



(51) International Patent Classification:

H04W 76/14 (2018.01) *H04W* 88/04 (2009.01)
H04W 72/12 (2009.01) *H04W* 52/02 (2009.01)

(21) International Application Number:

PCT/SE2021/050127

(22) International Filing Date:

15 February 2021 (15.02.2021)

(25) Filing Language:

English

(26) Publication Language:

English

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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, BW, 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, IT, 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, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(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,

(54) Title: SIDELINK OPTIMIZATION FOR IOT RELAYING

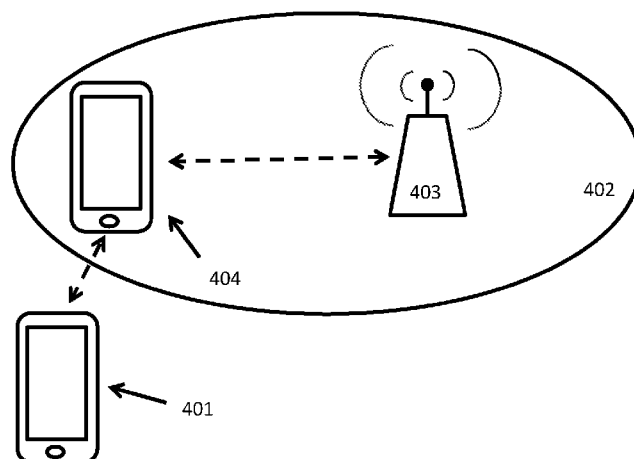


Figure 4

(57) Abstract: A first wireless communication device (401), WCD, selects (501) a resource for transmission to a second WCD (404), transmits (502) a control message indicating the selected resource, and transmits (503) a first message to the second WCD in the selected resource. The second WCD receives (601, 602) the control message and the first message. The first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD. The first WCD is not required to perform channel sensing during at least a time period located between the transmission of the control message and the transmission of the first message.



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).

Published:

- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed
contained color or greyscale and is available for download
from PATENTSCOPE*

Sidelink optimization for IoT relaying

TECHNICAL FIELD

The present disclosure generally relates to wireless communication, and in particular to
5 relaying for internet of things (IoT) devices.

BACKGROUND

Sidelink communication

Sidelink (SL) communication is introduced in 3rd generation partnership project (3GPP) long
10 term evolution (LTE) release 12, focusing on public safety use cases for the support of one-
to-many communications. In release 13, SL communication is enhanced to support user
equipment (UE) based relaying to extend the network coverage. It includes the support of
one-to-one SL communication, which is performed on the application layer transparent to
the access stratum.

15 From release 14 – release 15, SL communication is enhanced to support a new set of use
cases, called vehicle-to-vehicle and vehicle-to-infrastructure communications (V2X) using
LTE. With the support of the new radio (NR) radio interface introduced in release 15, NR
based SL communication has been studied in release 16 to support enhanced V2X services.
20 In release 17, there is a study item on single-hop (relay) SL communication over NR-SL (see
for example the 3GPP document RP-193253 entitled ‘New SID: Study on NR sidelink relay’).

The following sections provide a brief background description of the NR-SL interface designed
for V2X application. For more details about the NR-SL interface, see for example 3GPP TR
25 38.885 v16.0.0, TS 38.331 v16.3.1, TS 38.211 v16.4.0, TS 38.214 v16.4.0, TS 38.321 v16.3.0,
TS 24.386 v16.2.0, TS 24.334 v17.0.0, and TS 24.587 v17.0.0.

NR-SL protocol stacks

Figure 1a shows the user plane (UP) protocol stack for the sidelink interface, which is also
30 referred to as a PC-5 (or PC5) interface. The UP protocol stack includes service data
adaption protocol (SDAP), packet data convergence protocol (PDCP), radio link control
(RLC), medium access control (MAC), and physical (PHY) layers. The major difference
between the LTE V2X and NR V2X is that LTE V2X supports only broadcast messaging,
while NR V2X supports unicast, multicast, and group cast messaging at access stratum (AS)
35 layers.

Figure 1b shows the control plane (CP) protocol stack for NR V2X sidelink. It includes PDCP, RLC, MAC, and PHY layers. The control signals are transmitted over Physical Sidelink Control Channel (PSCCH) and can be used to transmit both Radio Resource Control (RRC) (that is, PC5-RRC) and non-access stratum (NAS) signaling (PC5-S). PC5-RRC signaling exchange is started after the initial link setup using PC5-S signaling.

Unicast link establishment

A unicast link establishment procedure in NR-V2X is shown in Figure 2. In Figure 2, UE1 is the initiating UE and UE2 is the destination UE. The following pre-conditions should be met by UE1 before initiating the connection establishment:

- The upper layer of UE1 has requested to send a packet over PC5.
- The application layer identifier (ID) (and hence the layer-2 ID) of UE1 is available. The application layer ID may for example be self-assigned or pre-configured.

The messages involved in the link establishment procedure is described in respective sections below. For more details about the link establishment procedure, see for example 3GPP TR 38.885 v16.0.0, TS 24.386 v16.2.0, 24.334 v17.0.0, and 24.587 v17.0.0.

Direct Communication request

UE1 initiates the connection establishment procedure by sending a Direct Communication Request (DCR) message. A DCR contains:

- The application layer ID of the UE1.
- It may also include the application layer ID of UE2, if known to UE1.
- A service identifier of the service that UE1 wants.
- A key establishment information container which contains information for PC5 unicast link key establishment.
- A Nonce_1 (a random number) set to a 128-bit nonce value produced by UE1 for the key establishment session.
- A list of security algorithms that UE1 supports to set-up security over the PC5 unicast link.
- K_{NRP} ID (a 256-bit root key to authenticate two UEs), if UE1 has an existing K_{NRP} for UE2 (that is, when there is already a PC5 unicast link between UE1 and UE2).
- 8 MSBs (Most Significant Bit) of the $K_{NRP-sess}$ ID that are selected by UE1 ($K_{NRP-sess}$ is the 256-bit key to protect the data exchange between the UEs).

Upon reception of the DCR from UE1, UE2 stores the layer-2 ID of UE1. Also, UE2 assigns a unique layer-2 ID for itself (mapped from the application layer-ID of UE2). When UE2 receives the DCR from UE1, UE2 proceeds to a link authentication procedure to derive the K_{NRP} .

Direct link authentication

Direct link authentication is performed for mutually authenticating UE1 and UE2, and to acquire a new security key shared between UE1, and UE2. To initiate the link authentication procedure, UE2 creates a direct link authentication request which includes the Key establishment information container IE (information element) and sends the direct link authentication request to UE1.

After receiving the direct link authentication request, UE1 decides whether to accept or reject the link based on the information contained in the Key establishment information container. If UE1 accepts the direct link authentication request, UE1 will create a direct link authentication response message towards UE2. If UE2 receives a direct link authentication reject message, UE2 aborts the unicast link establishment procedure.

Direct link security mode control

The direct link security mode control is used to set-up security between UE1 and UE2 in the course of the unicast connection establishment. UE2 initiates the procedure by sending a direct link security mode command to UE1. If UE1 accepts the direct link security mode command, UE1 will respond to UE2 by sending a direct link security mode complete message. After the successful security mode control, keys and security algorithms are employed to integrity protect and cipher all SL data communicated between UE1 and UE2. If UE2 receives the direct link security mode reject message, UE2 aborts the unicast link establishment procedure.

Direct link communication accept

After the successful direct link security mode control, UE2 will send a Direct Communication Accept (DCA) message to UE1. A DCA message contains the following information:

- Application layer ID of UE2
- PC5 quality of service (QoS) Flow ID (PQFI) and the corresponding QoS parameters.

Unicast data transmission

Upon receiving the unique application layer ID of UE2 in DCA, UE1 now has the application layer ID of UE2. UE1 stores the application layer ID of UE1 and UE2, and this pair of application layer IDs acts as a PC5 link identifier for the PC5 link between UE1 and UE2. After receiving the DCA, UE1 starts sending data to UE2, and UE1 tags each protocol data unit with the derived PC5 link identifier. Similarly, UE2 can also send data to UE1 using the PC5 link that has now been established.

Connection release and connection alive

After the data transfer, the communicating peer UEs can either keep the unicast link alive or release the link. Hence, there are two signaling mechanisms.

5

Keep the unicast link alive

A unicast link keep-alive procedure is performed to keep the PC5 unicast link alive between UE1 and UE2. To initiate the connection alive procedure, UE1 sends a direct link keep-alive request to UE2 over the existing PC5 link. UE1 has a keep-alive timer T5003 and a keep-alive counter to monitor the activities over the existing PC5 link between UE1 and UE2. A periodic actuation of the PC5 unicast link keep-alive procedure is triggered by the timer T5003. Also, every time UE1 receives an SL signaling message or SL user plane data from UE2, UE1 restarts the timer T5003. The direct link keep-alive request message contains the following information:

- 15 • Keep-alive counter for the PC5 unicast link.
- It optionally also includes a maximum inactivity period of UE1 over the existing PC5 link.

The maximum inactivity period is UE specific. The maximum inactivity period value of UE1 is chosen with an objective to keep the number of keep-alive transmissions to the lowest value possible. After receiving the 'direct link keep-alive request', UE2 will create a 'direct link keep alive response' message which includes a keep-alive counter value, and it is set to a value that is the same as what is received in the direct link keep-alive request message. When UE1 receives the direct link keep alive response message, UE1 restarts the timer T5003 and also increment the keep-alive counter. After the successful transmission of the direct link keep-alive request and response, the existing PC5 link identifier is used for the future communication between the two UEs. This stored PC5 link identifier enables to skip direct link authentication and direct link security mode command procedure in the subsequent periods.

Release the link

30 The connection release procedure is performed to release the existing PC5 unicast link between UE1 and UE2 and can be initiated from either UE1 or UE2. The initiating UE will create a direct link release request, send it to the destination UE using the existing PC5 link identifier. The following cause values indicate the reason for the connection release. The direct link release request from the initiating UE may contain one of these cause values:

- 35 • #1: direct communication with the destination UE not allowed
- #2: direct communication to the destination UE is not needed.

- #4: direct connection is not available anymore.
- #5 lack of resources for PC5 unicast link.

After receiving the direct link release request, the destination UE will stop the ongoing communication over the given PC5 link and then respond to the initiating UE with a direct link release accept message. Once the direct link release accept message is sent by the destination UE, the PC5 unicast link is released by the destination UE.

Resource allocation

NR sidelink transmissions have the following two modes of resource allocations:

- Mode 1: Sidelink resources are scheduled by a NR base station (gNodeB).
- Mode 2: The UE autonomously selects sidelink resources from a (pre-) configured sidelink resource pool(s) based on a channel sensing mechanism.

For an in-coverage UE, a gNodeB can be configured to adopt Mode 1 or Mode 2. For an out-of-coverage UE, only Mode 2 can be adopted.

Channel sensing for Mode-2 operation

In the mode-2 resource allocation, the UEs choose the resource for their transmissions (such as the messages shown in Figure 2) from a pre-configured resource pool. A resource may for example be a subchannel in a slot. Here, a subchannel includes a certain number of resource blocks (RB), for example 10 RB. Each RB includes 12 subcarriers. To avoid collisions in the resource selection, a resource sensing procedure (also referred to as a channel sensing procedure) is used. In the resource sensing procedure, the transmitting UE senses the channel to find candidate resources for its SL transmissions. In the resource sensing phase, a transmitting UE detects the Sidelink Control Information (SCI) transmitted by other UEs in the cell (or within range of the transmitting UE).

To reduce the complexity of the sensing procedure, a two-stage SCI principle is used in NR-SL. When a UE performs transmission in a slot, the UE includes the physical sidelink control channel (PSCCH) symbol and the physical sidelink shared channel (PSSCH) symbol in the same slot (that is, data and control signal are sent together in the same slot). The first stage SCI (also referred to as 1st stage SCI) is transmitted on the PSCCH, and the second stage SCI (also referred to as 2nd stage SCI) is carried over the PSSCH (multiplexed with the data). The first stage SCI carries information regarding the PSSCH resource used for transmitting the second stage SCI and data, PSSCH resources reserved for future transmissions, and a priority of the transmission in the first stage SCI. This first stage SCI is decodable by any peer UE in the cell. Based on the information contained in the first stage SCI, the sensing UEs can

choose the resources which are not occupied by peer UEs. The second stage SCI carries the remaining scheduling information for the PSSCH which is decodable only by the target UE.

The output of the resource sensing procedure by a UE is a candidate set of resources for its SL transmissions. The candidate resources are those resources which are unoccupied, and also those resources which are occupied by another UE but which have an interference level acceptable at the UE which is selecting the resources. The selection of resources via resource sensing is explained below with reference to Figure 3.

1. Let us assume that at a slot n , a transmit buffer of a UE receives a packet for transmission. We assume that the UE has been continuously monitoring the SCI transmitted by the other remote UEs (background sensing). The period over which the remote UE senses the SCIs from other UEs is called a sensing window, and the duration of this sensing window can be configured up to 1000 ms (that is, the UE checks the SCI transmitted from the other UEs within a window that is up to 1000 ms long before the n^{th} slot). In Figure 3, the sensing window spans from $(n - T_0)$ to $(n - T_{proc,0})$, where T_0 is the sensing window duration, and $T_{proc,0}$ is associated with the UE processing time for decoding the SCI and performing demodulation reference signal (DMRS) measurement.

2. The UE creates a list of resources within the selection window (selection window in Figure 3: $n + T_1$ to $n + T_2$) based on the output of the sensing procedure. Recall that the output of the sensing procedure is a set of resources which are available for a UE to use for its transmission. Here T_1 denotes the UE processing time from the resource selection trigger to the earliest candidate resource. The remote UE makes a list ($L1$) of potential resources that include all the resources in the selection window except the resources that meet both of the following two conditions:

- The UE has received a first stage SCI from a peer remote UE in the sensing window indicating that the peer remote UE will use this resource for a transmission.
- The UE measures a Reference Signal Received Power (RSRP) on the PSCCH containing the first stage SCI of the peer remote UEs, and checks if this RSRP is higher than a given RSRP threshold (which may be a configurable parameter). If the RSRP is high enough, this may indicate that there would be a collision, but if the RSRP is low enough, it may be fine to reuse the resource.

If these two conditions are met simultaneously, the remote UE excludes the resource from

$L1$. $L1$ should include at least 20% of all the resources in the selection window after

performing step 2. If this condition is not met, the remote UE increases the RSRP threshold by 3 dB, and iteratively executes step 2 until the target of 20% is met.

Then the UE makes a second list ($L2$) of resources. $L2$ is derived from $L1$, such that $L2$ contains the resources in $L1$ which have the lowest average Reference Signal Received Power (RSRP) in $L1$. Here, the average is taken over the sensing window in Figure 3 that spans from $(n - T_0)$ to $(n - T_{proc,0})$. The idea of taking the average is to select the subchannel (or RBs) which will have the lowest interference on the UE's transmission. For example, $L1$ contains two types of resources: A first set of resources that are not being occupied by any peer UEs, and a second set of resources that are being occupied by peer UEs, but have an interference level below the given threshold. Let us consider the second set of resources. For instance, the UE detects at the beginning of the sensing window that subchannel k will be occupied (but with an RSRP less than the threshold), and the UE also detects later in the sensing window that subchannel k will be occupied, but with a different measured RSRP value. Such a scenario is possible since pre-emption is supported in the NR-SL. In this case, the remote UE takes an average over the sensing window duration to find out the average level RSRP on the subchannel k . Hence, the list $L2$ contains the resources (time and frequency) from $L1$ which experience the lowest average RSRP. The UE randomly chooses one of the resources (time + frequency) in $L2$ and reserves it for its transmission. In Figure 3, the selected resource is shown as the box 301 in slot m . The resource selection made by the UE is only known to the UE itself, meaning that the UE does not broadcast this selection to the other UEs.

3. Since the UE does not broadcast its resource selection, other nearby UEs may choose the same resource for their transmissions. Hence, the UE keeps on sensing the channel until the slot m to identify if some other UE has selected the same resource 301 at slot m . If the UE detects a SCI transmission from another UE indicating a resource reservation at the same resource 301, the UE initiates a resource reselection procedure. This is illustrated in Figure 3. The box 301 in slot m represents the resource selected by the UE at slot n . Another UE sends a PSCCH reservation in the resource 302 in slot $n+1$. The PSCCH reservation indicates that the other UE has also selected the resource 301 for a transmission. The UE then initiates a resource reselection procedure.

For the resource reselection procedure, the UE selects the resources based on the sensing procedure (over the window from $M - T_3 - T_0$ to $M - T_3$, where T_3 is the resource re-selection processing time), and by following the procedure mentioned in steps 2 and 3.

The selection window for resource reselection spans from slot m to $m + T_2$. The reselected resource is shown as the box 303 in Figure 3. If no other UE has reserved the resource 303, the UE sends its PSCCH and PSSCH in the resource 303. Other UEs can now decode the PSCCH of the UE sent in the resource 303, and sense the future resources reserved by the UE. The future resources reserved by the UE are indicated in the first stage SCI transmitted via the PSCCH in the resource 303.

In the example scenario shown in Figure 3, $T_{\text{proc},0} = 1$ slot, $T_3 = T_{\text{proc},0} + 1$ slots, $T_1 = 2$ slots, sensing window duration = 100 ms or 1000 ms, and T_2 is limited by the packed delay budget (PDB).

In the unicast link (or connection) establishment procedure described above with reference to Figure 2, while sending the DCR, the UE also reserves a resource for its very next transmission (such as a direct link authentication response) based on the resource sensing performed. This reservation information is included in the first stage SCI. The UE keeps on sensing the channel until the slot where its future resources are reserved, to check if any other peer UE with higher priority (priority information is provided in the first stage SCI) has reserved the same resources. If the UE detects a higher priority reservation from a peer UE, the UE releases the reserved resources and re-starts the connection establishment procedure from the point at which the collision happened. So, the UE performs the sensing again, and chooses a new resource for transmission of the current transmission, and for a future transmission. This reservation interval for the next signaling/data transmission may for example be limited to 1000 ms (or may be equal to the sensing window). If the UE does not detect reservation from a higher priority peer UE, the UE transmits the direct link authentication response in the reserved resource, and also reserves a resource for its very next transmission (direct link security mode complete). This process continues until the connection has been established and a release or keep alive message has been transmitted.

IoT relaying

UE-based relaying may be employed to increase coverage. It would be desirable to provide relaying for IoT devices in a way that is compatible with an already existing procedure and/or interface for sidelink communication.

SUMMARY

Embodiments of methods, wireless communication devices, network nodes etc. are provided herein for addressing one or more of the issues indicated above.

A first aspect provides embodiments of a method at a first wireless communication device (WCD). The method comprises selecting a resource for transmission to a second WCD, transmitting a control message indicating the selected resource, and transmitting a first message to the second WCD in the selected resource. The first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD. The first WCD is not required to perform channel sensing during at least a time period located between the transmission of the control message and the transmission of the first message.

A second aspect provides embodiments of a first WCD. The first WCD is configured to select a resource for transmission to a second WCD, transmit a control message indicating the selected resource, and transmit a first message to the second WCD in the selected resource. The first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD. The first WCD is not required to perform channel sensing during at least a time period located between the transmission of the control message and the transmission of the first message. The first WCD may for example comprise processing circuitry configured to cause the first WCD to select the resource for transmission to the second WCD, transmit the control message indicating the selected resource, and transmit the first message to the second WCD in the selected resource.

A third aspect provides embodiments of a method at a second WCD. The method comprises receiving, from a first WCD, a control message indicating a selected resource, and receiving, from the first WCD, a first message in the selected resource. The first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD.

A fourth aspect provides embodiments of a second WCD. The second WCD is configured to receive, from a first WCD, a control message indicating a selected resource, and receive, from the first WCD, a first message in the selected resource. The first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD. The second WCD may for example comprise processing circuitry configured to cause the second WCD to receive, from the first WCD, the control message indicating the selected resource, and receive, from the first WCD, the first message in the selected resource.

BRIEF DESCRIPTION OF THE DRAWINGS

In what follows, example embodiments will be described in greater detail with reference to the accompanying drawings, on which:

Figure 1a shows the NR-SL user plane protocol stack;

Figure 1b shows the NR-SL control plane protocol stack;

5 Figure 2 shows a unicast link connection establishment procedure;

Figure 3 shows an example scenario for NR-SL resource sensing;

Figure 4 illustrates a relaying situation involving first and second WCDs, according to some embodiments;

Figure 5 is a flow chart of a method at a first WCD, according to some embodiments;

10 Figure 6 is a flow chart of a method at a second WCD, according to some embodiments;

Figure 7 shows a sidelink based relaying architecture for a partial coverage scenario, where a relay UE is in coverage of a gNodeB, and a remote UE is out-of-coverage of the gNodeB, according to some embodiment;

Figure 8 shows the method from Figure 5, but with an optional extra step, according to some
15 embodiments;

Figure 9 shows the method from Figure 6, but with an optional extra step, according to some embodiments;

Figure 10 illustrates use of priority values for avoiding collisions, according to some embodiments;

20 Figure 11 shows the method from Figure 5, but with optional extra steps, according to some embodiments;

Figure 12 shows the method from Figure 6, but with optional extra steps, according to some embodiments;

Figure 13 is a flow chart of a method at a first WCD, according to some embodiments;

25 Figure 14 is a flow chart of a method at a second WCD, according to some embodiments;

Figure 15 illustrates a contention based initial access approach, according to some embodiments;

Figure 16 shows the method from Figure 5, but with optional extra steps, according to some embodiments;

30 Figure 17 shows the method from Figure 6, but with optional extra steps, according to some embodiments;

Figure 18 illustrates a frame level slotted aloha system with a fixed time offset for resource reservations for future transmissions, according to some embodiments;

Figure 19 shows the method from Figure 5, but with optional extra steps, according to some
35 embodiments;

Figure 20 shows the method from Figure 6, but with optional extra steps, according to some embodiments;

Figure 21 shows the method from Figure 5, but with optional extra steps, according to some embodiments;

Figure 22 shows the method from Figure 6, but with an optional extra step, according to some embodiments;

5 Figure 23 shows a procedure for keeping a link alive between a remote UE and a relay UE, according to some embodiments;

Figure 24 shows the method from Figure 5, but with optional extra steps, according to some embodiments;

10 Figure 25 shows the method from Figure 6, but with optional extra steps, according to some embodiments;

Figure 26 shows the method from Figure 5, but with an optional extra step, according to some embodiments;

Figure 27 shows the method from Figure 6, but with optional extra steps, according to some embodiments;

15 Figure 28 illustrates an example of a communications network in which embodiments of the present disclosure may be implemented;

Figure 29 is a schematic block diagram of a WCD, according to some embodiments;

Figure 30 is a schematic block diagram of a network node, according to some embodiments; and

20 Figure 31 is a schematic block diagram that illustrates a virtualized embodiment of a network node.

All the figures are schematic, not necessarily to scale, and generally only show parts which are necessary in order to elucidate the respective embodiments, whereas other parts may be
25 omitted or merely suggested. Any reference number appearing in multiple drawings refers to the same object or feature throughout the drawings, unless otherwise indicated. Even if flow charts for methods performed by cooperating first and second WCDs are shown side by side, the positions of the method steps shown in the respective flow charts have not been selected to reflect the timing of the method steps performed by the first WCD relative to the timing of
30 method steps performed by the second WCD.

DETAILED DESCRIPTION

Some of the embodiments contemplated herein will now be described more fully with reference to the accompanying drawings. Other embodiments, however, are contained within
35 the scope of the subject-matter disclosed herein. The scope of the present disclosure should not be construed as limited to only the embodiments set forth herein. Rather, these

embodiments are provided by way of example to convey the scope of the disclosed subject matter to those skilled in the art.

Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. It will be appreciated that the word "comprising" does not exclude other elements or steps. The word "or" is not to be interpreted as an exclusive or (sometimes referred to as "XOR"). On the contrary, expressions such as "A or B" covers all the cases "A and not B", "B and not A" and "A and B". The mere fact that certain measures are recited in mutually different dependent claims or embodiments does not indicate that a combination of these measures cannot be used to advantage. Any feature of any of the embodiments or claims disclosed herein may be applied to any other embodiment or claim, wherever appropriate. Likewise, any advantage of any of the embodiments or claims may apply to any other embodiments or claims, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following description.

UE based SL relaying is an interesting option for supporting extended coverage in a NR network, without compromising the UE power efficiency. It's therefore an interesting option for enabling NR support for massive IoT use cases. The existing NR-SL interface and protocol (which were described above in the background section) do not support relay functionality. Hence, there is currently no relaying function over NR-SL to meet the coverage requirements for IoT application. The NR-SL is designed for V2X applications whose traffic characteristics are different from massive IoT use cases. Hence the current NR-SL connection establishment procedures are inefficient for supporting battery operated, low data rate IoT devices.

The present disclosure provides several ideas for how SL communication may be modified to make SL feasible for IoT. Several of these ideas involve modifications of the connection establishment procedure (also referred to herein as link establishment procedure) in the current NR-SL. As will be described further below, relaying for IoT applications using the NR-SL may be employed to increase the coverage of the IoT devices. At least some of the

modifications proposed herein may be employed to improve the battery lifetime of the devices and/or reduce signaling overhead.

Overview

- 5 Figure 4 illustrates a relaying situation, where a first wireless communication device (WCD) 401 is located outside a coverage area 402 of a network node 403. A second WCD 404 is located within the coverage area 402 of the network node 403 and is also within range of the first WCD 401. The second WCD 404 may therefore act as a relay for information between the first WCD 401 and the network node 403. In other words, information from the network
10 node 403 may be relayed to the first WCD 401 via the second WCD 404, and information from the first WCD 401 may be relayed to the network node 403 via the second WCD 404. The first WCD 401 is sometimes referred to herein as a remote WCD or remote UE. The second WCD 404 is sometimes referred to herein as a relay WCD or relay UE.
- 15 The first WCD 401 and the second WCD 404 are both illustrated in Figure 4 as smart phones, but it will be appreciated that these two WCDs may for example be of different types. The first WCD 401 and the second WCD 402 may be any type of device that is able to communicate wirelessly, for example with a wireless communication network (such as a cellular network). Some examples of a WCD include, but are not limited to, a User Equipment (UE) in a 3GPP
20 network, a Machine Type Communication (MTC) device, and an Internet of Things (IoT) device. The WCD may for example be (or may for example be integrated into) a mobile phone, smart phone, sensor device, meter, vehicle, household appliance, medical appliance, media player, camera, or any type of consumer electronic device, for instance, but not limited to, a television, radio, lighting arrangement, tablet computer, laptop, or personal computer (PC).
- 25 The WCD may for example be a portable, hand-held, computer-comprised, or vehicle-mounted mobile device, enabled to communicate voice and/or data via a wireless connection. The first WCD 401 may for example be an IoT device with limited power supply, while the second WCD 404 may not have the same need to save power as the first WCD 401.
- 30 The network node 403 may be any node in a communication network that is able to communicate wirelessly with a WCD, such as a node in a Radio Access Network (RAN) of a cellular communications network that operates to wirelessly transmit and/or receive signals. Some examples of a network node include, but are not limited to, a base station (for example a gNB (or gNodeB) in a 3GPP Fifth Generation (5G) NR network or an enhanced or evolved
35 Node B (eNB) in a 3GPP LTE network), a high-power or macro base station, a low-power base station (for example a micro base station, a pico base station, a home eNB, or the like), a relay node, a network node that implements part of the functionality of a base station (for

example a network node that implements a gNB Central Unit (gNB-CU) or a network node that implements a gNB Distributed Unit (gNB-DU) or a network node that implements part of the functionality of some other type of node in a RAN.

- 5 Figure 5 is a flow chart of a method 500 at the first WCD 401, according to some embodiments. The method 500 may for example be performed by the first WCD 401, or by one or more parts/portions/components of the first WCD 401. The method 500 illustrated in Figure 5 serves an overview or context of the more specific embodiments presented in the following sections.
- 10 The method 500 comprises selecting a resource for transmission to the second WCD 404. The resource may for example include one or more subcarriers in one or more symbols (such as orthogonal frequency division multiplexing (OFDM) symbols) in one or more slots (or in one or more subframes or frames). In other words, the resource may include time and/or frequency resources for transmitting one or more signals, data, messages etc. to the second WCD 404.
- 15 The resource may for example include a plurality of resource elements. The first WCD 401 may for example select the resource for transmission to the second WCD from a collection of resources. The first WCD 401 may for example select the resource randomly from the collection of resources, or may for example use an algorithm to make the selection in a non-random manner. The collection of resources may for example be indicated by the second
- 20 WCD 404, or may be determined by the first WCD 401, or may be predefined. The collection of resources may for example be fixed, or may change over time.

The method 500 comprises transmitting 502 a control message indicating the selected resource. The control message may for example be broadcasted or multicasted to multiple

25 WCDs, or may be transmitted in a dedicated manner to the second WCD 404. The control message may for example be a 1st stage sidelink control information (SCI) message carried on a Physical sidelink control channel (PSCCH), as specified in 3GPP TS 38.212 v16.3.0, or may for example be a SCI of a different/new format.

- 30 The method 500 comprises transmitting 503 a first message to the second WCD 404 in the selected resource (or on the selected resource, or using the selected resource). The first message may for example be part of a link establishment procedure for establishing a link between the first WCD 401 and the second WCD 404. The first message may for example be part of the link establishment procedure described above in the background section with
- 35 reference to Figure 2, which may for example be referred to as a direct link establishment procedure. The first message may for example be a direct communication request, or a direct link authentication response, or a direct link security mode complete message, or a direct link

release request, or a direct link keep alive request. The link establishment procedure may for example be intended for relaying of information (or of signals or messages) from the first WCD 401 to a network via the second WCD 404, as illustrated in Figure 4. In Figure 4, the network is represented by the single network node 403, but it will be appreciated that a network will typically include many nodes. Embodiments may also be envisaged in which the first message transmitted at step 503 is not part of a link establishment procedure. The first message may for example be a message transmitted after a link has been established between the first WCD 401 and the second WCD 404. The first message may for example be a message with data to be forwarded by the second WCD 404 to the network node 403.

If the NR-SL channel sensing and two stage SCI (described above in the background section with reference to Figure 3) is employed, the first WCD 401 would typically be required (or obliged) to perform channel sensing between the transmission 502 of the control message and the transmission 503 of the first message. As will be described below, other approaches may be employed, where such channel sensing is not needed. In other words, the first WCD 401 may not be required (or obliged, or expected) to perform channel sensing during at least a time period located between the transmission 502 of the control message and the transmission 503 of the first message.

Figure 6 is a flow chart of a method 600 at the second WCD 404, according to some embodiments. The method 600 may for example be performed by the second WCD 404, or by one or more parts/portions/components of the second WCD 404. The method 600 illustrated in Figure 6 serves an overview or context of the more specific embodiments presented in the following sections. The method 600 may for example be performed at the second WCD 404 in cooperation with the method 500 performed at the first WCD 401. It will therefore be appreciated that examples and advantages presented herein for features associated with the method 500 may apply also for corresponding features associated with the method 600.

The method 600 comprises receiving 601, from the first WCD 401, the control message indicating a selected resource (that is, the control message transmitted at step 502 in the method 500). The selected resource may for example include one or more subcarriers in one or more symbols in one or more slots. The second WCD 404 may for example have indicated to the first WCD 401 a collection of resources from which to select the resource. This indication may for example have been broadcasted or multicasted to multiple WCDs, or may have been transmitted to the first WCD 401 via a dedicated or UE-specific transmission.

The method 600 comprises receiving 602, from the first WCD 401, the first message in the selected resource (or on the selected resource, or using the selected resource). As described above in connection with the method 500, the first message may for example be part of a link establishment procedure for establishing a link between the first WCD 401 and the second WCD 404, for example for relaying of information from the first WCD 401 to a network via the second WCD 404.

Various ideas and associated optional extra steps for the methods 500 and 600 will be described below in the following sections. Please note that the ideas and optional steps presented in different sections may be combined to form further embodiments. For example, optional steps presented in one section will typically not be repeated in the other sections, despite the fact that those optional steps can be employed also in the scenarios/contexts presented in at least some of the other sections.

Layer-2 IDs corresponds to the relaying function

A new UE type called relay UE may be introduced with some added functionalities to support the relaying function described above with reference to Figures 4-6. The relay UE has both the PC-5 interface (towards the remote UE) and a Uu interface (towards the gNodeB), as shown in Figure 7. Figure 7 shows a sidelink based relaying architecture for a partial coverage scenario, where the relay UE is in the coverage of gNodeB, and the remote UE is out-of-coverage of the gNodeB. The remote UE corresponds to the first WCD 401 in Figure 4. The relay UE corresponds to the second WCD 404 in Figure 4. A new service type called 'Relaying' may be defined, and this service type is known to all the remote UEs in prior. The purpose of this service type is to inform the relay UE that a transmission (or data) from the remote UE is not a regular SL transmission to be terminated at the relay UE, but instead includes data that is intended to be forwarded to the network via relaying. When the remote UE initiates a connection with the relay UE, the 'Relaying' service type may be mapped to the layer-2 ID of the destination UE (relay UE) for the transmission of the direct communication request (DCR). By doing so, only relay UEs will respond to the request, since the remote UEs do not support the relaying service type and therefore ignore this request. That is, the new layer-2 ID can be used to distinguish the SL connection setup (or link establishment) for the purpose of end-to-end communication between the two involved UEs (that is, legacy device to device, D2D, communication) and SL connection setup (or link establishment) for the purpose of relaying to the network. A relaying capable UE can choose which layer-2 ID to include depending on the purpose of the SL connection. Thereby, the layer-2 ID could also be used in the discovery procedure. In this approach, the layer-2 ID of the initiating UE (the remote UE) can be derived from the international mobile subscriber identity (IMSI) of the initiating UE. When a relay UE

receives a DCR request from a remote IoT UE and responds to the remote IoT UE, the pair of the layer-2 ID of the relay UE and remote UE is unique. This is because when a relay UE responds to the DCR request, the relay UE sets its source layer-2 ID derived from the IMSI of the relay UE, and destination layer-2 to the IMSI of the remote IoT UE. In the case when a remote UE receives a response from two different relay UE for its DCR transmission, the remote IoT UE can choose the relay UE which has higher signal strength at the remote IoT UE side.

Hence, in the method 500, the first message transmitted at step 503 may indicate that a link to be set up between the first WCD 401 and the second WCD 404 is intended for relaying of information from the first WCD 401 to a network (or to the network node 403) via the second WCD 404. The first message transmitted at step 503 may for example be a direct communication request (DCR) comprising a service identifier indicating a relaying service type. For more information about DCR, see the description above in the background section regarding Figure 2. The relaying service type may for example be mapped to a layer-2 identity of the second WCD 404. The first message received at step 602 in the method 600 may for example be the same message as the first message transmitted at step 503 in the method 500, and may therefore have the same properties.

In another embodiment, a new service class (or service type) called 'IoT remote UE' is defined, and when the relay UE wants to send broadcast information (such as sidelink synchronization signal block (SL-SSB)), to the remote IoT UEs, this 'IoT remote UE' service class can be mapped to the destination layer-2 ID. The SL-SSB may for example have a bitfield with a value indicating that the SL-SSB is intended for IoT remote UEs. In this way, the broadcast information from the relay UE will be detected by the remote IoT UEs only, and the legacy SL UEs won't detect this broadcast information from the relay UE. Another alternative for the SL-SSB for relaying is to define a new SL-SSB format (for example both in content and in frequency) so that this SL-SSB from the relay UE will only be detected by the remote IoT UEs (that is, the legacy SL UEs will not detect the new SL-SSB). The advantage of having a new SL-SSB for relaying is that the remote IoT UEs don't waste time and energy on decoding SL-SSB broadcasted by the legacy SL UEs.

Hence, in the methods 500 and 600, the first WCD 401 may have a certain service class (such as 'IoT remote UE', but some other name may also be used for the service class). As shown in Figure 8, the method 500 from Figure 5 may optionally comprise receiving 801 a message from the second WCD 404, where the message indicates that it is intended for WCDs of the certain service class. Similarly, as shown in Figure 9, the method 600 from Figure 6 may

optionally comprise transmitting 901 a message indicating that it is intended for WCDs of the certain service class. The message received from the second WCD 404 at step 801 (and transmitted by the second WCD 404 at step 901) may for example be a sidelink synchronization signal block (SL-SSB). The SL-SSB may for example have a bit field with a value indicating that the SL-SSB is intended for WCDs of the certain service class. The SL-SSB may for example have a format indicating that the SL-SSB is intended for WCDs of the certain service class.

Using priority information in the SCI transmission to reduce the collision rate

In the legacy NR-SL designed for V2X, if two or more UEs are transmitting 1st stage SCI in different subchannels of the same slot, and they reserve the same resource (subchannel) for their future transmissions, the future transmissions from all these UEs may collide. The remote UEs may not detect this risk of collision because they may not be able to receive 1st stage SCI from the other remote UEs at the same time as they transmit their own 1st stage SCI. Hence, the collision may not be prevented, and the collision may instead be detected later when the remote UE is not able to receive the scheduled transmissions. In one embodiment for NR-SL relaying, the transmitting remote UE includes a priority value in the 1st stage SCI, and if the future reservations from multiple remote UEs collide, then the relay UE can decide which remote UE is allowed to transmit its next packet in the reserved resource based on the priority value included in the 1st stage SCI. The relay UE can convey this information to the remote UEs (that is, the remote UEs that transmitted the 1st stage SCI with the reservation information to the relay UE) in the same slot over the physical sidelink feedback channel (PSFCH). In this way, collision probability can be reduced. This is illustrated in Figure 10. In the left part of Figure 10, several remote UEs schedule the same resource but do not detect each other's 1st stage SCI, and thereby not the collision. The remote UEs therefore make the transmissions in vain, whereby energy is wasted and successful transmissions are delayed. The right part of Figure 10 shows the scenario where the relay UE makes use of priority values of the traffic in the first stage SCIs to determine which remote UE that should be allowed to transmit, and which remote UEs that should be told to back off. In Figure 10, we assume that the priority value for UE-3 is higher than for UE-1 and UE-2.

An example scenario for illustrating the use of priority information will now be described with reference to Figures 11 and 12. Figure 11 shows optional extra steps 1101-1104 of the method 500 from Figure 5 and Figure 12 shows optional extra steps 1201-1205 of the method 600 from Figure 6. This example scenario may for example be used with the two-stage SCI and channel sensing setup of NR-SL, described above in the background section.

As shown in Figure 11, prior to the step 501 of selecting a resource for transmitting the first message to the second WCD 404, the first WCD 401 may optionally have:

- selected 1101 a second resource for transmitting the first message to the second WCD 404;
- 5 • transmitted 1102 a second control message indicating the selected second resource, wherein the second control message indicates a priority level; and
- received 1103 an indication from the second WCD 404 that the selected second resource is not granted for transmitting the first message to the second WCD 404.

The negative indication received at step 1103 may cause the first WCD 401 to perform the step 501. In other words, the step 501 of selecting a resource for transmitting the first message to the second WCD 404 may be performed in response to:

- receipt of an indication from the second WCD 404 that a previously selected resource is not granted for transmitting the first message to the second WCD 404.

The step 501 of selecting a resource for transmitting the first message to the second WCD 404 could also be performed in response to:

- absence of an indication from the second WCD 404 that a previously selected resource is granted for transmitting the first message to the second WCD 404.

As shown in Figure 12, prior to the step 601 of receiving the control message, the second WCD 404 may optionally have performed the following steps:

- receiving 1201, from the first WCD 401, the second control message (transmitted by the first WCD 401 at step 1102) indicating the selected second resource for transmission of the first message from the first WCD 401 to the second WCD 404, wherein the second control message indicates a priority level;
- 25 • monitoring 1202 for receipt of one or more control messages from one or more other WCDs than the first WCD; and
- if the monitoring 1202 leads to detection of a control message with higher priority level than the priority level of the second control message and which indicates that another WCD has also selected the second resource for transmission to the second WCD 404, transmitting 1203 an indication to the first WCD 401 that the selected second resource is not granted for transmitting the first message to the second WCD 401.

In the present scenario, the monitoring 1202 resulted in detection of a control message with higher priority level than the priority level indicated by the second control message and which indicates that another WCD has also selected the second resource for transmission to the second WCD 404. The second WCD 404 therefore transmitted 1203 the indication to the first WCD 401 that the selected second resource is not granted for transmitting the first message

to the second WCD 401. This caused the first WCD 401 to select a new resource at step 501 for transmitting the first message to the second WCD 404. The indication transmitted at step 1203 (and received at step 1103) may for example be transmitted via a physical sidelink feedback channel (PSFCH).

5

The control message transmitted at step 502 and received at step 601 may indicate a priority level. As shown in Figure 12, the method 600 may comprise the optional steps of

- monitoring 1204 for receipt of control messages from other WCDs than the first WCD 401, and
- 10 • if the monitoring does not lead to detection of a control message with higher priority level than the priority level of the control message from the first WCD 401 and which indicates that another WCD has selected the same resource as the first WCD 401 for transmission to the second WCD 404, transmitting 1205 an indication to the first WCD 401 that the selected resource is granted for transmitting the first message to the
- 15 second WCD 404.

The step 602 of receiving the first message may be performed after the step 1205 of transmitting the indication. The indication may for example be transmitted 1205 via a PSFCH.

If, on the other hand, the monitoring 1204 leads to detection of a control message with higher
20 priority level than the priority level indicated by the control message from the first WCD 401 and which indicates that another WCD has also selected the resource for transmission to the second WCD 404, the second WCD 404 may transmit an indication to the first WCD 401 that the selected resource is not granted for transmitting the first message to the second WCD 404. The second WCD may then select a new resource for the transmission.

25

The idea presented above with reference to Figure 10 may also be employed in a scenario without priority levels in the control messages transmitted at steps 1102 and 502 and received at step 1201 and 601. For example, if the second WCD 404 detects that several WCDs have scheduled transmissions at the same resource, the second WCD 404 may instruct all of these
30 WCDs to back off and reschedule their transmissions. This may prevent waste of power by the WCDs 401 and/or may reduce time until successful transmissions can be made by the WCDs to the second WCD 404. Hence, the optional steps 1201-1203 may be expressed like this:

- receiving 1201, from the first WCD 401, a second control message indicating a
35 selected second resource for transmission of the first message from the first WCD 401 to the second WCD 404;

- monitoring 1202 for receipt of one or more control messages from one or more other WCDs than the first WCD 401; and
- if the monitoring indicates that another WCD has also selected the second resource for transmission to the second WCD 404, transmitting 1203 an indication to the first WCD 401 that the selected second resource is not granted for transmitting the first message to the second WCD 404.

And the optional steps 1204-1205 may be expressed like this:

- monitoring 1204 for receipt of control messages from other WCDs than the first WCD 401; and
- if the monitoring does not indicate that another WCD has selected the same resource as the first WCD 401 for transmission to the second WCD 404, transmitting 1205 an indication to the first WCD 401 that the selected resource is granted for transmitting the first message to the second WCD 404.

As an extension of the approach described above with reference to Figure 10, the relay UE can, if needed, re-schedule the remote UE transmission by sending the scheduling information for example via an extended PSFCH or via a new physical channel. As an example, if the remote UE chooses a subchannel k , at slot m , the relay UE can respond to this selection using a scheduling Table 1 as given below.

Table 1: An example of a relay UE scheduling a remote UE

00	Remain on selected same subchannel k
01	Assigned subchannel is $k+1$
10	Assigned subchannel is $k-1$
11	NACK

For example, if a future collision between two remote UEs is identified by the relay UE, the relay UE may reschedule one of the remote UEs to avoid the collision. Note that rescheduling by the relay UE is also possible without using any priority information at all. For example, the relay UE could reschedule all remote UEs involved in a detected collision.

Hence, the indication received at step 1103 or 1104 shown in Figure 11 could indicate that a different resource is to be used for the transmission 503 of the first message instead of using the selected resource. The first WCD 401 could then transmit the first message in this different resource instead of in the first resource. This different resource may for example have a different frequency position than the resource selected by the first WCD 401, and/or a different time position (or position in time) than the resource selected by the first WCD 401. The monitoring performed by the second WCD 404 at step 1202 or 1204 shown in Figure 12 could

indicate/reveal that the resource selected by the first WCD 401 has also been selected by some other WCD (for example with a higher priority level than the first WCD 401). But the monitoring could also reveal/indicate that another resource is unoccupied/available for transmitting 503 the first message to the second WCD 404. The second WCD 404 could then
5 indicate this unoccupied/available resource to the first WCD 401 via the indication transmitted at step 1203 or 1205 shown in Figure 12.

An example scenario involving rescheduling by the relay UE will now be described with reference to Figures 13 and 14. Figure 13 is a flow chart of a method 1300 performed by the
10 first WCD 401 and which could be regarded as a modified version of the method 500. Figure 14 is a flow chart of a method 1400 performed by the second WCD 404 and which could be regarded as a modified version of the method 600.

The method 1300 comprises:

- 15 • selecting 501 a resource for transmission to the second WCD 404;
- transmitting 502 a control message indicating the selected resource;
- receiving 1301 an indication from the second WCD 404 that a second resource is to be used for the transmission to the second WCD 404 instead of using the selected resource; and
- 20 • transmitting 1302 a first message to the second WCD 404 in the second resource.

The steps 501 and 502 are the same steps as in the method 500, while the steps 1301 and 1302 involve the new second resource indicated by the second WCD 404 instead of a resource selected by the first WCD 401. The indication may for example be received 1301 via a PSFCH. The second resource may for example have a different frequency position than the
25 selected resource, and/or a different time position (or position in time) than the selected resource. The first message transmitted at step 1302 may for example be part of a link establishment procedure for establishing a link between the first WCD 401 and the second WCD 404 for relaying of information from the first WCD 401 to a network via the second WCD 404.

30 The method 1400 comprises:

- receiving 601, from the first WCD 401, the control message indicating the selected resource;
- monitoring 1401 for receipt of one or more control messages from one or more other
35 WCDs than the first WCD 401;

- if the monitoring indicates that another WCD has selected the same resource as the first WCD 401 for transmission to the second WCD 404, transmitting 1402 the indication to the first WCD 401 that a second resource is to be used for transmission to the second WCD 404 instead of using the selected resource for the transmission; and
- receiving 1403, from the first WCD 401, the first message in the second resource.

The step 601 is the same step as in the method 600, while the steps 1402 and 1403 involve the new second resource indicated by the second WCD 404 instead of a resource selected by the first WCD 401. The monitoring step 1401 may be of the same type as the optional monitoring step 1204 in the method 600. The indication may for example be transmitted 1402 via a PSFCH. The second resource may for example have a different frequency position than the selected resource, and/or a different time position (or position in time) than the selected resource. The first message received at step 1403 may for example be part of a link establishment procedure for establishing a link between the first WCD 401 and the second WCD 404 for relaying of information from the first WCD 401 to a network via the second WCD 404.

The control message transmitted at step 502 and received at step 601 may for example comprise priority information (such as a priority level or priority value) regarding the first message and/or regarding the first WCD 401. This priority information may for example be employed at step 1402 in the method 1400. Step 1402 may then be expressed as:

- if the monitoring 1401 leads to detection of a control message with higher priority level than the priority level indicated by the control message from the first WCD 401 and which indicates that another WCD has selected the same resource as the first WCD 401 for transmission to the second WCD 404, transmitting an indication to the first WCD 401 that a second resource is to be used for the transmission to the second WCD 404 instead of using the selected resource for the transmission.

Contention based initial connection establishment to reduce the UE power consumption

One embodiment for a connection establishment procedure (also referred to herein as a link establishment procedure) is that all the signaling and data exchange in the connection establishment procedure is contention-based (which could also be referred to as collision-based). In a slot, all the remote UEs (UEs sending the direct communication request, authentication response, security mode complete, etc.) may randomly select a subchannel for the transmission of respective signaling/data from the preconfigured set of subchannels (that is, resources). In this contention-based access, the remote UEs do not perform the channel

sensing described above in the background section. Hence, we can omit the two-stage SCI principle described above in the background section. This is because the idea of two stages of SCI is to reduce the complexity of the sensing procedure. In the two-stage SCI setup, the first stage SCI contains information on PSSCH resources, the priority of the transmission and future PSSCH reservation, and the second stage SCI contains the remaining scheduling information of the PSSCH (like modulation and coding scheme (MCS) and UE-specific DMRS) to assist the destination UE to decode the PSSCH. In the proposed contention-based approach, since the peer remote UEs are not performing the channel sensing (for SCI from other remote UEs), we can avoid the two-stage SCI principle. Hence, information on the priority of transmission, future resource reservation, and all the scheduling information of the PSSCH can be included in a single-stage SCI. Also, a remote UE only needs to be awake when it has a packet to transmit, and the rest of the time the remote UEs may stay in an idle state. This procedure is different from legacy SL designed for V2X, where the remote UEs have to be receiving to sense the resource occupation by the peer remote UEs. Avoiding the channel sensing at the remote UEs is beneficial for UE energy consumption and enables long battery life. This is particularly beneficial for remote IoT UEs.

Hence, in the method 500 from Figure 5, the first WCD 401 may not be required to (or mandated to, or expected to) perform channel sensing during at least a time period located between the transmission 502 of the control message and the transmission 503 of the first message. Channel sensing may for example include monitoring of one or more channels for receipt of transmissions. Channel sensing may for example include monitoring of one or more channels (such as PSCCH) for receipt of control messages (such as first stage SCI) from other WCDs. Channel sensing may for example include monitoring to detecting whether one or more resources of a channel is occupied by one or more other WCDs. It will be appreciated that even if the first WCD 401 is not required to (or mandated to, or expected to) perform channel sensing during at least a time period located between the transmission 502 of the control message and the transmission 503 of the first message, the first WCD 401 may not be forbidden to perform channel sensing during that time period. The first WCD 401 could for example perform channel sensing for other purposes than to detect first stage SCI from other WCDs. As shown in Figure 16, the method 500 from Figure 5 may comprise the optional step of keeping 1601 a receiver (or receiving circuitry) of the first WCD 401 inactive during at least a time period located between the transmission 502 of the control message and the transmission 503 of the first message. The receiver of the first WCD 401 may for example be at least partially shut down or at least partially deactivated during this time period. There may be no need for the first WCD 401 to use the receiver during this time period, so power may be saved by keeping the receiver inactive. A transmitter of the first WCD 401 may for example

also be kept inactive (or at least partially shut down or at least partially deactivated) during this time period.

Similarly, the first WCD 401 may not be required to (or mandated to, or expected to) perform channel sensing during at least a time period before transmitting 503 the control message. It will be appreciated that even if the first WCD 401 is not required to (or mandated to, or expected to) perform channel sensing during at least a time period before transmitting 503 the control message, the first WCD 401 may not be forbidden to perform channel sensing during that time period. The first WCD 401 could for example perform channel sensing for other purposes than to detect first stage SCI from other WCDs. As shown in Figure 16, the method 500 from Figure 5 may comprise the optional step of keeping 1602 a receiver (or receiving circuitry) of the first WCD inactive during at least a time period before transmitting 502 the control message. The receiver of the first WCD 401 may for example be at least partially shut down or at least partially deactivated during this time period. There may be no need for the first WCD 401 to use the receiver during this time period, so power may be saved by keeping the receiver inactive. A transmitter of the first WCD 401 may for example also be kept inactive (or at least partially shut down or at least partially deactivated) during this time period. The time period before transmitting 502 the control message (during which the receiver of the first WCD 401 is kept inactive) may for example be located immediately before transmitting 502 the control message. In other words, the receiver of the first WCD 401 may not have been active for a certain period of time when the control message is transmitted 502 by the first WCD 401.

Figure 15 illustrates the proposed contention based initial access approach. As shown in Figure 15, if the subchannel chosen by a remote UE at a particular slot is not chosen by any other remote UE, the transmission is considered successful, and the remote UE gets the notification from the relay UE about its transmission via the PSFCH (note that the existing PSFCH needs to be modified to accommodate this new signaling). The feedback notification via the PSFCH may for example be provided with an offset, such that the remote UE receives the notification one or more slots after the slot in which the remote UE sent the scheduling message to the relay UE. Upon the successful transmission of the current signaling/data, the remote UE selects (for example randomly) a resource for its next transmission (according to the signal flow shown in Figure 2). If two or more remote UEs choose the same subchannel at a particular slot, transmission from all those remote UEs is considered as collided (shown as box 1501 in Figure 15). The collided UEs perform the back-off mechanism and retransmit the collided SL message (the remote UE won't restart the link establishment procedure from the beginning).

In some embodiments, upon the successful transmission of the initial transmission (DCR), the remote UE does not randomly select the subsequent resources for transmission. Instead, all remote UEs use the same fixed pattern of resources for transmission of subsequent messages. This eliminates the risk of subsequent collisions between remote UEs if the DCRs did not collide. (Note however that a subsequent transmission can still collide with a DCR from a new remote UE, but the collision risk is greatly reduced). As a simple example, subsequent transmission can be sent on the same subchannel with a delay of 5 slots. This ensures that there will be no collisions with remote UEs which submit their DRC on another subchannel, nor with remote UEs which submit their DRC on in the same subchannel but with an offset of 1 to 4 slots. Note that offsets of less than 5 slots (for example an offset of 1 slot) may be employed to reduce latency. Messages could also be combined into a larger message which is transmitted in one attempt.

Hence, as shown in Figure 16, the method 500 from Figure 5 may comprise the optional steps of:

- receiving 1603 a second indication from the second WCD 404 that the first message has been successfully received by the second WCD 404; and
- in response to receiving 1603 the second indication
 - selecting 1604 a second resource for transmission of a second message to the second WCD; and
 - transmitting 1605 a second control message indicating the selected second resource.

The second indication may for example be received 1603 via a PSFCH. Alternatively,

- the first message may be a direct communication request and the second indication may be a direct link authentication request; or
- the first message may be a direct link authentication response and the second indication may be a direct link security mode command message; or
- the first message may be direct link security mode complete message and the second indication may be a direct communication accept message; or
- the first message may be a direct link release request and the second indication may be a direct link release accept message; or
- the first message may be a direct link keep alive request and the second indication may be a direct link keep alive response.

The second resource for transmission of the second message to the second WCD 404 may for example be selected at step 1604 based on a frequency position and/or time position of the resource selected at step 501 for transmission of the first message to the second WCD 404. The second resource may for example have a fixed (or predefined or preconfigured) position in time and/or frequency relative to the resource selected at step 501. The second resource for transmission of the second message to the second WCD 404 may for example have the same frequency position as the resource selected at step 501 for transmission of the first message to the second WCD 404. The second resource for transmission of the second message to the second WCD 404 may for example be (or be comprised in) the same subchannel as the resource selected at step 501 for transmission of the first message to the second WCD 404. The second resource for transmission of the second message to the second WCD 404 may for example have a certain predefined (or preconfigured) time offset relative to the resource selected at step 501 for transmission of the first message to the second WCD 404. The second resource for transmission of the second message to the second WCD 404 may for example be selected at step 1604 based on a frequency position and a time position of the resource selected at step 501 for transmission of the first message to the second WCD 404.

The first WCD 401 may for example employ a fixed pattern for selection of resources for transmission of subsequent messages in the link establishment procedure relative to the resource selected at step 501 for transmission of the first message. The first message may for example be a direct communication request.

As shown in Figure 17, the method 600 from Figure 6 may comprise the optional steps of

- transmitting 1701 a second indication to the first WCD 401 that the first message has been successfully received; and
- receiving 1702, from the first WCD 404, a second control message indicating a selected second resource for transmission of a second message from the first WCD 401 to the second WCD 404.

The second indication transmitted at step 1701 may be the same indication as the second indication received at step 1603. The second control message received at step 1702 may be the same control message as the second control message transmitted at step 1605. The first message received at step 602 may for example be a direct communication request.

The embodiments described above with reference to Figures 16 and 17 relate to a scenario where the first message transmitted at step 503 is successfully received by the second WCD 404. However, one or more earlier attempts may have been made by the first WCD 401 to

transmit the first message (or some other message) to the second WCD 404 before the successful transmission 503. In the method 500, the selection 501 of the resource for transmission 503 of the first message to the second WCD 404 may for example be performed in response to:

- 5 • receipt of an indication from the second WCD 401 that a message previously transmitted by the first WCD 401 has not been successfully received by the second WCD 404; or
- absence of an indication from the second WCD 404 that a message previously transmitted by the first WCD 401 has been successfully received by the second WCD
10 404.

Prior to the step of receiving 601 the control message, the method 600 may for example comprise the step of transmitting an indication to the first WCD 401 that a message previously transmitted by the first 401 WCD has not been successfully received by the second WCD 404.

15 Frame-level slotted aloha system for link establishment

The link establishment procedure (also referred to as a connection establishment procedure) described above in the background section with reference to Figure 2 can be based on a frame-level slotted aloha system. The motivation behind this approach is to reduce the sensing duration of the remote UEs, and hence to reduce the power consumed by the remote
20 UEs. Such reduced power consumption may be particularly useful for remote IoT devices. The purpose of the sensing performed by a remote UE is to find out the resources reserved by other remote UEs. In the approach proposed here, the relay UE performs this sensing since the relay UE knows, for example at a slot n , what are reserved resources in the future slots (from slot $n+1$) because the relay UE received the SCIs from the remote UEs in the
25 previous slots (before slot n) indicating the reserved resources in the future slots. We propose that this information on the resource reservation is conveyed to the remote UEs by the relay UE. In this way the sensing is performed by the relay UE instead, and remote UEs do not need to perform continuous sensing and instead only need to listen to one transmission from the relay UE. For this approach, we propose a new time window called
30 ‘SL frame’, which consists of a number N consecutive slots, where N is a positive integer. The SL frames are also referred to herein as blocks of time slots, since a SL frame is a block of consecutive N slots. At the beginning slot of each SL frame, the relay node broadcasts the available unoccupied resources in the ongoing SL frame, and the remote UEs monitor this broadcasted information. For example, if a remote UE has chosen an SL frame for its
35 DCR transmission (please note that the remote UE will only use a small portion of the selected SL frame, such as one subchannel in a slot within the selected SL frame), at the very first slot of this SL frame, the remote UE listens to the broadcast information from the

relay UE mentioning the unoccupied resources in the SL frame. Based on this information on the unoccupied resources in the SL frame, the remote UE can select/choose (for example randomly) a resource for its DCR transmission from a set of unoccupied resources in the SL frame. An advantage of this approach is that remote UEs only need to monitor the first slot of the SL frame which it has selected for the DCR transmission. However, since the first slot of a SL frame is employed by the relay UE to broadcast available resources to the remote UEs, resources in the first slot of each SL frame cannot be used for transmissions from the remote UEs. Also, at the transmission of DCR, a remote UE will be unaware of transmissions that were indicated in SCI from other remote UEs after the start of the current SL frame, so the collision risk may be slightly higher compared to solutions where the remote UEs monitor continuously for SCI from other UEs. For IoT applications, such potential issues may typically be acceptable in view of the reduced energy consumption at the remote UEs.

If two or more remote UEs choose the same resource for the DCR transmission, the transmission is considered as collided, and the collided UE perform the back-off mechanism and retransmits the DCR. If the DCR transmission is successful, the remote UE may reserve the same resource (for example subchannel and slot) for future transmission with a constant offset. The procedure is explained below with reference to Figure 18, which illustrates a frame level slotted aloha system with a fixed time offset resource reservation for future transmissions. However, as described in the preceding section, some other fixed time and frequency pattern may be employed by the remote UEs for subsequent transmissions (instead of using the same subchannel and a fixed time offset for each of the subsequent messages as shown in Figure 18).

In the next SL frame, the remote UE reserves a resource for its future transmission in the same slot and in the same subchannel as was used for the current transmission in the current SL frame, as shown in Figure 18. A more detailed explanation of Figure 18 is given in the next paragraph. If the subchannel chosen by a remote UE for a particular slot for its ongoing transmission is not chosen by any other remote UE, the ongoing transmission is considered as successful. If the current transmission is successful, most likely the future transmission will also be successful. This is because the current transmission is successful only when no other remote UE has chosen the resource chosen by the transmitting remote UE. Then the transmitting remote UE chooses the same frequency resource in the next SL frame for its future transmission and informs the relay UE so that it knows about this reservation. The relay UE then broadcast this information at the beginning of the next SL frame to all other remote UEs that plan to transmit the DCR in that SL frame. (However, the relay UE could omit/skip the broadcasting of this information in case there are no remote UE

transmissions to report. That is, absence of this broadcast message may indicate that all resources in the SL Frame are unoccupied). Hence the remote UEs in the next SL window will exclude the reserved resources for their DCR transmissions. The relay UE informs the remote UE whether its reservation is successful or not via the PSFCH channel. The remote UE may for example receive this feedback from the relay UE before the end of the ongoing SL frame in which the current transmission takes place. The feedback via the PSFCH channel may for example be provided with a delay (or offset) of 2 slots. In other words, after sending the reservation information, the remote UE waits for 2 slots to receive the scheduling feedback from the relay UE.

As shown in Figure 18, at an SL frame K, there are four remote UEs (UE-1, UE-2, UE-3, UE-4). These remote UEs are sending the SL messages as indicated by the patterns of the boxes. At the SL frame K, since all the remote UE choose a different subchannel for SL message transmission, the transmission from these remote UEs do not collide. In SL frame K+1, UE-1 which was sending the DCR in the SL frame K has reserved a resource for an authentication response. Similarly, UE-2 reserves a resource for security mode complete response, UE-3 reserves for unicast data, and so on. As we can observe, since all the remote UEs have selected slot number 2 in SL frame K, the remote UE will choose the same slot number in SL frame K+1 SL frame also. The subchannel reserved by all these remote UEs in SL frame K+1 is the same as that used in SL frame K. At the first slot of SL frame K+1, the relay UE broadcasts to all nearby remote UEs that in SL frame K+1, in the second slot, subchannel 1, 3, m and n are reserved, and that those subchannels should not be selected for DCR in the second slot. In Figure 18, there is no remote UEs which transmits the DCR in SL frame K+1. But in SL frame K+2, there is a new remote UE (UE-5), and hence based on the reservation made by UE-1, UE-2, and UE-3 in SL frame K+2, the relay UE indicated to UE-5 in the first slot of SL frame K+2 that subchannels 3, m, n in the second slot should not be used for its DCR transmission. In this way, collision in the resource selection of the reserved resource can be avoided. Please note that if there is another remote UE (let's say UE-6) which chooses subchannel 2 in slot number 2 of SL frame K+2, then DCR transmissions of UE-5 and UE-6 will collide.

Since the remote UEs are awake only during the data/signaling transmission and at the beginning of the SL frame, the power consumption of the remote UEs is reduced. Moreover, since the remote UEs reserve the resources for the transmission of the next packet with the help of the relay UE, the collision probability is decreased as well. This is because for sending the DCR, the remote UE chooses the resources from the unoccupied resources in an SL frame, and thus the selection of the resources does not collide with the reserved

resource by another remote UE. But still, there could be a collision if the new remote UEs sending the DCR selects the same resource from the unoccupied resources in the SL frame. Compared to NR-SL V2X described above in the background section, here we can omit the two-stage SCI principle, as the peer UEs are not sensing the SCI transmission in the subchannels. If the reservation is successful, the remote UE transmits the packet in the reserved subchannel. The remote UE then reserves a subchannel for its next transmission (for example with a fixed offset/delay, as described above). However, instead of using the same subchannel and a fixed offset for each new transmission, the remote UEs could employ a fixed pattern in time and frequency for its transmission. In other words, if transmission of the DCR is successful, then the remaining messages in the link establishment procedure may be transmitted in accordance with a fixed pattern relative to the resource used for the DCR. This will also prevent transmissions from different remote UEs from colliding (except for potential collisions of DCR of two new remote UEs in the same SL frame).

In view of the above ideas, Figures 19 and 20 are flow charts showing optional extra steps that could be included in the methods 500 and 600 from Figures 5 and 6.

As shown in Figure 20, the method 600 may optionally comprise:

- monitoring 2001 for control messages from one or more WCDs indicating that one or more resources located in a time period have been selected by the one or more WCDs for transmission of one or more messages to the second WCD 404; and
- transmitting 2002 a report indicating which resources are still available for transmission to the second WCD 404 during the time period.

The resource selected by the first WCD 401 at step 501 for transmission of the first message to the second WCD 404 may be selected from among the resources indicated in the report transmitted at step 2002. The report may for example indicate the available resources explicitly, or may indirectly indicate the available resource (for example by indicating the occupied resources, whereby the available resources may be deduced by the first WCD 401).

The time period referred to in step 2001 may for example be a block of time slots (which is also referred to above as a SL frame). The second WCD 404 may for example transmit 2002 the report at the beginning of the block of time slots (for example in the first slot of the block of time slots). The monitoring 2001 may for example be performed at least in a block of slots directly preceding the block of slots at which the report is transmitted 2002. The report may for example be omitted if the monitoring 2001 indicates that no resources in the time period (or block of slots) have been selected by a WCD for transmitting a message to the second WCD 404.

As shown in Figure 19, the method 500 may optionally comprise receiving 1904 a report from the second WCD 404, wherein the report indicates which resources are available for transmission to the second WCD 404 during a time period. The first resource may be selected
5 by the first WCD 401 from the resources indicated in the report. The report received at step 1904 may be the same report as the report transmitted at step 2002. The time period referred to at step 1904 may for example be a block of time slots (also referred to above as a SL frame). The first WCD 401 may for example receive the report at the beginning of the block of time slots.

10

The first WCD 401 may for example not be required to (or mandated to, or obliged to, or expected to) perform channel sensing during a time period located between receipt 1904 of the report and the transmission 503 of the first message. Channel sensing may for example include monitoring of a channel for receipt of transmissions. Channel sensing may for example
15 include monitoring of a channel (such as PSCCH) for receipt of control messages (such as SCI) from other WCDs. Channel sensing may for example include monitoring for detecting whether one or more resources of a channel is occupied by one or more other WCDs. It will be appreciated that even if the first WCD 401 is not required (or mandated to, or expected to) to perform channel sensing during a time period located between receipt 1904 of the report
20 and the transmission 503 of the first message, the first WCD 401 may not be forbidden to perform channel sensing during that time period. The first WCD 401 could for example perform channel sensing for other purposes than to detect first control messages from other WCDs.

25

As shown in Figure 19, the method 500 may optionally comprise keeping 1905 a receiver (or receiving circuitry) of the first WCD 401 inactive during a time period located between receipt 1904 of the report and the transmission 503 of the first message. The receiver of the first WCD 401 may for example be at least partially shut down or at least partially deactivated during this time period. There may be no need for the first WCD 401 to use the receiver during this time period, so power may be saved by keeping the receiver inactive. A
30 transmitter of the first WCD 401 may for example also be kept inactive during this time period.

As shown in Figure 19, the method 500 may optionally comprise

- selecting 1902 a block of time slots in which to transit the first message to the second
35 WCD 404; and
- monitoring 1903 a beginning of the selected block of time slots for the report.

The first WCD 401 may for example not be required to (or mandated to, or obliged to, or expected to) perform channel sensing during a block of time slots which directly precedes the selected block of time slots or directly succeeds the selected block of time slots. In other words, there may be no need for the first WCD 401 to perform channel sensing in other
5 blocks of time slots than the block of time slots that the first WCD 401 intends to use for transmitting 503 the first message. Channel sensing may for example include monitoring of a channel for receipt of transmissions. Channel sensing may for example include monitoring of a channel (such as PSCCH) for receipt of control messages (such as SCI) from other
10 WCDs. Channel sensing may for example include monitoring for detecting whether one or more resources of a channel is occupied by one or more other WCDs. It will be appreciated that even if the first WCD 401 is not required (or mandated to, or expected to) to perform channel sensing during a certain time period, the first WCD 401 may not be forbidden to perform channel sensing during that time period. The first WCD 401 could for example perform channel sensing for other purposes than to detect first control messages from other
15 WCDs.

As shown in Figure 19, the method 500 may optionally comprise keeping 1901 a receiver (or receiving circuitry) of the first WCD 401 inactive during a block of time slots which directly precedes the selected block of time slots or directly succeeds the selected block of time
20 slots. The receiver of the first WCD 401 may for example be at least partially shut down or at least partially deactivated during such a block of time slots. There may be no need for the first WCD 401 to use the receiver during this block of time slots, so power may be saved by keeping the receiver inactive. A transmitter of the first WCD 401 may for example also be kept inactive during this block of time slots.

Access Barring

Access barring may be employed to control the number of remote UEs (correspond to the first WCD 401) that try to access the relay UE (corresponds to the second WCD 404). The relay UE may for example compute a barring factor (or barring threshold) and indicate the
30 barring factor to the remote UEs. Each of the remote UEs may generate a random value according to some prescribed procedure. If the random value is below the barring factor, the remote UE is allowed to transmit to the relay UE.

Hence, as shown in Figure 21, the method 500 from Figure 5 may comprise the following
35 optional steps:

- receiving 2101 a transmission from the second WCD 404 indicating a barring factor (or barring threshold); and

- generating 2102 a random value.

One or more of the steps 501-503 may for example be performed in response to a relation between the barring factor and the random value. The steps 501-503 may for example be performed if the random value is below (or does not exceed) the barring factor. If the random value exceeds the barring factor, the second WCD 404 may for example refrain from transmitting messages to the second WCD 404. Another relation than 'larger than' or 'less than' may also be used between the barring factor and the random variable. For example, the barring factor and/or the random variable may be scaled before the comparison is performed.

As shown in Figure 22, the method 600 from Figure 6 may comprise the following optional step:

- indicating 2201 a barring factor to the first WCD 401.

The second WCD 404 may for example transmit the actual value of the barring factor, or may for example transmit an index indicating the value of the barring factor. The barring factor may for example be determined by the second WCD 404 or by a network to which the second WCD 404 has access. The barring factor may for example be based on a number of available resources and an estimated number of WCDs contending for transmission to the second WCD 404.

An explicit example will now be provided for how to determine the barring factor for the frame-level slotted aloha system described above in the section 'Frame-level slotted aloha system for initial link establishment'. Barring factors may be determined in similar ways for the systems proposed in the other sections above.

In the present example, the relay UE determines the access barring factor (or parameter, or threshold) at the beginning slot of each SL frame, depending on the reserved resources in the SL frame. The proposed method to determine the barring parameter at each SL frame employs the following equation

$$\text{System capacity} = -L \times \log(1 - \text{collision probability})$$

In the above equation, 'System capacity' defines the maximum number of devices that can perform the DCR transmission in an SL frame by randomly choosing an unoccupied resource (such as a subchannel and a slot) in the SL frame, with a given collision probability. L represents the number of unoccupied resources in the SL frame.

The system capacity varies with time, based on the reservations made by the remote UEs performing the transmissions in the previous SL-frames (and hence L varies with each SL frame). A relay UE is aware of the unoccupied resources in an SL frame as the resource reservation by a remote UE in the previous SL frames are approved by the relay UE.

5

In the frame-level access mechanism with a fixed pattern for consecutive messages in the link establishment procedure (such as in the example shown in Figure 18), only the DCR transmission is contention-based. The slot for the transmission of DCR by the remote UEs is selected uniformly in the given packet arrival rate. Hence the average number of remote UEs contending in an SL frame is calculated as follows:

10

$$Device(n) = \left(\frac{ND}{N_{slot}} \right) + CLP(n)$$

In the above equation, $Device(n)$ is the number of devices contending for DCR in a slot, ND is the total number of devices in the system, N_{slot} is the total number of slots within the given inter-packet arrival time, $CLP(n)$ is the average number of devices that attempts the DCR in the n^{th} slot upon its collision in the previous slots. The $CLP(n)$ is calculated as:

15

$$CLP(n) = \sum_{k=1}^{n-1} \psi_k^{n-1} \times Collided(k)$$

In the above equation, $Collided(k)$ is the number of collided UEs at the k^{th} slot and ψ_k^{n-1} is the probability that a remote UE collided at the k^{th} slot will fall on the transmission window of the $(n-1)^{th}$ slot for its next DCR attempt, and is given by:

20

$$\psi_k^{n-1} = \begin{cases} \frac{1}{\left\lfloor \frac{BW}{t_{slot}} \right\rfloor} & \text{if } k + \left\lfloor \frac{BW}{t_{slot1}} \right\rfloor < n \\ 0 & \text{if } k + \left\lfloor \frac{BW}{t_{slot}} \right\rfloor \geq n \end{cases}$$

In the above equation, t_{slot} is the slot duration, BW is the back-off window length. The relay UE can record the number of collided devices in each slot to calculate the $CLP(n)$. Now the number of the average number of devices sending the DCR in an SL frame is calculated by summing the number of $Device(n)$ of all the slots within an SL frame, as is represented as:

25

$$Device_{SL}(j) = \sum_{n=(j \times SFL)+1}^{(j+1) \times SFL} Device(n)$$

In the above equation, $Device_{SL}(j)$ is the average number of devices attempting the DCR in the j^{th} SL frame and SFL is the SL frame length. Now the barring factor for the j^{th} SL frame is given by:

$$\text{Barring factor } (j) = \frac{\text{System capacity } (j)}{\text{Devices}_{SL}(j)}$$

If, in an SL frame, the barring factor is less than 1, there is a probability that remote UEs attempting the DCR will have collision probability higher than the desired collision rate. Hence, if the barring factor is less than 1 for an SL frame, relay UE broadcasts the barring factor in the first slot of that SL frame. Before sending the DCR in the SL frame, a remote UE, generates a random value between 0 and 1, and if the generated value is less than the barring factor broadcast by the relay UE, the remote UE is allowed to send the direct communication request.

10 Small data transmission: Keep the link alive between the relay UE and remote UE to reduce the signaling overhead and power consumption

In some embodiments associated with the link establishment procedure described above in the background section with reference to Figure 2, the DCR, the data packet, and the direct link keep alive request are sent all together in a single transmission instead of being transmitted in separate messages/transmissions. In other words, a DCR transmission may be provided, where the data and the keep the link alive request is bundled in the same transmission. The procedure is as follows:

1. In a first time period, we cannot bundle all the SL messages in a single transmission since the remote UE does not have a security set up with the relay UE. Hence the remote UE (UE1) follows the link establishment procedure as shown in **Error! Reference source not found.** to set the authentication and security with the relay UE (UE2). The procedure described above with reference to Figure 18 may for example be followed for reserving the resources during the link establishment procedure in the first period. That is, small data transmission may for example be built upon the frame-level access procedure described above in the section 'Frame-level slotted aloha system for link establishment'. This means that the relay UE updates the remote UE on unoccupied resources in an SL frame at the first slot of the SL frame, and the remote UE may randomly choose a resource for the DCR from unoccupied resources in the SL frame. The resources for the next SL messages may for example be selected with a constant offset as described above with reference to Figure 18.
2. If a remote UE (UE1) has successfully transmitted a direct link keep alive request in the first time period, in the second period the remote UE may transmit the DCR, a data packet, and a direct link keep alive request bundled in a single transmission following contention-based access, using the saved PC5 link identifier. Here also the remote UE

randomly chooses resources from the unoccupied resources in an SL frame (updated by the relay UE) for the transmission (which bundles the DCR, Data, and direct link keep alive request). But in this time period, the remote UE does not have to reserve a resource for a next transmission, since the remote UE already sends all the SL messages in a single transmission. This procedure continues for the following time periods as well if contention-based access is successful. The small data-based link establishment procedure is shown in Figure 23. In case a remote UE (UE1) cannot successfully transmit the keep the link alive request, the link establishment procedure shown in Figure 2 is followed.

Figure 23 shows a keep the link alive procedure between a remote UE (UE1), and a relay UE (UE2). In the small data transmission shown in Figure 23, the dashed lines are not present in the second period onwards for keeping the link alive between the remote UE (UE1), and the relay UE (UE2). In the first period, all the signaling exchanges (solid and dashed lines) of Figure 23 are present as the remote UE has not yet set up the security with the relay UE.

In an alternative embodiment of the above, the SL small data transmission procedure above is performed but without including the content of the DCR in the SL small data packet. The existing PC5 link identifier between the remote UE and relay UE can be used to establish the link between the remote UE and the relay UE.

In some embodiments, the SL small data transmission procedure described above may be performed, but omitting the channel sensing altogether. The rationale is that even with channel sensing, the DCR will be transmitted contention-based, and hence with the risk of collision. With very few transmissions, the benefit of the channel sensing therefore diminishes.

After a link has been established between the first WCD 401 (corresponds to the remote UE) and the second WCD 404 (corresponds to the relay UE) through a link establishment procedure, the link may be kept alive by transmission of direct link keep alive requests. However, if a small data packet is to be transmitted from the first WCD 401 to the second WCD 404, a direct link keep alive request may be bundled together with this data packet to save signaling overhead. This can be done if the data packet is small enough to fit together with the direct link keep alive request in a resource (such as a subchannel in a slot), which is often the case for data from IoT devices. The reduced number of transmissions also reduces the risk of collisions, whereby power may be saved.

Hence, as shown in Figure 24, the method 500 from Figure 5 may comprise the following optional steps:

- selecting 2401 a second resource for transmission to the second WCD 404;
- transmitting 2402 a control message indicating the selected second resource; and
- 5 • transmitting 2403 a direct link keep alive request and a data packet together in the selected second resource.

As shown in Figure 25, the method 600 from Figure 6 may comprise the following optional steps:

- 10 • receiving 2501 the control message (which was transmitted at step 2402) indicating the selected second resource; and
- receiving 2502 the direct link keep alive request and the data packet together in the selected second resource.

Network control functionality

- 15 In at least some embodiments, the network determines if a relay UE may attach to the network. In at least some embodiments, it is up to network control which of the different solutions (presented in the preceding sections of the detailed description) should be applied by the relay UE and the remote UE. In one example, a request from the relay UE to the gNodeB is transmitted to ask permission to act as a relay. Additional information can for example be
- 20 included with the request, such as which solutions to apply, whether to use gNodeB controlled radio resources or using a pre-determined pool of radio resources (mode 1 or mode 2), etc. The gNodeB then either grants or denies this request and can include the configuration which the relay UE should apply, for example with regard to which solution to apply (such as contention-based SL transmission or sensing based SL transmission), mode 1 or mode 2
- 25 radio resource allocation, cell barring, small data transmission, etc.

Hence, as shown in Figure 27, the method 600 from Figure 6 may optionally comprise:

- transmitting 2701 a request to the network node 403 for permission to act as a relay for information from one or more other WCDs; and
- 30 • receiving 2702 a grant or rejection from the network node 403.

As shown in Figure 27, the method 600 from Figure 6 may optionally comprise:

- receiving 2703, from the network node 403 in a network, an indication regarding which of a collection of approaches to apply for performing a link establishment procedure with the first WCD 401 for relaying of information from the first WCD 401 to the network
- 35 via the second WCD 404.

As shown in Figure 27, the method 600 from Figure 6 may optionally comprise:

- providing 2704, to the first WCD 401, an indication regarding which of a collection of approaches to apply for performing a link establishment procedure with the second WCD 404 for relaying of information from the first WCD 401 to a network via the second WCD 404.

5 As shown in Figure 26, the method 500 from Figure 5 may optionally comprise:

- receiving 2601, from the second WCD 404 or from the network node 403, an indication which of a collection of approaches to apply for performing a link establishment procedure with the second WCD 404 for relaying of information from the first WCD 401 to a network via the second WCD 404.

10 The collection of approaches referred to in the method steps 2703, 2704 and 2601 may for example include one or more of the approaches described in the preceding section of the detailed description.

15 If relay UEs are used for different purposes or services, Layer-2 IDs for relaying as described in the section 'Layer-2 IDs corresponds to the relaying function' may for example be used for differentiation and may be allocated by the network or the gNodeB.

Embodiments of WCDs, network nodes, computer programs etc.

Figure 28 illustrates an example of a communications network (or communications system) 20 2800 in which embodiments of the present disclosure may be implemented. In the present example, the communication network 2800 is a cellular communication system, such as a 5G system (5GS) including a Next Generation RAN (NG-RAN) (also referred to herein as a NR RAN), an Evolved Packet System (EPS) including an LTE RAN, or the like.

In the present example, the RAN includes base stations 2802-1 and 2802-2, which in the NG- 25 RAN are referred to as gNBs (NR base station) or ng-eNBs (LTE RAN nodes connected to 5GC) and in the LTE RAN are referred to as eNBs, controlling corresponding (macro) cells 2804-1 and 2804-2. The base stations 2802-1 and 2802-2 are generally referred to herein collectively as base stations 2802 and individually as base station 2802. Likewise, the (macro) cells 2804-1 and 2804-2 are generally referred to herein collectively as (macro) cells 2804 and 30 individually as (macro) cell 2804. The RAN may also include a number of low power nodes 2806-1 through 2806-4 controlling corresponding small cells 2808-1 through 2808-4. The low power nodes 2806-1 through 2806-4 can be small base stations (such as pico or femto base stations) or Remote Radio Heads (RRHs), or the like. Notably, while not illustrated, one or more of the small cells 2808-1 through 2808-4 may alternatively be provided by the base 35 stations 2802. The low power nodes 2806-1 through 2806-4 are generally referred to herein collectively as low power nodes 2806 and individually as low power node 2806. Likewise, the small cells 2808-1 through 2808-4 are generally referred to herein collectively as small cells

2808 and individually as small cell 2808. The communications network 2800 also includes a core network 2810, which in the 5GS is referred to as the 5G core (5GC). The base stations 2802 (and optionally the low power nodes 1406) are connected to the core network 2810.

5 The base stations 2802 and the low power nodes 2806 provide service to wireless communication devices (WCDs) 2812-1 through 2812-5 in the corresponding cells 2804 and 2808. The WCDs 2812-1 through 2812-5 are generally referred to herein collectively as WCDs 2812 and individually as WCD 2812. The WCDs 2812 may for example be UEs, but the present disclosure is not limited thereto. The first WCD 401 and/or the second WCD 404
10 described above with reference to Figure 4 may for example be one of the WCDs 2812 in Figure 28. The network node 403 described above with reference to Figure 4 may for example be one of the base stations 2802 or the low power nodes 2806 in Figure 28.

The methods 500 and 1300 described above with reference to Figures 5, 8, 11, 13, 16, 19,
15 21, 24 and 26 represent a first aspect of the present disclosure. The first WCD 401 described above with reference to Figure 4 represents a second aspect of the present disclosure. The first WCD 401 may for example be configured to perform the method of any of the embodiments (or example implementations) of the first aspect described above. The first WCD 401 may for example be configured to perform the method 500 (with or without any of the
20 optional features described above) or the method 1300.

The first WCD 401 may for example comprise means configured to cause the first WCD 401 to perform the method of any of the embodiments (or example implementations) of the first aspect described above. It will be appreciated that the first WCD 401 in Figure 4 need not
25 necessarily comprise all those components described below with reference to Figure 29.

The first WCD 401 may for example comprise processing circuitry (or one or more processors) configured to cause the first WCD 401 to perform the method of any of the embodiments (or example implementations) of the first aspect described above.

30

The first WCD 401 may for example comprise processing circuitry (or one or more processors) and a memory, the memory containing instructions executable by the processing circuitry whereby the first WCD 401 is operative to perform the method of any of the embodiments (or example implementations) of the first aspect described above.

35

In some embodiments, a computer program includes instructions which, when executed by processing circuitry (or one or more processors), cause the processing circuitry to carry out

the functionality of the first WCD 401 according to the method of any of the embodiments (or example implementations) of the first aspect described above.

In some embodiments, a carrier comprises the aforementioned computer program. The carrier is one of an electronic signal, an optical signal, a radio signal, or a computer readable storage medium (for example a non-transitory computer readable medium such as memory).

The methods 600 and 1400 described above with reference to Figures 6, 9, 12, 14, 17, 20, 22, 25 and 27 represent a third aspect of the present disclosure. The second WCD 404 described above with reference to Figure 4 represents a fourth aspect of the present disclosure. The second WCD 404 may for example be configured to perform the method of any of the embodiments (or example implementations) of the second aspect described above. The second WCD 404 may for example be configured to perform the method 600 (with or without any of the optional features described above) or the method 1400.

The second WCD 404 may for example comprise means configured to cause the second WCD 404 to perform the method of any of the embodiments (or example implementations) of the third aspect described above. It will be appreciated that the second WCD 404 in Figure 4 need not necessarily comprise all those components described below with reference to Figure 29.

The second WCD 404 may for example comprise processing circuitry (or one or more processors) configured to cause the second WCD 404 to perform the method of any of the embodiments (or example implementations) of the third aspect described above.

The second WCD 404 may for example comprise processing circuitry (or one or more processors) and a memory, the memory containing instructions executable by the processing circuitry whereby the second WCD 404 is operative to perform the method of any of the embodiments of the third aspect described above.

In some embodiments, a computer program includes instructions which, when executed by processing circuitry (or one or more processors), cause the processing circuitry to carry out the functionality of the second WCD 404 according to the method of any of the embodiments (or example implementations) of the third aspect described above.

In some embodiments, a carrier comprises the aforementioned computer program. The carrier is one of an electronic signal, an optical signal, a radio signal, or a computer readable storage medium (for example a non-transitory computer readable medium such as memory).

5 Figure 29 is a schematic block diagram of a WCD 2901 according to some embodiments of the present disclosure. The first WCD 401 and/or the second WCD 404, described above with reference to Figure 4, may for example be of the same type as the WCD 2901. As illustrated, the WCD 2901 includes one or more processors 2902 (for example Central Processing Units (CPUs), Application Specific Integrated Circuits (ASICs), Field
10 Programmable Gate Arrays (FPGAs), and/or the like), one or more memories 2904 (for example Read Only Memories (ROMs), Random Access Memories (RAMs), cache memories, flash memory devices, optical storage devices, and/or the like), and one or more transceivers 2906 each including one or more transmitters 2908 and one or more receivers 2910 coupled to one or more antennas 2912. The transceiver(s) 2906 includes radio-front
15 end circuitry connected to the antenna(s) 2912 that is configured to condition signals communicated between the antenna(s) 2912 and the processor(s) 2902, as will be appreciated by those of ordinary skill in the art. The processor(s) 2902 is also referred to herein as processing circuitry. The transceiver(s) 2906 is also referred to herein as radio circuitry. In some embodiments, the functionality of the WCD 2901 described above may be
20 fully or partially implemented in software (that is, for example stored in the memory 2904 and executed by the processor(s) 2902). Note that the WCD 2901 may include additional components not illustrated in Figure 29 such as, for example, one or more user interface components (for example an input/output interface including a display, buttons, a touch screen, a microphone, a speaker(s), and/or the like and/or any other components for
25 allowing input of information into the WCD 2901 and/or allowing output of information from the WCD 2901), a power supply (for example a battery and associated power circuitry), etc.

Figure 30 is a schematic block diagram of a network node 3001 according to some embodiments of the present disclosure. The network node 403 described above with
30 reference to Figure 4 may for example be of the same type as the network node 3001. The network node 3001 may be, for example, a base station 2802 or 2806 or a network node that implements all or part of the functionality of a base station. As illustrated, the network node 3001 includes a control system 3002 that includes one or more processors 3004 (for example CPUs, ASICs, FPGAs, and/or the like), one or more memories 3006 (for example
35 ROMs, RAMs, cache memories, flash memory devices, optical storage devices, and/or the like), and a network interface 3008. The one or more processors 3004 are also referred to herein as processing circuitry. In addition, the network node 3001 includes one or more radio

units 3010 that each includes one or more transmitters 3012 and one or more receivers 3014 coupled to one or more antennas 3016. The radio unit(s) 3010 may be referred to or be part of radio interface circuitry. In some embodiments, the radio unit(s) 3010 is external to the control system 3002 and connected to the control system 3002 via, for example, a wired
5 connection (for example, an optical cable). However, in some other embodiments, the radio unit(s) 3010 and potentially the antenna(s) 3016 are integrated together with the control system 3002. The one or more processors 3004 operate to provide one or more functions of a network node 3001 as described herein. In some embodiments, the function(s) are implemented in software that is stored, for example, in the memory 3006 and executed by
10 the one or more processors 3004.

Figure 31 is a schematic block diagram that illustrates a virtualized embodiment of the network node 3001 according to some embodiments of the present disclosure. As used herein, a “virtualized” network node is an implementation of the network node 3001 in which
15 at least a portion of the functionality of the network node 3001 is implemented as a virtual component(s) (for example via a virtual machine(s) executing on a physical processing node(s) in a network(s)). As illustrated, in this example, the network node 3001 includes one or more processing nodes 3100 coupled to or included as part of a network(s) 3102. Each processing node 3100 includes one or more processors 3104 (for example, CPUs, ASICs, FPGAs, and/or the like), one or more memories 3106 (for example ROMs, RAMs, cache
20 memories, flash memory devices, optical storage devices, and/or the like), and a network interface 3108. The network node 3001 may include the control system 3002 and/or the one or more radio units 3010, as described above. If present, the control system 3002 or the radio unit(s) 3010 are connected to the processing node(s) 3100 via the network 1702.

In this example, functions 3010 of the network node 3001 described herein are implemented at the one or more processing nodes 3100 or distributed across the one or more processing nodes 3100 and the control system 3002 and/or the radio unit(s) 3010 in any desired
25 manner. In some particular embodiments, some or all of the functions 3010 of the network node 3001 described herein are implemented as virtual components executed by one or more virtual machines implemented in a virtual environment(s) hosted by the processing node(s) 3001.
30

Any appropriate steps, methods, features, functions, or benefits disclosed herein may be performed through one or more functional units or modules of one or more virtual
35 apparatuses. Each virtual apparatus may comprise a number of these functional units. These functional units may be implemented via processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may

include Digital Signal Processor (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as Read Only Memory (ROM), Random Access Memory (RAM), cache memory, flash memory devices, optical storage devices, etc.

- 5 Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein. In some implementations, the processing circuitry may be used to cause the respective functional unit to perform corresponding functions according one or more embodiments of the present disclosure.
- 10 The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

CLAIMS

1. A method (500) at a first wireless communication device (401), WCD, the method comprising:

selecting (501) a resource for transmission to a second WCD (404);

5 transmitting (502) a control message indicating the selected resource; and

transmitting (503) a first message to the second WCD in the selected resource,

wherein the first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD, wherein the first WCD is not required to perform channel
10 sensing during at least a time period located between the transmission of the control message and the transmission of the first message.

2. The method of claim 1, further comprising:

keeping (1601) a receiver of the first WCD inactive during at least a time period

15 located between the transmission of the control message and the transmission of the first message.

3. The method of any of the preceding claims, further comprising:

keeping (1602) a receiver of the first WCD inactive during at least a time period

20 before transmitting the control message.

4. The method of any of the preceding claims, wherein the first message is:

a direct communication request; or

a direct link authentication response; or

25 a direct link security mode complete message; or

a direct link release request; or

a direct link keep alive request.

5. The method of any of the preceding claims, further comprising:

30 receiving (1104) an indication from the second WCD that the selected resource is granted for transmitting the first message to the second WCD, wherein the first message is transmitted in response to receipt of the indication.

6. The method of claim 5, wherein the indication is received via a physical sidelink feedback
35 channel (PSFCH).

7. The method of any of the preceding claims, wherein the selection of the resource for transmission to the second WCD is performed in response to:

receipt of an indication from the second WCD that a previously selected resource is not granted for transmitting the first message to the second WCD; or

5 absence of an indication from the second WCD that a previously selected resource is granted for transmitting the first message to the second WCD.

8. The method of any of the preceding claims, further comprising:

10 receiving (1603) a second indication from the second WCD that the first message has been successfully received by the second WCD.

9. The method of claim 8, wherein the second indication is received via a physical sidelink feedback channel (PSFCH).

15 10. The method of claim 8, wherein:

the first message is a direct communication request and the second indication is a direct link authentication request; or

the first message is a direct link authentication response and the second indication is a direct link security mode command message; or

20 the first message is direct link security mode complete message and the second indication is a direct communication accept message; or

the first message is a direct link release request and the second indication is a direct link release accept message; or

25 the first message is a direct link keep alive request and the second indication is a direct link keep alive response.

11. The method of any of claims 8-10, further comprising, in response to receiving the second indication:

30 selecting (1604) a second resource for transmission of a second message to the second WCD; and

transmitting (1605) a second control message indicating the selected second resource.

12. The method of claim 11, wherein the second resource for transmission of the second message to the second WCD is selected based on a frequency position and/or time position of the resource for transmission of the first message to the second WCD.

13. The method of claim 12, wherein the second resource for transmission of the second message to the second WCD has the same frequency position as the resource for transmission of the first message to the second WCD.

5 14. The method of any of claims 12-13, wherein the second resource for transmission of the second message to the second WCD is selected based on a frequency position and time position of the resource for transmission of the first message to the second WCD.

10 15. The method of any of claims 11-14, wherein the first WCD employs a fixed pattern for selection of resources for transmission of subsequent messages in the link establishment procedure relative to the resource selected for transmission of the first message.

16. The method claim 15, wherein the first message is a direct communication request.

15 17. The method of any of the preceding claims, wherein the selection of the resource for transmission to the second WCD is performed in response to:

receipt of an indication from the second WCD that a message previously transmitted by the first WCD has not been successfully received by the second WCD; or

20 absence of an indication from the second WCD that a message previously transmitted by the first WCD has been successfully received by the second WCD.

18. The method of any of the preceding claims, further comprising:

receiving (1904) a report from the second WCD, the report indicating which resources are available for transmission to the second WCD during a time period,
25 wherein the first resource is selected by the first WCD from the resources indicated in the report.

19. The method of claim 18, wherein said time period is a block of time slots, and wherein the first WCD receives the report at the beginning of the block of time slots.

30

20. The method of claim 19, further comprising:

selecting (1902) a block of time slots in which to transmit the first message to the second WCD; and

monitoring (1903) a beginning of the selected block of time slots for the report.

35

21. The method of claim 20, wherein the first WCD is not required to perform channel sensing during a block of time slots which directly precedes the selected block of time slots or directly succeeds the selected block of time slots.

5 22. The method of any of claims 20-21 further comprising:

keeping (1901) a receiver of the first WCD inactive during a block of time slots which directly precedes the selected block of time slots or directly succeeds the selected block of time slots.

10 23. The method of any of claims 18-22, wherein the first WCD is not required to perform channel sensing during a time period located between receipt of the report and the transmission of the first message.

24. The method of any of claims 18-23, further comprising:

15 keeping (1905) a receiver of the first WCD inactive during a time period located between receipt of the report and the transmission of the first message.

25. The method of any of the preceding claims, wherein the first WCD selects the resource for transmission to the second WCD randomly from a collection of resources.

20

26. The method of any of the preceding claims, wherein the first WCD selects the resource for transmission to the second WCD from a collection of resources, wherein the collection of resources is:

25 indicated by the second WCD; or
determined by the first WCD; or
predefined.

27. The method of any of the preceding claims, wherein the resource for transmission to the second WCD includes one or more subcarriers in one or more symbols in one or more slots.

30

28. The method of any of the preceding claims, wherein the control message comprises priority information regarding the first message and/or regarding the first WCD.

29. The method of any of the preceding claims, further comprising:

35 receiving (1301) an indication from the second WCD that a second resource is to be used for the transmission of the first message instead of using the selected resource,

wherein the WCD transmits the first message in the second resource instead of in the selected resource.

30. The method of claim 29, wherein the indication is received via a physical sidelink feedback channel (PSFCH).

31. The method of any of claims 29-30, wherein the second resource has:
a different frequency position than the selected resource; and/or
a different time position than the selected resource.

32. The method of any of the preceding claims, wherein the first message indicates that a link to be set up between the first WCD and the second WCD is intended for relaying of information from the first WCD to the network via the second WCD.

33. The method of claim 32, wherein the first message is a direct communication request comprising a service identifier indicating a relaying service type.

34. The method of claim 33, wherein the relaying service type is mapped to a layer-2 identity of the second WCD.

35. The method of any of the preceding claims, wherein the first WCD has a certain service class, and wherein the method further comprises:
receiving (801), from the second WCD, a message indicating that it is intended for WCDs of the certain service class.

36. The method of claim 35, wherein the message received from the second WCD is a sidelink synchronization signal block, SL-SSB, and wherein the SL-SSB has:

a bit field with a value indicating that the SL-SSB is intended for WCDs of the certain service class; or

a format indicating that the SL-SSB is intended for WCDs of the certain service class.

37. The method of any of the preceding claims, further comprising:

receiving (2101) a transmission from the second WCD indicating a barring factor;

and

generating (2102) a random value,

wherein one or more of the following steps is performed in response to a relation between the barring factor and the random value:

- the selection of the resource for transmission to the second WCD;
- the transmission of the control message indicating the selected resource; and
- 5 the transmission of the first message to the second WCD on the selected resource.

38. The method of any of the preceding claims, further comprising, after a link has been established between the first WCD and the second WCD through the link establishment procedure:

- 10 selecting (2401) a second resource for transmission to the second WCD;
- transmitting (2402) a control message indicating the selected second resource; and
- transmitting (2403) a direct link keep alive request and a data packet together in the selected second resource.

15 39. The method of any of the preceding claims, further comprising:

receiving (2601), from the second WCD or from a network node, an indication which of a collection of approaches to apply for performing the link establishment procedure with the second WCD for relaying of information from the first WCD to the network via the second WCD.

20

40. A method (600) at a second wireless communication device (404), WCD, the method comprising:

- receiving (601), from a first WCD (401), a control message indicating a selected resource; and
- 25 receiving (602), from the first WCD, a first message in the selected resource, wherein the first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD.

30 41. The method of claim 40, wherein the first message is:

- a direct communication request; or
- a direct link authentication response; or
- a direct link security mode complete message; or
- a direct link release request; or
- 35 a direct link keep alive request.

42. The method of any of claims 40-41, further comprising:

monitoring (1204) for receipt of control messages from other WCDs than the first WCD; and

if the monitoring does not indicate that another WCD has selected the same resource as the first WCD for transmission to the second WCD, transmitting (1205) an indication to the first WCD that the selected resource is granted for transmitting the first message to the second WCD, wherein the first message is received after transmitting the indication.

43. The method of any of claims 40-41, wherein the control message indicates a priority level, the method further comprising:

monitoring (1204) for receipt of control messages from other WCDs than the first WCD; and

if the monitoring does not lead to detection of a control message with higher priority level than the priority level of the control message from the first WCD and which indicates that another WCD has selected the same resource as the first WCD for transmission to the second WCD, transmitting (1205) an indication to the first WCD that the selected resource is granted for transmitting the first message to the second WCD, wherein the first message is received after transmitting the indication.

44. The method of any of claims 42-43, wherein the indication is transmitted via a physical sidelink feedback channel (PSFCH).

45. The method of any claims 40-44, further comprising, prior to receiving the control message:

receiving (1201), from the first WCD, a second control message indicating a selected second resource for transmission of the first message from the first WCD to the second WCD;

monitoring (1202) for receipt of control messages from other WCDs than the first WCD; and

if the monitoring indicates that another WCD has also selected the second resource for transmission to the second WCD, transmitting (1203) an indication to the first WCD that the selected second resource is not granted for transmitting the first message to the second WCD.

46. The method of any claims 40-44, further comprising, prior to receiving the control message:

receiving (1201), from the first WCD, a second control message indicating a selected second resource for transmission of the first message from the first WCD to the second WCD, wherein the second control message indicates a priority level;

monitoring (1202) for receipt of control messages from other WCDs than the first WCD; and

if the monitoring leads to detection of a control message with higher priority level than the priority level of the second control message and which indicates that another WCD has also selected the second resource for transmission to the second WCD, transmitting (1203) an indication to the first WCD that the selected second resource is not granted for transmitting the first message to the second WCD.

47. The method of any of claims 45-46, wherein the indication that the selected second resource is not granted for transmitting the first message to the second WCD is transmitted via a physical sidelink feedback channel (PSFCH).

48. The method of any of claims 40-47, further comprising:

transmitting (1701) a second indication to the first WCD that the first message has been successfully received.

49. The method of claim 48, wherein the second indication is transmitted via a physical sidelink feedback channel (PSFCH).

50. The method of claim 48, wherein:

the first message is a direct communication request and the second indication is a direct link authentication request; or

the first message is a direct link authentication response and the second indication is a direct link security mode command message; or

the first message is direct link security mode complete message and the second indication is a direct communication accept message; or

the first message is a direct link release request and the second indication is a direct link release accept message; or

the first message is a direct link keep alive request and the second indication is a direct link keep alive response.

51. The method of any of claims 48-50, further comprising, after transmitting the second indication:

receiving (1702), from the first WCD, a second control message indicating a selected second resource for transmission of a second message from to the first WCD to the second WCD.

5 52. The method of claim 51, wherein the second resource for transmission of the second message is based on a frequency position and/or time position of the resource in which the first message is received.

10 53. The method of claim 52, wherein the second resource for transmission of the second message has the same frequency position as the resource in which the first message is received.

15 54. The method of any of claims 52-53, wherein the second resource for transmission of the second message is based on a frequency position and time position of the resource in which the first message is received.

20 55. The method of any of claims 51-54, wherein the first WCD employs a fixed pattern for resources for transmission of subsequent messages in the link establishment procedure relative to the resource used for transmission of the first message.

56. The method claim 55, wherein the first message is a direct communication request.

25 57. The method of any of claims 40-56, further comprising, prior to receiving the control message:

transmitting an indication to the first WCD that a message previously transmitted by the first WCD has not been successfully received by the second WCD.

58. The method of any claims 40-57, further comprising:

30 monitoring (2001) for one or more control messages from one or more WCDs indicating that one or more resources located in a time period have been selected by the one or more WCDs for transmission of one or more messages to the second WCD; and
transmitting (2002) a report indicating which resources are still available for transmission to the second WCD during the time period,
wherein the selected resource for transmission of the first message is from among the
35 resources indicated in the report.

59. The method of claim 58, wherein said time period is a block of time slots, and wherein the second WCD transmits the report at the beginning of the block of time slots.

60. The method of claim 59, wherein the monitoring is performed at least in a block of slots
5 directly preceding the block of slots at which the report is transmitted.

61. The method of any of claims 58-60, wherein the report is omitted if the monitoring indicates that no resources in said time period have been selected by a WDC for transmitting a message to the second WCD.
10

62. The method of any claims 40-61, further comprising:
indicating to the first WCD a collection of resources from which to select the resource for transmission of the first message to the second WCD.

15 63. The method of any of claims 40-62, wherein the resource for transmission of the first message to the second WCD includes one or more subcarriers in one or more symbols in one or more slots.

64. The method of any of claims 40-63, wherein the control message comprises priority
20 information regarding the first message and/or regarding the first WCD.

65. The method of any of claims 40-64, further comprising:
monitoring (1401) for receipt of one or more control messages from one or more other WCDs than the first WCD; and
25 if the monitoring indicates that another WCD has selected the same resource as the first WCD for transmission to the second WCD, transmitting (1402) an indication to the first WCD that a second resource is to be used for the transmission of the first message instead of using the selected resource,
wherein the second WCD receives the first message in the second resource instead of in the
30 selected resource.

66. The method of any of claims 40-64, wherein the control message from the first WCD indicates a priority level, and wherein the method further comprises:

monitoring (1401) for receipt of one or more control messages from one or more
35 other WCDs than the first WCD; and

if the monitoring leads to detection of a control message with higher priority level than the priority level of the control message from the first WCD and which indicates that

another WCD has selected the same resource as the first WCD for transmission to the second WCD, transmitting (1402) an indication to the first WCD that a second resource is to be used for the transmission of the first message instead of using the selected resource, wherein the second WCD receives the first message in the second resource instead of in the selected resource.

67. The method of any of claims 65-66, wherein the indication is transmitted via a physical sidelink feedback channel (PSFCH).

68. The method of any of claims 65-67, wherein the second resource has:
a different frequency position than the selected resource; and/or
a different time position than the selected resource.

69. The method of any of claims 40-68, wherein the first message indicates that a connection to be set up between the first WCD and the second WCD is intended for relaying of information from the first WCD to the network via the second WCD.

70. The method of claim 69, wherein the first message is a direct communication request comprising a service identifier indicating a relaying service type.

71. The method of claim 70, wherein the relaying service type is mapped to a layer-2 identity of the second WCD.

72. The method of any of claims 40-71, wherein the first WCD has a certain service class, and wherein the method further comprises:

transmitting (901) a message indicating that it is intended for WCDs of the certain service class.

73. The method of claim 72, wherein the transmitted message is a sidelink synchronization signal block, SL-SSB, and wherein the SL-SSB has:

a bit field with a value indicating that the SL-SSB is intended for WCDs of the certain service class; or

a format indicating that the SL-SSB is intended for WCDs of the certain service class.

74. The method of any of claims 40-73, further comprising:
indicating (2201) a barring factor to the first WCD.

5 75. The method of claim 74, wherein the barring factor is based on a number of available resources and an estimated number of WCDs contending for transmission to the second WCD.

76. The method of any of claims 40-75, further comprising, after a link has been established
10 between the first WCD and the second WCD through the link establishment procedure:
receiving (2501) a control message indicating a selected second resource; and
receiving (2502) a direct link keep alive request and a data packet together in the
selected second resource.

15 77. The method of any of claims 40-76, further comprising:
transmitting (2701) a request to a network node for permission to act as a relay
for information from one or more other WCDs; and
receiving (2702) a grant or rejection from the network node.

20 78. The method of any of claims 40-77, further comprising:
receiving (2703), from a network node in the network, an indication regarding which
of a collection of approaches to apply for performing the link establishment procedure with
the first WCD for relaying of information from the first WCD to the network via the second
WCD.

25 79. The method of any of claims 40-78, further comprising:
providing (2704), to the first WCD, an indication regarding which of a collection of
approaches to apply for performing the link establishment procedure with the second WCD
for relaying of information from the first WCD to the network via the second WCD.

30 80. A first wireless communication device (401), WCD, configured to:
select a resource for transmission to a second WCD (404);
transmit a control message indicating the selected resource; and
transmit a first message to the second WCD in the selected resource,
35 wherein the first message is part of a link establishment procedure for establishing a link
between the first WCD and the second WCD for relaying of information from the first WCD to
a network via the second WCD, wherein the first WCD is not required to perform channel

sensing during at least a time period located between the transmission of the control message and the transmission of the first message.

81. The first WCD of claim 80, configured to perform the method of any of claims 2-39.

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82. A first wireless communication device (401), WCD, comprising processing circuitry (2902) configured to cause the first WCD to:

select a resource for transmission to a second WCD (404);

transmit a control message indicating the selected resource; and

10

transmit a first message to the second WCD in the selected resource,

wherein the first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD, wherein the first WCD is not required to perform channel sensing during at least a time period located between the transmission of the control message and the transmission of the first message.

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83. The WCD of claim 82, wherein the processing circuitry is configured to cause the first WCD to perform the method of any of claims 2-39.

20

84. A second wireless communication device (404), WCD, configured to:

receive, from a first WCD (401), a control message indicating a selected resource; and

receive, from the first WCD, a first message in the selected resource,

wherein the first message is part of a link establishment procedure for establishing a link

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between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD.

85. The second WCD of claim 84, configured to perform the method of any of claims 41-79.

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86. A second wireless communication device (404), WCD, comprising processing circuitry (2902) configured to cause the second WCD to:

receive, from a first WCD (401), a control message indicating a selected resource; and

receive, from the first WCD, a first message in the selected resource,

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wherein the first message is part of a link establishment procedure for establishing a link between the first WCD and the second WCD for relaying of information from the first WCD to a network via the second WCD.

87. The second WCD of claim 86, wherein the processing circuitry is configured to cause the second WCD to perform the method of any of claims 41-79.

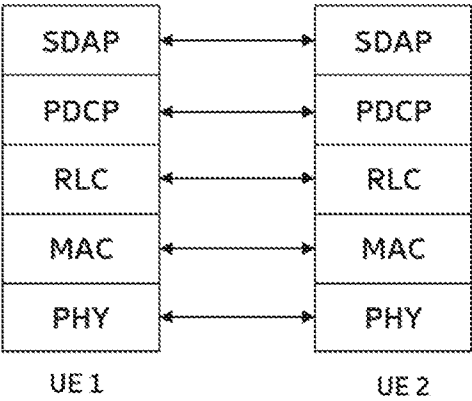


Figure 1a

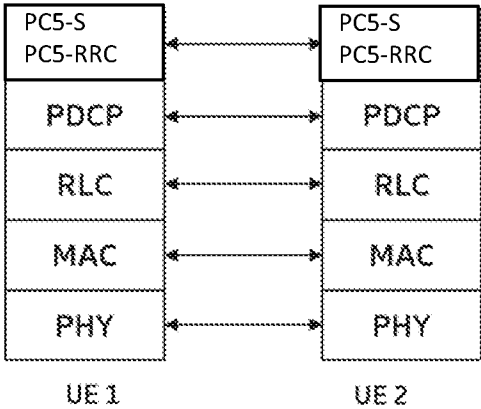


Figure 1b

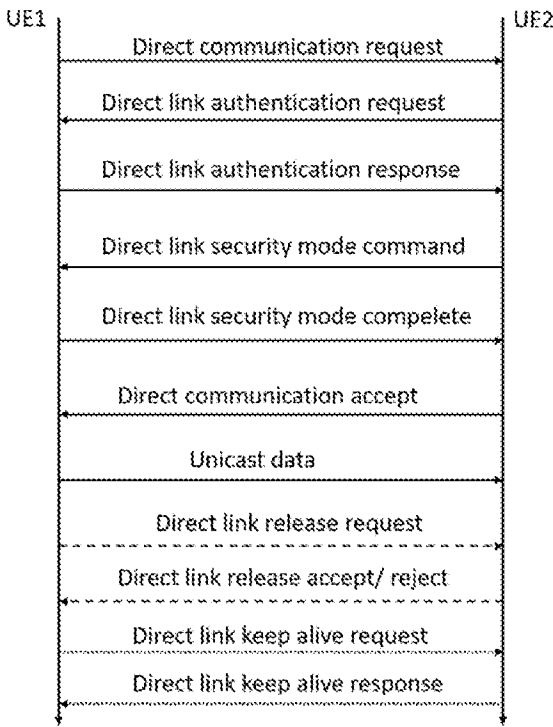


Figure 2

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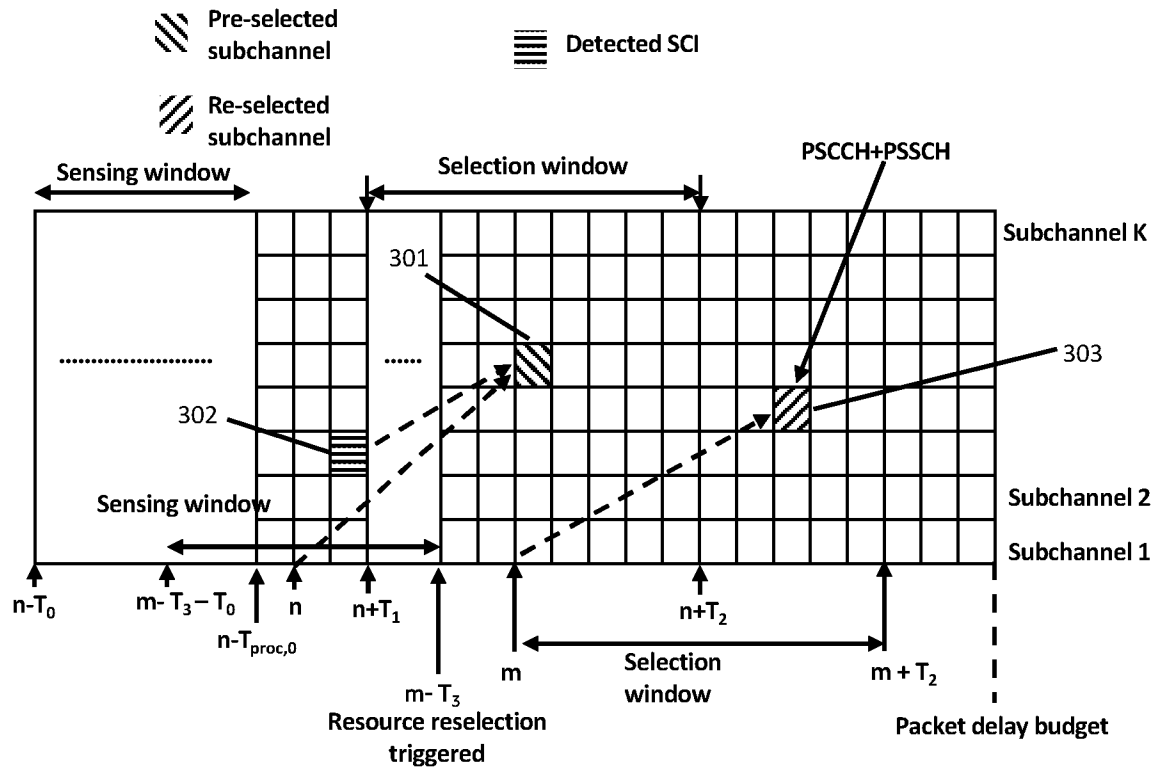


Figure 3

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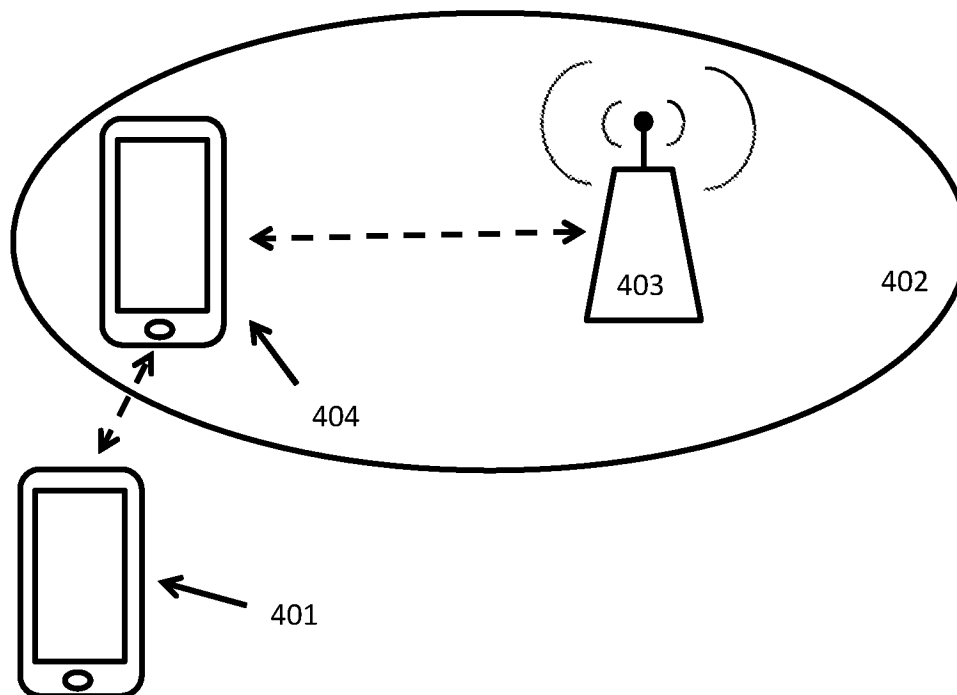


Figure 4

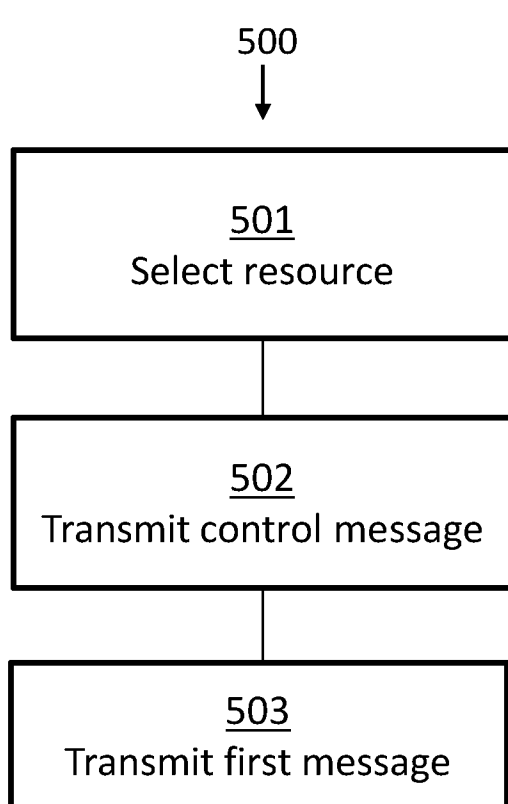


Figure 5

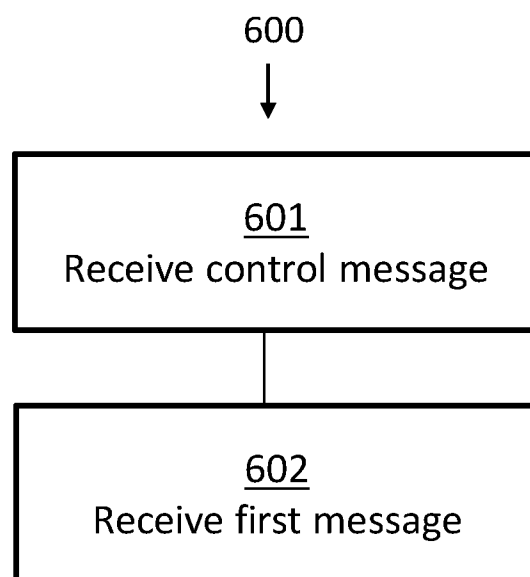


Figure 6

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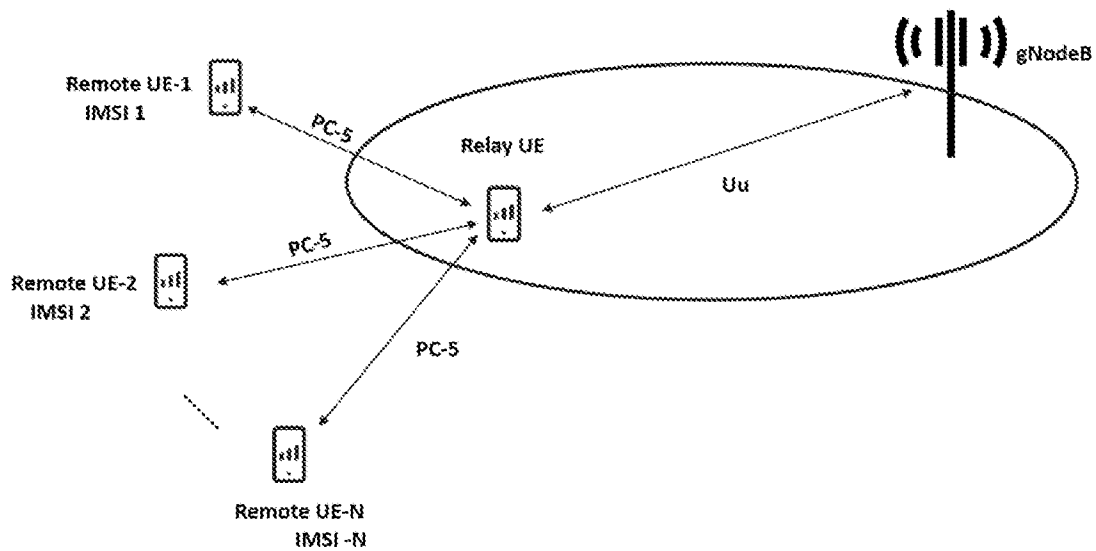


Figure 7

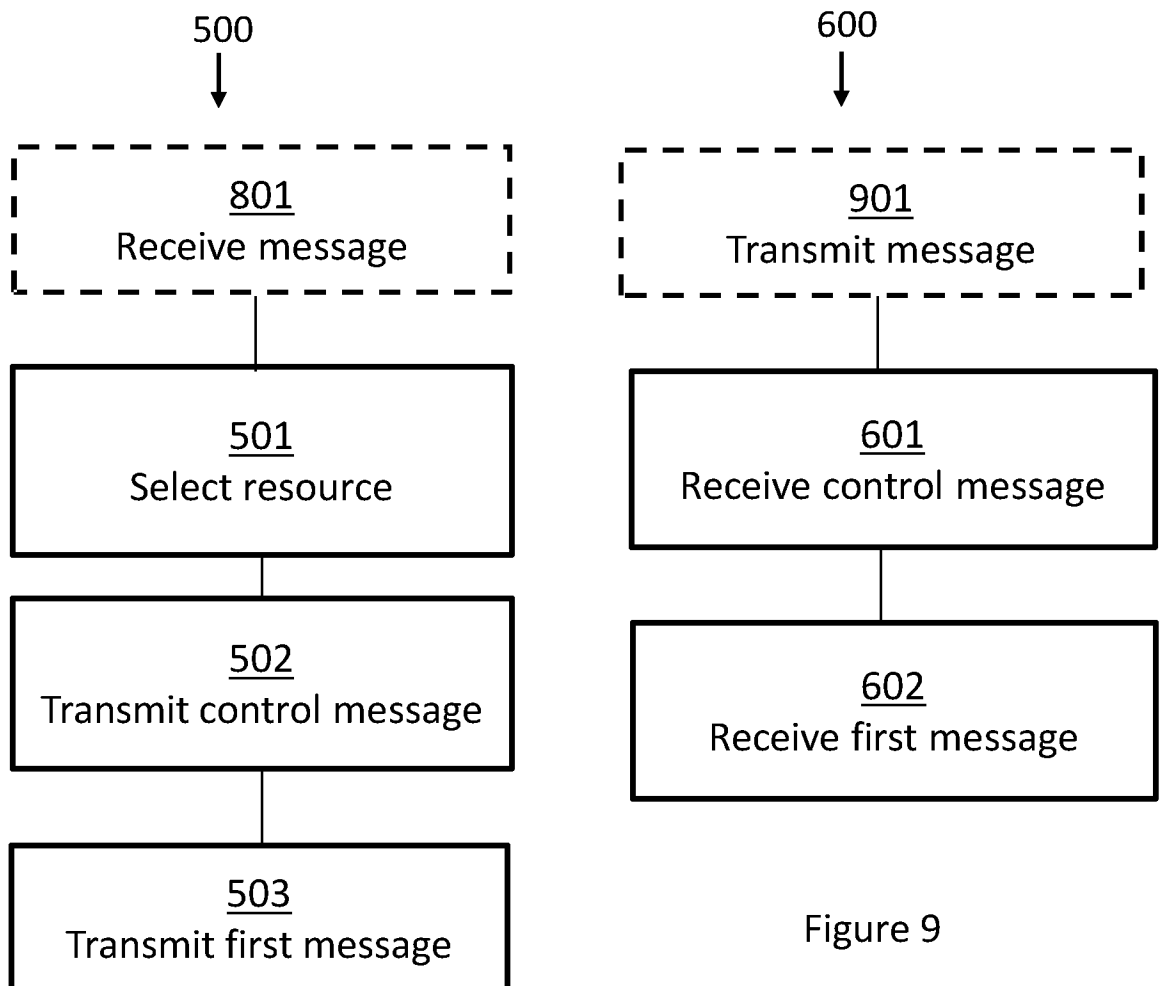


Figure 8

Figure 9

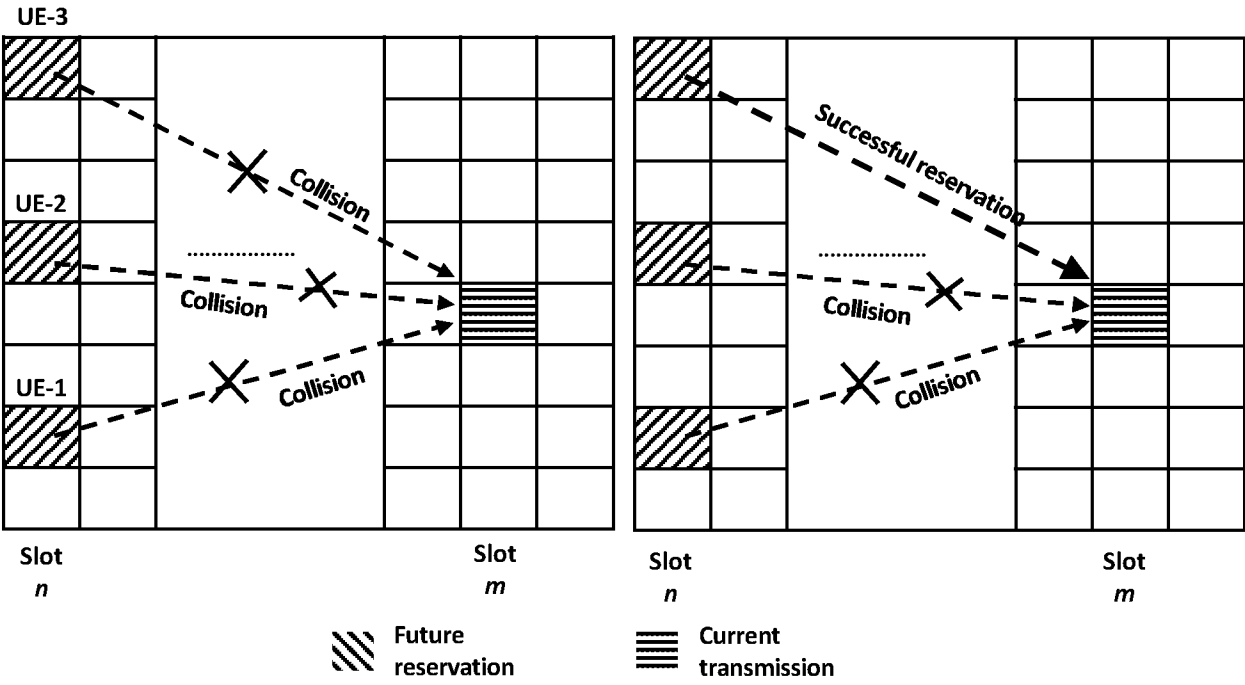


Figure 10

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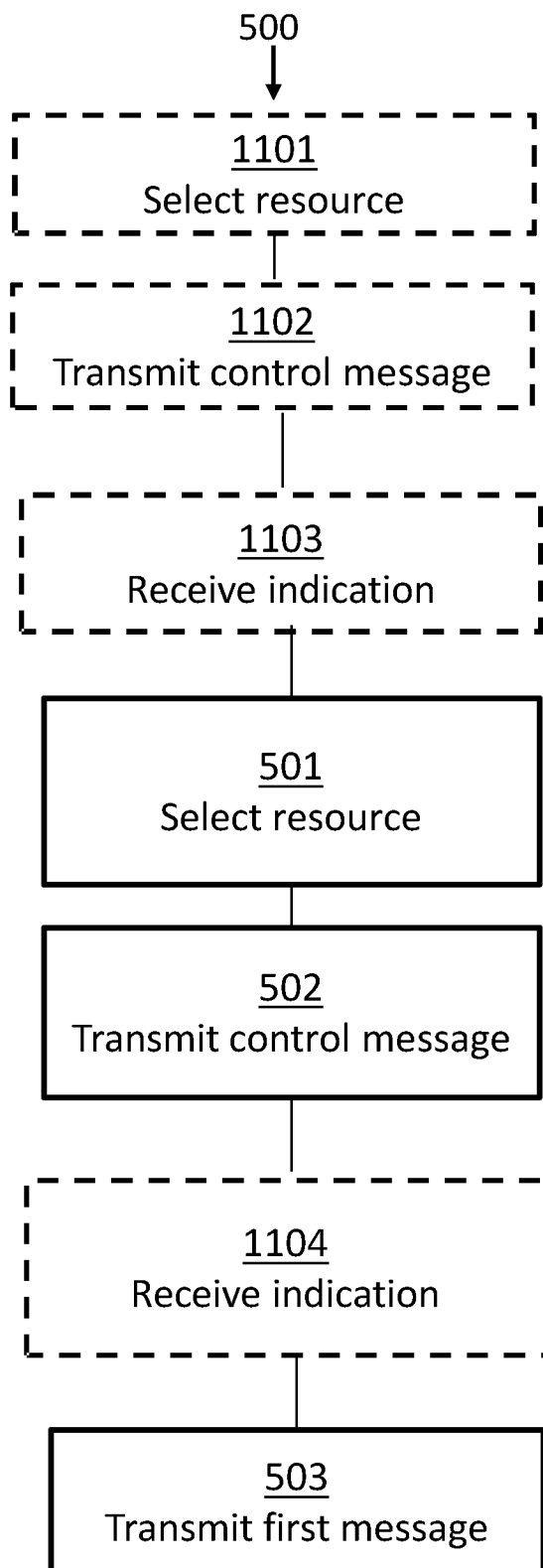


Figure 11

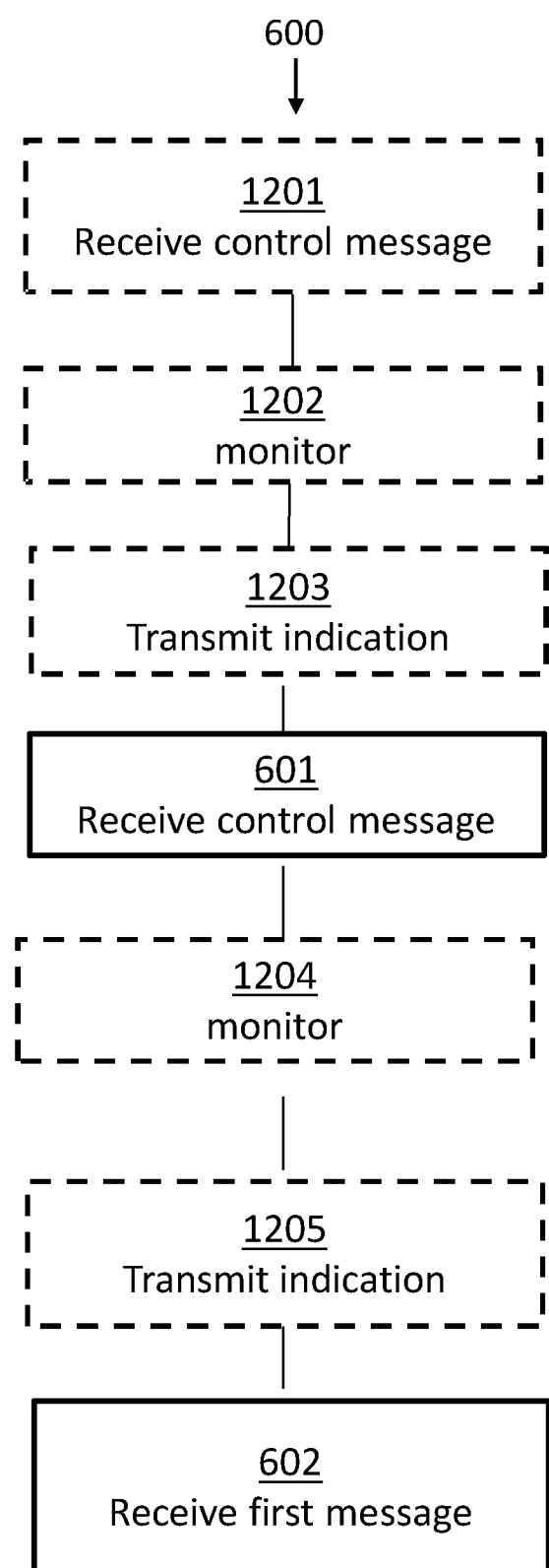


Figure 12

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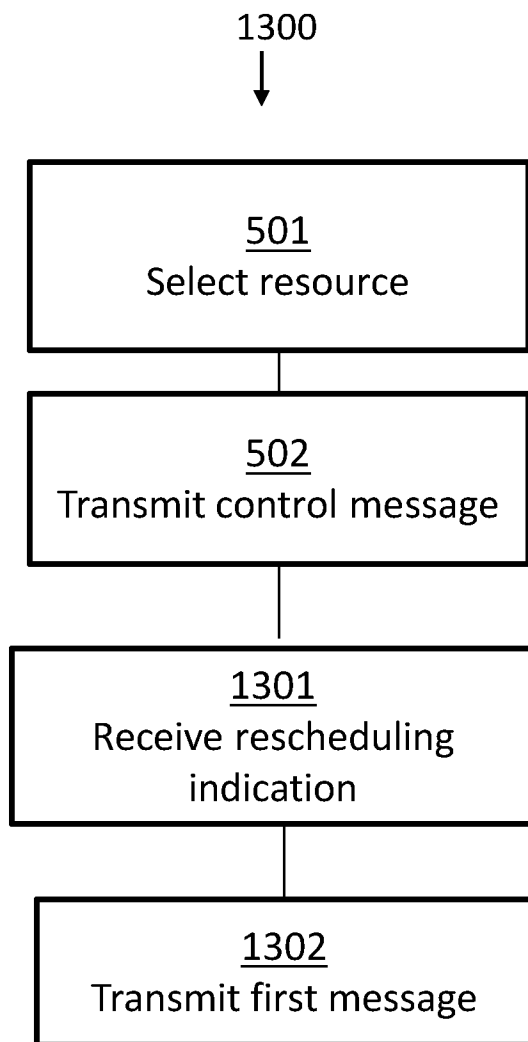


Figure 13

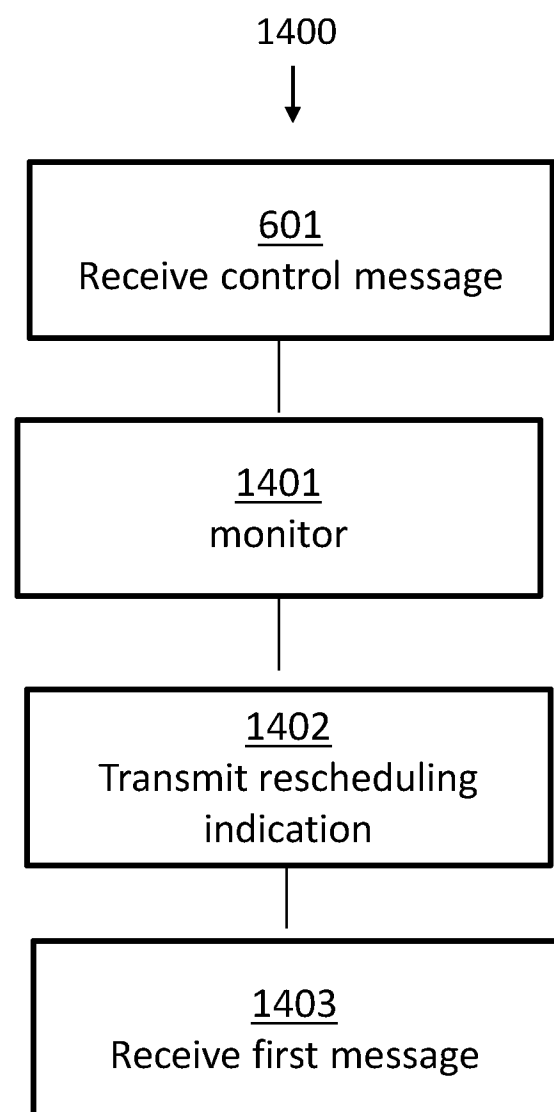


Figure 14

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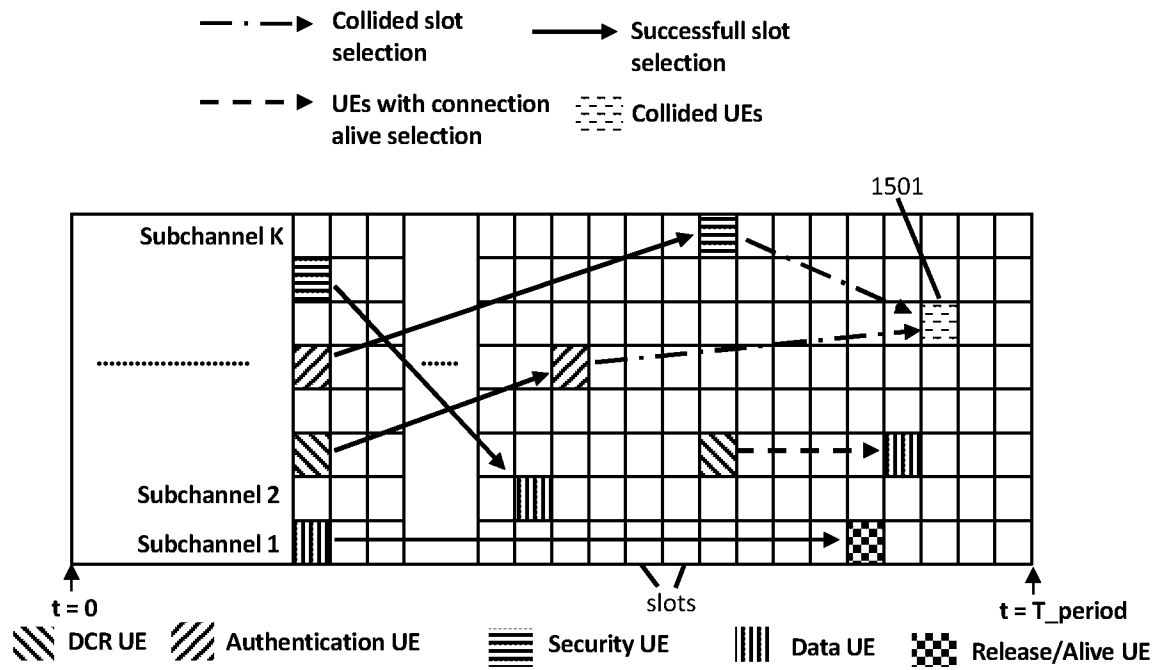


Figure 15

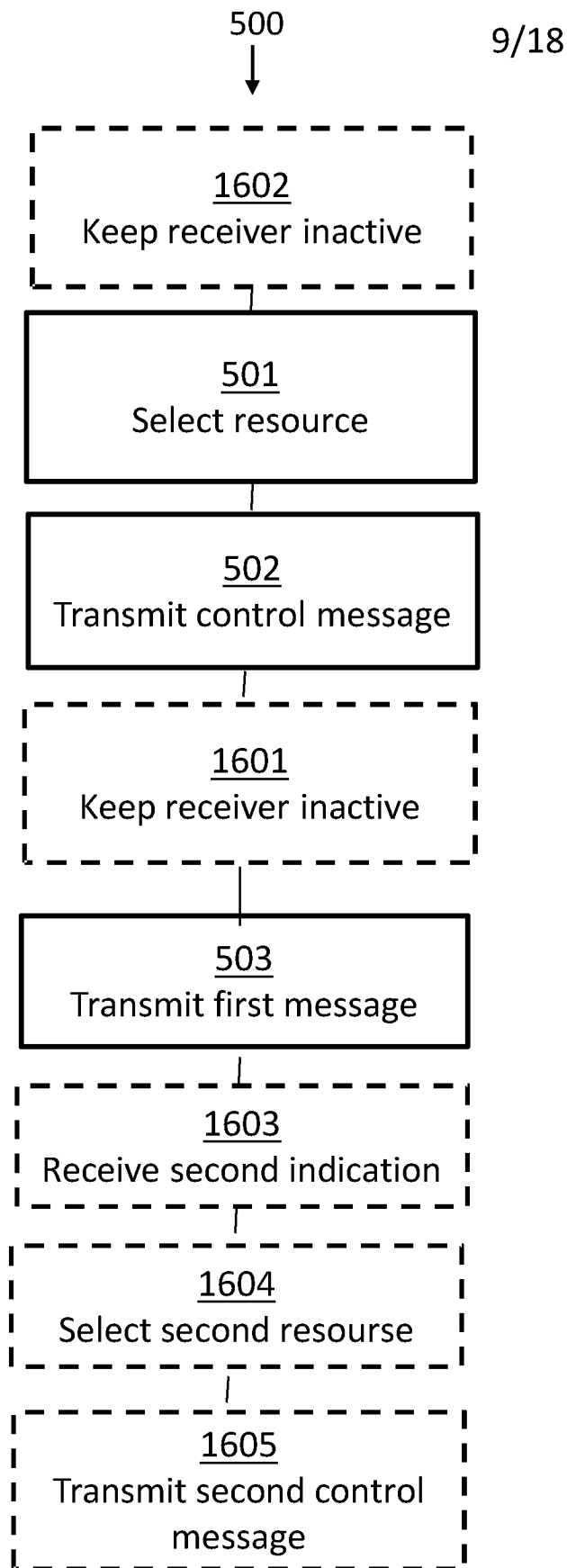


Figure 16

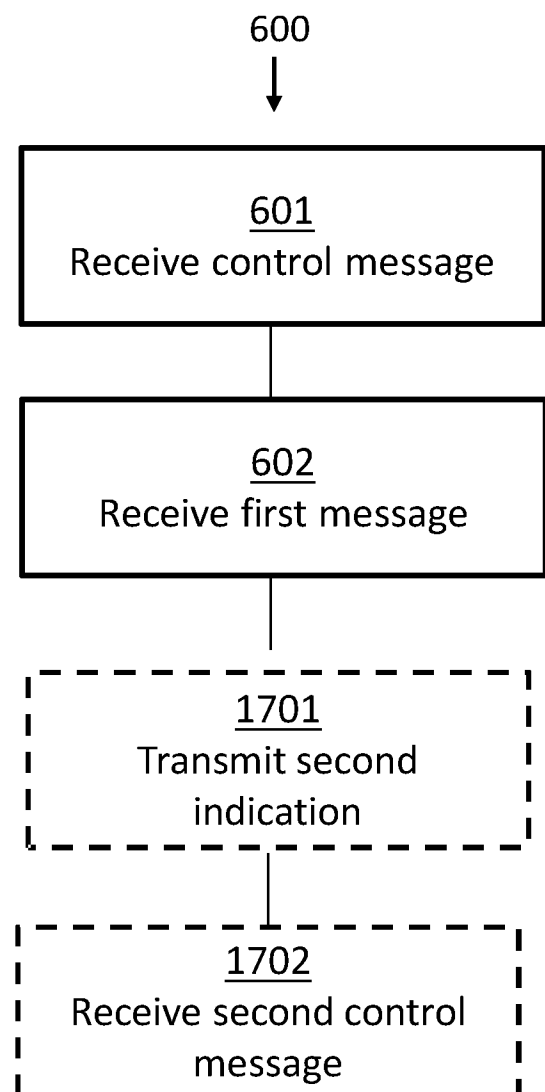


Figure 17

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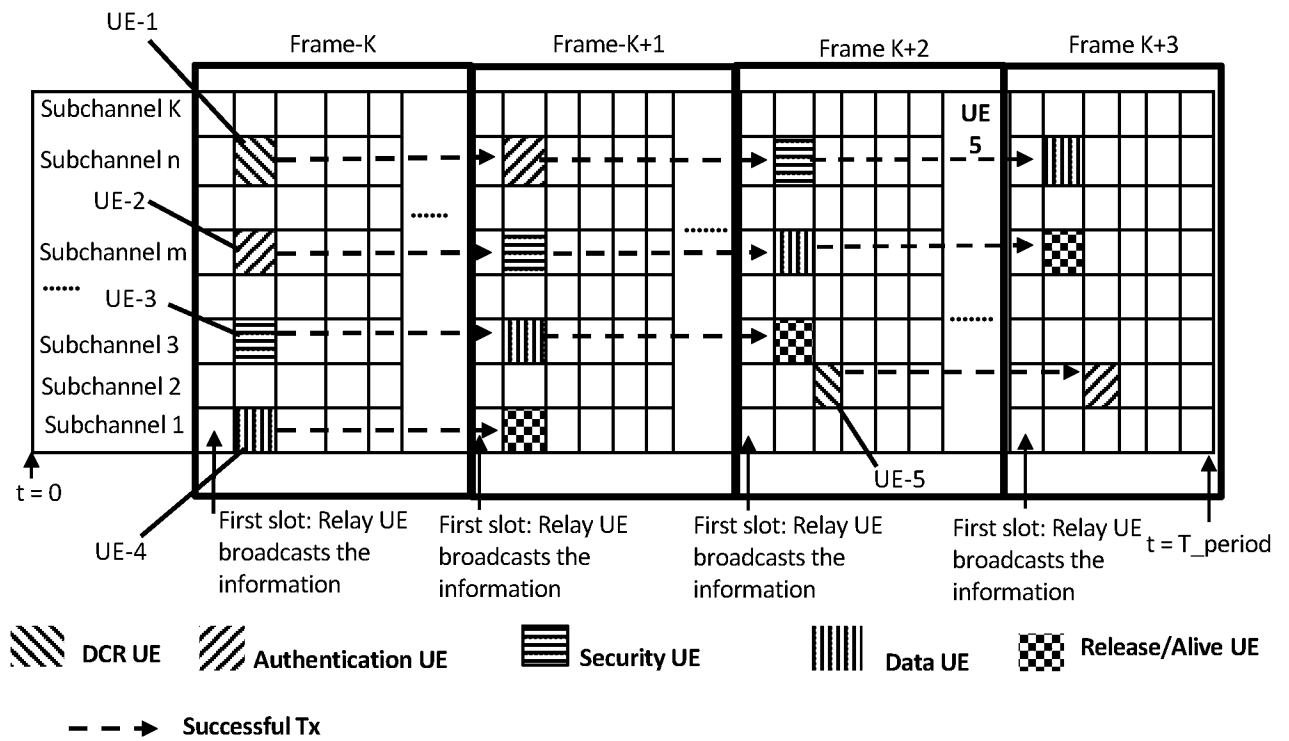


Figure 18

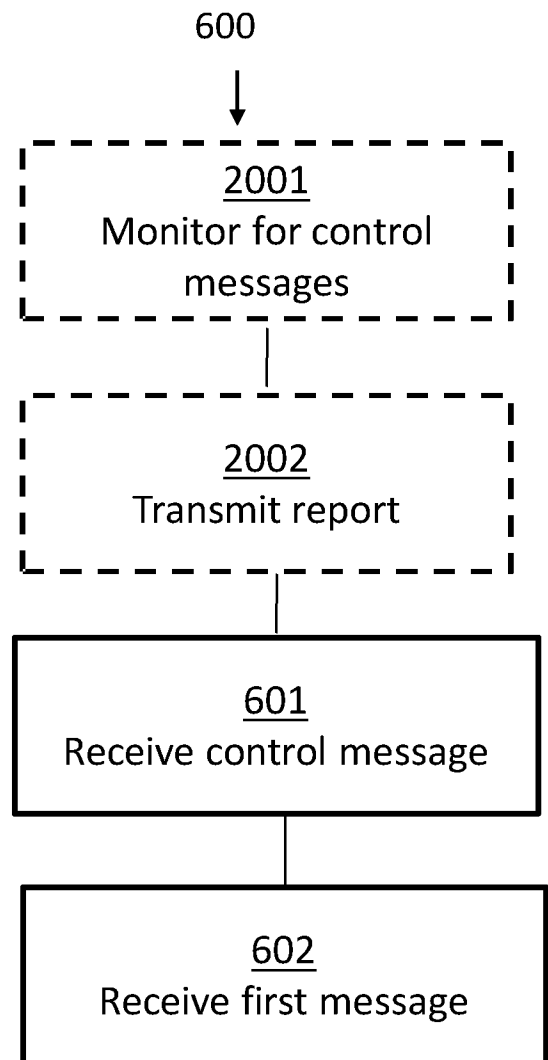
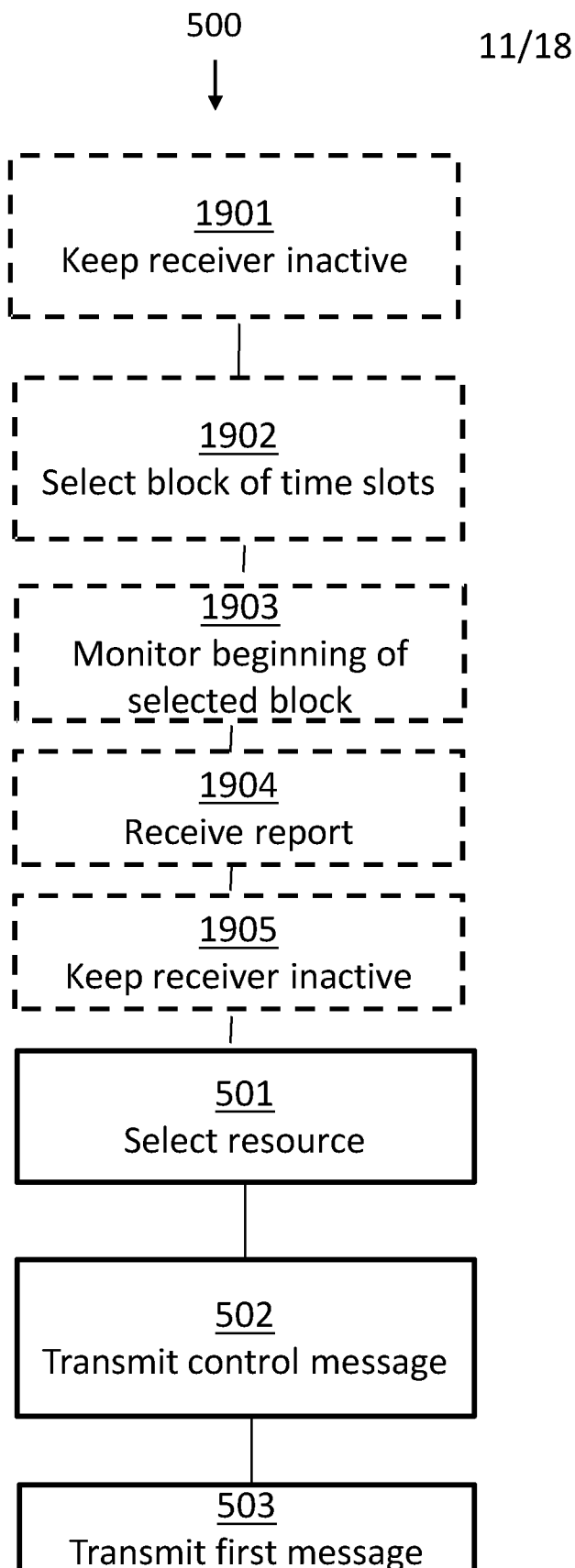


Figure 20

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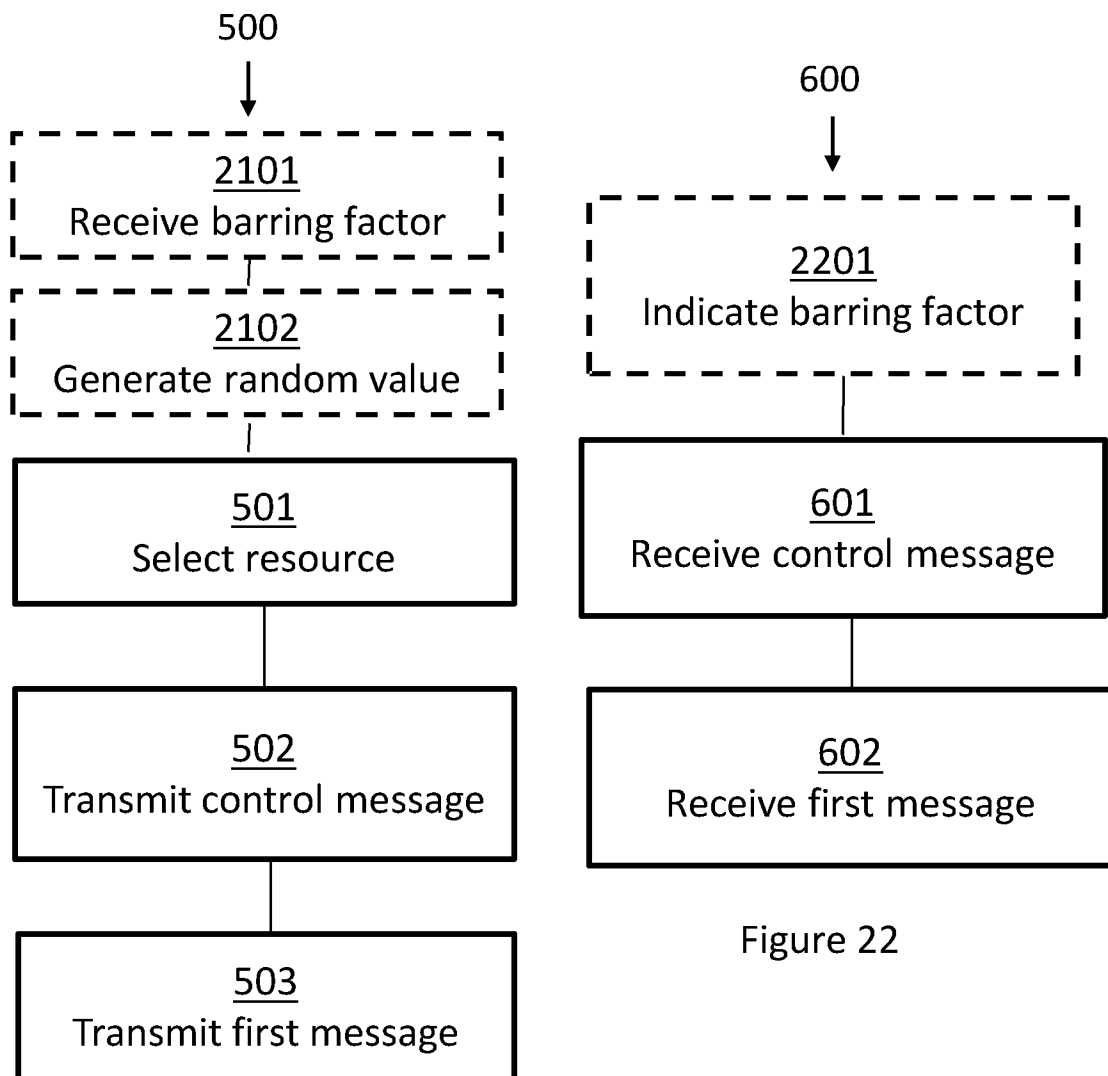


Figure 21

Figure 22

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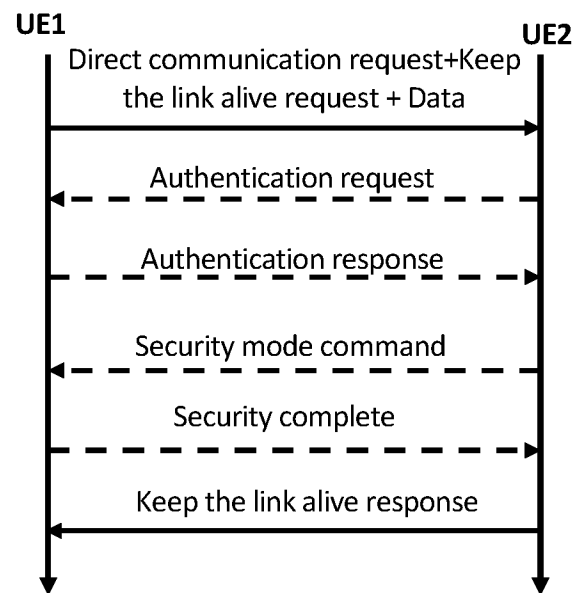


Figure 23

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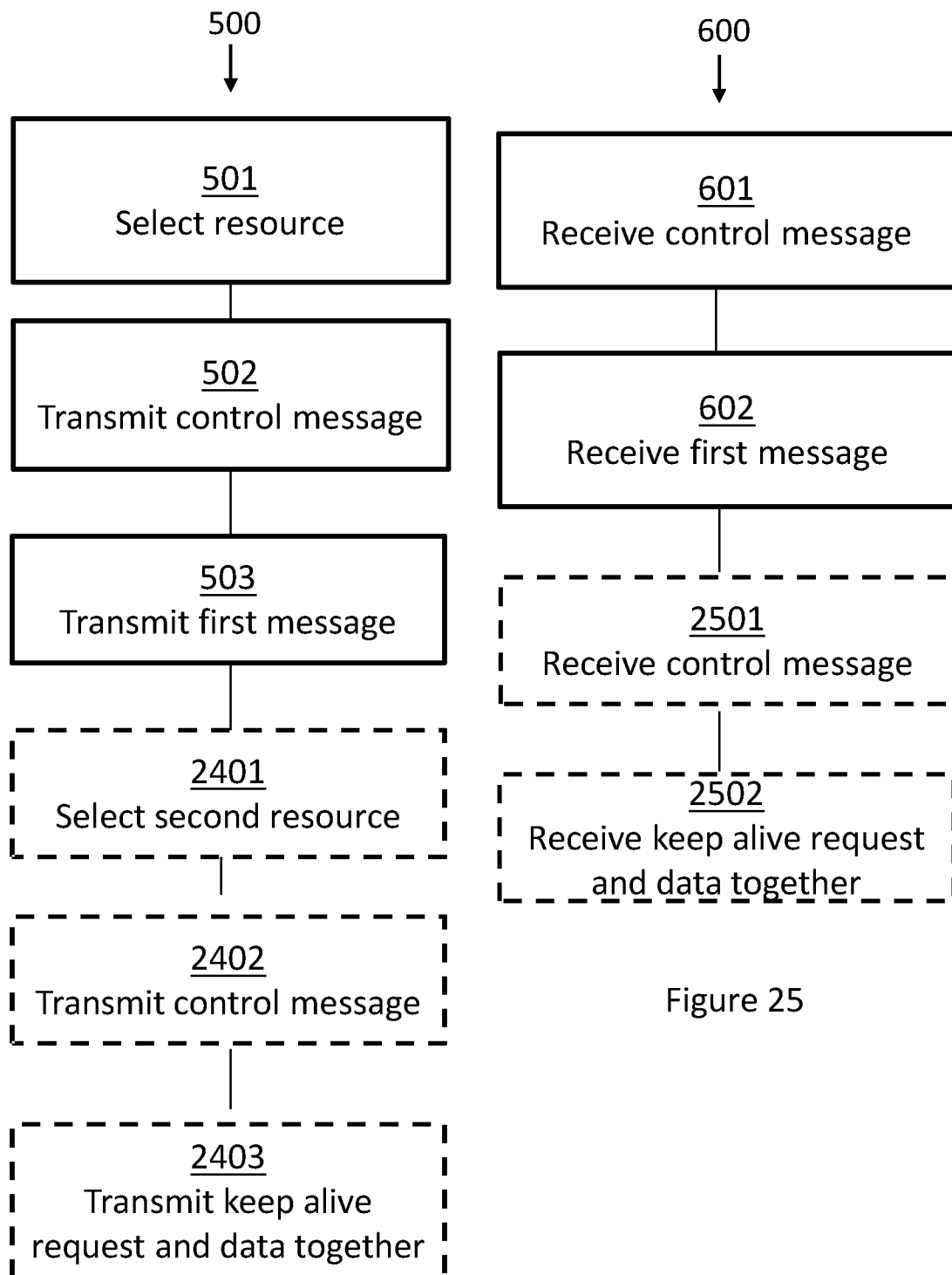


Figure 24

Figure 25

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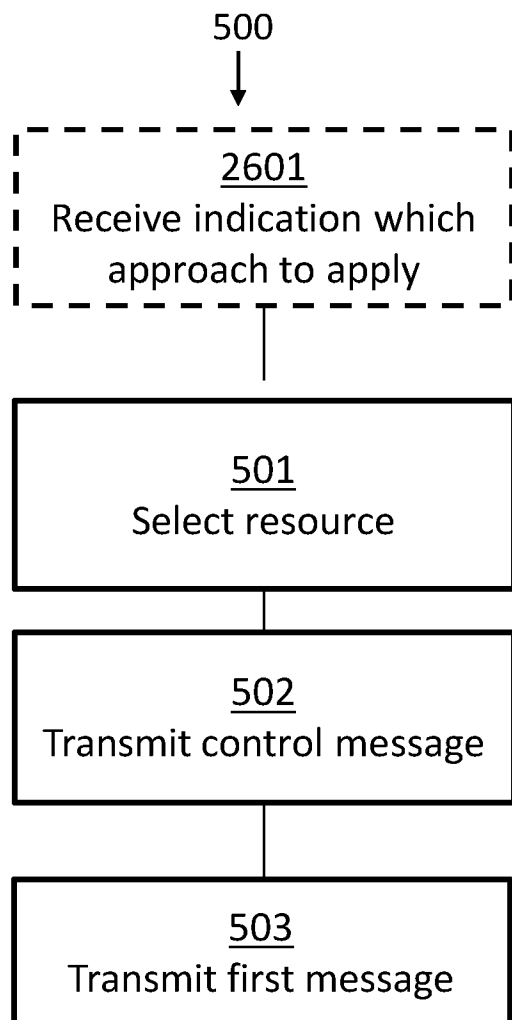


Figure 26

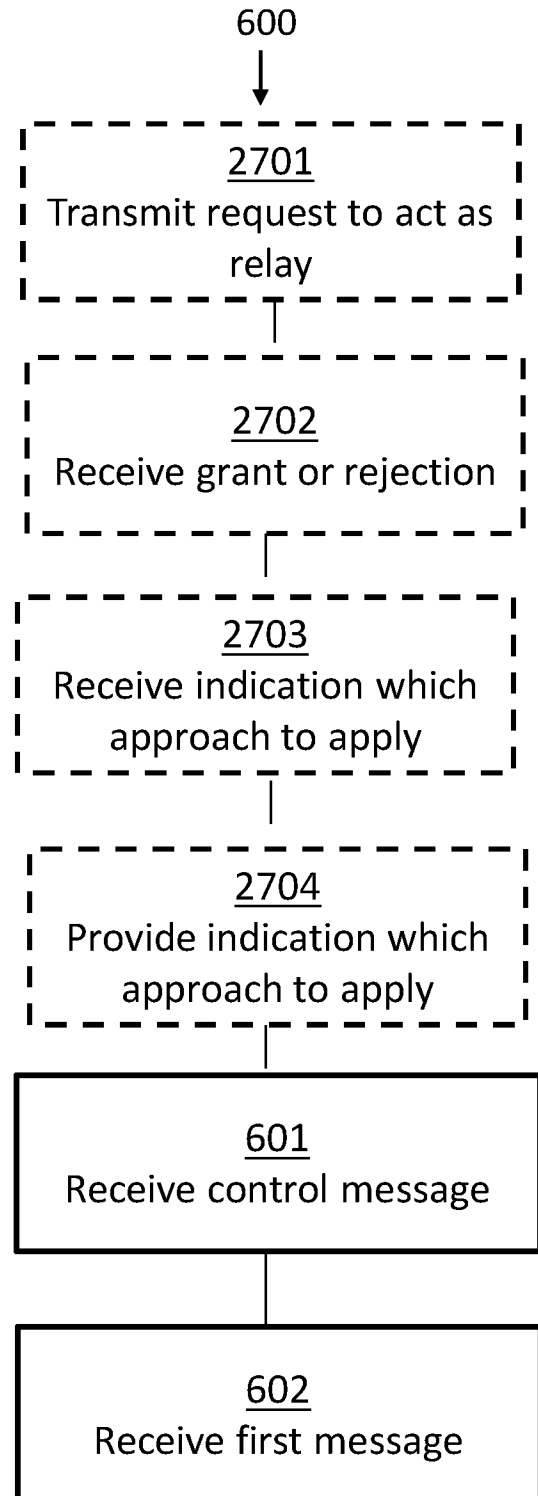


Figure 27

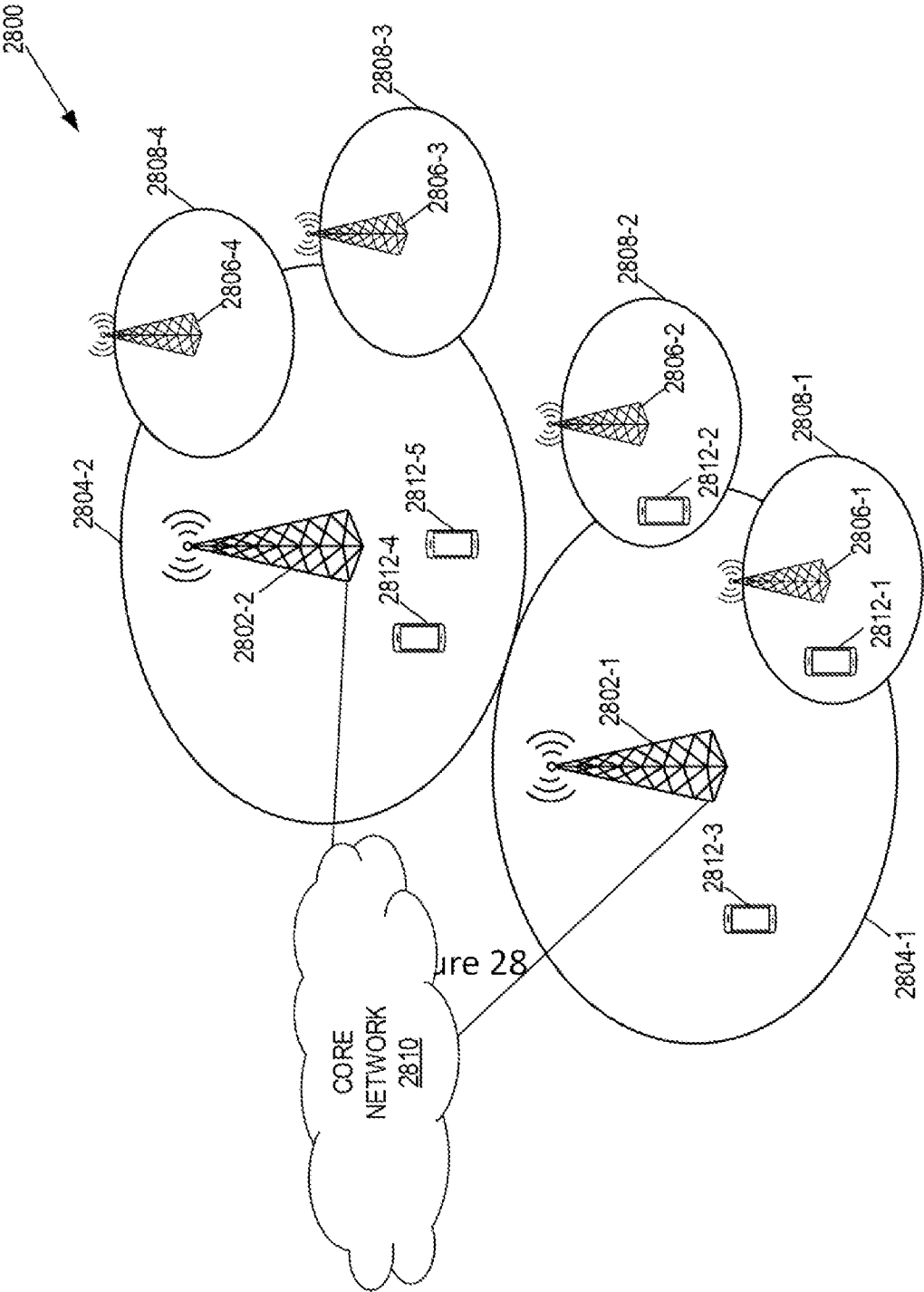


Figure 28

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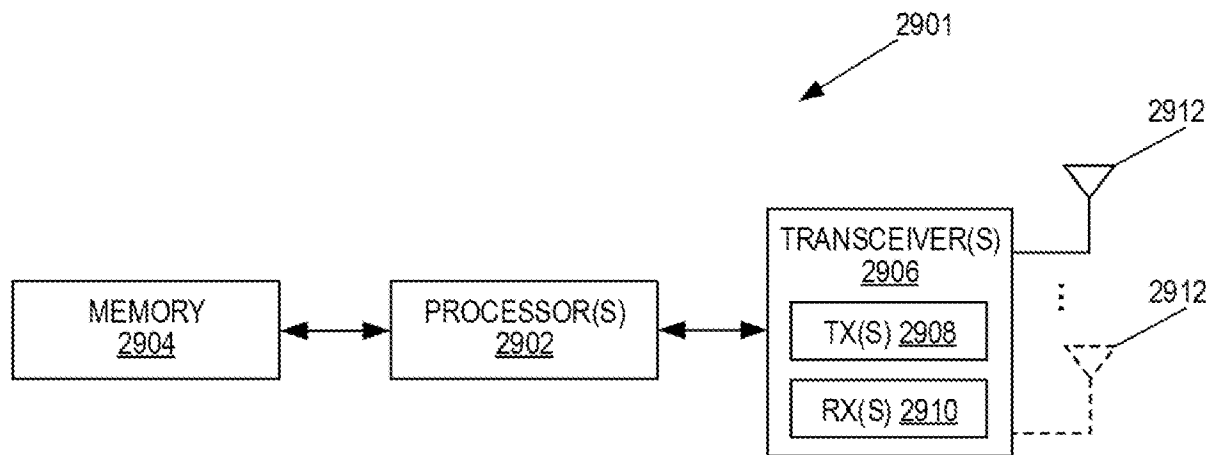


Figure 29

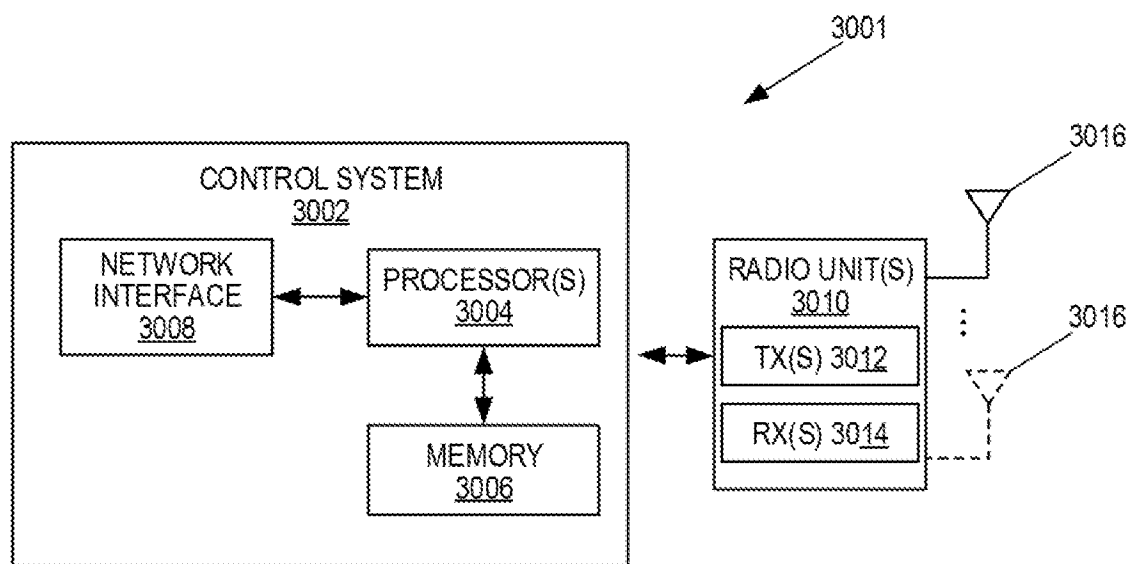


Figure 30

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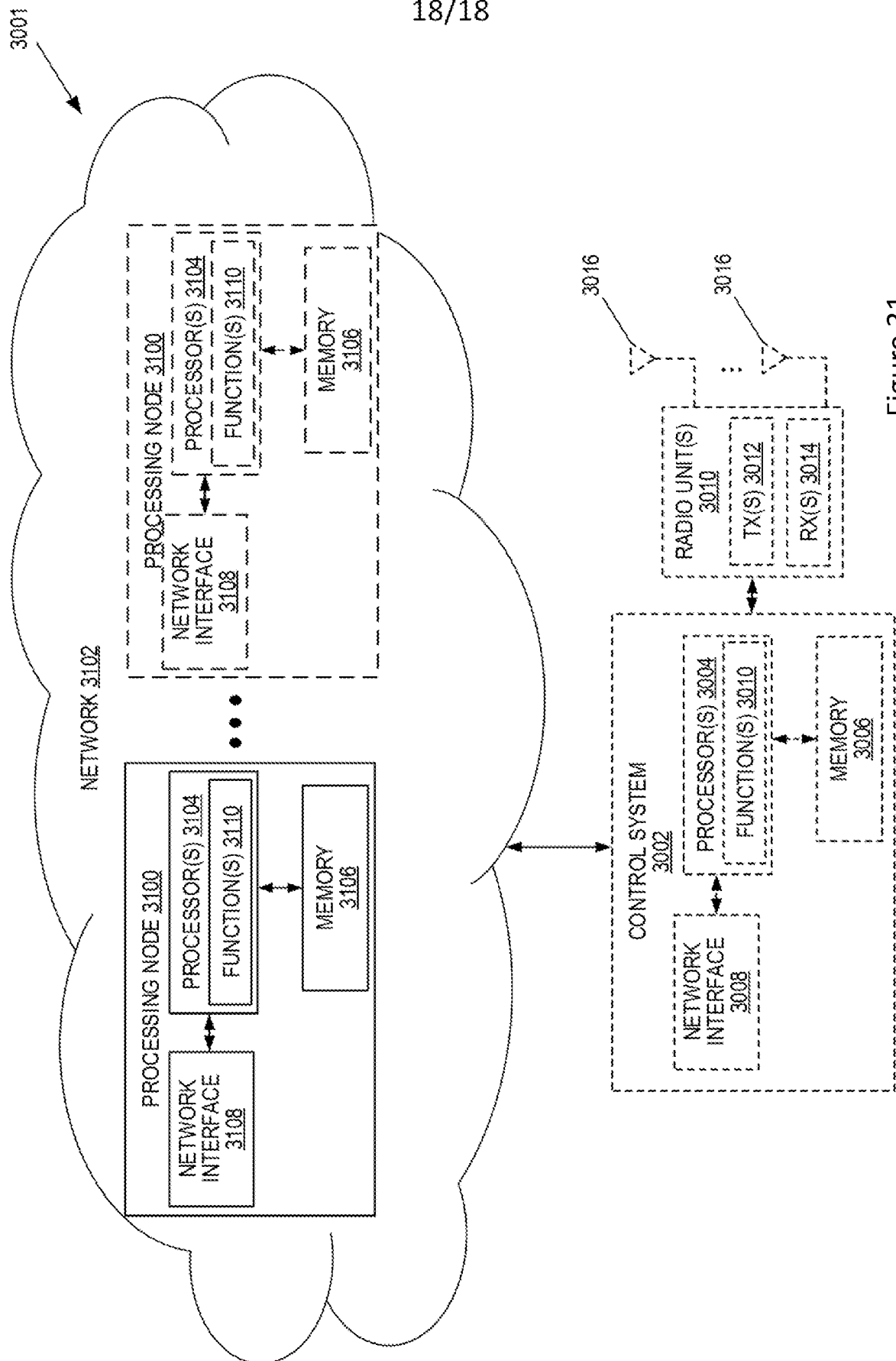


Figure 31

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2021/050127

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/14 H04W72/12 H04W88/04
ADD. H04W52/02

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)
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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 3 512 276 A1 (HUAWEI TECH CO LTD [CN]) 17 July 2019 (2019-07-17)	1-18, 23-36, 38-41, 48-57, 61-74, 76-87
A	paragraphs [0002] - [0150], [0191] - [0235] claims 1-43 figures 1-3b, 7	19-22, 37, 42-47, 58-60,75
A	----- WO 2020/200267 A1 (MEDIATEK SINGAPORE PTE LTD [SG]; CHEN TAO [CN] ET AL.) 8 October 2020 (2020-10-08) paragraphs [0004] - [0008], [0021] - [0111] claims 1-20 figures 3-9 ----- -/-	1-87



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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Date of the actual completion of the international search

7 October 2021

Date of mailing of the international search report

15/10/2021

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

Authorized officer

Rosken, Wilfried

INTERNATIONAL SEARCH REPORT

International application No

PCT/SE2021/050127

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"3 Generation Partnership Project; Technical Specification Group Core Network and Terminals; Vehicle-to-Everything (V2X) services in 5G System (5GS); Stage 3 (Release 17)", 3GPP STANDARD; TECHNICAL SPECIFICATION; 3GPP TS 24.587, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. CT WG1, no. V17.0.0 18 December 2020 (2020-12-18), pages 1-113, XP051999967, Retrieved from the Internet: URL:https://ftp.3gpp.org/Specs/latest/Rel-17/24_series/24587-h00.zip 24587-h00.docx [retrieved on 2020-12-18] cited in the application * chapters 6.1.2, 7.3 * -----	1-87
A	"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Proximity-services (ProSe) User Equipment (UE) to ProSe function protocol aspects; Stage 3 (Release 17)", 3GPP STANDARD; TECHNICAL SPECIFICATION; 3GPP TS 24.334, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. CT WG1, no. V17.0.0 18 December 2020 (2020-12-18), pages 1-264, XP051999958, Retrieved from the Internet: URL:https://ftp.3gpp.org/Specs/latest/Rel-17/24_series/24334-h00.zip 24334-h00.doc [retrieved on 2020-12-18] cited in the application * chapters 3.1, 5, 10.2.4, 10.4 - 10A.2.13.1, 11.2.5, 11.4.2 - 13.2 * -----	1-87

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2021/050127

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
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			EP 3512276 A1	17-07-2019
			US 2020029353 A1	23-01-2020
			WO 2018058684 A1	05-04-2018

WO 2020200267	A1	08-10-2020	NONE	
