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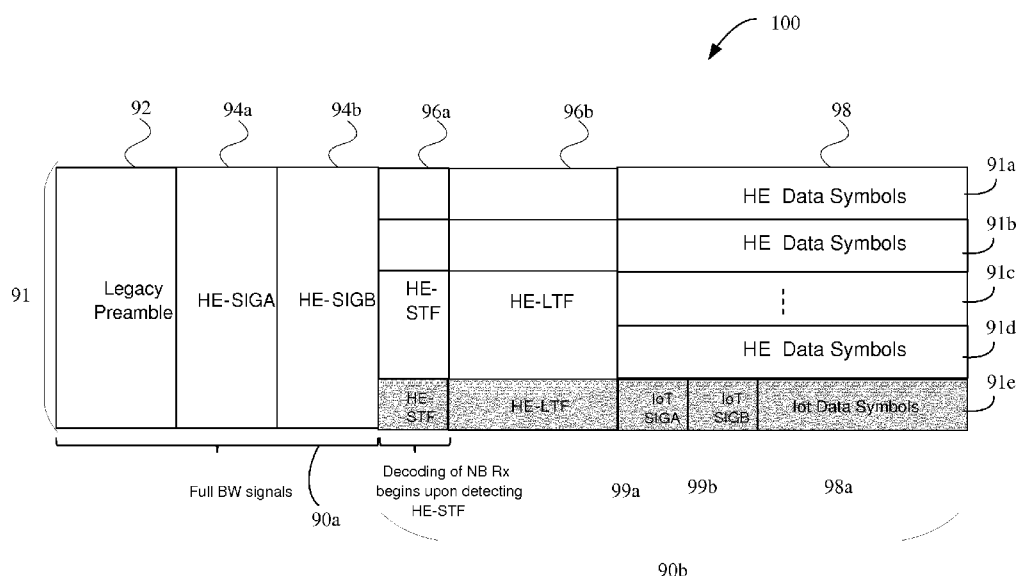


Fig. 2

(57) **Abstract:** An access point device and method for wireless communication comprising: a transmitter configured to allocate a dedicated low-band channel (DLBC) in an Orthogonal Frequency Division Multiple Access (OFDMA) wireless frame structure (OFDMA-WFS), the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS, and a modulator configured to produce in the DLBC a low-band signal field (LBSF) detectable in said lower bandwidth, for acquiring data symbols transmitted in the dedicated low-band channel. Further, a communication device and method comprising: a signal sensor configured to detect a low-band signal in the DLBC and to trigger a receiver to start receiving and decoding transmission in the DLBC, wherein the receiver is configured to receive and decode LBSF in the DLBC and to acquire data symbols transmitted in the DLBC based on information decoded from the LBSF.

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FRAME STRUCTURE FOR IOT CLIENTS WITHIN 802.11ax

BACKGROUND

The present invention, in some embodiments thereof, relates to Internet of Things (IOT) devices and, more specifically, but not exclusively, to communication methods of IOT devices.

Orthogonal Frequency Division Multiple Access (OFDMA) technology allows transmitting in a portion of the bandwidth. However, some transmission fields such as preamble and/or signal fields must be transmitted over the entire bandwidth in order to comply with existing wireless local area networks (LAN), i.e. IEEE 802.11 networks. Accordingly, devices in IEEE 802.11 networks must have the ability to receive transmissions and communicate in the full minimal bandwidth required by such network, which is usually 20 megahertz.

SUMMARY

According to an aspect of some embodiments of the present invention there is provided an access point device for wireless communication including a transmitter configured to allocate a dedicated low-band channel (DLBC) in an Orthogonal Frequency Division Multiple Access (OFDMA) wireless frame structure (OFDMA-WFS), the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS, and a modulator configured to produce in the DLBC a low-band signal field (LBSF) detectable in said lower bandwidth, for acquiring data symbols transmitted in the dedicated low-band channel.

Optionally, the transmitter is configured to allocate the DLBC in parallel to at least one High Efficiency (HE) OFDMA channel and after a HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS.

Optionally, the modulator allocates the LBSF after a training field in the DLBC, and is configured to produce the training field in parallel to a HE OFDMA training field in the OFDMA-WFS and after at least one HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS.

Optionally, the modulator allocates the LBSF after at least one training field in the DLBC, and is configured to produce the at least one training field in parallel to a HE OFDMA data symbol in the OFDMA-WFS and after a HE OFDMA training field.

Optionally, the modulator is configured to produce cascading low-band transmissions in the DLBC in parallel to a HE OFDMA data symbol in the OFDMA-WFS.

Optionally, the modulator is configured to produce a starter signal for starting a receiver at a receiving device and allocate the starter signal before the at least one produced training field.

5 Optionally, the duration of the produced training field is aligned with the duration of the HE OFDMA data symbols.

Optionally, the HE OFDMA full-band signal field includes an indication about the low-band channel.

10 Optionally, the modulator is configured to receive control signals and to produce the LBSF by de-multiplexing the control signals and extracting DLBC control data from the control signals into the DLBC.

Optionally, the modulator is configured to receive a data stream and to produce DLBC data symbols by de-multiplexing the data stream and extracting DLBC data from the data stream into the DLBC.

15 According to another aspect of some embodiments of the present invention there is provided a communication device, in particular limited to detection in a lower bandwidth than a required minimal bandwidth of an OFDMA-WFS, the device including a receiver configured to receive transmissions in a DLBC allocated in an OFDMA-WFS, the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS, and a signal sensor
20 configured to detect a low-band signal in the DLBC and to trigger the receiver to start receiving and decoding transmission in the DLBC, wherein the receiver is configured to receive and decode LBSF in the DLBC and to acquire data symbols transmitted in the DLBC based on information decoded from the LBSF.

25 Optionally, the communication device includes a transmitter configured to transmit in a DLBC in a delay of time determined according to duration of at least one HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS.

30 According to another aspect of some embodiments of the present invention there is provided a method for wireless communication including allocating by a transmitter a DLBC in an OFDMA-WFS, the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS, and producing by a modulator in the DLBC a LBSF detectable in said lower bandwidth, for acquiring data symbols transmitted in the dedicated low-band channel.

According to another aspect of some embodiments of the present invention there is provided a method for communication in a lower bandwidth than a required minimal bandwidth of an OFDMA-WFS, the method including detecting a low-band signal in a DLBC allocated in an OFDMA-WFS, the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS, and triggering a receiver to start receiving and decoding transmission in the DLBC, wherein the receiver is configured to receive and decode LBSF in the DLBC and to acquire data symbols transmitted in the DLBC based on information decoded from the LBSF.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a schematic illustration of an exemplary 802.11ax standard transmission frame structure;

FIG. 2 is a schematic illustration of a modified transmission frame structure according to some embodiments of the present invention;

FIG. 3 is a schematic flowchart illustrating a method for wireless communication according to some embodiments of the present invention;

FIG. 4 is a schematic illustration of a wireless communication access point device 200 according to some embodiments of the present invention;

FIG. 5 is a schematic flowchart illustrating a method for communication by a low-band device in an OFDMA frame structure, according to some embodiments of the present invention;

FIG. 6 is a schematic illustration of logical components of an access point device according to some embodiments of the present invention;

FIG. 7 is a schematic illustration of a modified transmission frame structure according to some embodiments of the present invention;

FIG. 8 is a schematic illustration of a modified transmission frame structure according to some embodiments of the present invention;

FIG. 9 is a schematic illustration of a modified transmission frame structure according to some embodiments of the present invention;

FIG. 10 is a schematic illustration of an uplink OFDMA transmission frame structure according to some embodiments of the present invention;

FIG. 11 is a schematic illustration of a frame structure and of a required time of delay of transmission by a transmitter of a low-band device according to some embodiments of the present invention; and

FIG. 12 is a schematic illustration of an uplink frame structure according to some embodiments of the present invention.

DETAILED DESCRIPTION

Devices that don't support the minimum bandwidth required in 802.11ax networks may be unable to communicate in such networks. For example, some embodiments of the present invention enable IOT clients to connect to OFDMA 802.11ax networks. Some IOT devices are expected to support smaller bandwidth than the minimum required in 802.11ax networks, and therefore are unable to receive mandatory full bandwidth transmission fields such as legacy preamble and/or signal fields. Since these fields are usually required for acquisition of the rest of the transmission, such devices may fail to connect to the network.

For example, a device that wishes to communicate in a 2 megahertz bandwidth still needs to employ radio-frequency (RF) capabilities of at least the required minimal bandwidth, for example 20 megahertz, in order to receive the mandatory full bandwidth transmission fields. Also, the current 802.11ax standard requires devices to transmit information on at least a minimal transmission bandwidth portion of 2 megahertz (26 tones, each occupies 78.125 kilohertz). Accordingly, in order to comply with the 802.11ax standard, a device must have the ability to communicate in a 20 megahertz bandwidth and cannot transmit information in a

bandwidth portion smaller than 2 megahertz. For example, a standard device may transmit information on a 2 megahertz (but not smaller) portion of the bandwidth, while transmitting zero energy on the rest of the bandwidth, i.e. the rest 18 megahertz.

However, it may be desired to enable communication in lower bandwidths, for example in order to extend the transmission's range and/or to save energy. Throughout the present description, low-band devices are devices with a capability to communicate in smaller bandwidths than the minimal bandwidths required by wireless LAN standards, such as IOT devices. Full-bandwidth devices are legacy devices and High Efficiency (HE) devices, which are devices that support the minimal bandwidths required by wireless LAN standards.

Additionally, throughout the present description, low-band signals or transmissions are signals or transmissions transmitted in the smaller bandwidth supported by low-band devices. Full-bandwidth transmission frame structures or Legacy/HE transmission frame structures are transmission frame structures that include the mandatory full bandwidth transmission fields mentioned herein.

Some embodiments of the present invention provide a solution for enabling low-band devices to connect to a standard wireless network that supports full-bandwidth devices as well. The solution is provided by bypassing the necessity to detect the mandatory wide-band signals. Instead, the low-band devices use low-band signals inserted in dedicated locations in a full-bandwidth transmission frame structure for the purpose of signal acquisition by the low-band devices.

Accordingly, in some embodiments of the present invention an OFDMA transmission frame structure is modified in order to support low-band devices by adding dedicated acquisition signals, while maintaining the rest of the frame structure to support both full-bandwidth and low-band devices. In some embodiments, the modified frame structure includes a wake-up low-band signal for alerting wake-up receivers in low-band devices that a low-band transmission is arriving.

Therefore, some embodiments of the present invention provide a technical solution for supporting low-band devices in standard wireless networks, with minimal modification of the frame structure and without harming the connectivity of full-bandwidth devices by the modified frame structure. The solution is enabled by inserting minimal modifications to access-point transmitters and by receivers especially designed for low-band devices, without needing to modify full-bandwidth devices, and thus saving the costs of developing new and expensive equipment to support low-band devices in standard wireless networks.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

The present invention may be a system, a method, and/or a computer program product. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing.

Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network.

The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart

illustrations and/or block diagrams, can be implemented by computer readable program instructions.

The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

Reference is now made to FIG. 1, which is a schematic illustration of an exemplary 802.11ax standard transmission frame structure 90. Frame structure 90 includes mandatory full-band transmission fields 90a that occupy a full transmission bandwidth 91, for example in the beginning of the transmission, and partial band-width fields 90b in partial bandwidth channels 91a-91e, for example High Efficiency (HE) OFDMA channels.

Although FIG. 1 shows five partial bandwidth channels 91a-91e, the invention is not limited in this respect and any suitable number of bandwidth portions may be included. As indicated herein, a minimal full bandwidth 91 required by wireless LAN networks is of about 20 megahertz. Partial bandwidth fields 90b include, in each of partial bandwidth channels 91a-91e, partial bandwidth training fields 96a and 96b and a partial bandwidth data field 98. In each of partial bandwidth channels 91a-91e, training fields 96a and 96b provide information for training a receiver to receive a corresponding data field 98 of the same partial bandwidth channel, such as channel estimation, automatic gain control and/or any other suitable training information.

Full-band transmission fields 90a include a legacy preamble field 92 and signal fields 94a and 94b, for transmitting information needed for acquisition of following data signals by full-bandwidth devices, i.e. legacy or HE devices, such as data rate information, symbol lengths, demodulation instructions, and/or any other suitable signal information. In some cases an HE device in the wireless LAN network only needs to receive a low-band signal transmitted

in a data symbol field 98 in one of partial bandwidth channels 91a-91e. However, as indicated herein, the device still must have the RF capability to receive the full bandwidth signal fields 94a and 94b in order to receive information needed for acquiring the low-band signal data symbols in data field 98.

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Reference is now made to FIG. 2, which is a schematic illustration of a modified transmission frame structure 100, according to some embodiments of the present invention. Reference is further made to FIG. 3, which is a schematic flowchart illustrating a method 300 for wireless communication according to some embodiments of the present invention, and to
10 FIG. 4, which is a schematic illustration of a wireless communication access point device 200 according to some embodiments of the present invention.

Access point device 200 may include a transmitter 10 and a modulator 12, which may produce signals for transmission in an OFDMA wireless frame structure (WFS) and transmit the signals to various devices in a wireless network, including low-band devices 20 and full-
15 bandwidth devices 40.

Low-band devices 20 may be communication devices limited to detection in a lower bandwidth than a required minimal bandwidth of an OFDMA WFS, as described in detail herein. A low band device 20 may include a receiver 22, configured to receive transmissions in a dedicated low-band channel, a signal sensor 24 and a transmitter 26.

20

Transmitter 10 may create a transmission having modified frame structure 100. For example, similarly to frame structure 90, modified frame structure 100 includes mandatory full-band transmission fields 90a that occupy a full transmission bandwidth 91, for example in the beginning of the transmission, and partial band-width fields 90b in partial bandwidth
25 channels, for example channels 91a-91e. Each partial bandwidth channel may include partial bandwidth training fields 96a and 96b used, for example, for time/frequency estimation and/or channel estimation, and a partial bandwidth data symbol field 98. Therefore, the ability of legacy/HE devices to communicate in the wireless network is not harmed.

As indicated in block 310, transmitter 10 may allocate a dedicated low-band channel in
30 an OFDMA WFS such as modified frame structure 100. For example, transmitter allocates partial bandwidth channel 91e to be a dedicated low-band channel for transmitting low-band signals to low-band devices 20. As mentioned herein, a low-band channel is a channel having a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS.

For example, transmitter 10 allocates partial bandwidth channel 91e in parallel to at least one HE OFDMA channel such as partial bandwidth channels 91a-91d. For example, transmitter 10 allocates partial bandwidth channel 91e after a HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS, such as signal fields 94a and 94b.

As indicated in block 320, modulator 12 may produce in the allocated partial bandwidth channel 91e a low-band signal field detectable by signal sensor 24 in the lower bandwidth. For example, a partial bandwidth data field 98 in partial bandwidth channel 91e may be modified to include low-band signal fields 99a and 99b before a low-band data field 98a. Accordingly, modified transmission frame structure 100 includes in partial bandwidth channel 91e low-band signal fields 99a and 99b, for transmitting information needed in order to enable low-band devices 20 to acquire the following low band data signals in a low-band data field 98a.

For example, modulator 12 allocates a low-band signal field such as low-band signal fields 99a and 99b after a low-band training field such as partial bandwidth training fields 96a and 96b in low-band channel 91e. For example, modulator 12 produces the low-band training fields in parallel to HE OFDMA training fields 96a and 96b in other partial bandwidth channels 91a-91d. For example, modulator 12 produces the low-band training fields after at least one HE OFDMA full-band signal field occupying the minimal required bandwidth of the OFDMA-WFS, such as signal fields 94a and 94b.

As indicated in block 330, transmitter 10 may transmit the transmission frame structure to a network including low-band devices 20 and optionally legacy/HE devices 40. Low-band devices 20 may receive, decode, transmit and/or perform other communication operations in a similar manner as full-bandwidth devices 40, only operating on a narrower bandwidth, for example of about 2-4 megahertz.

Reference is now made to FIG. 5, which is a schematic flowchart illustrating a method 500 for communication by a low-band device 20 in a OFDMA frame structure, according to some embodiments of the present invention.

As indicated in block 510, signal sensor 24 may detect a low-band signal in low-band channel 91e and trigger receiver 22 to start receiving and decoding a transmission in low-band channel 91e. As indicated in block 520, receiver 22 may receive and decode signal information from low-band signal fields 99a and 99b. As indicated in block 530, based on the signal information, receiver 22 may acquire data symbols transmitted in low-band data field 98a.

Reference is now made to FIG. 6, which is a schematic illustration of logical components of access point device 200 according to some embodiments of the present invention. Modulator 12 may receive control signals in a control bit-stream 121 and data stream in a data bit-stream 122 and generate a modulated stream composed of control bit-stream 121 and data bit-stream 122.

Modulator 12 may produce low-band signal data for transmission in fields 99a and 99b by de-multiplexing the received control signals, extracting low-band control data from the control signals, and mapping the low-band control data into dedicated low-band channel 91e. For example, modulator 12 may de-multiplex the modulated stream to extract low-band channel control data 124 designated for dedicated low-band channel 91e, and map the low-band channel control data 124 into the dedicated low-band channel 91e. HE OFDMA full-band control data 126 may be mapped into full-band fields 94a and/or 94b.

Similarly, modulator 12 may produce data symbols for transmission in field 98a in dedicated low-band channel 91e by de-multiplexing the received data stream, extracting low-band data symbols from the data stream, and mapping the low-band data symbols into dedicated low-band channel 91e. For example, modulator 12 may de-multiplex the modulated stream to extract low-band data symbols 125 designated for dedicated low-band channel 91e, and map the low-band data symbols 125 into the dedicated low-band channel 91e. HE OFDMA data symbols 127 may be mapped into data fields 98 in partial bandwidth channels 91a-91d.

The mapped low-band channel control data 124, HE OFDMA control data 126, low-band data symbols 125 and HE OFDMA data symbols 127 constitute a modulated frame structure in a frequency domain. After the mapping, access point device 200 may transform the modulated structure from the frequency domain to a time domain, for example by performing an inverse fast Fourier transform (IFFT), in order to construct a transmission frame structure in the time domain.

For example, transmitter 10 constructs the transmission frame structure in the time domain, by adding training signals in training fields, in order to facilitate receipt of the frame structure by receiving devices 20 and/or 40. For example, transmitter 10 adds legacy training signals 114 in a legacy training field 92 before the transformed modulated structure, HE OFDMA training signals 112 in HE OFDMA training fields 96a and 96b after full-band signal fields 94a and/or 94b, and/or low-band training signals 110 in training fields before low-band signal fields 99a and 99b, for example in training fields 96a and 96b of the dedicated low-band channel 91e or in dedicated low-band training fields described in more detail herein.

In order to receive the signal transmitted in allocated partial bandwidth channel 91e, a low-band device 20 may constantly scan potential received channels until a training field is detected by signal sensor 24 in one of the potential received channels, for example training field 96a is detected in partial bandwidth channel 91e. In such embodiments of the present invention, low-band device 20 may be connected to an electricity grid for continuous power supply, in order to enable the constant channel scanning. Once training field 96a is detected in partial bandwidth channel 91e, low-band device 20 may allow receiver 22 to continue receiving and/or decoding the transmission, including, for example, partial bandwidth training fields 96a and 96b, low-band signal fields 99a and 99b and low-band data field 98a.

In some embodiments of the present invention, signal information may be divided between low-band signal fields 99a and 99b. For example, low-band signal field 99a includes a Basic Service Set (BSS) color bit and/or an indication about a duration length of low-band signal field 99b, preparing receiver 22 to receive low-band signal field 99b. Low-band signal field 99b may include, for example, an indication of signal parameters of low-band data field 98a, target identification (ID) of the receiving low-band device 20, reduced modulation and coding scheme (MCS), transmission module, duration, and/or any other suitable signal information, which may enable a receiving low-band device 20 acquisition of signals in low-band data field 98a.

In some embodiments of the present invention, HE OFDMA full-band signal field 94b includes an indication that low-band signals for a low-band device 20 are included in a dedicated low-band channel 91e is included in transmission frame structure 100. The indication about low-band signals in dedicated low-band channel 91e prevents full-bandwidth devices 40 and/or low-band devices 20 from requesting information about the portion of the transmission bandwidth including dedicated channel 91e, for example from requesting for channel quality indicator (CQI), and/or from trying to receive and/or decode data from this channel.

Other variations of modified transmission frame structures are provide by some embodiments of the present invention. Reference is now made to FIG. 7, which is a schematic illustration of a modified transmission frame structure 101, according to some embodiments of the present invention.

In transmission frame structure 101, modulator 12 produces in partial bandwidth channel 91e a dedicated low-band training field such as training fields 97a and 97b, in addition to and following training fields 96a and 96b. For example, modulator 12 produces and places

low-band training fields 97a and 97b in parallel to data symbols in data fields 98 of channels 91a-91d.

For example, modulator 12 produces low-band training fields 97a and 97b after a HE OFDMA training field such as training fields 96a and 96b. Low-band device 20 may allow receiver 22 to continue receiving and/or decoding the transmission once training field 97a is detected in partial bandwidth channel 91e, e.g. only when channel 91e includes a dedicated low-band training fields 97a and 97b.

In some embodiments, low-band training field 97a may include a periodic signal used for time and/or frequency synchronization of receiver 22 of a receiving low-band device 20. Low-band training field 97b may include channel estimation data. A duration length of each of low-band training fields 97a and 97b may be equal and aligned with a duration length of a parallel HE OFDMA data symbol in a parallel data field 98 and thus, for example, orthogonality between two adjacent channels is maintained, as required in HE OFDMA frame structures.

A similar structure is shown in FIG. 8, which is a schematic illustration of a modified transmission frame structure 102, according to some embodiments of the present invention. Frame structure 102 includes in dedicated partial bandwidth channel 91e cascading low-band transmissions, for example after training fields 96a and 96b and/or in parallel to data symbols in data fields 98 of channels 91a-91d. For example, cascading transmissions are used for transmitting data packets to multiple low-band devices. For example, each of the cascading transmission may be addressed to another low-band device 20.

Each of the low-band cascading transmissions includes low-band training fields 97a and 97b, low-band signal fields 99a and 99b and low-band data field 98a. When low-band device 20 detects training field 97a by signal sensor 24, the detection implies the beginning of a new transmission, and a receiving low-band device 20 may allow receiver 22 to continue receiving and/or decoding the transmission. In some embodiments, signal sensor 24 is included in receiver 22, allowing receiver 22 to continue the receiving once training field 97a is detected.

Reference is now made to FIG. 9, which is a schematic illustration of a modified transmission frame structure 103, according to some embodiments of the present invention. Modulator 12 produce a starter signal 95 for starting receiver 22 at a receiving low-band device 20, i.e. for triggering receiver 22 to start receiving and decoding the transmission.

Modulator 12 may locate starter signal 95 before low-band training fields 97a and 97b. For example, training fields 97a and 97b may be located a sufficient period of time after starter signal 95, enabling receiver 22 to start decoding operation after receiver 22 is triggered. Once the decoding starts, low-band device 20 may synchronize in time and/or frequency with transmitter 10 and obtain channel estimation by information decoded from training fields 97a and 97b. Such embodiments of the present invention may be energy and cost efficient, since receiver 22 is only active when starter signal 95 is detected by low-band device 20, for example by a signal sensor, and no constant scanning of the channel is required. Therefore, in such embodiments device 20 may be powered by a battery and connection to an electricity grid is not required.

In some embodiments of the present invention, frame structure 103 may include cascading low-band transmissions, for transmitting data packets to multiple low-band devices. Each of the low-band cascading transmissions may include a starter signal 95, low-band training fields 97a and 97b, low-band signal fields 99a and 99b and low-band data field 98a. When low-band device 20 detects starter signal 95, receiver 22 of a receiving low-band device 20 is triggered to start receiving and/or decoding the transmission.

In addition to the solution described above for enabling low-band device acquisition of signals from a HE OFDMA frame structure, some embodiments of the present invention provide a solution to enable low-band devices transmission of signals in HE OFDMA frame structure.

Low-band devices can transmit only low-band signals, and therefore cannot transmit, for example, legacy preamble and/or other full-band signals. In some embodiments of the present invention, low-band devices 20 overcome this problem by starting a transmission in a delay, in parallel to HE OFDMA partial-bandwidth signals.

Reference is now made to FIG. 10, which is a schematic illustration of an uplink OFDMA transmission frame structure 104, i.e. a transmission from devices 40 and low-band devices 20 to access point device 200, according to some embodiments of the present invention.

For example frame structure 104 includes mandatory full-band transmission fields 80a that occupy a full transmission bandwidth 81 (that may be the same as bandwidth 91), for example in the beginning of the transmission, and partial band-width fields 80b in partial bandwidth channels, for example channels 81a-81e. Full-band transmission fields 81a may include a legacy preamble 82 and a full-band signal field 84. Each of partial bandwidth channels 81a-81d may include partial bandwidth HE OFDMA training fields 86a and 86b used,

for example, for time/frequency estimation and/or channel estimation, and a partial bandwidth data symbol field 88. Therefore, the ability of full-bandwidth devices 40 to transmit in the wireless network is not harmed.

Transmitter 26 may allocate partial bandwidth channel 81e as a dedicated low-band channel for transmitting low-band signals from low-band devices 20. For example, transmitter 26 allocates dedicated low-band channel 81e after a HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS, such as signal field 84.

Dedicated low-band channel 81e may include training fields 87a and 87b in parallel to HE OFDMA training fields 86a and 86b, i.e. in the same frequency locations as fields 86a and 86b, respectively. Training fields 87a and 87b may be the same as HE OFDMA training fields 86a and 86b or different from HE OFDMA training fields 86a and 86b. After training fields 87a and 87b, dedicated low-band channel 81e may include a low-band signal field 89 and a low-band data symbol field 88a.

In order to by-pass the full-band fields 80a, transmitter 26 may start a transmission in a delay, in dedicated low-band channel 81e parallel to HE OFDMA partial-bandwidth fields 81a-81d. The delay of time is determined according to a duration length of full-band signal fields 80a. Therefore, the start time of the transmission by transmitter 26 depends on whether at least one full-bandwidth device 40 is also transmitting in the same uplink frame structure.

Reference is now made to FIG. 11, which is a schematic illustration of frame structure 104 and of the required time of delay of transmission by transmitter 26, according to some embodiments of the present invention. As shown in FIG. 11, since frame structure 104 includes both full bandwidth and low bandwidth transmissions, transmitter 26 starts to transmit in dedicated low-band channel 81e after waiting the duration length of full-band signal fields 80a, in addition to a Short Inter-frame Space (SIFS) duration length 70 after receiving a downlink frame. This way frame structure 104 keeps the HE OFDMA structure that enables full-bandwidth devices 40 to transmit in the wireless network.

Reference is now made to FIG. 12, which is a schematic illustration of an uplink frame structure 105 according to some embodiments of the present invention. Frame structure 105 includes only low bandwidth transmissions in multiple low-band channels 81e, for example because no full-band device 40 is transmitting in this frame structure. Accordingly, transmitter 26 may start to transmit in dedicated low-band channels 81e without needing to wait after the SIFS duration length 70.

The descriptions of the various embodiments of the present invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described
5 embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

As used herein the term “about” refers to $\pm 10\%$.

10 The terms "comprises", "comprising", "includes", "including", “having” and their conjugates mean "including but not limited to". This term encompasses the terms "consisting of" and "consisting essentially of".

The phrase "consisting essentially of" means that the composition or method may include additional ingredients and/or steps, but only if the additional ingredients and/or steps
15 do not materially alter the basic and novel characteristics of the claimed composition or method.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

20 The word “exemplary” is used herein to mean “serving as an example, instance or illustration”. Any embodiment described as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

The word “optionally” is used herein to mean “is provided in some embodiments and
25 not provided in other embodiments”. Any particular embodiment of the invention may include a plurality of “optional” features unless such features conflict.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope
30 of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to

4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases “ranging/ranges between” a first
5 indicate number and a second indicate number and “ranging/ranges from” a first indicate number “to” a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

It is appreciated that certain features of the invention, which are, for clarity, described
10 in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential
15 features of those embodiments, unless the embodiment is inoperative without those elements.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any
20 reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

WHAT IS CLAIMED IS:

1. An access point device for wireless communication comprising:

a transmitter configured to allocate a dedicated low-band channel (DLBC) in an Orthogonal Frequency Division Multiple Access (OFDMA) wireless frame structure (OFDMA-WFS), the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS; and

a modulator configured to produce in the DLBC a low-band signal field (LBSF) detectable in said lower bandwidth, for acquiring data symbols transmitted in the dedicated low-band channel.

2. The device of claim 1, wherein the transmitter is configured to allocate the DLBC in parallel to at least one High Efficiency (HE) OFDMA channel and after a HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS.

3. The device of claim 1, wherein the modulator allocates the LBSF after a training field in the DLBC, and is configured to produce the training field in parallel to a HE OFDMA training field in the OFDMA-WFS and after at least one HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS.

4. The device of claim 1, wherein the modulator allocates the LBSF after at least one training field in the DLBC, and is configured to produce the at least one training field in parallel to a HE OFDMA data symbol in the OFDMA-WFS and after a HE OFDMA training field.

5. The device of claim 4, wherein the modulator is configured to produce cascading low-band transmissions in the DLBC in parallel to a HE OFDMA data symbol in the OFDMA-WFS.

6. The device of claim 4, wherein the modulator is configured to produce a starter signal for starting a receiver at a receiving device and allocate the starter signal before the at least one produced training field.

7. The device of claim 4, wherein the duration of the produced training field is aligned with the duration of the HE OFDMA data symbols.

8. The device of claim 2, wherein the HE OFDMA full-band signal field includes an indication about the low-band channel.

9. The device of claim 1, wherein the modulator is configured to receive control signals and to produce the LBSF by de-multiplexing the control signals and extracting DLBC control data from the control signals into the DLBC.

10. The device of claim 1, wherein the modulator is configured to receive a data stream and to produce DLBC data symbols by de-multiplexing the data stream and extracting DLBC data from the data stream into the DLBC.

11. A communication device, in particular limited to detection in a lower bandwidth than a required minimal bandwidth of an OFDMA-WFS, the device comprising:

a receiver configured to receive transmissions in a DLBC allocated in an OFDMA-WFS, the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS; and

a signal sensor configured to detect a low-band signal in the DLBC and upon detection to allow the receiver to receive and decode transmission in the DLBC,

wherein the receiver is configured to receive and decode LBSF in the DLBC and to acquire data symbols transmitted in the DLBC based on information decoded from the LBSF.

12. The device of claim 11, comprising a transmitter configured to transmit in a DLBC in a delay of time determined according to duration of at least one HE OFDMA full-band signal field occupying the required minimal bandwidth of the OFDMA-WFS.

13. A method for wireless communication comprising:

allocating by a transmitter a DLBC in an OFDMA-WFS, the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS; and

producing by a modulator in the DLBC a LBSF detectable in said lower bandwidth, for acquiring data symbols transmitted in the DLBC.

14. A method for communication in a lower bandwidth than a required minimal bandwidth of an OFDMA-WFS, the method comprising:

detecting a low-band signal in a DLBC allocated in an OFDMA-WFS, the DLBC has a lower bandwidth than a required minimal bandwidth of the OFDMA-WFS; and triggering a receiver to start receiving and decoding transmission in the DLBC, wherein the receiver is configured to receive and decode LBSF in the DLBC and to acquire data symbols transmitted in the DLBC based on information decoded from the LBSF.

5

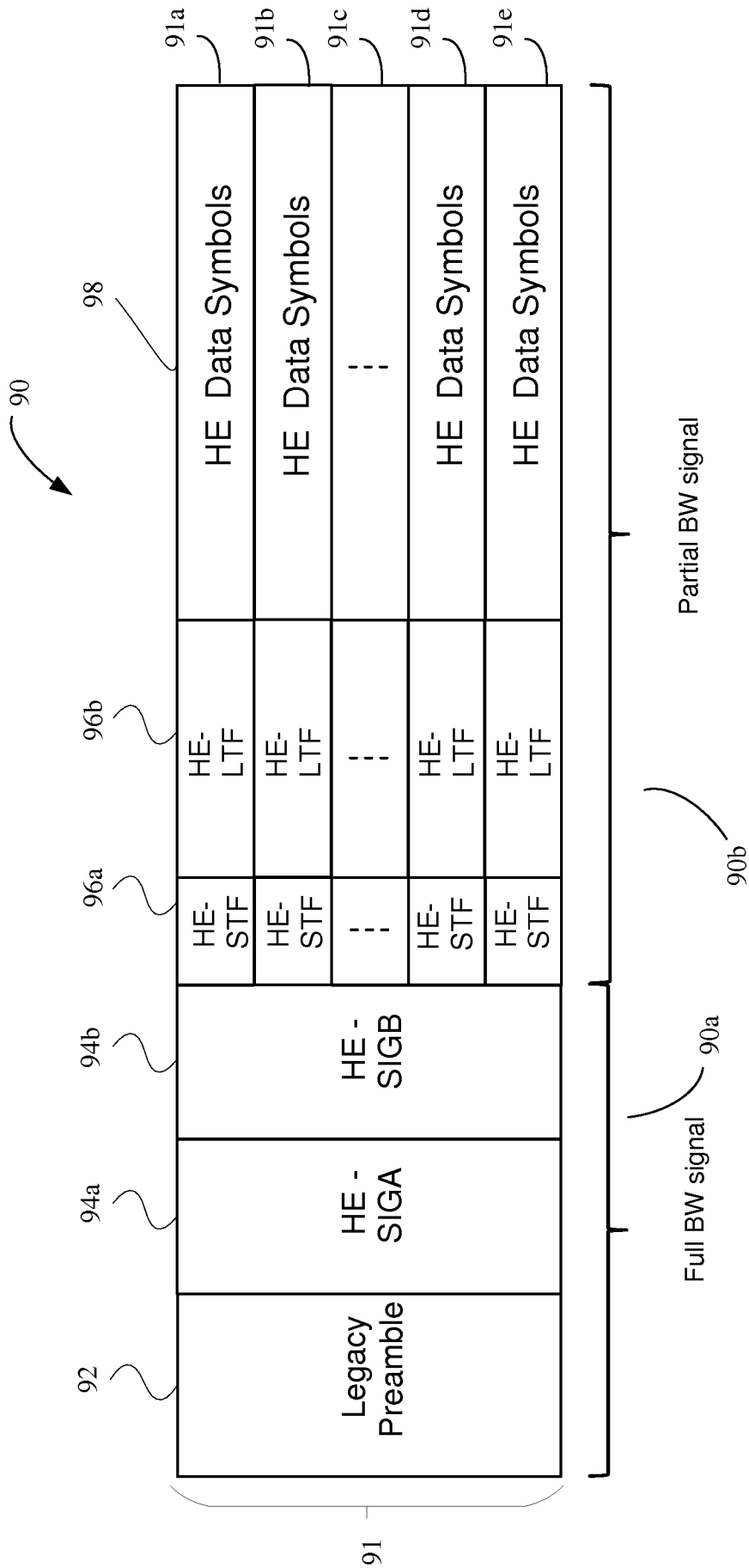


Fig. 1

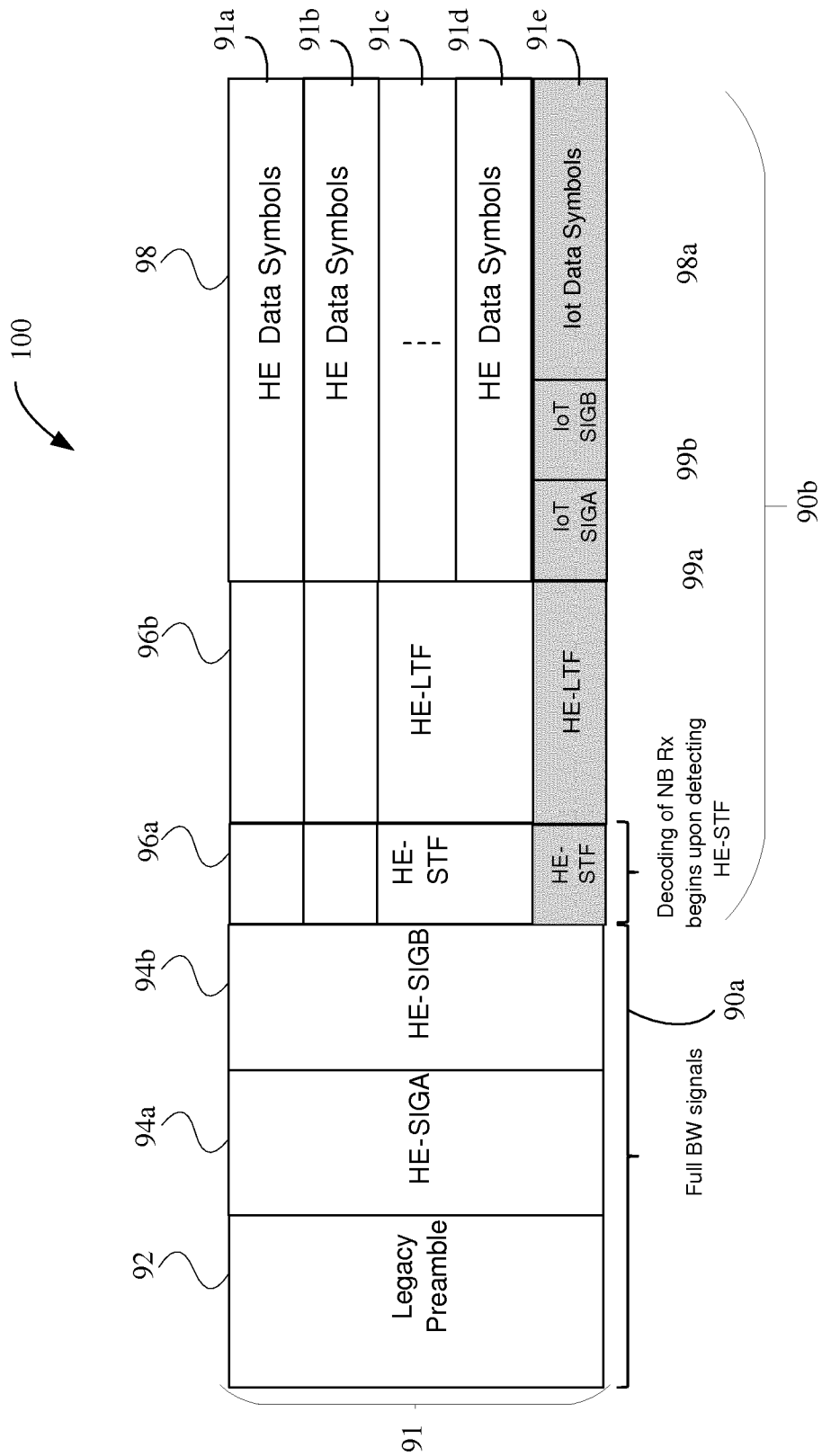


Fig. 2

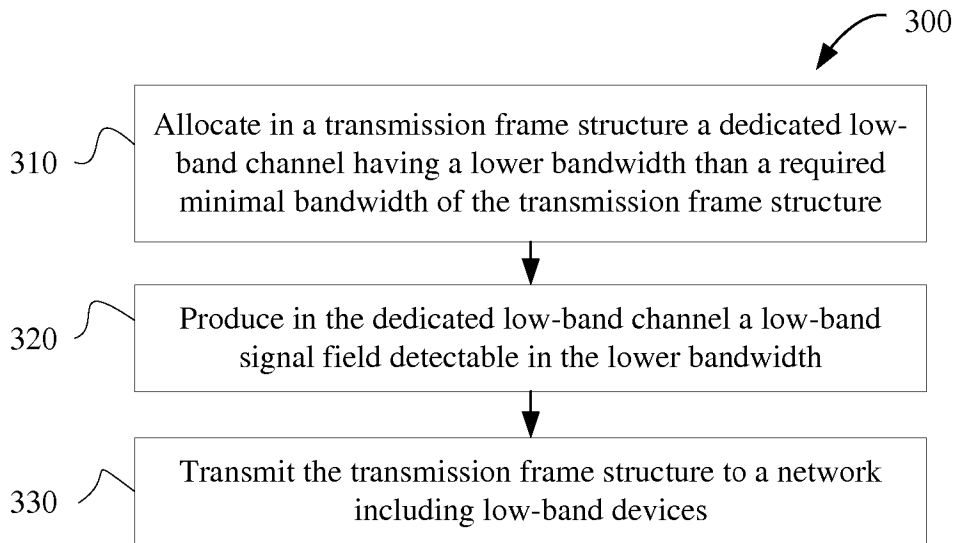


FIG. 3

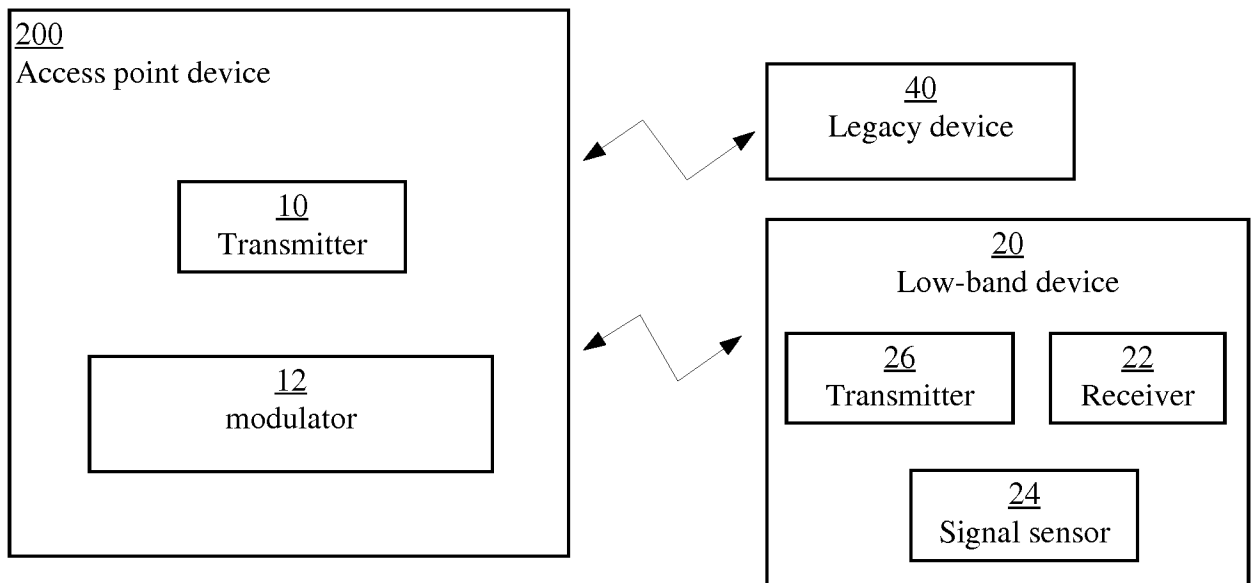


FIG. 4

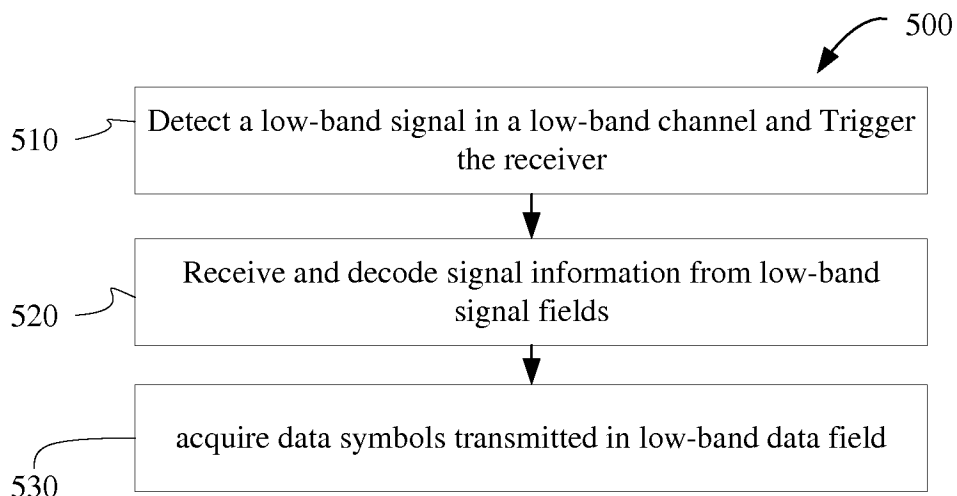


FIG. 5

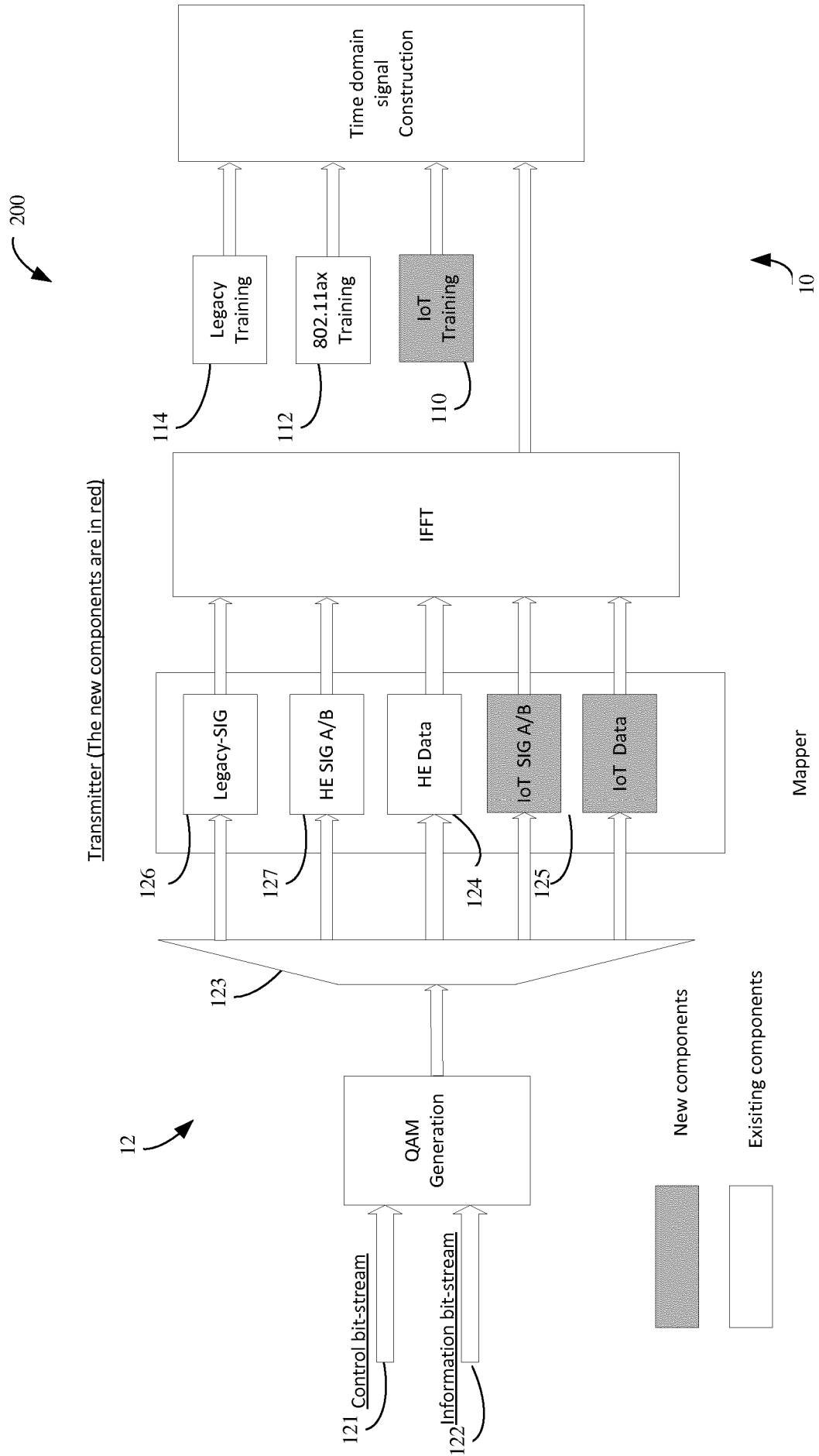


Fig. 6

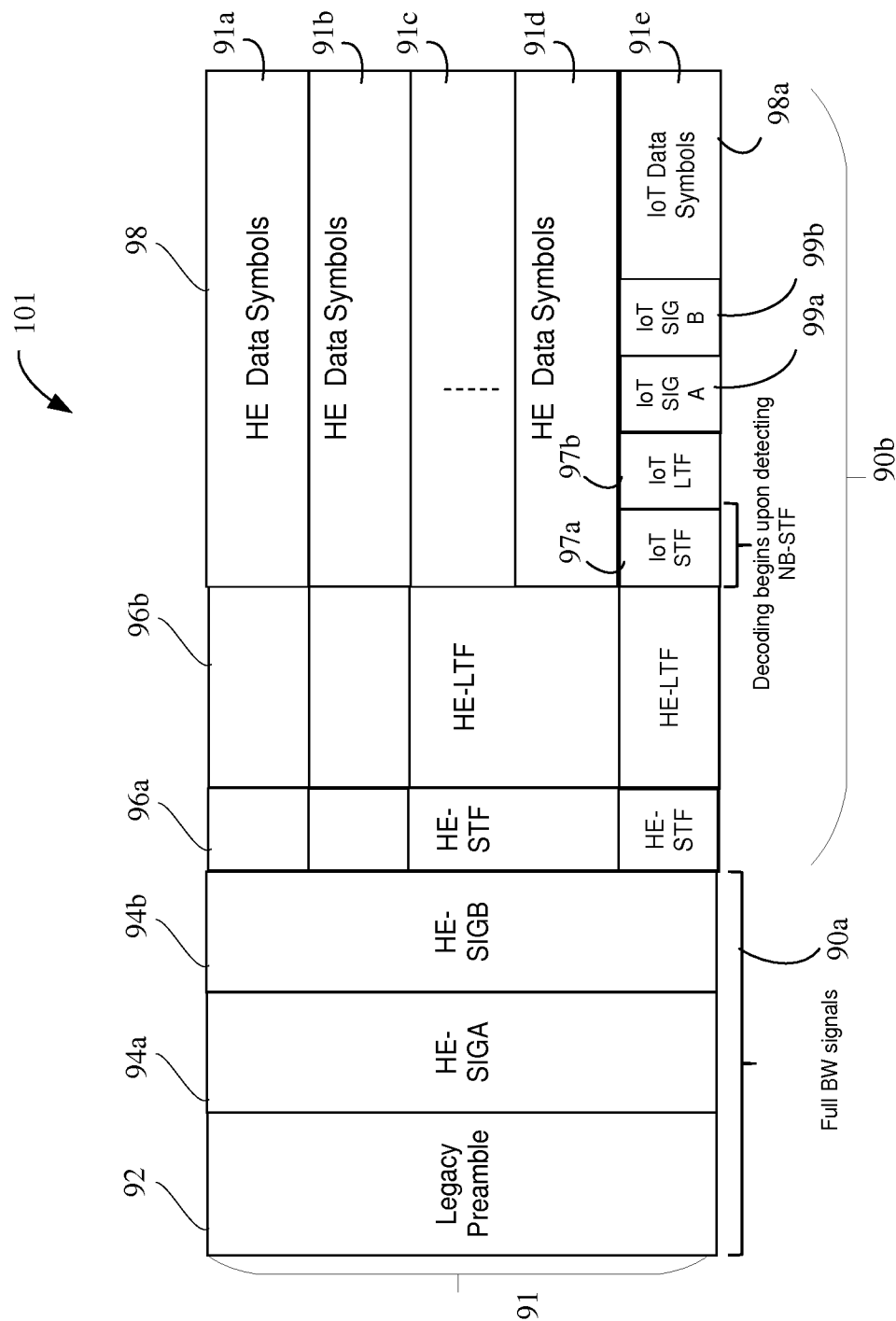


Fig. 7

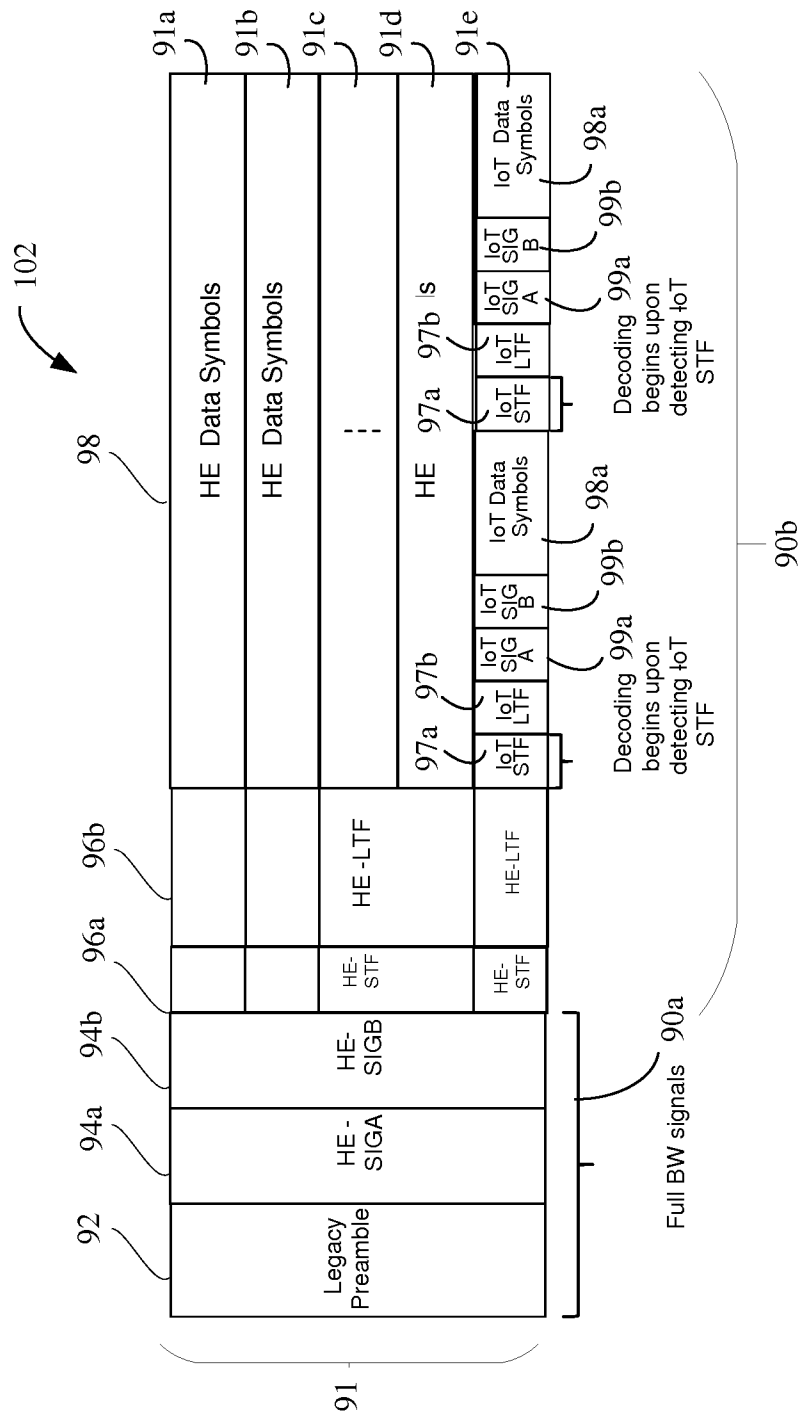


Fig. 8

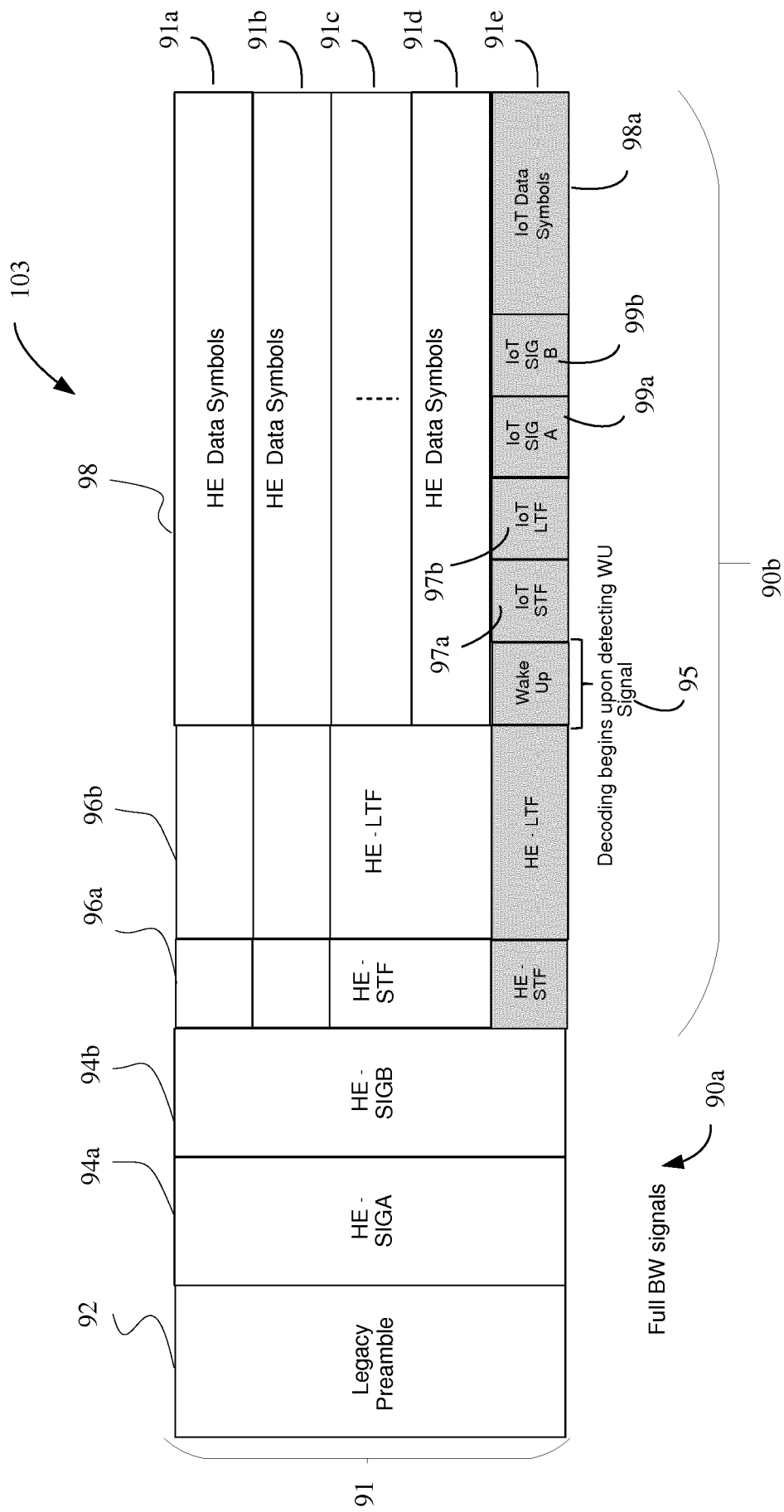


Fig. 9

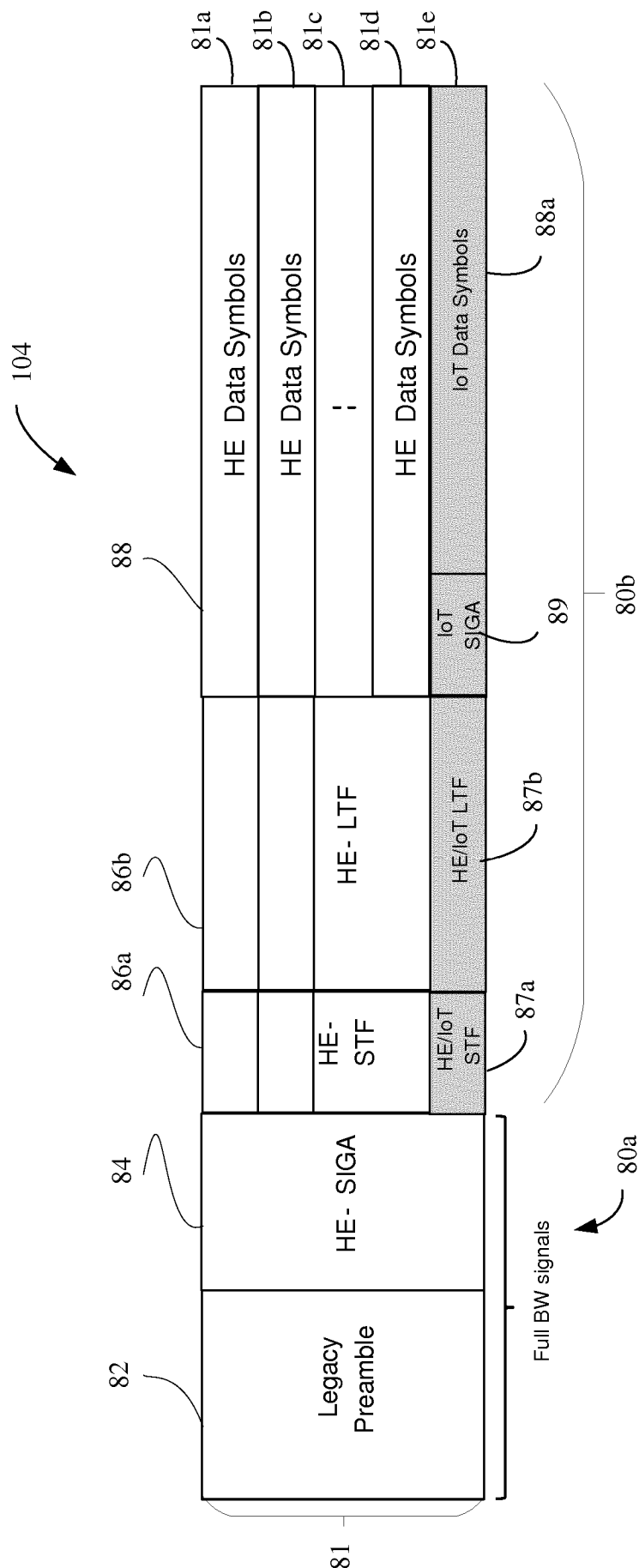


Fig. 10

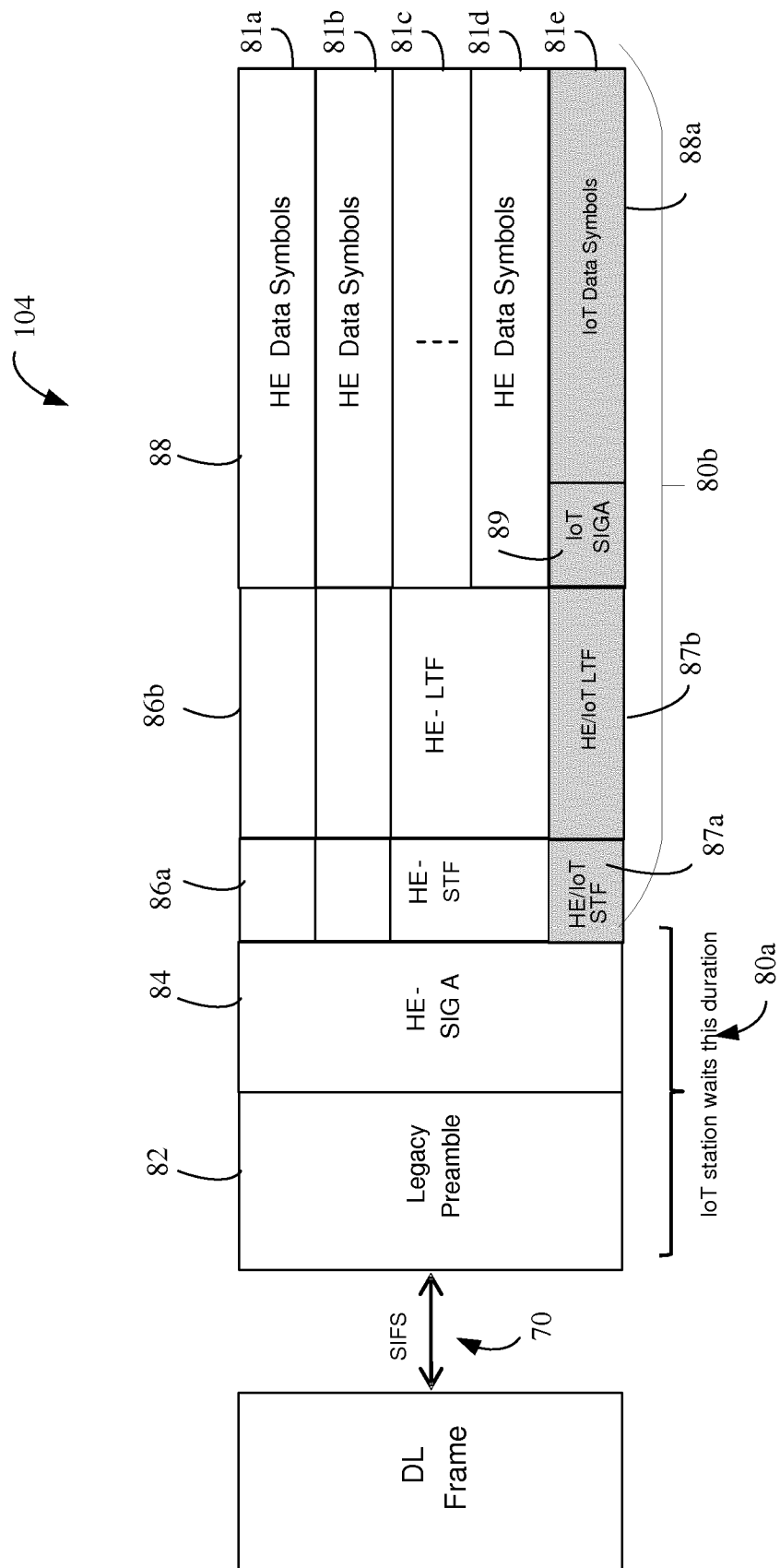


Fig. 11

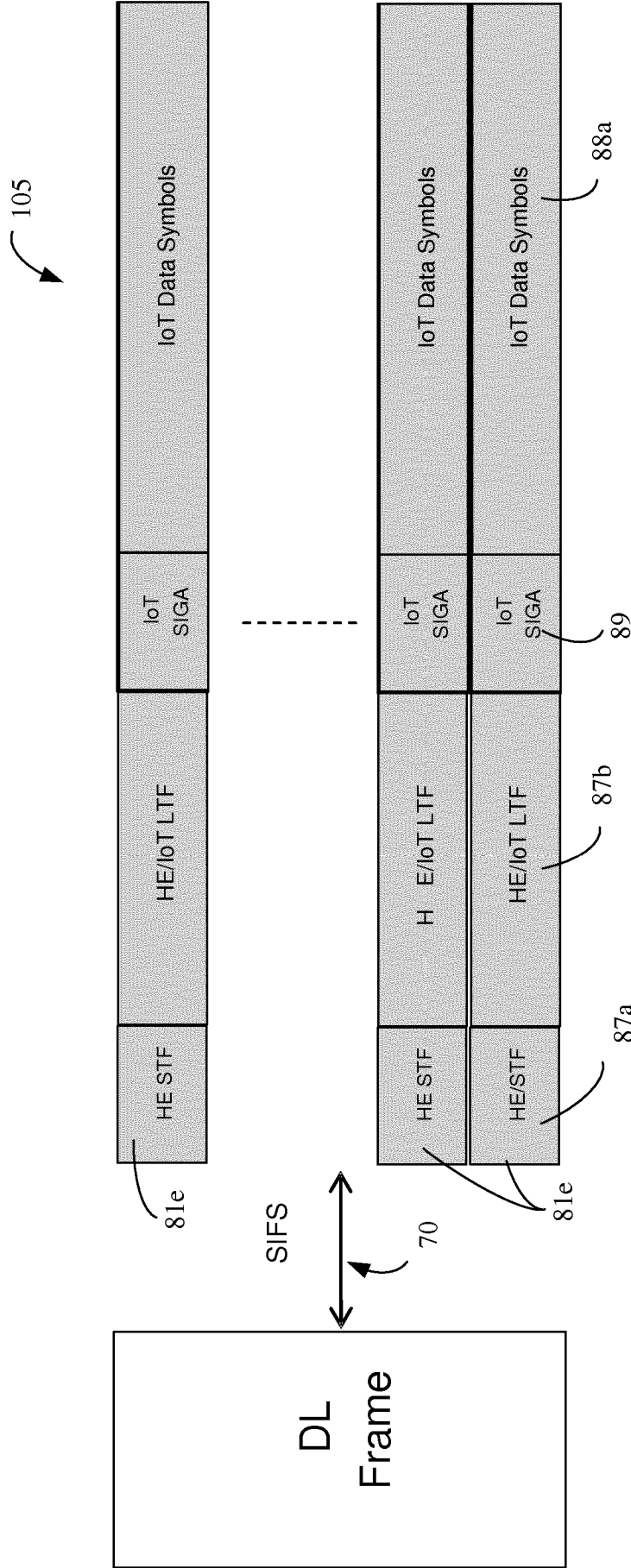


Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/078569A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L27/26
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SHIMI SHILO (HUAWEI): "11ax Support for IoT ; 11-15-1134-02-00ax-11ax-support-for-iot", IEEE DRAFT; 11-15-1134-02-00AX-11AX-SUPPORT-FOR-IOT, IEEE-SA MENTOR, PISCATAWAY, NJ USA, vol. 802.11ax, no. 2, 16 September 2015 (2015-09-16), pages 1-19, XP068098394, [retrieved on 2015-09-16] page 4 - page 12 ----- -/--	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

19 September 2017

Date of mailing of the international search report

10/10/2017

Name and mailing address of the ISA/

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Authorized officer

Douglas, Ian

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/078569

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	TIM GODFREY ET AL.: "Integrated Long Range Low Power Operation for IoT", 1 July 2015 (2015-07-01), pages 1-18, XP002773809, Retrieved from the Internet: URL:https://mentor.ieee.org/802.11/dcn/15/11-15-0775-01-0wng-integrated-long-range-low-power-operation.pptx [retrieved on 2017-09-15] page 6 page 11 - page 16 -----	1-14
A	SHIMI SHILO (HUAWEI): "11ax Support for IoT - Requirements and Technological Implications ; 11-15-1375-00-00ax-11ax-support-for-iot-requirements-and-technological-implications", IEEE DRAFT; 11-15-1375-00-00AX-11AX-SUPPORT-FOR-IOT-REQUIREMENTS-AND-TECHNOLOGICAL-IMPLICATIONS, IEEE-SA MENTOR, PISCATAWAY, NJ USA, vol. 802.11ax, 9 November 2015 (2015-11-09), pages 1-24, XP068099364, [retrieved on 2015-11-09] page 2 - page 3 page 9 - page 11 page 15 - page 16 page 21 - page 22 page 24 -----	1-14