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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 September 2017 (08.09.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/148510 A1

(51) International Patent Classification:
*H04L 1/08* (2006.01) *H04L 5/00* (2006.01)
*H04L 1/18* (2006.01)

(21) International Application Number:
PCT/EP2016/054380

(22) International Filing Date:
2 March 2016 (02.03.2016)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: NOKIA SOLUTIONS AND NETWORKS OY [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(72) Inventors: **KHOSRAVIRAD, Saeed Reza**; Podwale 2/89, 50043 Wroclaw (PL). **VENKATASUBRAMANIAN, Venkatkumar**; Strzegomska 202/713, 54-432 Wroclaw (PL). **FREDERIKSEN, Frank**; Hornbækvej 4, 9270 Klarup (DK).

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

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

**Published**:

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

(54) **Title**: USE OF TINY RETRANSMISSION RESOURCE FOR PARTIAL PACKET RETRANSMISSION FOR WIRELESS NETWORKS

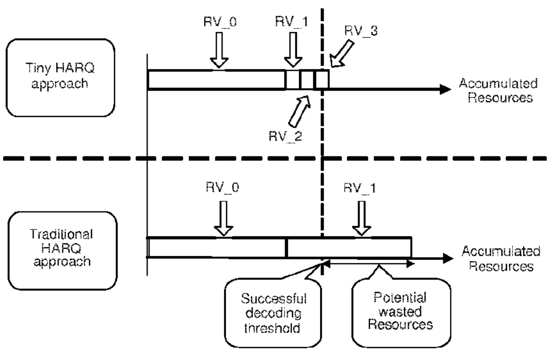


**FIG. 3**

(57) **Abstract**: A technique includes transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; making a decision to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

WO 2017/148510 A1

# DESCRIPTION

## TITLE

Use of Tiny Retransmission Resource for Partial Packet Retransmission For Wireless Networks

## TECHNICAL FIELD

**[0001]** This description relates to communications, and in particular, to a use of a tiny retransmission resource for partial packet retransmission for wireless networks.

## BACKGROUND

**[0002]** A communication system may be a facility that enables communication between two or more nodes or devices, such as fixed or mobile communication devices. Signals can be carried on wired or wireless carriers.

**[0003]** An example of a cellular communication system is an architecture that is being standardized by the 3rd Generation Partnership Project (3GPP). A recent development in this field is often referred to as the long-term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. E-UTRA (evolved UMTS Terrestrial Radio Access) is the air interface of 3GPP's Long Term Evolution (LTE) upgrade path for mobile networks. In LTE, base stations or access points (APs), which are referred to as enhanced Node AP (eNBs), provide wireless access within a coverage area or cell. In LTE, mobile devices, or mobile stations are referred to as user equipments (UE). LTE has included a number of improvements or developments.

**[0004]** Many modern communication systems, including LTE, employ a combination of forward error correction coding and ARQ (automatic repeat request), known as hybrid ARQ (HARQ). HARQ uses forward error correction (FEC) codes to correct a subset of errors and relies on error detection to detect uncorrectable errors. Erroneously received packets are discarded and the receiver requests a retransmission of the corrupted packet(s) by sending a negative acknowledgement (NAK) to the transmitter. This is a combination of FEC and ARQ. A version of the original packet is then retransmitted, and the receiver may combine multiple received versions of the packet.

## SUMMARY

**[0005]** According to an example implementation, a method may include transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0006]** According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: transmit, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; make a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and retransmit, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0007]** According to an example implementation, an apparatus includes means for transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; means for making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and means for retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the means for retransmitting by the transmitter includes means for continuing retransmitting until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0008]** According to an example implementation, a computer program product includes a computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0009]** According to an example implementation, a method may include receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; detecting, by the receiver, that decoding of the packet is unsuccessful; receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; detecting that decoding of the packet is successful; and transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0010]** According to an example implementation, an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; detect, by the receiver, that decoding of the packet is unsuccessful; receive a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; detect that decoding of the packet is successful; and transmit an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0011]** According to an example implementation, an apparatus includes means for receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; means for detecting, by the receiver, that decoding of the packet is unsuccessful; means for receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; means for detecting that decoding of the packet is successful; and means for transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0012]** According to an example implementation, a computer program product includes a computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; detecting, by the receiver, that decoding of the packet is unsuccessful; receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; detecting that decoding of the packet is successful; and transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0013]** The details of one or more examples of implementations are set forth 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 THE DRAWINGS

**[0014]** FIG. 1 is a block diagram of a wireless network according to an example implementation.

**[0015]** FIG. 2 is a diagram illustrating available bandwidth for a first transmission and for a retransmission using a tiny retransmission resource according to an example implementation.

**[0016]** FIG. 3 is a diagram illustrating resource usage after a first failed transmission for tiny HARQ approach that uses tiny retransmission resources as compared to the traditional HARQ according to an example implementation.

**[0017]** FIG. 4 is a diagram illustrating a resource allocation for HARQ redundancy versions in two consecutive subframes according to an example implementation.

**[0018]** FIG. 5 is a diagram illustrating a tiny HARQ example in which tiny retransmission resources (TR) are shown for three subframes according to an example implementation.

**[0019]** FIG. 6 is a flow chart illustrating operation of a transmitter according to an example implementation.

**[0020]** FIG. 7 is a flow chart illustrating operation of a receiver according to an example implementation.

**[0021]** FIG. 8 is a block diagram of a node or wireless station (e.g., base station/access point or mobile station/user device/UE) according to an example implementation.

## DETAILED DESCRIPTION

**[0022]** FIG. 1 is a block diagram of a wireless network 130 according to an example implementation. In the wireless network 130 of FIG. 1, user devices 131, 132, 133 and 135, which may also be referred to as mobile stations (MSs) or user equipment (UEs), may be connected (and in communication) with a base station (BS) 134, which may also be referred to as an access point (AP), an enhanced Node B (eNB) or a network node. At least part of the functionalities of an access point (AP), base station (BS) or (e)Node B (eNB) may be also be carried out by any node, server or host which may be operably coupled to a transceiver, such as a remote radio head. BS (or AP) 134 provides wireless coverage within a cell 136, including to user devices 131, 132, 133 and 135. Although only four user devices are shown as being connected or attached to BS 134, any number of user devices may be provided. BS 134 is also connected to a core network 150 via a S1 interface 151. This is merely one simple example of a wireless network, and others may be used.

**[0023]** A user device (user terminal, user equipment (UE)) may refer to a portable computing device that includes wireless mobile communication devices operating with or without a subscriber identification module (SIM), including, but not limited to, the following types of devices: a mobile station (MS), a mobile phone, a cell phone, a smartphone, a personal digital assistant (PDA), a handset, a device using a wireless modem (alarm or measurement device, etc.), a laptop and/or touch screen computer, a tablet, a phablet, a game console, a notebook, and a multimedia device, as examples. It should be appreciated that a user device may also be a nearly exclusive uplink only device, of which an example is a camera or video camera loading images or video clips to a network.

**[0024]** In LTE (as an example), core network 150 may be referred to as Evolved Packet Core (EPC), which may include a mobility management entity (MME) which may handle or assist with mobility/handover of user devices between BSs, one or more gateways that may forward data and control signals between the BSs and packet data networks or the Internet, and other control functions or blocks.

**[0025]** The various example implementations may be applied to a wide variety of wireless technologies or wireless networks, such as LTE, LTE-A, 5G, cmWave, and/or mmWave band networks, or any other wireless network. LTE, 5G, cmWave and mmWave band networks are provided only as illustrative examples, and the various example implementations may be applied to any wireless technology/wireless network.

**[0026]** For example, in an illustrative implementation, the various techniques or implementations described herein may be applied to Internet of Things (IoT) devices/user devices, such as narrowband (NB) IoT devices. IoT may refer to an ever-growing group of objects that may have Internet or network connectivity, so that these objects may send information to and receive information from other network devices. For example, many sensor type applications or devices may monitor a physical condition or a status, and may send a report to a server or other network device, e.g., when an event occurs. In some cases, IoT devices may be delay tolerant, e.g., the data needs to be communicated, but the exact timing (or delay) of the transmission of such data may not be critical to a number of such IoT devices/applications.

**[0027]** According to an example implementation, the wireless network in FIG. 1 may employ a combination of forward error correction coding and ARQ (automatic repeat request), referred to as hybrid ARQ (HARQ). With such an approach, for example for data transmission in the downlink direction, BS 134 (as an example transmitter) may transmit a packet (or codeword, e.g., a group of coded bits) to user device 132, for example. User device 132 (as an example receiver) may use forward error correction (FEC) codes to correct errors in the received packet, where possible. User device 132 may use error detection to detect uncorrectable errors. If the received packet cannot be decoded by user device 132 due to errors, user device may send a negative acknowledgement (NAK) for the packet to the BS 134. In response to receiving the NAK, BS 134 may resend (retransmit) the packet or a redundancy version of the packet to the user device 132. User device 132 may combine multiple received versions of the packet to decode the packet, which may sometimes be referred to as soft combining. User device 132 may then send an acknowledgement (ACK) for the packet to BS 134 to acknowledge that the packet was received and decoded. A similar process may be followed for uplink data transmission, where the user device 132 may send data to the BS 134.

**[0028]** The advantages of this approach may include, for example: 1) this approach can provide quick ACK/NAK feedback to the transmitter; and 2) this approach allows for quick retransmission of additional coded versions (e.g., a complete packet) of the packet to the receiver, which may decrease the delay or amount of time until the receiver is able to decode the packet. Disadvantages of this approach may include: 1) overhead on the uplink control signal in terms of ACK/NAK bits; 2) overhead on the downlink to schedule retransmissions of the corrupted packet; and 3) a reduction in data throughput for the network based on the one or more retransmissions of the (original) packet, because the same amount of resources (e.g., time/frequency resources) are typically used for each retransmission that were used to transmit the original packet.

**[0029]** However, with soft combining (or other data combining techniques), a full HARQ retransmission of the complete packet may not be necessary for the receiver to decode the packet via soft combining. For example, in some cases, a receiver may be able to decode a packet via soft combining or other data combining technique by a retransmission of only a relatively small portion (a subset) of the packet. In other words, in some cases, the retransmission of a complete packet may not be necessary to recover from the error and be able to decode the packet. Thus, in such cases, this may result in a waste of spectral resources, e.g., by retransmitting the complete packet, when, at least in some cases, a retransmission of only a portion of the packet is all that is required for the receiver to decode the packet, e.g., via soft combining/data combining.

**[0030]** Therefore, according to an example implementation, a tiny HARQ retransmission resource is used to retransmit only a portion (subset) of a packet for (or during) each of one or more subsequent time intervals. Thus, rather than retransmitting the complete packet in response to an ACK (which would at least double the amount of resources used to transmit the packet), the transmitter may advantageously use one or more tiny retransmission resources (e.g., only one or a few subcarriers offered each time slot or subframe for this purpose) to retransmit a portion (or subset) of the packet (or codeword) for one or subsequent time intervals (e.g., time slots or subframes). According to an example implementation, the retransmission of a portion(s) of the packet via the tiny retransmission resource(s) may be performed, for example, either automatically by the transmitter (e.g., without waiting for a NAK for the transmitted packet), or in response to the transmitter (e.g., BS 134) receiving a NAK from the receiver (e.g., user device 132). Also, for example, the retransmission of a portion(s) of the packet via a tiny retransmission resource(s) for one or more subsequent time intervals (e.g., time slots or subframes) may continue by the transmitter until a predetermined number (e.g., k) of portions of the subframe have been retransmitted or until the transmitter receives an ACK for the packet from the receiver (e.g., indicating that the receiver has received/decoded the packet, and thus, retransmitting the portions is no longer necessary).

**[0031]** The use of a tiny retransmission resource (e.g., one subcarrier or a few subcarriers in a subframe) to retransmit only a (e.g., small) portion (subset) of the packet over one or more time intervals (e.g., one or more time slots or subframes) may cause the HARQ retransmission to be stretched or extended over a number of time intervals (e.g., subframes), e.g., until an ACK is received for the packet or a predetermined number (e.g., k) of retransmissions have been performed. As a result, by extending the retransmission of the packet over one or more time slots or subframes, this may increase the delay (or the amount of time) until the user device 132 can decode the packet. Thus, for example, the use of a tiny retransmission resource to retransmit a portion(s) of a packet may, for example, be advantageously used to communicate data to user devices/applications that are delay tolerant, such as machine type communications (MTC) devices, and/or Internet of Things (IoT) devices, for example. The use of the tiny retransmission resource may be applied to a wide variety of devices or applications, and the MTC and IoT devices are merely some illustrative examples.

**[0032]** According to an example implementation, a technique may include transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network. The technique may also include making a decision to retransmit portions of the packet to the receiver over one or more subsequent time intervals, and retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources. According to an example implementation, the retransmitting by the transmitter may continue until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt (e.g., successful decoding) of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0033]** Thus, according to an example implementation, a new way of assigning physical layer resources (e.g., frequency resources) for HARQ operation such that the HARQ retransmission is “stretched” in time (or extended over multiple time intervals/subframes) and allows for more granularity of the energy/resource filling for the scheduled retransmissions. This technique may include one or more of the following:

**[0034]**

1) Retransmission of a failed packet is addressed by assigning smaller amounts of physical (time/frequency) resources as compared to the first transmission of a packet (codeword). This set of smaller physical resources dedicated to a HARQ process may be referred to as a tiny retransmission resource(s), or as tiny HARQ resource(s). .

2) The tiny retransmission resources could be scheduled through sub-carrier level scheduling in the downlink, and might be persistent in time for a certain amount of time (e.g., persistently scheduled over X subframes), thereby providing a set of physical resources corresponding to the original resources used for the initial transmission of the packet or codeword.

3) Tiny retransmission resources can be multiplexed with the physical resources assigned to new data packets of the same user over a narrow bandwidth (e.g., within a PRB (physical resource block) of 180 KHz)

4) Tiny retransmission resources can also be multiplexed with new resources of another user over the same narrow bandwidth (e.g., within a PRB of 180 KHz)

**[0035]** In general, a ACK/NAK feedback mode may be set to either multiplexed feedback in which an ACK/NAK sent is for only one packet, or a bundled/combined feedback in which one ACK/NAK is for a group of packets.

**[0036]** The tiny HARQ process can be supported using the following feedback approaches, for example:

1) Multiplexed (muxed) feedback (e.g., ACK or NAK) associated to physical resources assigned for new data and the tiny retransmission resources. A muxed feedback is where a feedback (ACK/NAK) per individual packet is transmitted (multiplexed over the resources).

2) Bundled feedback for (combined transmission that includes both) new data and tiny retransmission resources (especially for dynamic TDD (time division duplexing)). A bundled feedback may include, for example, when the individual feedbacks are XORed together, meaning it will be ACK only if all the individual feedbacks are ACK, otherwise it is NAK. According to an example implementation, feedback regarding the tiny retransmission resource and the feedback regarding the new data bandwidth (both transmitted over the same DL TTI (downlink transmission time interval) can be multiplexed over the UL (uplink) feedback channel. Also, according to an example implementation, ACK/NAK feedback for a tiny retransmission is not configured, but such feedback for the tiny retransmission is used only when resources are available in the uplink (UL), e.g., in order to reduce signalling overhead.

3) Combination of the above two (Multiplexed feedback for new data with bundled feedback for tiny retransmission resources or vice versa).

4) No or reduced feedback options for the tiny retransmission resources (after a few

subframes upper layer ARQ may triggered).

**[0037]** The resources (e.g., specific time/frequency resources or subcarriers) of tiny retransmission resources can be set or fixed (i.e., dedicated), dynamically scheduled in a sub-carrier level, or can be semi-statically allocated for longer time interval.

**[0038]** According to an example implementation, in order to reduce the control overhead of ACK/NACK over UL (uplink) from possibly a large number of users/user devices that may be communicating with a BS, an alternative transmission scheme is provided that may use, for example, a minimum two times ACK/NACK feedback for each HARQ process. This is different from conventional HARQ transmission where ACK/NACK feedback is intended for every transmission attempt in a single process, while this approach will provide an ACK/NAK signal after the first transmission, and then one or more ACK/NAK signals during the retransmission process. The proposed idea considers a “tiny” portion of the available bandwidth to be allocated for retransmission of failed packets (e.g., failed blocks or codewords). This is shown in FIG. 2, as a $\alpha$ portion of the bandwidth (BW) is allocated as the tiny retransmission resources for HARQ retransmissions.

**[0039]** According to an example implementation, the new HARQ scheme may include two successive modes operation as defined in the following. FIG. 2 is a diagram illustrating available bandwidth for a first transmission (mode_1) and for a retransmission using a tiny retransmission resource (mode_2) according to an example implementation. The amount of bandwidth (1- $\alpha$) is provided for mode_1, which involves an initial transmission of a (full/complete) packet or codeword. Also, as shown in FIG. 2, the amount of bandwidth ($\alpha$) is provided for mode_2. Thus, according to an example implementation, as shown in FIG. 2, a smaller bandwidth (e.g., a smaller number of subcarriers) is provided for mode_2 (which includes the transmitter retransmitting a portion of the packet via tiny retransmission resource(s) via one or more subsequent time intervals), as compared to mode_1 (which involves the transmitter initially transmitting a packet to the receiver).

**[0040]** An example description of mode_1 and mode_2 may include the following:

**[0041]** 1) Mode_1 (Conventional Decodable HARQ): This is the HARQ process mode for the first transmission attempt (RV_0), where RV_0 refers to the packet or data (e.g., redundancy version) transmitted at time 0. From a coded block B for user 1 (U1) a self-decodable RV_0 (or packet) is generated. The amount of physical resources for transmission of RV_0 can be chosen relatively larger compared to regular HARQ based on optimization for reliability and latency sensitivity. The generated RV_0 is then transmitted on the allocated bandwidth for mode_1 as shown in FIG. 2. The transmitter may then wait for the ACK/NAK feedback (waiting to receive a NAK for the RV_/packet) before entering into mode_2. Alternatively, the receiver may automatically enter mode_2 (e.g., enter mode_2 in the absence of receiving an ACK for such packet/RV_0) to begin retransmitting a portion(s) of the packet via tiny retransmission resource(s) even without receiving a NAK for the packet transmission.

**[0042]** 2) Mode_2 (tiny HARQ/use of tiny retransmission resources): According to an example implementation, if the feedback corresponding to transmission of RV_0 (initial packet) shows a failure in decoding, then the proposed HARQ scheme enters mode_2. In mode_2, K number of RVs (redundancy versions that are portions of originally transmitted packet/RV_0) are generated and transmitted to the receiver. RV_1...RV_k refers to redundancy versions of the portion(s) of the packet that may be transmitted in mode_2, where each RV (other than RV_0) is a portion or subset of the RV_0 (packet), and each subsequent RV (packet portions, RV_1...RV_k) may have a much smaller size as compared to RV_0 (initial packet transmitted in mode_1). The HARQ process of the transmitter may, for example, transmit (which is a retransmission) one RV (portion of the original packet/RV_0) per time frame and continues the retransmission for up to K consecutive transmission time intervals/TTIs (i.e., until RV_1,..., RV_K are transmitted), or until an ACK is received by the transmitter from the receiver for the packet. According to an example implementation, only one ACK/NAK feedback is necessary to be sent in mode_2, which may occur after transmission of RV_K (e.g., ACK/NACK feedback transmission for the rest of RVs will only happen if there is available tiny retransmission resources in the UL). In an example implementation, there could be an option for the user device to indicate ACK on a specific reserved channel to indicate that the packet has been successfully decoded and the retransmission attempts can be terminated, thereby reducing the resource utilization of the tiny retransmission resources, which would open such tiny retransmission resources to be use for retransmission for other packets.

**[0043]** According to an example implementation, transmissions in mode_2 may, for example, be allocated only in the tiny HARQ retransmission bandwidth (α). The sizes of RV_1,...,RV_K may, for example, be much smaller than RV_0. RV_1,...,RV_K (portions of the packet that are retransmitted) can be chosen equal-sized (or all the same size) or can be chosen as different sizes, e.g., according to a priori optimized table of variable RV sizes.

**[0044]** According to an example implementation, the $\alpha$ value (indicating the amount of bandwidth or number of subcarriers allocated for mode_2 or for tiny retransmission resources) is fixed during one subframe but can dynamically change based from one subframe to another by scheduler, e.g., based on changing block error rate (BLER), or other criteria. According to an example implementation, amount of bandwidth α (e.g., number of subcarriers) allocated to mode_2 (for tiny retransmission resources) may be based on a block error rate (BLER) (e.g., either a BLER calculated at the transmitter based on the received ACK/NAK feedbacks or a BLER experienced by the receiver and reported to the transmitter) for the first transmission which indicates whether more or less resources for retransmission are needed. The HARQ process for a packet of data may include transmitting a limited number of redundancy versions (RV) until the user end (receiver) is capable of successfully decoding the message/packet. Each transmission attempt has a corresponding ACK/NACK feedback and the HARQ process may continue until ACK is fed back to the transmitter, or until the maximum or threshold (e.g., k) number of retransmissions have occurred.

**[0045]** FIG. 3 is a diagram illustrating resource usage after a first failed transmission for tiny HARQ approach that uses tiny retransmission resources as compared to the traditional HARQ according to an example implementation. As shown in FIG. 3, in the traditional HARQ approach, the initial transmission (RV_0) is transmitted, but is not decoded, and a NAK is received by the transmitter. Thus, in the traditional HARQ approach, a redundancy version of the packet (complete packet) is retransmitted as RV_1. However, as shown in FIG. 3, the entire retransmitted packet (RV_1) was not necessary to enable the receiver to decode the packet. Rather, as indicated by the successful decoding threshold, the receiver could have decoded the packet with only a retransmission of a portion of the retransmission. The portion of the retransmission that is beyond the threshold may be considered as potential wasted resources (e.g., as potentially unnecessary).

**[0046]** As shown in FIG. 3, in contrast, for the tiny HARQ approach, either with or without receiving the NAK (depending on the implementation), the transmitter transmits only a portion (or subset) of the initial transmission via one or more of the tiny retransmission resources. Thus, in the example shown in FIG. 3, the retransmissions RV_1, RV_2 and RV_3 are transmitted from the transmitter to the receiver, and then receiver then responds with an ACK, e.g., which may cause the transmitter to stop/cease retransmitting the portions of the initial packet via the tiny retransmission resources. Thus, by retransmitting the portions of the packet (e.g., RV_1, RV_2 and RV_3) via tiny retransmission resources over a period of time, fewer resources (only about the threshold amount of resources) are required to allow the receiver to decode the packet. For example, an ACK from the receiver may be sent and cause the transmitter to cease or discontinue retransmitting the portion of the packet or RVs via the tiny retransmission resources. Thus, while potentially increasing the delay from the receiver's perspective, the use of the tiny retransmission resources to provide an extended or stretched HARQ retransmission may provide a more efficient use of spectral resources.

**[0047]** It is shown that the most efficient way (in terms of overall throughput where latency sensitivity is low) to perform the HARQ process is to follow up the first transmission, in case of NAK (negative acknowledgement), with relatively very small amounts of redundancy (as HARQ retransmission, see FIG. 3), e.g., via the tiny retransmission resources. Also, considering the limited resources for UL feedback for mMTC (massive machine type communications) users, it is possible to support HARQ process for this type of users only by limiting the number of feedback (ACK/NAK) reporting.

**[0048]** **Example 1:** As an example, for the case of equal-sized RV_1, …, RV_K, the relation between sizes of different RVs can be easily investigated/determined as follows for an example design, e.g., the portion of bandwidth allocated for mode_1 and mode_2 (or α, the amount of bandwidth allocated for tiny retransmission resources) may be determined based on block error rate (such as BLER of initial packet transmission).

Assuming a 10% expected BLER for the bandwidth available, and a total 10 HARQ retransmission attempts, for equal-sized mode_2 RV, we have the following relation:

$$\frac{\alpha}{1-\alpha} = \frac{BLER * \max\_HARQ\_retrans * RV\_mode\_2\_Size}{RV\_0\_Size} = \frac{0.1 * 10 * RV\_mode\_2\_Size}{RV\_0\_Size} \quad (1)$$

**[0049]** FIG. 4 is a diagram illustrating a resource allocation for HARQ redundancy versions in two consecutive subframes. As shown in FIG. 4, the two subframes shown are subframe #1 and subframe #2. In this example, out of 12 subcarriers of the subframe, 2 subcarriers (α=2/12) are assumed to be allocated as the tiny retransmission resources for the retransmissions in mode_2. The remaining 10 subcarriers in each time slot (TS) will be allocated to one or multiple number of packets (or codewords) based on the data size (e.g., packet/codeword can have the mode_1 resources for half of a time slot, or one time slot or two time slots depending on the transport block size). In other words, a packet/codeword is mapped to a set of OFDM symbols in a TTI (transmission time interval) within a subframe. TTI sizes can be a variable. Moreover, each subframe has 4 tiny resources (TR) (tiny retransmission resources) that will be used in mode_2 of HARQ operation, e.g., with each tiny retransmission resource including 2 subcarriers in this illustrative example.

**[0050]** **Feedback Types:** The feedback message (FB) of a HARQ process can be designed in different types based on the available resources for control data in the uplink and the data bandwidth in the downlink. The different types of feedback design may be, for example, as follows.

**[0051]** **Feedback for mode_1:**

**[0052]** Feedback messages happen after the subframe. The feedback (ACK/NACK) in mode_1 is needed to decide whether or not it is needed to proceed to mode_2. This feedback is per UE in the UL.

**[0053]** In case a UE has multiple CWs scheduled in the DL across a single subframe, then two different (example) approaches may be used for feedback in mode_1 for this user device. Decision between these two approaches may be determined based on the available resources in the UL for feedback.

1) Bundled single-bit ACK/NACK (bundled feedback, where 1 bit may indicate ACK or NAK for a group of packets): If the UL resources for control data is limited, a single-bit ACK/NACK feedback can be exploited. This feedback will be ACK only if all the packets/codewords for the corresponding have been successfully decoded. Else, the feedback will be NACK and the respective set of packets/codewords that were transmitted across one subframe, will be pushed forward to mode_2 of

operation (requiring retransmission of a portion of the packet via tiny retransmission resource(s) for one or more time intervals).

2) High resolution multi-bit feedback (multiplexed feedback, with 1 bit to ACK or NAK each packet): A high resolution feedback might be available when resources on the UL are not tight or restricted (e.g., not congested cell). In this case, every packet in the DL will be ACK/NACKed separately in the UL.

**[0054] Feedback for mode_2:**

**[0055]** While in mode_2, one example approach is to not transmit feedback unless there is resources for it available on the UL. Based on this, three different cases that are possible, by way of example.

**[0056]** 1) Minimum UL resources feedback (feedback(FB)_Case_1, with expiry retransmission counter): In this case, due to having no resources in the UL for feedback (ACK/NAK), HARQ process operates in mode_2 with no feedback transmission. Therefore, HARQ process ends only after RV_K is transmitted. The UE/user device decoder may receive and decode the transmitted extra redundancy on the tiny HARQ BW (tiny retransmission resources) until successful decoding happens or the maximum K retransmissions are over. A feedback is only necessary in this case after K retransmissions in mode_2, when the HARQ process is terminated. In case of failure in decoding after K retransmissions in mode_2, a higher layer retransmission protocol (like RLC ARQ (radio link control entity automatic repeat request)) will be triggered to take action.

**[0057]** 2) Medium/Occasionally available UL resources for feedback (FB_Case_2): This process is the same as in FB_case_1. However, in mode_2 operation, whenever resources are available for the UE/user device on the UL (for example, eNB/BS has available resources in the UL and can schedule the same UE for UL transmission of control signal and/or data for after 5 subframes into the mode_2 operation), the UE/user device can send a feedback message (with ACK/NAK) regarding the status of the HARQ process up to that point. If at the availability of this occasional resource in the UL, decoding has not succeeded yet, no feedback will be sent and the transmission of extra physical packets containing the redundancies in the DL over tiny HARQ BW (tiny retransmission resources) will continue (until the end of K retransmission attempts or another occasional resource in the UL for the same UE).

**[0058]** Generous feedback resources on the UL (FB_Case_3): In case that feedback (e.g., ACK/NAK) resources are available after each subframe for the UE/user device in mode_2, the HARQ process can be treated as conventional HARQ with feedback after each retransmission attempt.

**[0059]** Also, for a UE/user device with multiple packets/codewords in mode_2 (e.g., transmitting a packet portion via a tiny retransmission resource for multiple packets), feedback can also happen in bundled or multiplexed approaches that was explained earlier, depending on the available resources in the UL. The availability of tiny resources for retransmission only makes it possible to have all the three modes above available for this design.

**[0060]** **Example 2:** In FIG. 5, three consecutive TTIs (or subframes) are shown for the tiny HARQ scheme according to an example implementation. A packet/codeword may have an arbitrary size determined by the scheduler. A retransmission in mode_2 will only happen in the tiny resources (2 subcarriers out of 12 of the PRB in this example). As shown in Table 1 below, possible sizes of the first transmission for packet in mode_1, may include: [¼ subframe length (SL) x 10 subcarriers (SC)]; [½ SL x 10 SC]; or, [1 SL x 10 SC]. In an illustrative example, as shown in table 1, a retransmission size can be also selected by the scheduler to be for example a minimum of [1 subframe length (SL) x 1 subcarrier (SC)] or any multiplication of that from the example Table 1 below, such as [1 SL x 2 SC] or [2 SL x 1 SC], or [2 SL x 2SC]. These are merely some illustrative examples.

| **Size of the first transmission for packet/codeword in mode_1** | **Size of retransmission (portion/subset of packet) in mode_2 for the same packet/codeword** |
|---|---|
| ¼ SL x 10 SC | 1 SL x 1 SC |
| 1/2 SL x 10 SC | 1 SL x 2 SC or 2 SL x 1 SC |
| 1 SL x 10 SC | 2 SL x 2 SC |

Table 1

**[0061]** FIG. 5 is a diagram illustrating a tiny HARQ example in which tiny retransmission resources (TR) are shown for three subframes according to an example implementation. In the example shown in FIG. 5, codewords (packets) initially transmitted and portions (or subsets of the CWs/packets) transmitted via tiny retransmission resources (TR) are shown. There are four tiny transmission resources (TRs) provided for each subframe, with two TRs per timeslot, and two timeslots per subframe, according to this illustrative example.

**[0062]** With respect to FIG. 5, in subframe #1, two codewords or packets (CWs) are allocated to be transmitted in mode_1. A tiny portion of the resources (e.g., 2 subcarriers out of 12) in every subframe is allocated to mode_2, which is shown by TR1 to TR4. As we can see, TR1, TR2 and TR4 in subframe #1 are already allocated to mode_2 retransmissions for failed code words that were sent prior to CW_1. Also, TR3 in subframe #1 is not scheduled and is an available resource.

**[0063]** After transmission of subframe #1, the feedback message FB_1 will be sent over the UL resources. As shown in FIG. 5, CW_1 has been decoded successfully and decoding of CW_2 has failed. In subframe #2, TR1 and TR2 are still in use by the scheduler for mode_2 retransmission of previously failed CWs. TR3 and TR4 are free in subframe #2 and scheduler allocates TR3 in subframe #2 for tiny retransmission of a portion of CW_2 in mode_2. Also, CW_3, CW_4 and CW_5 (initial transmission of complete packets) will be transmitted in mode_1 in subframe #2. FB_2 shows that CW_4 is failed. As a result TR4 in subframe #3 that is available, will be allocated for mode_2 retransmissions for CW_4. As shown in FIG. 5, TR_3 in subframe #3 is still being used for mode_2 retransmissions for CW_2, which implies that the corresponding UE has not been scheduled in the UL and didn't have access to any occasional UL feedback resources (FB_case_2).

**[0064]** **Scheduling control signal overhead for tiny resource (semi-static allocation):** The tiny retransmission resources of tiny HARQ can be dedicated by a fixed value, e.g., first and last subcarrier on a symbol, or can be dynamically indicated per user using scheduling information on a subcarrier level. An allocation can also be made semi-statically as follows. For example, a user device/UE will only need to be scheduled once, and for the first transmission in mode_2. The rest of the retransmissions in mode_2 for a UE may, for example, be allocated to the same resources in the following consecutive TRs (tiny transmission resources in subsequent or consecutive subframes) until the maximum retransmission attempts (e.g., k) have occurred (or the scheduler decides to change the mode_2 allocation size for this user at some point – reduce it because of low availability of resources or increasing it because there are not that many users to be scheduled). This will reduce the control overhead in the DL. At any moment during mode_2, if a packet/codeword is successfully decoded, then user device/UE can stop listening (receiving and decoding) to the allocated resource in TR (tiny retransmission resource) to save power. Also, as mentioned above, at any occasional availability of the resources in the UL for this UE, the UE/user device can send an acknowledgment (ACK) about the decoding status.

**[0065]** **mode_2 delay timer (e.g., when no tiny retransmission resource is available):** As shown in FIG. 5, CW_6 transmitted in subframe#3 is delivered successfully according to FB_3. However, it can be seen that for the case of having failure for this codeword (CW_6), a retransmission is needed to begin for this CW_6, although it doesn't seem to be possible due to lack of resources in the tiny mode_2 section of the resources. For this scenario, firstly, based on the simple calculation presented in Example 1, if the scheduler chooses $\alpha$ portion wisely, the chances of this scenario happening is very low. Although, for the low chances of this happening, a timer may be used. The way this timer works is that whenever a CW/packet is passed from mode_1 to mode_2 due to NAK, if there is not resources available in the tiny HARQ retransmission portion of the bandwidth, the scheduler will start a timer for this codeword. The mode_2 retransmission of this CW/packet should start somewhere before the timer has expired, otherwise the CW/packet is dropped and a message is sent to the higher layer protocol entity (e.g., RLC layer) so that the higher layer protocol entity (e.g., RLC entity) can take care of ARQ retransmission of this CW/packet.

**[0066]** **Averaging effects**: According to an example implementation, the tiny retransmission resources are defined such that they seem to be occurring in the same physical resources, but in reality, the resources may follow a "hopping pattern" such that the available resources for the tiny HARQ are being represented over the full system bandwidth. For example, a TR1 in consecutive subframes may hop from SC1, SC7, SC3, SC9, SC12, according to a specific subcarrier hopping pattern, e.g., to provide some frequency diversity for the tiny retransmission resources for tiny HARQ. In this way, there the subsequent transmission of retransmissions on the tiny retransmission resources will ensure that the UE/user device will experience the average channel conditions and hence the expected performance of the tiny HARQ operation will be more predictable (according to long term averages instead of instantaneous channel conditions).

**[0067]** The example implementations may include a number of advantages, such as, for example:

- Increases the number of connected devices, e.g., a larger number of devices are kept in connected state in downlink by using subcarrier level retransmission (using smaller/tiny retransmission resources)

- Increases downlink throughput – by multiplexing tiny HARQ with new data, the useful downlink throughput can be increased

- Increased DL efficiency to support UL bundling: UL ACK/NACK bundling of a user is particularly useful when the user experiences low SINR, i.e., many codewords of the user may experience decoding error. Therefore, if bundled ACK/NACK is performed, in legacy systems full re-transmission of the codewords will take place. A full retransmission implicitly does not take into account the energy/resources that have already accumulated in the first (few) transmission(s) of the codewords. Thus a tiny HARQ, using tiny retransmission resources, provides better efficiency by using an incremental amount of resources to accumulate 'just enough' energy/resources for successful decoding of the codewords/packets. In addition, multiplexed feedback of the tiny HARQ can then further reduce the amount of time spent for tiny HARQ.

**[0068]** FIG. 6 is a flow chart illustrating operation of a transmitter according to an example implementation. Operation 610 includes transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network. Operation 620 includes making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time interval. Operation 630 includes retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources. Operation 640 includes wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0069]** According to an example implementation of the method of FIG. 6, the method may further include receiving, by the transmitter from the receiver, an acknowledgement for the packet; and ceasing, by the transmitter, the retransmitting of portions of the packet based on receiving the acknowledgement.

**[0070]** According to an example implementation of the method of FIG. 6, the method may further include configuring an acknowledgement resource from receiver to transmitter for the first packet transmission; and restraining from configuring acknowledgement resources from the receiver to the transmitter for the retransmissions. For example, according to an example implementation, ACK/NAK feedback for a tiny retransmission is not configured, but such ACK/NAK feedback for the tiny retransmission is used only when resources are available in the uplink (UL), e.g., in order to reduce signaling overhead.

**[0071]** According to an example implementation of the method of FIG. 6, the retransmitting may include ceasing, by the transmitter, the retransmitting of portions of the packet based on performing the predetermined number of retransmissions of a portion of the packet without receiving an acknowledgement for the packet.

**[0072]** According to an example implementation of the method of FIG. 6, the method may further include initiating a reception process for a higher layer acknowledgement feedback after ceasing the retransmissions based on performing the predetermined number of retransmissions without receiving an acknowledgement for the packet.

**[0073]** According to an example implementation of the method of FIG. 6, wherein the making a decision may include: determining, by the transmitter, that at least one of the following has occurred after transmitting the packet: that the transmitter has received from the receiver a negative acknowledgement (NAK) for the packet; and that the transmitter has not received from the receiver an acknowledgement that acknowledges receipt of the packet; and making a decision, by the transmitter based on the determining, to retransmit portions of the packet to the receiver over the one or more subsequent time intervals.

**[0074]** According to an example implementation of the method of FIG. 6, the making a decision may include: determining, by the transmitter, that a feedback channel from the receiver to the transmitter is congested; and making a decision, by the transmitter based on the determining, to retransmit portions of the packet to the receiver over the one or more subsequent time intervals.

**[0075]** According to an example implementation of the method of FIG. 6, the method may further include adjusting, by the transmitter, a size of one or more of the second sets of frequency resources based on one or more of the following: an error rate for transmissions from the transmitter to the receiver; the predetermined number of retransmissions before ceasing the retransmissions; and a size of the first set of resources.

**[0076]** According to an example implementation of the method of FIG. 6, the packet comprises a first packet and the second set of resources is a subset of the first set of resources, and wherein the method further includes: transmitting, by the transmitter during at least one of the one or more subsequent time intervals, a second packet via a third set of frequency resources that at least partially overlaps the first set of frequency resources.

**[0077]** According to an example implementation of the method of FIG. 6, the retransmitting may include: retransmitting, by the transmitter, a different portion of the packet during a different time interval via the second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources.

**[0078]** According to an example implementation of the method of FIG. 6, the transmitting a packet is performed on a packet that is coded using a first coding scheme; and the retransmitting a portion of the packet is performed on one or more portions that were coded using a second coding scheme that is different than the first coding scheme.

**[0079]** According to an example implementation of the method of FIG. 6, the making a decision to retransmit only portions of the packet in the retransmissions is automatic and is performed without receiving a request from the receiver to retransmit a portion of the packet.

**[0080]** According to an example implementation of the method of FIG. 6, the method may further include scheduling the second set of resources to the receiver.

**[0081]** According to an example implementation of the method of FIG. 6, the scheduled second set of resources are persistent in time for a predetermined duration.

**[0082]** According to an example implementation of the method of FIG. 6, the second set of resources vary within a plurality of subsequent time intervals.

**[0083]** According to an example implementation of the method of FIG. 6, the method may further include starting a timer with a predetermined duration upon detecting that there is currently not enough available space in the second set of resources for retransmitting portions of the packet in the second set of resources; triggering the retransmission of the portions of the packet via the second set of resources upon detecting that there is sufficient amount of available space in the second set of resources and that the timer has not yet expired; upon detecting that the timer expires without enough free space becoming available in the second set of resources, dropping the packet and informing one or more higher protocol layers that the packet was not transmitted.

**[0084]** According to an example implementation of the method of FIG. 6, the portions of the packet vary within a plurality of subsequent time intervals.

**[0085]** According to an example implementation, a computer program product may include a computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0086]** An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0087]** According to an example implementation, an apparatus may include: means (e.g., 802A/802B and/or 804, FIG. 8) for transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network; means (e.g., 802A/802B and/or 804, FIG. 8) for making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and means (e.g., 802A/802B and/or 804, FIG. 8) for retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and wherein the means for retransmitting by the transmitter includes means (e.g., 802A/802B and/or 804, FIG. 8) for continuing retransmitting until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

**[0088]** FIG. 7 is a flow chart illustrating operation of a receiver according to an example implementation. Operation 710 includes receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources. Operation 720 includes detecting, by the receiver, that decoding of the packet is unsuccessful. Operation 730 includes receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein each portion of the packet is a subset of the packet. Operation 740 includes detecting that decoding of the packet is successful. And, operation 750 includes transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0089]** According to another example implementation, a computer program product includes a computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method of: receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; detecting, by the receiver, that decoding of the packet is unsuccessful; receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; detecting that decoding of the packet is successful; and transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0090]** According to another example implementation, an apparatus may include at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; detect, by the receiver, that decoding of the packet is unsuccessful; receive a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; detect that decoding of the packet is successful; and transmit an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0091]** According to another example implementation, an apparatus may include means (e.g., 802A/802B, and/or 804, FIG. 8) for receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources; means (e.g., 802A/802B, and/or 804, FIG. 8) for detecting, by the receiver, that decoding of the packet is unsuccessful; means (e.g., 802A/802B, and/or 804, FIG. 8) for receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet; means (e.g., 802A/802B, and/or 804, FIG. 8) for detecting that decoding of the packet is successful; and means (e.g., 802A/802B, and/or 804, FIG. 8) for transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

**[0092]** FIG. 8 is a block diagram of a wireless station (e.g., AP or user device) 800 according to an example implementation. The wireless station 800 may include, for example, one or two RF (radio frequency) or wireless transceivers 802A, 802B, where each wireless transceiver includes a transmitter to transmit signals and a receiver to receive signals. The wireless station also includes a processor or control unit/entity (controller) 804 to execute instructions or software and control transmission and receptions of signals, and a memory 806 to store data and/or instructions.

**[0093]** Processor 804 may also make decisions or determinations, generate frames, packets or messages for transmission, decode received frames or messages for further processing, and other tasks or functions described herein. Processor 804, which may be a baseband processor, for example, may generate messages, packets, frames or other signals for transmission via wireless transceiver 802 (802A or 802B). Processor 804 may control transmission of signals or messages over a wireless network, and may control the reception of signals or messages, etc., via a wireless network (e.g., after being down-converted by wireless transceiver 802, for example). Processor 804 may be programmable and capable of executing software or other instructions stored in memory or on other computer media to perform the various tasks and functions described above, such as one or more of the tasks or methods described above. Processor 804 may be (or may include), for example, hardware, programmable logic, a programmable processor that executes software or firmware, and/or any combination of these. Using other terminology, processor 804 and transceiver 802 together may be considered as a wireless transmitter/receiver system, for example.

**[0094]** In addition, referring to FIG. 8, a controller (or processor) 808 may execute software and instructions, and may provide overall control for the station 800, and may provide control for other systems not shown in FIG. 8, such as controlling input/output devices (e.g., display, keypad), and/or may execute software for one or more applications that may be provided on wireless station 800, such as, for example, an email program, audio/video applications, a word processor, a Voice over IP application, or other application or software.

**[0095]** In addition, a storage medium may be provided that includes stored instructions, which when executed by a controller or processor may result in the processor 804, or other controller or processor, performing one or more of the functions or tasks described above.

**[0096]** According to another example implementation, RF or wireless transceiver(s)

802A/802B may receive signals or data and/or transmit or send signals or data. Processor 804 (and possibly transceivers 802A/802B) may control the RF or wireless transceiver 802A or 802B to receive, send, broadcast or transmit signals or data.

**[0097]** The embodiments are not, however, restricted to the system that is given as an example, but a person skilled in the art may apply the solution to other communication systems. Another example of a suitable communications system is the 5G concept. It is assumed that network architecture in 5G will be quite similar to that of the LTE-advanced. 5G is likely to use multiple input – multiple output (MIMO) 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.

**[0098]** It should be appreciated that future networks will most probably utilise network functions virtualization (NFV) which is a network architecture concept that proposes virtualizing network node functions into "building blocks" or entities that may be operationally connected or linked together to provide services. A virtualized network function (VNF) may comprise one or more virtual machines running computer program codes using standard or general type servers instead of customized hardware. Cloud computing or data storage may also be utilized. In radio communications this may mean node operations may be carried out, at least partly, in a server, host or node operationally coupled to a remote radio head. It is also possible that node operations will be distributed among a plurality of servers, nodes or hosts. It should also be understood that the distribution of labour between core network operations and base station operations may differ from that of the LTE or even be non-existent.

**[0099]** Implementations of the various techniques described herein may be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Implementations may implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device or in a propagated signal, for execution by, or to control the operation of, a data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. Implementations may also be provided on a computer readable medium or computer readable storage medium, which may be a non-transitory medium. Implementations of the various techniques may also include implementations provided via transitory signals or media, and/or programs and/or software implementations that are downloadable via the Internet or other network(s), either wired networks and/or wireless networks. In addition, implementations may be provided via machine type communications (MTC), and also via an Internet of Things (IOT).

**[00100]** 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, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers.

**[00101]** Furthermore, implementations of the various techniques described herein may use a cyber-physical system (CPS) (a system of collaborating computational elements controlling physical entities). CPS may enable the implementation and exploitation of massive amounts of interconnected ICT devices (sensors, actuators, processors microcontrollers,...) embedded in physical objects at different locations. Mobile cyber physical systems, in which the physical system in question has inherent mobility, are a subcategory of cyber-physical systems. Examples of mobile physical systems include mobile robotics and electronics transported by humans or animals. The rise in popularity of smartphones has increased interest in the area of mobile cyber-physical systems. Therefore, various implementations of techniques described herein may be provided via one or more of these technologies.

**[00102]** A computer program, such as the computer program(s) described above, can be written in any form of programming language, including compiled or interpreted languages, and can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit or part of it suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

**[00103]** Method steps may be performed by one or more programmable processors executing a computer program or computer program portions to perform functions by operating on input data and generating output. Method steps also may be performed by, and an apparatus may be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

**[00104]** Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer, chip or chipset. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. Elements of a computer may include at least one processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer also may include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory may be supplemented by, or incorporated in, special purpose logic circuitry.

**[00105]** To provide for interaction with a user, implementations may be implemented on a computer having a display device, e.g., a cathode ray tube (CRT) or liquid crystal display (LCD) monitor, for displaying information to the user and a user interface, such as a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input.

**[00106]** Implementations may be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation, or any combination of such back-end, middleware, or front-end components. Components may be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network (LAN) and a wide area network (WAN), e.g., the Internet.

**[00107]** While certain features of the described implementations have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the various embodiments.

WHAT IS CLAIMED IS:

1. A method comprising:

transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network;

making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and

retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and

wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

2. The method of claim 1 and further comprising:

receiving, by the transmitter from the receiver, an acknowledgement for the packet; and

ceasing, by the transmitter, the retransmitting of portions of the packet based on receiving the acknowledgement.

3. The method of any of claims 1-2, further comprising:

configuring an acknowledgement resource from receiver to transmitter for the first packet transmission; and

restraining from configuring acknowledgement resources from the receiver to the transmitter for the retransmissions.

4. The method of any of claims 1-3 wherein the retransmitting comprises:

ceasing, by the transmitter, the retransmitting of portions of the packet based on performing the predetermined number of retransmissions of a portion of the packet without receiving an acknowledgement for the packet.

5. The method of claim 4, further comprising:

initiating a reception process for a higher layer acknowledgement feedback after ceasing the retransmissions based on performing the predetermined number of retransmissions without receiving an acknowledgement for the packet.

6. The method of any of claims 1-5 wherein the making a decision comprises:

determining, by the transmitter, that at least one of the following has occurred after transmitting the packet:

that the transmitter has received from the receiver a negative acknowledgement (NAK) for the packet; and

that the transmitter has not received from the receiver an acknowledgement that acknowledges receipt of the packet; and

making a decision, by the transmitter based on the determining, to retransmit portions of the packet to the receiver over the one or more subsequent time intervals.

7. The method of any of claims 1 to 4 wherein the making a decision comprises:

determining, by the transmitter, that a feedback channel from the receiver to the transmitter is congested; and

making a decision, by the transmitter based on the determining, to retransmit portions of the packet to the receiver over the one or more subsequent time intervals.

8. The method of any of claims 1-7 and further comprising:

adjusting, by the transmitter, a size of one or more of the second sets of frequency resources based on one or more of the following:

an error rate for transmissions from the transmitter to the receiver;

the predetermined number of retransmissions before ceasing the retransmissions; and

size of the first set of resources.

9. The method of any of claims 1-8 wherein the packet comprises a first packet and the second set of resources is a subset of the first set of resources, and wherein the method further comprises:

transmitting, by the transmitter during at least one of the one or more subsequent time intervals, a second packet via a third set of frequency resources that at least partially overlaps the first set of frequency resources.

10. The method of any of claims 1-9 wherein the retransmitting comprises:

retransmitting, by the transmitter, a different portion of the packet during a different time interval via the second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources.

11. The method of any of claims 1-10 wherein:

the transmitting a packet is performed on a packet that is coded using a first coding scheme; and

the retransmitting a portion of the packet is performed on one or more portions that were coded using a second coding scheme that is different than the first coding scheme.

12. The method of any of claims 1-11 wherein making a decision to retransmit only portions of the packet in the retransmissions is automatic and is performed without receiving a request from the receiver to retransmit a portion of the packet.

13. The method of any of claims 1-12 and further comprising:

scheduling the second set of resources to the receiver.

14. The method of claim 13 wherein the scheduled second set of resources are persistent in time for a predetermined duration.

15. The method of any of claims 1-14 wherein the second set of resources vary within a plurality of subsequent time intervals.

16. The method of any of claims 1-15 further comprising:

starting a timer with a predetermined duration upon detecting that there is currently not enough available space in the second set of resources for retransmitting portions of the packet in the second set of resources;

triggering the retransmission of the portions of the packet via the second set of resources upon detecting that there is sufficient amount of available space in the second set of resources and that the timer has not yet expired;

upon detecting that the timer expires without enough free space becoming available in the second set of resources, dropping the packet and informing one or more higher protocol layers that the packet was not transmitted.

17. The method of any of claims 1-16 wherein the portions of the packet vary within a plurality of subsequent time intervals.

18. A computer program product, the computer program product comprising a computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method of any of claims 1- 17.

19. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to perform the method of any of claims 1- 17.

20. An apparatus comprising:

means for transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network;

means for making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals; and

means for retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources; and

wherein the means for retransmitting by the transmitter comprises means for continuing retransmitting until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter.

21. A method, comprising:

receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources;

detecting, by the receiver, that decoding of the packet is unsuccessful;

receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet;

detecting that decoding of the packet is successful; and

transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

22. A computer program product, the computer program product comprising a computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method of:

receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources;

detecting, by the receiver, that decoding of the packet is unsuccessful;

receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet;

detecting that decoding of the packet is successful; and

transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

23. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to:

receive, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources;

detect, by the receiver, that decoding of the packet is unsuccessful;

receive a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet;

detect that decoding of the packet is successful; and

transmit an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

24. An apparatus comprising:

means for receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources;

means for detecting, by the receiver, that decoding of the packet is unsuccessful;

means for receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet;

means for detecting that decoding of the packet is successful; and

means for transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission.

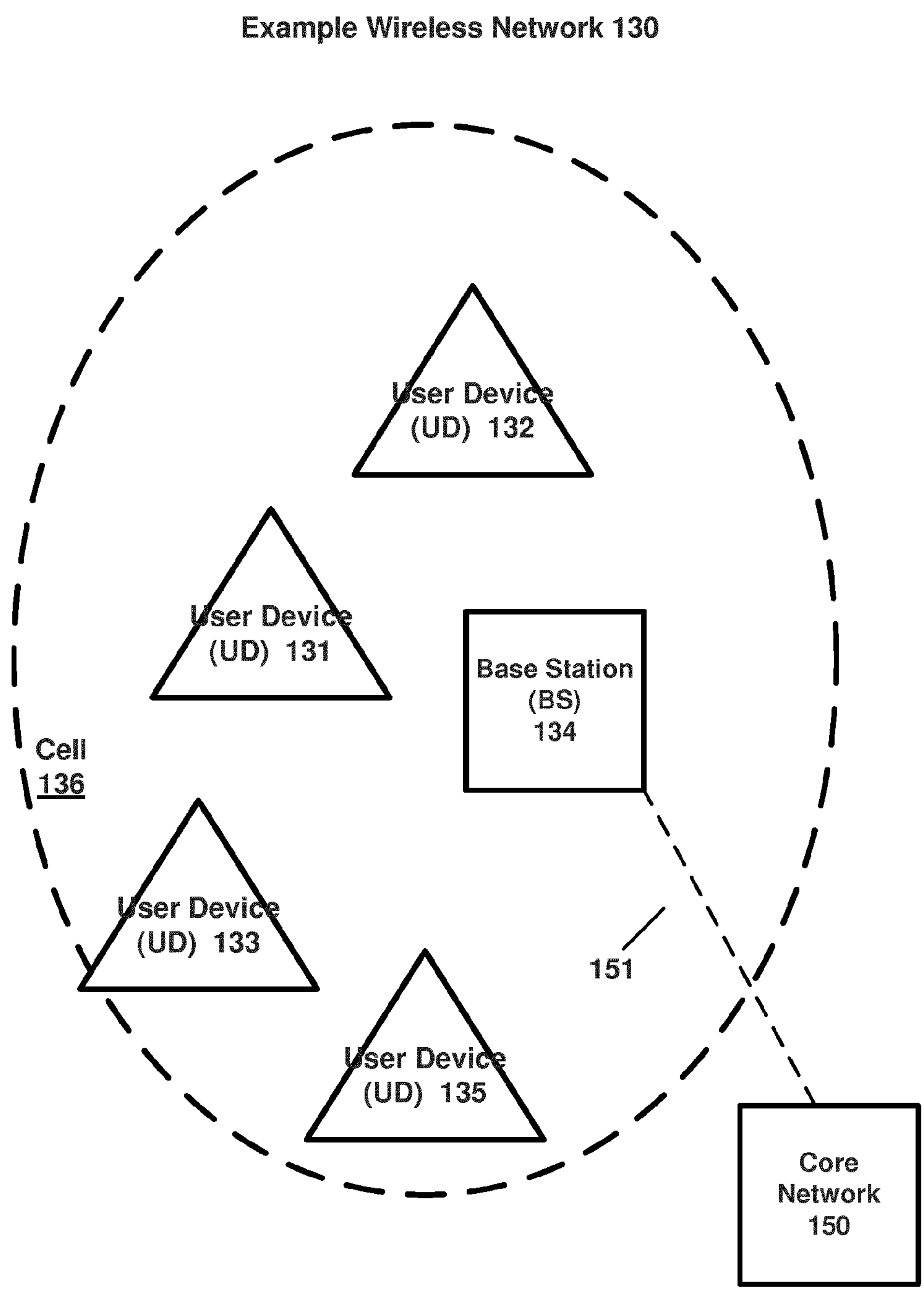
Example Wireless Network 130
User Device
(UD) 132
User Device
(UD) 131
Base Station
(BS)
134
Cell
136
User Device
(UD) 133
151
User Device
(UD) 135
Core
Network
150

FIG. 1

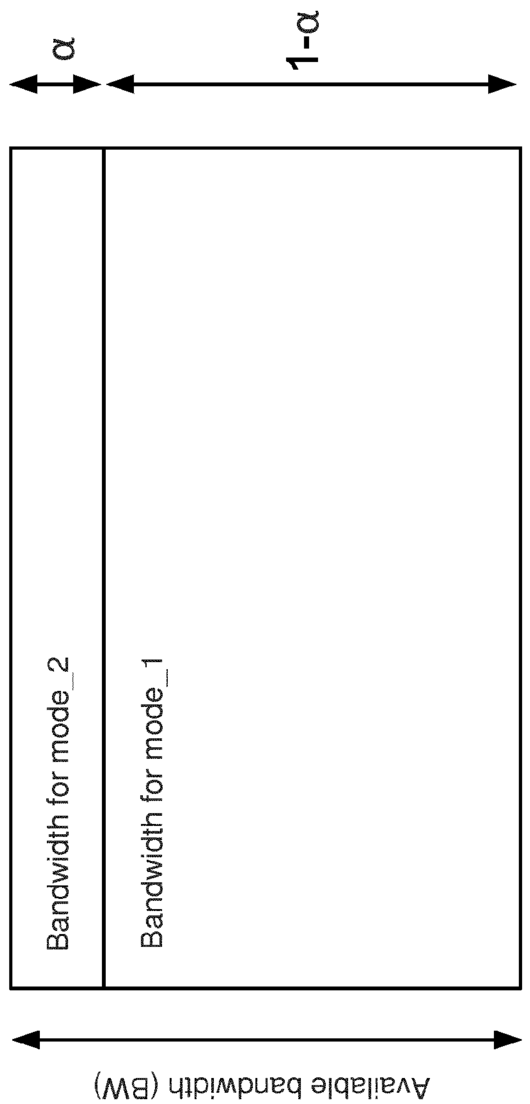
α
1-α
Bandwidth for mode_2
Bandwidth for mode_1
Available bandwidth (BW)

FIG. 2

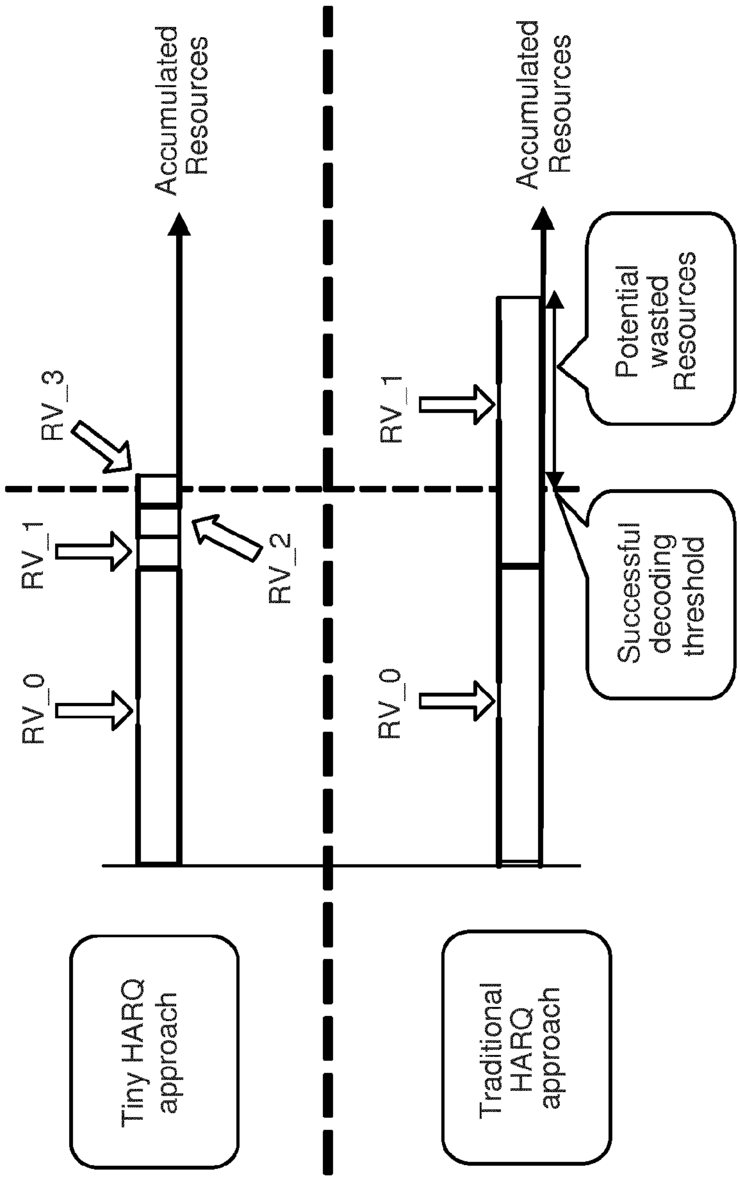
Tiny HARQ approach
RV_0
RV_1
RV_2
RV_3
Accumulated Resources
Traditional HARQ approach
RV_0
RV_1
Accumulated Resources
Successful decoding threshold
Potential wasted Resources

FIG. 3

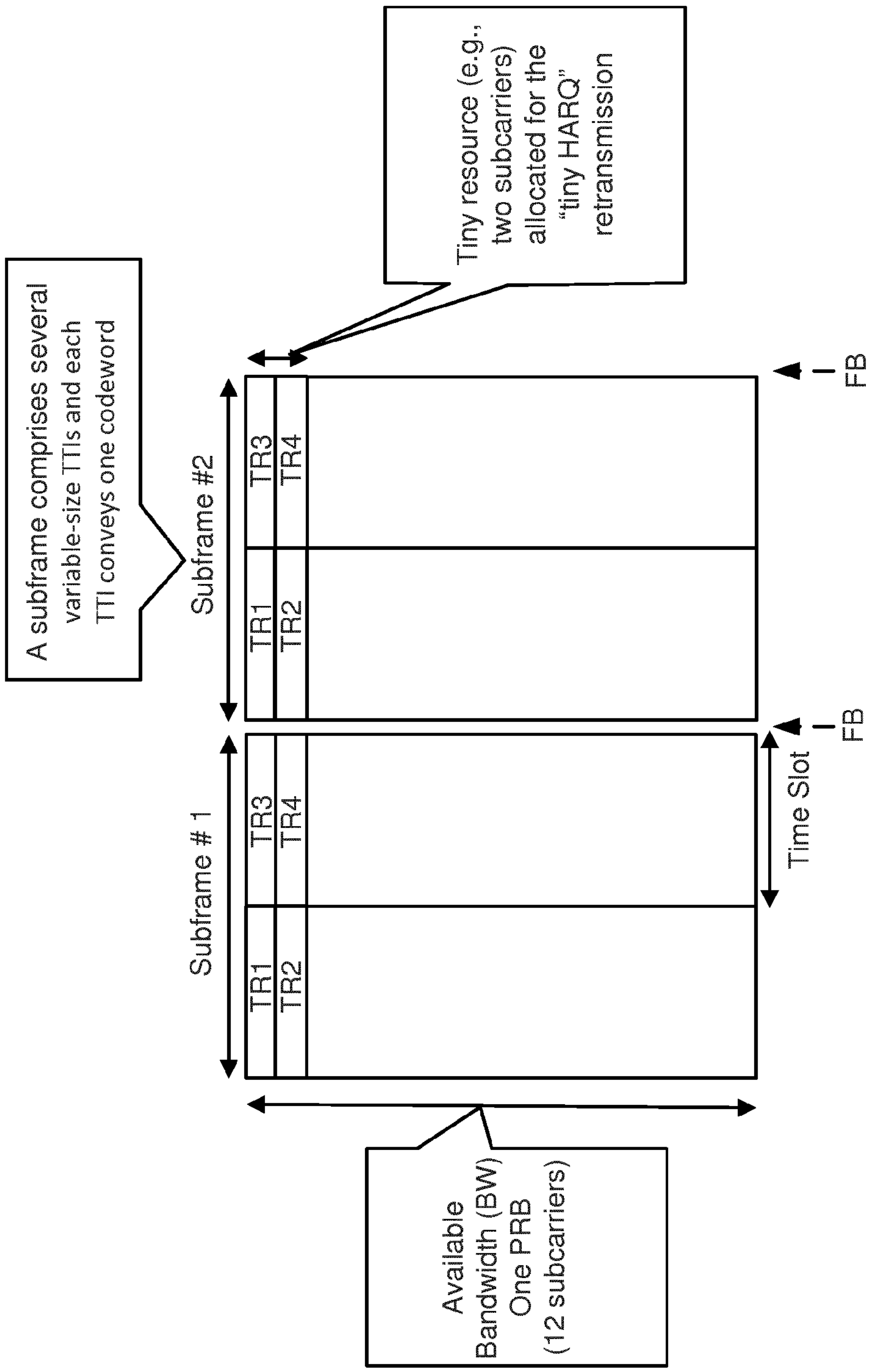
Tiny resource (e.g., two subcarriers) allocated for the "tiny HARQ" retransmission
A subframe comprises several variable-size TTIs and each TTI conveys one codeword
Subframe #2
TR1
TR2
TR3
TR4
FB
Subframe # 1
TR1
TR2
TR3
TR4
Time Slot
FB
Available Bandwidth (BW) One PRB (12 subcarriers)

FIG. 4

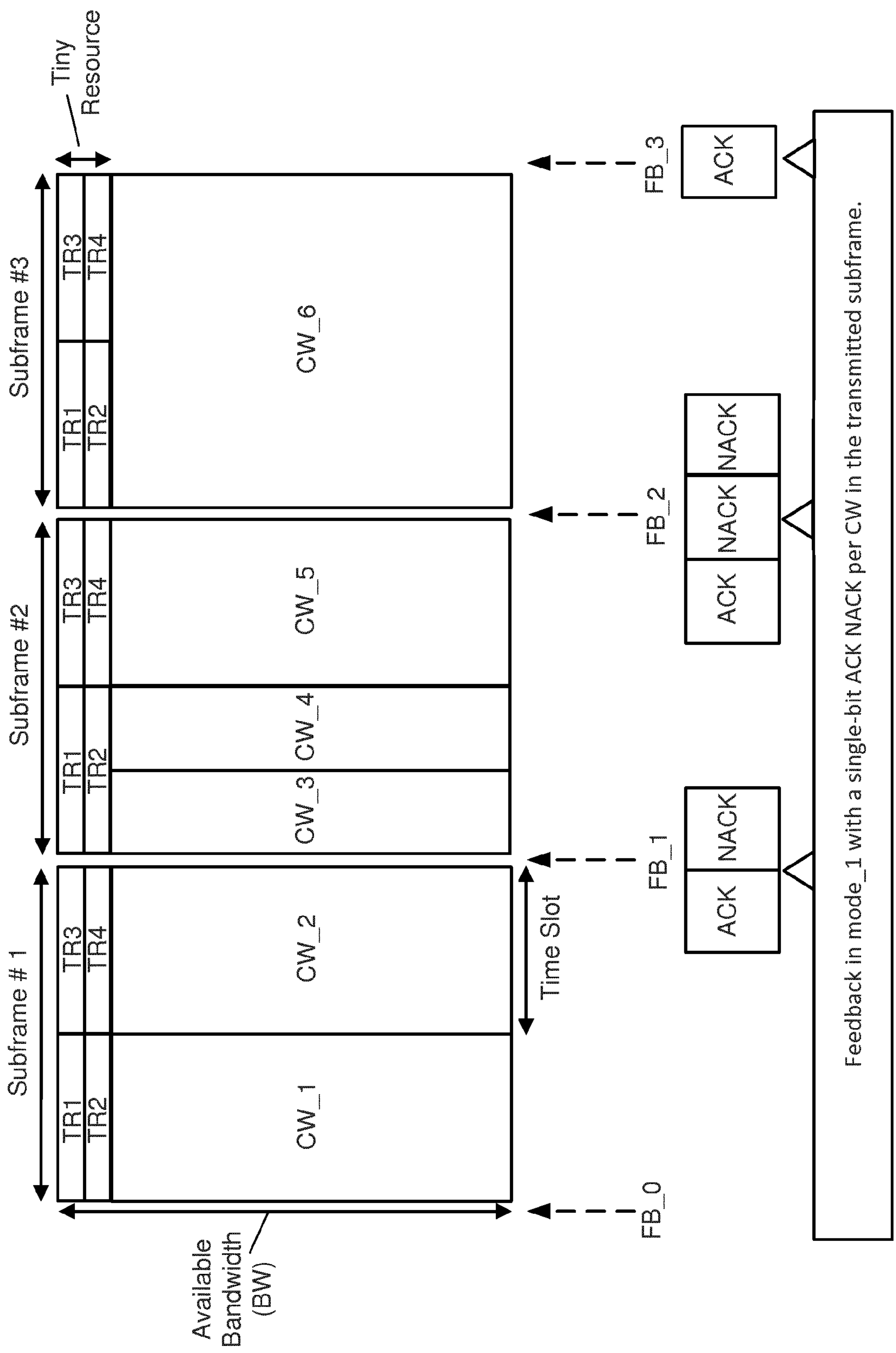
Tiny Resource
Subframe # 1
Subframe #2
Subframe #3
TR1
TR2
TR3
TR4
CW_1
CW_2
CW_3
CW_4
CW_5
CW_6
Time Slot
Available Bandwidth (BW)
FB_0
FB_1
FB_2
FB_3
ACK
NACK
ACK
NACK
NACK
ACK
Feedback in mode_1 with a single-bit ACK NACK per CW in the transmitted subframe.

FIG. 5

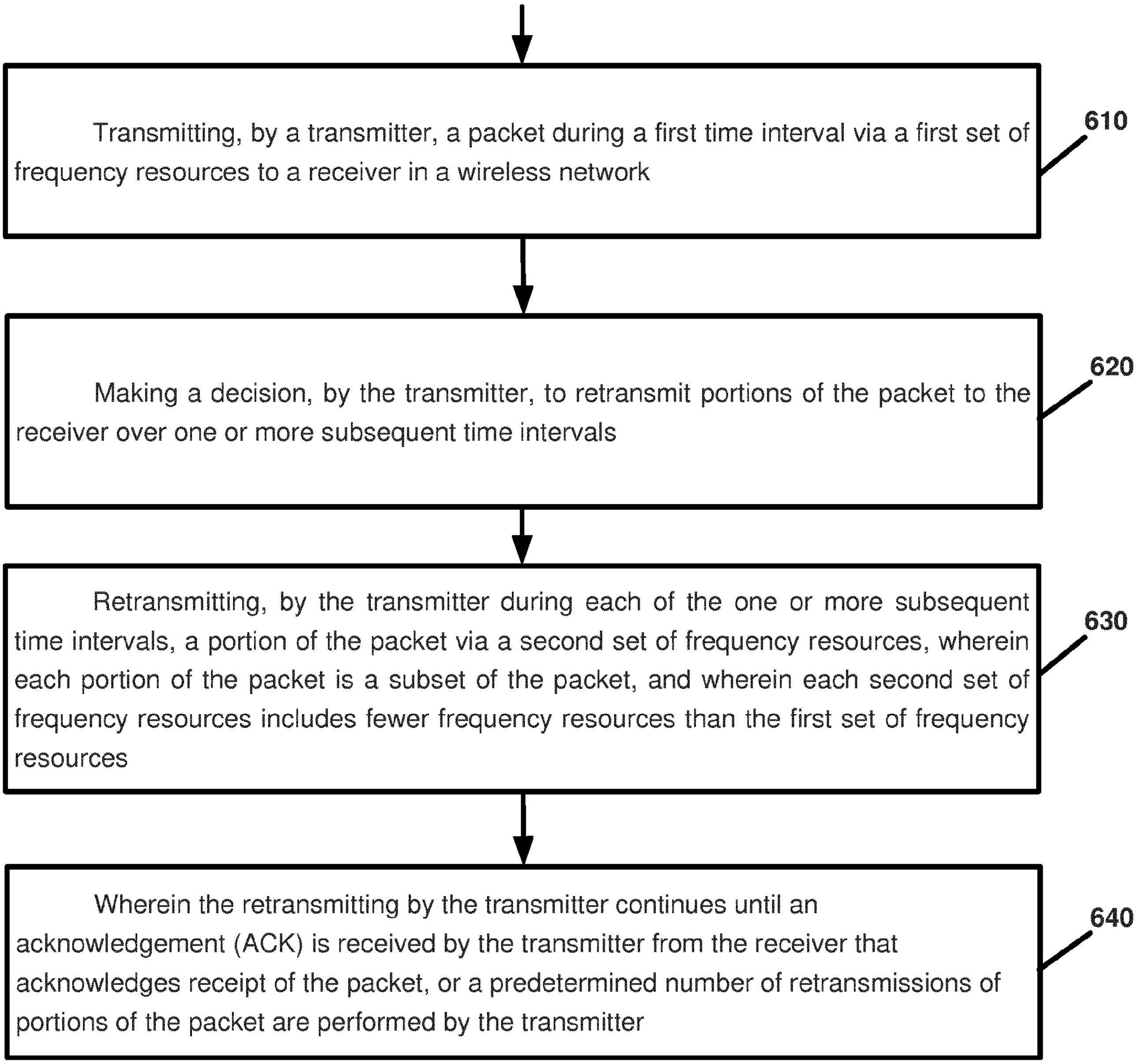
Transmitting, by a transmitter, a packet during a first time interval via a first set of frequency resources to a receiver in a wireless network
610
Making a decision, by the transmitter, to retransmit portions of the packet to the receiver over one or more subsequent time intervals
620
Retransmitting, by the transmitter during each of the one or more subsequent time intervals, a portion of the packet via a second set of frequency resources, wherein each portion of the packet is a subset of the packet, and wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources
630
Wherein the retransmitting by the transmitter continues until an acknowledgement (ACK) is received by the transmitter from the receiver that acknowledges receipt of the packet, or a predetermined number of retransmissions of portions of the packet are performed by the transmitter
640

**FIG. 6**

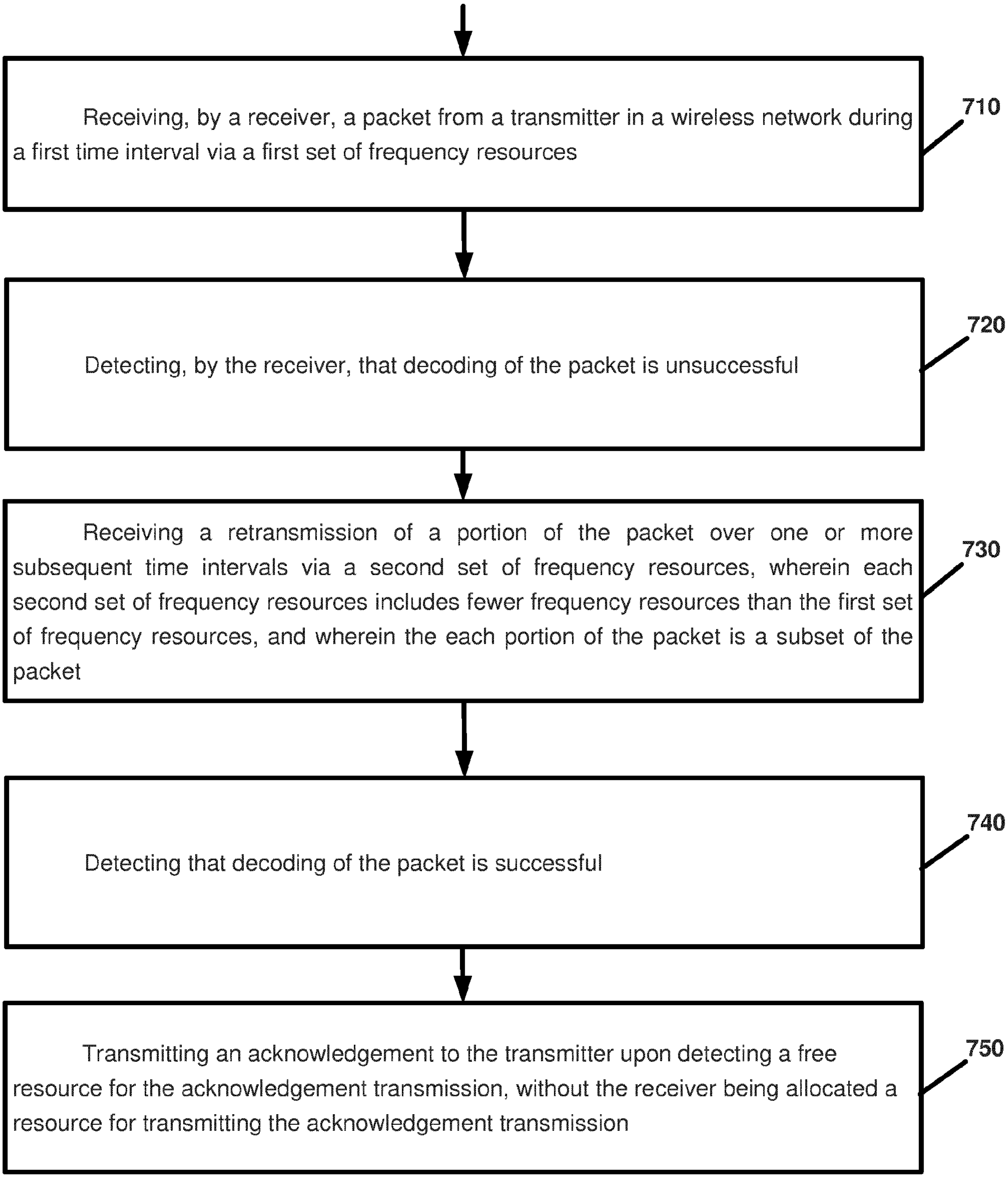
Receiving, by a receiver, a packet from a transmitter in a wireless network during a first time interval via a first set of frequency resources
710
Detecting, by the receiver, that decoding of the packet is unsuccessful
720
Receiving a retransmission of a portion of the packet over one or more subsequent time intervals via a second set of frequency resources, wherein each second set of frequency resources includes fewer frequency resources than the first set of frequency resources, and wherein the each portion of the packet is a subset of the packet
730
Detecting that decoding of the packet is successful
740
Transmitting an acknowledgement to the transmitter upon detecting a free resource for the acknowledgement transmission, without the receiver being allocated a resource for transmitting the acknowledgement transmission
750

FIG. 7

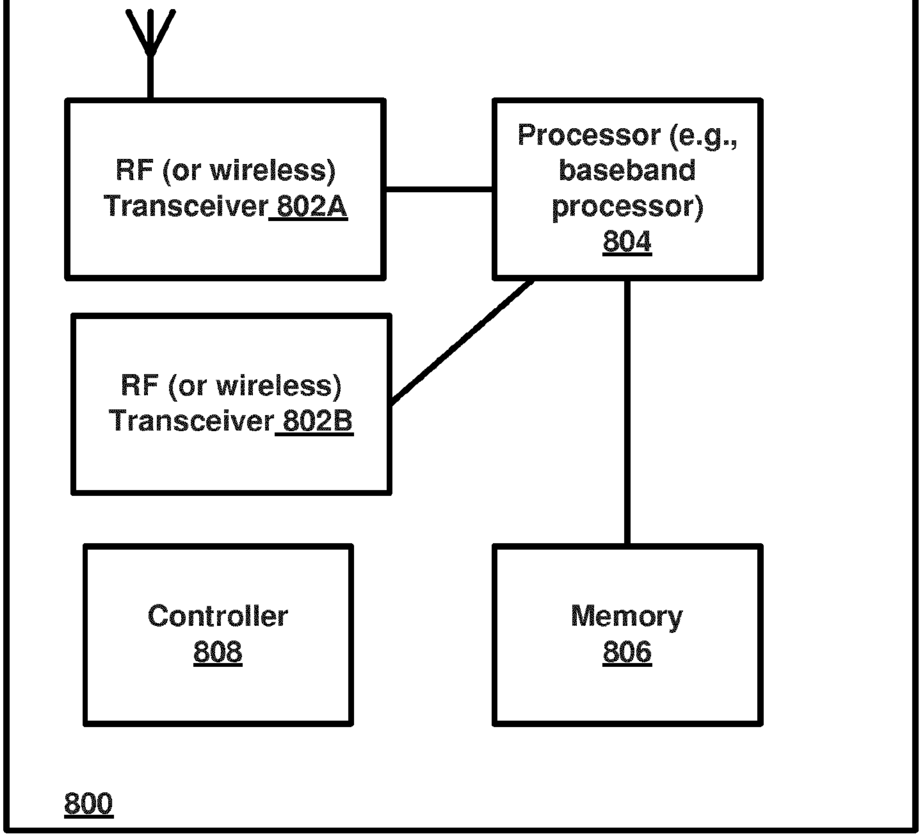
RF (or wireless) Transceiver 802A
Processor (e.g., baseband processor) 804
RF (or wireless) Transceiver 802B
Controller 808
Memory 806
800

FIG. 8

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/054380

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. H04L1/08 H04L1/18 H04L5/00
ADD.

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
H04L

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

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

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2015/341146 A1 (CHUNLONG BAI [CA] ET AL) 26 November 2015 (2015-11-26) | 1,2,6, 10,15, 17-20 |
| Y | paragraph [0003] | 4,5 |
| A | paragraph [0005]<br>paragraph [0009]<br>paragraph [0023] - paragraph [0026]<br>paragraph [0037]<br>paragraph [0041] - paragraph [0043]<br>claims 1,8,10<br>----- | 7 |
| X | US 2012/159278 A1 (JEN YU-CHIH [TW] ET AL) 21 June 2012 (2012-06-21)<br><br>paragraph [0006] - paragraph [0009]<br>paragraph [0021] - paragraph [0027]<br>paragraph [0035]<br>----- | 1,2,6, 10,15, 17-20 |
| | -/-- | |

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

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 18 November 2016 | 27/01/2017 |

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

2

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 6 631 127 B1 (AHMED MANSOOR [US] ET AL) 7 October 2003 (2003-10-07) | 1,2,6, 10,15, 17-20 |
| Y | column 2, line 32 - line 44<br>column 3, line 56 - column 4, line 16<br>column 5, line 34 - line 59<br>----- | 4 |
| Y | US 2005/013303 A1 (GOPALAKRISHNAN NANDU [US] ET AL) 20 January 2005 (2005-01-20)<br>paragraph [0009]<br>paragraph [0037] - paragraph [0038]<br>----- | 5 |

2

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1, 2, 4-7, 10, 15, 17-20

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1, 2, 4-7, 10, 15, 17-20

   method and apparatuses for determining whether to continue or to cease retransmitting data

   ---

2. claims: 3, 21-24

   method and apparatuses for configuring transmission resources for the transmission of acknowledgements from the receiver to the transmitter

   ---

3. claims: 8, 11

   method for adapting the transmission parameters of retransmissions

   ---

4. claim: 9

   method multiplexing retransmissions with other transmissions on the allocated resources

   ---

5. claims: 12-14, 16

   method for scheduling retransmissions

   ---

# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/EP2016/054380

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2015341146 A1 | 26-11-2015 | US 2013223485 A1 | 29-08-2013 |
| | | US 2015341146 A1 | 26-11-2015 |
| | | US 2016353454 A1 | 01-12-2016 |
| US 2012159278 A1 | 21-06-2012 | CN 102299783 A | 28-12-2011 |
| | | EP 2400685 A1 | 28-12-2011 |
| | | TW 201212580 A | 16-03-2012 |
| | | US 2012159278 A1 | 21-06-2012 |
| US 6631127 B1 | 07-10-2003 | AT 462237 T | 15-04-2010 |
| | | AU 2003231263 A1 | 19-12-2003 |
| | | CN 1656719 A | 17-08-2005 |
| | | EP 1508213 A1 | 23-02-2005 |
| | | JP 4370245 B2 | 25-11-2009 |
| | | JP 2005528058 A | 15-09-2005 |
| | | US 6631127 B1 | 07-10-2003 |
| | | WO 03103200 A1 | 11-12-2003 |
| US 2005013303 A1 | 20-01-2005 | NONE | |