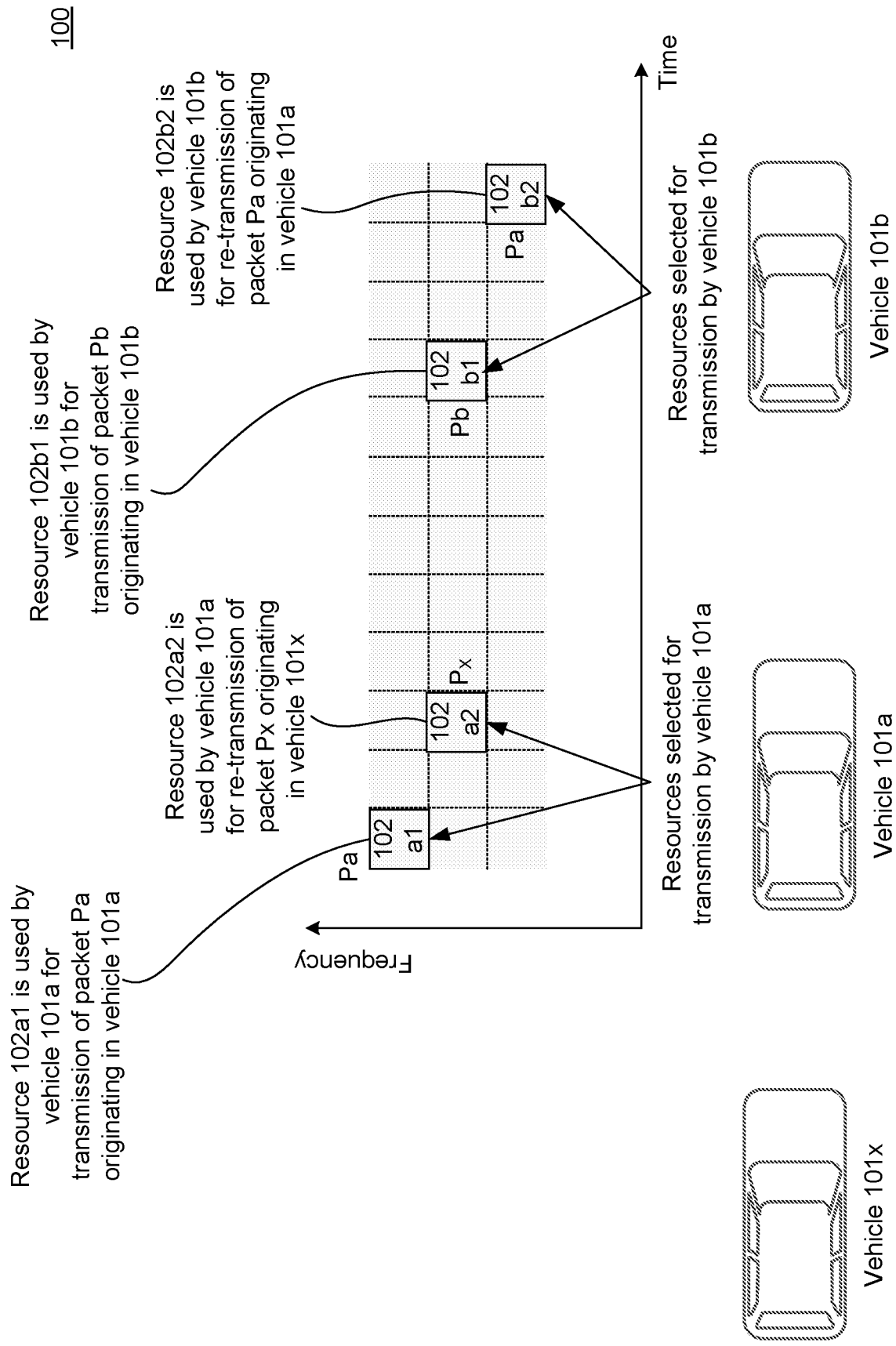


Fig. 1

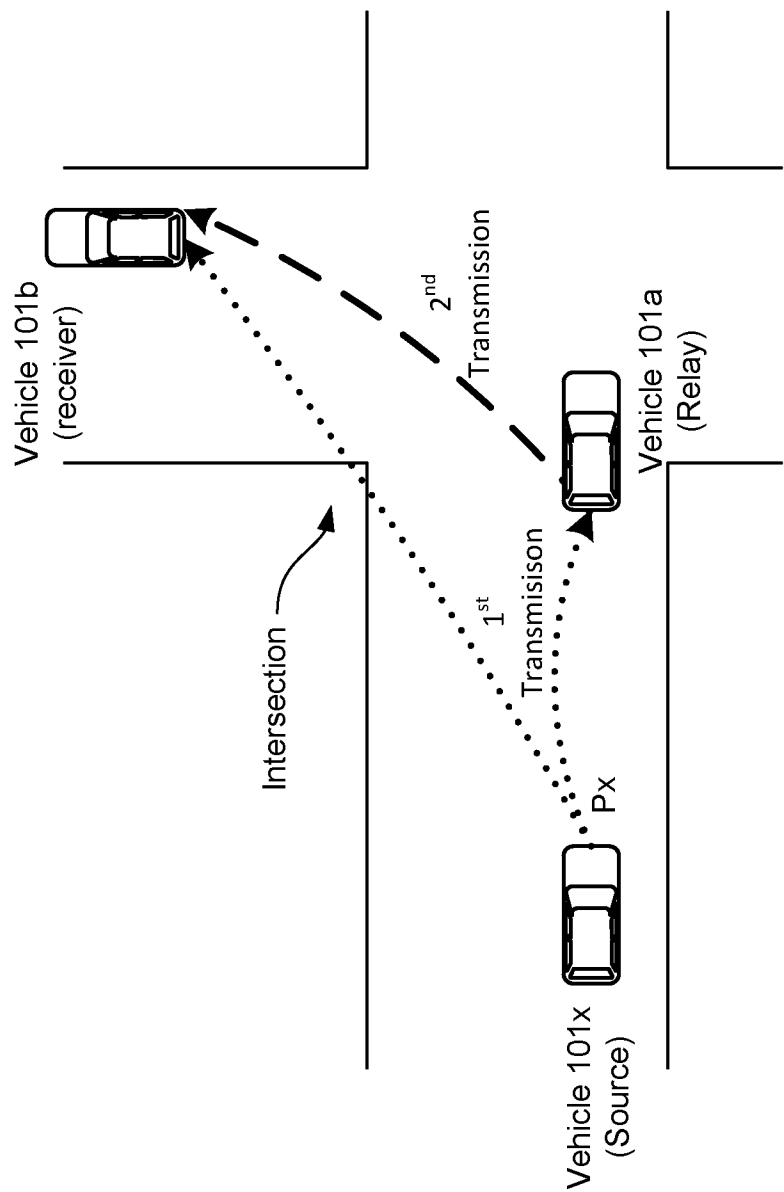


Fig. 2

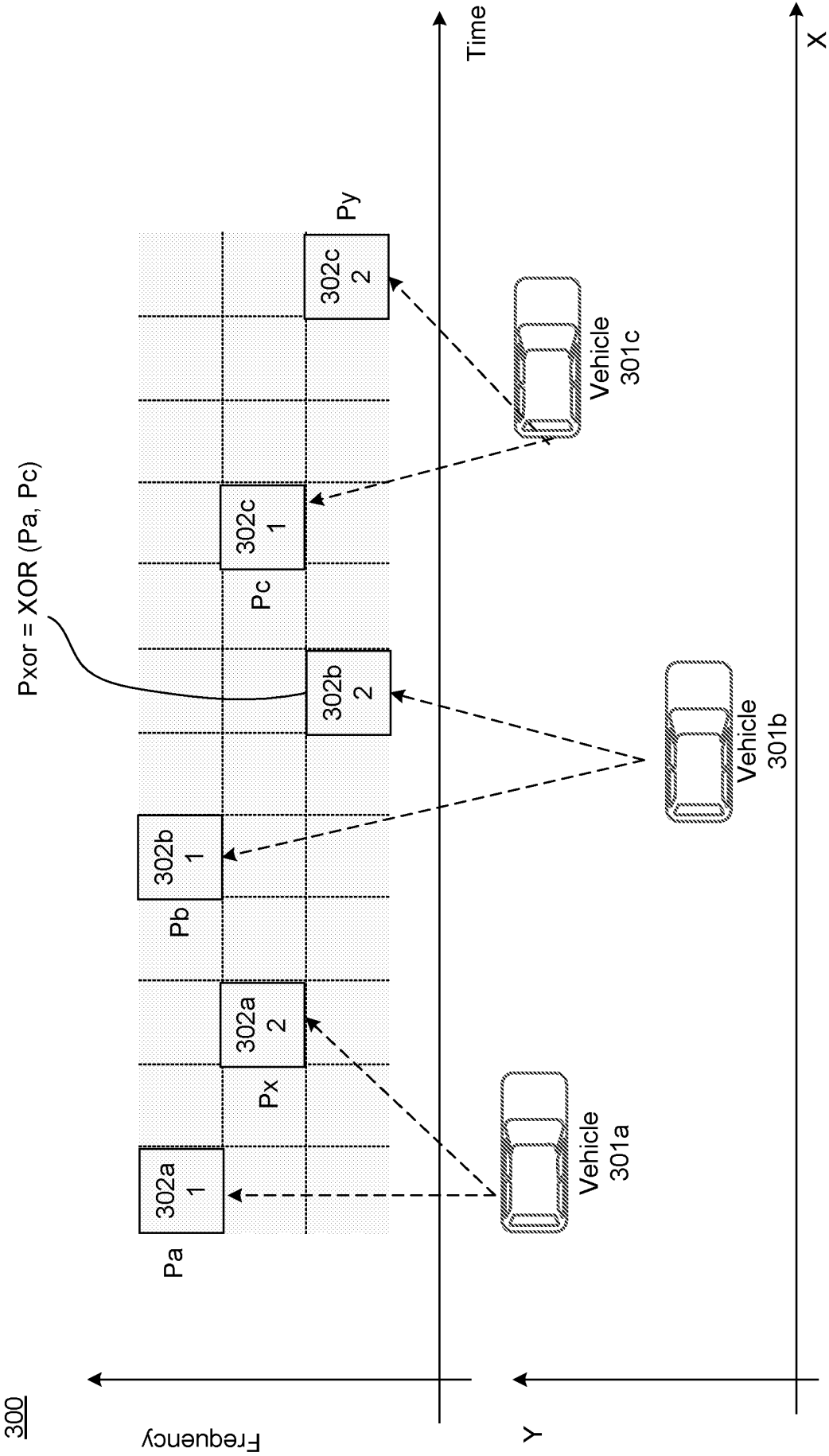


Fig. 3

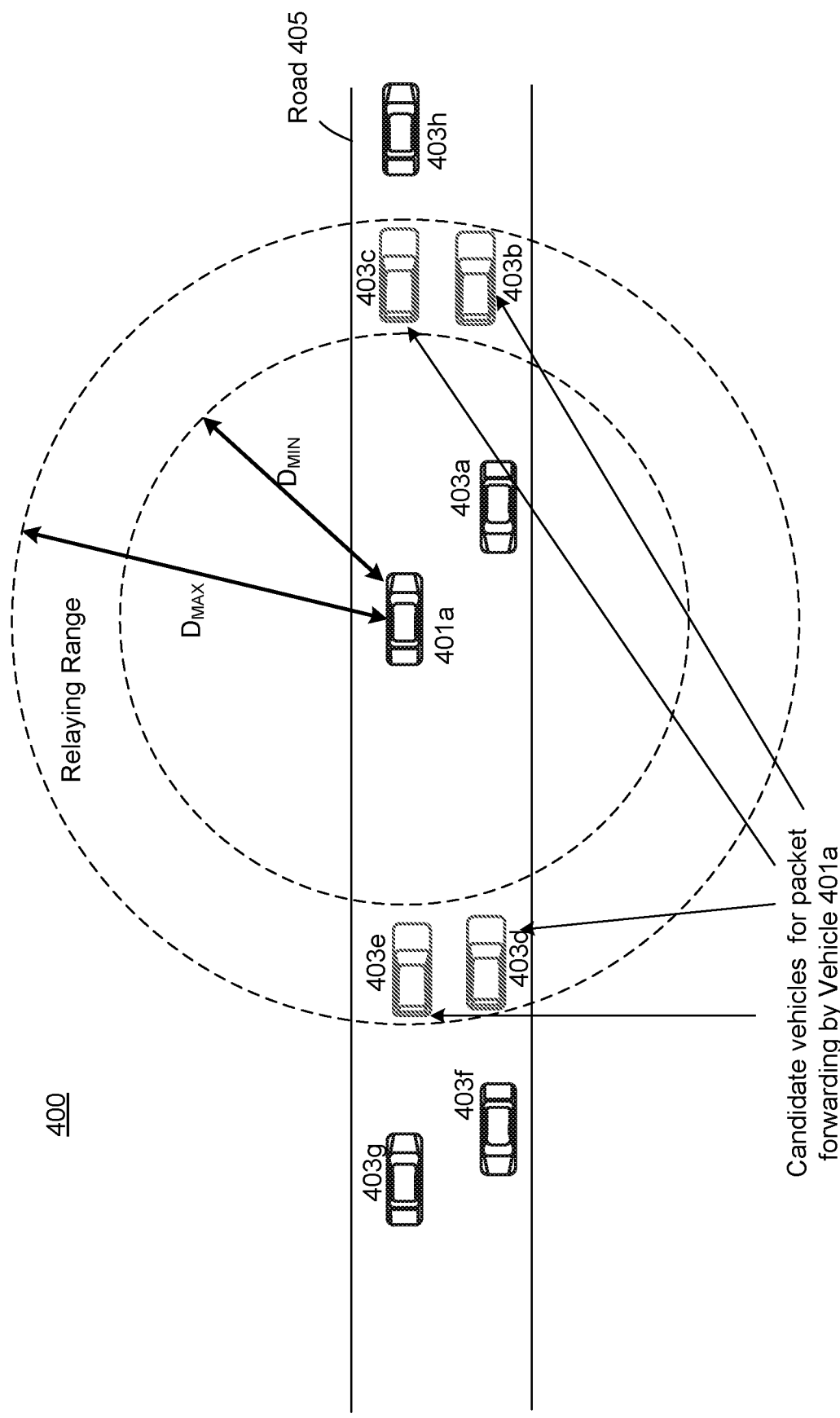


Fig. 4

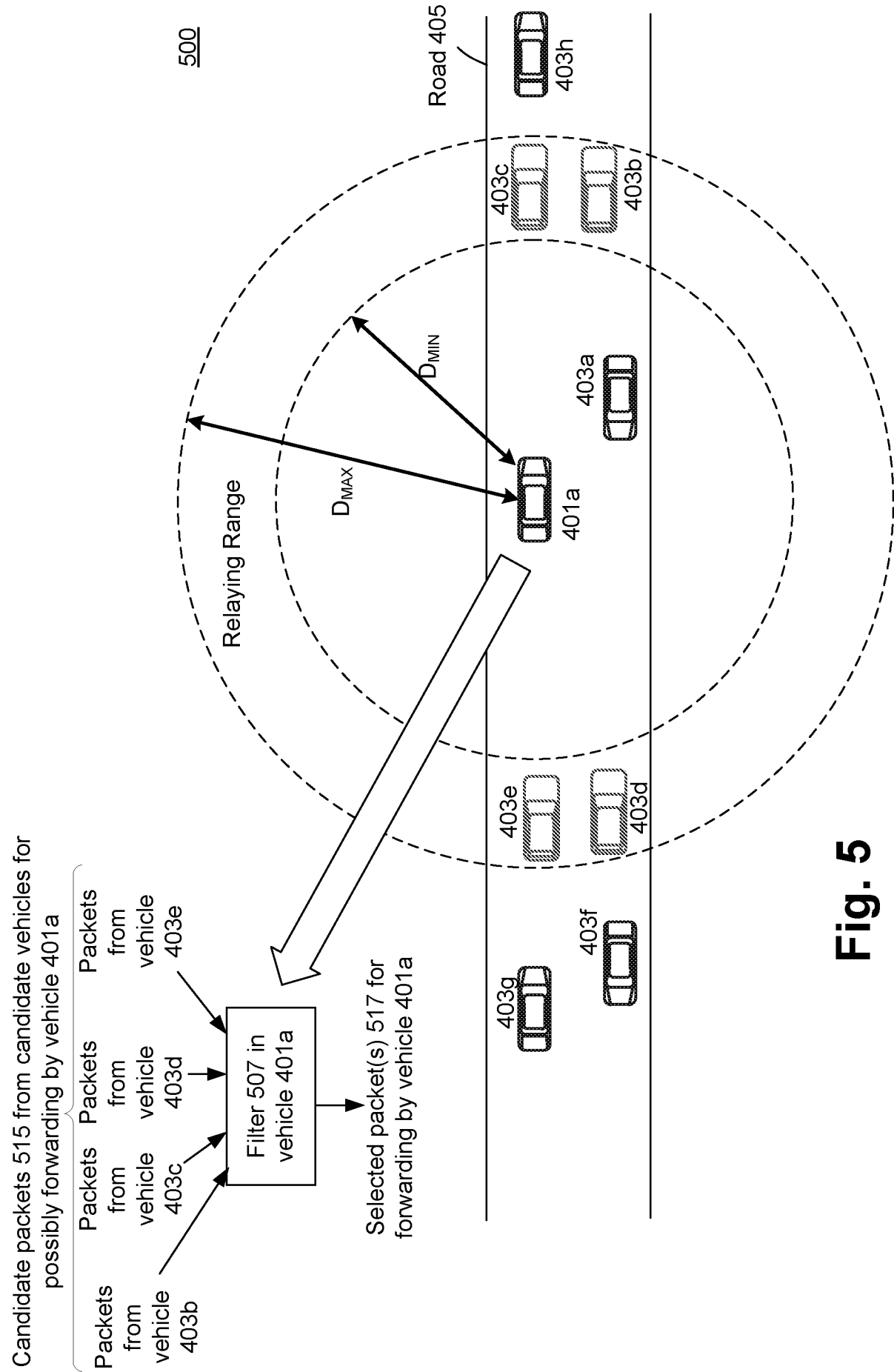


Fig. 5

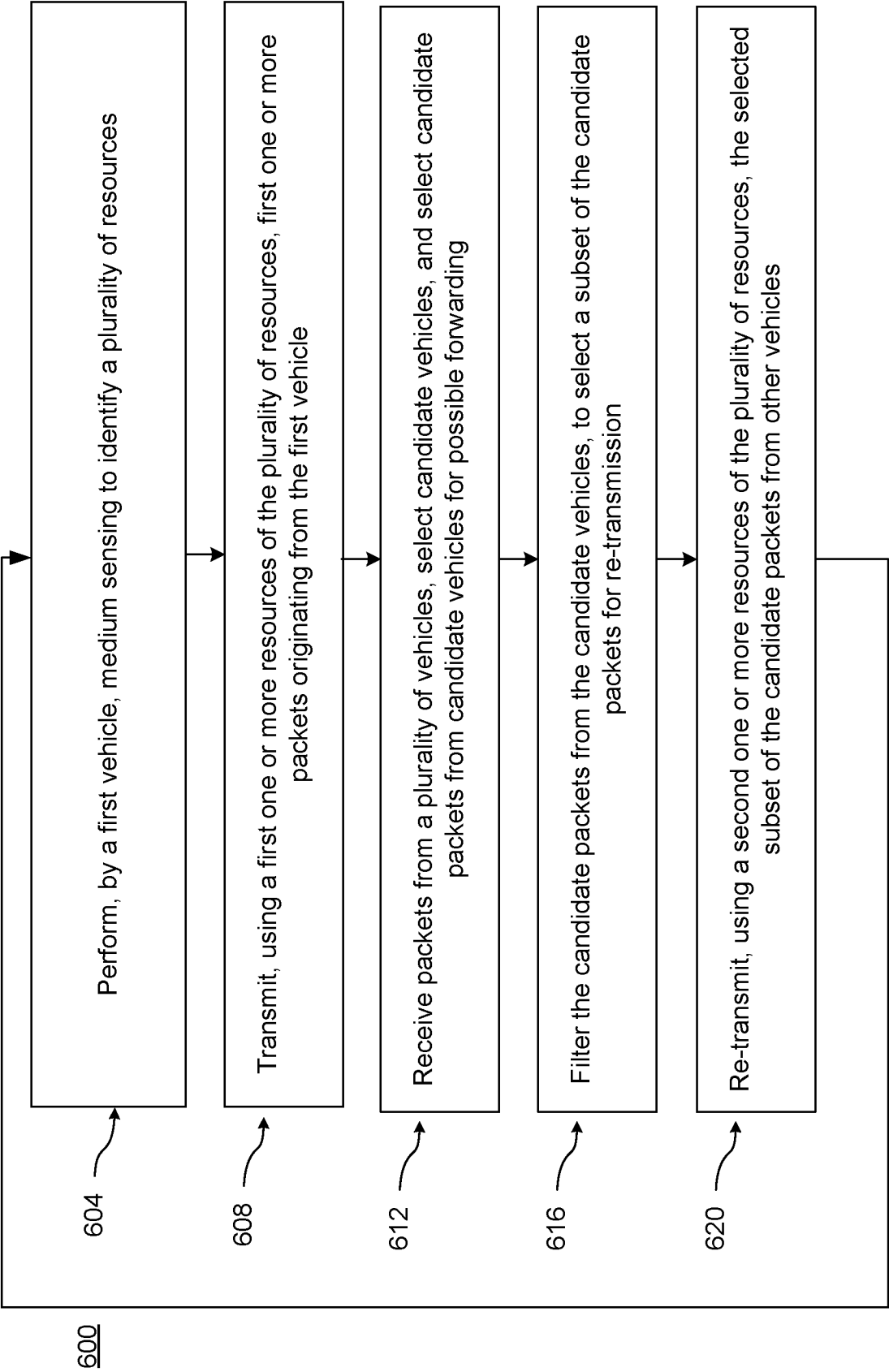


Fig. 6

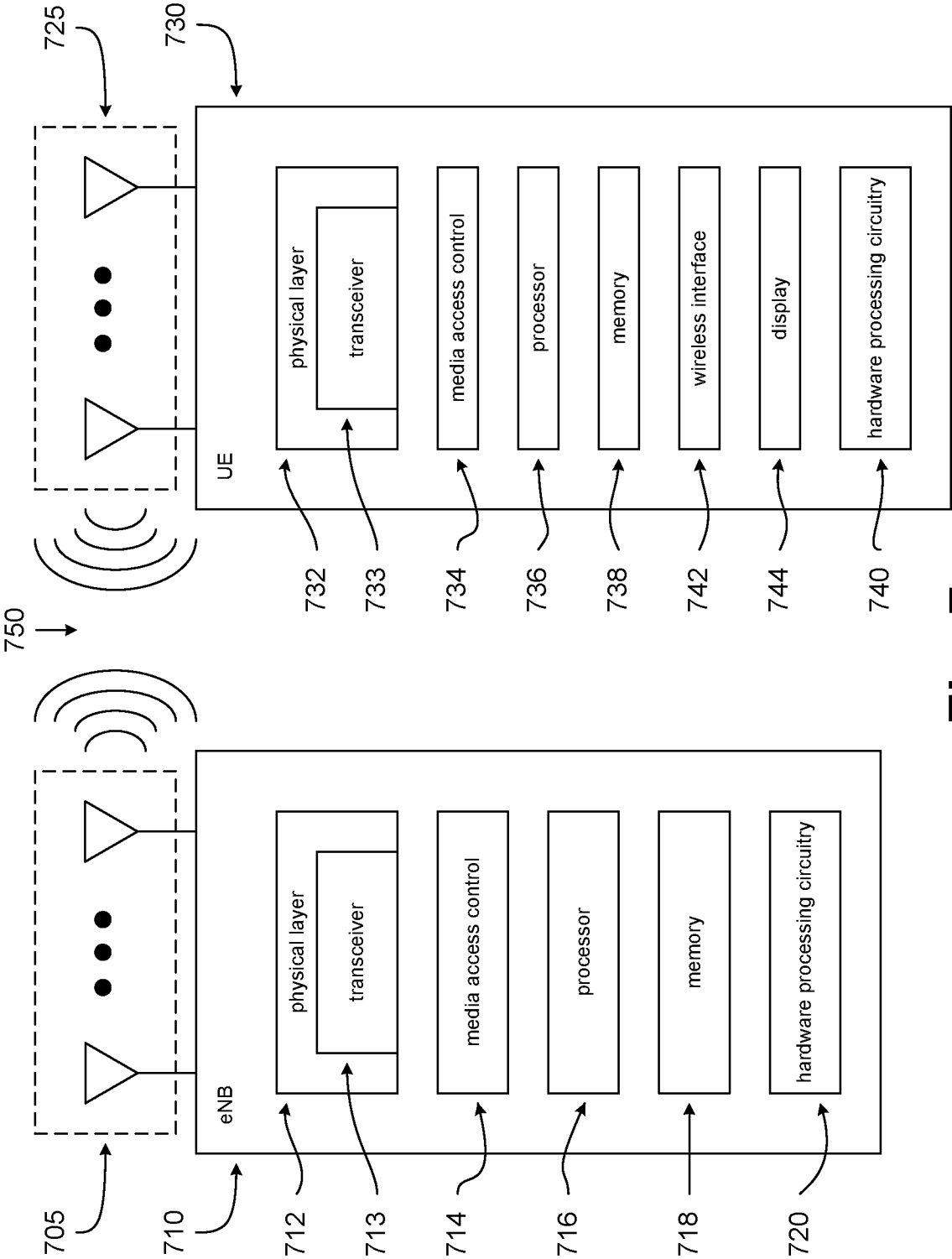


Fig. 7

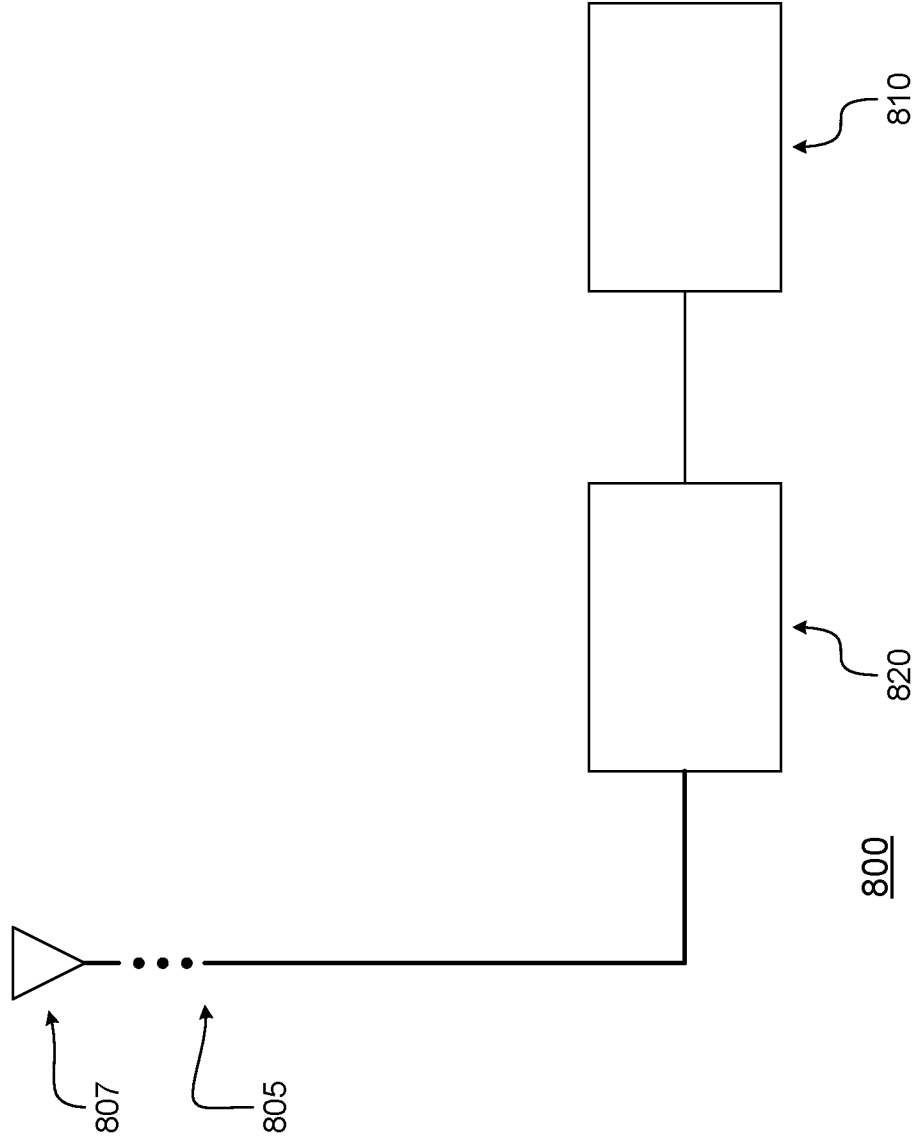


Fig. 8

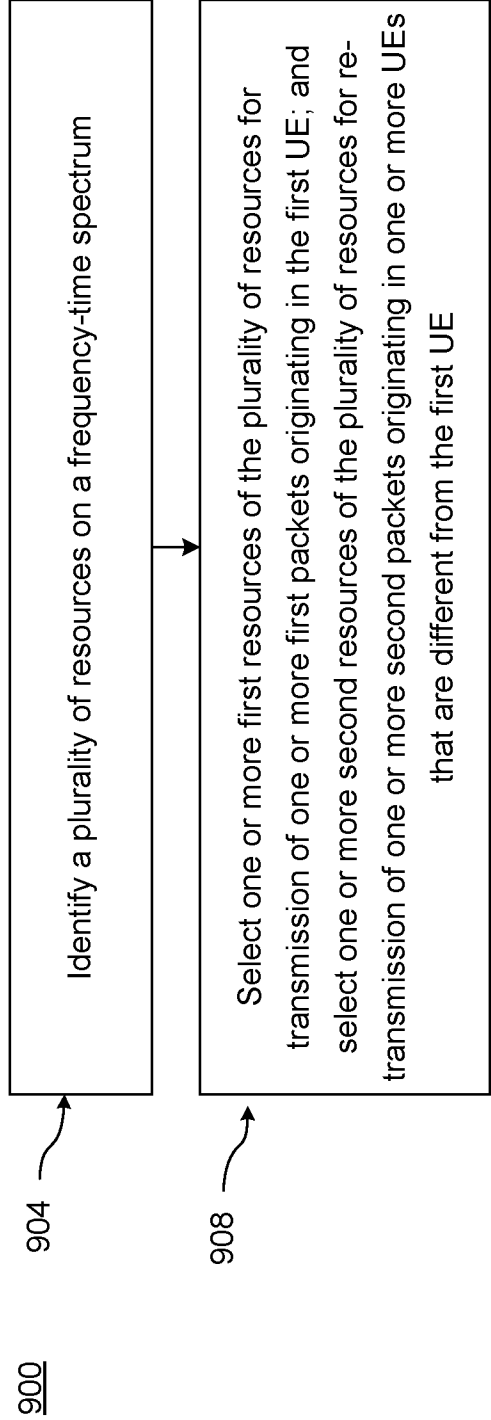


Fig. 9

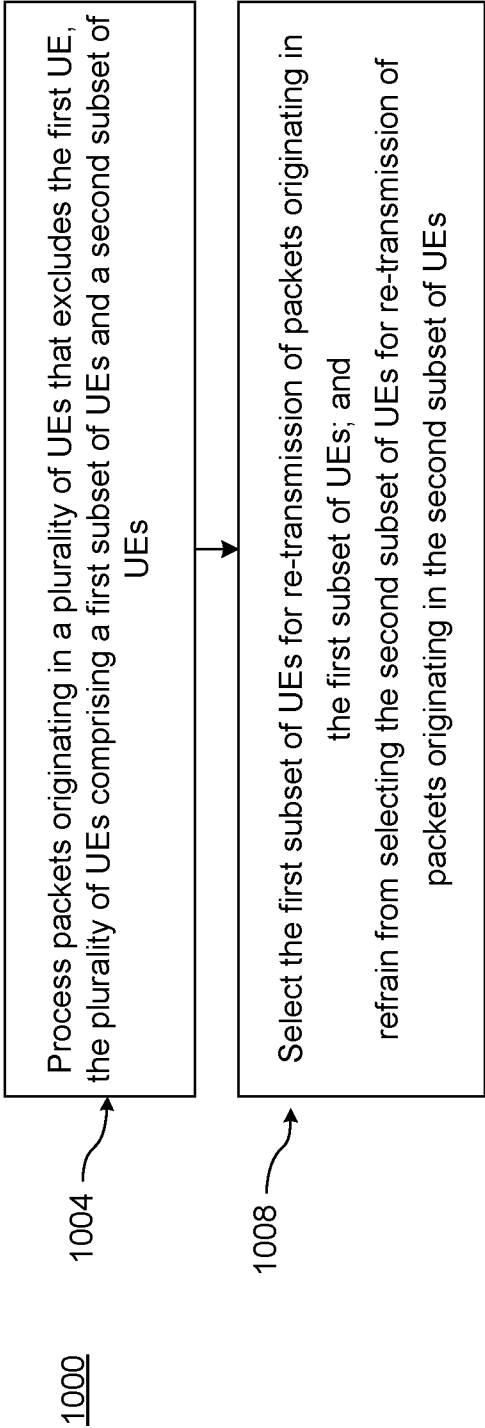


Fig. 10

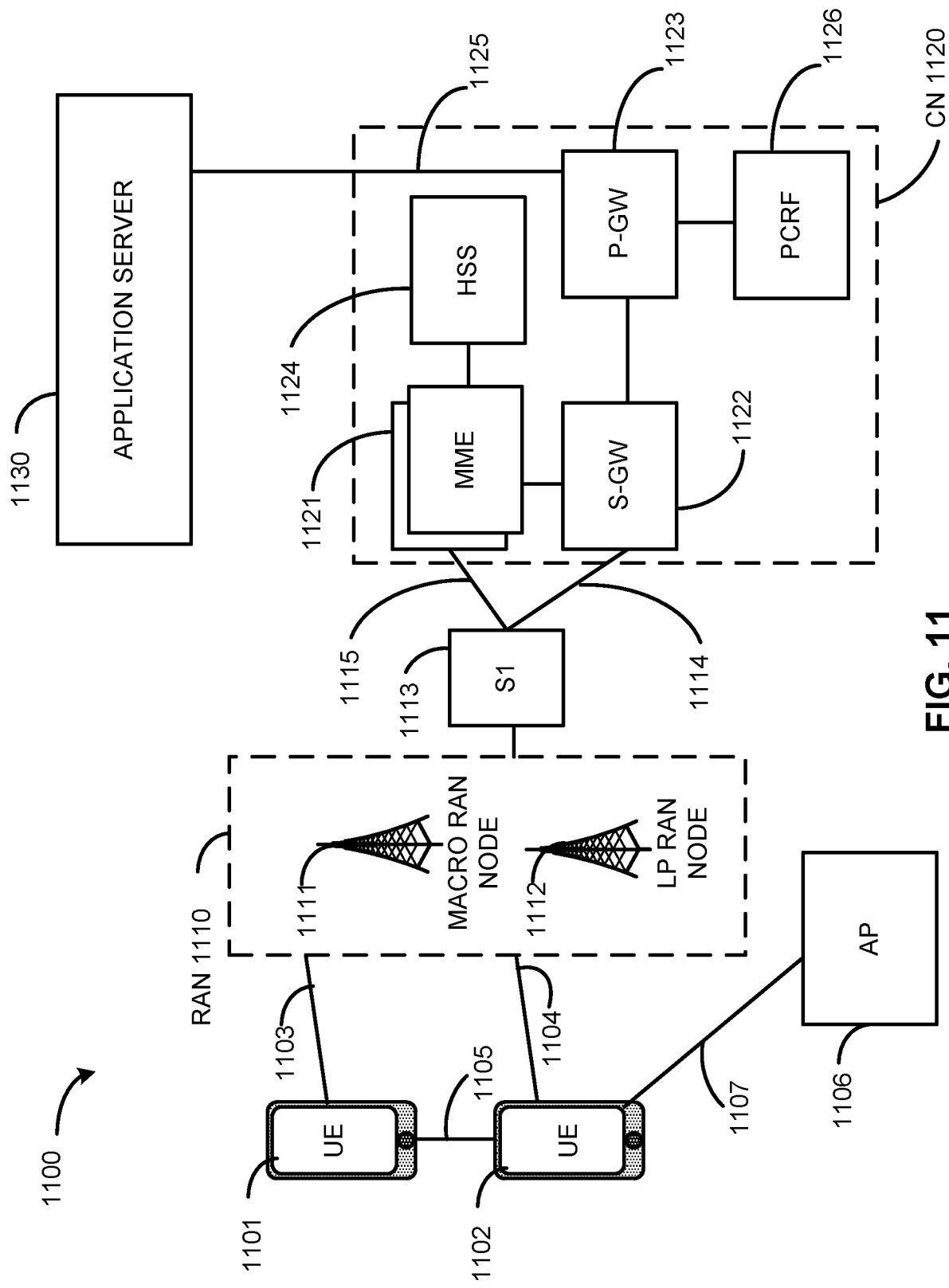


FIG. 11

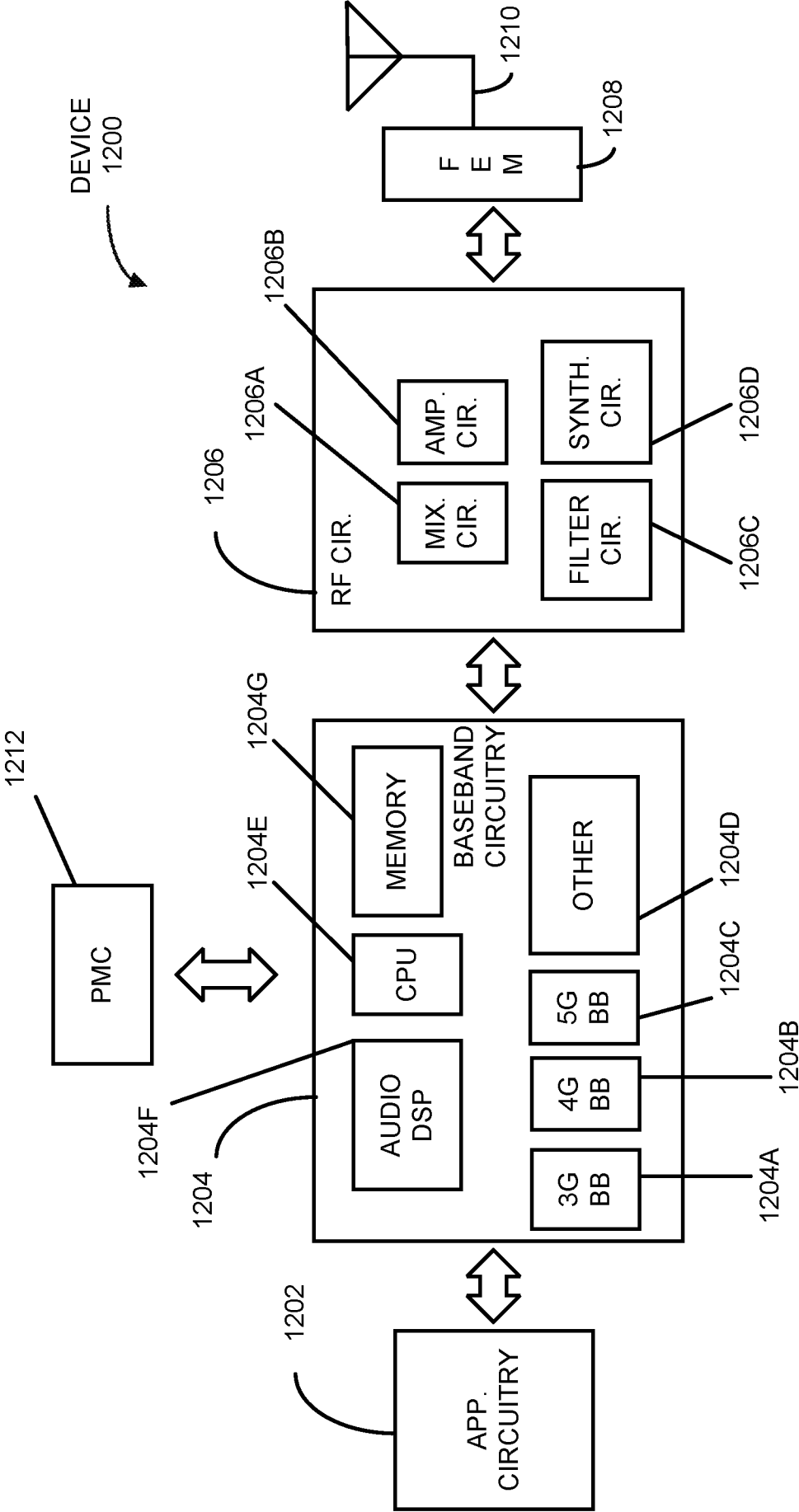


FIG. 12

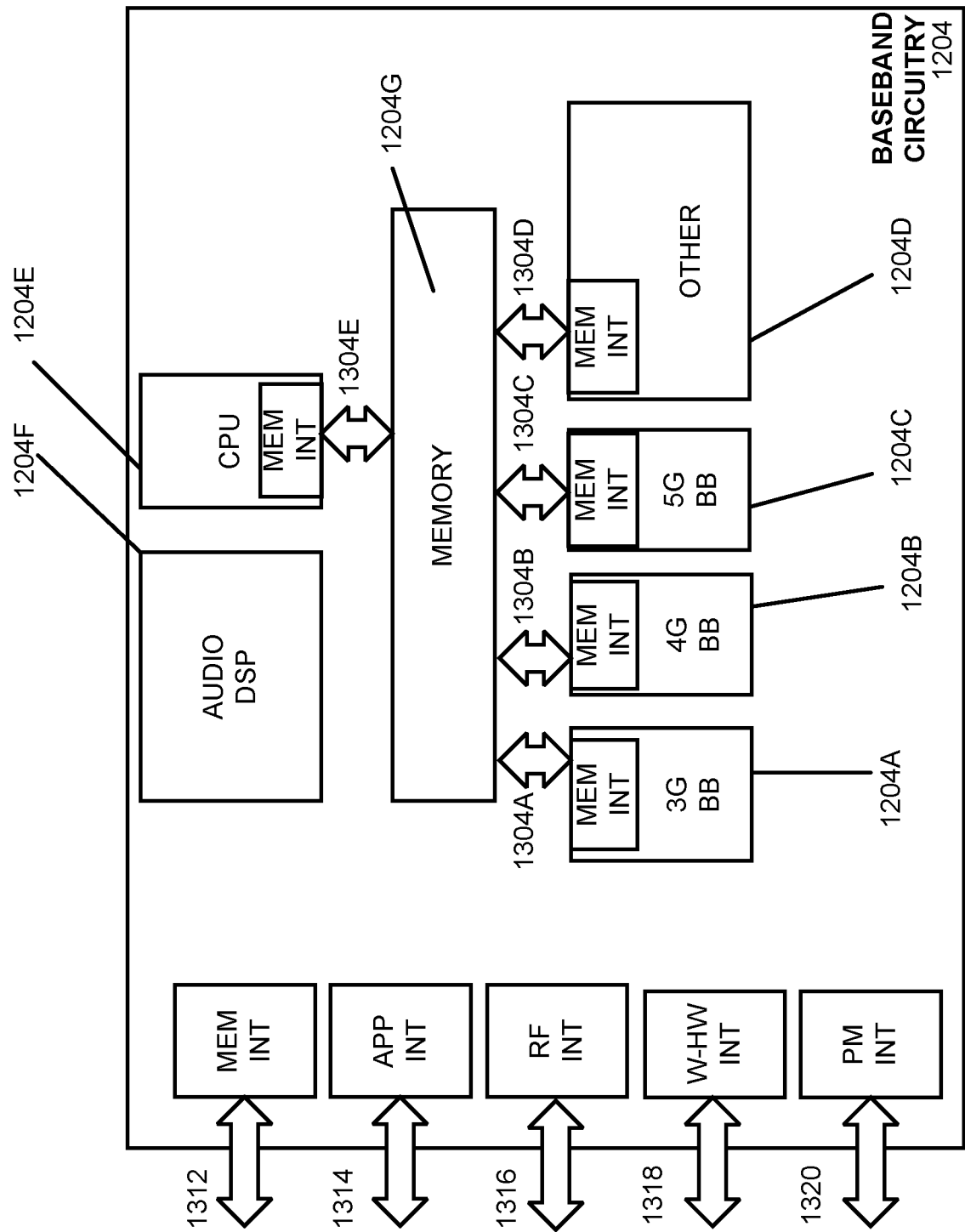


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/045862

A. CLASSIFICATION OF SUBJECT MATTER INV. H04L5/00 H04W4/00 H04W72/04 H04W84/00 H04W84/18 ADD. H04W88/04 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04L H04W Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2016/135109 A1 (HAMPEL KARL GEORG [US] ET AL) 12 May 2016 (2016-05-12) paragraph [0003] - paragraph [0004] paragraph [0069] - paragraph [0075] paragraph [0042] paragraph [0097] figures 2,6 ----- -/--	1-4,6, 8-14,16, 18-25 5,7,15, 17
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 18 October 2017		Date of mailing of the international search report 27/10/2017
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Tanbourgi, Ralph

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/045862

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>ZTE: "Considerations on the UE-to-Network Relays", 3GPP DRAFT; R2-151169 - CONSIDERATIONS ON THE UE-TO-NETWORK RELAYS, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRA</p> <p>, vol. RAN WG2, no. Bratislava, Slovakia; 20150420 - 20150424 19 April 2015 (2015-04-19), XP050936143, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2015-04-19]</p>	1-5, 7-15,17
A	<p>sec.3.1; page 2, paragraph 1 sec.3.3.2,sec.3.3.3, and sec.3.3.4; page 5 - page 6 figure 7</p>	6,16, 18-25
X	<p>-----</p> <p>QUALCOMM (RAPPORTEUR): "Report of email discussion [91bis#27][LTE/eD2D] UE-to NW relays (Qualcomm)", 3GPP DRAFT; R2-156703 REPORT OF 91BIS#27UE-TO-NW RELAYS V1, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG2, no. Anaheim, USA; 20151116 - 20151120 16 November 2015 (2015-11-16), XP051006055, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2015-11-16]</p>	1-4,9-14
A	<p>page 7, last paragraph - page 8, paragraph 3</p> <p>-----</p>	5-8, 15-25

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/045862

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2016077003 A1	19-05-2016
