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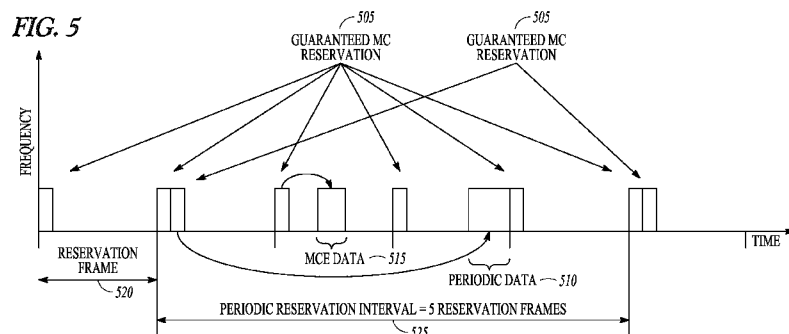
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(57) **Abstract:** Embodiments of mission critical (MC) device-to-device (D2D) channel access mechanism are generally described herein. A user equipment (UE) decodes a first reservation request for a guaranteed reservation, the guaranteed reservation for transmission of a MC packet to a second UE using D2D communication. The UE encodes, in a reservation window (RW) of a reservation frame, a second reservation request to reserve a contention-free allocated resource, wherein the contention-free allocated resource occupies resources in the reservation frame immediately adjacent to the RW. The UE configures the MC packet for D2D transmission on the contention-free allocated resource.



MISSION CRITICAL DEVICE-TO-DEVICE CHANNEL ACCESS
MECHANISM

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PRIORITY CLAIM

[0001] This application claims priority under 35 U.S.C. § 119 to United States Provisional Patent Application Serial No. 62/266,982, filed December 14, 2015, and titled, “MISSION CRITICAL PEER-TO-PEER CHANNEL ACCESS MECHANISM FOR FIFTH GENERATION COMMUNICATION,” which is incorporated herein by reference in its entirety.

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TECHNICAL FIELD

[0002] Embodiments pertain to wireless communications. Some embodiments relate to peer-to-peer communication, device-to-device communication, medium access protocol, mission critical communications, and radio access network layer 2 (RAN2) in fifth generation (5G) systems. Some embodiments relate to a peer-to-peer channel access mechanism for mission critical communications.

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BACKGROUND

[0003] Within a cellular network, short-range (e.g., within 100 meters) vehicle to X (e.g., vehicle, infrastructure, or pedestrian) communication may be desirable to communicate mission critical information, for example, if a driver loses control of a vehicle or a vehicle is about to run a red light. More broadly, peer-to-peer communication may be used for this purpose.

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[0004] Thus, there are general needs for short-range peer-to-peer communication techniques to exchange mission critical information.

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 [0005] FIGS. 1A-1B illustrate example use cases for vehicle to vehicle communication in accordance with some embodiments.
- [0006] FIG. 2 illustrates an example transmission period in accordance with some embodiments.
- [0007] FIG. 3 illustrates an example V2V communication system in accordance with some embodiments.
- 10 [0008] FIG. 4 illustrates an example reservation frame that may be used for mission critical device to device communications in accordance with some embodiments.
- [0009] FIG. 5 illustrates an example time/frequency graph that includes guaranteed mission critical reservations, periodic data, and mission critical event data in accordance with some embodiments.
- 15 [0010] FIG. 6 illustrates an example frame structure for hybrid radio access with a reservation window defined in the time domain in accordance with some embodiments.
- [0011] FIG. 7 illustrates an example frame structure for hybrid radio access with a reservation window defined using orthogonal frequencies in one slot in accordance with some embodiments.
- 20 [0012] FIG. 8 illustrates an example of mission critical event packet transmission opportunities within a reservation frame in accordance with some embodiments.
- [0013] FIG. 9 illustrates an example reservation frame including a bitmap indicating claimed reservations in accordance with some embodiments.
- [0014] FIG. 10 illustrates an example reservation frame where a base station assigns unclaimed reservations in accordance with some embodiments.
- [0015] FIG. 11 illustrates an example reservation frame 1100 with periodic reservation opportunities in accordance with some embodiments.
- 30 [0016] FIG. 12 illustrates an example reservation frame and reservation window configuration in accordance with some embodiments.

[0017] FIG. 13 is a functional diagram of a wireless network in accordance with some embodiments.

[0018] FIG. 14 illustrates components of a communication device in accordance with some embodiments.

5 [0019] FIG. 15 illustrates a block diagram of a communication device in accordance with some embodiments.

[0020] FIG. 16 illustrates another block diagram of a communication device in accordance with some embodiments.

10 DETAILED DESCRIPTION

[0021] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0022] Fifth Generation (5G) networks may support, among other things, mission critical vehicular safety and remote control applications. In particular, next generation connected and autonomous vehicles will require vehicle to X (V2X, where X may be a vehicle, infrastructure, a pedestrian or any other type of device) communications to improve transportation systems safety and sustainability, and to enable new data-driven mobility services, such as traffic planning, intelligent traffic control, roadway weather management, and travelers information services. The National Highway Traffic Safety Administration (NHTSA) in the United States has estimated that up to 80% of fatalities can be avoided by implementing vehicle to vehicle (V2V) safety applications. The impact of connected vehicles goes beyond safety, as auto accidents cost an estimated \$871 Billion per year.

30 [0023] FIGS. 1A-1B illustrate example use cases for vehicle to vehicle communication. FIGS. 1A-1B illustrate two mission critical (MC) use cases where V2V communications can be used to improve safety. As shown, in FIG. 1A, Vehicle B is failing to stop at a red light, and Vehicle A is to be informed

accordingly. In FIG. 1B, the driver of Vehicle B lost control of the vehicle, and Vehicle A needs to be informed accordingly. Once a mission critical event/situation (e.g. potential crash, control loss of a vehicle) requiring immediate action is detected by one or more vehicles (or a local infrastructure such as a supporting node (e.g., roadside unit) installed at intersection), these vehicles (or the local infrastructure) need to communicate to the surrounding vehicles (and/or infrastructure/pedestrian-devices) within an extremely short time period (e.g., 1 ms) with very high reliability in order to enable each device to take appropriate action to avoid or mitigate a safety problem. For instance, once vehicle A detects that vehicle B is in a collision path, it can take action locally (e.g. activate security systems in the car) and transmit a pre-crash warning that can be used by vehicle B and other vehicles in the area to act accordingly.

[0024] V2V use cases such as pre-crash warning/notification and mitigation may have extremely high reliability and very low latency (e.g., 1 ms) which are not achievable with existing communication technologies, such as Dedicated Short Range Communications (DSRC). DSRC, which is based on 802.11p radios and uses a contention-based medium access protocol, has reliability issues, especially in dense scenarios, and has not been widely deployed despite the availability of standards and dedicated spectrum.

[0025] Existing cellular systems, such as long term evolution (LTE) and 5G, are being considered as an alternative to DSRC/802.11p given their large scale coverage and efficient spectrum utilization. However, the architecture of current cellular systems (up to Fourth Generation (4G) and LTE-A) has been designed for human centric communications and may be revisited in order to enable mission critical applications. LTE may be enhanced to support V2X safety applications based on its device to device (D2D) communication functionality, also known as ProSe (Proximity Services). However, future LTE V2X solutions based on the ProSe functionality might not meet the sub-ms latency and high reliability requirements of mission critical V2X applications expected for 5G.

[0026] Non-deterministic quality of service (QoS) for MC traffic within contention-based D2D resource pools is discussed below.

[0027] The LTE ProSe functionality (D2D) may be used for V2V communications. Two radio access modes are defined in the current LTE Release (Rel.) 12 ProSe specification, namely, scheduled (evolved NodeB (eNB) controlled or mode 1) and autonomous (mode 2). The scheduled mode assumes
5 the eNB grants dedicated resources to the user equipment (UE), which can be used for direct communication. Although the scheduled mode may provide reliable access, the overhead required to track and schedule each individual V2V link within a cell is high. Scheduling V2V links is more challenging due to the lack of link quality information at the eNB. The control overhead required to
10 provide such information might be high, especially in high mobility scenarios, which is a typical case in V2V communications. Interference management between highly mobile V2V links is another problem for centralized scheduling.

[0028] In autonomous mode, a resource pool, assigned by the eNB, is reserved (signaled by the eNB) for direct communication between UEs using
15 contention based access. Control and data resources are defined within the pool, which are repeated periodically as illustrated in FIG. 2. As shown, FIG. 2 illustrates a transmission period 200 that includes a control pool 210 and a data pool 220. Note that in LTE, such resource pools are separated (using part of the uplink (UL) frequencies, in frequency division duplex (FDD) systems) from the
20 regular LTE communication resources. UEs indicate their selected resources in the control channel. Both control and data packets are sent in several physical (PHY) transmissions (using a pre-defined frequency hopping pattern). The autonomous mode is simpler to implement, as UEs can individually decide which resources to use for transmission. This mode enables outside coverage
25 operation in case a resource pool is pre-configured. However, UEs may select the same resources, which may lead to collisions. Therefore, existing autonomous resource allocation and access mode in LTE might not meet MC reliability and latency requirements.

[0029] Contention-based access is also used in existing 802.11p/DSRC
30 V2X solutions. It is also known that performance of carrier sense multiple access (CSMA) based 802.11p access is highly dependent on the traffic load, which might be high in dense urban scenarios. Even priority schemes, such as the

different access categories in 802.11e, might not guarantee the deterministic QoS needed for MC traffic.

[0030] Radio access in existing and upcoming V2X system (LTE and 802.11p/DSRC) is either contention-based or scheduled, independent of the type of traffic and QoS requirements. Even though LTE V2X supports two access
5 of traffic and QoS requirements. Even though LTE V2X supports two access modes, only one of them can be used at a given time within a resource pool.

[0031] Deterministic QoS for MC V2V traffic through reservation based access while supporting non-MC traffic with reasonable complexity, low overhead, and in distributed mode may be useful. A new flexible radio access
10 protocol is useful to enable efficient access to both MC and non-MC traffic, as well as continuous service outside network coverage and/or using shared spectrum. Given the fundamental limits on available/usable spectrum, it may be desirable for future communication systems to use the spectrum efficiently while accommodating heterogeneous traffic requirements.

[0032] In some aspects, the subject technology provides a new hybrid medium access control protocol for P2P (e.g., V2V) communications supporting both guaranteed reservation for low-latency high reliability, and priority based contention access in the same system.

[0033] One assumption of the operation of some aspects is that MC V2V
20 communications are needed mainly between UEs in close proximity as shown in FIG. 3, which illustrates an example V2V communication system 300 that includes vehicles 305A, 305B, and 305B in a V2V group 310 that has access to a base station (BS) 315. In other examples, the vehicles lack network access. In other cases, vehicles approaching an intersection or moving along a highway are
25 one target of MC safety messages generated in the area. In some embodiments, it is assumed that a group of nearby vehicles that need to communicate will remain stable for a few seconds. The worst case scenario could be vehicles moving in opposite directions in a highway at high speeds (e.g. 140 km/h) for a stable lifetime of a group constituted by nearby vehicles. In this case, the time available
30 for communication is approximately 4 seconds (assuming a communication range of 300m), which is enough to support several MC transmissions. In some cases, group membership (e.g., membership in the V2V group 310 or another

V2V or D2D group) is determined and managed by the network (e.g., by a base station or eNB, such as BS 315).

[0034] Aspects of the subject technology are directed to a new hybrid access protocol that enables UEs to use different access protocols depending on the packet QoS classes within the same resource pool. In some cases, UEs reserve resources (for MC D2D or V2V traffic) as well as use contention-based transmissions (for non-MC data) within a resource pool shared by a group of UEs (e.g., V2V group 310 of FIG. 3). The access protocol operates in D2D/distributed mode and can be used inside and outside network coverage once resource pools are configured by the network.

[0035] The radio access procedure is based on the packet's MC quality of service (QoS) class, which is configured by a convergence layer that provides an interface between the applications (Including Internet Protocol (IP) and non-IP applications) and the radio access layer protocols. Access methods that may be used with the subject technology are described below.

[0036] FIG. 4 illustrates a reservation frame 400 that may be used for MC D2D (e.g., V2V) communications. As shown, the reservation frame 400 includes a reservation window 410, which includes multiple slots 405A, 405B, and 405C – one slot for each UE in the group. The reservation corresponding to slot 405A is transmitted in block 415A, which includes MC data, retransmission information, and acknowledgement (ACK) information. As shown, a new reservation frame similar to the reservation frame 400 follows the reservation frame 400 in the time axis.

[0037] The guaranteed reservation mode is used for data in the MC Event (MCE) QoS class, which have the highest priority in the system. A periodic reservation frame includes the Reservation Window (RW) 410 at the beginning, followed by data resources (e.g., block 415A). A dedicated reservation resource (slot) - for example slots 405A, 405B, and 405C, as shown - is assigned to each active MC UE to request resources for MCE packets. The reservation requests are sent in a periodic contention-free reservation window (RW 410) which is monitored by all UEs in the group in order determine reserved resources, resources they need to receive MCE data and resources that are not claimed. The un-claimed resources may be accessed in contention-based

mode. Priority based access may be defined for various traffic types for un-claimed resources. In order to achieve low latency for MCE packets, the periodic reservation frame size has to be configured accordingly. For instance, a frame size of 0.1 ms or 0.2 ms may be needed to ensure less than 0.5 ms latency. The
5 configuration of the RW 410 is also important to reduce latency. Time-domain orthogonality may be used for small groups as shown in FIG. 4, but a more efficient mode may be used for larger groups, where multiple reservations are sent in different frequency/codes in a time slot 405A, 405B, or 405C. The RW configuration may be managed by the network. RW configuration options are
10 described below.

[0038] FIG. 5 illustrates a time/frequency graph 500 that includes guaranteed MC reservations 505, periodic data 510, and MCE data 515. A reservation frame 520 is illustrated. As shown, the periodic reservation interval 525 is five reservation frames. However, in alternative implementations, the
15 periodic reservation interval may have a different length.

[0039] The periodic reservation mode may be used for periodic sensing (PS) and D2D discovery (DI) traffic which have a known repetition pattern and fixed packet sizes. For instance, V2V UEs may use this mode to send their safety beacons (300 bytes sent every 100 ms). In this case, a UE may request a number
20 of resources distributed across several reservation frames with granularity of no more than one resource per periodic reservation interval. Given the relaxed latency requirements for the PS and DI traffic compared to MCE traffic, periodic reservations do not need to be requested in every reservation frame. The periodic reservation interval may be set to lower granularity, such as several (e.g., five)
25 reservation frames as illustrated in FIG. 5. Alternatively, guaranteed and periodic reservations may use different frequency resources. UEs may be equipped with multiple transceivers to access different frequency bands simultaneously.

[0040] Priority based contention-access is a contention-based
30 asynchronous mode that may be used for any type of traffic. In this case, the UE listens to the channel (i.e., performs energy detection) in non-reserved resources (see FIG. 4) and transmits if the channel is free for a certain amount of time (similar to the arbitration inter-frame spacing (AIFS) concept in 802.11e). The

AIFS is defined based on the QoS classes. In order to receive packets in this mode, UEs listen to the channel during non-scheduled resources and determine the length and target destination from the packet header.

[0041] MC UEs announce their reservation requests in a periodic contention-free reservation window. All UEs in the group monitor the reservation window to determine resources that have been claimed by other UEs. UEs can use listen before talk (LBT) to transmit in case resources have not been reserved. The reservation window can also be used to discover other UEs and enable UEs to join the group. FIG. 4 illustrates the basic concept of the proposed reservation-based guaranteed access method. The mechanism can also be used with other methods of defining contention-free resources (e.g., combination of time, frequency, and code). More details are provided below.

[0042] Aspects of the subject technology relate to a frame structure where resources are defined in frequency and time domain as illustrated in FIG. 6. The same frame may carry multiple data from multiple QoS classes (MCE data, periodic resource (PR) data, and non-MC data).

[0043] FIG. 6 illustrates an example frame structure for hybrid radio access with a reservation window (RW) defined in the time domain. FIG. 6 shows a reservation frame 600. As shown, the reservation frame 600 includes a reservation window 610 with multiple slots 615. The reservation frame 600 includes blocks (defined on the time vs. frequency graph) for MCE data 620, non-MC data 630, and PR data 640.

[0044] FIG. 7 illustrates an example frame structure for hybrid radio access with a reservation window (RW) defined using orthogonal frequencies in one slot. FIG. 7 shows a reservation frame 700. The single-slot RW 710 is divided into blocks 715 in the frequency domain for reserving MCE data blocks 720. The reservation frame 700 also includes blocks, defined in the time and frequency domains, for non-MC data 730 and PR data 740.

[0045] In some aspects of the subject technology, the UEs in the group are all time synchronized. This can be achieved with assistance of the network or via an external source, for example, a global positioning system (GPS).

[0046] According to some implementations, the reservation frame 600 includes N slots and F sub-channels, where the 1 slot x 1 sub-channel is the

smallest resource allocation unit that can be reserved or allocated. The first W slots 615 within the reservation frame 610 are used for the contention-free RW 610. The RW 610 may be configured with orthogonal resources in time (the slots 610 of FIG. 6) or in the frequency (or code) domain (multiple frequencies of the blocks 715 in the RW 710 of FIG. 7).

[0047] In conjunction with some aspects, UEs are able to receive and decode a message within a slot time. UEs are also able to prepare a short reservation request message for the next slot (as discussed in conjunction with the guaranteed reservation details below). The slot time may include the transmission/ reception times as well as processing/ preparation overheads. Given the assumptions about local V2V group communications, the impact of propagation delays may, in some cases, be very small.

[0048] In some cases, a RW configuration where multiple resources in the same slot (e.g., blocks 715 in the single-slot RW 710) are used by different MC UEs may be used. In these cases, UEs may be able to transmit and receive simultaneously.

[0049] The amount of resources for one MCE packet transmission opportunity is defined within the reservation frame. For instance, in the example of FIG. 6, 12 resource blocks are occupied per MCE packet 620 transmission (two slots across all channels).

[0050] FIG. 8 illustrates an example of MCE packet transmission opportunities within a reservation frame. FIG. 8 illustrates a reservation frame 800 that includes an RW 810 with multiple slots 815. The reservation frame 800 includes an MCE transmission opportunities region 830, defines in the time axis. MCE data blocks 820 reside within the MCE transmission opportunities region 830.

[0051] In some examples, a maximum number of MCE packet transmission opportunities may be allocated within the reservation frame 800. A total of 12 MCE packets can be transmitted in the example shown in Figure 8. Different resource allocation patterns may be used, but the amount and location of the resources is defined and communicated to all MC UEs. The specific allocation of resources is configured by the network (e.g., by an eNB or BS) and,

in some cases, depends on the capabilities of the UEs and system requirements, such as expected packet sizes, group sizes and latency requirements.

[0052] In some embodiments, the first MCE transmission opportunity

starts at slot $W+2$, where W is the number of slots in the RW. In these

5 embodiments, the $W+1$ slot cannot be reserved as it is left unallocated to enable new UEs to join the group and send a request quickly, as described in more details below.

[0053] In making reservation requests in the RW, each MC UE is

assigned a contention-free resource (e.g. one slot) within the RW to send a

10 reservation request for one MCE transmission within the frame. Each UE sends only one reservation request within the RW.

[0054] In order to avoid collisions and guarantee QoS for MCE traffic,

all UEs in the group are able to receive all reservation requests for a given frame.

In the example in FIG. 8, reservation requests are orthogonal in time and sent

15 across all frequencies. In this RW configuration, when sending a reservation request, the UE ensures it avoids MCE transmission opportunities already reserved by other UEs. In other words, UEs must decode every reservation request before their assigned reservation slot within a RW.

[0055] In some cases, there is a low probability of multiple MC events

20 within a frame, making it relatively unlikely that fairness would be an issue as UEs in the early reservation slots are able to reserve resources first. However, enhancements such as a slot rotation mechanism may be implemented to avoid such issues. Table 1 illustrates an example of fields of a reservation request message.

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Table 1: Example of Reservation Request Message.

Field Name	Size (bits)	Description
UE_TempGroupID	8	This is a unique temporary media access control (MAC) layer identifier used to address the MC UE within a group. This ID may be assigned by the eNB or acquired with support from another UE within the group (e.g. cluster head).
Reservation_type	1	0 – Guaranteed Reservation (GR) 1 – Periodic Reservation (PR)

TONumber	4	Each value indicates a transmission opportunity number, which maps to a specific resource location for a within a reservation frame. Depending on the Reservation_type (GR or PR), the actual location of the resources may be different. The number to resource location mapping can be configured by the network and communicated to UEs during registration.
PRframe_offset		Used to indicate the number of frames offset with respect to the current frame within which the reservation is requested. This is used for periodic reservations which may be requested for future frames.
Target_UEID	8	Address of the destination UE, sub-group or broadcast. This field may be omitted if all MC communications are transmitted as broadcast within the group.

[0056] A different RW configuration may be used where reservation resources per UE are orthogonal in frequency (or code) as shown in FIG. 7. In this case, collisions cannot be avoided by sequentially decoding and reserving the resources as multiple UEs must transmit their requests simultaneously. Therefore, in order to avoid collisions, a fixed mapping between the reservation slot and the location of MCE transmission opportunity should be defined. In this RW configuration, a single bit may be used to replace the TONumber in the request to indicate whether the UE will be using the reservation in the current frame.

[0057] In some cases, network assisted confirmation of claimed reservations may be implemented. FIG. 9 illustrates an example reservation frame 900 including a bitmap 920 indicating claimed reservations. The reservation frame 900 includes a reservation window 910 divided into blocks 915 for reservation requests. The reservation frame 900 also includes blocks, defined on the time and frequency graph, for MCE data 930, non-MC data 940 and PR data 950.

[0058] In order to add one extra level of reliability when coverage to the network is available, the BS receives the reservation requests and transmits a confirmation of the claimed reservations to all UEs within the group. In one

embodiment, the BS sends the bitmap 920 indicating which transmission opportunities have been claimed for the current reservation frame. The bitmap 920 may be sent in a resource within the RW 910. For instance, the last slot of the RW 910 could be reserved for the BS to send a confirmation of all
5 reservations. In this way, the RW 910 is extended to include UE's reservation requests plus one final confirmation from the BS. Alternatively, the BS may use another available channel (e.g. downlink or broadcast control channels), if it is able to meet timing alignment and latency requirements before the start of the data part of the reservation frame 900.

10 [0059] In some cases, unclaimed reservations may be re-used. UEs transmit requests with a null reservation even when they do not have a MCE packet to send, such that the other UEs know when the MCE transmission opportunities are used or when they are not claimed. If MCE transmission opportunities are not claimed, they may be used by any other UE using the
15 contention-based mode.

[0060] The RW can also be used to discover and track other UEs in the group. The reservation request can be used as a very small periodic beacon (or hello message) to help UEs track each other. However, such requests may not be able to carry application data payloads required by D2D discovery traffic. In this
20 case, the D2D discovery payloads (e.g. Society of Automotive Engineers (SAE) J2735 Basic Safety Messages) may be transmitted using periodic reservations or using contention-based mode.

[0061] FIG. 10 illustrates an example reservation frame 1000 where a base station assigns unclaimed reservations in accordance with some
25 embodiments. As shown, the reservation frame 1000 includes a RW 1010, reservation blocks 1015, a base station block 1020, MCE data blocks 1030, non-MC data blocks 1040, and PR data blocks 1050 defined on the time and frequency axes.

[0062] In one embodiment, the network (i.e. BS) may receive the
30 reservation requests from UEs, detect un-claimed MC reservations and assign the un-reserved resources by transmitting assignments at the end of the RW 1010 (in BS block 1020) as shown in FIG. 10. This method may be used while the group is within coverage to improve resource utilization efficiency.

[0063] The eNB (or BS) may assign a reservation resource (slot) to each MC UE when the MC UE joins the group, if the group is operating within network coverage.

[0064] A UE may join an existing group that is outside a coverage area.

- 5 If the group is operating autonomously outside network coverage and a new UE wants to join the group, it may use the slot after the RW (W+1) and the last slot in the reservation frame (N) to send a request to join the group. A UE operating as cluster head monitors these slots and respond to confirm/ deny the requests as well as assign an identifier for the UE within the group. The response is
10 transmitted using the contention-based access mode.

- [0065] The group joining request may also include a MCE reservation request in case the UE has already the resource configuration parameters necessary to format the request and it is sent in the W+1 slot. However, the joining/ requesting UE may wait for a confirmation from another UE before
15 proceeding with its requested MCE transmission. The confirmation may be transmitted during unreserved MCE transmission opportunities. Therefore, the joining UE is only able to request MCE transmission opportunities towards the end of the frame in order to leave enough time for receiving an acknowledgment/ confirmation from a cluster head before the requested slots. A MC UE may also
20 use the slots W+1 and N to acquire a RW slot, in case it has not been assigned a slot by the eNB, but it has valid system configuration parameters and is time synchronized.

- [0066] Aspects of the subject technology may implement collision resolution during joining slots when outside of the coverage area. Multiple UEs
25 may access the joining slots simultaneously leading to collisions. Collisions can be handled similarly as other random access procedures where UEs use contention-free access codes to transmit in the same resource. Since joining messages do not carry guaranteed reservation requests (as they must be confirmed by another UE/ cluster head), collisions in the joining slots do not
30 interfere with guaranteed reservation with the frame.

[0067] Some aspects provide periodic reservation (PR) access. MC UEs with periodic sensing (PS) and/or D2D discovery (DI) traffic may also send Periodic Reservation (PR) requests during reservation slots, if there is no urgent

MCE traffic. A PR transmission opportunity may be reserved within the frame as discussed in conjunction with FIG. 6.

[0068] FIG. 11 illustrates an example reservation frame 1100 with periodic reservation opportunities. The reservation frame 1100 includes a RW
 5 1110 with multiple slots 1115. The reservation frame 1100 also includes PR data blocks 1120 defined in the time vs. frequency graph.

[0069] When requesting resources in the PR mode, the UE gives priority to resources at the end of the reservation frame. In this way, more resources at the beginning of the frame will be available for MCE packets, which helps
 10 reducing latency. FIG. 11 shows an example of PR transmission opportunities 1120 at the end of the reservation frame 1100.

[0070] A period reservation may be preempted by a guaranteed reservation. In other words, if the UE detects a guaranteed reservation overlapping its own periodic reservation resources, the UE does not transmit and
 15 gives the priority to the MCE packet transmission.

[0071] The periodic reservations (PR) are generally used for traffic with higher delay tolerance than MCE packets and a known transmission period, such as V2X safety beacons (e.g., 100 msec). Therefore, a PR transmission opportunity may also be reserved several frames in advance (see FIG. 5) by
 20 using the PRframe_offset parameter in the request (see Table 1).

[0072] If a MC UE has already an assigned reservation slot within the RW, it may use the slot to send a PR reservation whenever there is no MCE traffic for that frame. However, in some examples, the UE does not send the PR request in every reservation frame if the UE is not expected to generate MCE
 25 packets. For instance, a UE may operate as a sensor, which only sends data to a controller. In this case, reservation requests may be sent at a larger interval, defined as the Periodic Reservation Interval, which may be set to several frames. In this particular case, UEs acquire a RW slot before every PR request transmission. This can be done using the eNB (within coverage) or the joining
 30 slots in outside coverage with a confirmation from another UE/ cluster head as described above.

[0073] In order to avoid collisions with existing reservations, new UEs monitor the reservation window for at least the Periodic Reservation Interval before sending their request for this type of reservation.

[0074] Some aspects provide contention-based best effort access.

- 5 Resources that have not be reserved within the frame can be used for Best Effort (BE) traffic in contention-based mode. In order to identify which resources are available, UEs must decode all reservations requests in the RW for a given frame. In addition, a listen before talk mechanism is used to access the available (unclaimed) resources.
- 10 [0075] The UE performs energy detection in slot (or sub-slot, depending on the slot size) intervals before accessing the contention-based resources, which must be well defined within the frame. In one example (see FIG. 6), one slot across all channels defines the minimal contention-based resource. Multiple slots could be combined to transmit non-MC data traffic. However, a maximum
- 15 contention-based transmission opportunity (Max_CB_TX) should be defined in order to prevent BE traffic from overloading the channel. In this way, large packets could be segmented and transmitted in unclaimed resources, while MC UEs would still have the opportunity to acquire the channel in contention based mode for higher priority MCE data packets. The contention-based mode would
- 20 operate similar to an 802.11 network. In order to enable communication in this mode, UEs shall listen in each slot (or sub-slot) and decode oncoming physical (PHY) packets, detect the destination address in the header and decide if it has to send the packet to the higher layer (in case the packet is directed to the UE or it is a broadcast).
- 25 [0076] The UE may apply Arbitration Inter-frame Spacing (AIFS) access parameters based on the QoS class before transmitting. The lower the AIFS the higher the priority given to a certain class. The MCE traffic has the highest priority, followed by PS/DI and Best Effort (BE) traffic. In this way, lower priority traffic can be transmitted most of the time when there is no MC event.
- 30 Since MC events are expected to be sparse, this mode can considerably improve the system utilization while still giving the needed priority to reserved transmissions. Exponential backoff mechanism may also be used to avoid collisions when the medium is detected busy. This flexible design also helps the

MCE packets that arrive at the MAC layer after the RW to be transmitted in the same frame using contention mode with higher priority.

[0077] FIG. 12 illustrates an example reservation frame and reservation window configuration. FIG. 12 illustrates a reservation frame 1200 that includes the reservation window 1210. The reservation window hosts multiple (e.g., 18) MCE reservations 1215, defined along the time and frequency axes. Each MCE reservation corresponds to a slot, such as the slot 1225, in the MCE transmission opportunities 1220. In summary, FIG. 12 illustrates one example of system configuration that could support up to 18 simultaneous MCE data transmissions in a 0.25 ms frame. As described earlier, different configurations may be used depending on the requirements, spectrum resources available and UE capabilities.

[0078] As used herein, D2D communication may refer to sidelink communication, and a D2D channel may be a sidelink channel. D2D and sidelink each encompass their plain and ordinary meaning and may be used interchangeably.

[0079] FIG. 13 shows an example of a portion of an end-to-end network architecture of a Long Term Evolution (LTE) network 1300 with various components of the network in accordance with some embodiments. As used herein, an LTE network refers to both LTE and LTE Advanced (LTE-A) networks as well as other versions of LTE networks to be developed. The network 1300 may comprise a radio access network (RAN) (e.g., as depicted, the E-UTRAN or evolved universal terrestrial radio access network) 1301 and core network 1320 (e.g., shown as an evolved packet core (EPC)) coupled together through an S1 interface 1315. For convenience and brevity, only a portion of the core network 1320, as well as the RAN 1301, is shown in the example. The network 1300 includes the UE 1302, which is configured to implement the techniques described in conjunction with Example 1, below. The network 1300 includes the eNBs 1304, which are configured to implement the techniques described in conjunction with Example 13, below.

[0080] The core network 1320 may include a mobility management entity (MME) 1322, serving gateway (serving GW) 1324, and packet data network gateway (PDN GW) 1326. The RAN 1301 may include evolved node

Bs (eNBs) 1304 (which may operate as base stations) for communicating with user equipment (UE) 1302. The eNBs 1304 may include macro eNBs 1304a and low power (LP) eNBs 1304b. In some cases, the connection between a UE 1302 and an eNB 1304 is a LTE-Uu connection. In some cases, one or more of the
5 UEs 1302 includes a ProSe application for D2D communication via a PC5 connection. The UEs may have a PC3 connection to a ProSe Function 1330.

[0081] The MME 1322 may be similar in function to the control plane of legacy Serving GPRS Support Nodes (SGSN). The MME 1322 may manage mobility aspects in access such as gateway selection and tracking area list
10 management. The serving GW 1324 may terminate the interface toward the RAN 1301, and route data packets between the RAN 1301 and the core network 1320. In addition, the serving GW 1324 may be a local mobility anchor point for inter-eNB handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy
15 enforcement. The serving GW 1324 and the MME 1322 may be implemented in one physical node or separate physical nodes.

[0082] The PDN GW 1326 may terminate a SGi interface toward the packet data network (PDN). The PDN GW 1326 may route data packets between the EPC 1320 and the external PDN, and may perform policy enforcement and
20 charging data collection. The PDN GW 1326 may also provide an anchor point for mobility devices with non-LTE access. The external PDN can be any kind of IP network, as well as an IP Multimedia Subsystem (IMS) domain. The PDN GW 1326 and the serving GW 1324 may be implemented in a single physical node or separate physical nodes.

[0083] The eNBs 1304 (macro and micro) may terminate the air interface protocol and may be the first point of contact for a UE 1302. In some
25 embodiments, an eNB 1304 may fulfill various logical functions for the RAN 1301 including, but not limited to, RNC (radio network controller functions) such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In
30 accordance with embodiments, UEs 1302 may be configured to communicate orthogonal frequency division multiplexed (OFDM) communication signals with an eNB 1304 over a multicarrier communication channel in accordance with an

OFDMA communication technique. The OFDM signals may comprise a plurality of orthogonal subcarriers.

[0084] The S1 interface 1315 may be the interface that separates the RAN 1301 and the EPC 1320. It may be split into two parts: the S1-U, which
5 may carry traffic data between the eNBs 1304 and the serving GW 1324, and the S1-MME, which may be a signaling interface between the eNBs 1304 and the MME 1322. The X2 interface may be the interface between eNBs 1304. The X2 interface may comprise two parts, the X2-C and X2-U. The X2-C may be the control plane interface between the eNBs 1304, while the X2-U may be the user
10 plane interface between the eNBs 1304.

[0085] With cellular networks, LP cells 1304b may be typically used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with dense usage. In particular, it may be desirable to enhance the coverage of a wireless communication system using cells of
15 different sizes, macrocells, microcells, picocells, and femtocells, to boost system performance. The cells of different sizes may operate on the same frequency band, or may operate on different frequency bands with each cell operating in a different frequency band or only cells of different sizes operating on different frequency bands. As used herein, the term LP eNB refers to any suitable
20 relatively LP eNB for implementing a smaller cell (smaller than a macro cell) such as a femtocell, a picocell, or a microcell. Femtocell eNBs may be typically provided by a mobile network operator to its residential or enterprise customers. A femtocell may be typically the size of a residential gateway or smaller and generally connect to a broadband line. The femtocell may connect to the mobile
25 operator's mobile network and provide extra coverage in a range of typically 30 to 50 meters. Thus, a LP eNB 1304b might be a femtocell eNB since it is coupled through the PDN GW 1326. Similarly, a picocell may be a wireless communication system typically covering a small area, such as in-building (offices, shopping malls, train stations, etc.), or more recently in-aircraft. A
30 picocell eNB may generally connect through the X2 link to another eNB such as a macro eNB through its base station controller (BSC) functionality. Thus, LP eNB may be implemented with a picocell eNB since it may be coupled to a macro eNB 1304a via an X2 interface. Picocell eNBs or other LP eNBs LP eNB

1304b may incorporate some or all functionality of a macro eNB LP eNB 1304a. In some cases, this may be referred to as an access point base station or enterprise femtocell.

[0086] In some embodiments, the UE 1302 may communicate with an
5 access point (AP) 1304c. The AP 1304c may use only the unlicensed spectrum (e.g., WiFi bands) to communicate with the UE 1302. The AP 1304c may communicate with the macro eNB 1304A (or LP eNB 1304B) through an Xw interface. In some embodiments, the AP 1304c may communicate with the UE
10 1302 independent of communication between the UE 1302 and the macro eNB 1304A. In other embodiments, the AP 1304c may be controlled by the macro eNB 1304A and use LWA, as described in more detail below.

[0087] Communication over an LTE network may be split up into 10ms frames, each of which may contain ten 1ms subframes. Each subframe of the frame, in turn, may contain two slots of 0.5ms. Each subframe may be used for
15 uplink (UL) communications from the UE to the eNB or downlink (DL) communications from the eNB to the UE. In one embodiment, the eNB may allocate a greater number of DL communications than UL communications in a particular frame. The eNB may schedule transmissions over a variety of frequency bands (f_1 and f_2). The allocation of resources in subframes used in one
20 frequency band and may differ from those in another frequency band. Each slot of the subframe may contain 6-7 OFDM symbols, depending on the system used. In one embodiment, the subframe may contain 12 subcarriers. A downlink resource grid may be used for downlink transmissions from an eNB to a UE, while an uplink resource grid may be used for uplink transmissions from a UE to
25 an eNB or from a UE to another UE. The resource grid may be a time-frequency grid, which is the physical resource in the downlink in each slot. The smallest time-frequency unit in a resource grid may be denoted as a resource element (RE). Each column and each row of the resource grid may correspond to one OFDM symbol and one OFDM subcarrier, respectively. The resource grid may
30 contain resource blocks (RBs) that describe the mapping of physical channels to resource elements and physical RBs (PRBs). A PRB may be the smallest unit of resources that can be allocated to a UE. A resource block may be 180 kHz wide in frequency and 1 slot long in time. In frequency, resource blocks may be either

12 x 15 kHz subcarriers or 24 x 7.5 kHz subcarriers wide. For most channels and signals, 12 subcarriers may be used per resource block, dependent on the system bandwidth. In Frequency Division Duplexed (FDD) mode, both the uplink and downlink frames may be 10ms and frequency (full-duplex) or time (half-duplex) separated. In Time Division Duplexed (TDD), the uplink and downlink subframes may be transmitted on the same frequency and are multiplexed in the time domain. The duration of the resource grid 400 in the time domain corresponds to one subframe or two resource blocks. Each resource grid may comprise 12 (subcarriers) * 14 (symbols) = 168 resource elements.

10 [0088] Each OFDM symbol may contain a cyclic prefix (CP) which may be used to effectively eliminate Inter Symbol Interference (ISI), and a Fast Fourier Transform (FFT) period. The duration of the CP may be determined by the highest anticipated degree of delay spread. Although distortion from the preceding OFDM symbol may exist within the CP, with a CP of sufficient duration, preceding OFDM symbols do not enter the FFT period. Once the FFT period signal is received and digitized, the receiver may ignore the signal in the CP.

[0089] There may be several different physical downlink channels that are conveyed using such resource blocks, including the physical downlink control channel (PDCCH) and the physical downlink shared channel (PDSCH). Each subframe may be partitioned into the PDCCH and the PDSCH. The PDCCH may normally occupy the first two symbols of each subframe and carries, among other things, information about the transport format and resource allocations related to the PDSCH channel, as well as H-ARQ information related to the uplink shared channel. The PDSCH may carry user data and higher layer signaling to a UE and occupy the remainder of the subframe. Typically, downlink scheduling (assigning control and shared channel resource blocks to UEs within a cell) may be performed at the eNB based on channel quality information provided from the UEs to the eNB, and then the downlink resource assignment information may be sent to each UE on the PDCCH used for (assigned to) the UE. The PDCCH may contain downlink control information (DCI) in one of a number of formats that indicate to the UE how to find and decode data, transmitted on PDSCH in the same subframe, from the resource

grid. The DCI format may provide details such as number of resource blocks, resource allocation type, modulation scheme, transport block, redundancy version, coding rate etc. Each DCI format may have a cyclic redundancy code (CRC) and be scrambled with a Radio Network Temporary Identifier (RNTI) that identifies the target UE for which the PDSCH is intended. Use of the UE-specific RNTI may limit decoding of the DCI format (and hence the corresponding PDSCH) to only the intended UE.

[0090] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 14 illustrates components of a UE in accordance with some embodiments. At least some of the components shown may be used in an eNB or MME, for example, such as the UE 1302 or eNB 1304 shown in FIG. 13. The UE 1400 and other components may be configured to use the synchronization signals as described herein. The UE 1400 may be a stationary, non-mobile device or may be a mobile device. In some embodiments, the UE 1400 may include application circuitry 1402, baseband circuitry 1404, Radio Frequency (RF) circuitry 1406, front-end module (FEM) circuitry 1408 and one or more antennas 1410, coupled together at least as shown. At least some of the baseband circuitry 1404, RF circuitry 1406, and FEM circuitry 1408 may form a transceiver. In some embodiments, other network elements, such as the eNB may contain some or all of the components shown in FIG. 141. Other of the network elements, such as the MME, may contain an interface, such as the S1 interface, to communicate with the eNB over a wired connection regarding the UE.

[0091] The application or processing circuitry 1402 may include one or more application processors. For example, the application circuitry 1402 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0092] The baseband circuitry 1404 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1404 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 1406 and to generate baseband signals for a transmit signal path of the RF circuitry 1406. Baseband processing circuitry 1404 may interface with the application circuitry 1402 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1406. For example, in some embodiments, the baseband circuitry 1404 may include a second generation (2G) baseband processor 1404a, third generation (3G) baseband processor 1404b, fourth generation (4G) baseband processor 1404c, and/or other baseband processor(s) 1404d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1404 (e.g., one or more of baseband processors 1404a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1406. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1404 may include FFT, precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1404 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0093] In some embodiments, the baseband circuitry 1404 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (E-UTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 1404e of the baseband circuitry 1404 may be configured to run elements of the protocol stack for

signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 1404f. The audio DSP(s) 1404f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1404 and the application circuitry 1402 may be implemented together such as, for example, on a system on a chip (SOC).

[0094] In some embodiments, the baseband circuitry 1404 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1404 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1404 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry. In some embodiments, the device can be configured to operate in accordance with communication standards or other protocols or standards, including Institute of Electrical and Electronic Engineers (IEEE) 802.16 wireless technology (WiMax), IEEE 802.11 wireless technology (WiFi) including IEEE 802.11 ad, which operates in the 60 GHz millimeter wave spectrum, various other wireless technologies such as global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE), GSM EDGE radio access network (GERAN), universal mobile telecommunications system (UMTS), UMTS terrestrial radio access network (UTRAN), or other 2G, 3G, 4G, 5G, etc. technologies either already developed or to be developed.

[0095] RF circuitry 1406 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1406 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network.

RF circuitry 1406 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1408 and provide baseband signals to the baseband circuitry 1404. RF circuitry 1406 may also include a transmit signal path which may include circuitry to up-convert
5 baseband signals provided by the baseband circuitry 1404 and provide RF output signals to the FEM circuitry 1408 for transmission.

[0096] In some embodiments, the RF circuitry 1406 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1406 may include mixer circuitry 1406a, amplifier circuitry 1406b and
10 filter circuitry 1406c. The transmit signal path of the RF circuitry 1406 may include filter circuitry 1406c and mixer circuitry 1406a. RF circuitry 1406 may also include synthesizer circuitry 1406d for synthesizing a frequency for use by the mixer circuitry 1406a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1406a of the receive signal path may
15 be configured to down-convert RF signals received from the FEM circuitry 1408 based on the synthesized frequency provided by synthesizer circuitry 1406d. The amplifier circuitry 1406b may be configured to amplify the down-converted signals and the filter circuitry 1406c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted
20 signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 1404 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1406a of the receive signal path may comprise passive mixers, although the
25 scope of the embodiments is not limited in this respect.

[0097] In some embodiments, the mixer circuitry 1406a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1406d to generate
RF output signals for the FEM circuitry 1408. The baseband signals may be
30 provided by the baseband circuitry 1404 and may be filtered by filter circuitry 1406c. The filter circuitry 1406c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0098] In some embodiments, the mixer circuitry 1406a of the receive signal path and the mixer circuitry 1406a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 1406a of the receive signal path and the mixer circuitry 1406a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1406a of the receive signal path and the mixer circuitry 1406a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 1406a of the receive signal path and the mixer circuitry 1406a of the transmit signal path may be configured for super-heterodyne operation.

[0099] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1406 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1404 may include a digital baseband interface to communicate with the RF circuitry 1406.

[00100] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[00101] In some embodiments, the synthesizer circuitry 1406d may be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1406d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00102] The synthesizer circuitry 1406d may be configured to synthesize an output frequency for use by the mixer circuitry 1406a of the RF circuitry 1406 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1406d may be a fractional N/N+1 synthesizer.

[00103] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1404 or the applications processor 1402 depending on the desired output frequency. In some
5 embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1402.

[00104] Synthesizer circuitry 1406d of the RF circuitry 1406 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the
10 phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these
15 embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[00105] In some embodiments, synthesizer circuitry 1406d may be
20 configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to
25 each other. In some embodiments, the output frequency may be a LO frequency (f_{LO}). In some embodiments, the RF circuitry 1406 may include an IQ/polar converter.

[00106] FEM circuitry 1408 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more
30 antennas 1410, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1406 for further processing. FEM circuitry 1408 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF

circuitry 1406 for transmission by one or more of the one or more antennas 1410.

[00107] In some embodiments, the FEM circuitry 1408 may include a TX/RX switch to switch between transmit mode and receive mode operation.

- 5 The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1406). The transmit signal path of the FEM circuitry 1408 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1406), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1410).

- [00108]** In some embodiments, the UE 1400 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface as described in more detail below. In some embodiments, the UE 1400 described herein may be part of a portable wireless communication device, such as a personal digital assistant (PDA), a laptop or portable computer with wireless communication capability, a web tablet, a wireless telephone, a smartphone, a wireless headset, a pager, an instant messaging device, a digital camera, an access point, a television, a medical device (e.g., a heart rate monitor, a blood pressure monitor, etc.), or other device that may receive and/or transmit information wirelessly. In some embodiments, the UE 1400 may include one or more user interfaces designed to enable user interaction with the system and/or peripheral component interfaces designed to enable peripheral component interaction with the system. For example, the UE 1400 may include one or more of a keyboard, a keypad, a touchpad, a display, a sensor, a non-volatile memory port, a universal serial bus (USB) port, an audio jack, a power supply interface, one or more antennas, a graphics processor, an application processor, a speaker, a microphone, and other I/O components. The display may be an LCD or LED screen including a touch screen. The sensor may include a gyro sensor, an accelerometer, a proximity sensor, an ambient light sensor, and a positioning unit. The positioning unit may communicate with

components of a positioning network, e.g., a global positioning system (GPS) satellite.

5 **[00109]** The antennas 1410 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some multiple-input multiple-output (MIMO) embodiments, the antennas 1410 may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result.

10 **[00110]** Although the UE 1400 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or
15 more microprocessors, DSPs, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more
20 processing elements.

[00111] Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described
25 herein. A computer-readable storage device may include any non-transitory mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices
30 and media. Some embodiments may include one or more processors and may be configured with instructions stored on a computer-readable storage device.

[00112] FIG. 15 is a block diagram of a communication device 1500 in accordance with some embodiments. The communication device 1500 may be a

UE or eNB, for example, such as the UE 1302 or eNB 1304 shown in FIG. 13. The physical layer circuitry 1502 may perform various encoding and decoding functions that may include formation of baseband signals for transmission and decoding of received signals. The communication device 1500 may also include

5 medium access control layer (MAC) circuitry 1504 for controlling access to the wireless medium. The communication device 1500 may also include processing circuitry 1506, such as one or more single-core or multi-core processors, and memory 1508 arranged to perform the operations described herein. The physical layer circuitry 1502, MAC circuitry 1504 and processing circuitry 1506 may

10 handle various radio control functions that enable communication with one or more radio networks compatible with one or more radio technologies. The radio control functions may include signal modulation, encoding, decoding, radio frequency shifting, etc. For example, similar to the device shown in FIG. 2, in some embodiments, communication may be enabled with one or more of a

15 WMAN, a WLAN, and a WPAN. In some embodiments, the communication device 1500 can be configured to operate in accordance with 3GPP standards or other protocols or standards, including WiMax, WiFi, WiGig, GSM, EDGE, GERAN, UMTS, UTRAN, or other 3G, 3G, 4G, 5G, etc. technologies either already developed or to be developed. The communication device 1500 may

20 include transceiver circuitry 1512 to enable communication with other external devices wirelessly and interfaces 1514 to enable wired communication with other external devices. As another example, the transceiver circuitry 1512 may perform various transmission and reception functions such as conversion of signals between a baseband range and a Radio Frequency (RF) range.

25 **[00113]** The antennas 1501 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some MIMO embodiments, the antennas 1501 may be effectively separated to take advantage of spatial

30 diversity and the different channel characteristics that may result.

[00114] Although the communication device 1500 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured

elements, such as processing elements including DSPs, and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, FPGAs, ASICs, RFICs and combinations of various hardware and logic circuitry for performing at least the functions described
5 herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements. Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one
10 processor to perform the operations described herein.

[00115] FIG. 16 illustrates another block diagram of a communication device 1600 in accordance with some embodiments. The communication device 1300 may correspond to the UE 1302 or the eNB 1304. In alternative embodiments, the communication device 1600 may operate as a standalone
15 device or may be connected (e.g., networked) to other communication devices. In a networked deployment, the communication device 1600 may operate in the capacity of a server communication device, a client communication device, or both in server-client network environments. In an example, the communication device 1600 may act as a peer communication device in peer-to-peer (P2P) (or
20 other distributed) network environment. The communication device 1600 may be a UE, eNB, PC, a tablet PC, a STB, a PDA, a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any communication device capable of executing instructions (sequential or otherwise) that specify actions to be taken by that communication device.
25 Further, while only a single communication device is illustrated, the term “communication device” shall also be taken to include any collection of communication devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer
30 cluster configurations.

[00116] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and

may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a communication device readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[00117] Accordingly, the term “module” is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times.

Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[00118] Communication device (e.g., computer system) 1600 may include a hardware processor 1602 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 1604 and a static memory 1606, some or all of which may communicate with each other via an interlink (e.g., bus) 1608. The communication device 1600 may further include a display unit 1610, an alphanumeric input device 1612 (e.g., a keyboard), and a user interface (UI) navigation device 1614 (e.g., a mouse). In an example, the display unit 1610, input device 1612 and UI navigation device 1614 may be a touch screen display. The communication device 1600 may additionally include a storage device (e.g., drive unit) 1616, a signal generation device 1618 (e.g., a speaker), a network

interface device 1620, and one or more sensors 1621, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The communication device 1600 may include an output controller 1628, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g.,
5 infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[00119] The storage device 1616 may include a communication device readable medium 1622 on which is stored one or more sets of data structures or instructions 1624 (e.g., software) embodying or utilized by any one or more of
10 the techniques or functions described herein. The instructions 1624 may also reside, completely or at least partially, within the main memory 1604, within static memory 1606, or within the hardware processor 1602 during execution thereof by the communication device 1600. In an example, one or any combination of the hardware processor 1602, the main memory 1604, the static
15 memory 1606, or the storage device 1616 may constitute communication device readable media.

[00120] While the communication device readable medium 1622 is illustrated as a single medium, the term "communication device readable medium" may include a single medium or multiple media (e.g., a centralized or
20 distributed database, and/or associated caches and servers) configured to store the one or more instructions 1624.

[00121] The term "communication device readable medium" may include any medium that is capable of storing, encoding, or carrying instructions for execution by the communication device 1600 and that cause the communication
25 device 1600 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting communication device readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of communication device readable media
30 may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks;

magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, communication device readable media may include non-transitory communication device readable media. In some examples, communication device readable media may include communication
5 device readable media that is not a transitory propagating signal.

[00122] The instructions 1624 may further be transmitted or received over a communications network 1626 using a transmission medium via the network interface device 1620 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user
10 datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers
15 (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®, IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 1620 may include one or
20 more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 1626. In an example, the network interface device 1620 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), MIMO, or multiple-input single-output (MISO) techniques. In some examples, the
25 network interface device 1620 may wirelessly communicate using Multiple User MIMO techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the communication device 1600, and includes digital or analog communications signals or other intangible medium to facilitate
30 communication of such software.

[00123] The subject technology is described below in conjunction with various examples.

[00124] Example 1 is an apparatus of a user equipment (UE), the apparatus comprising: processing circuitry and memory, the processing circuitry to: decode a first reservation request for a guaranteed reservation, the guaranteed reservation for transmission of a mission critical (MC) packet to a second UE
5 using device-to-device (D2D) communication; encode, in a reservation window (RW) of a reservation frame, a second reservation request to reserve a contention-free allocated resource, wherein the contention-free allocated resource occupies resources in the reservation frame immediately adjacent to the RW; and configure the MC packet for D2D transmission on the contention-free
10 allocated resource.

[00125] In Example 2, the subject matter of Example 1 optionally includes that the UE comprises a vehicle computer, and wherein the D2D communication comprises vehicle-to-vehicle (V2V) communication.

[00126] In Example 3, the subject matter of any of Examples 1-2
15 optionally includes that the RW occupies a set of resources at a beginning of the reservation frame.

[00127] In Example 4, the subject matter of any of Examples 1-2 optionally includes that a set of resources at an end of the reservation frame are for periodic data traffic.

20 [00128] In Example 5, the subject matter of Example 4 optionally includes that a set of resources between the contention-free allocated resource and the resources for periodic data traffic are for non-MC data traffic.

[00129] In Example 6, the subject matter of Example 5 optionally includes that the processing circuitry is further to encode a third reservation request for a
25 periodic data packet.

[00130] In Example 7, the subject matter of any of Examples 1-2 optionally includes that the reservation frame has a reservation frame structure that is defined using a time domain or a frequency domain and received from an evolved NodeB (eNB), and wherein the reservation frame structure specifies
30 positions of the RW and the contention-free allocated resource.

[00131] In Example 8, the subject matter of any of Examples 1-2 optionally includes that the reservation frame comprises a vehicle-to-vehicle (V2V) safety beacon.

[00132] In Example 9, the subject matter of any of Examples 1-2 optionally includes that the processing circuitry comprises a baseband processor.

[00133] In Example 10, the subject matter of any of Examples 1-2 optionally includes transceiver circuitry to transmit the MC packet on the
5 contention free allocated resource.

[00134] In Example 11, the subject matter of Example 10 optionally includes that the transceiver circuitry is to transmit the MC packet using a millimeter-wave frequency.

[00135] In Example 12, the subject matter of Example 10 optionally
10 includes an antenna coupled to the transceiver circuitry.

[00136] Example 13 is an apparatus of an evolved NodeB (eNB), the apparatus comprising: processing circuitry and memory, the processing circuitry to: assign a contention-free allocated resource of a reservation frame to a first user equipment (UE) requesting a resource for a guaranteed reservation, the
15 guaranteed reservation for transmission of a mission critical (MC) packet to a second UE using device-to-device (D2D) communication; and encode, using a reservation window (RW), an assignment of the contention-free allocated resource in downlink control information (DCI) for transmission to the first UE via physical downlink control channel (PDCCH).

20 [00137] In Example 14, the subject matter of Example 13 optionally includes that the first UE comprises a vehicle computer, and wherein the D2D communication comprises vehicle-to-vehicle (V2V) communication.

[00138] In Example 15, the subject matter of Example 13 optionally includes that the processing circuitry is further to: process a request, from the
25 first UE, for transmission of periodic data or non-MC data using a contention-based mechanism to access non-MC resources of the reservation frame.

[00139] In Example 16, the subject matter of Example 13 optionally includes that the RW comprises a single slot in a time domain, wherein the RW is subdivided, in a frequency domain, into reservation blocks for UEs to reserve
30 contention-free resources.

[00140] In Example 17, the subject matter of Example 16 optionally includes that the reservation frame comprises an eNB slot immediately following

the RW, and the processing circuitry is further to encode, in the eNB slot, allocations of unclaimed slots in the reservation frame for non-MC data.

[00141] In Example 18, the subject matter of Example 13 optionally includes that the reservation frame comprises blocks for MC events, blocks for
5 non-MC data, and blocks for periodic data defined in a time domain or a frequency domain.

[00142] In Example 19, the subject matter of Example 18 optionally includes that the blocks for periodic data reside at an end of the reservation frame, and the blocks for periodic data are occupied by MC data in a case where
10 the blocks for MC events are occupied.

[00143] Example 20 is a computer-readable storage medium that stores instructions for execution by processing circuitry of a user equipment (UE) to configure the UE to perform operations for device-to-device (D2D) communications, the processing circuitry configured to: decode a first
15 reservation request for a guaranteed reservation, the guaranteed reservation for transmission of a mission critical (MC) packet to a second UE using device-to-device (D2D) communication; encode, in a reservation window (RW) of a reservation frame, a second reservation request to reserve a contention-free allocated resource, wherein the contention-free allocated resource occupies
20 resources in the reservation frame immediately adjacent to the RW; and configure the MC packet for D2D transmission on the contention-free allocated resource.

[00144] In Example 21, the subject matter of Example 20 optionally includes that the UE comprises a vehicle computer, and wherein the D2D
25 communication comprises vehicle-to-vehicle (V2V) communication.

[00145] In Example 22, the subject matter of Example 20 optionally includes that the RW occupies a set of resources at a beginning of the reservation frame.

[00146] Example 23 is an apparatus of a user equipment (UE), the
30 apparatus comprising: means for decoding a first reservation request for a guaranteed reservation, the guaranteed reservation for transmission of a mission critical (MC) packet to a second UE using device-to-device (D2D) communication; means for encoding, in a reservation window (RW) of a

reservation frame, a second reservation request to reserve a contention-free allocated resource, wherein the contention-free allocated resource occupies resources in the reservation frame immediately adjacent to the RW; and means for configuring the MC packet for D2D transmission on the contention-free allocated resource.

[00147] In Example 24, the subject matter of Example 23 optionally includes that the UE comprises a vehicle computer, and wherein the D2D communication comprises vehicle-to-vehicle (V2V) communication.

[00148] In Example 25, the subject matter of Example 23 optionally includes that the RW occupies a set of resources at a beginning of the reservation frame.

[00149] Although an embodiment has been described with reference to specific example embodiments, it will be evident that various modifications and changes may be made to these embodiments. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. The accompanying drawings that form a part hereof show, by way of illustration, and not of limitation, specific embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

[00150] Although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

[00151] In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, UE, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[00152] The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

What is claimed is:

1. An apparatus of a user equipment (UE), the apparatus comprising:
5 processing circuitry and memory; the processing circuitry to:
 decode a first reservation request for a guaranteed reservation, the
 guaranteed reservation for transmission of a mission critical (MC) packet to a
 second UE using device-to-device (D2D) communication;
 encode, in a reservation window (RW) of a reservation frame, a second
10 reservation request to reserve a contention-free allocated resource, wherein the
 contention-free allocated resource occupies resources in the reservation frame
 immediately adjacent to the RW; and
 configure the MC packet for D2D transmission on the contention-free
 allocated resource.
15
2. The apparatus of claim 1, wherein the UE comprises a vehicle computer,
 and wherein the D2D communication comprises vehicle-to-vehicle (V2V)
 communication.
- 20 3. The apparatus of any of claims 1-2, wherein the RW occupies a set of
 resources at a beginning of the reservation frame.
4. The apparatus of any of claims 1-2, wherein a set of resources at an end
 of the reservation frame are for periodic data traffic.
- 25 5. The apparatus of claim 4, wherein a set of resources between the
 contention-free allocated resource and the resources for periodic data traffic are
 for non-MC data traffic.
- 30 6. The apparatus of claim 5, wherein the processing circuitry is further to:
 encode a third reservation request for a periodic data packet.

7. The apparatus of any of claims 1-2, wherein the reservation frame has a reservation frame structure that is defined using a time domain or a frequency domain and received from an evolved NodeB (eNB), and wherein the reservation frame structure specifies positions of the RW and the contention-free allocated resource.
8. The apparatus of any of claims 1-2, wherein the reservation frame comprises a vehicle-to-vehicle (V2V) safety beacon.
9. The apparatus of any of claims 1-2, wherein the processing circuitry comprises a baseband processor.
10. The apparatus of any of claims 1-2, further comprising transceiver circuitry to transmit the MC packet on the contention free allocated resource.
11. The apparatus of claim 10, wherein the transceiver circuitry is to transmit the MC packet using a millimeter-wave frequency.
12. The apparatus of claim 10, further comprising an antenna coupled to the transceiver circuitry.
13. An apparatus of evolved node B (eNB), the apparatus comprising:
processing circuitry and memory; the processing circuitry to:
assign a contention-free allocated resource of a reservation frame to a first user equipment (UE) requesting a resource for a guaranteed reservation, the guaranteed reservation for transmission of a mission critical (MC) packet to a second UE using device-to-device (D2D) communication; and
encode, using a reservation window (RW), an assignment of the contention-free allocated resource in downlink control information (DCI) for transmission to the first UE via physical downlink control channel (PDCCH).

14. The apparatus of claim 13, wherein the first UE comprises a vehicle computer, and wherein the D2D communication comprises vehicle-to-vehicle (V2V) communication.
- 5 15. The apparatus of claim 13, wherein the processing circuitry is further to:
process a request, from the first UE, for transmission of periodic data or non-MC data using a contention-based mechanism to access non-MC resources of the reservation frame.
- 10 16. The apparatus of claim 13, wherein the RW comprises a single slot in a time domain, wherein the RW is subdivided, in a frequency domain, into reservation blocks for UEs to reserve contention-free resources.
- 15 17. The apparatus of claim 16, wherein the reservation frame comprises an eNB slot immediately following the RW, and wherein the processing circuitry is further to:
encode, in the eNB slot, allocations of unclaimed slots in the reservation frame for non-MC data.
- 20 18. The apparatus of claim 13, wherein the reservation frame comprises blocks for MC events, blocks for non-MC data, and blocks for periodic data defined in a time domain or a frequency domain.
- 25 19. The apparatus of claim 18, wherein the blocks for periodic data reside at an end of the reservation frame, and wherein the blocks for periodic data are occupied by MC data in a case where the blocks for MC events are occupied.

20. A computer-readable storage medium that stores instructions for execution by processing circuitry of a user equipment (UE) to configure the UE to perform operations for device-to-device (D2D) communications, the processing circuitry configured to:
- 5 decode a first reservation request for a guaranteed reservation, the guaranteed reservation for transmission of a mission critical (MC) packet to a second UE using device-to-device (D2D) communication;
- encode, in a reservation window (RW) of a reservation frame, a second reservation request to reserve a contention-free allocated resource, wherein the
- 10 contention-free allocated resource occupies resources in the reservation frame immediately adjacent to the RW; and
- configure the MC packet for D2D transmission on the contention-free allocated resource.
- 15 21. The computer-readable storage medium of claim 20, wherein the UE comprises a vehicle computer, and wherein the D2D communication comprises vehicle-to-vehicle (V2V) communication.
22. The computer-readable storage medium of claim 20, wherein the RW
- 20 occupies a set of resources at a beginning of the reservation frame.
23. An apparatus of a user equipment (UE), the apparatus comprising:
- means for decoding a first reservation request for a guaranteed reservation, the guaranteed reservation for transmission of a mission critical
- 25 (MC) packet to a second UE using device-to-device (D2D) communication;
- means for encoding, in a reservation window (RW) of a reservation frame, a second reservation request to reserve a contention-free allocated resource, wherein the contention-free allocated resource occupies resources in the reservation frame immediately adjacent to the RW; and
- 30 means for configuring the MC packet for D2D transmission on the contention-free allocated resource.

24. The apparatus of claim 23, wherein the UE comprises a vehicle computer, and wherein the D2D communication comprises vehicle-to-vehicle (V2V) communication.
- 5 25. The apparatus of claim 23, wherein the RW occupies a set of resources at a beginning of the reservation frame.

10

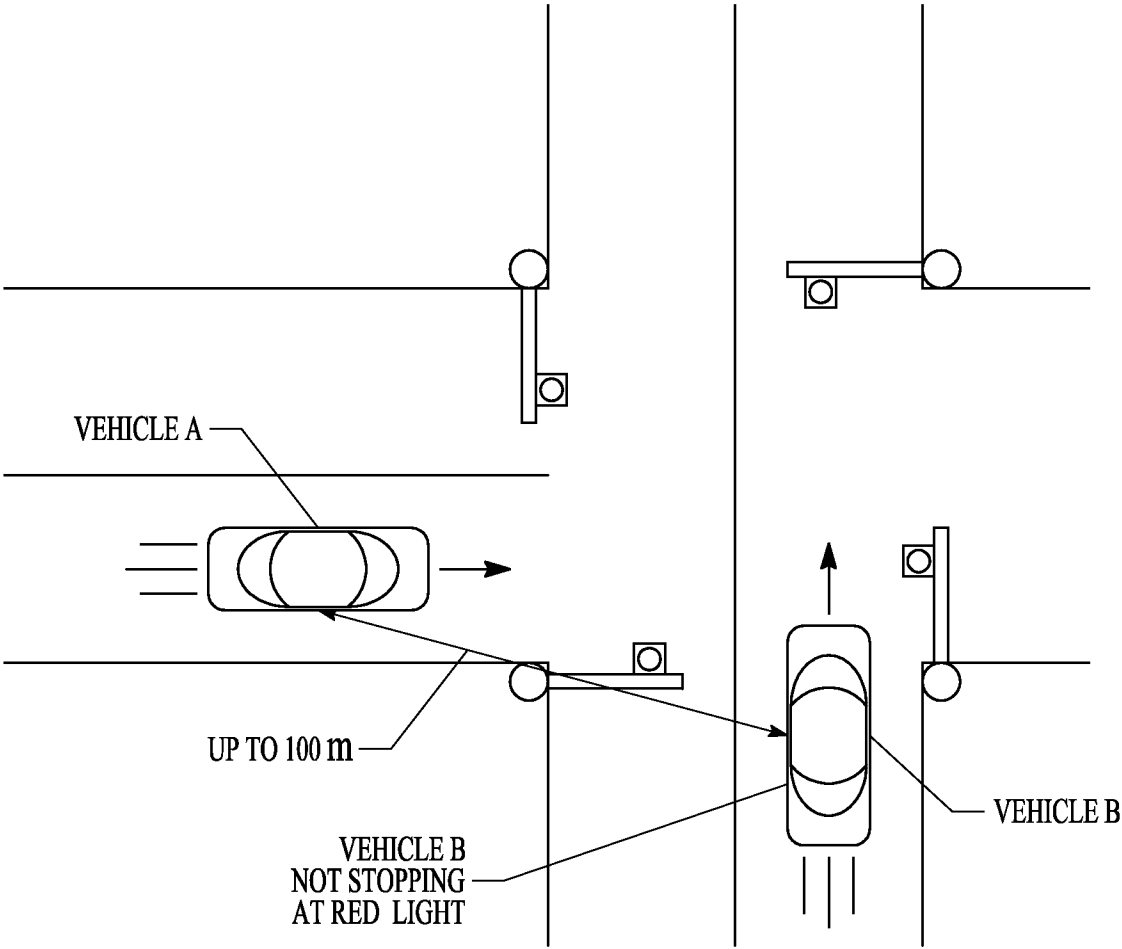


FIG. 1A

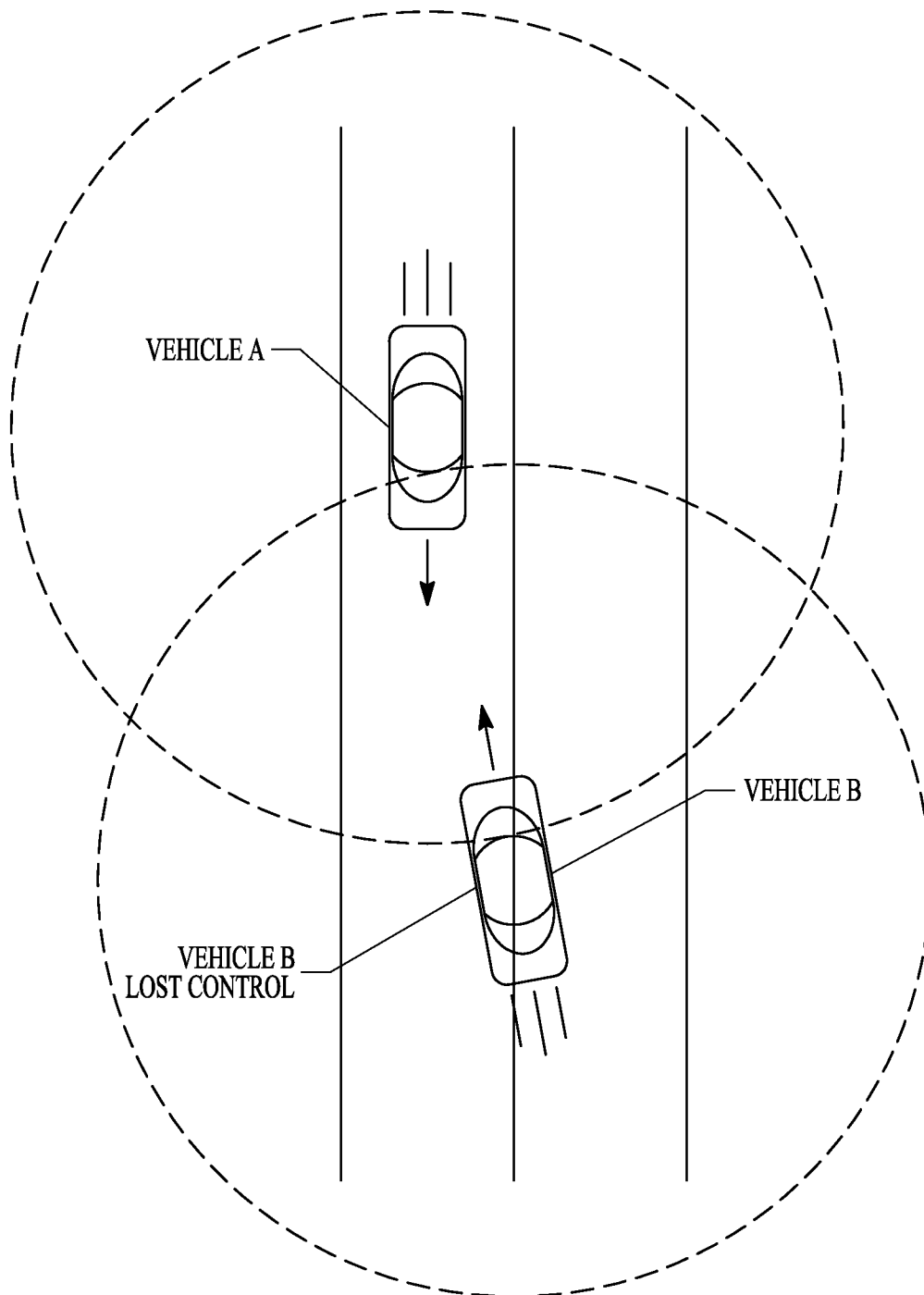


FIG. 1B

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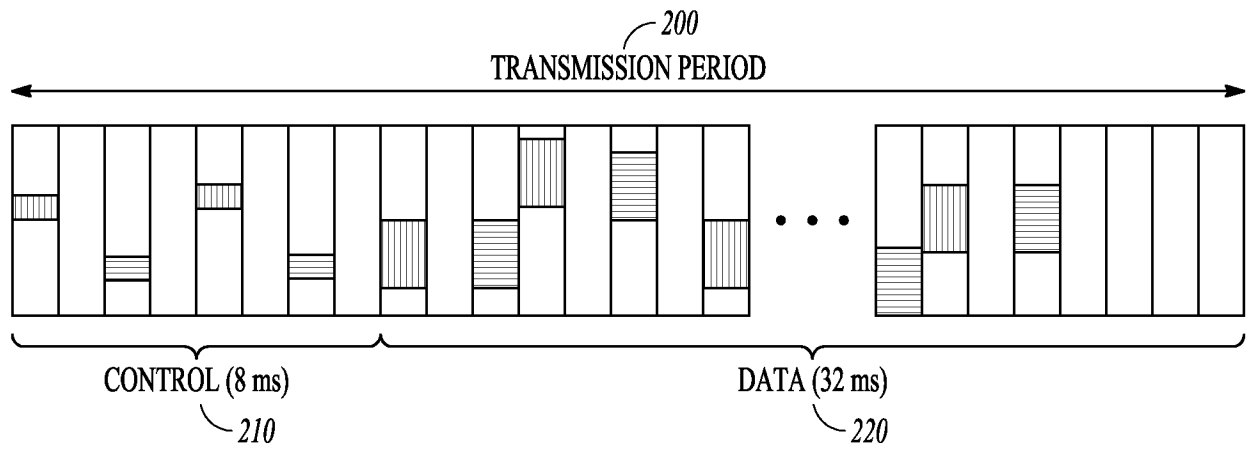


FIG. 2

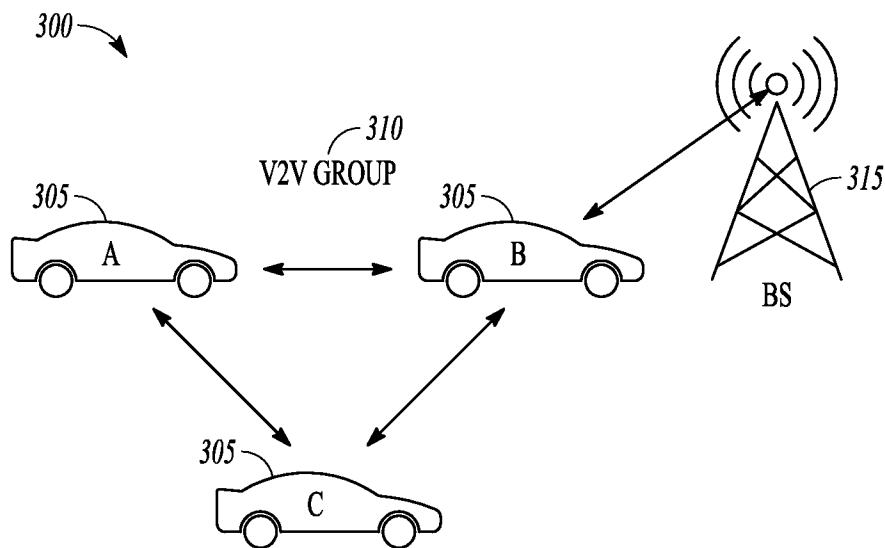


FIG. 3

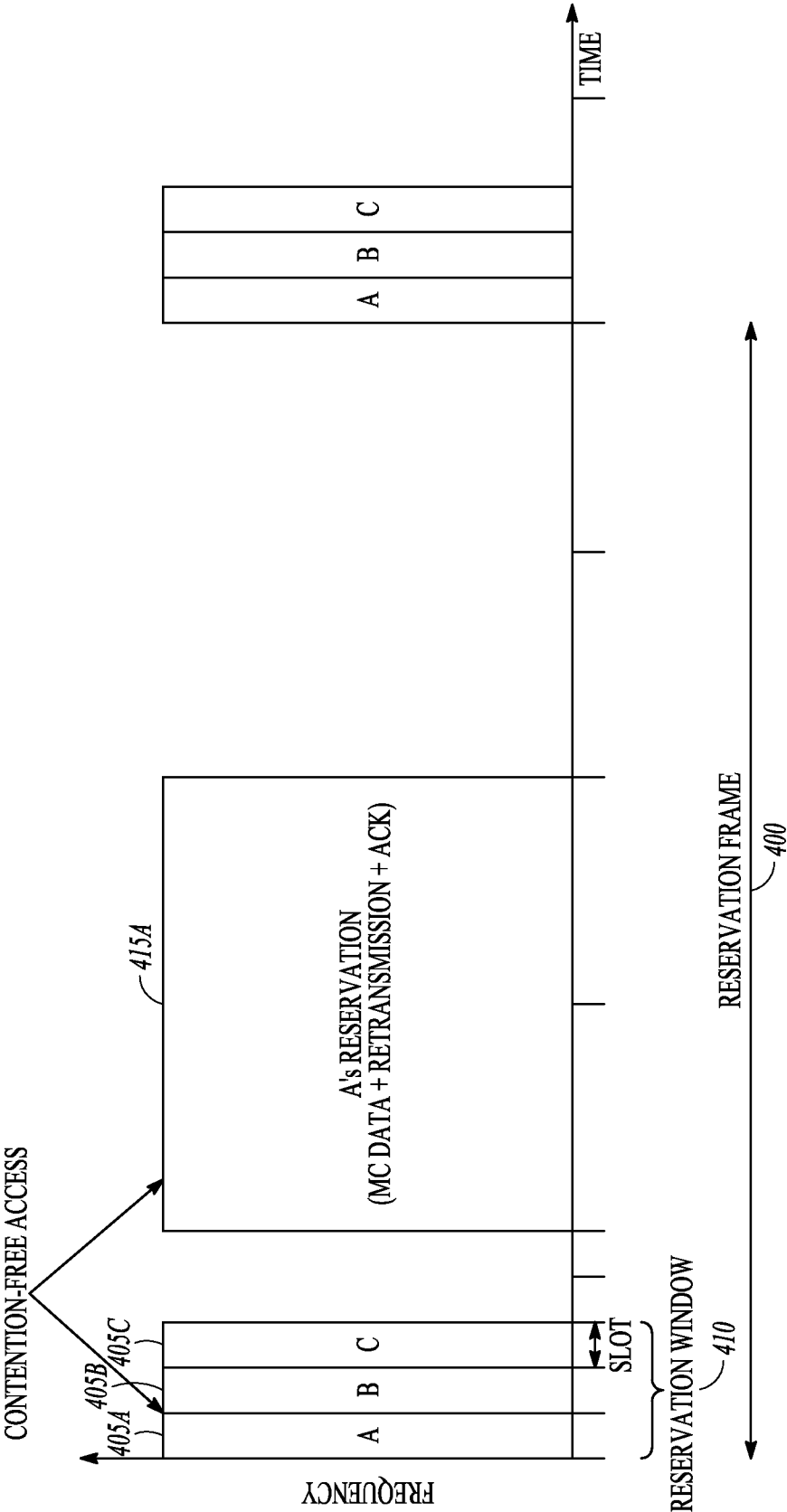


FIG. 4

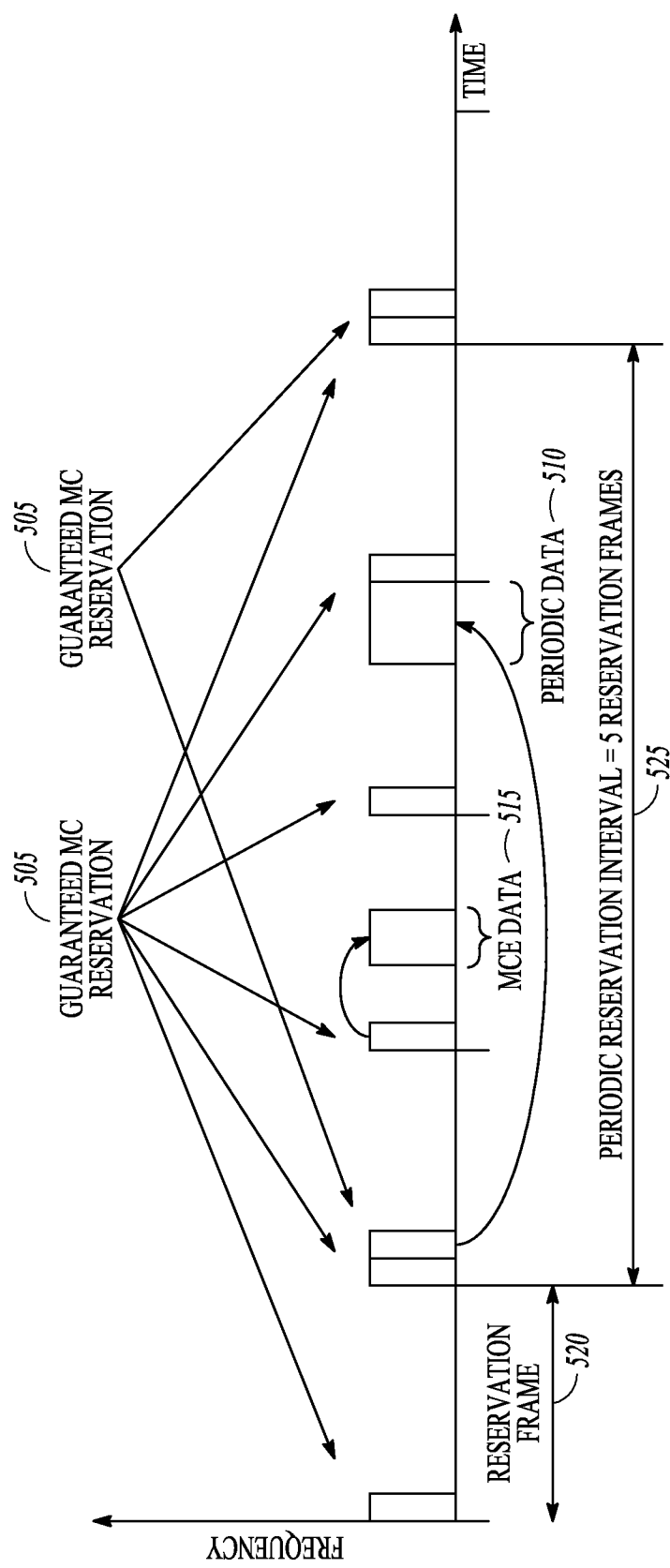


FIG. 5

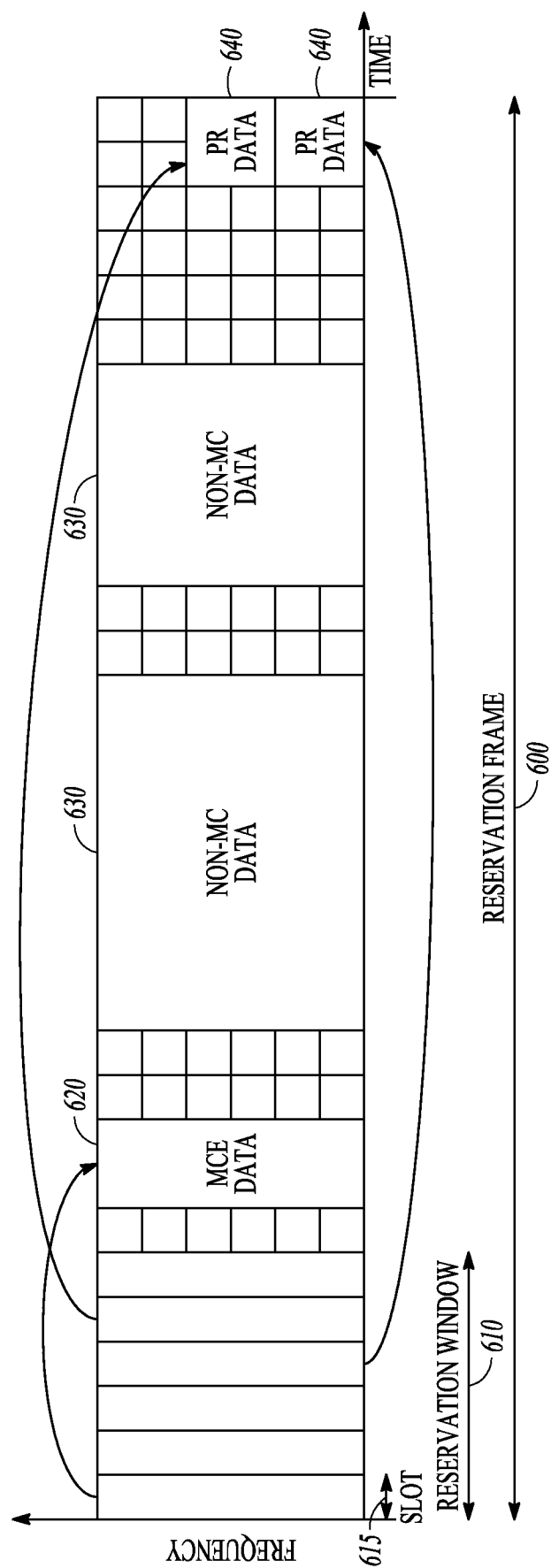


FIG. 6

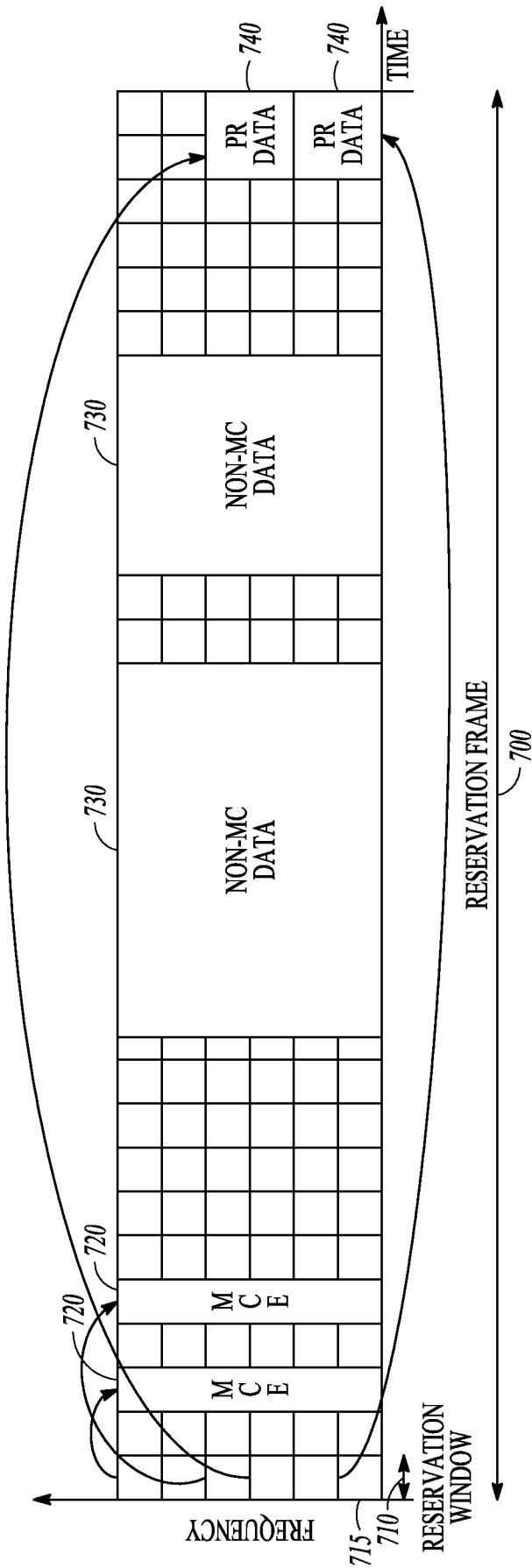


FIG. 7

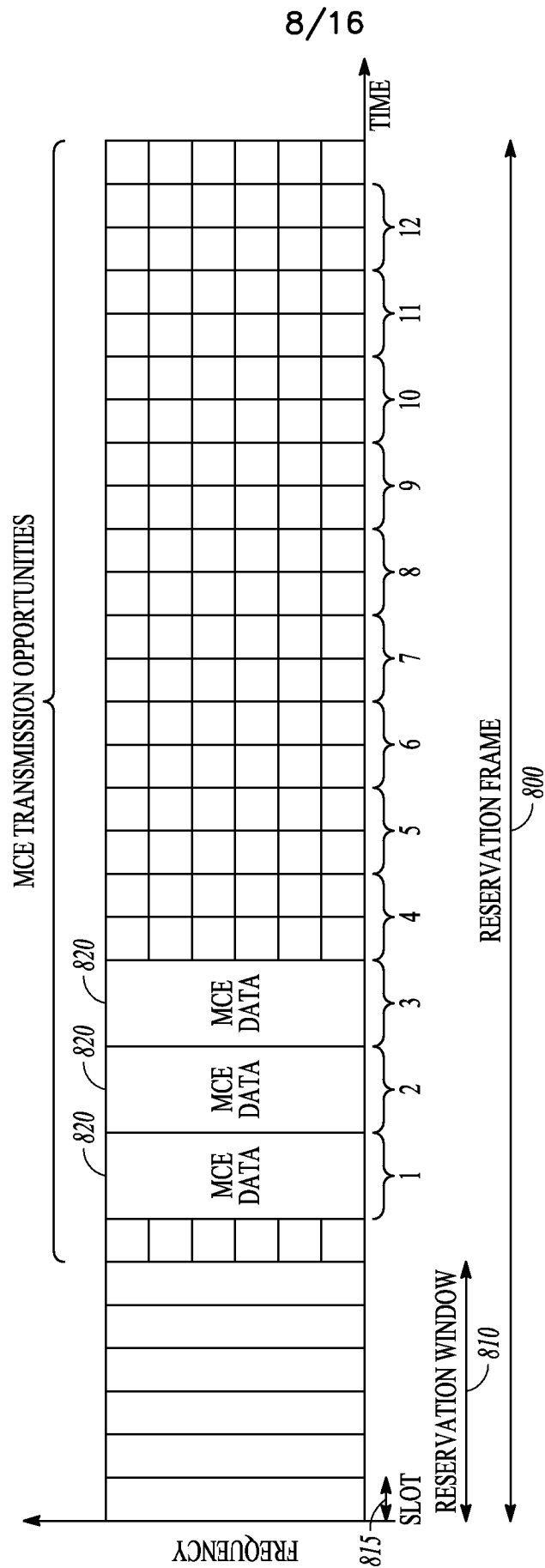


FIG. 8

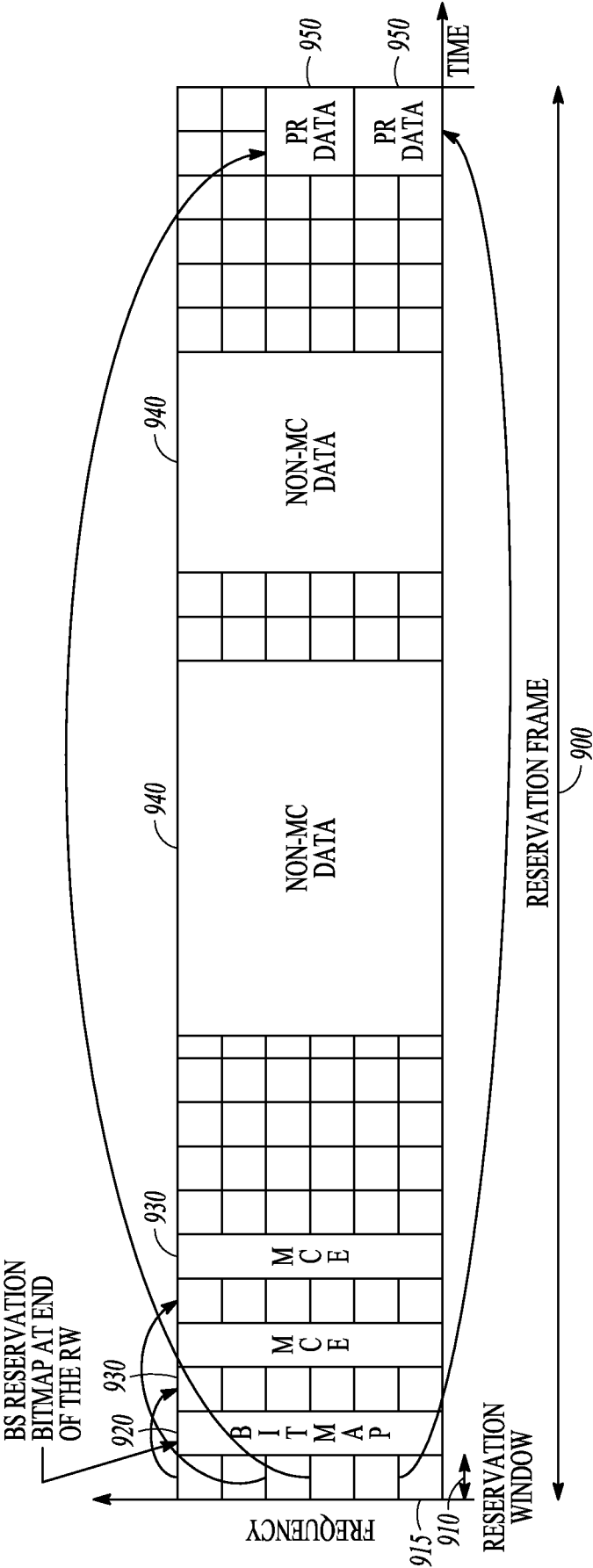


FIG. 9

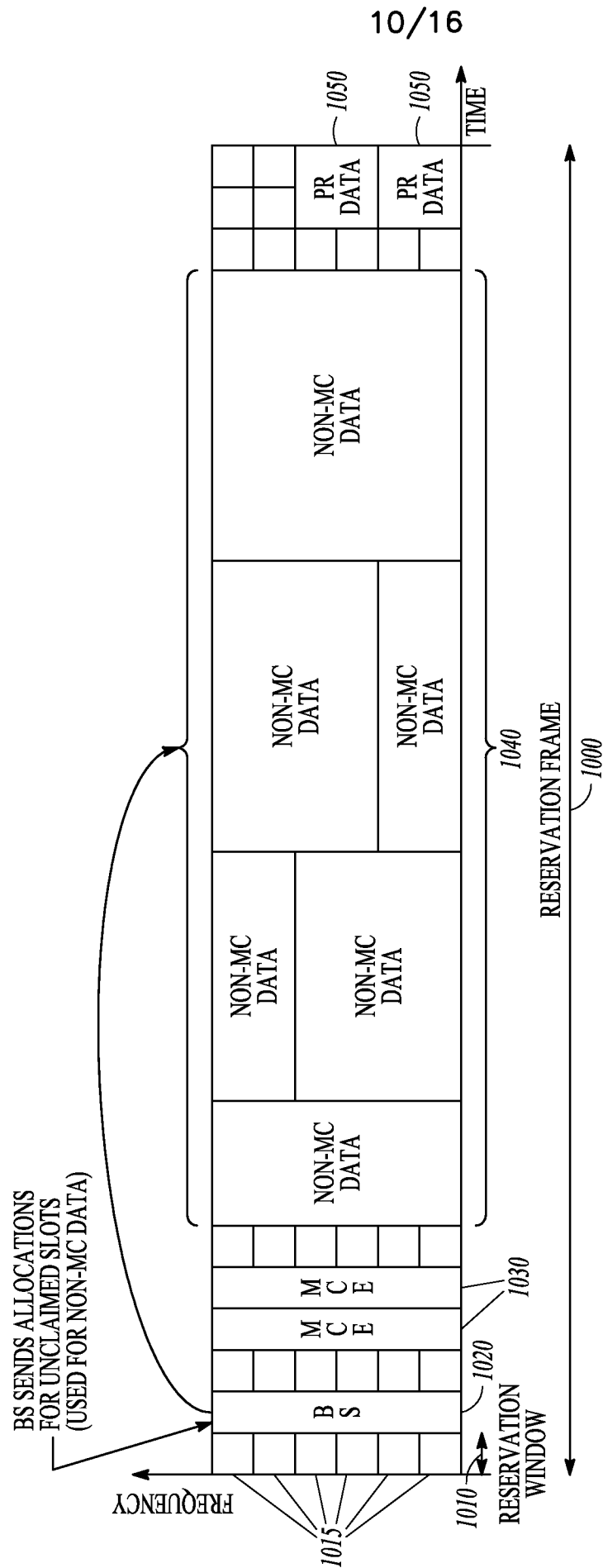


FIG. 10

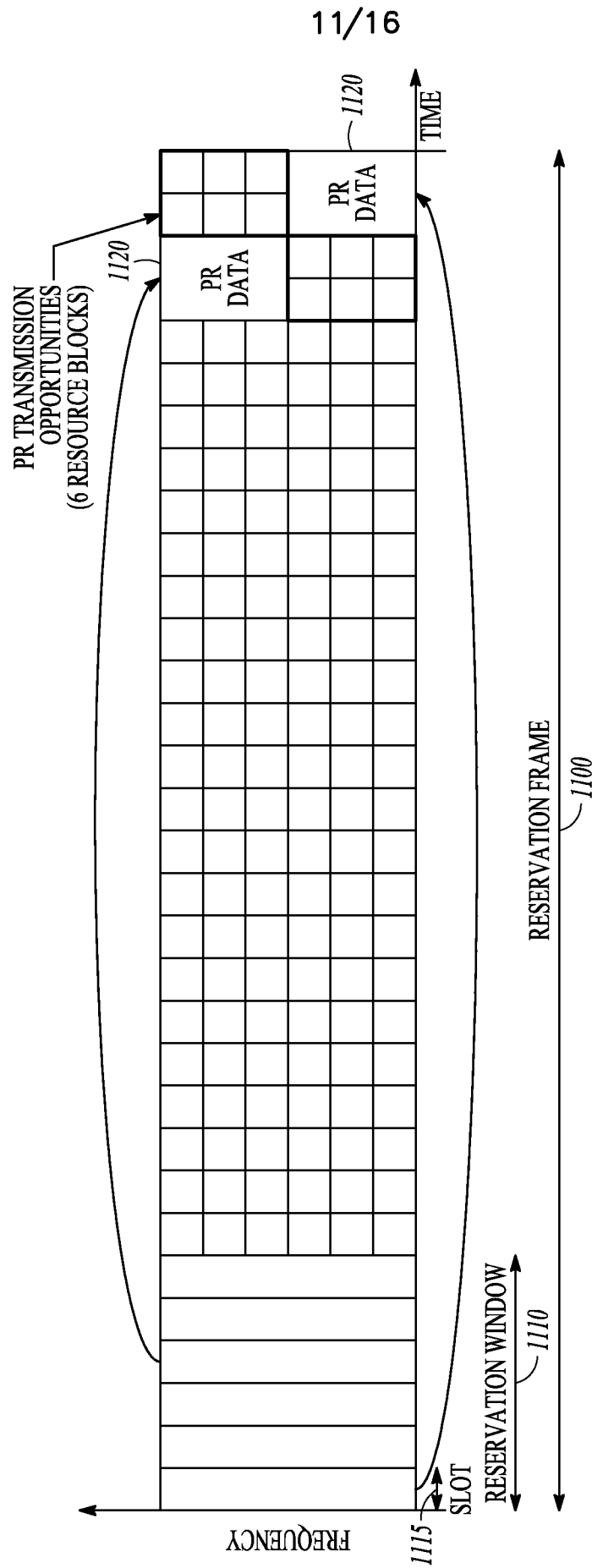


FIG. 11

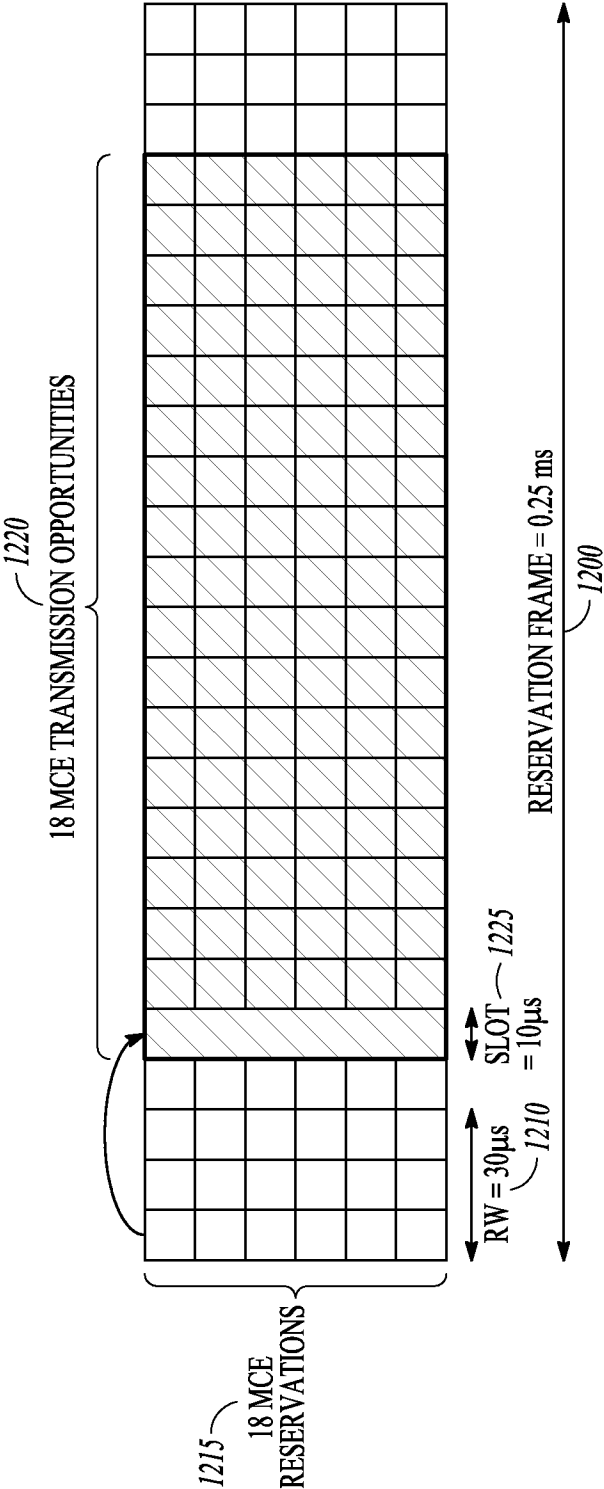


FIG. 12

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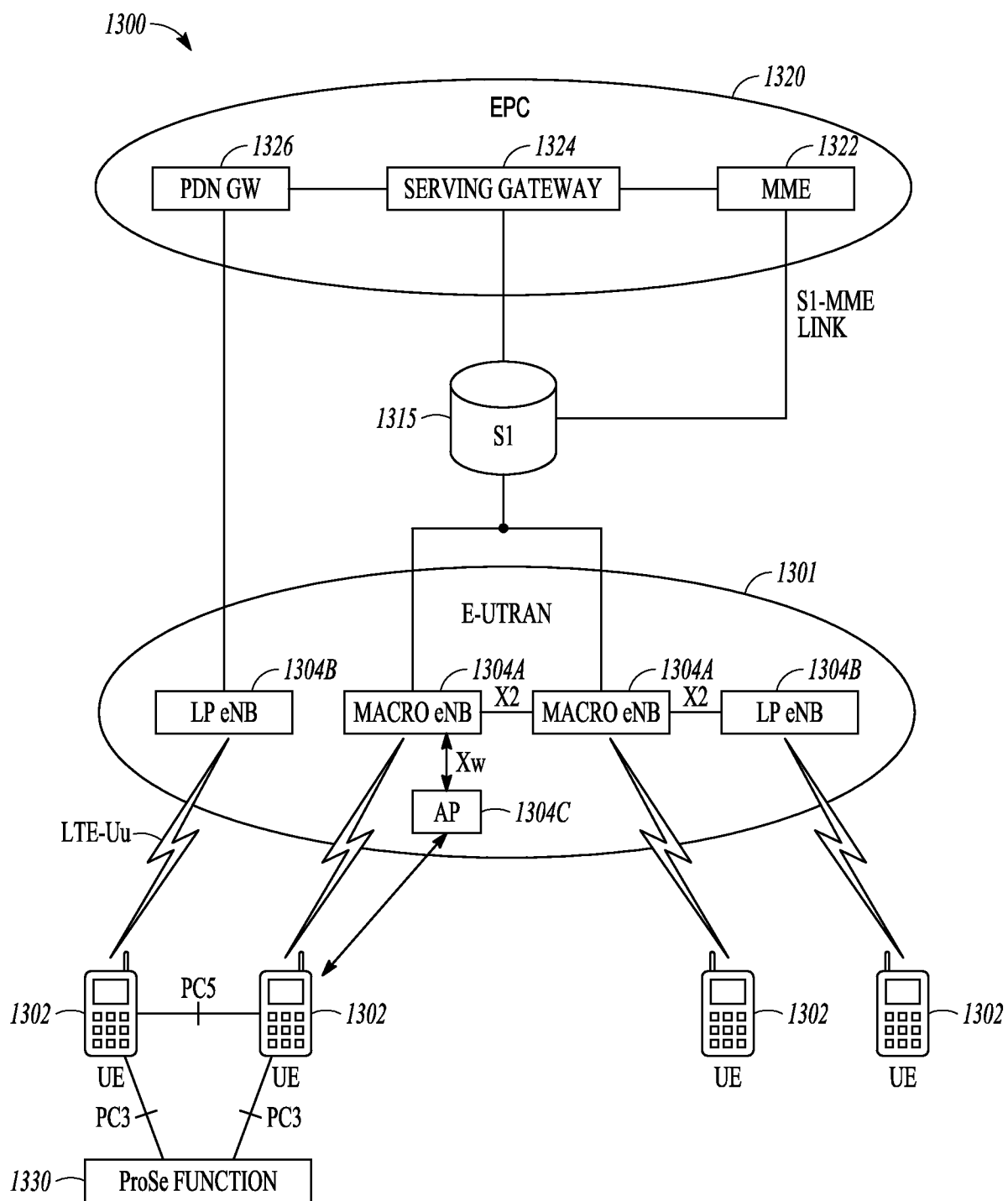
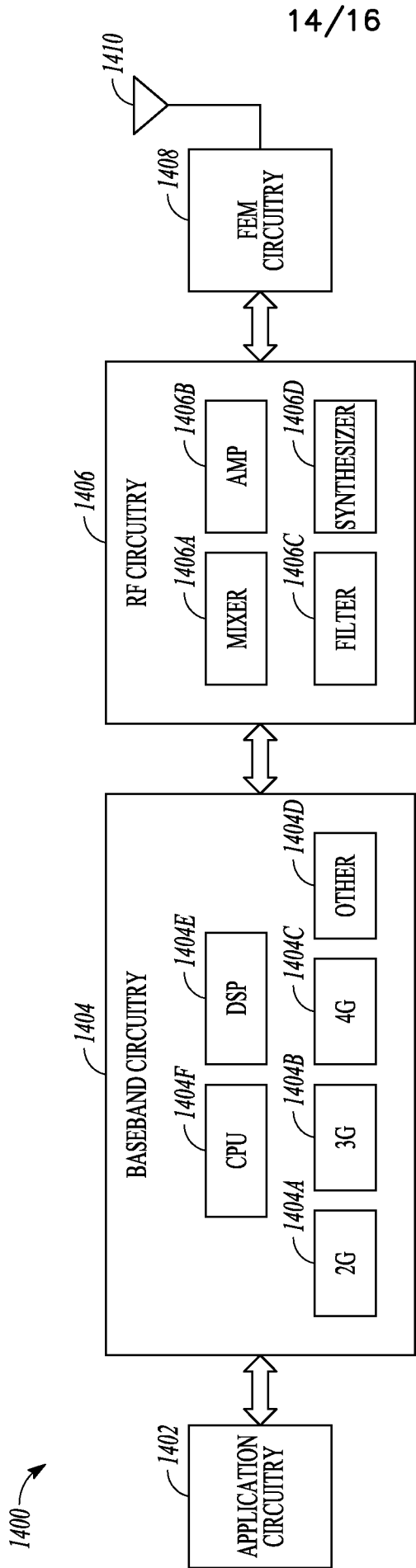


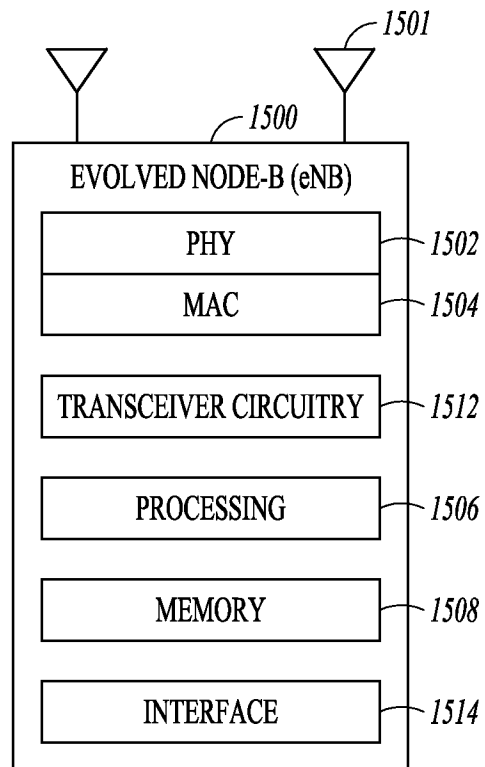
FIG. 13



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FIG. 14

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*FIG. 15*

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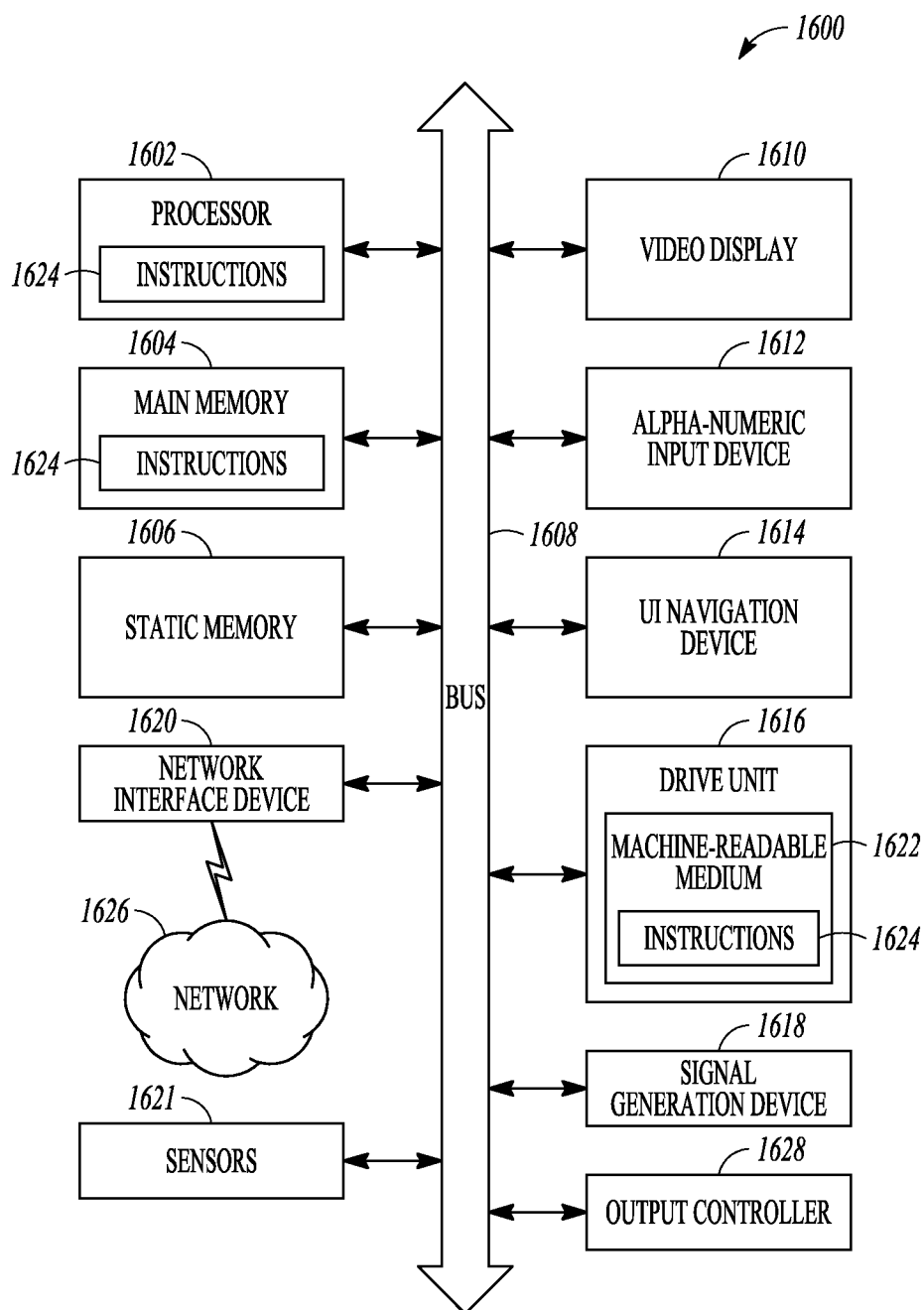


FIG. 16

A. CLASSIFICATION OF SUBJECT MATTER**H04L 1/18(2006.01)I, H04W 74/08(2009.01)I, H04L 5/00(2006.01)I, H04L 29/08(2006.01)I, H04W 4/00(2009.01)I**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L 1/18; H04W 76/02; H04W 4/08; H04W 8/00; H04W 4/02; H04W 72/04; H04W 72/10; H04J 3/00; H04W 74/08; H04L 5/00; H04L 29/08; H04W 4/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: device to device, mission critical packet, guaranteed reservation, reservation request, contention-free allocated source

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2015-160158 A1 (LG ELECTRONICS INC.) 22 October 2015 See page 100, lines 9-13, page 106, line 1 - page 107, line 17, claims 8-11 and figure 37.	1-25
A	WO 2013-181515 A2 (INTERDIGITAL PATENT HOLDINGS, INC.) 05 December 2013 See paragraphs [0026], [0048], [0154]-[0167], claims 1-3 and figure 6.	1-25
A	US 2015-0195827 A1 (XIANJUN FENG et al.) 09 July 2015 See paragraphs [0047]-[0052], [0088]-[0099], claims 10-12 and figures 1-2.	1-25
A	US 2015-0131571 A1 (TELEFONAKTIEBOLAGET L M ERICSSON (PUBL)) 14 May 2015 See paragraphs [0008]-[0012], [0016]-[0021], [0049]-[0057], claim 1 and figure 2.	1-25
A	US 2009-0310571 A1 (RAINER MATISCHEK et al.) 17 December 2009 See paragraphs [0018]-[0019], [0050]-[0053], claim 1 and figure 4.	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

05 October 2016 (05.10.2016)

Date of mailing of the international search report

05 October 2016 (05.10.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

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Information on patent family members

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