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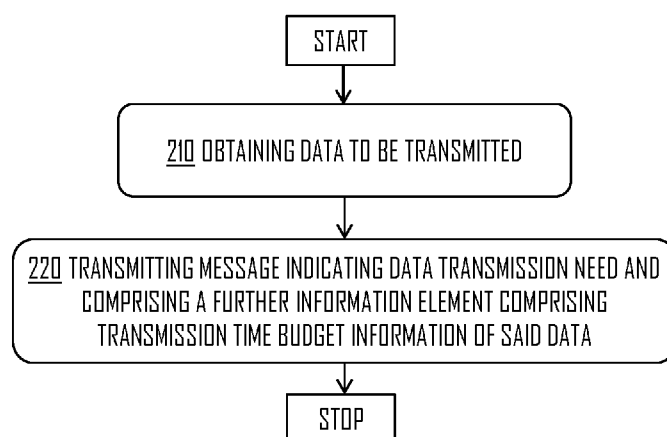


Fig. 2

(57) Abstract: There is provided a method comprising: obtaining, by a device of a wireless network, at least one data unit to be transmitted by the device; and transmitting, by the device to a network element of the wireless network, a message comprising an information element indicating a need to transmit said at least one data unit, wherein the message comprises a further information element comprising transmission time budget information associated with said at least one data unit. Accordingly, there is provided an apparatus for performing the provided method. The message can for example be a scheduling request or a report message indicating data buffer state of the device.



IMPROVING UPLINK COMMUNICATION EFFICIENCY IN A WIRELESS NETWORK

TECHNICAL FIELD

The invention relates to communications.

BACKGROUND

5 In a communication network, data may be transferred between network elements and terminal devices. Latency requirements for the data transfer are increasingly becoming more rigorous at least for some types of data. Therefore, providing solutions that enable communication network to more efficiently schedule needed resources for the data transfer may be beneficial for the overall
10 performance of the communication network.

BRIEF DESCRIPTION

According to an aspect, there is provided the subject matter of the independent claims. Some embodiments are defined in the dependent claims.

15 One or more examples of implementations are set forth in more detail in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

In the following embodiments will be described in greater detail with reference to the attached drawings, in which

20 Figure 1 illustrates an example radio system to which embodiments of the invention may be applied;

Figures 2 and 3 illustrate flow diagrams according to some embodiments;

25 Figures 4A to 5C illustrate signal diagrams according to some embodiments;

Figures 6A to 6B illustrate block diagrams according to some embodiments;

Figures 7A to 7B illustrate examples of some benefits according to some embodiments; and

30 Figures 8, 9, and 10 illustrate block diagrams of apparatuses according to some embodiments.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

The following embodiments are exemplifying. Although the specification may refer to “an”, “one”, or “some” embodiment(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

Embodiments described may be implemented in a radio system, such as in at least one of the following: Worldwide Interoperability for Micro-wave Access (WiMAX), Global System for Mobile communications (GSM, 2G), GSM EDGE radio access Network (GERAN), General Packet Radio Service (GRPS), Universal Mobile Telecommunication System (UMTS, 3G) based on basic wideband-code division multiple access (W-CDMA), high-speed packet access (HSPA), Long Term Evolution (LTE), and/or LTE-Advanced.

The embodiments are not, however, restricted to the system given as an example but a person skilled in the art may apply the solution to other communication systems provided with necessary properties. Another example of a suitable communications system is the 5G concept. 5G is likely to use multiple input – multiple output (MIMO) techniques (e.g. antennas), many more base stations or nodes than the LTE (a so-called small cell concept), including macro sites operating in co-operation with smaller stations and perhaps also employing a variety of radio technologies for better coverage and enhanced data rates. 5G will likely be comprised of more than one radio access technology (RAT), each optimized for certain use cases and/or spectrum. 5G mobile communications will have a wider range of use cases and related applications including video streaming, augmented reality, different ways of data sharing and various forms of machine type applications, including vehicular safety, different sensors and real-time control. 5G is expected to have multiple radio interfaces, namely below 6GHz, cmWave and mmWave, and also being integratable with existing legacy radio access technologies, such as the LTE. Integration with the LTE may be implemented, at least in the early phase, as a system, where macro coverage is provided by the LTE and 5G radio interface access comes from small cells by aggregation to the LTE. In other words, 5G is planned to support both inter-RAT operability (such as LTE-5G) and inter-RI operability (inter-radio interface operability, such as below 6GHz – cmWave, below 6GHz – cmWave – mmWave). One of the concepts considered to be used in 5G networks is network slicing in

which multiple independent and dedicated virtual sub-networks (network instances) may be created within the same infrastructure to run services that have different requirements on latency, reliability, throughput and mobility.

Figure 1 illustrates example of a radio system (also referred to as a cellular communication system or cellular system) to which embodiments of the invention may be applied. Radio communication networks (also referred to as cellular communication networks), such as the Long Term Evolution (LTE), the LTE-Advanced (LTE-A) of the 3rd Generation Partnership Project (3GPP), or the predicted future 5G solutions, are typically composed of at least one network element, such as a network element 102, providing a cell 104. In the example of Figure 1, cells 104, 114, 124 may be shown. The cell 114 may be provided by a network element 112, and the cell 124 may be provided by a network element 122, for example. The cell 104 may be provided by the network element 102. It is, however, possible that a network element of the radio system may provide more than one cell. Thus, for example, the network element 102 may provide the cell 104, the cell 114, and/or the cell 124. In general, the system may comprise one or more network elements (similar to those described with reference to Figure 1), wherein each network element provides one or more cells providing service to one or more terminal devices in the cells.

Each cell of the radio communication network may be, e.g., a macro cell, a micro cell, a femto, or a pico-cell, for example, meaning that there may be one or more of each of the described cells. Each network element of the radio communication network, such as the network elements 102, 112, 122, may be an evolved Node B (eNB) as in the LTE and LTE-A, a radio network controller (RNC) as in the UMTS, a base station controller (BSC) as in the GSM/GERAN, or any other apparatus capable of controlling radio communication and managing radio resources within a cell. That is, there may be one or more of each of the described apparatuses or entities. To give couple of examples, the network element 102 may be an eNB, for example. The network element 112 may also be an eNB. For example, network element 102 may provide a macro cell and the network element 112 may provide a micro cell.

For 5G solutions, the implementation may be similar to LTE-A, as described above. The network elements 102, 112, 122 may be base station(s) or a small base station(s), for example. In the case of multiple eNBs in the communication network, the eNBs may be connected to each other with an X2 interface 190 as specified in the LTE. Example of this may be shown in Figure 1,

wherein the network element 112 may be shown to be connected to the network element 102 via the X2 interface 190. Other communication methods between the network elements may also be possible. At least some of the network elements 102, 112, 122 may be further connected via an S1 interface to an evolved packet core, more specifically to a mobility management entity (MME) and to a system architecture evolution gateway (SAE-GW). So in general, the network elements of Figure 1 may be communicatively connected (wireless and/or wired) to each other using one or more circuitries. The X2 interface 190 is one example of how to realize such communication.

10 The cells 114, 124 may also be referred to as sub-cells or local area cells, for example. The network elements 112, 122 may be referred to as sub-network elements or local area access nodes, for example. The cell 104 may be referred also to as a macro cell, for example. The network element 102 may be referred to as a macro network element, for example. In an embodiment, the local area access nodes are network elements similar to the network element 102. Thus, for example, the local area access node 112 may be an eNB or a macro eNB.

 The cells 104, 114, 124 may provide service for at least one terminal device 110, 120, 130, 140, wherein the at least one terminal device 110, 120, 130, 140 may be located within or comprised in at least one of the cells 104, 114, 124. The at least one terminal device 110, 120, 130, 140 may communicate with the network elements 102, 112, 122 using communication link(s), which may be understood as communication link(s) for end-to-end communication, wherein source device transmits data to the destination device. It needs to be understood that the cells 104, 114, 124 may provide service for a certain area, and thus the at least one terminal device 110, 120, 130, 140 may need to be within said area in order to be able to use said service (horizontally and/or vertically). For example, a third terminal device 130 may be able to use service provided by the cells 104, 114, 124. On the other hand, fourth terminal device 140 may be able to use only service of the cell 104, for example.

30 The cells 104, 114, 124 may be at least partially overlapping with each other. Thus, the at least one terminal device 110, 120, 130, 140 may be enable to use service of more than one cell at a time. For example, the sub-cells 114, 124 may be small cells that are associated with the macro cell 104. This may mean that the network element 102 (e.g. macro network element 102) may at least partially control the network elements 112, 122 (e.g. local area access nodes). For example, the macro network element 102 may cause the local area access nodes 112, 122 to

transmit data to the at least one terminal device 110, 120, 130, 140. It may also be possible to receive data, by the network element 102, from the at least one terminal device 110, 120, 130, 140 via the network elements 112, 122. To further explain the scenario, the cells 114, 124 may be at least partially within the cell 104.

5 In an embodiment, the at least one terminal device 110, 120, 130, 140 is able to communicate with other similar devices via the network element 102 and/or the local area access nodes 112, 122. For example, a first terminal device 110 may transmit data via the network element 102 to a third terminal device 130. The other devices may be within the cell 104 and/or may be within other cells
10 provided by other network elements. The at least one terminal device 110, 120, 130, 140 may be stationary or on the move. In an embodiment, the at least one terminal device 110, 120, 130, 140 may communicate directly with other terminal devices using, for example, Device-to-Device (D2D) communication.

 The radio system may support Dual Connectivity (DC). This may be
15 enabled by the network element 102 and a second network element (e.g. the local area access nodes(s) 112, 122), for example. Naturally, in order to use DC, the at least one terminal device 110, 120, 130, 140 may also need to support DC. The DC may be a radio system feature, wherein the at least one terminal device 110, 120, 130, 140 may simultaneously receive from and/or may simultaneously transmit to
20 at least two network points. Similarly, the radio system of Figure 1 may support Multiple-Input and Multiple-Output (MIMO). Thus, the network elements and/or the terminal devices of the radio system may comprise more than one antenna for data transfer.

 The radio system may support Carrier Aggregation (CA). CA may enable
25 increasing usable bandwidth between the terminal devices and network elements of the radio system. For example, in the 3GPP, CA may be used for LTE-A in order to support wider transmission bandwidths enhancing increased potential peak data rates to meet LTE-A requirements. For example, more than one component carriers may be aggregated, by a network element (e.g. network element 102),
30 contiguously and/or non-contiguously to provide a wider bandwidth. In uplink carrier aggregation, multiple uplink component carriers may be aggregated and can be allocated in a subframe to a terminal device. Further, the radio system may support intra-band CA with contiguous and/or non-contiguous resource allocation. The radio system may also support inter-band CA enabling non-contiguous
35 resource allocation from more than one radio band.

It may be possible that the radio system of Figure 1 supports Licensed-Assisted Access (LAA) which relates to using unlicensed radio band(s) for data transfer. For example, the network element 102 and/or a second network element 112 may provide one or more unlicensed cells in order to increase data transfer capability on the radio communication system. For example, the network element 102 may allocate radio resources of the one or more unlicensed cell for the at least one terminal device 110, 120 through CA, thus increasing the data transfer between the at least one terminal device 110, 120 and the network element(s).

One example of utilizing unlicensed and/or licensed radio bands may be an aggregation technique that utilizes Wireless Local Area Network (WLAN) (sometimes referred to as WiFi communication). For example, the network element 102 may provide a primary cellular service for a terminal device in a cell (e.g. Primary Serving Cell (PSC)). Further, the same network element 102 or some other network element may provide a secondary cell (e.g. Secondary Serving Cell (SSC)), the secondary cell providing, for example, WLAN service to said terminal device. Said WLAN service may at least partially be controlled by the network element 102. Thus, for example, data rates may be increased. In some examples, the WLAN service may be provided by a small base station or small network element (e.g. element 112). Thus, in some embodiments, the radio system may support enhanced LTE/WLAN aggregation (eLWA). The LTE link or service may be provided by a master or primary network element (e.g. Master eNB (MeNB)) and the WLAN link or service may be provided by the same master network element or a secondary network element (e.g. Secondary eNB (SeNB)). The WLAN communication may utilize said unlicensed radio band(s).

It may also be possible that the radio system of Figure 1 supports Machine Type Communication (MTC). MTC may enable providing service for a large amount of MTC capable devices. Such communication may increase the load of the radio communication network and thus solutions to enhance such communication may be beneficial.

The at least one terminal device 110, 120, 130, 140 may comprise mobile phones, smart phones, tablet computers, laptops and other devices used for user communication with the radio communication network. These devices may provide further functionality compared to the MTC schema, such as communication link for voice, video and/or data transfer. However, it needs to be understood that the at least one terminal device 110, 120, 130, 140 may also comprise MTC capable devices, such as sensor devices providing position,

acceleration and/or temperature information to name a few examples. That said the radio communication network of Figure 1 may comprise different types of devices (e.g. phones, laptops, tablets, MTC devices) and communication methods (e.g. CA, DC). The amount of devices and data transfer requirements may increase
5 burden of the radio communication network. The Internet of Things (IoT) may even further increase the amount of devices within the radio communication network.

One aspect related to 5G systems may be an Ultra-reliable and low-latency communications (URLLC) feature. This feature may enable emerging new
10 applications and services from various verticals on top of regular cellular communication, such as industrial automations, autonomous driving, vehicular safety, e-health services, and so on. In general, the targets (e.g. 3GPP) for future systems, such as the 5G systems, may be to provide connectivity with reliability corresponding to a Block Error Rate (BLER) of 10^{-5} and up to 1 millisecond (ms)
15 latency in the future networks. In the cellular communication systems, such as the system of Figure 1, at least in some instances, latency may be regarded as “the time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 (L2/L3) Service Data Unit (SDU) ingress point to the radio protocol layer 2/3 (L2/L3) SDU egress point via the radio interface in both uplink
20 and downlink directions”. Thus, the increasingly stringent requirements may require new and novel solutions implemented in the radio systems.

As described, for example, URLLC may provide stringent requirements for reliability and latency. For some applications, it may be beneficial to provide the latency and reliability simultaneously. This entails that a payload should be
25 delivered with high success probability with a limited number of transmission attempts. In one example regarding 5G frame structure, payload should be delivered within less than 5 subframes (e.g. with 0.125 ms subframe length), from the time instance that the L2/L3 data packet is prepared for transmission, to meet the 1ms latency requirement.

Let us refer to Figure 4A to identify some aspects which may be enhanced by a proposed solution. Referring to Figure 4A, Media Access Protocol (MAC) Protocol Data Unit (PDU) (i.e. MAC PDU may be referred to as MPDU) is used as one example, but the proposed solution can be extended to data packet from different layers depending on the definition of latency. Still using LTE as an
30 example, once Scheduling Request (SR) is triggered, User Equipment (UE) (e.g. terminal device 110 or similar) calculates SR periodicity and offset which may be
35

based on sr-ConfigIndex Information Element (IE). After transmitting (block 402) the first SR on Physical Uplink Control Channel (PUCCH), if the UE doesn't receive uplink resources from the eNB, then based on the periodicity, the UE re-sends or retransmits the SR on PUCCH to the eNB. Example of this may be seen in Figure 4B in which the UE retransmits the SR to the eNB (block 416).

This process continues till the UE transmits SR for dsr-TransMax number of times on PUCCH, if the UE doesn't receive uplink resources from the eNB (e.g. resources received in block 404). The content of SR may not change between subsequent SR transmissions (e.g. if retransmission is needed). In the uplink L2 data packet transmissions and with adaptive resource allocation (used for sporadic traffic model), UE may need to send a SR message asking for radio resources for MAC PDU. In LTE, the SR may be delivered using PUCCH format 1. If the eNB can decode this message correctly, it will allocate radio resources for MAC PDU transmissions. However, using more than one transmission may cause additional delay and thus the latency requirement (e.g. 1ms) may be even harder to achieve. Further, the delay budget for MAC PDU transmissions may vary for different payloads. The variation can be due to the delay in MAC PDU processing and preparation, periodicity of radio resources for PUCCH, and/or error in decoding SR message. In particular, the error in decoding SR can be significant for users located at the cell edge.

There is provided a solution for improving communication efficiency between a terminal device and a communication network (e.g. between the terminal device 110 and the network element 102). In particular, the provided solution may enhance resource allocation by the communication network in the case that the terminal device 110 requests radio resources for transmitting one or more data units or data packets. In particular, the provided solution may enhance resource allocation by the communication network in the case that the terminal device 110 reports, to the communication network, that it has one or more data units or packets to be transmitted. The communication network may thus allocate resources accordingly. The communication network may be, for example, a wireless network, such as cellular communication network.

Figure 2 illustrates a flow diagram according to an embodiment. Referring to Figure 2, a device of a wireless network may obtain at least one data unit to be transmitted by the terminal device (block 210); and transmit, to a network element of the wireless network, a message comprising an information element indicating a need to transmit said at least one data unit, wherein the

message comprises a further information element comprising transmission time budget information associated with said at least one data unit (block 220).

The device performing the steps of Figure 2 may be one of the terminal devices 110, 120, 130, 140, for example. In some embodiments, one or more circuitries comprised in the device may cause performing said method steps. The network element described in relation to Figure 2 may be or be comprised in the network element 102, the network element 112, and/or the network element 122. Thus, for example, the network element may be eNB of the cellular communication system. In some embodiments, the network element may be referred also to as network node.

Figure 3 illustrates a flow diagram according to an embodiment. Referring to Figure 3, a network element of a wireless network may acquire, from a device of the wireless network, a message comprising an information element indicating a need, by the device, to transmit at least one data unit, wherein the message comprises a further information element comprising transmission time budget information associated with said at least one data unit (block 310); initiate decoding of said message (block 320); and upon successful decoding of said message, generating a radio resource message, based at least partly on the transmission time budget information, indicating radio resources for transmitting said at least one data unit and transmitting said radio resource message to the terminal device (block 330). The acquiring may mean, for example, that the network element receives the message directly from the terminal device or via some other network element (e.g. local area network element) from the terminal device.

The network element performing the steps of Figure 3 may be, for example, the network element 102 or one or more circuitries comprised in the network element 102. Therefore, for example, said network element may be a base station or eNB. In some embodiments, the network element may be referred also to as network node. The device referred to in Figure 3 may be a terminal device, such as terminal device 110, 120, 130, for example.

As indicated above, the communication efficiency may improve when the device indicates transmission time budget of said at least one data unit to the network element, wherein the network element may utilize said information when allocating, scheduling and/or indicating radio resources to the terminal device for transmitting said at least one data unit. One example of such indication may be the transmission of SR from the device to the network element. Another such example,

may be the transmission of Buffer Status Report (BSR) from the device to the network element. However, in general, the provided solution may be applicable to different situations and use cases in which the device indicates that it has data to be transmitted (e.g. requests resources) and further indicates, using the same message, transmission time budget information of the data. In general, the transmission time budget information may be indicative of how much time there is left for delivering the particular data to meet the latency and/or delay requirements.

Let us then look closer at some examples and embodiments. Reference is made to terminal device, such as terminal device 110. However, the solution maybe applicable to other devices of a wireless network. Thus, the device mentioned above with respect to Figures 2 and 3 may also be configured to carry out embodiments discussed hereinafter. Further, reference is made to cellular network or cellular communication network. It needs to be pointed out that these terms may be specific examples of a wireless network (e.g. wireless network of Figures 2 and 3) to which the embodiments may also be applicable.

Figures 4A to 4B illustrate some embodiments. It needs to be pointed out that Figures 4A and 4B were also referred to above, but the solution proposed with respect to Figures 2 and 3 provides novel and inventive aspects to both Figures 4A and 4B. Referring to Figure 4A, a situation in which the terminal device 110 transmits SR to the network element 102 is shown (block 402). The SR may be transmitted in order to obtain radio resources for transmitting one or more data units. The SR of block 402 may comprise said further information element comprising the transmission time budget information associated with the one or more data units indicated also in the SR.

As the network element 102 may successfully decode (i.e. receive and decode) said SR, the network element 102 may provide radio resources to the terminal device 110 by transmitting a radio resource message to the terminal device 110 (block 404). It is further pointed out that the generated, allocated and/or indicated radio resources may be at least partially based on the transmission time budget information received with the SR. Therefore, radio resources may be such that the latency and/or delay requirements of said at least one data unit may be attained.

In an embodiment, the radio resource message is referred to as a grant message. The grant message may indicate specific radio resources or it may indicate a pool of radio resources from which the terminal device 110 may

determine at least some radio resources to be used. For example, the grant message may be an uplink grant message.

In block 406, the terminal device 110 may perform transmission(s) of said at least one data unit on the indicated radio resources. In some embodiments, the terminal device 110 selects which radio resources to use from an indicated pool of radio resources.

Further, in some embodiments, the transmission(s) of block 406 are performed to the network element 102 or via the network element 102. Thus, the network element 102 may receive the transmission(s) and possibly decode the at least one data unit from the transmission(s). However, in some embodiments, the network element 102 fails to either receive or decode the at least one data unit. This is shown in block 408. In the case of failed decoding, the network element 102 may indicate this to the terminal device 110 (not shown in Figure 4A, may be a non-acknowledgement (NACK) message, for example) and the terminal device 110 may retransmit (block 410) said at least one data unit. Retransmission may be performed as a response to receiving the indication of failed decoding or failed detection. However, if the transmission of block 406 is not detected at all by the network element 102, the network element 102 may be unable to indicate this to the terminal device 110. In such case, the terminal device 110 may continue to transmit said at least one data unit periodically for a predetermined number of times or a predetermined time or until an acknowledgement message is received from the network element 102.

However, one aspect in the example of Figure 4A is that the SR transmitted in block 402 may comprise the transmission time budget information on the at least one data unit and that the network element 102 may allocate radio resources for transmitting said at least one data unit at least partly on the basis of said transmission time budget information. For example, the radio resources may be allocated such that said at least one data unit may be allowed to be transmitted for predetermined number of times. For example, once, twice, thrice or four times. That is, the retransmission may be allowed or possible in the case of detection error. If said at least one data unit is decoded successfully, there may be no need the retransmit it. Allowed and/or possible number of times in this instance may mean that how many times the at least one data unit can be transmitted in order to attain the latency and/or delay requirements.

In an embodiment, still referring to Figure 4A, the terminal device 110 acquires, as a response to the transmitted message (e.g. SR transmitted in block

402), a radio resource message from the network element 102 (block 404); and on the basis of said radio resource message, initiates transmission of said at least one data unit (block 406, possibly block 410). Although in this example SR is used to acquire radio resources, it may be possible to similarly utilize BSR or some other message to acquire radio resources from the network element 102. To give an example, in block 402, the terminal device 110 may transmit a BSR indicating that it needs to transmit at least one data unit, wherein the BSR further comprises transmission time budget information associated with said at least one data unit. As a response, resource message may be received from the network element 102 (block 404), if the transmitted BSR is successfully decoded. If there is no response or response is non-acknowledgement, the terminal device 110 may retransmit said SR or BSR to the network element with a new or updated transmission time budget (example given in Figure 4B). The process may continue to steps 406 and possibly to steps 408, 410 with both SR and BSR examples.

Referring to Figure 4B, a similar SR transmission situation as in Figure 4A is shown. Again it is reminded that SR is an example and similar functionality can be applicable to, for example, BSR transmission. So the terminal device 110 may transmit a SR indicating the need to transmit at least one data unit and associated transmission time budget information (i.e. both may be in the same SR message). However, the network element 102 may in some instances be unable to receive and/or decode the transmitted SR (block 414). Understandably, this kind of detection error may increase delay of transmission of the at least one data unit, e.g. transmission time budget may decrease or a value that is compared with the transmission time budget may increase.

In an embodiment, the terminal device 110 retransmits the message (e.g. SR) to the network element 102, wherein the retransmitted message comprises updated said transmission time budget information (block 416). In a similar way, BSR may be retransmitted with updated transmission time budget information. The retransmission may occur a predetermined number of times (e.g. 0, 1, 2, 3, 4, 5, 6, 7, to name a few examples) or until the network element 102 responds with the radio resource message indicating radio resources for transmitting said at least one data unit (block 418).

Thus, in an embodiment, the network element 102 is configured to receive or receives another message from the terminal device 110 (block 416), said another message indicating the need, by the terminal device 110, to transmit said at least one data unit, wherein the said another message comprises updated said

transmission time budget information. Thus, as explained above, the transmission time budget information may be updated if the SR or BSR needs to be retransmitted. For example, if initially two transmission attempts were possible (e.g. message of block 412), the retransmitted message (e.g. block 416) may
5 indicate that only one transmission attempt is possible. Thus, the network element 102 may determine suitable radio resources to attain this target and indicate them to the terminal device (e.g. block 418).

Throughout this description reference is made to data unit or at least one data unit. Data unit may be understood as a unit that carries data (e.g. one or
10 more information elements associated or coupled with each other). Data unit may for example be a PDU or a Service Data Unit (SDU) of the MAC layer. Data unit may also be understood as a data packet carrying data. Data unit(s) or data packet(s) may also be processed before transmitting them over air-interface to another device or network element.

Also, it may be beneficial to explain when and how the described SR
15 transmission may occur. SR may be a special Physical Layer message as in for example 3GPP LTE, delivered using PUCCH format 1 employing energy detection, for a terminal device to ask network to send uplink (UL) Grant so that the terminal device may transmit on Physical Uplink Shared Channel (PUSCH). For example, if
20 there is no PUCCH configured for the transmitting terminal device, the terminal device may need to perform Random Access Procedure on Random Access Channel (RACH) with the network to acquire PUCCH access. After this, the terminal device may transmit the SR on PUCCH to a network element (e.g. eNB) and further, receive radio resources for transmitting data on PUSCH. Similarly, BSR may be understood
25 as a MAC layer Control Element (CE) from terminal device to network carrying information on how much data is in terminal device buffer to be transmitted. There are different kinds of BSRs, such as long and short BSRs.

The proposed solution allows the network element 102 or some other network element to perform resource allocations efficiently. For example, it may
30 be beneficial if the network element 102 knows how many transmission attempts can be performed for delivering the at least one data unit (e.g. payload). That is, how many attempts may be performed to still attain the latency requirements. For example, if two transmission attempts can be performed, the initial transmission may be performed, by the terminal device 110, with a moderate BLER target, for
35 example, BLER may be around 10%. If the initial transmission (e.g. block 406) is not received or cannot be decoded by the network element 102, the retransmission

(e.g. block 410) may be performed with a lower BLER target.

In another example, if the at least one data unit should be delivered with only one transmission attempt, the BLER target may be quite low, e.g. less than tolerable error rate. This may mean that a very robust modulation and coding
5 scheme (MCS) may be selected for the transmission, resulting in a relatively low transmission rate. However, if only one transmission attempt is allowable or available, the robust MCS may be beneficial to be selected and indicated by the network element 102 to the terminal device 110.

Therefore, the transmission time budget information may enable the
10 network element 102 to generate or allocate needed radio resources (e.g. and indicate them in block 404 or 418). For example, MCS may be selected on the basis of the transmission time budget information. That is, in an embodiment, the network element 102 determines MCS to be used in the transmission of the at least one data unit by the terminal device 110. The determined MCS may be indicated to
15 the terminal device 110 using the radio resource message (e.g. blocks 404, 418), for example. The fewer the number of allowed transmissions attempts of the at least one data unit, the lower the transmission rate or data rate resulting from the determined MCS may be. Thus, transmission or data rate may be relative to the number of allowed transmission attempts such that the transmission or data rate
20 increases as the number of allowed transmission attempts increases.

In an embodiment, said radio resource message (e.g. block 404 or 418) indicates radio resources for transmitting the at least one data unit, the indicated radio resources being dependent at least on said transmission time budget information. Examples of this were given above. For example, MCS may be selected
25 on the basis of the transmission time budget information (e.g. indicating one or two transmission attempt(s)). One other example may be to allocate more subframes for transmission in a case of only one transmission attempt compared with a case of two or more transmission attempts.

In an embodiment, said message, transmitted by the terminal device
30 110 to the network element 102, indicating the need to transmit the at least one data unit is a scheduling request message (e.g. transmitted in block 402 or in block 412) or a report message (e.g. BSR) indicating data buffer status of the terminal device 110. Said message may be received by the network element 102. Said message may be retransmitted in a case where the network element 102 fails to
35 decode said message.

Although examples of Figures 4A and 4B are illustrated separately, the

examples may also be applicable to scenarios in which SR or BSR is retransmitted one or more times and the data transmission is retransmitted one or more times.

Let us then look closer on Figures 5A to 5C illustrating some embodiments. Referring to Figure 5A, the terminal device 110 may acquire data
5 (e.g. at least one data unit) to be transmitted to another terminal device or some network element (e.g. network element 102) (block 502). The terminal device 110 may transmit, to the network element 102, a first message indicating a need to transmit at least one data unit and comprising transmission time budget information associated with the at least one data unit (block 504). If the network
10 element 102 is not successful in decoding said first message (block 506), the terminal device 110 may transmit a second message to the network element 102 indicating the need to transmit said at least one data unit and comprising updated transmission time budget information associated with the at least one data unit (block 508). It is possible that the terminal device retransmits said message more
15 than twice, each time with updated transmission time budget information. When the network element 102 successfully decodes said message, it may respond with a radio resource message (block 510) indicating radio resources for transmitting said at least one data unit by the terminal device 110. In block 512, the terminal device 110 may transmit said at least one data unit. Retransmission(s) of the at
20 least one data unit may also occur as described above.

In an embodiment, the network element 102 is further configured to perform the following actions: acquiring, from the terminal device 110, a first message indicating the need to transmit said at least one data unit and transmission time budget information on said at least one data unit (block 504);
25 upon unsuccessful decoding of the first message, transmitting a non-acknowledgement message to the terminal device 110 and acquiring, from the terminal device 110, a second message indicating the need to transmit said at least one data unit and updated transmission time budget information on said at least one data unit (block 508). As we explained before, the NACK message may not be
30 necessary in all embodiments as the terminal device may continue transmitting said message for a predetermined number of times if no response is received, for example.

Referring to Figure 5B, in block 522, the terminal device 110 may obtain one or more data units to be transmitted to some other device or element. In block
35 524, the terminal device 110 may transmit a report or status message (e.g. BSR) to the network element 102. The report message may comprise indication about the

at least one data unit to be transmitted and transmission time budget information on said at least one data unit. In an embodiment, the network element 102 responds, after successful decoding, with a radio resource message (block 526). In block 528, the terminal device 110 may perform one or more transmissions on
5 radio resources determined from or indicated by the radio resource message of block 526.

In an embodiment, the at least one data unit comprises a plurality of data units. In an embodiment, the message (e.g. block 402, 412, 416, 504, 508, 524) comprises transmission time budget information for each of the plurality of data
10 units. In an embodiment, the transmission time budget information is data unit - specific. Thus, for example, said message may indicate two data units: first data unit and second data unit, wherein said message further comprises first transmission time budget information associated with the first data unit and second transmission time budget information associated with the second data unit.
15 Therefore, for example, said message may indicate that two transmission attempts may be performed for the first data unit and only one transmission attempt may be performed for the second data unit. The network element 102, after successful decoding of said message, may generate or allocate radio resources for transmitting the first and/or second data units accordingly.

Referring to Figure 5C, in block 532, the terminal device 110 may obtain
20 data (e.g. at least one data unit) to be transmitted. The terminal device 110 may further transmit a first report message and a second report message to the network element 102, wherein the first report message is associated with a first communication link and the second report message is associated with a second
25 communication link (block 534). The first and second report messages may be similar as described above (e.g. first BSR and second BSR). In an embodiment, the network element 102 receives the first and second report messages. In an embodiment, the network element 102 determines based on the first and second status messages whether to allocate radio resources from first and/or second
30 communication link to the terminal device 110 (block 536). Thus, in block 538, the terminal device 110 may transmit the at least one data unit utilizing the first and/or second communication links.

In an embodiment, contents of the first and second report messages are comprised in one report message that is transmitted by the terminal device 110 to
35 the network element 102.

In an embodiment, the first communication link is between the terminal

device 110 and the network element 102. In an embodiment, the second communication link is between the terminal device 110 and a second network element 112. In an embodiment, the first communication link is primary link and the second communication link is secondary link (e.g. carrier aggregation case). In an embodiment, the first communication link is cellular communication link (e.g. LTE, LTE-A, 5G) and the second communication link is a WLAN link. Thus, in an embodiment, the proposed solution may be applicable to LWA or eLWA system in which WLAN may be used for carrier aggregation. Thus, for example, BSR for WLAN link and BSR for cellular link (i.e. primary link) may both be transmitted to the primary network element (e.g. network element 102, in some instances referred to as MeNB), wherein the primary network element may perform scheduling decisions based on said BSRs.

In an embodiment, the terminal device 110 records delay-related information on both the first and second communication links. This information may be incorporated into the appropriate report messages (block 534). The delay-related information may comprise, for example, allowed number of transmission for a data unit on that communication link or delay budget for a data unit on that communication link. The delay-related information may comprise also the used time for previous data unit transmission.

In an embodiment, the terminal device 110 transmits a plurality of report messages to the network element 102, wherein the plurality of report messages is associated with a plurality of communication links such that each report message of the plurality of report messages is associated with a specific communication link of the plurality of communication links.

In an embodiment, the network element 102 may receive a plurality of report messages from the terminal device 110, wherein the plurality of report messages is associated with a plurality of communication links such that each report message of the plurality of report messages is associated with a specific communication link of the plurality of communication links.

The plurality of communication links may be between the terminal device 110 and some other device or network element. For example, one link may be between the terminal device 110 and the network element 102 and some other may be between the terminal device and the network element 112. There may be further communication links, e.g. 3, 4, 5 and so forth.

In an embodiment, the network element 102 selects a communication link among the plurality of communication links on the basis of the transmission

time budget information of the plurality of report messages; and generates the radio resource message indicating radio resources on the selected communication link and transmits said radio resource message to the terminal device 110.

In an embodiment, the terminal device receives a radio resource
5 message from the network element 102, the radio resource message indicating radio resources on a specific communication link among the plurality of communication links; and on the basis of said radio resource message, initiates transmission of said at least one data unit. Thus, the terminal device 110 may use the radio resources on the indicated communication link. In some embodiments,
10 the network element 102 may indicate radio resources on a plurality of communication link using said radio resource message. Thus, the terminal device 110 may perform transmission(s) on more than one communication link.

One specific example of transmitting plurality of messages (e.g. report messages) discussed above may be the transmission of plurality of BSRs, wherein
15 each BSR is associated with a specific communication link among a plurality of communication links. This may enable the terminal device 110 to report delay information of a plurality of communication links to the network element 102. The network element 102 may then use this indicated delay information on the plurality of communication links to select one or more of the plurality of
20 communication links from which radio resources are granted to the terminal device 110. Thus, for example, a communication link with a lower recorded delay than some other communication link may be selected and utilized.

Let us then look closer on what kind of information the transmission time budget information may comprise. Figures 6A and 6B illustrate block
25 diagrams according to some embodiments. Referring first to Figure 6A, a message 600 is shown. The message 600 may be or be similar to the messages transmitted in blocks 402, 412, 416, 504, 524, 534, for example. Thus, the message 600 may comprise an information element (IE) 610 indicating at least one data unit (i.e. indicating need to transmit said at least one data unit). Further, the message 600
30 may comprise a further information element 620 comprising transmission time budget information associated with or on the at least one data unit (indicate with information element 610). In an embodiment, the IE 610 comprises regular SR information.

In an embodiment, said transmission time budget information (e.g.
35 indicated with IE 620) is indicative of remaining time (block 622) for attaining latency requirements of said at least one data unit. That is, the terminal device 110

may be aware or presume certain latency requirements for the at least one data unit. Therefore, the terminal device 110 may indicate how much there is time left to attain the latency requirements for said at least one data unit. The remaining time 622 may be indicated in time 622A (e.g. 0.5ms or 1ms) or in subframes 522B (e.g. 5 subframes, wherein one subframe may be, for example, 0.125ms). So in general if there is 1ms latency requirement for a data unit, the terminal device 110 may determine how much this time has already been used and indicate the used time, or calculate how much time is still left and indicate the calculated time to the network element 102, for example. If retransmission(s) are required, each retransmitted message may have updated information on remaining time.

In an embodiment, said transmission time budget information (e.g. indicated with IE 620) is indicative of a number of allowed transmission attempts (block 624) of said at least one data unit to attain said latency requirements. For example, the terminal device 110 may indicate that one, two, or three transmission attempts may be performed. For example, if three transmission attempts are allowed, the network element 102 may first grant resources with higher data rate and change to lower data rate if the initial transmission fails. If a retransmission is required, the number of initially allowed transmission attempts may be reduced (e.g. if first message indicates two transmission attempts and retransmission is required, the retransmitted message may indicate only one transmission attempt) and this newly calculated value may be comprised in the retransmitted message.

In an embodiment, said transmission time budget information (e.g. indicated with IE 620) is indicative of elapsed time (block 626) between the obtaining said at least one data unit and the transmitting said message. For example, the terminal device 110 may calculate time between obtaining said at least one data unit in block 210 and transmitting the message 600 to the network element 102 in block 220. Thus, the elapsed time may be used by the network element 102 to calculate or estimate how much time is still left for attaining the latency requirements for said at least one data unit. If a retransmission is required, the elapsed time may be the time between the obtaining the data unit and retransmitting the message indicating the data transmission need.

In an embodiment, said transmission time budget information (e.g. indicated with IE 620) is indicative of a number of transmitted messages 600 (block 628), by the terminal device 110, that are transmitted to indicate the need to transmit said at least one data unit. For example, when said at least one data unit is obtained, the terminal device 110 may transmit an initial message 600

requesting radio resources for transmitting said at least one data unit. The message may further indicate that said message is a first message (e.g. binary representation of 0 using k bits). However, if the decoding of said message fails, a retransmission may be performed if possible. Thus, the second message 600 may further indicate
5 that said second message is a second message (e.g. binary representation of 1 using k bits). Thus, the network element 102 may know how many times a particular SR or BSR has been transmitted. Therefore, it may estimate or determine how many transmission attempts are allowed for said at least one data unit and grant radio resources accordingly. Based on such information and the overall latency target,
10 the network element 102 may estimate how long time has passed and what is the remaining time budget concerning the received SR. In case there is only one chance for retransmitting SR, one bit information may be sufficient. Thus, for example, the IE 620 may in some embodiments comprise only one bit for indicating said transmission time budget information. This may be quite efficient way to inform
15 the network element 102 and cause quite minimal load to the cellular communication network. In some other embodiments, the IE 620 comprises a plurality of bits which may enable more complex information (e.g. more accurate) to be informed.

In an embodiment, the number of transmitted messages (block 628), by
20 the terminal device 110, indicates the number of transmitted messages, to the network element 102, to indicate the need to transmit said at least one data unit. Thus, each of the transmitted messages may be transmitted to the network element 102.

In the example above, the first message may mean that the message has
25 not been transmitted before for indicating the need to transmit said at least one data unit. Thus, the first message may in some embodiments mean that it is the first message that has been transmitted to acquire radio resources for transmitting said at least one data unit. Accordingly, the second message may mean that the message is transmitted a second time. The transmission time budget information may be
30 updated for the second message, as explained with numerous examples. In an embodiment, the IE 620 comprises one or more of the IEs 622-628.

In an embodiment, the further IE 620 comprises k bits, wherein k bits can be assigned to demonstrate 2^k number of different values. Value k may be a positive integer value. Thus, for example, k bits may be used to indicate elapsed
35 time 626. For example, the values can represent elapsed time relative to the determined delay for selected Quality of Service (QoS). Assuming that the selected

QoS corresponds to delay of D , the i th sequence may represent elapsed time up to $i \frac{D}{2^k}$, wherein $0 \leq i \leq 2^k - 1$. The elapsed time may be considered from the instance that the MAC PDU is generated or prepared to be transmitted until the time that SR is sent, in the example where SR is transmitted indicating one or more
 5 MAC PDUs.

In an embodiment, the network element 102 determines, based on said transmission time budget information, remaining time for attaining latency requirements of said at least one data unit, wherein the radio resource message is generated at least partly on the basis of said remaining time 622. That is, either the
 10 message 600 comprises directly said remaining time or the network element 102 calculates said remaining time from one or more values indicated with IE 620 (e.g. remaining time in block 622).

In an embodiment, the network element 102 determines, based on said transmission time budget information, a number of possible transmission attempts
 15 of said at least one data unit, by the terminal device 110, to attain latency requirements of said at least one data unit, wherein the radio resource message is generated at least partly on the basis of said number of possible transmission attempts. E.g. the allowed number of data transmission attempts may be indicated in block 624.

In an embodiment, the network element 102 determines, based on said transmission time budget information, elapsed time between obtaining, by the terminal device 110, said at least one data unit and transmitting, by the terminal device 110, said message indicating the need to transmit said at least one data unit, wherein the radio resource message is generated at least partly on the basis of said
 25 elapsed time. E.g. the elapsed time may be indicated in block 626.

In an embodiment, the network element 102 determines, based on said transmission time budget information, number of transmitted messages, by the terminal device, that are transmitted to indicate the need to transmit said at least one data unit, wherein the radio resource message is generated at least partly on
 30 the basis of said number of transmitted messages. E.g. the elapsed time may be indicated in block 628.

Particularly, for BSR transmission(s) (e.g. example of Figure 5C), the BSR may comprise indication of at least one data unit associated with information of how many transmission attempts are allowed for each at least one data unit (e.g.
 35 block 624).

So above there are given a number of different ways to indicate the

transmission time budget information on at least one data unit. There may be differences and different benefits between different methods, but essentially the purpose may be to inform, by the terminal device 110 to the network element 102, of remaining time budget for delivering said at least one data unit. Thus, the
5 network element 102 may use this information to generate and/or allocate radio resources for the terminal device 110. Thus, the generation, allocation, and/or utilization of radio resources may be made more effective, for example.

Let us discuss a bit more about some specific examples related to the described solution. Referring to Figures 4A and 4B, one example may relate to
10 URLLC. It may further be assumed that the payload (e.g. at least one data unit) should be delivered within 5 subframes from the time instance that the terminal device 110 sends the initial SR message (block 402 or 412). In case the SR is decoded correctly with the initial attempt, two transmission attempts can be performed for the payload as shown in Figure 4A. If the initial SR message is not
15 decoded successfully (e.g. block 414), the terminal device may retransmit the SR (block 416). In this case (example of Figure 4B), only one MAC PDU transmission attempt may be performed according to the required latency performance (e.g. 5 subframes). Along with the SR, one bit may be carried for indicating the elapsed time. The bit may be set to 0 when the initial SR is sent, while the bit may be set to
20 1 when SR is retransmitted. It should be pointed out without such enhancement, it may not be possible for the network element 102 to know the updated transmission time budget information (e.g. elapsed time, how many transmissions are still allowed etc.). For example, without having IE 620 to indicate the transmission time budget information, the network element 102 may always
25 assume that there is possibility for retransmission. For example and referring to Figure 4B, the network element 102 may assume that SR transmitted in block 416 is initial SR if the initial SR (block 412) is not received or decoded properly. Thus, for example, network element 102 may select MCS based on the assumption that two transmission attempts are still available (although only one would be), and grant resources accordingly. So, in general, the network element 102 may, when
30 the transmission time budget information is indicated to it, allocate radio resources more efficiently. That is, if there is a lot of transmission time budget available, the network element 102 may select a less robust MCS which may provide an increased data rate.

35 Let us then look at Figures 7A to 7B which indicate some benefits of the provided solution with different target BLERs. In Figure 7A, the target BLER may

be 10^{-5} and the error for detecting the SR is $3 \cdot 10^{-3}$. In Figure 7B, the target BLER may be 10^{-6} and the error for detecting the SR is $1 \cdot 10^{-3}$. Further, both examples consider MAC PDU transmission, but the benefits shown may be achievable for other types of data transmission.

5 For conventional LTE PUCCH format 1 (i.e. without the transmission time budget information) that carries the SR, MCS_1 and MCS_2 can be selected as MCS for the initial transmission and retransmission respectively for a given MAC PDU. The probability of decoding the MAC PDU, by the network element 102, may be expressed as:

10
$$P_{success} = (1 - \varepsilon_{SR})\{(1 - P_1) + P_1(1 - P_{1,2})\} + \varepsilon_{SR}(1 - \varepsilon_{SR})(1 - P_1),$$

where, ε_{SR} is the probability of unsuccessful detection of the SR message on PUCCH format 1. P_1 is the error probability of decoding the MAC PDU in the initial transmission round, while $P_{1,2}$ is the error probability of decoding the MAC PDU in the second transmission round, using received information in both rounds.

15 The average transmission rate or data rate can be expressed as:

$$\bar{R} = r_1\{(1 - \varepsilon_{SR})(1 - P_1) + \varepsilon_{SR}\} + \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}}(1 - \varepsilon_{SR})P_1,$$

where r_1 and r_2 are the corresponding transmission rates for MCS_1 and MCS_2 respectively. The optimal resource allocations may be derived to maximize the average transmission rate:

20
$$m_1, m_2 = \underset{MCS_1, MCS_2}{\operatorname{argmax}} \bar{R} \quad \text{subject to} \quad P_{success} \geq 1 - \varepsilon,$$

where ε is the corresponding BLER for the reliability target.

When the transmission time budget information associated with the at least one data unit (i.e. in this example MAC PDU) is added to the message (i.e. in this example SR on PUCCH format 1) some benefits may be obtainable. In such case,
25 MCS_1 and MCS_2 are selected for the initial transmission and retransmission respectively for a MAC PDU, if the SR is received and decoded, by the network element 102, correctly with first attempt. So if the SR is acquired by the network element 102 from the terminal device 110 with first attempt as in the example of Figure 4A, two different MCSs may be used, wherein one is configured to be used
30 with the first transmission attempt and the other with the second transmission attempt (if the first attempt fails) (see example of Figure 4A in which SR may be decoded accordingly with first attempt, but the data transmission may require two attempts). However, if the SR is received in the second attempt, MCS_3 may be selected for the MAC PDU transmission. Example of this may be seen in Figure 4B,
35 where retransmission of SR is required and thus the network element 102 may

cause the terminal device to perform transmission of the at least one data unit with the MCS_3 .

The probability of decoding a MAC PDU can be expressed as:

$$P_{success}^* = (1 - \varepsilon_{SR})\{(1 - P_1) + P_1(1 - P_{1,2})\} + \varepsilon_{SR}(1 - \varepsilon_{SR})(1 - P_3),$$

5 where P_3 is the probability of decoding the MPDU using the initial transmission according to the employed MCS_3 . The average transmission rate is:

$$\bar{R}^* = r_1(1 - \varepsilon_{SR})(1 - P_1) + \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}}(1 - \varepsilon_{SR})P_1 + r_3(1 - \varepsilon_{SR})\varepsilon_{SR},$$

10 where r_3 is the transmission rate corresponding to the MCS_3 . The optimal resource allocations can be derived maximizing the average transmission rate:

$$m_1, m_2, m_3 = \underset{MCS_1, MCS_2, MCS_3}{\operatorname{argmax}} \bar{R}^* \quad \text{subject to} \quad P_{success}^* \geq 1 - \varepsilon.$$

To illustrate power of this kind of arrangement, reference is made to Figures 7A and 7B, in which the conventional SR transmission on PUCCH format 1 is illustrated with lines 710 and 730 and the enhanced SR transmission on PUCCH format 1 (e.g. comprising the additional transmission time budget information) is illustrated with dotted lines 720, 740. The graphs or lines 710, 720, 730, 740 illustrate transmission rate or data rate (bits per second/Hz (bps/Hz)) as function of Signal-to-Noise Ratio (SNR) (decibel (dB)). As the Figures 7a and 7B show, is gain may increase as the required BLER increases. One reason for this may be that when the error in SR detection increases, the conventional PUCCH 710, 730 entails to perform the initial MAC PDU transmissions with high reliability, as the network element 102 is not sure whether the retransmission is feasible or not. However, the enhanced PUCCH 720, 740 may allow performing the first MAC PDU transmissions attempts with high transmission rate or data rate when the network element 102 may be aware (due to the additional transmission time budget information) that another transmission attempt of the MAC PDU may be performed. In case the network element 102 determines that the only one transmission may be performed due to, for example, delay caused by unsuccessful decoding of initial SR transmission, the network element 102 may select a more robust MCS for the MAC PDU transmission.

30 In an embodiment, with reference to Figure 4A, the network element 102 is configured to determine that a message (e.g. SR), transmitted by the terminal device 110 in block 402, indicating a need to transmit at least one data unit and comprising transmission time budget information about said at least one data unit is a first message. That is, said first message is not a retransmission, but is transmitted for the first time by the terminal device 110 for said at least one data

unit. The network element 102 may further determine, based at least on said transmission time budget information, that one or more transmissions of the at least one data unit is allowed. In the case that only one transmission is allowed, the network element 102 may select a third MCS and grant radio resources according to the third MCS to the terminal device 110. In the case that at least two transmissions are allowed, the network element 102 may select a first and a second MCSs, and grant radio resources according to the first and second MCSs to the terminal device 110. In an embodiment, the third MCS results in a lower transmission or data rate compared with the first MCS. In an embodiment, the third MCS results in a lower transmission or data rate compared with the second MCS. In an embodiment, the first MCS results in a higher transmission or data rate compared with the second MCS.

In an embodiment, the network element 102 only grants, based on the transmission time budget information, radio resources for one transmission attempt of the at least one data unit. That is, if only one transmission attempt may be performed in order to attain latency requirements, the network element 102 may not waste radio resources by reserving or granting radio resources for a second transmission attempt of the at least one data unit.

Figures 8 to 9 provide apparatuses 800, 900 comprising a control circuitry (CTRL) 810, 910, such as at least one processor, and at least one memory 830, 930 including a computer program code (software) 832, 932, wherein the at least one memory and the computer program code (software) 832, 932, are configured, with the at least one processor, to cause the respective apparatus 800, 900 to carry out any one of the embodiments of Figures 2 to 7B, or operations thereof.

Referring to Figures 8 to 9, the memory 830, 930, may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The memory 830, 930 may comprise a database 834, 934 for storing data.

The apparatuses 800, 900 may further comprise radio interface (TRX) 820, 920 comprising hardware and/or software for realizing communication connectivity according to one or more communication protocols. The TRX may provide the apparatus with communication capabilities to access the radio access network, for example. The TRX may comprise standard well-known components such as an amplifier, filter, frequency-converter, (de)modulator, and

encoder/decoder circuitries and one or more antennas. For example, the TRX may enable communication between the terminal device 110 and the network element 102 (e.g. on PUCCH, PUSCH). Further, the TRX may provide access to the X2-interface for the network element 102, for example.

5 The apparatuses 800, 900 may comprise user interface 840, 940 comprising, for example, at least one keypad, a microphone, a touch display, a display, a speaker, etc. The user interface 840, 940 may be used to control the respective apparatus by a user of the apparatus 800, 900. For example, a network element may be configured using the user interface comprised in said network
10 element or using a remote user interface. Naturally, a terminal device may comprise a user interface.

 In an embodiment, the apparatus 800 may be or be comprised in a device, such as a mobile phone or cellular phone, for example. The apparatus 800 may be the terminal device 110, for example. In an embodiment, the apparatus 800
15 is comprised in the terminal device 110 or in some other terminal device. Further, the apparatus 800 may be the device performing the steps of Figure 2, for example.

 Referring to Figure 8, the control circuitry 810 may comprise a data obtaining circuitry 812 configured to obtain at least one data unit to be transmitted by a device; and a message transmitting circuitry 814 configured to cause
20 transmission of a message comprising an information element indicating a need to transmit said at least one data unit, wherein the message comprises a further information element comprising transmission time budget information associated with said at least one data unit.

 In an embodiment, the apparatus 900 may be or be comprised in a base
25 station (also called a base transceiver station, a Node B, a radio network controller, or an evolved Node B (eNB), for example). The apparatus 900 may be the network element 102, for example. Further, the apparatus 900 may be the network element performing the steps of Figure 3. In an embodiment, the apparatus 900 is comprised in the network element 102 and configured to cause performing of any
30 one of the embodiments described in relation to Figure 2 to 7B.

 Referring to Figure 9, the control circuitry 910 comprises a message acquiring circuitry 912 configured to acquire, from a terminal device of a cellular communication network, a message comprising an information element indicating
35 a need, by the terminal device, to transmit at least one data unit, wherein the message comprises a further information element comprising transmission time budget information associated with said at least one data unit; a decoding circuitry

914 configured to initiate decoding of said message; and a radio resource circuitry 916 configured to, upon successful decoding of said message by the decoding circuitry 914, generate a radio resource message, based at least partly on the transmission time budget information, indicating radio resources for transmitting
5 said at least one data unit and transmitting said radio resource message to the terminal device.

In an embodiment of Figure 10, at least some of the functionalities of the apparatus 900 (e.g. the network element 102) may be shared between two physically separate devices, forming one operational entity. Therefore, the
10 apparatus may be considered to depict the operational entity comprising one or more physically separate devices for executing at least some of the above-described processes. Thus, the apparatus of Figure 10, utilizing such a shared architecture, may comprise a remote control unit (RCU), such as a host computer or a server computer, operatively coupled (e.g. via a wireless or wired network) to
15 a remote radio head (RRH) located at a base station site. In an embodiment, at least some of the described processes of the network node may be performed by the RCU. In an embodiment, the execution of at least some of the described processes may be shared among the RRH and the RCU. In such a context, the RCU may comprise the components illustrated in Figure 10, and the radio interface 920 may
20 provide the RCU with the connection to the RRH. The RRH may then comprise radio frequency signal processing circuitries and antennas, for example.

In an embodiment, the RCU may generate a virtual network through which the RCU communicates with the RRH. In general, virtual networking may involve a process of combining hardware and software network resources and
25 network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into the server computer or the host computer (i.e. to the RCU). External
30 network virtualization is targeted to optimized network sharing. Another category is internal virtual networking which provides network-like functionality to the software containers on a single system. Virtual networking may also be used for testing the terminal device.

In an embodiment, the virtual network may provide flexible
35 distribution of operations between the RRH and the RCU. In practice, any digital signal processing task may be performed in either the RRH or the RCU and the

boundary where the responsibility is shifted between the RRH and the RCU may be selected according to implementation.

As used in this application, the term 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in
5 only analog and/or digital circuitry, and (b) combinations of circuits and soft-ware (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a
10 microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their)
15 accompanying software and/or firmware. The term 'circuitry' would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.

In an embodiment, at least some of the processes described in
20 connection with Figures 2 to 7B may be carried out by an apparatus comprising corresponding means for carrying out at least some of the described processes. Some example means for carrying out the processes may include at least one of the following: detector, processor (including dual-core and multiple-core processors), digital signal processor, controller, receiver, transmitter, encoder,
25 decoder, memory, RAM, ROM, software, firmware, display, user interface, display circuitry, user interface circuitry, user interface software, display software, circuit, antenna, antenna circuitry, and circuitry. In an embodiment, the at least one processor, the memory, and the computer program code form processing means or comprises one or more computer program code portions for carrying out
30 one or more operations according to any one of the embodiments of Figures 2 to 7B or operations thereof.

According to yet another embodiment, the apparatus carrying out the embodiments comprises a circuitry including at least one processor and at least one memory including computer program code. When activated, the circuitry
35 causes the apparatus to perform at least some of the functionalities according to any one of the embodiments of Figures 2 to 7B, or operations thereof.

Some benefits of the proposed solution were discussed with respect to Figures 7A and 7B. It needs to be noted that those examples were related to SR transmission, but the benefits may be applicable to other types of transmissions, such as BSR transmission. Some general advantages may include:

- 5 • Better resource allocations:
 - In case there is a high demand for uplink data transmissions in at certain time, the network element 102 may use the transmission time budget information, such as the elapsed time (block 626 of Figure 6B), in order to give higher priority to the
 - 10 terminal devices with shorter time budget for delivering data, for instance, terminal devices that may need to perform SR retransmission.
- Avoiding unnecessary resource allocations and Acknowledgement/Non-Acknowledgement (ACK/NACK)
- 15 transmissions. For example, in the LTE, the MAC PDU retransmissions may be continued until ACK is received or the maximum number of retransmission is reached. Employing the proposed PUCCH format 1
- scheme, the terminal device may inform the eNodeB whether this TTI is the last chance for allocating resources for data transmission or not. In
- 20 case this is the last chance, data retransmission may not be required in the later TTI. So, the eNodeB may not allocate extra radio resources if it does not receive ACK. Even the terminal device may avoid transmitting
- ACK/NACK for the last transmission round.

The proposed enhancement suitable for, for example, PUCCH may be

25 utilized in the future 5G system to offer URLLC with quite high transmission rates. This may be achieved by embedding additional information in uplink (UL) control channel for performing scheduling request (SR). The solution may be applicable to all air interface solutions applying a grant based access methods, e.g. services with higher reliability and delay requirements in LTE may also benefit. The solution may

30 be applicable to the WLAN air interface where UL grants for WLAN may also be supported, e.g. developed IEEE 802.11ax standard and the like.

The techniques and methods described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more

35 modules), or combinations thereof. For a hardware implementation, the apparatus(es) of embodiments may be implemented within one or more

application-specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, the implementation can be carried out through modules of at least one chip set (e.g. procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case, it can be communicatively coupled to the processor via various means, as is known in the art. Additionally, the components of the systems described herein may be rearranged and/or complemented by additional components in order to facilitate the achievements of the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be appreciated by one skilled in the art.

Embodiments as described may also be carried out in the form of a computer process defined by a computer program or portions thereof. Embodiments of the methods described in connection with Figures 2 to 7B may be carried out by executing at least one portion of a computer program comprising corresponding instructions. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example, the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. The computer program medium may be a non-transitory medium. Coding of software for carrying out the embodiments as shown and described is well within the scope of a person of ordinary skill in the art. In an embodiment, a computer-readable medium comprises said computer program.

Even though the invention has been described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but can be modified in several ways within the scope of the appended claims. Therefore, all words and expressions should be interpreted

broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be
5 combined with other embodiments in various ways.

CLAIMS

1. A method comprising:
obtaining, by a device of a wireless network, at least one data unit to be transmitted by the device; and
5 transmitting, by the device to a network element of the wireless network, a message comprising an information element indicating a need to transmit said at least one data unit,
wherein the message comprises a further information element comprising transmission time budget information associated with said at least one
10 data unit.
2. The method of claim 1, wherein said transmission time budget information is indicative of remaining time for attaining latency requirements of said at least one data unit.
15
3. The method of any preceding claim, wherein said time budget information is indicative of a number of allowed transmission attempts of said at least one data unit to attain said latency requirements.
- 20 4. The method of any preceding claim, wherein said transmission time budget information is indicative of elapsed time between the obtaining said at least one data unit and the transmitting said message.
- 25 5. The method of any preceding claim, wherein said transmission time budget information is indicative of a number of transmitted messages, by the device, that are transmitted to indicate the need to transmit said at least one data unit.
- 30 6. The method of any preceding claim, further comprising:
retransmitting the message to the network element, wherein the retransmitted message comprises updated said transmission time budget information.
- 35 7. The method of any preceding claim, further comprising:
acquiring, as a response to the transmitted message, a radio resource message from the network element; and

on the basis of said radio resource message, initiating transmission of said at least one data unit.

8. The method of any preceding claim, wherein said radio resource
5 message indicates radio resources for transmitting the at least one data unit, the indicated radio resources being dependent at least on said transmission time budget information.

9. The method of any preceding claim, wherein said message indicating
10 the need to transmit the at least one data unit is a scheduling request message or a report message indicating data buffer status of the device.

10. The method of claim 9, further comprising:
transmitting a plurality of report messages to the network element,
15 wherein the plurality of report messages is associated with a plurality of communication links such that each report message of the plurality of report messages is associated with a specific communication link of the plurality of communication links.

20 11. The method of claim 10, further comprising:
receiving a radio resource message from the network element, the radio resource message indicating radio resources on a specific communication link among the plurality of communication links; and
on the basis of said radio resource message, initiating transmission of
25 said at least one data unit.

12. The method of claim 10 or claim 11, wherein the plurality of communication links comprises a first communication link and a second communication link, and wherein the first communication link is a cellular
30 communication link and the second communication link is a Wireless Local Area Network, WLAN, link.

13. A method comprising:
acquiring, by a network element of a wireless network from a device of
35 the wireless network, a message comprising an information element indicating a need, by the device, to transmit at least one data unit, wherein the message

comprises a further information element comprising transmission time budget information associated with said at least one data unit;

initiating decoding of said message; and

5 upon successful decoding of said message, generating a radio resource message, based at least partly on the transmission time budget information, indicating radio resources for transmitting said at least one data unit and transmitting said radio resource message to the device.

14. The method of claim 13, further comprising:

10 determining, based on said transmission time budget information, remaining time for attaining latency requirements of said at least one data unit, wherein the radio resource message is generated at least partly on the basis of said remaining time.

15 15. The method of any preceding claim 13 to 14, further comprising:

determining, based on said transmission time budget information, a number of possible transmission attempts of said at least one data unit, by the device, to attain latency requirements of said at least one data unit,

20 wherein the radio resource message is generated at least partly on the basis of said number of possible transmission attempts.

16. The method of any preceding claim 13 to 15, further comprising:

25 determining, based on said transmission time budget information, elapsed time between obtaining, by the device, said at least one data unit and transmitting, by the device, said message indicating the need to transmit said at least one data unit,

wherein the radio resource message is generated at least partly on the basis of said elapsed time.

30 17. The method of any preceding claim 13 to 16, further comprising:

determining, based on said transmission time budget information, number of transmitted messages, by the device, that are transmitted to indicate the need to transmit said at least one data unit,

35 wherein the radio resource message is generated at least partly on the basis of said number of transmitted messages.

18. The method of any preceding claim 13 to 17, further comprising:
receiving another message from the device, said another message
indicating the need, by the device, to transmit said at least one data unit, wherein
the said another message comprises updated said transmission time budget
5 information.

19. The method of any preceding claim 13 to 18, wherein said message
indicating the need to transmit the at least one data unit, by the device, is a
scheduling request message or a report message indicating data buffer status of the
10 device.

20. The method of claim 19, further comprising:
receiving a plurality of report messages from the device, wherein the
plurality of report messages is associated with a plurality of communication links
15 such that each report message of the plurality of report messages is associated with
a specific communication link of the plurality of communication links.

21. The method of claim 20, further comprising:
selecting a communication link among the plurality of communication
20 links on the basis of the transmission time budget information of the plurality of
report messages; and
generating the radio resource message indicating radio resources on
the selected communication link and transmitting said radio resource message to
the device.

25

22. An apparatus comprising:
at least one processor, and
at least one memory comprising a computer program code, wherein the
at least one memory and the computer program code are configured, with the at
30 least one processor, to cause a device of a wireless network to perform operations
comprising:
obtaining, at least one data unit to be transmitted by the device; and
transmitting, to a network element of the wireless network, a message
comprising an information element indicating a need to transmit said at least one
35 data unit,
wherein the message comprises a further information element

comprising transmission time budget information associated with said at least one data unit.

23. The apparatus of claim 22, wherein said transmission time budget
5 information is indicative of remaining time for attaining latency requirements of said at least one data unit.

24. The apparatus of any preceding claim 22 to 23, wherein said time
budget information is indicative of a number of allowed transmission attempts of
10 said at least one data unit to attain said latency requirements.

25. The apparatus of any preceding claim 22 to 24, wherein said
transmission time budget information is indicative of elapsed time between the
obtaining said at least one data unit and the transmitting said message.
15

26. The apparatus of any preceding claim 22 to 25, wherein said
transmission time budget information is indicative of a number of transmitted
messages, by the device, that are transmitted to indicate the need to transmit said
at least one data unit.
20

27. The apparatus of any preceding claim 22 to 26, wherein the at least
one memory and the computer program code are configured, with the at least one
processor, to cause the device further to perform operations comprising:
retransmitting the message to the network element, wherein the
25 retransmitted message comprises updated said transmission time budget
information.

28. The apparatus of any preceding claim 22 to 27, wherein the at least
one memory and the computer program code are configured, with the at least one
30 processor, to cause the device further to perform operations comprising:

acquiring, as a response to the transmitted message, a radio resource
message from the network element; and

on the basis of said radio resource message, initiating transmission of
said at least one data unit.
35

29. The apparatus of any preceding claim 22 to 28, wherein said radio

resource message indicates radio resources for transmitting the at least one data unit, the indicated radio resources being dependent at least on said transmission time budget information.

5 30. The apparatus of any preceding claim 22 to 29, wherein said message indicating the need to transmit the at least one data unit is a scheduling request message or a report message indicating data buffer status of the device.

10 31. The apparatus of claim 30, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the device further to perform operations comprising:

transmitting a plurality of report messages to the network element, wherein the plurality of report messages is associated with a plurality of communication links such that each report message of the plurality of report
15 messages is associated with a specific communication link of the plurality of communication links.

20 32. The apparatus of claim 31, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the device further to perform operations comprising:

receiving a radio resource message from the network element, the radio resource message indicating radio resources on a specific communication link among the plurality of communication links; and

25 on the basis of said radio resource message, initiating transmission of said at least one data unit.

33. The apparatus of claim 31 or claim 32, wherein the plurality of communication links comprises a first communication link and a second communication link, and wherein the first communication link is a cellular
30 communication link and the second communication link is a Wireless Local Area Network, WLAN, link.

34. An apparatus comprising:

at least one processor, and

35 at least one memory comprising a computer program code, wherein the at least one memory and the computer program code are configured, with the at

least one processor, to cause a network element of a wireless network to perform operations comprising:

- acquiring, from a device of the wireless network, a message comprising an information element indicating a need, by the device, to transmit at least one data unit, wherein the message comprises a further information element comprising transmission time budget information associated with said at least one data unit;
- initiating decoding of said message; and
- upon successful decoding of said message, generating a radio resource message, based at least partly on the transmission time budget information, indicating radio resources for transmitting said at least one data unit and transmitting said radio resource message to the device.

35. The apparatus of claim 34, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations comprising:

- determining, based on said transmission time budget information, remaining time for attaining latency requirements of said at least one data unit, wherein the radio resource message is generated at least partly on the basis of said remaining time.

36. The apparatus of any preceding claim 34 to 35, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations comprising:

- determining, based on said transmission time budget information, a number of possible transmission attempts of said at least one data unit, by the device, to attain latency requirements of said at least one data unit, wherein the radio resource message is generated at least partly on the basis of said number of possible transmission attempts.

37. The apparatus of any preceding claim 34 to 36, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations comprising:

- determining, based on said transmission time budget information,

elapsed time between obtaining, by the device, said at least one data unit and transmitting, by the device, said message indicating the need to transmit said at least one data unit,

5 wherein the radio resource message is generated at least partly on the basis of said elapsed time.

38. The apparatus of any preceding claim 34 to 37, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations
10 comprising:

determining, based on said transmission time budget information, number of transmitted messages, by the device, that are transmitted to indicate the need to transmit said at least one data unit,

15 wherein the radio resource message is generated at least partly on the basis of said number of transmitted messages.

39. The apparatus of any preceding claim 34 to 38, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations
20 comprising:

receiving another message from the device, said another message indicating the need, by the device, to transmit said at least one data unit, wherein the said another message comprises updated said transmission time budget information.

25

40. The apparatus of any preceding claim 34 to 39, wherein said message indicating the need to transmit the at least one data unit, by the device, is a scheduling request message or a report message indicating data buffer status of the device.

30

41. The apparatus of claim 40, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the network element further to perform operations comprising:

35 receiving a plurality of report messages from the device, wherein the plurality of report messages is associated with a plurality of communication links such that each report message of the plurality of report messages is associated with

a specific communication link of the plurality of communication links.

42. The apparatus of claim 41, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause
5 the network element further to perform operations comprising:

selecting a communication link among the plurality of communication links on the basis of the transmission time budget information of the plurality of report messages; and

generating the radio resource message indicating radio resources on
10 the selected communication link and transmitting said radio resource message to the device.

43. A computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when loaded
15 into an apparatus, execute the method according to any of claims 1 to 21.

44. A computer program product comprising program instructions which, when loaded into an apparatus, execute the method according to any of claims 1 to 21.
20

45. A computer-readable medium comprising the computer program product of claim 44.

46. An apparatus, comprising means for performing the method
25 according to any of claims 1 to 21.

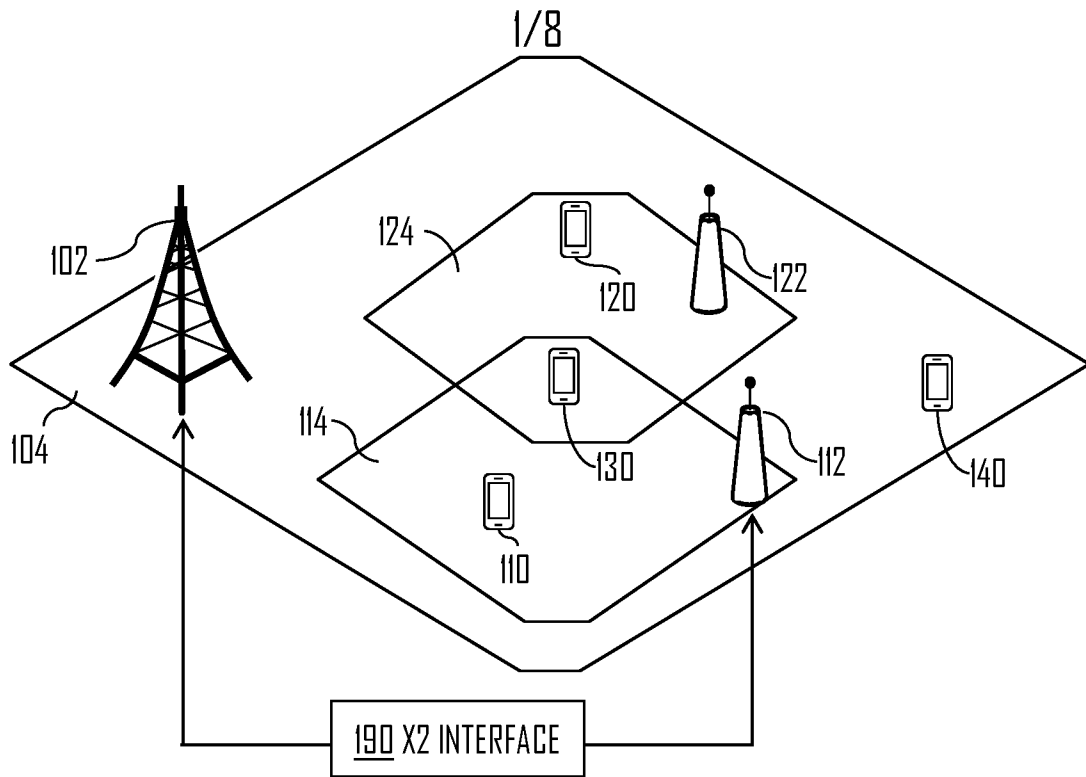


Fig. 1

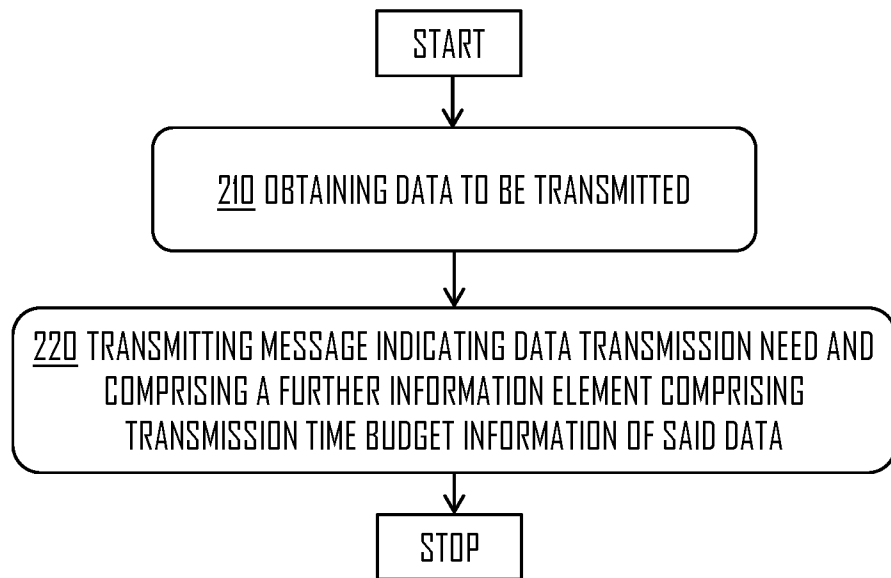


Fig. 2

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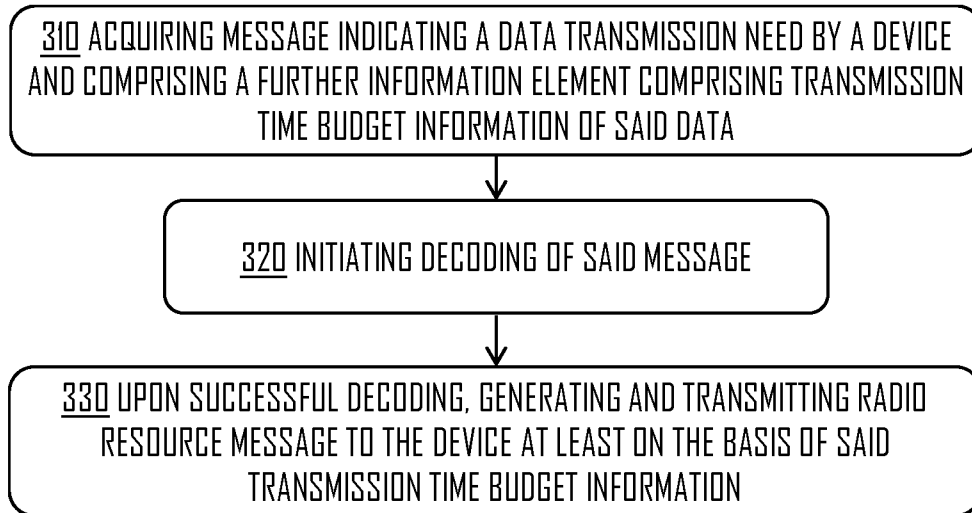


Fig. 3

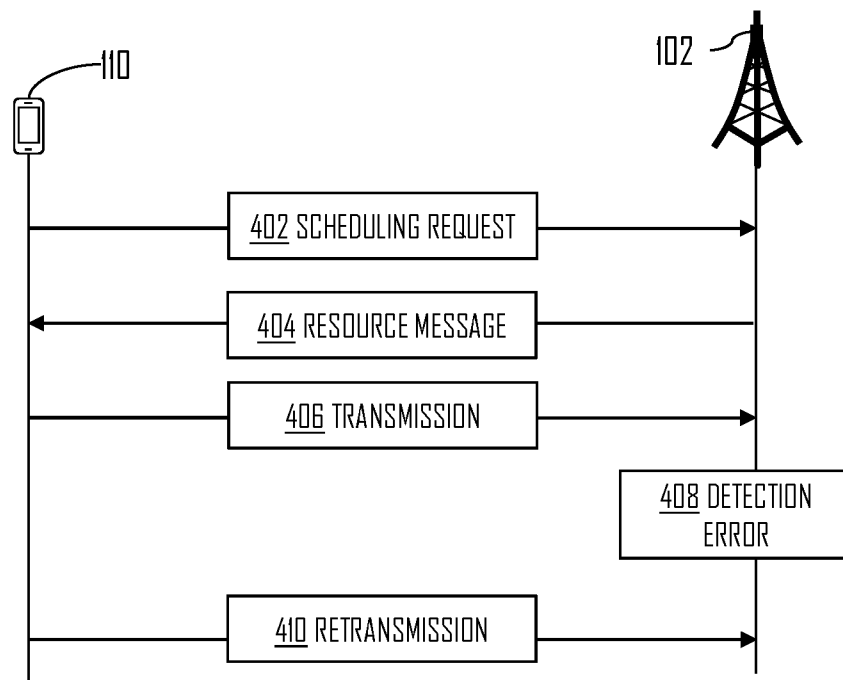


Fig. 4A

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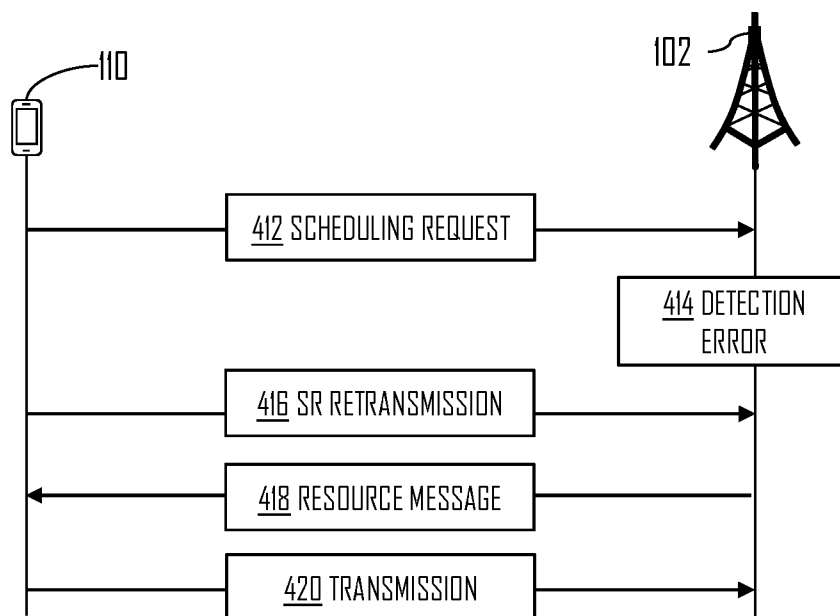


Fig. 4B

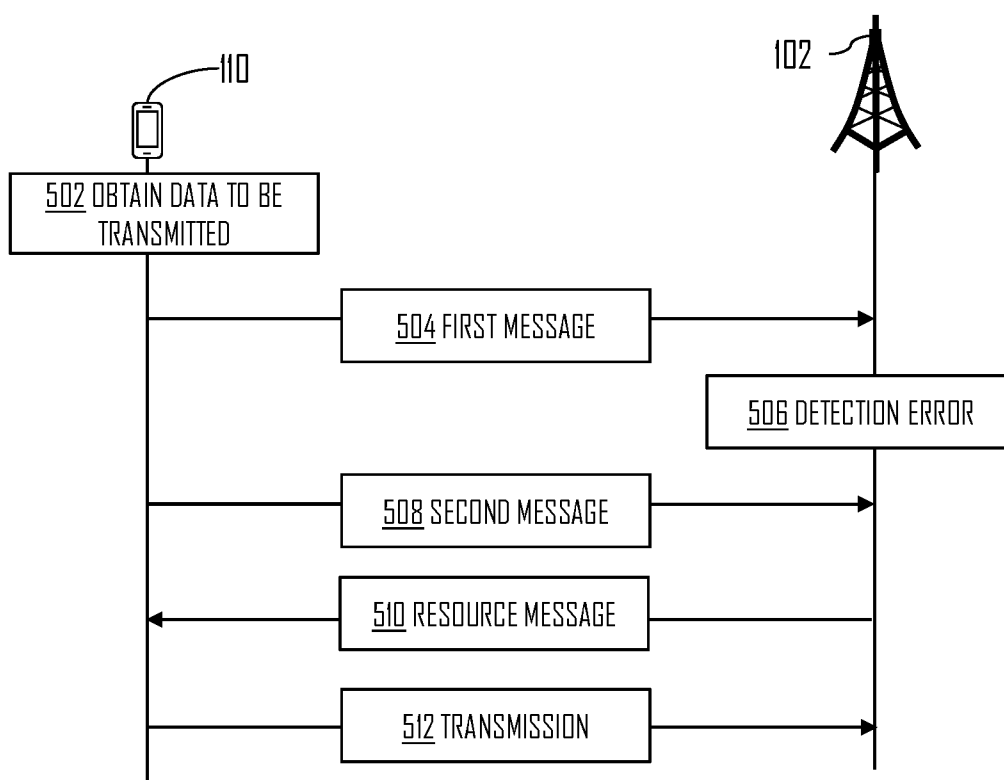


Fig. 5A

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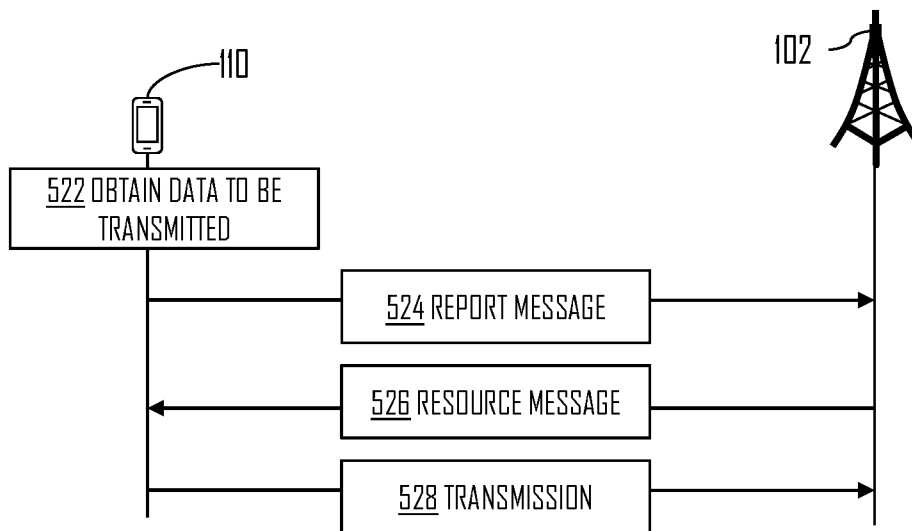


Fig. 5B

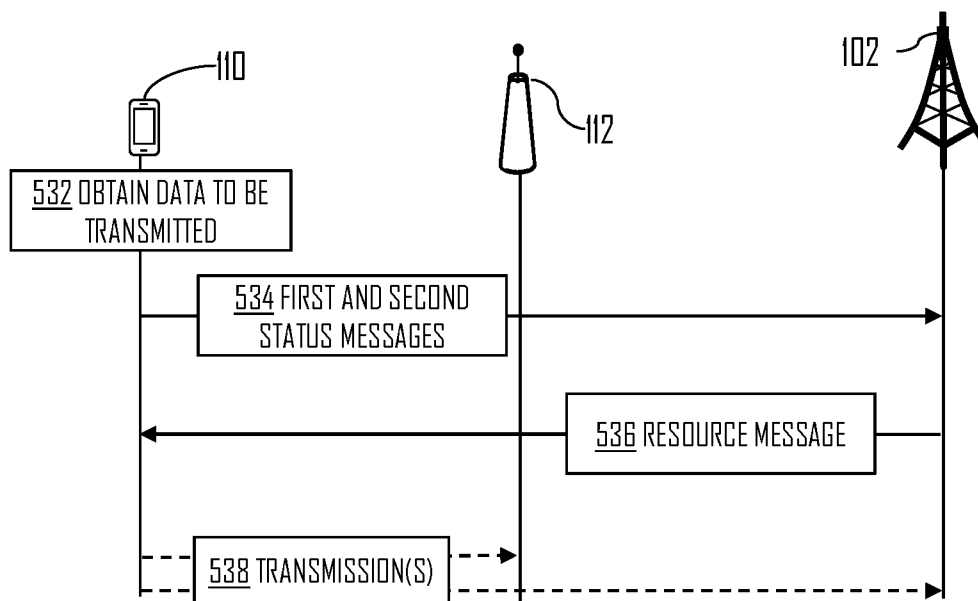


Fig. 5C

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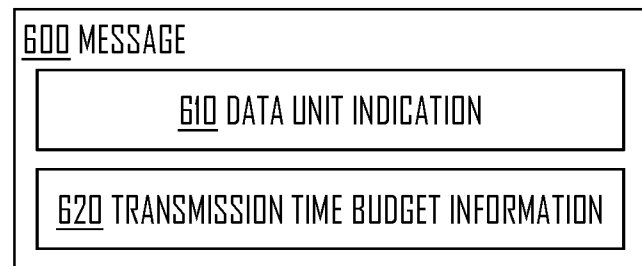


Fig. 6A

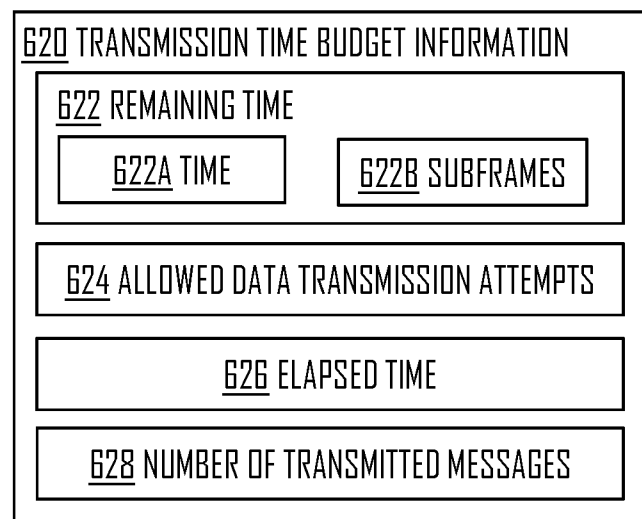


Fig. 6B

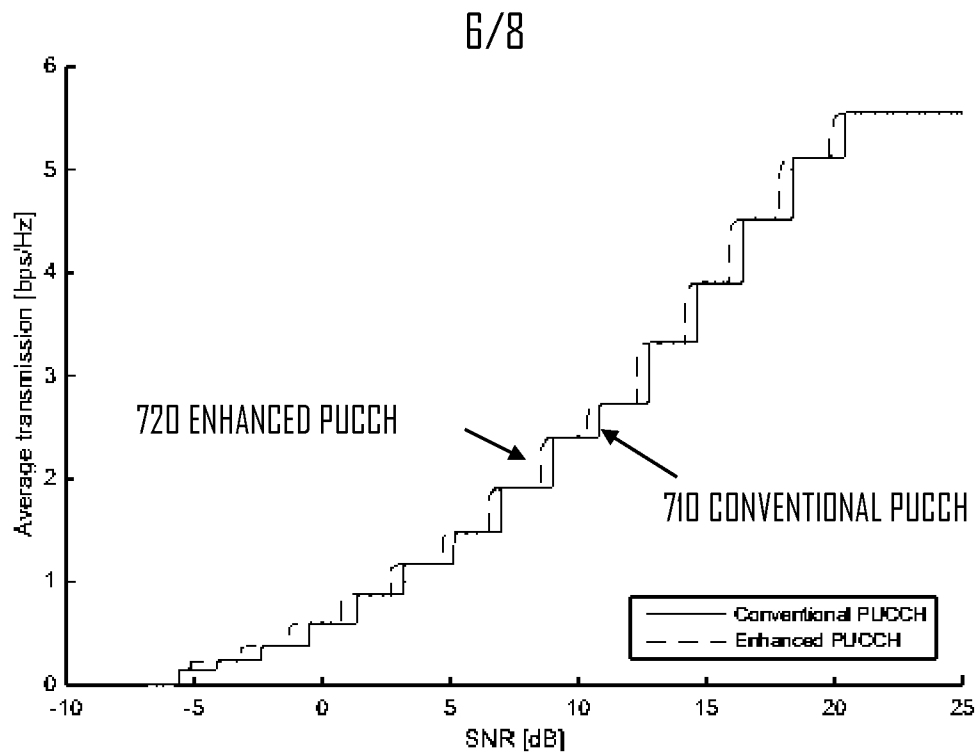


Fig. 7A

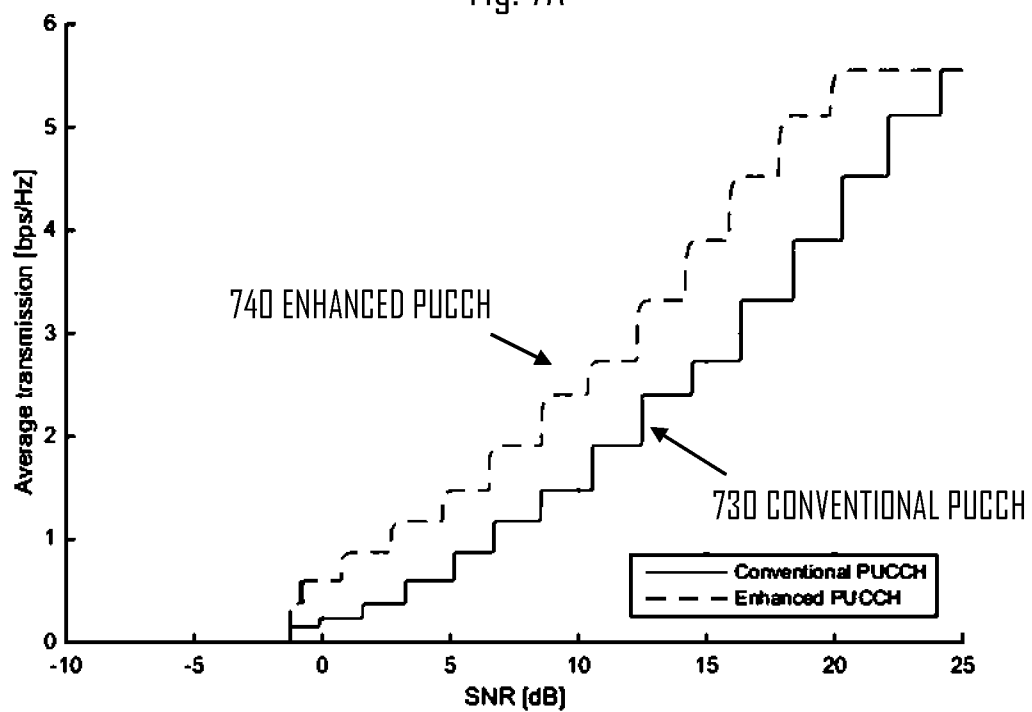


Fig. 7B

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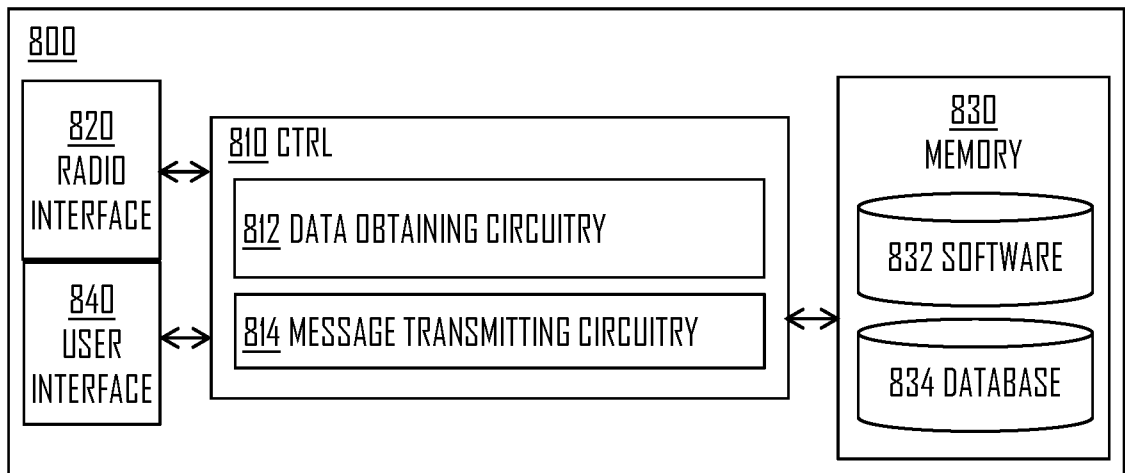


Fig. 8

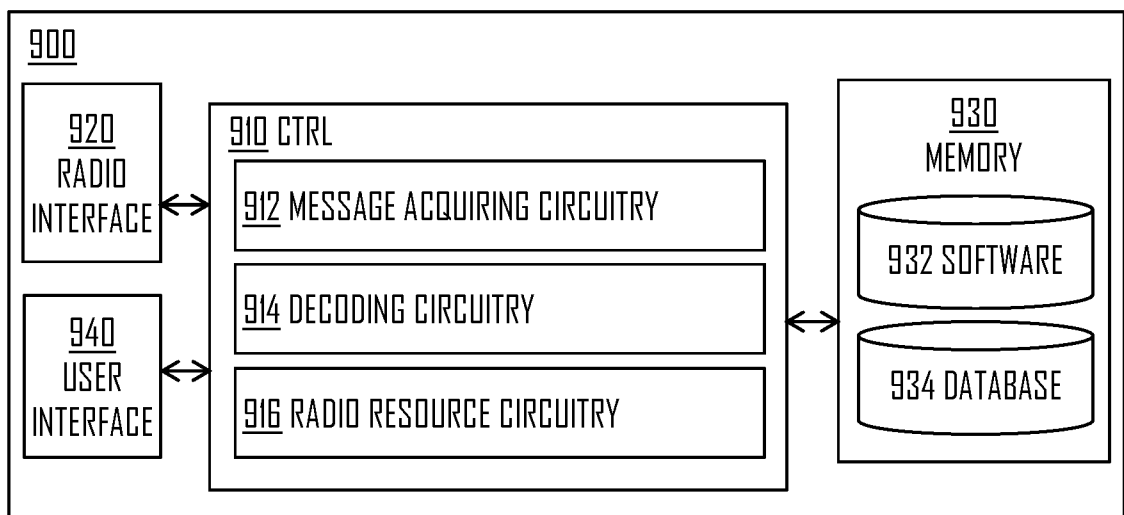


Fig. 9

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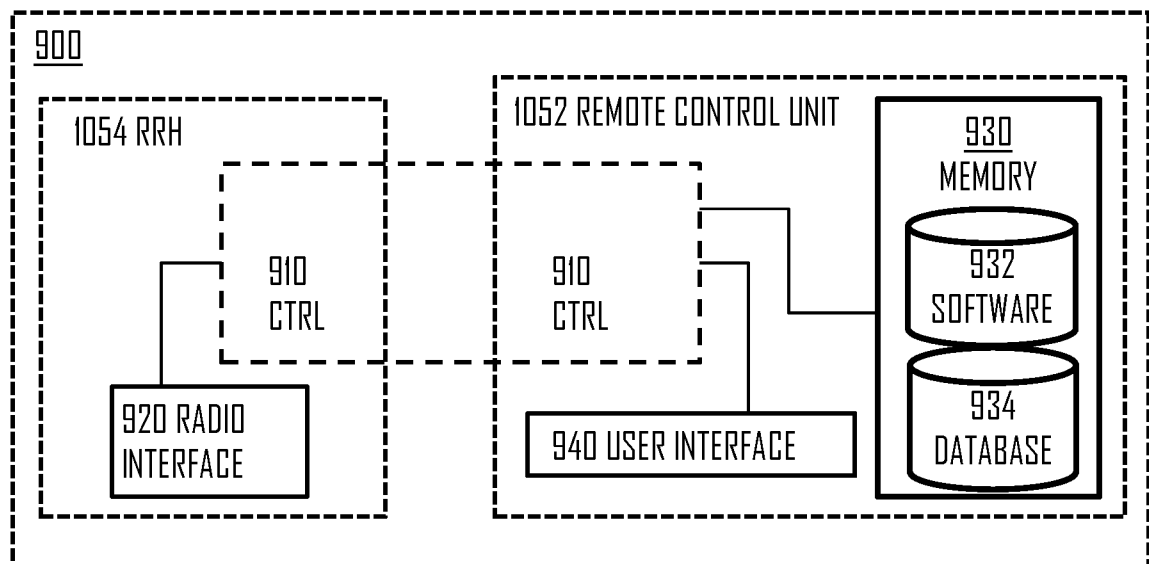


Fig. 10

International application No
PCT/EP2016/070096

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/070096

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/176984 A1 (SUSITAIVAL RIIKKA [FI] ET AL) 12 July 2012 (2012-07-12)	1-9, 11-19, 22-30, 34-40, 43-46
Y	paragraphs [0068], [0104] - [0107], [0114] - [0117]	10-12, 20,21, 31-33, 41,42
Y	----- US 2013/058220 A1 (YI SEUNGJUNE [KR] ET AL) 7 March 2013 (2013-03-07)	10-12, 20,21, 31-33, 41,42
A	paragraph [0060] -----	1-9, 13-19, 22-30, 34-40, 43-46

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/070096

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 2016014803	A1	14-01-2016	CN 106489294 A	08-03-2017
			EP 3167672 A1	17-05-2017
			KR 20170032235 A	22-03-2017
			US 2016014803 A1	14-01-2016
			WO 2016007774 A1	14-01-2016

US 2012176984	A1	12-07-2012	EP 2474146 A1	11-07-2012
			ES 2424913 T3	09-10-2013
			US 2012176984 A1	12-07-2012
			WO 2011025434 A1	03-03-2011

US 2013058220	A1	07-03-2013	EP 2584714 A2	24-04-2013
			KR 20130096630 A	30-08-2013
			US 2013058220 A1	07-03-2013
			WO 2011159102 A2	22-12-2011
