Description

Title of Invention: COMMUNICATION APPARATUS AND COMMUNICATION METHOD FOR LOW LATENCY TRANSMISSION

TECHNICAL FIELD

[1] The present disclosure relates to communication apparatuses and methods for low latency transmission, and more particularly, when a low latency traffic directed to another communication apparatus is received during an ongoing transmission of a signal.

BACKGROUND

[2] In the standardization of next-generation WLAN, a new radio access technology (ultra high reliability or UHR) necessarily having backward compatibility with Institute of Electrical and Electronics Engineers (IEEE) 802.11a/b/g/n/ac/ax/be technologies has been discussed in the UHR Study Group (UHR SG).

[3] A key objection of UHR is to reduce latency. There has been much relevant discussion in UHR SG to find a solution for low latency (LL) traffic to achieve low latency. LL traffic refers to traffic requiring delay smaller than a specific threshold (e.g., 4-100 milliseconds). In IEEE 802.11be, Restricted Target Wake Time (R-TWT) enables STAs in a Basic Service Set (BSS) to use enhanced medium access protection and resource reservation mechanism for delivery of predictable latency sensitive traffic. However, this mechanism cannot provide protection for an unpredictable event-based LL traffic.

[4] In UHR SG, pre-emption and reusing preamble puncturing have been discussed to protect unpredictable event-based low latency transmitted in a BSS. However, such methods have the following disadvantages: (a) pre-emption within a physical layer protocol data unit (PPDU) is highly complex as it requires a lots of actions within both media access control (MAC) and physical (PHY) layers to map bits of LL traffic to ongoing payload transmission; (b) pre-emption within a transmission opportunity (TXOP) is easy to implement but less efficient as it requires interframe space and preamble for the LL packet; (c) reusing preamble puncturing is easy but it cannot ensure that the target receiver's working channel overlaps with the punctured channel.

[5] There is thus a need for communication apparatuses and methods for low latency transmission to address the issues, more particularly, a LL traffic method that can satisfy efficiency, easy implementation and successful transmission.

[6] Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[7] Non-limiting and exemplary embodiments facilitate providing communication apparatuses and communication methods for subcarriers modulation across multiple spatial streams in context of WLAN.

[8] In an embodiment, the present disclosure provides a first communication apparatus comprising: circuitry, which in operation, is configured to generate a first signal comprising a plurality of segmented signals carrying a first type of data; and a transmitter, which in operation, transmits the first signal to one or more second communication apparatuses, wherein, in response to obtaining a second type of data from an upper layer by the circuitry when the transmitter is transmitting a segmented signal of the plurality of segmented signals: the circuitry is configured to insert a second signal between the transmitted segmented signal and a successive segmented signal next to the transmitted segmented signal, the second signal carrying the second type of data; and the transmitter transmits the second signal and continues transmitting successive segmented signals of the first signal starting from the segmented signal next to the transmitted segmented signal.

[9] In another embodiment, the present disclosure provides a second communication apparatus comprising: a receiver, which in operation, receives a first signal from a first communication apparatus, the first signal comprising a plurality of segmented signals carrying a first type of data and a second signal inserted between two of the plurality of segmented signals, the second signal carrying a second type of data; and circuitry, which in operation, is configured to decode and demodulate the first signal.

[10] In yet another embodiment, the present disclosure provides a communication method comprising: generating a first signal comprising a plurality of segmented signals carrying a first type of data; transmitting the firs signal; obtaining a second type of data

from an upper layer when transmitting a segmented signal of the plurality of segmented signal; inserting a second signal carrying the second type of data between the transmitted segmented signal and a successive segmented signal next to the transmitted segmented signal; and transmitting the second signal and continuing the transmission of succussive segmented signals of the first signal starting from the successive segmented signal next to the transmitted segmented signal.

[11] It should be noted that general or specific embodiments may be implemented as a system, a method, an integrated circuit, a computer program, a storage medium, or any selective combination thereof.

[12] Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[13] Embodiments of the disclosure will be better understood and readily apparent to one of ordinary skilled in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[14] Figure 1 depicts a schematic diagram illustrating a single-user (SU) communication between an access point (AP) and a station (STA) in a multiple-input multiple-output (MIMO) wireless network.

[15] Figure 2 depicts a schematic diagram illustrating downlink multi-user (MU) communication between an AP and multiple STAs in a MIMO wireless network.

[16] Figure 3 depicts a schematic diagram illustrating a trigger-based (TB) uplink MU communication between an AP and multiple STAs in a MIMO wireless network.

[17] Figure 4 shows a pre-emption within a PPDU for LL transmission

[18] Figure 5A shows a pre-emption within a TXOP without illustrating a latency-sensitive traffic.

[19] Figure 5B shows a pre-emption within a TXOP illustrating a latency-sensitive traffic.

[20] Figure 6 shows a PPDU with a punctured channel for LL traffic.

[21] Figure 7 shows a schematic diagram illustrating a LL traffic transmission procedure according to another proposed method of pre-emption within TXOP.

[22] Figure 8 shows an example format of an Extremely High Throughput (EHT) MU PPDU used in the proposed method of pre-emption of Figure 7.

[23] Figure 9 shows an example transmitter processing used to process a data field according to various embodiments of the present disclosure.

[24] Figure 10 shows a schematic view of a communication apparatus according to the present disclosure.

[25] Figure 11 shows a flowchart illustrating a communication method for low latency transmission.

[26] Figure 12 shows a schematic diagram illustrating low latency traffic transmission procedure among an AP and two STAs according to various embodiments of the present disclosure.

[27] Figure 13 shows a processing by a MAC layer and a PHY layer of an AP to generate a PPDU comprising a LL PB according to various embodiments of the present disclosure.

[28] Figure 14 shows an example UHR PPDU format for low latency transmission according to an embodiment of the present disclosure.

[29] Figure 15 shows an example initial payload to be segmented into multiple PBs for low latency transmission according to an embodiment of the present disclosure.

[30] Figure 16 shows another example initial payload to be segmented into multiple PBs for low latency transmission according to an embodiment of the present disclosure.

[31] Figure 17 shows an example transmitter processing used to process a data field per resource unit for a single user according to an embodiment of the present disclosure.

[32] Figure 18 shows example original PBs prepared by an AP for low latency transmission according to an embodiment of the present disclosure.

[33] Figure 19 shows an example transmitter processing used to process a data field per resource unit per original PB for a single user according to an embodiment of the present disclosure.

[34] Figure 20 shows an example UHR PPDU format according to an embodiment of the present disclosure.

[35] Figure 21 shows a schematic diagram illustrating a first example low latency transmission procedure of the first embodiment of the present disclosure.

[36] Figure 22 shows a schematic diagram illustrating a second example low latency transmission procedure of the first embodiment of the present disclosure.

[37] Figure 23 shows a schematic diagram illustrating a third example low latency transmission procedure of the first embodiment of the present disclosure.

[38] Figure 24 shows an example UHR-SIG field of the UHR PPDU used in the third example low latency transmission procedure of the first embodiment of the present disclosure.

[39] Figure 25 shows a flow chart illustrating a low latency transmission procedure implemented by an AP according to the first embodiment of the present disclosure.

[40] Figure 26 shows a flow chart illustrating a low latency transmission procedure implemented by a non-AP STA according to the first embodiment of the present disclosure.

[41] Figure 27 shows a schematic diagram illustrating a first example low latency transmission procedure of the second embodiment of the present disclosure.

[42] Figure 28 shows an example UHR-SIG field of an UHR PPDU for the first example low latency transmission procedure of the second embodiment of the present disclosure.

[43] Figure 29 shows a schematic diagram illustrating a second example low latency transmission procedure of the second embodiment of the present disclosure.

[44] Figure 30 shows a flow chart illustrating a low latency transmission procedure implemented by a non-AP STA, which is not a target receiver of an UHR PPDU, according to the second embodiment of the present disclosure.

[45] Figure 31 shows an example UHR PPDU format per RU/MRU implementing the first LL traffic identification option according to an embodiment of the present disclosure.

[46] Figure 32 shows an example UHR PPDU format per RU/MRU implementing the second LL traffic identification option according to an embodiment of the present disclosure.

[47] Figure 33 shows an example UHR-SIG field of the UHR PPDU of Figure 32.

[48] Figure 34 shows an example LL PB implementing the third LL traffic identification option according to an embodiment of the present disclosure.

[49] Figure 35 shows a schematic diagram illustrating a low latency transmission procedure according to the third embodiment of the present disclosure.

[50] Figure 36 shows a schematic diagram illustrating another example low latency transmission procedure according to the third embodiment of the present disclosure.

[51] Figure 37 shows a schematic diagram illustrating yet another example low latency transmission procedure according to the third embodiment of the present disclosure.

[52] Figure 38 shows a schematic diagram illustrating a fourth example low latency transmission procedure according to the third embodiment of the present disclosure.

[53] Figure 39 shows a flow chart illustrating the fourth low latency transmission procedure of Figure 38 implemented by a non-AP STA according to the third embodiment of the present disclosure.

[54] Figure 40 shows a first example UHR PPDU for low latency transmission according to the fourth embodiment of the present disclosure.

[55] Figure 41 shows an example UHR-SIG field of an UHR PPDU according to the fourth embodiment of the present disclosure.

[56] Figure 42 shows a second example UHR PPDU for low latency transmission according to the fourth embodiment of the present disclosure.

[57] Figure 43 shows a flow chart illustrating a low latency transmission procedure implemented by an AP according to the fourth embodiment of the present disclosure.

[58] Figure 44 shows a flow chart illustrating a low latency transmission procedure implemented by a non-AP STA according to the fourth embodiment of the present disclosure.

[59] Figure 45 shows a schematic diagram illustrating a low latency transmission procedure according to the fifth embodiment of the present disclosure.

[60] Figure 46 shows an example configuration of a communication apparatus.

[61] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flow charts may be exaggerated in respect to other elements to help an accurate understanding of the present embodiments.

DETAILED DESCRIPTION

[62] Some embodiments of the present disclosure will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[63] In the following paragraphs, certain exemplifying embodiments are explained with reference to an access point (AP) and a station (STA) for subcarriers modulation across multiple spatial streams, especially in a multiple-input multiple-output (MIMO) wireless network.

[64] In the context of IEEE 802.11 (Wi-Fi) technologies, a station, which is interchangeably referred to as a STA, is a communication apparatus that has the capability to use the IEEE 802.11 protocol. Based on the IEEE 802.11-2016 definition, a STA can be any device that contains an IEEE 802.11-conformant media access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

[65] For example, a STA may be a laptop, a desktop personal computer (PC), a personal digital assistant (PDA), an access point or a Wi-Fi phone in a wireless local area network (WLAN) environment. The STA may be fixed or mobile. In the WLAN environment, the terms “STA”, “wireless client”, “user”, “user device”, and “node” are often used interchangeably.

[66] Likewise, an AP, which may be interchangeably referred to as a wireless access point (WAP) in the context of IEEE 802.11 (Wi-Fi) technologies, is a communication apparatus that allows STAs in a WLAN to connect to a wired network. The AP usually connects to a router (via a wired network) as a standalone device, but it can also be integrated with or employed in the router.

[67] As mentioned above, a STA in a WLAN may work as an AP at a different occasion, and vice versa. This is because communication apparatuses in the context of IEEE 802.11 (Wi-Fi) technologies may include both STA hardware components and AP hardware components. In this manner, the communication apparatuses may switch between a STA mode and an AP mode, based on actual WLAN conditions and/or requirements.

[68] In a MIMO wireless network, “multiple” may refer to multiple antennas used simultaneously for transmission and multiple antennas used simultaneously for reception, over a radio channel. In this regard, “multiple-input” may refer to multiple transmitter

antennas, which input a radio signal into the channel, and “multiple-output” may refer to multiple receiver antennas, which receive the radio signal from the channel and into the receiver. For example, in an N × M MIMO network system, N is the number of transmitter antennas, M is the number of receiver antennas, and N may or may not be equal to M. For the sake of simplicity, the respective numbers of transmitter antennas and receiver antennas are not discussed further in the present disclosure.

[69] In a MIMO wireless network, single-user (SU) communications and multi-user (MU) communications can be deployed for communications between communication apparatuses such as APs and STAs. MIMO wireless network has benefits like spatial multiplexing and spatial diversity, which enable higher data rates and robustness through the use of multiple spatial streams.

[70] In various embodiments below, each of the terms “channel” and “subchannel” may be used interchangeably with any one of “band”, “subband” and “frequency segments”. The term “circuitry” may be used interchangeably with “module”.

[71] Figure 1 depicts a schematic diagram illustrating a SU communication 100 between an AP 102 and a STA 104 in a MIMO wireless network. As shown, the MIMO wireless network may include one or more STAs (e.g., STA 104, STA 106, etc.). If the SU communication 100 in a channel is carried out over whole channel bandwidth, it is called full bandwidth SU communication. If the SU communication 100 in a channel is carried out over a part of the channel bandwidth (e.g., one or more 20MHz subchannels within the channel is punctured), it is called punctured SU communication. In the SU communication 100, the AP 102 transmits multiple space-time streams using multiple antennas (e.g., four antennas as shown in Figure 1) with all the space-time streams directed to a single communication apparatus, i.e., the STA 104. For the sake of simplicity, the multiple space-time streams directed to the STA 104 are illustrated as a grouped data transmission arrow 108 directed to the STA 104.

[72] The SU communication 100 can be configured for bi-directional transmissions. As shown in Figure 1, in the SU communication 100, the STA 104 may transmit multiple space-time streams using multiple antennas (e.g., two antennas as shown in Figure 1) with all the space-time streams directed to the AP 102. For the sake of simplicity, the multiple space-time streams directed to the AP 102 are illustrated as a grouped data transmission arrow 110 directed to the AP 102.

[73] As such, the SU communication 100 depicted in Figure 1 enables both uplink and downlink SU transmissions in a MIMO wireless network.

[74] Figure 2 depicts a schematic diagram illustrating a downlink MU (multiple-user) communication 200 between an AP 202 and multiple STAs 204, 206, 208 in a MIMO wireless network. The MIMO wireless network may include one or more STAs (e.g., STA 204, STA 206, STA 208, etc.). The MU communication 200 may be an OFDMA (orthogonal frequency division multiple access) communications or a MU-MIMO communication. For an OFDMA communication in a channel, the AP 202 transmits multiple streams simultaneously to the STAs 204, 206, 208 in the network at different resource units (RUs) within the channel bandwidth. For a MU-MIMO communication in a channel, the AP 202 transmits multiple streams simultaneously to the STAs 204, 206, 208 at same RU(s) within the channel bandwidth using multiple antennas via spatial mapping or precoding techniques. If the RU(s) for the OFDMA or MU-MIMO communication occupies whole channel bandwidth, the OFDMA or MU-MIMO communications is called full bandwidth OFDMA or MU-MIMO communications. If the RU(s) for the OFDMA or MU-MIMO communication occupies a part of channel bandwidth (e.g., one or more 20MHz subchannel within the channel is punctured), the OFDMA or MU-MIMO communication is called punctured OFDMA or MU-MIMO communications. For example, two space-time streams may be directed to the STA 206, another space-time stream may be directed to the STA 204, and yet another space-time stream may be directed to the STA 208. For the sake of simplicity, the two space-time streams directed to the STA 206 are illustrated as a grouped data transmission arrow 212, the space-time stream directed to the STA 204 is illustrated as a data transmission arrow 210, and the space-time stream directed to the STA 208 is illustrated as a data transmission arrow 214.

[75] To enable uplink MU transmissions, trigger-based communication is provided to the MIMO wireless network. In this regard, Figure 3 depicts a schematic diagram illustrating a trigger-based (TB) uplink MU communication 300 between an AP 302 and multiple STAs 304, 306, 308 in a MIMO wireless network.

[76] Since there are multiple STAs 304, 306, 308 respectively participating in the trigger-based uplink MU communication, the AP 302 needs to coordinate simultaneous transmissions of multiple STAs 304, 306, 308.

[77] To do so, as shown in Figure 3, the AP 302 transmits triggering frames 310, 314, 318 simultaneously to STAs 304, 306, 308 respectively to indicate user-specific resource

allocation information (e.g., the number of space-time streams, a starting STS number and the allocated RUs) that each STA can use. In response to the triggering frames, STAs 304, 306, 308 may then transmit their respective space-time streams simultaneously to the AP 302 according to the user-specific resource allocation information indicated in the triggering frames 310, 314, 318. For example, two space-time streams may be directed to the AP 302 from STA 306, another space-time stream may be directed to the AP 302 from STA 304, and yet another space-time stream may be directed to the AP 302 from STA 308. For the sake of simplicity, the two space-time streams directed to the AP 302 from STA 306 are illustrated as a grouped data transmission arrow 316, the space-time stream directed to the AP 302 from STA 304 is illustrated as a data transmission arrow 312, and the space-time stream directed to the AP 302 from STA 308 is illustrated as a data transmission arrow 320.

[78] Due to packet/PPDU (physical layer protocol data unit) based transmission in the Enhanced Distributed Channel Access (EDCA) mechanism and distributed MAC (medium access control) scheme in IEEE 802.11 WLAN, frequency and spatial resource scheduling is performed on a packet basis. In other words, resource allocation information is on a PPDU basis in the EDCA mechanism.

[79] WLAN supports non-trigger-based communications as illustrated in Figures 1 and 2 and trigger-based communications as illustrated in Figure 3. In non-trigger-based communications, a communication apparatus transmits a PPDU to one other communication apparatus or more than one other communication apparatus in an unsolicited manner. In trigger-based communications, a communication apparatus transmits a PPDU to one other communication apparatus or more than one other communication apparatus only after a soliciting triggering frame is received.

[80] In ultra high reliability (UHG) transmission, pre-emption and reusing preamble puncturing are proposed to protect unpredictable event-based low latency transmitted in a basic service set (BSS).

[81] Under pre-emption method, LL traffic enjoys higher priority within an ongoing PPDU or TXOP. Figure 4 shows a pre-emption within a PPDU 400 for LL transmission. The PPDU 400 contains a preamble and a multi-RA (recipient address) aggregated-MDPU (a-MDPU) which contains multiple MAC protocol data units (MPDUs). In this example, the PPDU 400 contains multiple MPDUs addressed to STA1 and during on-

going transmission of the PPDU 400, a MPDU 402 containing LL traffic addressed to STA2 is inserted as a pre-emption within the PPDU 400.

[82] Figure 5A shows a pre-emption within a TXOP without illustrating a latency-sensitive traffic. Figure 5B shows a pre-emption within a TXOP illustrating a latency-sensitive traffic. The PPDU 500 may comprises a header (HDR) and multiple (PPDU) payloads. As shown in Figure 5B, when a latency-sensitive traffic 501 arrives, during the first PPDU payload 502 is transmitted, an PPDU end marker 503 is appended to the first PPDU payload 502 to mark the end of the transmission of the PPDU 502. After a short interframe space (SIFS), a second PPDU 504 comprising a HDR and a latency-sensitive payload 506 carrying the latency-sensitive traffic 501 is transmitted. Subsequently, after another SIFS, a third PPDU 508 comprising a HDR and the remaining payloads is transmitted.

[83] Under reusing preamble puncturing method, an event-based LL traffic is transmitted on a deterministic punctured channel. Figure 6 shows a PPDU 600 with a punctured channel for LL traffic. The PPDU 600 contains a deterministic punctured channel 602 or frequency band, for example, at the second lowest 20 MHz channel, and a LL traffic is transmitted in such deterministic punctured channel 602.

[84] As mentioned earlier, the conventional methods have the following disadvantages: (a) pre-emption within a physical layer protocol data unit (PPDU) may be efficiency but it is highly complex as it requires a lots of actions within both media access control (MAC) and physical (PHY) layers to map bits of LL traffic to ongoing payload transmission; (b) pre-emption within a transmission opportunity (TXOP) may be easy to implement but is less efficient as it requires interframe space and preamble for the LL packet; (c) reusing preamble puncturing may be easy but it cannot ensure that the target receiver's working channel overlaps with the punctured channel.

[85] Figure 7 shows a schematic diagram 700 illustrating a LL traffic transmission procedure according to another proposed method of pre-emption within TXOP. Although the horizontal axes for AP, STA1 and STA2 in Figure 7 are not ended with arrows, it will be appreciated by those skilled in the art that these horizontal axes may be plotted in a similar manner to that shown in the schematic diagrams illustrating embodiments of the present disclosure, i.e., ended by arrows. In this proposed method, a large non-LL traffic is broken into pieces, each of them carried by a short downlink (DL) PPDU 702a, 702b,

702c. An example PPDU used for the LL traffic transmission procedure of Figure 7 is illustrated in Figure 8. The short DL PPDUs 702a, 702b, 702c are transmitted with a time of xIFS in between each short DL PPDUs 702a, 702b, 702c within the TXOP. When a LL traffic arrives, in this case, during the first DL PPDU 702a is transmitted, a DL LL PPDU 704 carrying the LL traffic can be transmitted right after the first DL PPDU 702a and the time of xIFS 703 following the first DL PPDU 702a . This method is easy to implement and can ensure the waiting time for a LL traffic is short. However, the time of xIFs between each PPDU and the preamble of each PPDU is a waste.

[86] Figure 8 shows an example format of an Extremely High Throughput (EHT) MU PPDU used in the proposed method of pre-emption of Figure 7. The PPDU 800 may include a Legacy Short Training Field (L-STF), a Legacy Long Training Field (L-LTF), a Legacy SIGNAL (L-SIG) field, a Repeated L-SIG (RL-SIG) field, a Universal SIGNAL (U-SIG) field, a EHT SIGNAL (EHT-SIG) field, a EHT Short Training Field (EHT-STF), a EHT Long Training Field (EHT-LTF) and a Data field.

[87] Figure 9 shows an example transmitter processing 900 used to process a data field according to various embodiments of the present disclosure. The transmitter processing may start at a Pre-Forward Error Correction (FEC) Physical Layer (PHY) Padding unit where redundant information is added to the data bits before the data is output to a Scrambler for scrambling the data bits to reduce long runs of identical bits on the transmission layer. An FEC encoder unit encodes the data bits using forward error correction code such as binary convolutional code (BCC) or Low-Density Parity Check (LDPC) encoder before the encoded data is output to a Post-FEC PHY Padding unit to add padding bits such that the number of bits match the number of bits required for a symbol.

[88] A Stream Parser unit then divides the encoded bits into multiple blocks that are sent through multiple spatial streams correspondingly. In this case, the number of spatial streams N_{SS} is equal or less than 8. The single spatial stream corresponding to a block of the encoded bits is sent to a Constellation Mapper unit. The BCC Interleaver unit may be omitted depending on the employed FEC code type. The Constellation Mapper unit maps respective blocks of the encoded bits into constellation points or complex numbers (herein referred to as modulation symbols). A LDPC Tone Mapper unit uses a selected modulation scheme to process constellation points from the Constellation Mapper unit and ensure the constellation points are mapped to OFDM subcarriers separated by a

sufficient distance to maximize frequency diversity gain. Optionally, in some spatial streams, a Cycle Shift Diversity (CSD) per SS unit transforms the spatial diversity of the OFDM subcarriers into frequency diversity to avoid intersymbol interference.

[89] Subsequently, the spatial streams will be sent to a Spatial and Frequency Mapper unit to map onto one or multiple transmit chains. Each transmit chain is sent to an Inverse Fourier Discrete Fourier Transform (IDFT) unit. Each IDFT unit converts OFDM subcarriers on the transmit chain, which are frequency-domain data, into time-domain data for transmission. The time-domain data of the IDFT unit is then sent to an Insert Guard Interval (GI) And Window unit to insert GI at the start of each OFDM symbol in the transmit chain where each OFDM symbol may also be windowed to minimize adjacent channel interference. The time-domain data in each transmit chain is then sent to an Analog and Radio Frequency (RF) unit to prepare the data for transmission through an antenna.

[90] Figure 10 shows a schematic view of a communication apparatus 1000 according to the present disclosure. The communication apparatus 1000 may be implemented as an AP or a STA.

[91] As shown in Figure 10, the communication apparatus 1000 may include circuitry 1014, at least one radio transmitter 1002, at least one radio receiver 1004, and at least one antenna 1012 (for the sake of simplicity, only one antenna is depicted in Figure 10 for illustration purposes). The circuitry 1014 may include at least one controller 1006 for use in software and/or hardware aided execution of tasks that the at least one controller 1006 is designed to perform, including but not limited to control of communications with one or more other communication apparatuses in a MIMO wireless network. The circuitry 1014 may further include at least one transmission signal generator 1008 and at least one receive signal processor 1010. The at least one controller 1006 may control the at least one transmission signal generator 1008 for generating PPDUs to be sent through the at least one radio transmitter 1002 to one or more other communication apparatuses. Here, the PPDU, for example, may be PPDUs used for downlink transmissions if the communication apparatus 1000 is an AP. Alternatively, the PPDU may be PPDUs used for trigger-based uplink transmissions if the communication apparatus 1000 is a STA. The at least one controller 1006 may control the at least one receive signal processor 1010 for processing MAC frames and PPDUs received through the at least one radio receiver 1004 from the one or more other communication apparatuses under the control of the at

least one controller 1006. Here the PPDU, for example, may be PPDUs used for trigger-based uplink transmissions if the communication apparatus 1000 is an AP. Alternatively, the PPDU may be PPDUs used for downlink transmissions if the communication apparatus 1000 is a STA. The at least one transmission signal generator 1008 and the at least one receive signal processor 1010 may be stand-alone modules of the communication apparatus 1000 that communicate with the at least one controller 1006 for the above-mentioned functions, as shown in Figure 10. Alternatively, the at least one transmission signal generator 1008 and the at least one receive signal processor 1010 may be included in the at least one controller 1006. It is appreciable to those skilled in the art that the arrangement of these functional modules is flexible and may vary depending on the practical needs and/or requirements. The data processing, storage and other relevant control apparatus can be provided on an appropriate circuit board and/or in chipsets. In various embodiments, when in operation, the at least one radio transmitter 1002, at least one radio receiver 1004, and at least one antenna 1012 may be controlled by the at least one controller 1006.

[92] The communication apparatus 1000, when in operation, may provide functions required for low latency transmission. For example, the communication apparatus 1000 may be an AP, and the circuitry 1014 (for example the at least one transmission signal generator 1008 of the circuitry 1014, respectively) may be configured to generate a first signal comprising a plurality of segmented signals carrying a first type of data (e.g., non-LL traffic). The at least one radio transmitter 1002 may transmit the first signal to the one or more second communication apparatuses (STA1, STA2). The circuitry 1014 (for example the at least one controller 1006) may obtain a second type of data (LL traffic) from an upper layer (e.g., MAC layer) when the at least one radio transmitter 1002 is transmitting a segmented signal of the plurality of segmented signals, and in response to that, the at circuitry 1014 (for example the at least one transmission signal generator 1008) is configured to insert a second signal between the transmitted segmented signal and a successive segmented signal next to the transmitted segmented signal, the second signal carrying the second type of data. The at least one radio transmitter 1002, in such case, may transmit the second signal and continue transmitting successive segmented signals of the first signal starting from the segmented signal next to the transmitted segmented signal.

[93] In one embodiment, where the first type of data and the second type of data are directed to a same second communication apparatus (STA1), the at least one radio transmitter 1002 may transmit the second signal on a first resource unit to the one of the one

or more second communication apparatuses and the successive segmented signals either on the first resource unit or on both the first resource unit and a second resource unit to the second communication apparatus (STA1). In a further embodiment, the at least one radio transmitter 1002 may transmit one of the successive segmented signal on the second resource unit RU2 to another second communication apparatus (STA2) at a same time when the at least one radio transmitter 1002 may transmit is transmitting the second signal on the resource unit (RU1) to the same second communication apparatus (STA1).

[94] In another embodiment, wherein the second type of data is directed to a third communication apparatus (STA3), different from the one or more second communication apparatuses (STA1, STA2) which are the target receivers of the first signal, the at least one radio transmitter 1002 may transmit the second signal on one or more first resource units (RU1 or RU1+RU2) to the third communication apparatus (STA3) and continue transmitting the successive segmented signals on the one or more first resource units (RU1 or RU1+RU2) to the one or more second communication apparatuses (STA1, STA2).

[95] In yet another embodiment, the circuitry 1014 (for example the at least one controller 1006) may obtain a second type of data (LL traffic) from an upper layer (e.g., MAC layer) when the at least one transmitter 1002 is transmitting the segmented signal, and in response to that, the at least one radio transmitter 1002 may continue to further transmit one or more second successive signals of the first signal next to the transmitted successive signals beyond the indicated length of the first signal, wherein a number of the transmitted one or more second successive segmented signals is based on a number or a length of the second signal.

[96] In one embodiment, one or more first resource units (RU1 and/or RU2) is specifically configured for transmitting the first type of data and a second resource unit (RU3) is specifically configured for transmitting the second type of data. The circuitry 1014 (for example the at least one controller 1006) may obtain a second type of data (LL traffic) from an upper layer (e.g., MAC layer) when the at least one radio transmitter 1002 is transmitting the first signal, and in response to that, the at least one radio transmitter 1002 may then transmit the second signal carrying the second type of data on the second resource unit. In a first further embodiment, where the second resource unit (RU3) comprises a resource unit allocated to a second communication apparatus (e.g., STA2), the at least one radio transmitter 1002 may transmit the first signal carrying the first type

of data (e.g., non-LL traffic) on the one or more first resource units (RU1 and/or RU2) to the other second communication apparatus (e.g., STA1) and the second signal carrying the second type of data (e.g., LL traffic) on the second resource unit (RU3) to the second communication apparatus (e.g., STA2). In an alternative embodiment, where the second resource unit (RU3) corresponds to a third communication apparatus (STA3), different from the one or more second communication apparatuses (STA1, STA2) which are the target receivers of the first signal, the at least one radio transmitter 1002 may transmit the first signal on the one or more first resource units (RU1 and/or RU2) to the one or more second communication apparatuses (STA1, STA2) and the second signal carrying the second type of data (e.g., LL traffic) on the second resource unit (RU3) to the third communication apparatus (STA3). In an alternative embodiment, where the second type of data (e.g., LL traffic) are directed to more than one other communication apparatus (STA1, STA2 and/or STA3), the at least one radio transmitter 1002 may transmit the first signal carrying the first type of data (non-LL traffic) on the one or more first resource units to the one or more second communication apparatuses (STA1 and/or STA2) and, for each of the more than one other communication apparatus (STA1, STA2 and/or STA3), a second signal carrying the second type of data (LL traffic) on the second resource unit (RU3) to the each of the more than one other communication apparatus (STA1, STA2 and/or STA3).

[97] In one embodiment, where the circuitry 1014 (for example the at least one controller 1006) may obtain a second type of data (LL traffic) from an upper layer (e.g., MAC layer) when the at least one transmitter 1002 is transmitting the segmented signal, the circuitry (for example the at least one transmission signal generator 1008 of the circuitry 1014) is configured to generate a third signal carrying the second type of data and a fourth signal comprising the successive segmented signals, wherein each of the third signal and the fourth signal comprises a preamble shorter than that comprised on the first signal; and the at least one radio transmitter 1002 may separately transmit the third signal and the fourth signal (separate PPDUs) after the transmission of the segmented signal.

[98] For example, the communication apparatus 1000 may be a STA, and the at least one radio receiver 1004 may receive a first signal from another communication apparatus, the first signal comprising a plurality of segmented signals carrying a first type of data (e.g., non-LL traffic) and a second signal between two of the plurality of segmented signals, the second signal comprising a second type of data (e.g., LL traffic). The circuitry

1014 (for example the at least one receive signal processor 1010 of the circuitry 1014) may be configured to decode and demodulate the first signal.

[99] In an embodiment, the circuitry 1014 (for example the at least one receive signal processor 1010 of the circuitry 1014) may, in response to receiving the second signal carrying the second type of data, update a length (e.g., indicated PPDU length) of the first signal to a new length (updated PPDU length). The at least one radio receiver 1004 may further receive one or more successive segmented signals of the plurality of segmented signal beyond the indicated length of the first signal based on the new length, wherein a number of the one or more successive segmented signals is based on a number or a length of the second signal. The circuitry 1014 (for example the at least one receive signal processor 1010 of the circuitry 1014) may further decode and demodulate the one or more successive segmented signals.

[100] Figure 11 shows a flowchart 1100 illustrating a communication method for low latency transmission. The communication method may be implemented by a communication apparatus, for example, may be an AP according to various embodiments of the present disclosure. In step 1102, a step of generating a first signal comprising a plurality of segmented signals carrying a first type of data is carried out. In step 1104, a step of transmitting the first signal is carried out. In step 1106, a step of obtaining a second type of data from an upper layer when transmitting a segmented signal of the plurality of segmented signal. In step 1108, a step of inserting a second signal carrying the second type of data between the transmitted segmented signal and a successive segmented signal of the plurality of segmented signals next to the transmitted segmented signal is carried out. In step 1110, a step of transmitting the second signal and continuing the transmission of successive segmented signals of the first signal starting from the segmented signal next to the transmitted segmented signal is carried out.

[101] Figure 12 shows a schematic diagram 1200 illustrating low latency traffic transmission procedure among an AP and two STAs (STA1, STA2) according to various embodiments of the present disclosure. An original PB refers to a payload block carrying the original data transmitted by the UHR PPDU and LL PB refers to a payload block carrying a LL traffic. The AP may send an UHR PPDU with multiple payload blocks (PB) and when a low latency (LL) traffic arrives during the transmission of an original PB (in this case, original PB1), and insert a LL traffic for the time duration of a payload block, therefore forming a LL PB, into the UHR PPDU to transmit the LL traffic after the LL traffic

arrives. The AP may indicate LL parameters in an UHR PPDU to a non-AP STA and a LL PB may be specified with a pre-defined or indicated identification. The block time duration can be decided by the AP prior to the UHR PPDU transmission based on estimated packet length of LL traffic predicted by artificial intelligence or machine learning. The AP may have more than one buffer, to process and embed data from upper layer into the UHR PPDU, for example, one buffer to process and embed the original data into the original PB, another buffer to process and embed the potential LL traffic into the LL PB. It will be appreciated by those skilled in the art that the buffers here at least may be implemented as a part of circuitry, for example, circuitry 1014.

[102] The AP and non-AP STAs (STA1, STA2) may indicate the capability of supporting such LL traffic prior to a LL traffic transmission, for example, using an element (e.g., LL element, UHR capabilities element) carried in a Beacon or a Probe Request/Response frame (not shown). Advantageously, the LL traffic can be transmitted by a LL PB during transmission of the UHR PPDU with actions only on physical (PHY) layer, which is highly efficient, easy to implement and more reliable transmission (transmission guaranteed).

[103] For example, referring to Figure 12, an AP may transmit an UHR PPDU targeted at two stations, STA1, STA2. The UHR PPDU contains 4 PBs (Original PB 1-4) addressed to both STA1, STA2. During the transmission, the Original PB 1-4 are transmitted to STA1 and STA2. A LL traffic targeted at STA2 arrives in the midst of transmitting Original PB 1. Consequently, Original PB 2 is held and a LL PB carrying LL traffic is inserted to the UHR PPDU for transmission to STA2. After the LL traffic finishes, subsequent original PBs will continue to transmit if the indicated PPDU length allows. In this case, Original PB 2 and Original PB 3 are transmitted to STA1 and STA2 after the LL PB is transmitted to STA2. However, the transmission of Original PB 4 may be given up as the signal has exceeded the indicated PPDU length after the transmission of the Original PB 3. Alternatively, the AP may continue to transmit Original PB 4 if the STAs is capable of updating the PPDU length. More details relating to these two implementations will be described below.

[104] Figure 13 shows a processing by a MAC layer and a PHY layer of an AP to generate a PPDU comprising a LL PB according to various embodiments of the present disclosure. In the MAC layer, an aggregated MPPU (A-MPDU) addressed to STA1 and STA2 is generated. The A-MPDU is then sent to the PHY layer for further processing into PSDU addressed to STA1 and STA2. According to the present disclosure, the PSDU is then segmented to multiple PBs (original PBs), in this case, four PBs (Original PBs 1-4).

When a LL PSDU for STA2 arrives/is obtained when the Original PB 1 is being transmitted, the PHY layer then insert the LL PSDU into the PPDU forming a LL PB between the Original PB 1 and subsequent PBs, i.e., Original PB 2-4. In other words, LL traffic and non-LL traffic is separately processed and the necessary actions to receive, process and transmit LL PSDU only happen within PHY layer.

[105] Figure 14 shows an example UHR PPDU format 1400 for low latency transmission according to an embodiment of the present disclosure. The UHR PPDU may comprise a preamble and a data field. The data field may comprise multiple original payload blocks (PBs), each original payload block comprising multiple OFDM symbols, in this case, N OFDM symbols (OFDM SYM 1-N). The AP may prepare the data field through the following options:
Option (1) preparing OFDM symbols for initial payload (e.g., in a same manner as in IEEE802.11be EHT) and segmenting the initial payload into N_{PB} original PBs where $N_{PB}$is an integer;
Option (2) preparing OFDM symbols for each original PB separately.

[106] In a first example under Option (1), an initial payload with M OFDM symbols may be prepared by the AP and then segmented by the AP into N_{PB} original PBs. The first $N_{PB}-1$ original PBs each contains $\left\lceil \frac{M}{N_{PB}} \right\rceil$OFDM symbols while the ${N_{PB}}^{th}$ original PB contains $M-\left\lceil \frac{M}{N_{PB}} \right\rceil * (N_{PB}-1)$ OFDM symbols. Figure 15 shows an example initial payload to be segmented into multiple PBs for low latency transmission, in particular, under the first example of Option (1) of preparing OFDM symbols, according to an embodiment of the present disclosure. In this example, the initial payload with 83 OFDM symbols may be segmented into four original PBs, the first 3 original PBs each containing 21 OFDM symbols while the 4th original PB containing 20 OFDM symbols.

[107] In a second example under Option (1), an initial payload with M OFDM symbols may be prepared by the AP and then segmented by the AP into N_{PB} original PBs. The first $N_{PB}-1$ original PBs each contains $\left\lceil \frac{M}{N_{PB}} \right\rceil$OFDM symbols while the ${N_{PB}}^{th}$ original PB contains $M-\left\lceil \frac{M}{N_{PB}} \right\rceil * (N_{PB}-1)$ OFDM symbols from the initial payload and $-\left\lceil \frac{M}{N_{PB}} \right\rceil * (N_{PB}-M)$ padding OFDM symbols. Figure 16 shows another example initial payload to be segmented into multiple original PBs for low latency transmission, in particular, under the second example of Option (1) of preparing OFDM symbols, according to an

embodiment of the present disclosure. In ‘this example, the initial payload with 83 OFDM symbols may be segmented into four original PBs, the first 3 original PBs each containing 21 OFDM symbols while the 4th original PB containing 20 OFDM symbols and 1 padding OFDM symbol.

[108] Figure 17 shows an example transmitter processing 1700 used to process a data field per resource unit for a single user, in particular, under Option (1) of preparing OFDM symbols, according to an embodiment of the present disclosure. The transmitter processing may start at a Pre-FEC PHY Padding unit where redundant information is added to the data bits before the data is output to a Scrambler for scrambling the data bits to reduce long runs of identical bits on the transmission layer. An FEC encoder unit then encodes the data bits using forward error correction code such as BCC encoder before the encoded data is output to a Post-FEC PHY Padding unit to add padding bits such that the number of bits match the number of bits required for a symbol.

[109] A Stream Parser unit then divides the encoded bits into multiple blocks that are sent through multiple RUs correspondingly. The block of the encoded bits of each RU is sent to a Constellation Mapper unit. The BCC Interleaver unit may be omitted depending on the employed FEC code type. The Constellation Mapper unit maps respective blocks of the encoded bits into constellation points or complex numbers (herein referred to as modulation symbols). Optionally, in some RUs, a CSD per SS unit transforms the spatial diversity of the OFDM subcarriers into frequency diversity to avoid intersymbol interference.

[110] Subsequently, the blocks will be sent to a Spatial and Frequency Mapper unit to map onto multiple transmit chains. Each transmit chain is broken into original PBs before it is sent to an Inverse Fourier Discrete Fourier Transform (IDFT) unit. Each IDFT unit converts OFDM subcarriers on the transmit chain, which are frequency-domain data, into time-domain data for transmission. The time-domain data of the IDFT unit is then sent to an Insert Guard Interval (GI) And Window unit to insert GI at the start of each OFDM symbol in the transmit chain where each OFDM symbol may also be windowed to minimize adjacent channel interference. The time-domain data in each transmit chain is then sent to an Analog and Radio Frequency (RF) unit to prepare the data for transmission through an antenna.

[111] Under Option (2), the OFDM symbols within each original PB is prepared in a similar manner as in IEEE802.11be EHT. Figure 18 shows example original PBs prepared

by an AP for low latency transmission, in particular, under Option (1) of preparing OFDM symbols, according to an embodiment of the present disclosure. A PSDU that will be contained in an original PB is passed from MAC layer to PHY layer, with partial pre-FEC padding bits on the MAC layer appended behind. A Service field is added ahead of the appended PSDU on the PHY later is the PSDU would be contained in the first original PB. After that, the pre-FEC padding bits on PHY layer will be appended behind. Those bits will be input to FEC encoder, and output as coded bits. Post-FE padding bits will be appended after the coded bits, and used to construct OFDM symbols in an original PB. In other words, multiple PSDUs may be contained in the payload.

[112] Each PSDU contained in the original PB may be of different length. The AP may carefully plan the original PBs using multiple PSDUs with similar length to avoid large number of padding bits when mapping to original PBs. Advantageously, in this Option (2), as data carried by each PSDU for a non-AP STA is independent from each other, so even if there is any original PB being given up due to LL traffic, the data of other PBs are not affected.

[113] Figure 19 shows an example transmitter processing 1900 used to process a data field per resource unit per original PB for a single user, in particular, under Option (2) of preparing OFDM symbols, according to an embodiment of the present disclosure. The transmitter processing may start at a Pre-FEC PHY Padding unit where redundant information is added to the data bits before the data is output to a Scrambler for scrambling the data bits to reduce long runs of identical bits on the transmission layer. An FEC encoder unit then encodes the data bits us using forward error correction code such as BCC encoder before the encoded data is output to a Post-FEC PHY Padding unit to add padding bits such that the number of bits match the number of bits required for a symbol.

[114] A Stream Parser unit then divides the encoded bits into multiple blocks that are sent through multiple RUs correspondingly. The block of the encoded bits of each RU is sent to a Constellation Mapper unit. The BCC Interleaver unit may be omitted depending on the employed FEC code type. The Constellation Mapper unit maps respective blocks of the encoded bits into constellation points or complex numbers (herein referred to as modulation symbols). Optionally, in some RUs, a CSD per SS unit transforms the spatial diversity of the OFDM subcarriers into frequency diversity to avoid intersymbol interference.

[115] Subsequently, the blocks will be sent to a Spatial and Frequency Mapper unit to map onto multiple transmit chains. Each transmit chain is sent to an Inverse Fourier Discrete Fourier Transform (IDFT) unit. Each IDFT unit converts OFDM subcarriers on the transmit chain, which are frequency-domain data, into time-domain data for transmission. The time-domain data of the IDFT unit is then sent to an Insert Guard Interval (GI) And Window unit to insert GI at the start of each OFDM symbol in the transmit chain where each OFDM symbol may also be windowed to minimize adjacent channel interference. The time-domain data in each transmit chain is then sent to an Analog and Radio Frequency (RF) unit to prepare the data for transmission through an antenna.

[116] In an UHR PPDU that contains multiple original PBs, parameters relating to LL traffic/transmission (hereinafter may referred to as LL parameters) may be indicated in the preamble for a non-AP STA to process the data field. Figure 20 shows an example UHR PPDU format 2000 according to an embodiment of the present disclosure. The UHR PPDU 2000 may include a L-STF, a L-LTF, a L-SIG field, a RL-SIG field, a U-SIG field, a UHR-SIG field, a UHR-STF, a UHR-LTF and a Data field comprising multiple PBs. LL parameters may be included in U-SIG field and/or UHR SIG field and may include (i) a number of original PBs (N_{PB}) and/or a length of an original PB, (ii) transmit parameters for LL traffic, and (iii) LL traffic identification. Table 1 shows various signal fields contained in a U-SIG field of a UHR PPDU according to an embodiment of the present disclosure, where “Disregard” and “Validate” bits in 802.11be are used as a LL Parameter field. Table 2 shows various signal fields contained in a Common field of a UHR-SIG field of a UHR PPDU according to an embodiment to the present disclosure, where “Disregard” bits in 802.11be are used as a LL Parameters.

U-SIG part	**Bit**	**Field**
U-SIG-1	B0-B2	PHY Version Identifier
	B3-B5	BW
	B6	UL/DL
	B7-B12	BSS Color
	B13-B19	TXOP
	B20-B25	LL Parameters
U-SIG-2	B0-B1	PPDU Type and Compression Mode
	B2	Validate
	B3-B7	Punctured Channel Information

	B8	Validate
	B9-B10	EHT-SIG MCS
	B11-B15	Number Of EHT-SIG Symbols
	B16-B19	Cyclic Redundancy Check (CRC)
	B20-B25	Tail

[Table 1]

Bit	**Field**
B0-B3	Spatial Reuse
B4-B5	GI+LTF Size
B6-B8	Number Of UHR-LTF Symbols
B9	LDPC Extra Symbol Segment
B10-B11	Pre-FEC Padding Factor
B12	PE Disambiguity
B13-B16	LL Parameters
B17-end	RU Allocation + CRC + Tail

[Table 2]

[117] In one case, if a non-AP STA is a receiver of both the UHR PPDU and a LL traffic, transmit parameters for the LL traffic may be same as the transmit parameters for the original data of the UHR PPDU, so there is no need to signal the transmit parameter for the LL traffic.

[118] When a non-AP STA receives an UHR PPDU that contains multiple original PBs, it may have more than one buffers to process the UHR PPDU, for example, one buffer to store and process the original data transmitted by the UHR PPDU and another buffer to store and process the potential LL traffic. It will be appreciated by those skilled in the art that the buffers here at least may be implemented as a part of circuitry.

[119] In the following paragraphs, a first embodiment of the present disclosure is described, where a LL traffic arrives at an AP during on on-going UHR PPDU transmission with multiple original PBs and the LL traffic is targeted at a receiver (non-AP STA) of the UHR PPDU, and the UHR PPDU remains within its indicated PPDU length.

[120] In the first embodiment, when LL traffic for a receiver (non-AP STA) of the UHR PPDU arrives at an AP, there are three options to transmit the LL traffic: (1) in the LL PB, only the LL traffic is transmitted on the RU/MRU assigned to the receiver (non-AP STA), and the full bandwidth original PBs transmission is put off; and (2) in the LL PB, the LL traffic is transmitted on the RU/MRU assigned to the receive (non-AP STA), but the transmission on other RU/MRU to other non-AP STAs are not affected; (3) in the LL PB, the LL traffic is transmitted on a larger RU/MRU compared with the RU/MRU assigned to the non-AP STA. The full bandwidth original PBs transmission is put off.

[121] Figure 21 shows a schematic diagram illustrating a first example low latency transmission procedure (Option (1)) of the first embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively. In this example, a LL traffic for STA2 arrives when the AP is transmitting the original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. Under Option (1), when the LL PB is transmitted on RU2, the full bandwidth original PBs during the block time duration is put off, therefore the UHR PPDU contains dummy bits on RU1.

[122] After the LL traffic finishes, subsequent original PBs will be transmitted if the indicated PPDU length allows. In this case, Original PB 2 and Original PB 3 are transmitted to STA1 and STA2 as usual after the LL PB is transmitted to STA2. However, the transmission of Original PB 4 may be given up as the signal has exceeded the indicated PPDU length after the transmission of the Original PB 3 on both RU1 and RU2. This first example low latency transmission according to the first embodiment is easy to implement.

[123] Figure 22 shows a schematic diagram illustrating a second example low latency transmission procedure (Option (2)) of the first embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively. In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. Under Option (2), when the LL PB is transmitted

on RU2, the transmission of subsequent original PBs (Original PBs 2-4) on other RU such as RU1 are not affected, hence during the block time duration, Original PB 2 is transmitted on RU1 to STA1. After the LL PB is transmitted, subsequent original PBs on RU2 will be transmitted if the indicated PPDU length allows. In this case, Original PB 2 and Original PB 3 are transmitted on RU2 to STA2. However, the transmission of Original PB 4 may be given up as the signal has exceeded the indicated PPDU length after the transmission of the Original PB 3 on RU2. This second example low latency transmission according to the first embodiment eliminates the waste on original PBs on RU/MRU assigned to other non-AP STAs.

[124] Figure 23 shows a schematic diagram illustrating a third example low latency transmission procedure (Option (3)) of the first embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively. In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP then inserts LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. Under Option (3), when the LL PB is transmitted on RU2, the full bandwidth original PBs during the block time duration is put off.

[125] The first OFDM symbol of the LL PB is transmitted only on RU2 assigned to STA2 and a dummy bit is transmitted on the other RU (RU1) while the remaining OFDM symbols of the LL PB are transmitted on a larger RU/MRU (e.g., RU1+RU2). Each non-AP STA on the larger RU/MRU (STA1, STA2 in this case), when receive the signal, will determine whether a PB is a LL PB and whether the LL traffic is for it based on the first OFDM symbol.

[126] After the LL traffic finishes, subsequent original PBs will be transmitted if the indicated PPDU length allows. In this case, Original PB 2 and Original PB 3 are transmitted to STA1 and STA2 as usual after the LL PB is transmitted to STA2. However, the transmission of Original PB 4 is given up as the signal has exceeded the indicated PPDU length after the transmission of the Original PB 3 on both RU1 and RU2. This first example low latency transmission according to the first embodiment is easy to implement.

[127] This third example low latency transmission according to the first embodiment allows that more frequency resources can be assigned to LL traffic, and the block time duration decided by the AP may be shorter correspondingly.

[128] Figure 24 shows an example UHR-SIG field 2400 of the UHR PPDU used in the third example low latency transmission procedure (Option (3)) of the first embodiment of the present disclosure. The UHR-SIG field comprises a Common field and a User Specific field. The Common field further comprises a U-SIG overflow, a RU Allocation field, Cyclic Redundancy Check (CRC) bits and tail bits. The RU Allocation field further comprises a LL RU Allocation subfield and a RU Allocation subfield. The LL RU Allocation subfield may be indicated by Disregard bits (26*8 entries in 11be). In the case of the third example low latency transmission procedure (Option (3)) shown in Figure 23, the RU Allocation subfield may indicate the RU1 allocation and RU2 allocation to STA1 and STA2, respectively. The User specific field comprises an encoding block with 2 User Fields, CRC bits and Tail bits for each user, except the final user encoding block comprising 1 or 2 User fields, CRC bits and Tail bits, and padding bits (if needed). In this example, the first encoding block comprises a LL User field and a User field 1. The position of LL RU Allocation of Common field and LL User field in User Specific field corresponds to each other, as indicated by the arrow 2402.

[129] Figure 25 shows a flow chart 2500 illustrating a low latency transmission procedure implemented by an AP according to the first embodiment of the present disclosure. In step 2502, an integer i is set to 1, an integer l is set to 0 and an integer N is set to the number of original PBs that can be transmitted by the indicated PPDU length. In step 2504, a step of transmitting i^{th} original PB is carried out. In step 2506, a step of determining if a next PB is a LL PB. If the next PB is a LL PB, step 2508 is carried out; otherwise step 2512 is carried out. In step 2508, a step of transmitting $(l+1)^{th}$ LL PB is carried out. In step 2510, a step of incrementing l value by 1 is carried out and the process returns to step 2506. In step 2512, a step of incrementing i value by 1 is carried out. In step 2514, a step of determining whether $i+1 \leq N$ is true is carried out. If it is true, the process returns to step 2504; otherwise the process may end.

[130] Figure 26 shows a flow chart 2600 illustrating a low latency transmission procedure implemented by a non-AP STA according to the first embodiment of the present disclosure. In step 2602, an UHR PPDU with multiple PBs is received. In step 2604, an integer i is set to 1 and a step of obtaining the number of PBs, N , from the preamble of

the UHR PPDU is carried out. In step 2606, the first OFDM symbol of i^{th} PB is received and decoded. Next, in step 2608, a step of incrementing i value by 1 is carried out. In step 2610, a step of determining whether the PB is an original PB is carried out. If the PB is an original PB, then step 2616 is carried out; otherwise step 2612 is carried out. In step 2616, a step of storing and processing the data carried by the PB into non-LL buffer is carried out. In step 2612, a step of determining whether the PB is a LL PB for the non-AP STA is carried out. If it is a LL PB for the non-AP STA, step 2614 is carried out; otherwise the process returns to step 2606. In step 2614, a step of storing and processing the data carried by the PB into LL buffer is carried out. In step 2618, a step of determining whether $i + 1 \leq N$ is true is carried out. If it is true, the process returns to step 2606; otherwise the process may end.

[131] In the following paragraphs, a second embodiment of the present disclosure is described, where a LL traffic arrives at an AP during on on-going UHR PPDU transmission with multiple original PBs and the LL traffic is targeted at a non-AP STA which is not a receiver of the UHR PPDU, and the UHR PPDU remains within its indicated PPDU length.

[132] In the second embodiment, when LL traffic for a non-AP STA which is not a receiver of the UHR PPDU arrives at an AP, there are two options to transmit the LL traffic: (1) the LL PB is transmitted on a full bandwidth/largest RU the non-AP STA can receive of a LL PB, and the full bandwidth original PBs transmission is put off; or alternatively (2) the LL PB is transmitted by an RU/MRU of a LL PB and the transmission on other RU/MRU to other non-AP STAs are not affected.

[133] Figure 27 shows a schematic diagram 2700 illustrating a first example low latency transmission procedure (Option (1)) of the second embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively (not shown). In this example, a LL traffic for STA3 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the original PB 1. The block time duration is decided by the AP. Under Option (1), when the LL PB is transmitted on a full bandwidth/largest RUs that STA3 can receive of a LL PB. In this case, STA3 can receive the full bandwidth (RU1 + RU2) so the LL PB is transmitted on a full bandwidth. The full bandwidth original PBs during the block time duration is put off.

[134] After the LL traffic finishes, subsequent original PBs will be transmitted if the indicated PPDU length allows. In this case, Original PB 2 and Original PB 3 are transmitted to STA1 and STA2 as usual after the LL PB is transmitted to STA3. However, the transmission of Original PB 4 is given up as the signal has exceeded the indicated PPDU length after the transmission of the Original PB 3.

[135] Figure 28 shows an example UHR-SIG field 2800 of an UHR PPDU for the first example low latency transmission procedure (Option (1)) of the second embodiment of the present disclosure. The UHR-SIG field comprises a Common field and a User Specific. The transmission parameters for LL traffic may be indicated in the User field of UHR-SIG field. The User specific field comprises an encoding block with 2 User Fields, CRC bits and Tail bits, except the final user encoding block comprising 1 or 2 User fields, CRC bits and Tail bits, and padding bits (if needed). Table 3 shows various signal subfields contained in a user field in a User Specific field of a UHR-SIG field of a UHR PPDU for low latency transmission according to an embodiment to the present disclosure.

Bit	**Subfield**	**Number of bits**
B0-B10	STA-ID	11
B11-B14	MCS	4
B15	LL Indication	1
B16-B19	NSS	4
B20	Beamformed	1
B21	Coding	1

[Table 3]

[136] The MCS assigned to the non-AP STA (STA3), at which the LL traffic is targeted, must be different from what is assigned to other non-AP STAs which are the receiver of the UHR PPDU to serve as a LL identification. Through the LL Indication subfield, the non-STA (e.g., STA3 in Figure 27) knows it is a potential receiver of a LL traffic, and transmit parameters indicated in the User field are for the LL traffic transmission.

[137] Figure 29 shows a schematic diagram 2900 illustrating a second example low latency transmission procedure (Option (2)) of the second embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of multiple original PBs, for example, four original PBs (Original

PBs 1-4),wherein each original PB is addressed to STA1 and STA2 on RU1 and RU2, respectively (not shown). In this example, a LL traffic for STA3 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after completing the transmission of Original PB 1. The block time duration may be decided by the AP. Under Option (2), when the LL PB is transmitted on one of the RUs, in this case, for example, RU2, the transmission of subsequent original PBs (Original PBs 2-4) on other RUs such as RU1 will not be affected, hence during the block time duration, original data that is carried by RU1 of Original PB2 is transmitted on RU1 of LL PB to STA1. After the LL PB is transmitted, subsequent original PBs will be transmitted if the indicated PPDU length allows. In this example, Original PB 2 and Original PB 3 may be transmitted to both STA1 and STA2. However, the transmission of Original PB 4 may be given up if the signal has exceeded the indicated PPDU length after the transmission of the Original PB 3. This second example low latency transmission according to the second embodiment eliminates the waste on original PBs on RU/MRU assigned to other non-AP STAs.

[138] In the preamble for example using UHR-SIG field, information (e.g., transmit parameters and RU/MRU) for the possible LL traffic transmission may be indicated to all non-AP STA. A non-AP STA receiving such information may keep decoding the first OFDM symbol of each PB to receive the LL traffic. In particular, the format UHG-SIG field used for this second example low latency transmission procedure (Option (2)) of the second embodiment of the present disclosure is identical to the format shown in Figure 24, and the position of LL RU Allocation of the Common field and User field for the potential receiver non-AP STA in User Specific field corresponds to each other.

[139] In a scenario where a large number of non-AP STAs are indicated as potential receivers of a potential LL traffic, those non-AP STAs may need to keep listening to the channel until end of the UHR PPDU, which may cause high power consumption. In order to address this, the AP may schedule service period for a non-AP STA prior to a transmission of UHR PPDU containing multiple PBs. During a scheduled service period, a non-AP STA may need to keep listening; after a scheduled service period ends, a non-AP STA may stop listening and enter sleep status. The scheduling of service period may be determined based on artificial intelligence/machine learning prediction by the AP.

[140] Figure 30 shows a flow chart 3000 illustrating a low latency transmission procedure implemented by a non-AP STA, which is not a target receiver of an UHR PPDU, according

to the second embodiment of the present disclosure. In step 3002, an UHR PPDU not targeting at the non-AP STA but indicating potential LL traffic for the non-AP STA is obtained. In step 3004, an integer i is set to 1 and a step of obtaining the number of PBs N is carried out. In step 3006, the first OFDM symbol of i^{th} PB is received and decoded. In step 3008, a step of incrementing i value by 1 is carried out. In step 3010, a step of determining if the PB is a LL PB for the non-AP STA is carried out. If the PB is a LL PB for the non-AP STA, step 3012 is carried out; otherwise the process return to step 3006. In step 3012, a step of storing and processing the data carried by the PB into LL buffer is carried out. In step 3014, a step of determining whether $i \leq N$ is true is carried out. If it is true, the process returns to step 3006; otherwise the process may end.

[141] The following paragraphs describe three LL traffic identification options to specify a LL PB carrying LL traffic in an UHR PPDU carrying multiple original PBs and assist a STA to identify LL PB and LL traffic among multiple original PBs: (1) a first OFDM symbol is modulated in a different way from other OFDM symbols; (2) all OFDM symbols are modulated with a constellation mapper indicated in preamble; (3) a subheader may be contained in each PB.

[142] Figure 31 shows an example UHR PPDU format per RU/MRU 3100 implementing the first LL traffic identification option according to an embodiment of the present disclosure. In an RU, constellation mapper for the original data transmitted to STA 1 is indicated as Binary Phase-shift keying (BPSK), and Transmit Parameters for a LL traffic is same as the Transmit Parameters for the original data. The first OFDM symbol of the LL PB is modulated with rotated constellation mapper (e.g., Q-BPSK) on a same RU/MRU, different from other OFDM symbols of the LL PB. Non-AP STAs may determine whether a received PB is a LL PB when demodulate the first OFDM symbol. Value of rotation phase may be a predefined number, or a number indicated in LL Parameters of preamble. Non-AP STAs may tell a LL PB apart even the LL traffic is transmitted with the same Transmit Parameters of Original PB.

[143] Figure 32 shows an example UHR PPDU format per RU/MRU 3200 implementing the second LL traffic identification option according to an embodiment of the present disclosure. The preamble indicates the constellation mapper to be used to modulate all OFDM symbols. In other words, in a LL PB, all OFDM symbols are modulated with constellation mapper that has been indicated in LL Parameters of preamble. Non-AP STAs may determine whether a received PB is a LL PB by blind decoding when

demodulate the first OFDM symbol. The constellation mapper used by a LL PB must be different than the original PBs. In this example, the MCS for the original data transmitted to STA1 is indicated as MCS (1/2R, 16-QAM) whereas the MCS for a LL traffic is indicated as MCS0 (1/2R, BPSK).

[144] Figure 33 shows an example UHR-SIG field 3300 of the UHR PPDU 3200 of Figure 32. The UHR-SIG field comprises a Common field and a User Specific field. The User specific field comprises an encoding block with 2 User Fields, CRC bits and Tail bits for each user, except the final user encoding block comprising 1 or 2 User fields, CRC bits and Tail bits, and padding bits (if needed). In this example, the first encoding block contains 1 LL User field and a User field 1. The transmit parameters for LL traffic may be indicated in the LL User field. The LL User field is broadcasted to all non-AP STAs. Table 4 shows various signal subfields contained in an LL user field in a User Specific field of a UHR-SIG field of a UHR PPDU for low latency transmission according to an embodiment to the present disclosure. The LL STA-ID may be set as a number that is reserved in 11be (e.g., 2010) to let non-AP STAs know that this is a User field to indicate transmit parameters for a LL traffic (STA_ID values between 2008 and 2044 are reserved in 11be).

Bit	**Subfield**	**Number of bits**
B0-B10	LL STA-ID	11
B11-B14	MCS	4
B15	Reserved	1
B16-B19	NSS	4
B20	Beamformed	1
B21	Coding	1

[Table 4]

[145] Figure 34 shows an example LL PB 3400 implementing the third LL traffic identification option according to an embodiment of the present disclosure. A PB, in this example, a 80 MHz PB, may start with a subheader consisted of one or more OFDM symbols on each 20 MHz subchannel. The UHR-SIG field comprises a Common field and a User Specific field. In the subheader, information including LL identification, Target receiver and LL RU/MRU may be indicated. A non-AP STA receiving the UHR PPDU may

need to decode the subheader of each PB on a certain 20 MHz subchannel where its allocated RU/MRU allocated on, and determines whether the PB is LL PB.

[146] In the following paragraphs, a third embodiment of the present disclosure is described, where a LL traffic arrives at an AP during on on-going UHR PPDU transmission with multiple original PBs and the LL traffic is targeted at a receiver (non-AP STA) of the UHR PPDU, and the non-AP STA when it receives LL PB may update PPDU length to receive more original data, for example, original PBs beyond the original indicated PPDU length that would otherwise be given up.

[147] The non-AP STA may update the PPDU length by following equation (1):

$$\text{Updated PPDU length} = \text{Original PPDU length} + N_{LLPB} * L_{PB} \quad \text{equation (1)}$$

where original PPDU length is the value of PPDU length indicated in L-SIG field, N_{LLPB} is the number of LL PB(s) the non-AP STA received and L_{PB} is the length of an original PB indicated in LL Parameters of U-SIG/UHR-SIG field.

[148] Figure 35 shows a schematic diagram 3500 illustrating a low latency transmission procedure according to the third embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively (not shown). In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. In this case, the LL PB is transmitted on full bandwidth to STA2, and the full bandwidth original PBs during the block time duration is put off. STA1 and STA2 may update the PPDU length to the new updated PPDU length.

[149] After the LL traffic finishes, the AP transmitting the UHR PPDU keep transmitting the original data if TXOP allows. Advantageously, all original data may be transmitted if TXOP allows. In this case, all original PBs after LL PB are transmitted to STA1 and STA2.

[150] Figure 36 shows a schematic diagram 3600 illustrating another example low latency transmission procedure according to the third embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is

segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively. In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. When the LL PB is transmitted on RU2, the full bandwidth original PBs during the block time duration is put off, therefore the UHR PPDU contains dummy bits on RU1. Upon LL traffic transmission, all target receiver non-AP STAs of the UHR PPDU, STA1 and STA2, need to update the PPDU length to the updated PPDU length, so all non-AP STAs may receive all the original data.

[151] After the LL traffic finishes, the AP transmitting the UHR PPDU keep transmitting the original data if TXOP allows. In this case, all original PBs after LL PB are transmitted to STA1 and STA2 as usual.

[152] Figure 37 shows a schematic diagram 3700 illustrating yet another example low latency transmission procedure according to the third embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively. In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. When the LL PB is transmitted on RU2, the full bandwidth original PBs during the block time duration is put off. Upon LL traffic transmission, all target receiver non-AP STAs of the UHR PPDU, STA1 and STA2, need to update the PPDU length to the updated PPDU length, so all non-AP STAs may receive all the original data.

[153] The first OFDM symbol of the LL PB is transmitted only on RU2 assigned to STA2 and a dummy bit is transmitted on the other RU (RU1) while the remaining OFDM symbols of the LL PB are transmitted on a larger RU/MRU (e.g., RU1+RU2). Each non-AP STA on the larger RU/MRU (STA1, STA2 in this case), when receive the signal, will determine whether a PB is a LL PB and whether the LL traffic is for it based on the first OFDM symbol.

[154] After the LL traffic finishes, the AP transmitting the UHR PPDU keep transmitting the original data if TXOP allows. In this case, all original PBs after LL PB are transmitted to STA1 and STA2 as usual.

[155] Figure 38 shows a schematic diagram 3800 illustrating a fourth example low latency transmission procedure according to the third embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively. In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP then inserts a LL PB for a block time into the array of original PBs to transmit the LL PB immediately after the Original PB 1. The block time duration is decided by the AP. When the LL PB is transmitted on RU2, the transmission of subsequent original PBs (Original PBs 2-4) on other RU such as RU1 are not affected. In other words, the AP transmitting the UHR PPDU keep transmitting the original data on RU1 to STA1, in this case, Original PB 2 during the block time duration.

[156] Upon LL traffic transmission, only the target receiver non-AP STA of the LL traffic and the non-AP STAs whose data is affected, in this case STA2, need to update the PPDU length.

[157] After the LL traffic finishes, the AP transmitting the UHR PPDU keep transmitting the original data on RU2 if TXOP allows. Non-AP STAs that are not target receiver of the LL traffic or non-AP STAs whose data is not affected, in this case, may stop receiving at the original PPDU length indicated by the L-SIG field. The AP may transmit dummy bits when there is no other original data left to transmit on a RU.

[158] Figure 39 shows a flow chart 3900 illustrating the fourth low latency transmission procedure of Figure 38 implemented by a non-AP STA according to the third embodiment of the present disclosure. In step 3902, an UHR PPDU with multiple PBs is received. In step 3904, an integer i is set to 1 and a step of obtaining the number of PBs N from the preamble of the UHR PPDU is carried out. In step 3906, the first OFDM symbol of i^{th} PB is received and decoded. In step 3908, a step of incrementing i value by 1 is carried out. In step 3910, a step of determining whether the PB is an original PB is carried out. If the PB is an original PB, step 3912 is carried out; otherwise step 3914 is carried out. In step 3912, a step of storing and processing the data carried by the PB into non-LL buffer is

carried out. In step 3914, a step of determining whether the PB is a LL PB for the non-AP STA is carried out. If it is a LL PB for the non-AP STA, step 3916 is carried out; otherwise the process returns to step 3906. In step 3916, a step of storing and processing the data carried by the PB into LL buffer is carried out. In step 3918, a step of incrementing N value by 1 is carried out. In step 3920, a step of determining whether $i + 1 \leq N$ is true is carried out. If it is true, the process returns to step 3906; otherwise the process may end.

[159] In the following paragraphs, a fourth embodiment of the present disclosure is described, where a specific RU is reserved for LL traffic during ongoing UHR PPDU transmission.

[160] An AP may transmit a LL traffic by reserving frequency domain resource unit (RU) for LL traffic during an ongoing UHR PPDU transmission to a non-AP STA. The AP may insert LL traffic on an assigned LL RU/MRU at starting time of any OFDM symbol after it arrives. The AP may indicate LL RU/MRU and transmission parameters for the LL traffic in the preamble of the UHR PPDU. A non-AP STA receiving such information in the UHR PPDU will keep listening to the LL RU/MRU until end of the UHR PPDU. The AP may determine whether to reserve an RU/MRU for LL traffic based on artificial intelligence/machine learning prediction. Advantageously, the LL traffic can be transmitted at starting time of any OFDM symbol during payload transmission of the UHR PPDU without collision, which is highly efficient, easy to implement and reliable (transmission guaranteed) especially when LL traffic may happen frequently.

[161] According to this embodiment, a LL RU/MRU is assigned to a specific non-AP STA. The specific non-AP STA can be (1) a target receiver non-AP STA of the UHR PPDU, in which case, the LL RU/MRU is assigned together with an RU/MRU on which the original data is transmitted to the receiver non-AP STA, and the receiving non-AP STA receiving such information may need to keep listening to the LL RU/MRU while receive the original data; or (2) a non-AP STA that is not a receiver of the UHR PPDU, in which case, the non-AP STA receiving such information may need to keep listening to the LL RU/MRU. The merit of such assignment of LL RU/MRU to a specific non-AP STA is that it is easy to implement.

[162] The LL RU/MRU and transmission parameters for LL traffic may be indicated in UHR-SIG field. The UHR-SIG field and the subfields of the UHR-SIG field used to indicate

the LL RU/MRU and transmission parameters for LL traffic is shown in Figure 28 and Table 3, respectively.

[163] Figure 40 shows a first example UHR PPDU 4000 for low latency transmission according to the fourth embodiment of the present disclosure. The UHR PPDU is targeted at STA1 and STA3. RU1 is assigned to STA1; LL RU is assigned to STA2; RU2 is assigned to STA3. During the transmission, non-LL traffic is transmitted on RU1 and RU2 to STA1 and STA3, correspondingly, while a LL traffic arrives in the midst and is transmitted on LL RU to STA2.

[164] Alternatively, a LL RU/MRU is broadcasted to all non-AP STAs. The LL RU/MRU is broadcasted so every non-AP STA may need to keep listening to the LL RU/MRU and determine whether a traffic carried by an OFDM symbol is targeted for it. In this case, a LL traffic targeted at a non-AP STA may need an identification to differentiate from other LL traffic targeted at other non-AP STAs. The identification may be an indicated MCS, or indicated in subheader. Figure 41 shows an example UHR-SIG field 4100 of an UHR PPDU according to the fourth embodiment of the present disclosure. The UHR-SIG field 4100 comprises a Common field and a User Specific field. The User specific field comprises an encoding block with 2 User Fields, CRC bits and Tail bits for each user, except the final user encoding block comprising 1 or 2 User fields, CRC bits and Tail bits, and padding bits (if needed). In this example, the last encoding block comprises a User field N, a LL User field, a MCS list field, the MCS list field comprising a MCS subfield for each non-AP STA, the MCS for each STA corresponding to the sequence of the User fields in the User Specific field. For associated non-AP STAs that are target receivers of the UHR PPDU, transmit parameters may be indicated by a LL User field together with a MCS list. For associated non-AP STAs that are not a target receiver of the UHR PPDU, transmit parameters may be indicated by a User field with LL indication.

[165] Importantly, in this alternative embodiment, on the LL RU/MRU, the AP may also send multiple LL traffics to multiple non-AP STAs successively. Such low latency transmission needs more signalling than assigning of LL RU/MRU to a specific non-AP STA but is highly efficient. Figure 42 shows a second example UHR PPDU 4200 for low latency transmission according to the fourth embodiment of the present disclosure. The UHR PPDU 4200 is targeted at STA1 and STA2. RU1 is assigned to STA1; RU2 is assigned to STA2; LL RU is broadcasted. During the transmission, non-LL traffic is transmitted on RU1 and RU2 to STA1 and STA2 correspondingly, while LL traffic for STA1

and LL traffic for STA3 arrived in the midst is transmitted on LL RU to STA1 and STA3 correspondingly.

[166] Figure 43 shows a flow chart 4300 illustrating a low latency transmission procedure implemented by an AP according to the fourth embodiment of the present disclosure. In step 4302, a step of reserving a LL RU/MRU for LL traffic in an UHR PPDU. In step 4304, a step of transmitting the UHR PPDU. In step 4306, a step of determining whether there is a LL traffic during the transmission. In step 4308, a step of transmitting LL traffic on the LL RU/MRU and the process may end.

[167] Figure 44 shows a flow chart 4400 illustrating a low latency transmission procedure implemented by a non-AP STA according to the fourth embodiment of the present disclosure. In step 4402, an UHR PPDU indicating that there could be a LL traffic transmitted on a LL RU/MRU for the non-AP STA is received. In step 4404, a step of determining whether there is data targeted at the non-AP STA transmitted by the UHR PPDU. If there is data targeted at the non-AP STA, step 4406 is carried out; otherwise step 4408 is carried out. In step 4406, the data is received on the assigned RU/MRU and the non-AP STA keeps listening to the LL RU/MRU. In step 4408, the non-AP STA only keeps listening to the LL RU/MRU. In step 4410, a step of determining whether there is data transmitted on the LL RU/MRU. If there is data transmitted on the LL RU/MRU, step 4412 is carried out, otherwise the process may end. In step 4412, a step of determining whether the data is a LL traffic for the non-AP STA is carried out. If the data is a LL traffic for the non-AP STA, step 4414 is carried; otherwise the process may end. In 4414, a step of storing and processing the data into LL buffer is carried out and the process may end.

[168] In following paragraphs, a fifth embodiment of the present disclosure is described, where the ongoing transmission of the UHR PPDU is aborted after a LL traffic arrives, and separate PPDUs carrying the LL traffic and subsequent original data/PBs, each with a shorted preamble, is transmitted.

[169] In particular, in a TXOP, an AP may abort an ongoing transmission of an UHR PPDU containing multiple PBs and transmit a LL traffic in a PPDU with a shorted preamble. The shorted preamble may be designed contain L-STF, L-LTF, L-SIG, RL-SIG, UHR-STF, UHR-LTF fields. Other necessary information may be indicated in the preamble of the UHR PPDU. After transmission of LL traffic ends, the AP may continue to transmit the original PBs in a new UHR PPDU with a shortened preamble.

[170] Figure 45 shows a schematic diagram 4500 illustrating a low latency transmission procedure according to the fifth embodiment of the present disclosure. An AP transmits an UHR PPDU to STA1 and STA2, in which the data field is segmented to an array of four original PBs (Original PBs 1-4, Original PB 4 not shown), each original PB addressed to STA1 and STA2 on RU1 and RU2, respectively (not shown). In this example, a LL traffic for STA2 arrives when the AP is transmitting the Original PB 1, the AP abort the transmission of the UHR PPDU after transmitting the Original PB1. The AP then transmit a second PPDU carrying a shortened preamble and the LL PB, and then transmit a third PPDU carrying also a shortened preamble and subsequent Original PBs to keep transmitting the original data if TXOP allows. In this case, only third PPDU carries Original PB 2 and Original PB 3 only to STA1 and STA2 and Original PB 4 may be given up as the TXOP does not allow transmission of any additional data.

[171] Figure 46 shows an example configuration of a communication apparatus 4600. The communication apparatus 4600 is implemented as an AP or non-AP STA for low latency transmission in accordance with various embodiments of the present disclosure. The communication apparatus 4600 comprises a power source 4602, a memory 4604, a central processing unit (CPU) 4606 comprising at least one process, a secondary storage 4608, a wired interface (I/F) 4610 and a wireless I/F 4612. The memory 4604 may be a non-transitory computer-readable storage medium having stored therein data representing instructions executable by the at least one processor of the CPU 4606 to communicate with the wireless I/F 4612 to perform enhanced client discovery procedure according to various embodiments described in the present disclosure. The Wireless I/F 4612 comprises a MAC layer 4614 and a PHY layer 4616. The PHY layer 4616 connects with a radio transmitter (not shown), a radio receiver (not shown) and an antenna 4622 used for transmitting/receiving signals to/from other communication apparatuses (e.g., STAs). Alternatively, the communication apparatus 4600 may transmit/receive signals to/from other communication apparatus (e.g., STAs) via the Wired I/F 4610. The secondary storage 4608 may be configured to store AIDs of associated communication apparatus.

[172] The PHY layer 4616 may comprise a module (not shown) configured to modify the signal to perform the low latency transmission procedure according to various embodiments described above.

[173] The present disclosure can be realized by software, hardware, or software in cooperation with hardware. Each functional block used in the description of each embodiment described above can be partly or entirely realized by an LSI such as an integrated circuit, and each process described in each embodiment may be controlled partly or entirely by the same LSI or a combination of LSIs. The LSI may be individually formed as chips, or one chip may be formed so as to include a part or all of the functional blocks. The LSI may include a data input and output coupled thereto. The LSI here may be referred to as an IC, a system on a chip (SoC), a system LSI, a super LSI, or an ultra LSI depending on a difference in the degree of integration. However, the technique of implementing an integrated circuit is not limited to the LSI and may be realized by using a dedicated circuit, a general-purpose processor, or a special-purpose processor. In addition, an FPGA (Field Programmable Gate Array) that can be programmed after the manufacture of the LSI or a reconfigurable processor in which the connections and the settings of circuit cells disposed inside the LSI can be reconfigured may be used. The present disclosure can be realized as digital processing or analogue processing. If future integrated circuit technology replaces LSIs as a result of the advancement of semiconductor technology or other derivative technology, the functional blocks could be integrated using the future integrated circuit technology. Biotechnology can also be applied.

[174] The present disclosure can be realized by any kind of apparatus, device or system having a function of communication, which is referred to as a communication apparatus.

[175] Some non-limiting examples of such a communication apparatus include a phone (e.g., cellular (cell) phone, smart phone), a tablet, a personal computer (PC) (e.g., laptop, desktop, netbook), a camera (e.g., digital still/video camera), a digital player (digital audio/video player), a wearable device (e.g., wearable camera, smart watch, tracking device), a game console, a digital book reader, a telehealth/telemedicine (remote health and medicine) device, and a vehicle providing communication functionality (e.g., automotive, airplane, ship), and various combinations thereof.

[176] The communication apparatus is not limited to be portable or movable, and may also include any kind of apparatus, device or system being non-portable or stationary, such as a smart home device (e.g., an appliance, lighting, smart meter, control panel), a vending machine, and any other “things” in a network of an “Internet of Things (IoT)”.

[177] The communication may include exchanging data through, for example, a cellular system, a wireless LAN system, a satellite system, etc., and various combinations thereof.

[178] The communication apparatus may comprise a device such as a controller or a sensor which is coupled to a communication device performing a function of communication described in the present disclosure. For example, the communication apparatus may comprise a controller or a sensor that generates control signals or data signals which are used by a communication device performing a communication function of the communication apparatus.

[179] The communication apparatus also may include an infrastructure facility, such as a base station, an access point, and any other apparatus, device or system that communicates with or controls apparatuses such as those in the above non-limiting examples.

[180] It will be understood that while some properties of the various embodiments have been described with reference to a device, corresponding properties also apply to the methods of various embodiments, and vice versa.

[181] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present disclosure as shown in the specific embodiments without departing from the spirit or scope of the disclosure as broadly described. The present embodiments are, therefore, to be considered in all respects illustrative and not restrictive.

CLAIMS

1. A first communication apparatus comprising:

circuitry, which in operation, is configured to generate a first signal comprising a plurality of segmented signals carrying a first type of data; and

a transmitter, which in operation, transmits the first signal to one or more second communication apparatuses,

wherein, in response to obtaining a second type of data from an upper layer by the circuitry when the transmitter is transmitting a segmented signal of the plurality of segmented signals:

the circuitry is configured to insert a second signal between the transmitted segmented signal and a successive segmented signal next to the transmitted segmented signal, the second signal carrying the second type of data; and

the transmitter transmits the second signal and continues transmitting successive segmented signals of the first signal starting from the segmented signal next to the transmitted segmented signal.

2. The first communication apparatus of claim 1, wherein the first type of data and the second type of data are directed to one of the one or more second communication apparatuses, the transmitter transmits the second signal on a first resource unit to the one of the one or more second communication apparatuses and the successive segmented signals either on the first resource unit or on both the first resource unit and a second resource unit to the one or more second communication apparatuses.

3. The first communication apparatus of claim 2, wherein the transmitter transmits one of the successive segmented signals on the second resource unit to another second communication apparatus of the one or more second communication apparatuses at a same time when the transmitter is transmitting the second signal on the first resource unit to the one of the one or more second communication apparatuses.

4. The first communication apparatus of claim 2, wherein the second signal comprises multiple OFDM symbols, and the transmitter transmits a first OFDM symbol of the multiple OFDM symbols on the first resource unit and the remaining OFDM symbols of the multiple OFDM symbols on both the first resource unit and the second resource unit to the one of the one or more second communication apparatuses.

5. The first communication apparatus of claim 1, wherein the second type of data is directed to a third communication apparatus, and the transmitter transmits the second signal to the third communication apparatus on one or more first resource units to the third communication apparatus and continues transmitting the successive segmented signals on the one or more first resource units to the one or more second communication apparatuses.

6. The first communication apparatus of claim 5, wherein the transmitter transmits one of the successive segmented signals on one or more second resource units at a same time when the transmitter is transmitting the second signal on the one or more first resource units to the third communication apparatus.

7. The first communication apparatus of any one of claims 1-6, wherein the first signal comprises a first signal field indicating a length of the first signal, and in response to obtaining the second type of data from the upper layer by the circuitry when the transmitter is transmitting the segmented signal:

the transmitter continues to further transmit one or more second successive segmented signals of the first signal next to the transmitted successive signals beyond on the indicated length of the first signal, wherein a number of the transmitted second successive segmented signals is based on a number or a length of the second signal.

8. The first communication apparatus of any one of claims 1-7, wherein the first signal comprises a second signal field indicating a transmit parameter for the second type of data.

9. The first communication apparatus of any one of claims 1-8, wherein the circuitry, when inserting the second signal into the first signal, is further configured to modulate the second signal using a process different from that used to modulate the first signal.

10. The first communication apparatus of claim 9, wherein the first signal comprises a third signal field indicating the process to modulate the second type of data.

11. The first communication apparatus of claim 1, wherein one or more first resource units are configured for transmitting the first type of data and a second resource unit are configured for transmitting the second type of data, the transmitter transmits the first signal on the one or more first resource units, and wherein, in response to obtaining the second type of data from the upper layer by the circuitry when the transmitter is transmitting the first signal:

the transmitter further transmits the second signal carrying the second type of data on the second resource unit.

12. The first communication apparatus of claim 11, wherein the second resource unit comprises a resource unit allocated to one of the one or more second communication apparatuses, and the transmitter transmits the first signal on the one or more first resource units to one or more other second communication apparatuses of the one or more second communication apparatuses and the second signal on the second resource unit to the one of the one or more second communication apparatus.

13. The first communication apparatus of claim 11, wherein the second resource unit is allocated to a third communication apparatus and the one or more first resource units are allocated to the one or more second communication apparatuses,, and the transmitter transmits the first signal on the one or more first resource units to the one or more second communication apparatuses and the second signal on the second resource unit to the third communication apparatus.

14. The first communication apparatus of claim 11, wherein the second type of data are directed to more than one other communication apparatus, and the transmitter transmits the first signal on the one or more first resource units to the one or more second communication apparatuses and, for each of the more than one other communication apparatus, the second signal carrying the second type of data on the second resource unit to the each of the more than one other communication apparatus.

15. The first communication apparatus of any one of claims 11-14, wherein the first signal comprises a fourth signal field comprising information relating to the second resource unit configured for transmitting the second type of data.

16. The first communication apparatus of claim 1, wherein, in response to obtaining the second type of data from the upper layer by the circuitry when the transmitter is transmitting the segmented signal of the plurality of segmented signals:

the circuitry is configured to generate a third signal carrying the second type of data signal and a fourth signal comprising the successive segmented signals, wherein each of the third signal and the fourth signal comprises a preamble shorter than that comprised on the first signal; and

the transmitter separately transmits the third signal and the fourth signal after the transmission of the segmented signal.

17. The first communication apparatus of any one of claims 1-16, wherein each of the plurality of segmented signals comprises multiple Orthogonal Frequency Division Multiplexing (OFDM) symbols.

18. The first communication apparatus of claim 17, wherein the each of the plurality of segmented signals carries a Physical Layer Convergence Protocol Service Data Unit comprising the multiple OFDM symbols.

19. A second communication apparatus comprising:

a receiver, which in operation, receives a first signal from a first communication apparatus, the first signal comprising a plurality of segmented signals carrying a first type of data and a second signal inserted between two of the plurality of segmented signals, the second signal carrying a second type of data; and

circuitry, which in operation, is configured to decode and demodulate the first signal.

20. The second communication apparatus of claim 19, wherein the first signal comprises a first signal field indicating a length of the first signal, and, in response to receiving the second signal carrying the second type of data, the circuitry is configured update the length of the first signal to a new length; the receiver further receives one or more successive segmented signals of the plurality of segmented signals beyond the indicated length of the first signal based on the new length, wherein a number of the one or more successive segmented signals is based on a number or a length of the second signal; and circuitry is configured to further decode and demodulate the one or more successive segmented signals.

21. The second communication apparatus of claim 19 or 20, wherein the first signal comprises a second signal field comprising information relating to a resource unit on which the second signal will be received.

22. A communication method comprising:

generating a first signal comprising a plurality of segmented signals carrying a first type of data;

transmitting the first signal;

obtaining a second type of data from an upper layer when transmitting a segmented signal of the plurality of segmented signal;

inserting a second signal carrying the second type of data between the transmitted segmented signal and a successive segmented signal next to the transmitted segmented signal; and

transmitting the second signal and continuing the transmission of successive segmented signals of the first signal starting from the successive segmented signal next to the transmitted segmented signal.