(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 August 2017 (10.08.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/134578 A1

(51) International Patent Classification:
H04W 76/02 (2009.01) *H04W 4/04* (2009.01)
H04W 72/12 (2009.01) *H04W 84/04* (2009.01)

(21) International Application Number:
PCT/IB2017/050542

(22) International Filing Date:
1 February 2017 (01.02.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/291,281 4 February 2016 (04.02.2016) US

(71) Applicant: **TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)** [SE/SE]; SE-164 83 Stockholm, SE-164 83 Stockholm (SE).

(72) Inventors: **LI, Yunxi**; Slåttervägen 38, SE-175 50 Järfälla (SE). **WÄNSTEDT, Stefan**; Östra Brunnsgatan 30 B, SE-972 51 Luleå (SE). **BELLESCHI, Marco**; Framnäsbacken 8, SE-171 66 Solna (SE).

(74) Agents: **GERLACH, Tim** et al.; 6300 Legacy Drive, Plano, Texas 75024 (US).

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

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

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

(54) Title: LATENCY REDUCTION FOR COMMUNICATION ELEMENTS

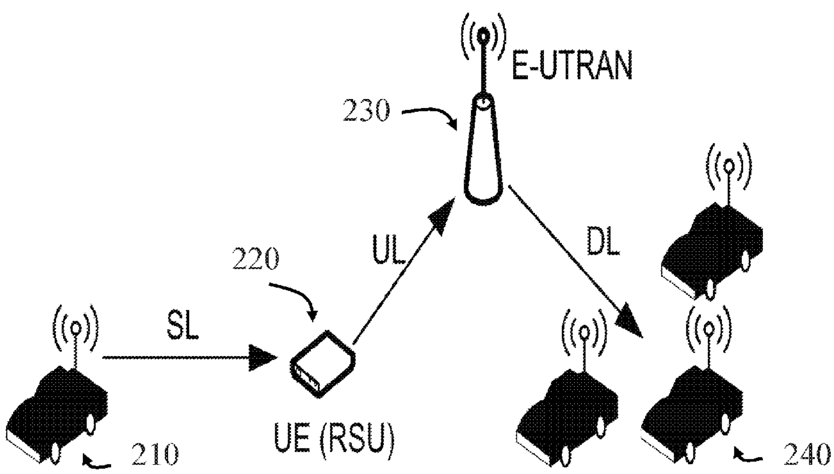

FIGURE 2

(57) Abstract: A communication element operable with a wireless device and a radio access node, and method of operating the same. In one embodiment, the communication element is configured to provide a scheduling request to the radio access node to communicate data from the wireless device, and receive an uplink grant from the radio access node. The communication element is also configured to receive the data from the wireless device, and forward the data therefrom.

WO 2017/134578 A1

LATENCY REDUCTION FOR COMMUNICATION ELEMENTS

This application claims the benefit of U.S. Provisional Application No. 62/291,281 entitled "LATENCY REDUCTION FOR UE-TYPE ROADSIDE UNITS," filed February 4, 2016, which is incorporated herein by reference.

TECHNICAL FIELD

The present invention is generally directed communication systems and, more specifically, to a system and method to reduce latency at a communication element such as a roadside unit.

BACKGROUND

During Release 12 (Rel-12), the Long Term Evolution ("LTE") standard has been extended to support device-to-device ("D2D") (specified as "sidelink") features targeting both commercial and public safety applications. An application enabled by Rel-12 LTE includes device discovery, where devices are able to sense the proximity of another device and an associated application by broadcasting and detecting discovery messages that carry device and application identities. Another application includes direct communication based on physical channels terminated directly between devices.

Direct communication between wireless devices employing out of network coverage has become a growing condition for public safety and commercial users. An objective of direct communication between non-network devices is directed to public safety considerations, which may be performed outside or partially within network coverage. A characteristic of such direct communication is latency in communicating or relaying messages. Direct communication without employing an intervening network access point requires detection of proximity of a public safety or other user device.

Accordingly, in view of recent changes to standards, there is a need for improved systems and methods that facilitate direct communication between wireless devices that support device-to-device features, that can be performed with reduced latency, and that work in combination with existing communication systems.

SUMMARY

These and other problems are generally solved or circumvented, and technical advantages are generally achieved, by advantageous embodiments of the present invention for a communication element operable with a wireless device and a radio access node. In an embodiment, the communication element is configured to provide a scheduling request to the radio access node to communicate data from the wireless device, receive an uplink grant from the radio access node, and provide a buffer status report to the radio access node. The communication element is also configured to receive another uplink grant from the radio access node, receive the data from the wireless device, and forward the data to the radio access node.

In another embodiment, the communication element is configured provide a scheduling request to the radio access node to communicate data from the wireless device, receive an uplink grant from the radio access node, and provide a sidelink buffer status report to the radio access node. The communication element is also configured to receive a sidelink grant from the radio access node, receive the data from the wireless device, and forward the data to another wireless device.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter, which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGUREs 1 and 2 illustrate system level diagrams of embodiments of communication systems;

FIGUREs 3 to 9 illustrate signaling diagrams of embodiments of operations of a communication system; and

FIGURE 10 illustrates a block diagram of an embodiment of a communication element.

Corresponding numerals and symbols in the different figures generally refer to corresponding parts unless otherwise indicated, and may not be redescribed in the interest of brevity after the first instance. The FIGUREs are drawn to illustrate the relevant aspects of exemplary embodiments.

DETAILED DESCRIPTION

The making and using of the present exemplary embodiments are discussed in detail below. It should be appreciated, however, that the embodiments provide many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the systems, subsystems, and modules associated with a communication element operable in a communication system.

A system will be described herein with respect to exemplary embodiments in a specific context, namely, a wireless communication system including a process and method to reduce latency at a communication element such as a roadside unit. While the principles will be described in the environment of a cellular communication system, any environment such as a Wi-Fi or WiMAX communication system that may benefit from such a system and method that enables these functionalities is well within the broad scope of the present disclosure.

Turning now to FIGURE 1, illustrated is a system level diagram of an embodiment of a communication system embodied in an LTE-based network. One of the potential extensions for the device-to-device ("D2D") communication includes support for V2X communication, which includes any combination of direct communication between vehicles, pedestrians and network infrastructure. In particular, under the umbrella of V2X, different types of traffic are considered. As examples, vehicle-to-vehicle ("V2V") is illustrated through wireless communication path 110, vehicle-to-infrastructure ("V2I") is illustrated through wireless communication path 120 (wherein a vehicle 160 communicates with an infrastructure element such as a roadside unit 150), vehicle-to-pedestrian ("V2P") is illustrated through wireless communication path 130, and vehicle-to-network ("V2N") is illustrated through wireless communication path 140.

Despite the terminology, there may be some overlap between use cases and specific V2X services. For instance, V2V services may employ either a direct link ("D2D") (*e.g.,* communication path 120, also referred to as an "interface") between vehicles or an Uu link (*e.g.,* communication path 140, also referred to as an "interface") towards a radio access node such as a base station (an eNB such as an eNodeB associated with an Evolved Universal Terrestrial Radio Access Network), which in turn can re-route the V2V messages within the cell, to neighbor cells, and/or to a V2V server in a core network. Therefore, V2X communication may take advantage of a network infrastructure when available, but at least basic V2X connectivity should be possible, even in the case of lack of coverage. Providing an LTE-based V2X interface may be economically advantageous because of the LTE economies of scale, and it may enable tighter integration between communications with the network infrastructure (V2I) and V2P and V2V communications, as compared to using a dedicated V2X technology.

The V2X communications may carry both safety and non-safety information, wherein each of the applications and services may be associated with specific requirement sets (for example, in terms of latency, reliability, capacity, *etc.*). The European Telecommunications Standards Institute ("ETSI") has defined two types of messages for road safety, namely, a co-operative awareness message ("CAM") and a decentralized environmental notification message ("DENM").

The CAM is intended to enable vehicles, including emergency vehicles, to notify their presence and other relevant parameters in a broadcast fashion. Such messages target other vehicles, pedestrians, and infrastructure, and are handled by their applications. The CAM also serves as active assistance to safety driving for normal traffic. The availability of a CAM is indicatively checked every 100 milliseconds ("ms"), yielding a maximum detection latency requirement of less than (or equal to) 100 ms for most messages. The DENM is event-triggered, such as by braking, and the availability of a DENM is also checked for every 100 ms.

Depending on the use, the case latency requirements for CAM and DENM may vary significantly. As an example, latency may vary from 20 ms (for pre-crash warnings) to 100 ms (for emergency stop or queue warnings), or 1000 ms (for non-safety related use cases such as traffic flow optimization, curve speed warnings, *etc.*).

The package size of the CAM and DENM varies from 100 to 800 plus bytes and the typical size is around 300 bytes depending on the specific V2X use case, message type (*e.g.*, DENM is supposed to be larger than CAM) and on the security format included in the packet (*i.e.*, full certificate or certificate digest). The message is supposed to be detected by all vehicles in proximity. The Society of the Automotive Engineers ("SAE") also defined a basic safety message ("BSM") for dedicated short range communications ("DSRC") with various message sizes. According to the importance and urgency of the messages, the BSMs are further classified into different priorities.

A roadside unit ("RSU") is as an entity (a communication or network element or node) that supports V2I service that can transmit to, and receive from a wireless device such as a user equipment ("UE") using a V2I application. The UE supporting V2I applications sends application layer information to the RSU, and the RSU sends application layer information to a group of UEs or to a UE supporting V2I applications without necessarily propagating such information to the core network. For this reason, a RSU is tailored to disseminate local information in a relatively small area, for instance, traffic intersections, parking areas, *etc*.

The RSU functionalities can be implemented either in a radio access unit such as an eNB (eNB-type RSU) or in a UE (UE-type RSU). From both physical layer and layer-2 (*i.e.*, media access control ("MAC") packet data convergence protocol ("PDCP")) perspectives, the functionalities of an eNB-type RSU and a UE-type RSU are different. An eNB-type RSU operates over a Uu interface (*e.g.*, communication path 140 of FIGURE 1) towards UEs and it is connected to any other legacy eNBs on the network via X2/S1 interfaces. A UE-type RSU has a sidelink via a PC5 interface (*e.g.*, communication path 120 of FIGURE 1) towards vehicles (as in D2D communications such as 3GPP Rel. 12 proximity services ("ProSe")) and possibly a connection over the Uu interface towards an eNB. However, from an application layer perspective, both a UE-type RSU and an eNB-type RSU support V2I use cases. The V2I use cases are, for example, emergency stop warnings, queue warnings, automated parking systems, *etc*. In such cases, the vehicles report updates to the RSU, which disseminates the information in a larger area or to a specific group of interested UEs. A RSU can also be used for V2V applications such as pre-crash warnings, cruise control, for extending coverage and propagate V2V information, or V2N applications in which case the RSU will propagate a V2N message to the core network and a centralized V2X server will collect data from a macro area.

Turning now to FIGURE 2, illustrated is a system level diagram of an embodiment of a communication system embodied in an LTE-based network. The communication system demonstrates an operating scenario for a UE-type RSU over a sidelink ("SL") and Uu operations towards vehicles and E-UTRAN, respectively. As illustrated in FIGURE 2, a vehicle 210 makes a sidelink request to a UE-type RSU 220 that in turn transmits data on an uplink ("UL") to a radio access node such as a base station 230. The base station 230 communicates on a downlink ("DL") to vehicles (one of which is designated 240).

The proximity services (also known as D2D or LTE-direct) technology has been firstly standardized in 3GPP Rel. 12. The proximity services are designed for a scenario in which the UEs are semi-static (no-mobility support for ProSe) and few UEs are contending the sidelink. Therefore, even though V2X will target more challenging scenarios (*e.g.*, high mobility in a highly loaded network), V2X is inherently a type of proximity service. For this reason, it is natural to assume that the V2X framework will continue to be developed in 3GPP taking the proximity services as a benchmark.

In the proximity services, D2D UEs share the same spectrum as the cellular system, for example, by reserving some of the cellular uplink resources for device-to-device purposes. Allocating dedicated spectrum for device-to-device purposes is a less likely alternative as spectrum is a scarce resource and (dynamic) sharing between the device-to-device services and cellular services is more flexible and provides higher spectrum efficiency. A transmission mode of sending data during D2D communication may be unicast (a specific UE is the receiver), multicast (also denoted "groupcast," a group of UEs are receivers), and broadcast (all UEs are receivers).

In the absence of cellular network coverage, D2D data can be sent from one device to another device without prior arrangement to reduce overhead and increase communication capacity, which is beneficial in emergency situations. The source device transmits data to one (unicast) or more (multicast/groupcast/broadcast) devices, without first ensuring that the recipients are available and ready to receive the data. Such communication may be used for one-to-one or one-to-many communication, but it is particularly effective for broadcast and group communication. The communication may be realized, for instance, via physical layer ("PHY") unicast/multicast/groupcast/broadcast transmissions. With PHY broadcast transmissions, the transmissions may still be turned into unicast/groupcast/multicast communication at higher layers. For example, in the media access control ("MAC") layer, multicast or even unicast addresses may be used. Alternatively, if using broadcast on both PHY and MAC layers, multicast or unicast Internet protocol ("IP") addresses may be used at the IP layer.

One of the ways to efficiently support D2D communication is to use a scheduling assignment ("SA"), also known as "SCI (sidelink control information) format 0", followed by the data transmission. The scheduling assignments are control messages used for direct scheduling of D2D communication. The scheduling assignments are transmitted by the UE that intends to transmit the D2D data, and they are received by the UEs that are potentially interested in such data. The scheduling assignments are transmitted on dedicated resources characterized by time and frequency, and are typically a sparse resource. The scheduling assignments provide useful information that can be used by a receiver, for example, to correctly decode the D2D data transmission associated with the scheduling assignment (*e.g.*, the resources for data transmission, the modulation/coding parameters, timing information, identities for the transmitter and/or receiver, *etc.*). The scheduling assignments may be transmitted prior to actual data transmission, so that a receiver is able to selectively receive the data based on the content of the assignment. The data transmissions organized by the scheduling assignments are often referred to as a "transmission pattern."

Turning now to FIGURE 3, illustrated is a signaling diagram of an embodiment of an operation of a communication system. The signaling diagram between a user equipment (designated "UE"), a roadside unit (designated "RSU") and a radio access node such as a base station (designated "eNB") demonstrates latency that may be induced due to Uu resource allocation. When a UE transmits data to the network via a RSU, the RSU receives data via a sidelink from the UE and transmits the data to the base station via a cellular link. After receiving data from the UE, the

RSU requests uplink resources from the base station prior to transmitting the data thereto. The procedure of a RSU requesting uplink resources may include sending a scheduling request ("SR") and receiving a corresponding uplink ("UL") grant, as well as sending a buffer status report ("BSR") and receiving a corresponding UL grant. This procedure will lead to additional delay in the RSU.

As illustrated in FIGURE 3, the UE is coupled over a PC5 interface to the RSU that in turn is coupled over a Uu interface to the base station. The UE transmits sidelink control information ("SCI") followed by data to the RSU. The RSU transmits a scheduling request ("SR") to the base station, which responds with an uplink grant. The RSU then transmits a buffer status report ("BSR") to the base station, which responds in turn with a further uplink grant. The RSU then transmits the data to the base station. As shown in FIGURE 3, delays associated with communication between the UE and the RSU range between 16 and 86 milliseconds ("ms"). In a typical deployment, the delays include 40 ms for the scheduling assignment ("SA") period, 8 ms for the SCI period, 32 ms for the data period, 10 ms for the SR periodicity and 3 ms for the UE/base station processing. The uplink block error rate may be in the range of 10 percent. Given the above configuration, an estimation of the mean delay due to Uu resource allocation is 24.3 ms.

Turning now to FIGURE 4, illustrated is a signaling diagram of an embodiment of an operation of a communication system. Analogous to FIGURE 3, the communication system demonstrates the latency when the RSU forwards a packet to other UEs (such as UE-2) in the surroundings rather than to the base station. The signaling diagram includes a first user equipment (designated "UE-1"), a roadside unit (designated "RSU"), a base station (designated "eNB") and a second user equipment (designated "UE-2"). The UE-1 transmits sidelink control information ("SCI") followed by data to the RSU. The RSU transmits a scheduling request ("SR") to the base station, which responds with an uplink grant. The RSU transmits a sidelink buffer status report ("SL-BSR") to the base station, which responds in turn with a sidelink ("SL") grant. The RSU then transmits the data to the UE-2. Analogous to FIGURE 3, the delays associated with communication between the UE and the RSU range between 16 and 86 ms, and an estimation of the mean delay due to Uu resource allocation is 24.3 ms. In this case, the RSU may request resources for sidelink transmission before transmitting over the sidelink to the UE-2. The latency, however, may even be higher since the uplink grant provided by the base station might not be large enough to allocate a SL-BSR if the UE-1 has also triggered a BSR (which has higher priority than SL-BSR). Thus, further SR and UL grants may be needed to finally provide the SL-BSR to the base station.

As introduced herein, when a RSU relays data from a UE to a base station or to any other UE, there will be some delay in the RSU due to requesting resources for PC5/Uu transmission. It would be advantageous to reduce or remove the delay. By more efficiently requesting resources (from the base station) for the Uu transmission, the delay associated with the RSU can be reduced. Optimizing resource allocation on the Uu interface according to the pattern of the data to be transmitted reduces the delay and resource consumption.

In order to improve the delay, the RSU may request resources for the Uu transmission before it receives the data from the UE. The RSU can estimate when and the quantity of resources that will be needed according to information in the SCI, which is received from the UE prior to the data. The RSU can also request resources for the Uu transmission before it receives an SCI from the UE, which will improve the performance at the beginning of the data period. The base station can grant resources to a RSU without receiving any SR/BSR, which further reduces latency. Separate SR resources can be configured to be used to provide a more suitable uplink grant by the base station.

The embodiments disclosed herein apply to an RSU that forwards packets received from the sidelink to base station or to any other UE (with possible modification of the payload) regardless of the layer. In particular, the forwarding operation can happen at lower layers (*e.g.*, in packet data convergence protocol ("PDCP")), or at higher layers (*e.g.*, IP, in which case the RSU operates as an IP router/relay), or at an application layer implying possible modifications of the original packet payload received over the PC5 interface. For instance, multiple packets received over the PC5 interface can be bundled into a single UL/PC5 transmission over the Uu/PC5 interface.

Turning now to FIGURE 5, illustrated is a signaling diagram of an embodiment of an operation of a communication system. The signaling diagram includes a user equipment (designated "UE"), a roadside unit (designated "RSU") and a radio access node such as a base station (designated "eNB"). The UE transmits sidelink control information ("SCI") to the RSU. The RSU transmits a scheduling request ("SR") to the base station, which responds with an uplink grant. The RSU transmits a buffer status report ("BSR") to the base station, which responds in turn with an uplink grant. At a time T1, the UE then transmits data to the RSU, which forwards the data to the base station at a time T2.

When the RSU receives the SCI from the UE, the UE has not requested any Uu resources for the data associated with this SCI. Thus, the RSU estimates the time T1 and amount of data (also referred to as "DATA_AMOUNT") needed for the communication and requests the cellular uplink resources from the base station as part of the SR and/or the BSR. The RSU estimates the time T1 and the amount of data according to the information carried by the SCI such as resource block assignment, modulation and coding scheme, *etc*.

As mentioned above, the RSU requests the cellular uplink resources from the base station and can indicate the amount of data for the communication via a BSR. The triggering mechanisms for the BSR may be modified to reduce latency. Since the UE traffic may be suffering from latency issues (due to the two hops to reach the base station), a BSR may be triggered at the reception of the SCI. Also, a D2D BSR may be triggered by the RSU if the priority of the incoming UE traffic is higher than the priority of other remote-UE packets (possibly belonging to other remote UEs) currently queued in a RSU buffer.

As part of the uplink resource request, the RSU may estimate when the time T2 (at which time the RSU can send data to the base station) will occur after the time T1. The RSU, however, may delay the uplink resource request until it receives a sidelink-shared channel ("SL-SCH") transmission from the UE associated with the SCI (*i.e.*, the RSU sends the uplink resource request after the time T1).

The RSU may also determine the timing of transmitting a resource request as set forth below. The RSU estimates a delay from sending the uplink resource request to the time when it can transmit data using granted uplink resources (also referred to as "GRANT_DELAY"). The GRANT_DELAY should take into account, for instance, an estimation of the time it takes to send a scheduling request (SR) until a subsequent BSR is granted by the network, as well as the time needed by the RSU to process the uplink grant (in LTE, *e.g.*, 4 ms). The above GRANT_DELAY can be based on historical information. Therefore, the timing of transmitting the resource request is greater than or equal to T1 – GRANT_DELAY.

In another embodiment, upon reception of an SR (and before reception of a BSR), the base station sends an uplink grant that is larger for the case that the UE acts as an RSU as opposed to the case of non-RSU UE. Since the base station as shown in FIGURE 5 does not know the buffer status upon reception of the SR, the first uplink grant should be sufficiently large to accommodate the BSR and also some data. Since it is expected that the RSU buffer will contain more data (both data generated by the RSU itself and by the UE), the size of the uplink grant should be larger.

In another embodiment, the SR is sent before the time T1 on the basis of the GRANT_DELAY estimation, but the BSR is sent after the time T1. This provides a better BSR estimation, since from SCI the UE may not be able to learn the priorities of incoming UE traffic.

In the event that the estimate of the GRANT_DELAY is difficult to ascertain, the base station (after sending an uplink grant) assumes that the uplink grant is valid for longer than 4 ms, and does not expect the RSU to send the uplink data on the physical uplink shared channel ("PUSCH") within 4 ms of the uplink grant reception. In this way, even if the RSU has not yet received any data from the UE, it can still consider that the uplink grant is valid for a longer time period without sending another SR. Clearly, the 8 ms hybrid automatic repeat request ("HARQ") process mechanism should be maintained. In other words, if no data has been received in a subframe for which the uplink grant is valid, the same uplink grant can be used 8 ms, 16 ms or so, later. Under this time and before data becomes available at the UE, the UE may fill the uplink grant with padding bits or may just skip the grant. In both cases, it can be configurable for a certain threshold (*e.g.*, maximum number of MAC protocol data units ("PDUs") with padding, or maximum number of skipped grants, or a timer) above which the grant has to be considered not valid.

Rather than a dynamic uplink grant as mentioned above, the uplink grant can be a semi-persistent scheduling ("SPS") grant that applies to every "n" subframes, wherein "n" is the periodicity of the SPS configuration. Rules for the validity of the SPS grant are as described above.

Turning now to FIGURE 6, illustrated is a signaling diagram of an embodiment of an operation of a communication system. The signaling diagram includes a first user equipment (designated "UE-1"), a roadside unit (designated "RSU"), a radio access node such as a base station (designated "eNB") and a second user equipment (designated "UE-2"). The UE-1 transmits sidelink control information ("SCI") to the RSU. The RSU transmits a scheduling request ("SR") to the base station, which responds with an uplink grant. The RSU transmits a sidelink buffer status report ("SL-BSR") to the base station, which responds in turn with a sidelink ("SL") grant. At a time T1, the UE-1 then transmits data to the RSU, which forwards the data to the UE-2 at a time T2. Thus, the RSU forwards the data to other UEs over the PC5 interface rather than to the base station over the Uu interface. The delays range from 16 and 86 ms for the UE to transmit the SCI and the data to the RSU.

Turning now to FIGURE 7, illustrated is a signaling diagram of an embodiment of an operation of a communication system. The signaling diagram includes a user equipment (designated "UE"), a roadside unit (designated "RSU") and a radio access node such as a base station (designated "eNB"). The RSU transmits a scheduling request ("SR") to the base station, which responds with a first uplink grant to accommodate a buffer status report ("BSR"). The UE then transmits sidelink control information ("SCI") to the RSU. The RSU transmits the BSR to the base station, which responds in turn with a second uplink grant. The UE then transmits data to the RSU, which forwards the data to the base station. The delay for the above-described process can extend from 16-86 ms. When the RSU is predicting some V2X data from a UE (*e.g.*, triggered by a V2X application) or the RSU intends to monitor SCI, the RSU can send the SR to the base station to request resources without receiving any SCI/data from the UE.

The first uplink grant can be used for the whole duration of the SCI period until a BSR is not included in the MAC PDU. Alternatively, after receiving a certain amount of MAC PDUs with padding, the first uplink grant may no longer be valid and discarded. Additionally, the second uplink grant is also not provided. After reception of the BSR, however, the second uplink grant is sent for transmission of data. Similar rules to those described above can be used to determine the validity of such an uplink grant. Of course, the rules can be extended to the case in which the RSU forwards packets to other UEs over the PC5 interface rather than to the base station over the Uu interface.

Turning now to FIGURE 8, illustrated is a signaling diagram of an embodiment of an operation of a communication system. The signaling diagram includes a user equipment (designated "UE"), a roadside unit (designated "RSU") and a radio access node such as a base station (designated "eNB"). The base station provides a first uplink grant to the RSU even prior to receiving a buffer status report ("BSR") in response to sidelink control information ("SCI"). The base station can provide the first uplink grant because the base station is aware of SCI time-frequency resources. After receiving the first uplink grant, the RSU receives the SCI from the UE. In response thereto, the RSU transmits the BSR to the base station, which responds in turn with a second uplink grant. The UE then transmits data to the RSU, which forwards the data to the base station. The delay for the above-described process can extend from 16-86 ms.

During a "busy period" (*e.g.*, if there is no ongoing uplink transmission from the RSU to base station), the base station grants resources to the RSU for transmission of the BSR. Similar rules to those described above can be used to determine the validity of such an uplink grant. What is described herein can be extended to the case in which the RSU forwards packets to other UEs over the PC5 rather than to the base station over the Uu interface.

Turning now to FIGURE 9, illustrated is a signaling diagram of an embodiment of an operation of a communication system. The signaling diagram includes a user equipment (designated "UE"), a roadside unit (designated "RSU") and a radio access node such as a base station (designated "eNB"). The base station provides an uplink grant to the RSU before a sidelink control information ("SCI") period starts. The base station, therefore, preconfigures uplink resources before the SCI period starts. Such preconfiguration may also contain an offset to indicate the subframe from which the preconfiguration starts applying. The preconfiguration can be provided either via RRC signaling or by an uplink grant (either dynamic or SPS) on a physical downlink control channel ("PDCCH"). After receiving the uplink grant, the RSU receives the SCI from the UE. In response thereto, the UE then transmits data to the RSU, which forwards the data to the base station. Again, this can be extended to the case in which the RSU forwards packets to other UEs over the PC5 interface rather than to the base station over the Uu interface. As illustrated in aforementioned embodiments, the delays range from 16 and 86 ms for the UE to transmit the SCI and the data to the RSU.

Different scheduling requests can be used for the RSU to transmit V2X data to the base station and for ordinary uplink traffic. The scheduling requests may depend on characteristics of the uplink data (including V2X data) to be transmitted to the base station. Once the base station receives a scheduling request, according to the resources being used, the base station can allocate resources based on (*e.g.*, optimized) for the characteristics of the data. For example, the base station can allocate a separate scheduling request to the base station to be used in case the RSU needs to monitor the SCI and possibly forward data received over the PC5 interface as disclosed herein. Once receiving a scheduling request in a scheduling request resource, the base station provides a large enough grant for one BSR and an uplink grant for data that can be both valid longer than a specified period such as four ms.

The base station can also allocate separate scheduling request resources depending on the size of the data to be transmitted so that the base station can properly dimension the uplink grant to allow the RSU to include not only a BSR but also uplink data in the next uplink transmission. What is described above can be extended to the case in which the RSU forwards packets to other UEs over the PC5 interface rather than to the base station over the Uu interface. For instance, different scheduling request resources can be dedicated for the sake of sidelink communications.

In some cases, the RSUs will experience uplink data in different patterns. For some RSUs, the UE traffic will be busy during certain time periods of the day such as 7 to 9 AM and 4 to 6 PM in weekdays. The number of UEs communicating with the RSUs and resulting traffic will be much less during other time periods. For other RSUs, there will always be heavy traffic or always be lighter traffic. For other RSUs, there is a high traffic load during the weekends, but less or no traffic during weekdays.

A base station can record historical information of uplink traffic from the RSU and predict the future uplink traffic (*e.g.*, for the next minute or more). If there is no or very little uplink traffic from the RSU for the next minute or more, the base station may consider that the RSU is free; otherwise, the base station may consider the RSU busy. What is described above can be extended to the case in which the RSU forwards packets to other UEs over the PC5 interface rather than to the base station over the Uu interface.

Turning now to FIGURE 10, illustrated is a block diagram of an embodiment of a communication element 1000. The communication element 1000 may be a communication node such as a radio access node such as a base station, roadside unit and/or a wireless device such as a user equipment. The communication element 1000 includes an interface 1010, a processor 1020, a memory 1030 and an antenna 1040. These components may work together to provide the communication element 1000 functionality, such as providing wireless connections in a wireless network. In different embodiments, the wireless network may include any number of wired or wireless networks, base stations, controllers, wireless devices, relay stations, and/or any other components that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections.

The communication element 1000 may be coupled to or a part of a core network such as one or more Internet Protocol ("IP") networks, public switched telephone networks ("PSTNs"), packet data networks, optical networks, wide area networks ("WANs"), local area networks ("LANs"), wireless local area networks ("WLANs"), wired networks, wireless networks, metropolitan area networks, and other networks to enable communication between devices.

The components of the communication element 1000 are depicted as single boxes located within a single larger box. In practice, however, the communication element 1000 may include multiple different physical components that make up a single illustrated component (*e.g.*, the interface 1010 may include terminals for coupling wires for a wired connection and a radio transceiver for a wireless connection). As another example, the communication element 1000 may be a virtual network node in which multiple different physically separate components interact to provide the functionality thereof (*e.g.*, the processor 1020 may include three separate processors located in three separate enclosures, wherein each processor is responsible for a different function for a particular instance of the communication element 1000). Similarly, the communication element 1000 may be composed of multiple physically separate components (*e.g.*, a NodeB component and a radio network controller ("RNC") component, a base transceiver station ("BTS") component and a base station controller ("BSC") component, *etc.*), which may each have their own respective processor, memory, and interface components. In certain scenarios in which the communication element 1000 includes multiple separate components, one or more of the separate components may be shared among several communication elements. For example, a single RNC may control multiple NodeBs. In such a scenario, each unique NodeB and BSC pair, may be a separate communication element. In some embodiments, the communication element 1000 may be configured to support multiple radio access technologies ("RATs"). In such embodiments, some components may be duplicated (*e.g.*, the memory 1030 for the different RATs) and some components may be reused (*e.g.*, the same antenna 1040 may be shared by the RATs). The communication element 1000 may be any type of wireless endpoint, mobile station, mobile phone, wireless local loop phone, smartphone, user equipment, desktop computer, personal digital assistant ("PDA"), cell phone, tablet, laptop, Voice over Internet Protocol ("VoIP") phone or handset.

The processor 1020 may be a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other base station components such as the memory 1030, the communication element 1000 functionality. For example, the processor 1020 may execute instructions stored in the memory 1030. Such functionality may include providing various wireless features discussed herein to a wireless device including any of the features or benefits disclosed herein.

The memory 1030 may include any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid state memory, remotely mounted memory, magnetic media, optical media, random access memory ("RAM"), read-only memory ("ROM"), removable media, or any other suitable local or remote memory component. The memory 1030 may store any suitable instructions, data or information, including software and encoded logic, utilized by the communication element 1000. The memory 1030 may be used to store any calculations made by the processor 1020 and/or any data received via the interface 1010.

The communication element 1000 also includes the interface 1010 which may be used in the wired or wireless communication of signaling and/or data in a communication system. For example, the interface 1010 may perform any formatting, coding, or translating that may be needed to allow the communication element 1000 to send and receive data in the communication system. The interface 1010 may also include a radio transmitter and/or receiver (also referred to as a "transceiver") that may be coupled to or a part of the antenna 1040. The radio transceiver may receive digital data that is to be sent out to other communication elements. The radio transceiver may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters. The radio signal may then be transmitted via the antenna 1040 to the appropriate recipient.

The antenna 1040 may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In some embodiments, the antenna 1040 may include one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals between, for example, 2 gigahertz ("GHz") and 66 GHz. An omni-directional antenna may be used to transmit/receive radio signals in any direction, a sector antenna may be used to transmit/receive radio signals from

Certain aspects of the inventive concept have mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, embodiments other than the ones disclosed above are equally possible and within the scope of the inventive concept. Similarly, while a number of different combinations have been discussed, all possible combinations have not been disclosed. One skilled in the art would appreciate that other combinations exist and are within the scope of the inventive concept. Moreover, as is understood by the skilled person, the herein disclosed embodiments are as such applicable also to other standards and communication systems and any feature from a particular figure disclosed in connection with other features may be applicable to any other figure and or combined with different features.

Thus, the present disclosure introduces a communication element (RSU) operable with a wireless device (UE) and a radio access node (eNB), and method of operating the same. The communication element (RSU) includes a processor (1020), and a memory (1030) including computer program code. The processor (1020), the memory (1030), and the computer program code are collectively operable to provide a scheduling request (SR) to the radio access node (eNB) to communicate data from the wireless device (UE), receive an uplink grant from the radio access node (eNB), provide a buffer status report (BSR) to the radio access node (eNB), receive another uplink grant from the radio access node (eNB), receive the data from the wireless device (UE), and forward the data to the radio access node (eNB).

The memory (1030) and the computer program code are further configured to, with the processor (1020) cause the communication element (RSU) to receive sidelink control information (SCI) from the wireless device (UE) prior to providing the scheduling request (SR) to the radio access node (eNB). Additionally, the memory (1030) and the computer program code are further configured to, with the processor (1020) cause the communication element (RSU) to estimate resources for the data prior to providing the scheduling request (SR) to the radio access node (eNB). The resources may include an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward the data. The estimated time (T1, T2) to forward the data takes into account a grant delay (GRANT_DELAY).

The present disclosure also discloses a radio access node (eNB) operable with a communication element (RSU) and a wireless device (UE), and method of operating the same. The radio access node (eNB) includes a processor (1020), and a memory (1030) including computer program code. The processor (1020), the memory (1030), and the computer program code are collectively operable to receive a scheduling request (SR) from the communication element (RSU) to communicate data from the wireless device (UE), provide an uplink grant to the communication element (RSU), receive a buffer status report (BSR) from the communication element (RSU), provide another uplink grant to the communication element (RSU), and receive the data from the wireless device (UE) via the communication element (RSU).

The memory (1030) and the computer program code are further configured to, with the processor (1020) cause the radio access node (eNB) to receive the scheduling request (SR) from the communication element (RSU) in response to sidelink control information (SCI) from the wireless device (UE). Additionally, the memory (1030) and the computer program code are further configured to, with the processor (1020) cause the radio access node (eNB) to receive the scheduling request (SR) from the communication element (RSU) in response to an estimate of resources for the data. The resources may include an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward the data. The estimated time (T1, T2) to forward the data takes into account a grant delay (GRANT_DELAY).

The present disclosure also introduces a communication element (RSU) operable with a wireless device (UE-1) and a radio access node (eNB), and method of operating the same. The communication element (RSU) includes a processor (1020), and a memory (1030) including computer program code. The processor (1020), the memory (1030), and the computer program code are collectively operable to provide a scheduling request (SR) to the radio access node (eNB) to communicate data from the wireless device (UE-1), receive an uplink grant from the radio access node (eNB), provide a sidelink buffer status report (SL BSR) to the radio access node (eNB), receive a sidelink (SL) grant from the radio access node (eNB), receive the data from the wireless device (UE-1), and forward the data to another wireless device (UE-2).

The memory (1030) and the computer program code are further configured to, with the processor (1020) cause the communication element (RSU) to receive sidelink control information (SCI) from the wireless device (UE-1) prior to providing the scheduling request (SR) to the radio access node (eNB). Additionally, the memory (1030) and the computer program code are further configured to, with the processor (1020) cause the communication element (RSU) to estimate resources for the data prior to providing the scheduling request (SR) to the radio access node (eNB). The resources may include an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward the data. The estimated time (T1, T2) to forward the data takes into account a grant delay (GRANT_DELAY).

The present disclosure also discloses a radio access node (eNB) operable with a communication element (RSU) and a wireless device (UE-1), and method of operating the same. The radio access node (eNB) includes a processor (1020), and a memory (1030) including computer program code. The processor (1020), the memory (1030), and the computer program code are collectively operable to receive a scheduling request (SR) from the communication element (RSU) to communicate data from the wireless device (UE-1), provide an uplink grant to the communication element (RSU), receive a sidelink buffer status report (SL BSR) from the communication element (RSU), and provide a sidelink (SL) grant to the communication element (RSU) to allow data to be forwarded from the wireless device (UE-1) to another wireless device (UE-2).

The memory (1030) and the computer program code are further configured to, with the processor (1020) cause the radio access node (eNB) to receive the scheduling request (SR) from the communication element (RSU) in response to sidelink control information (SCI) from the wireless device (UE-1). Additionally, the memory (1030) and the computer program code are further configured to, with the processor (1020) cause the radio access node (eNB) to receive the scheduling request (SR) from the communication element (RSU) in response to an estimate of resources for the data. The resources may include an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward the data. The estimated time (T1, T2) to forward the data takes into account a grant delay (GRANT_DELAY).

The foregoing description of embodiments of the present proposed solution has been presented for the purpose of illustration and description. It is not intended to be exhaustive or to limit the proposed solution to the present form disclosed. Alternations, modifications and variations can be made without departing from the spirit and scope of the present proposed solution.

As described above, the exemplary embodiment provides both a method and corresponding apparatus consisting of various modules providing functionality for performing the steps of the method. The modules may be implemented as hardware (embodied in one or more chips including an integrated circuit such as an application specific integrated circuit), or may be implemented as software or firmware for execution by a processor. In particular, in the case of firmware or software, the exemplary embodiment can be provided as a computer program product including a computer readable storage medium embodying computer program code (*i.e.*, software or firmware) thereon for execution by the computer processor. The computer readable storage medium may be non-transitory (*e.g.*, magnetic disks; optical disks; read only memory; flash memory devices; phase-change memory) or transitory (*e.g.*, electrical, optical, acoustical or other forms of propagated signals-such as carrier waves, infrared signals, digital signals, *etc.*). The coupling of a processor and other components is typically through one or more busses or bridges (also termed bus controllers). The storage device and signals carrying digital traffic respectively represent one or more non-transitory or transitory computer readable storage medium. Thus, the storage device of a given electronic device typically stores code and/or data for execution on the set of one or more processors of that electronic device such as a controller.

Although the embodiments and its advantages have been described in detail, it should be understood that various changes, substitutions, and alterations can be made herein without departing from the spirit and scope thereof as defined by the appended claims. For example, many of the features and functions discussed above can be implemented in software, hardware, or firmware, or a combination thereof. Also, many of the features, functions, and steps of operating the same may be reordered, omitted, added, *etc.*, and still fall within the broad scope of the various embodiments.

Moreover, the scope of the various embodiments is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be develop d, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized as well. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

IN THE CLAIMS:

1. A communication element (RSU) operable with a wireless device (UE) and a radio access node (eNB), comprising:

a processor (1020); and

a memory (1030) including computer program code, wherein said processor (1020), said memory, and said computer program code are collectively operable to:

provide a scheduling request (SR) to said radio access node (eNB) to communicate data from said wireless device (UE);

receive an uplink grant from said radio access node (eNB);

provide a buffer status report (BSR) to said radio access node (eNB);

receive another uplink grant from said radio access node (eNB);

receive said data from said wireless device (UE); and

forward said data to said radio access node (eNB).

2. The communication element (RSU) as recited in Claim 1 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said communication element (RSU) to receive sidelink control information (SCI) from said wireless device (UE) prior to providing said scheduling request (SR) to said radio access node (eNB).

3. The communication element (RSU) as recited in Claim 1 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said communication element (RSU) to estimate resources for said data prior to providing said scheduling request (SR) to said radio access node (eNB).

4. The communication element (RSU) as recited in Claim 3 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

5. The communication element (RSU) as recited in Claim 4 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

6. A method of operating a communication element (RSU) operable with a wireless device (UE) and a radio access node (eNB), comprising:

providing a scheduling request (SR) to said radio access node (eNB) to communicate data from said wireless device (UE);

receiving an uplink grant from said radio access node (eNB);

providing a buffer status report (BSR) to said radio access node (eNB);

receiving another uplink grant from said radio access node (eNB);

receiving said data from said wireless device (UE); and

forwarding said data to said radio access node (eNB).

7. The method as recited in Claim 6 further comprising receiving sidelink control information (SCI) from said wireless device (UE) prior to providing said scheduling request (SR) to said radio access node (eNB).

8. The method as recited in Claim 6 further comprising estimating resources for said data prior to providing said scheduling request (SR) to said radio access node (eNB).

9. The method as recited in Claim 8 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

10. The method as recited in Claim 9 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

11. A radio access node (eNB) operable with a communication element (RSU) and a wireless device (UE), comprising:

a processor (1020); and

a memory (1030) including computer program code, wherein said processor (1020), said memory (1030), and said computer program code are collectively operable to:

receive a scheduling request (SR) from said communication element (RSU) to communicate data from said wireless device (UE);

provide an uplink grant to said communication element (RSU);

receive a buffer status report (BSR) from said communication element (RSU);

provide another uplink grant to said communication element (RSU); and receive said data from said wireless device (UE) via said communication element (RSU).

12. The radio access node (eNB) as recited in Claim 11 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said radio access node (eNB) to receive said scheduling request (SR) from said communication element (RSU) in response to sidelink control information (SCI) from said wireless device (UE).

13. The radio access node (eNB) as recited in Claim 11 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said radio access node (eNB) to receive said scheduling request (SR) from said communication element (RSU) in response to an estimate of resources for said data.

14. The radio access node (eNB) as recited in Claim 13 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

15. The radio access node (eNB) as recited in Claim 14 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

16. A method of operating a radio access node (eNB) operable with a communication element (RSU) and a wireless device (UE), comprising:

receiving a scheduling request (SR) from said communication element (RSU) to communicate data from said wireless device (UE);

providing an uplink grant to said communication element (RSU);

receiving a buffer status report (BSR) from said communication element (RSU);

providing another uplink grant to said communication element (RSU); and

receiving said data from said wireless device (UE) via said communication element (RSU).

17. The method as recited in Claim 16 wherein said receiving said scheduling request (SR) from said communication element (RSU) is in response to sidelink control information (SCI) from said wireless device (UE).

18. The method as recited in Claim 16 wherein said receiving said scheduling request (SR) from said communication element (RSU) is in response to an estimate of resources for said data.

19. The method as recited in Claim 18 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

20. The method as recited in Claim 19 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

21. A communication element (RSU) operable with a wireless device (UE-1) and a radio access node (eNB), comprising:

a processor (1020); and

a memory (1030) including computer program code, wherein said processor (1020), said memory (1030), and said computer program code are collectively operable to:

provide a scheduling request (SR) to said radio access node (eNB) to communicate data from said wireless device (UE-1);

receive an uplink grant from said radio access node (eNB);

provide a sidelink buffer status report (SL BSR) to said radio access node (eNB);

receive a sidelink (SL) grant from said radio access node (eNB);

receive said data from said wireless device (UE-1); and

forward said data to another wireless device (UE-2).

22. The communication element (RSU) as recited in Claim 21 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said communication element (RSU) to receive sidelink control information (SCI) from said wireless device (UE-1) prior to providing said scheduling request (SR) to said radio access node (eNB).

23. The communication element (RSU) as recited in Claim 21 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said communication element (RSU) to estimate resources for said data prior to providing said scheduling request (SR) to said radio access node (eNB).

24. The communication element (RSU) as recited in Claim 23 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

25. The communication element (RSU) as recited in Claim 24 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

26. A method of operating a communication element (RSU) operable with a wireless device (UE-1) and a radio access node (eNB), comprising:

receiving an uplink grant from said radio access node (eNB);

providing a sidelink buffer status report (SL BSR) to said radio access node (eNB);

receiving a sidelink (SL) grant from said radio access node (eNB);

receiving said data from said wireless device (UE-1); and

forwarding said data to another wireless device (UE-2).

27. The method as recited in Claim 26 further comprising receiving sidelink control information (SCI) from said wireless device (UE-1) prior to providing said scheduling request (SR) to said radio access node (eNB).

28. The method as recited in Claim 26 further comprising estimating resources for said data prior to providing said scheduling request (SR) to said radio access node (eNB).

29. The method as recited in Claim 28 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

30. The method as recited in Claim 29 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

31. A radio access node (eNB) operable with a communication element (RSU) and a wireless device (UE-1), comprising

a processor (1020); and

a memory (1030) including computer program code, wherein said processor (1020), said memory (1030), and said computer program code are collectively operable to:

receive a scheduling request (SR) from said communication element (RSU) to communicate data from said wireless device (UE-1);

provide an uplink grant to said communication element (RSU);

receive a sidelink buffer status report (SL BSR) from said communication element (RSU); and

provide a sidelink (SL) grant to said communication element (RSU) to allow data to be forwarded from said wireless device (UE-1) to another wireless device (UE-2).

32. The radio access node (eNB) as recited in Claim 31 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said radio access node (eNB) to receive said scheduling request (SR) from said communication element (RSU) in response to sidelink control information (SCI) from said wireless device (UE-1).

33. The radio access node (eNB) as recited in Claim 31 wherein said memory (1030) and said computer program code are further configured to, with said processor (1020) cause said radio access node (eNB) to receive said scheduling request (SR) from said communication element (RSU) in response to an estimate of resources for said data.

34. The radio access node (eNB) as recited in Claim 33 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

35. The radio access node (eNB) as recited in Claim 34 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

36. A method of operating a radio access node (eNB) operable with a communication element (RSU) and a wireless device (UE-1), comprising:

receiving a scheduling request (SR) from said communication element (RSU) to communicate data from said wireless device (UE-1);

providing an uplink grant to said communication element (RSU);

receiving a sidelink buffer status report (SL BSR) from said communication element (RSU); and providing a sidelink (SL) grant to said communication element (RSU) to allow data to be forwarded from said wireless device (UE-1) to another wireless device (UE-2).

37. The method as recited in Claim 36 wherein said receiving said scheduling request (SR) from said communication element (RSU) is in response to sidelink control information (SCI) from said wireless device (UE-1).

38. The method as recited in Claim 36 wherein said receiving said scheduling request (SR) from said communication element (RSU) is in response to an estimate of resources for said data.

39. The method as recited in Claim 38 wherein said resources comprise an estimated amount of data (DATA_AMOUNT) and an estimated time (T1, T2) to forward said data.

40. The method as recited in Claim 38 wherein said estimated time (T1, T2) to forward said data takes into account a grant delay (GRANT_DELAY).

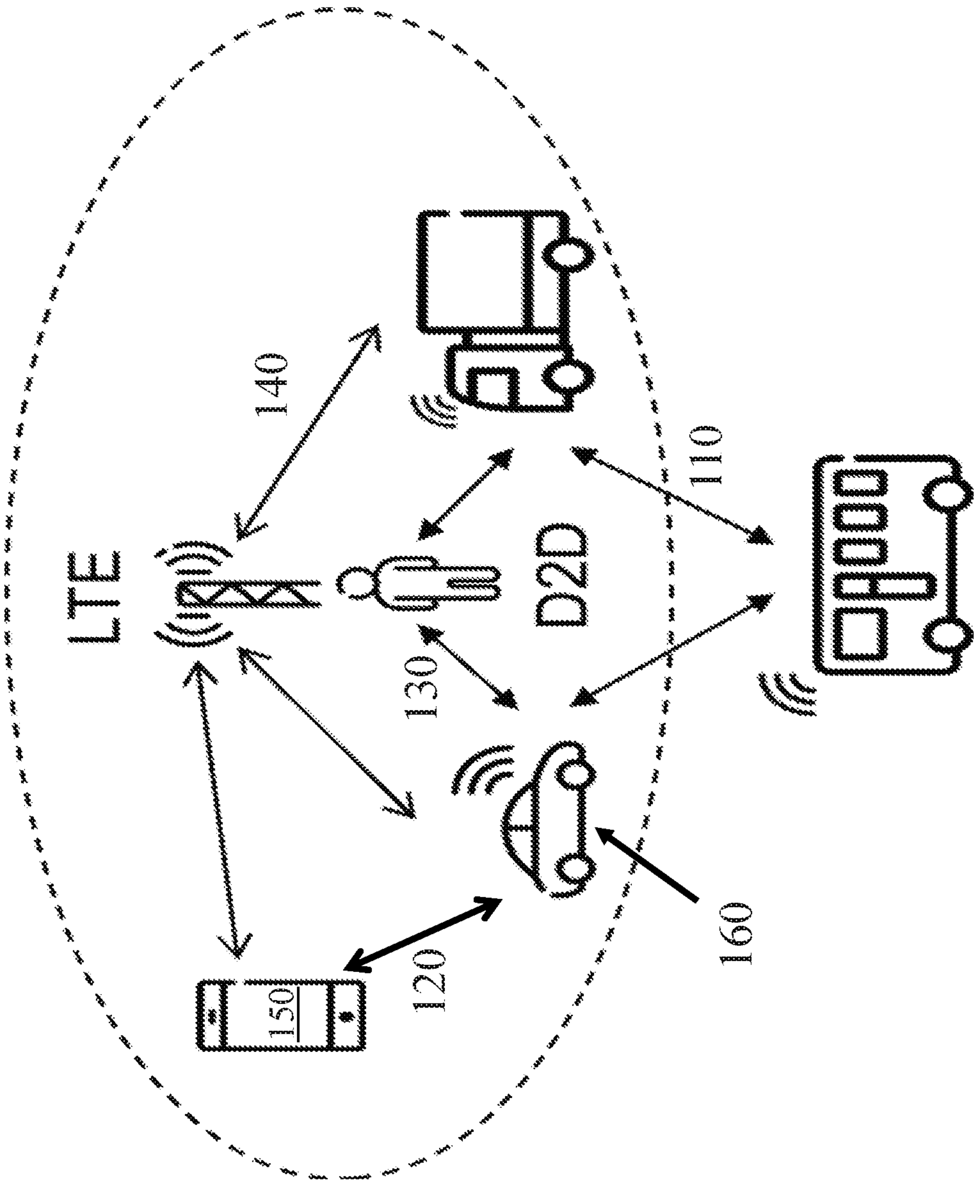

FIGURE 1

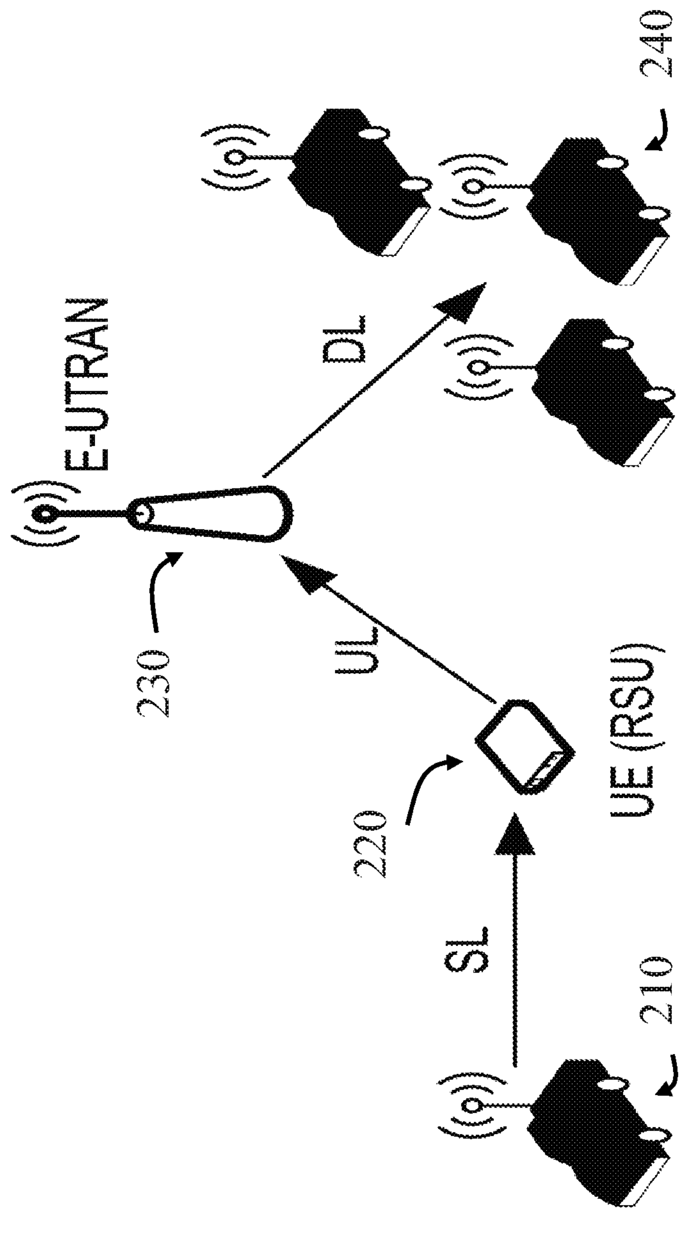

FIGURE 2

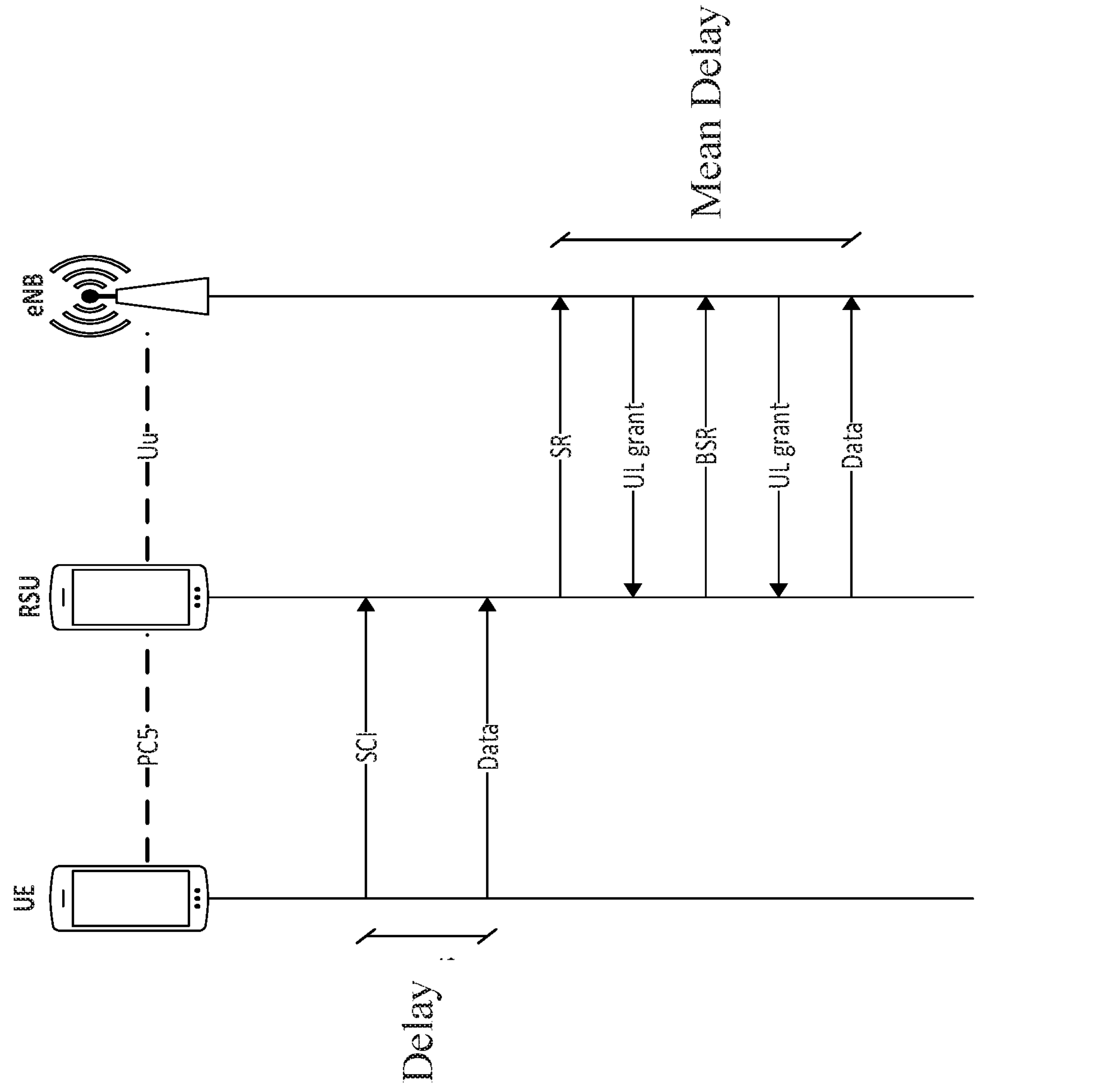
UE
RSU
eNB
PC5
Uu
SCI
Data
SR
UL grant
BSR
UL grant
Data
Delay
Mean Delay

FIGURE 3

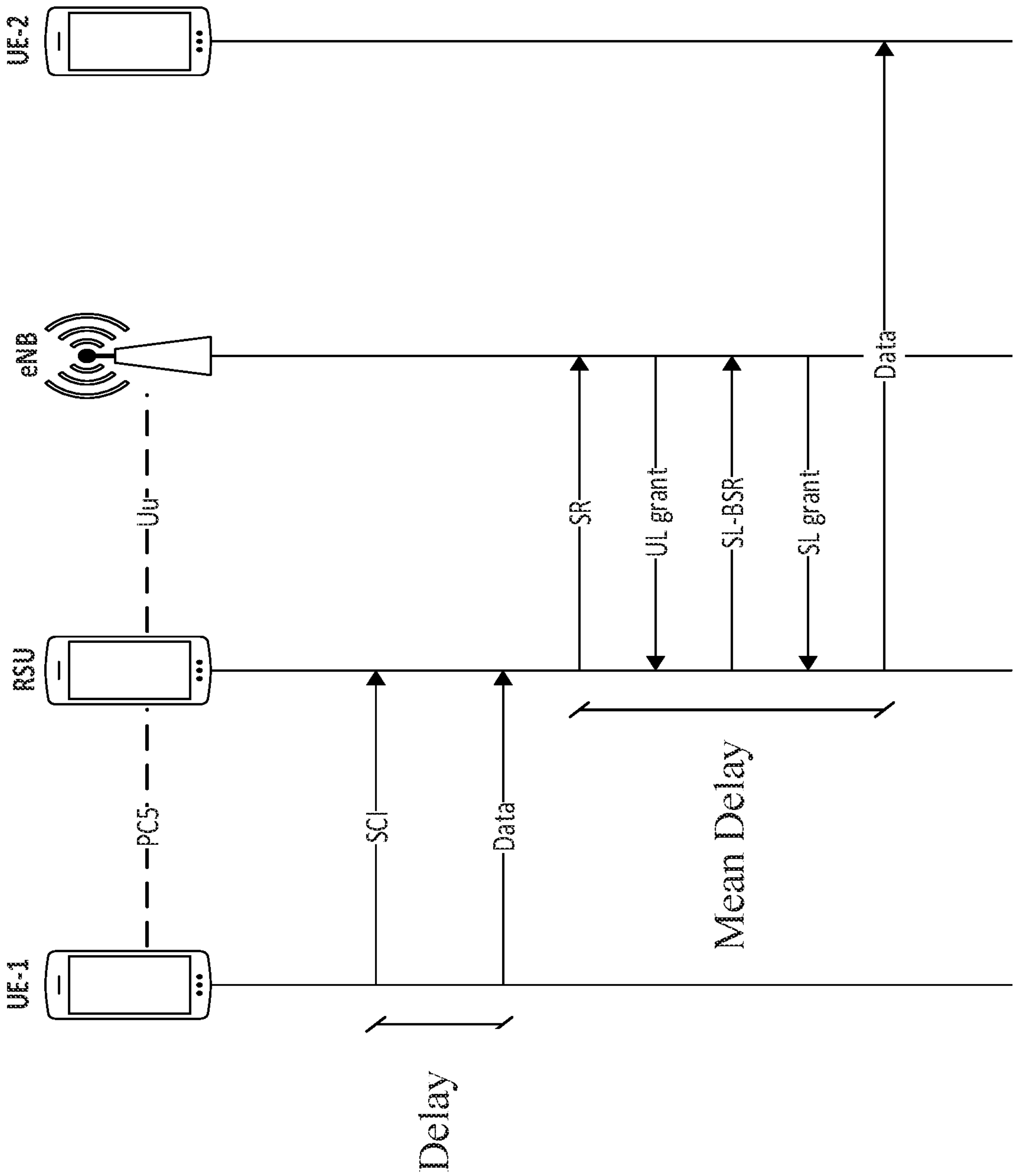
UE-1
RSU
eNB
UE-2
PC5
Uu
SCI
Data
SR
UL grant
SL-BSR
SL grant
Data
Delay
Mean Delay

FIGURE 4

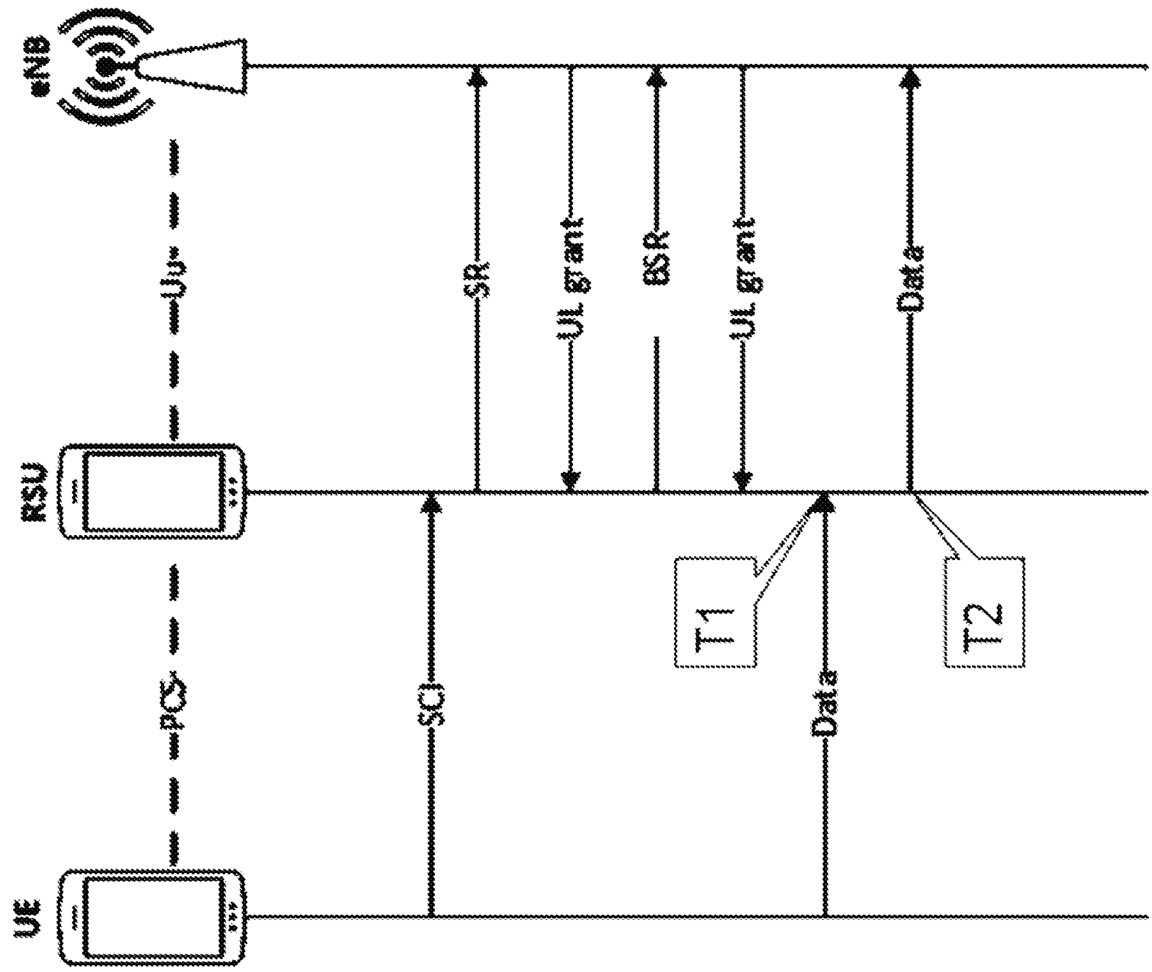

FIGURE 5

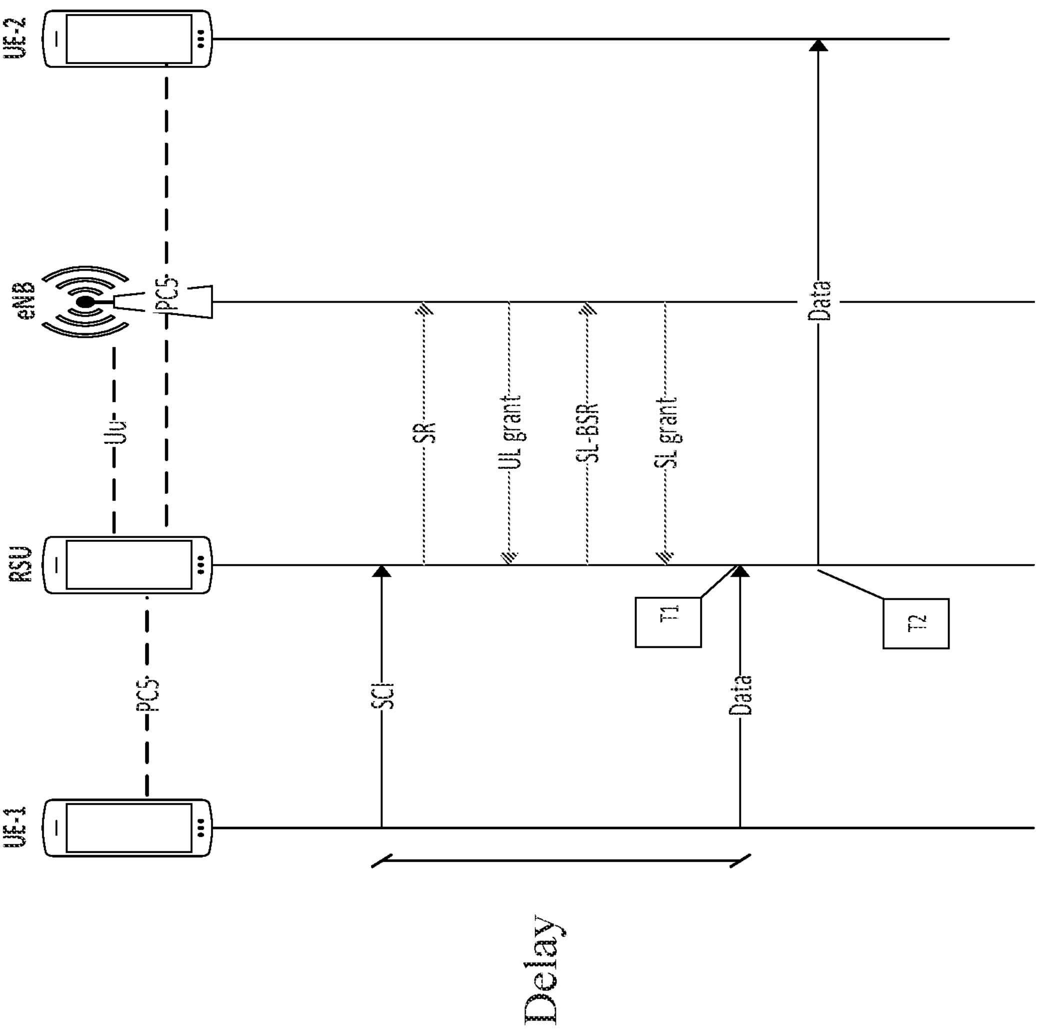
UE-1
RSU
eNB
UE-2
PC5
Uu
PC5
SCI
Data
SR
UL grant
SL-BSR
SL grant
Data
T1
T2
Delay

FIGURE 6

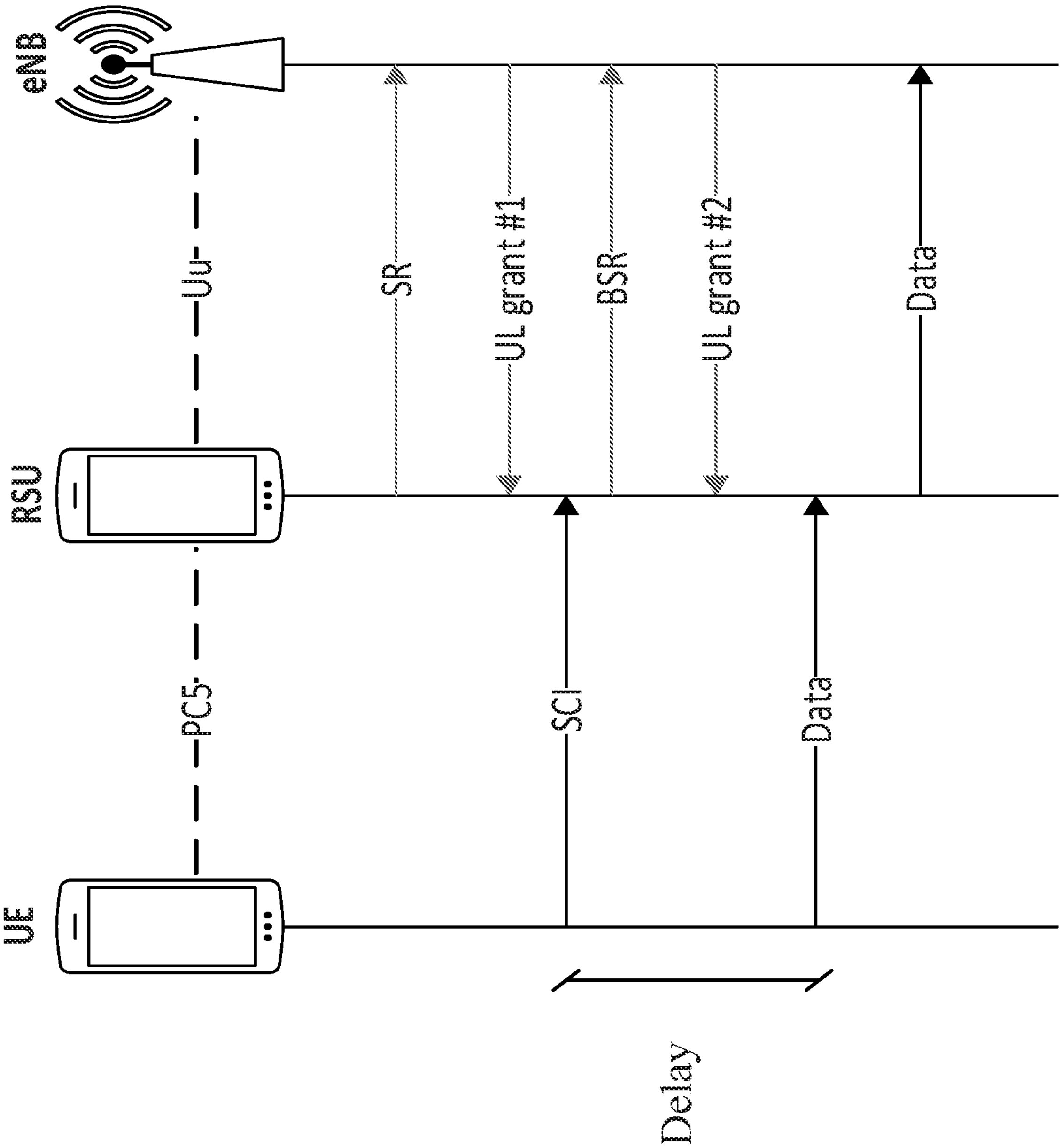
eNB
RSU
UE
Uu
PC5
SR
UL grant #1
BSR
UL grant #2
Data
SCI
Data
Delay

FIGURE 7

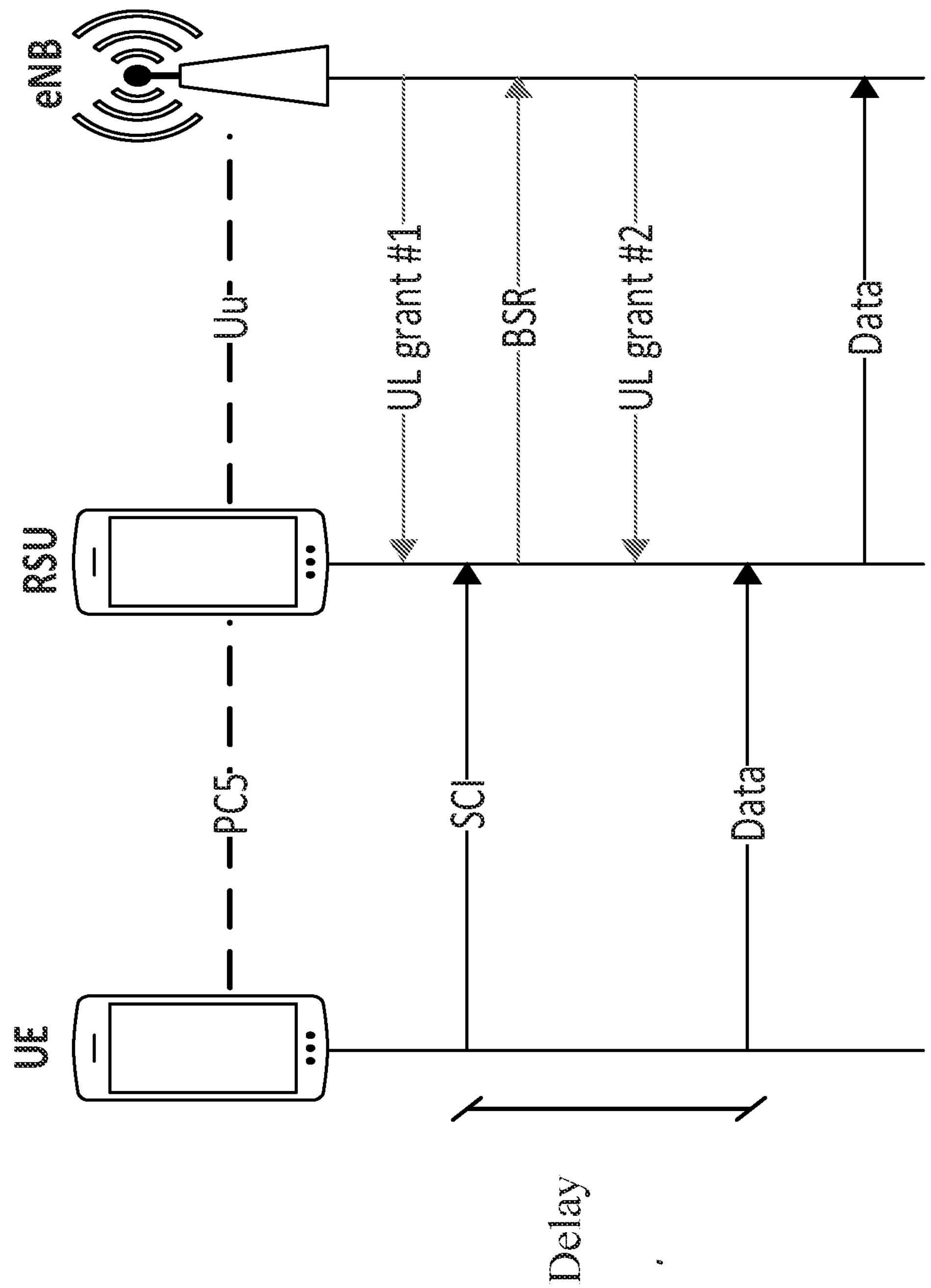

FIGURE 8

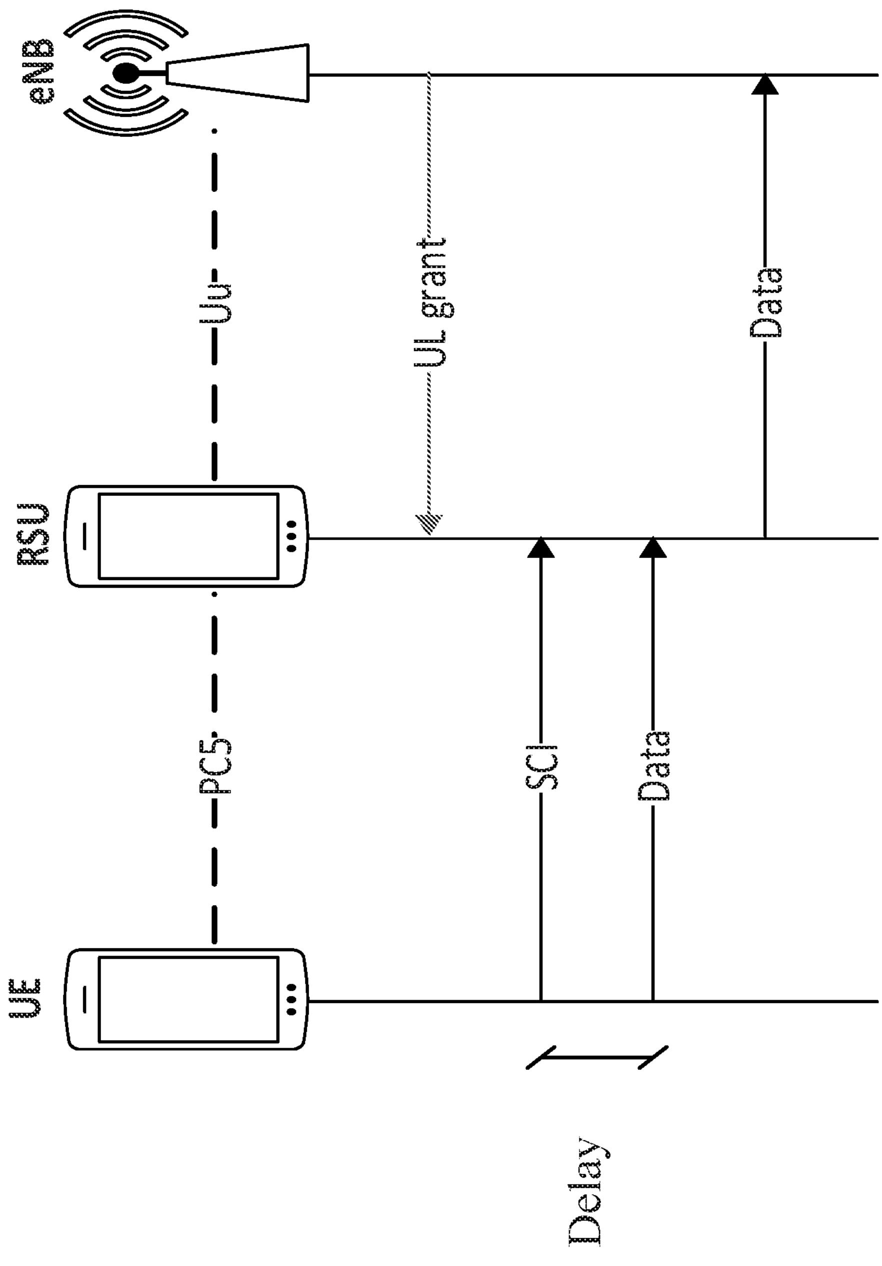

FIGURE 9

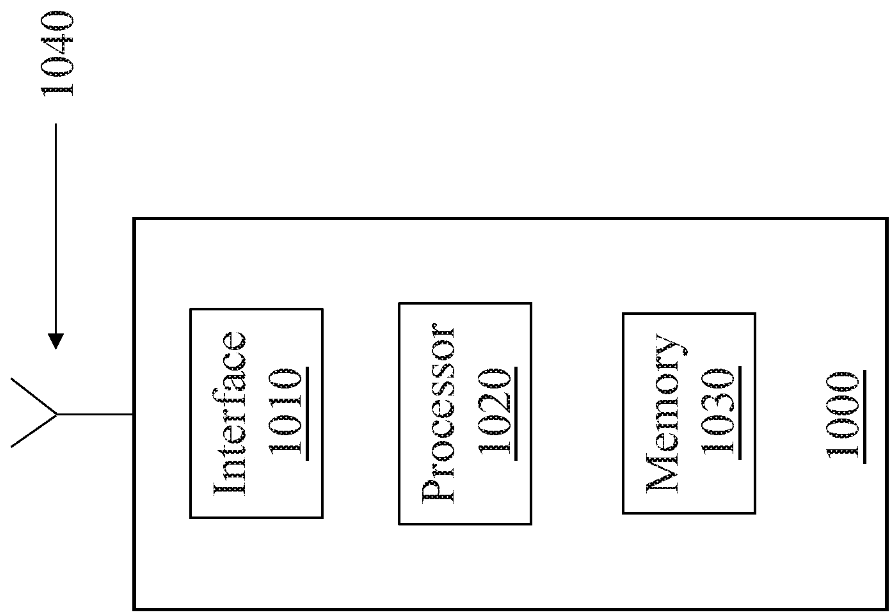

FIGURE 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/050542

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W76/02 H04W72/12
ADD. H04W4/04 H04W84/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W G08G G07B G07C H04L H04B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/269393 A1 (OESTERGAARD JESSICA [SE] ET AL) 3 November 2011 (2011-11-03) paragraphs [0002] - [0022], [0031] - [0070]; figures 1-7 -----	1-40
X	WO 2015/160158 A1 (LG ELECTRONICS INC [KR]) 22 October 2015 (2015-10-22) cf. passages of EP 3 133 842 A1 (translation in accordance with Art. 153(4) EPC) & EP 3 133 842 A1 (LG ELECTRONICS INC [KR]) 22 February 2017 (2017-02-22) paragraphs [0001] - [0024], [0029] - [0063], [0068] - [0100], [0111] - [0253], [0329] - [0531]; figures 1, 2, 4-24, 27-39 -----	1-40
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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	Date of mailing of the international search report
11 April 2017	20/04/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jaster, Nicole

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LG ELECTRONICS INC: "Email discussion - [91bis#36][LTE/V2X] Latency analysis", 3GPP DRAFT; R2-156505 V2X LATENCY ANALAYSIS_FINAL, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Anaheim, CA, USA; 20151116 - 20151120 11 November 2015 (2015-11-11), XP051024984, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_92/Docs/ [retrieved on 2015-11-11] sections 1, 2 and 3 -----	1-40
A	US 2011/227757 A1 (CHEN WAI [US] ET AL) 22 September 2011 (2011-09-22) paragraphs [0001] - [0008], [0031] - [0082]; figures 1-22 -----	1-40
E	WO 2017/029646 A1 (TELEFONAKTIEBOLAGET LM ERICSSON [SE]) 23 February 2017 (2017-02-23) page 1, line 2, to page 7, line 5; page 7, line 31, to page 19, line 8; figures 1-8 -----	1-20

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2017/050542

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011269393 A1	03-11-2011	EP 2567589 A1	13-03-2013
		US 2011269393 A1	03-11-2011
		WO 2011139220 A1	10-11-2011
WO 2015160158 A1	22-10-2015	EP 3133842 A1	22-02-2017
		KR 20160140756 A	07-12-2016
		WO 2015160158 A1	22-10-2015
US 2011227757 A1	22-09-2011	US 2011227757 A1	22-09-2011
		WO 2011115920 A1	22-09-2011
WO 2017029646 A1	23-02-2017	NONE	