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Kim et al.

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(54) **RECEIVER METHOD AND APPARATUS FOR VARIABLE HEADER REPETITION IN A WIRELESS OFDM NETWORK WITH DIFFERENT CHANNEL BANDWIDTHS**

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(51) **Int. Cl.**
H04L 27/26 (2006.01)
H04L 1/08 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 27/2601*** (2013.01); ***H04B 1/38*** (2013.01); ***H04L 1/08*** (2013.01); ***H04L 27/2613*** (2013.01); ***H04L 69/22*** (2013.01)

(58) **Field of Classification Search**
CPC .. H04B 1/38; H04B 7/00; H04B 7/155; H04J 1/00; H04J 3/00; H04J 3/24; H04J 11/00;
(Continued)

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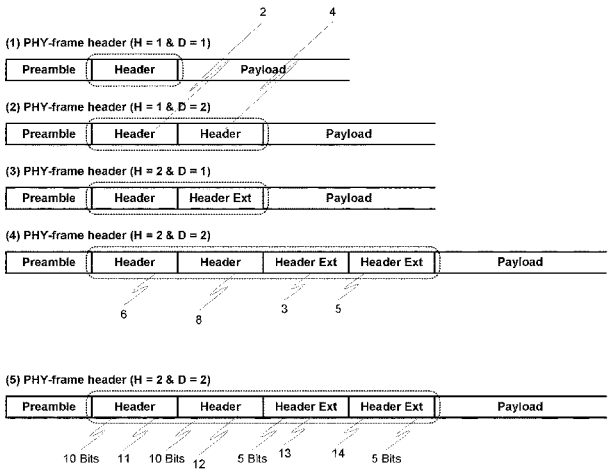
(57) **ABSTRACT**

Method and apparatus for use within a wireless OFDM network that receives a first packet type in a first channel bandwidth and a second packet type in a second channel bandwidth, the first channel bandwidth being at least two times wider than the second channel bandwidth. The first packet type has a header field with two parts with each part comprising a different set of header bits. The two parts of the header field are received using two OFDM symbols. The second packet type has a header field with four parts with the first and second parts comprising the same first set of header bits and the third and the fourth part comprising the same second set of header bits. The four parts of the header field are received using four OFDM symbols. The second packet
(Continued)



type provides more reliable reception than the first packet type.

20 Claims, 8 Drawing Sheets

Related U.S. Application Data

continuation of application No. 15/958,519, filed on Apr. 20, 2018, now Pat. No. 10,079,707, which is a continuation of application No. 15/476,284, filed on Mar. 31, 2017, now Pat. No. 9,973,361, which is a continuation of application No. 15/350,418, filed on Nov. 14, 2016, now Pat. No. 9,614,566, which is a continuation of application No. 13/376,856, filed as application No. PCT/US2010/046088 on Aug. 20, 2010, now Pat. No. 9,584,262.

(60) Provisional application No. 61/235,909, filed on Aug. 21, 2009.

(51) **Int. Cl.**
H04B 1/38 (2015.01)
H04L 29/06 (2006.01)

(58) **Field of Classification Search**
CPC H04L 1/00; H04L 1/08; H04L 5/00; H04L 12/26; H04L 12/43; H04L 12/54; H04L 12/56; H04L 12/403; H04L 27/28; H04L 27/2601; H04L 27/2613; H04L 69/22; H04M 1/00; H04W 4/00; H04W 24/00; H04W 52/02; H04W 72/04; H04W 72/12; H04W 74/08
USPC 370/207, 229, 242, 252, 294, 328, 329, 370/330, 336, 338, 356, 389, 44, 9, 474; 375/130, 219, 259, 260, 261, 267, 295, 375/316
See application file for complete search history.

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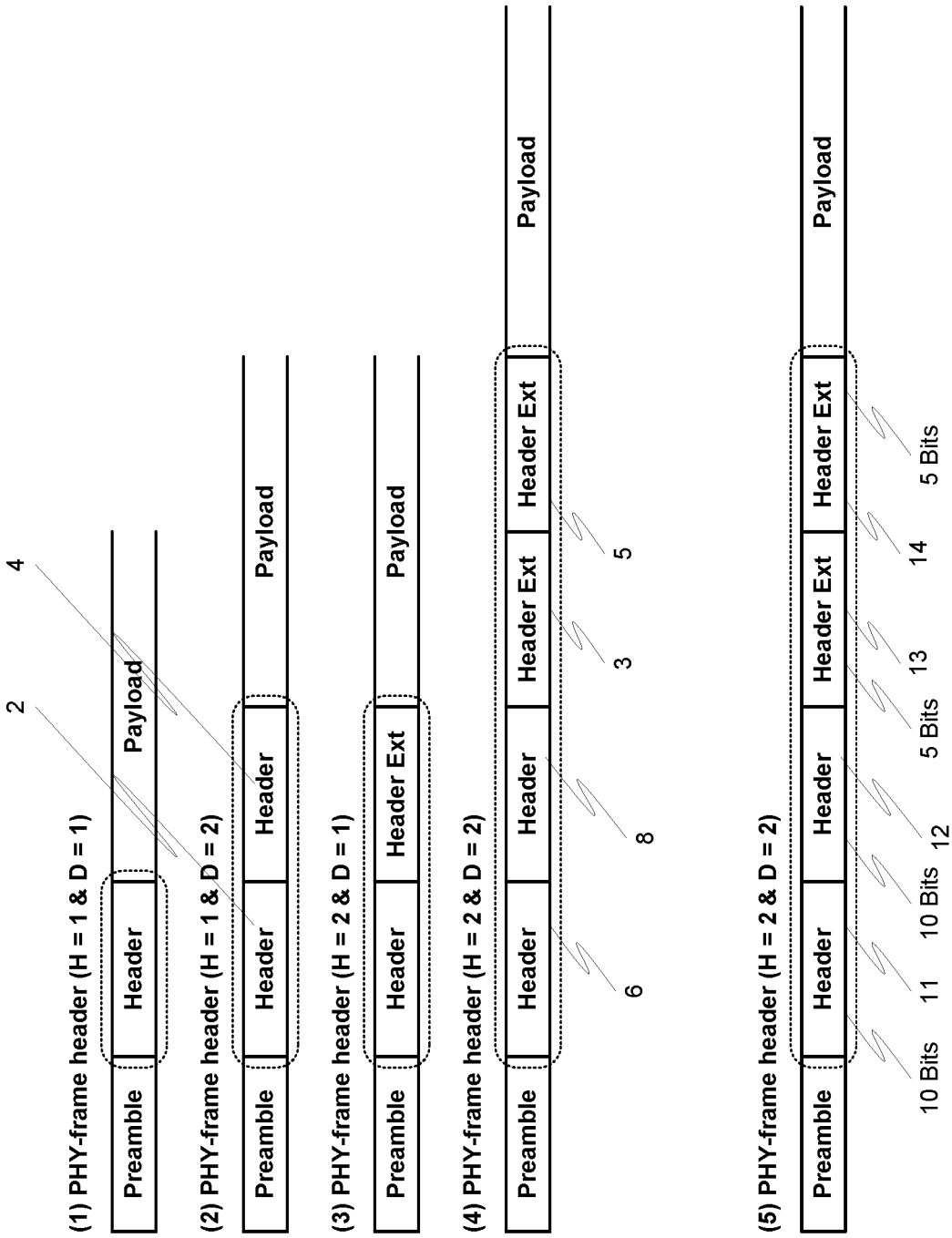
(1) PHY-frame header (H = 1 & D = 1)
Preamble
Header
Payload
(2) PHY-frame header (H = 1 & D = 2)
Preamble
Header
Payload
(3) PHY-frame header (H = 2 & D = 1)
Preamble
Header
Header Ext
Payload
(4) PHY-frame header (H = 2 & D = 2)
Preamble
Header
Header Ext
Header Ext
Payload
(5) PHY-frame header (H = 2 & D = 2)
Preamble
Header
Header Ext
Header Ext
Payload
2
4
3
5
6
8
10 Bits
11
10 Bits
12
5 Bits
13
14
5 Bits

Fig. 1

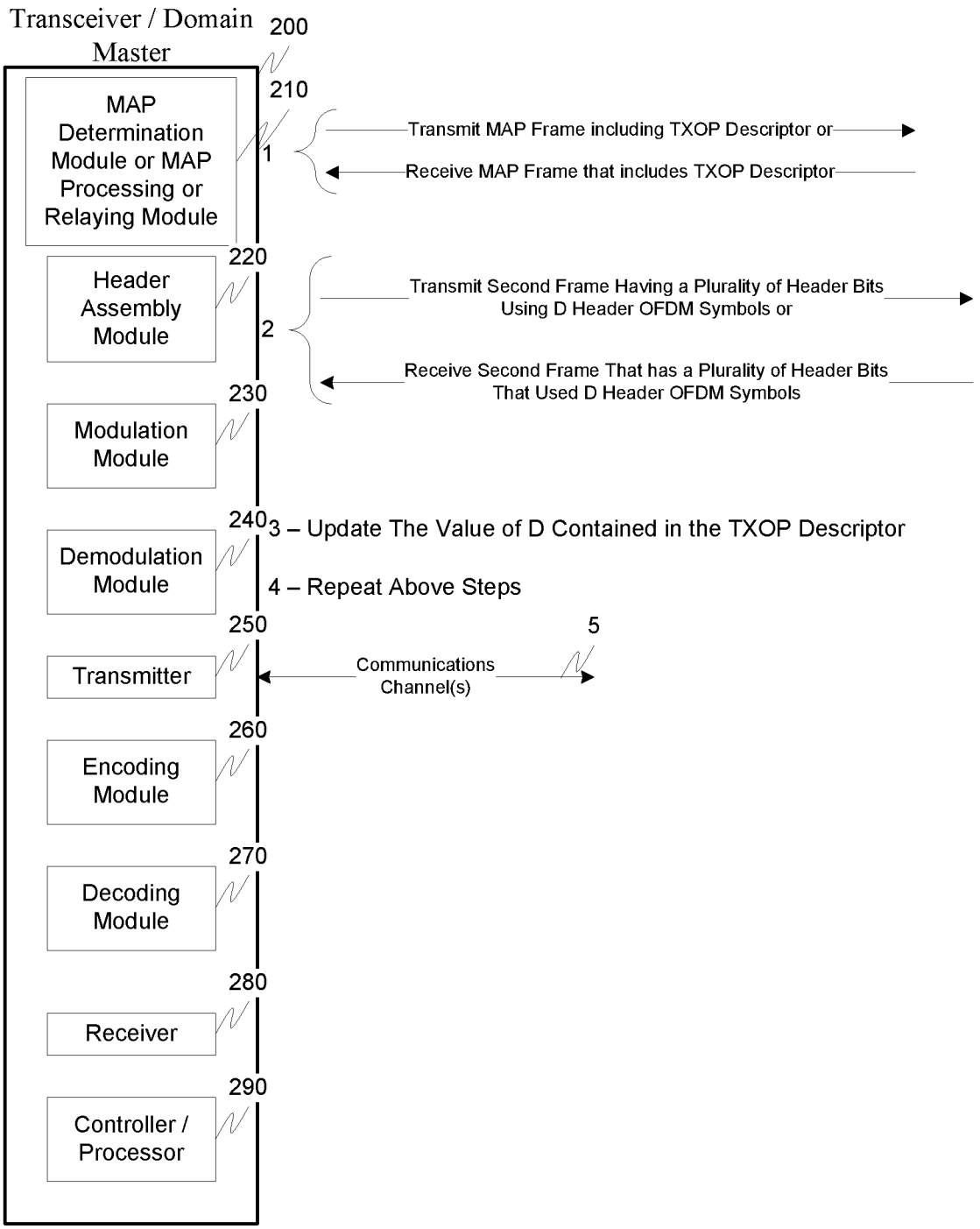
Transceiver / Domain Master
200
MAP Determination Module or MAP Processing or Relaying Module
210
1
Transmit MAP Frame including TXOP Descriptor or
Receive MAP Frame that includes TXOP Descriptor
Header Assembly Module
220
2
Transmit Second Frame Having a Plurality of Header Bits Using D Header OFDM Symbols or
Receive Second Frame That has a Plurality of Header Bits That Used D Header OFDM Symbols
Modulation Module
230
Demodulation Module
240
3 – Update The Value of D Contained in the TXOP Descriptor
4 – Repeat Above Steps
Transmitter
250
5
Communications Channel(s)
Encoding Module
260
Decoding Module
270
Receiver
280
Controller / Processor
290

Fig. 2

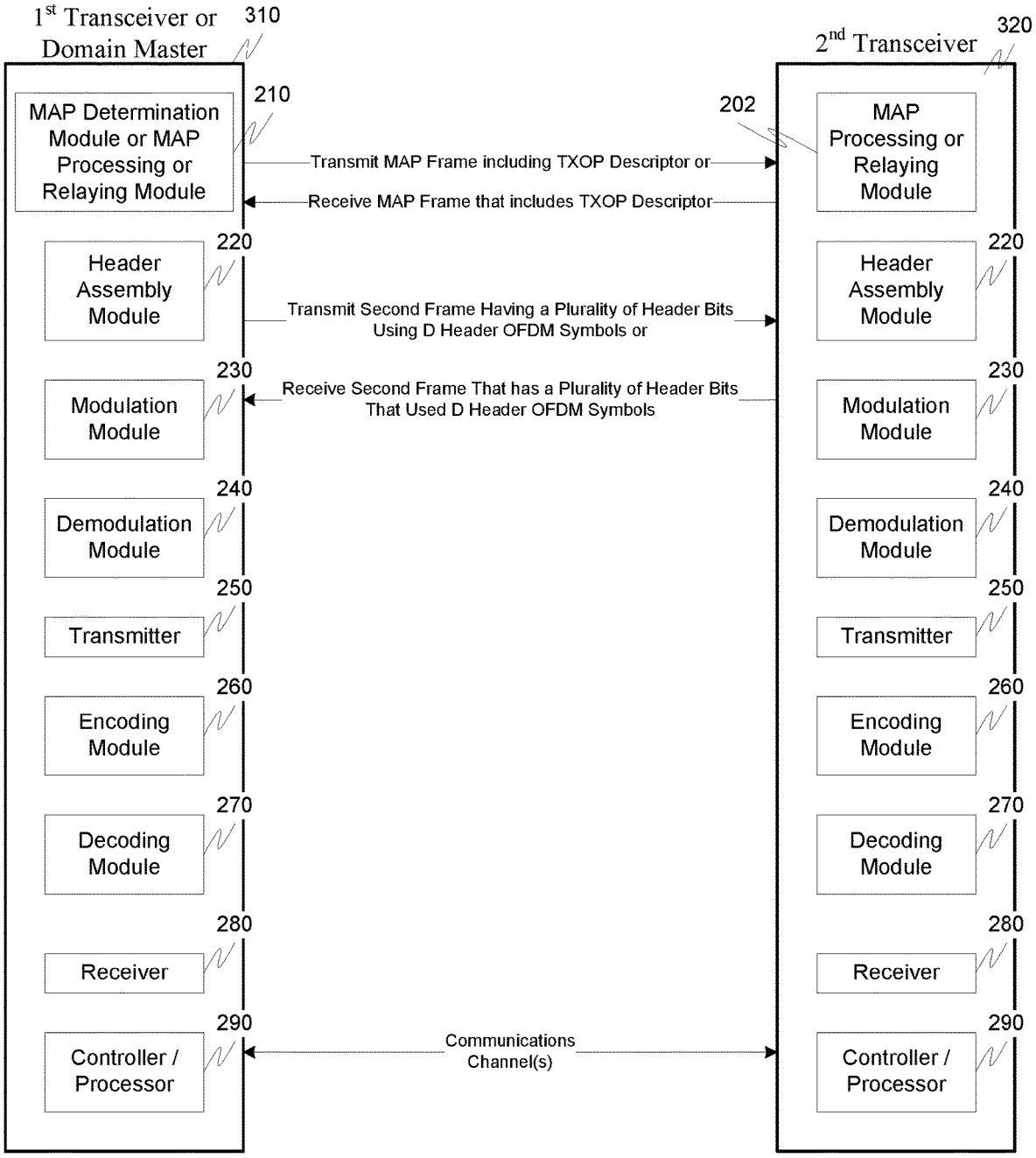
1st Transceiver or Domain Master
310
2nd Transceiver
320
MAP Determination Module or MAP Processing or Relaying Module
210
202
MAP Processing or Relaying Module
Transmit MAP Frame including TXOP Descriptor or
Receive MAP Frame that includes TXOP Descriptor
Header Assembly Module
220
Transmit Second Frame Having a Plurality of Header Bits Using D Header OFDM Symbols or
Modulation Module
230
Receive Second Frame That has a Plurality of Header Bits That Used D Header OFDM Symbols
Demodulation Module
240
Transmitter
250
Encoding Module
260
Decoding Module
270
Receiver
280
Controller / Processor
290
Communications Channel(s)

Fig. 3

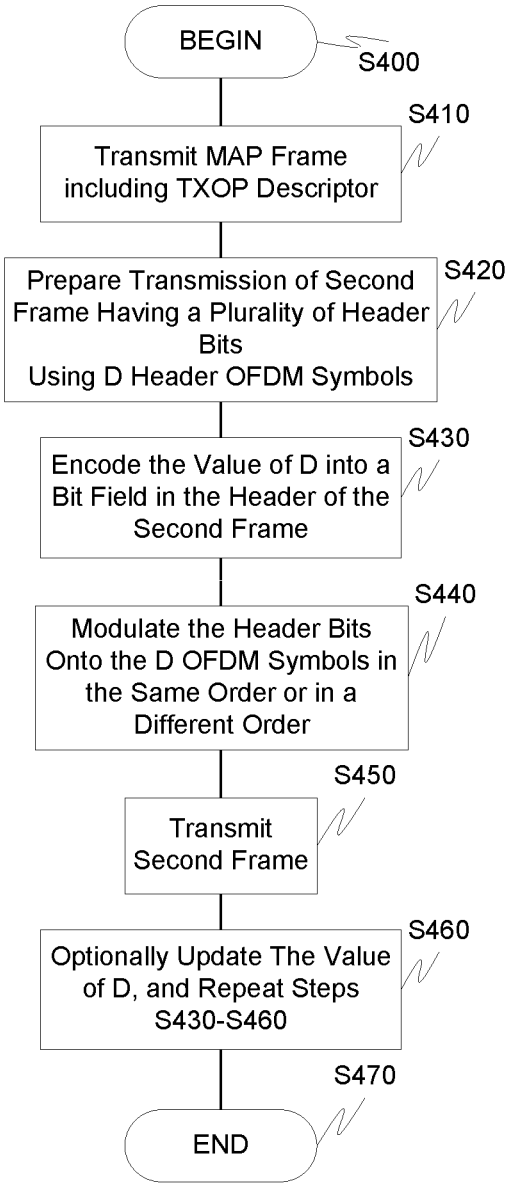
BEGIN
S400
S410
Transmit MAP Frame including TXOP Descriptor
S420
Prepare Transmission of Second Frame Having a Plurality of Header Bits Using D Header OFDM Symbols
S430
Encode the Value of D into a Bit Field in the Header of the Second Frame
S440
Modulate the Header Bits Onto the D OFDM Symbols in the Same Order or in a Different Order
S450
Transmit Second Frame
S460
Optionally Update The Value of D, and Repeat Steps S430-S460
S470
END

Fig. 4

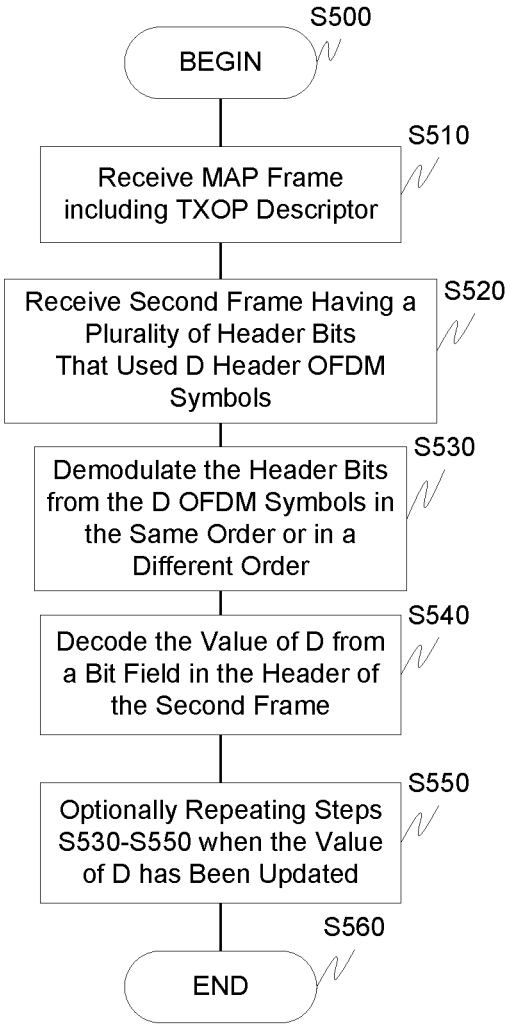
S500
BEGIN
S510
Receive MAP Frame including TXOP Descriptor
S520
Receive Second Frame Having a Plurality of Header Bits That Used D Header OFDM Symbols
S530
Demodulate the Header Bits from the D OFDM Symbols in the Same Order or in a Different Order
S540
Decode the Value of D from a Bit Field in the Header of the Second Frame
S550
Optionally Repeating Steps S530-S550 when the Value of D has Been Updated
S560
END

Fig. 5

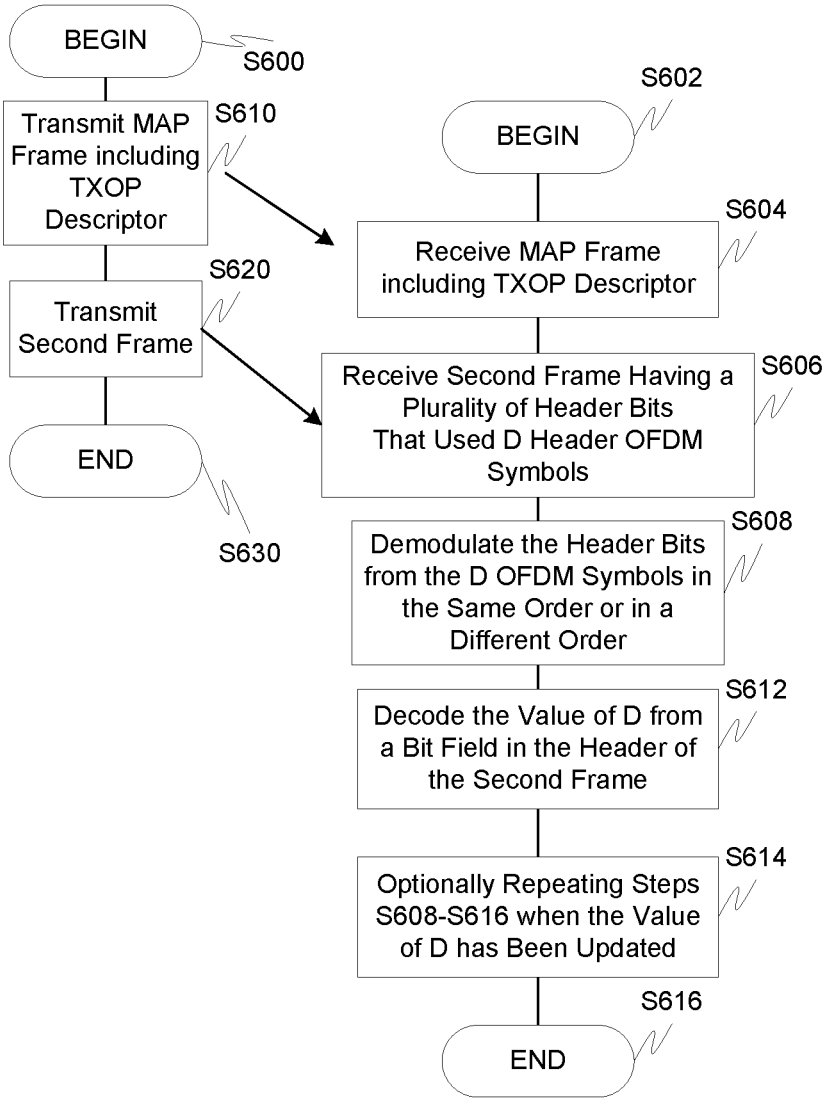
BEGIN
S600
Transmit MAP Frame including TXOP Descriptor
S610
Transmit Second Frame
S620
END
S630
S602
BEGIN
S604
Receive MAP Frame including TXOP Descriptor
S606
Receive Second Frame Having a Plurality of Header Bits That Used D Header OFDM Symbols
S608
Demodulate the Header Bits from the D OFDM Symbols in the Same Order or in a Different Order
S612
Decode the Value of D from a Bit Field in the Header of the Second Frame
S614
Optionally Repeating Steps S608-S616 when the Value of D has Been Updated
S616
END

Fig. 6

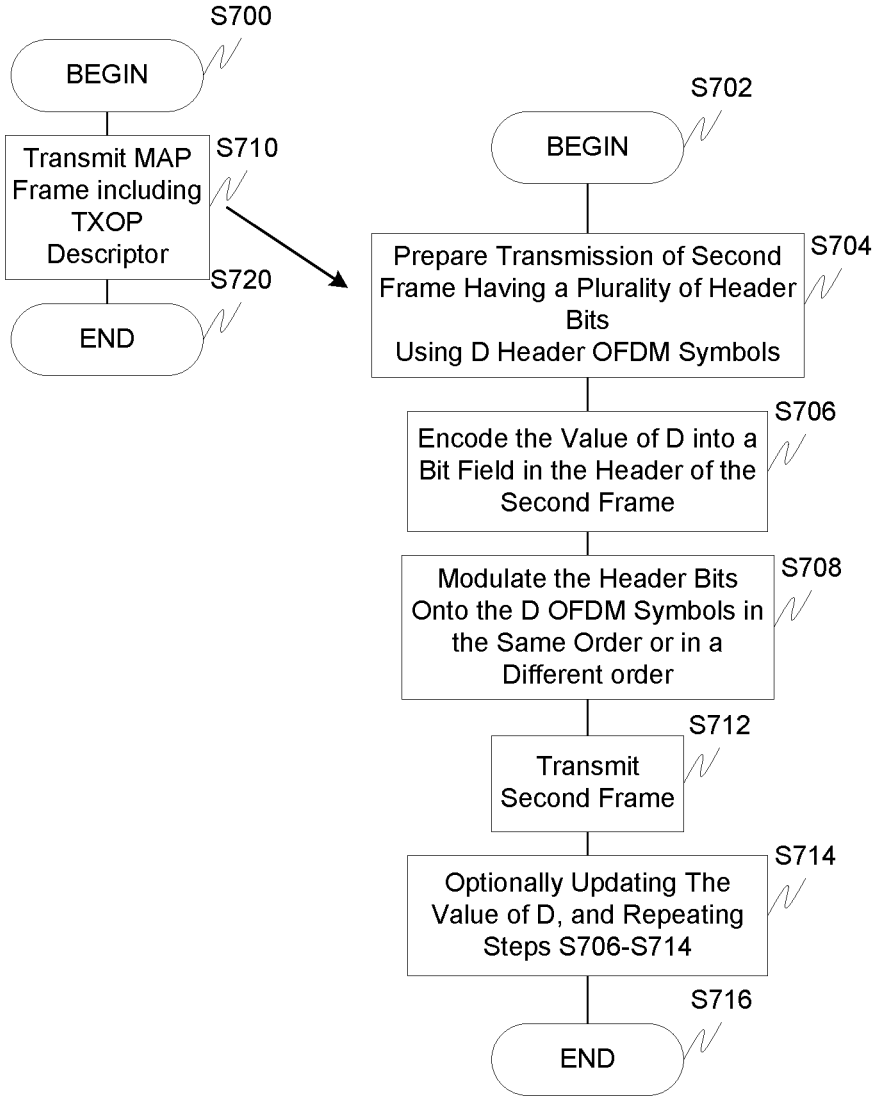
S700
BEGIN
Transmit MAP Frame including TXOP Descriptor
S710
S720
END
S702
BEGIN
Prepare Transmission of Second Frame Having a Plurality of Header Bits Using D Header OFDM Symbols
S704
Encode the Value of D into a Bit Field in the Header of the Second Frame
S706
Modulate the Header Bits Onto the D OFDM Symbols in the Same Order or in a Different order
S708
Transmit Second Frame
S712
Optionally Updating The Value of D, and Repeating Steps S706-S714
S714
END
S716

Fig. 7

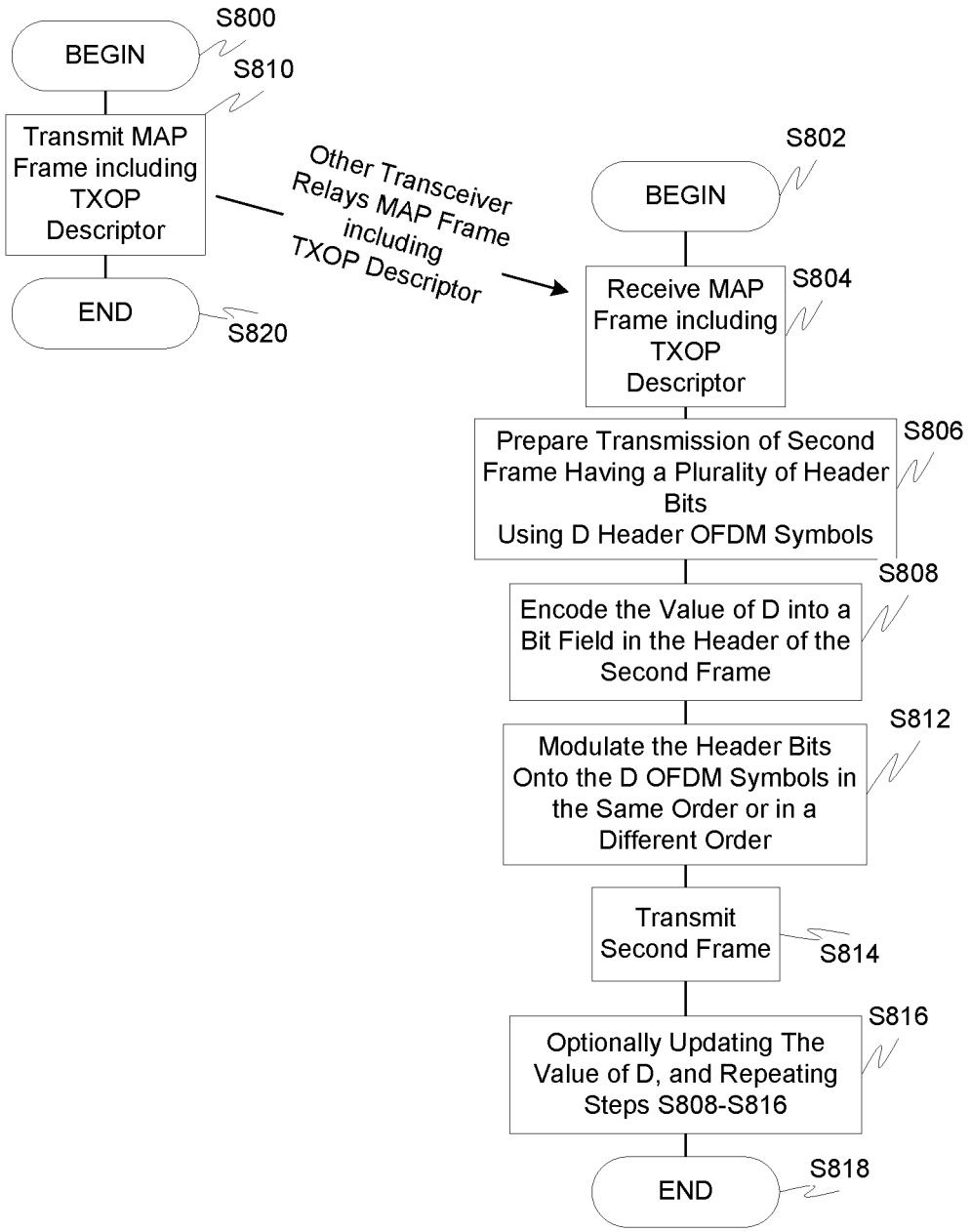
S800
BEGIN
S810
Transmit MAP Frame including TXOP Descriptor
END
S820
Other Transceiver Relays MAP Frame including TXOP Descriptor
S802
BEGIN
S804
Receive MAP Frame including TXOP Descriptor
S806
Prepare Transmission of Second Frame Having a Plurality of Header Bits Using D Header OFDM Symbols
S808
Encode the Value of D into a Bit Field in the Header of the Second Frame
S812
Modulate the Header Bits Onto the D OFDM Symbols in the Same Order or in a Different Order
Transmit Second Frame
S814
S816
Optionally Updating The Value of D, and Repeating Steps S808-S816
END
S818

Fig. 8

RECEIVER METHOD AND APPARATUS FOR VARIABLE HEADER REPETITION IN A WIRELESS OFDM NETWORK WITH DIFFERENT CHANNEL BANDWIDTHS

RELATED APPLICATION DATA

This application is a continuation of U.S. patent application Ser. No. 16/125,206, filed Sep. 7, 2018, now U.S. Pat. No. 10,291,449, which is a continuation of U.S. patent application Ser. No. 15/958,519, filed Apr. 20, 2018, now U.S. Pat. No. 10,079,707, which is a continuation of U.S. patent application Ser. No. 15/476,284, filed Mar. 31, 2017, now U.S. Pat. No. 9,973,361, which is a continuation of U.S. patent application Ser. No. 15/350,418, filed Nov. 14, 2016, now U.S. Pat. No. 9,614,566, which is a continuation of U.S. patent Ser. No. 13/376,856, filed Feb. 8, 2012, now U.S. Pat. No. 9,584,262, which is a national stage application under 35 U.S.C. 371 of PCT Application No. PCT/US2010/046088, having an international filing date of Aug. 20, 2010, which designated the United States, which PCT application claims the benefit of and priority under 35 U.S.C. § 119(e)to U.S. Patent Application No. 61/235,909, filed Aug. 21, 2009, entitled "Header Repetition Scheme in Packet-Based OFDM Systems," each of which are incorporated herein by reference in their entirety.

FIELD

An exemplary aspect of this invention relates to communications systems. More specifically, exemplary methods, systems, means, protocols and computer-readable storage media, are directed toward header repetition in a communications environment.

BACKGROUND

Conventional multi-user communications system use frame-based (or packet-based) transmission to communication between two or more users over a shared channel based on Orthogonal Frequency Division Multiplexing (OFDM)—(OFDM is also sometimes referred to as multicarrier modulation.) A packet is usually formed by a preamble, header, and payload, and transmitted using time-sharing or contention-based media access methods. An example of such a system includes IEEE 802.11 (Wireless LAN), IEEE 802.16 (WiMAX), and ITU G.9960 (G.hn). These systems use OFDM transmission, which is also sometimes referred to as Discrete Multi-Tone (DMT) which divides the transmission frequency band into multiple subcarriers (also referred to as tones or sub-channels), with each sub-carrier individually modulating a bit or a collection of bits.

The header contains important control information for the receiver to decode the payload properly, and also provides information about the packet length for virtual carrier sensing. Hence, it is essential to decode the header reliably. In G.9960, which is incorporated herein by reference in its entirety, and should be familiar to those skilled in the art, the header containing PHY_H bits (header information block) is carried over one or two OFDM symbols (D=1 or 2), and within each symbol, multiple header information blocks are repeated over the entire frequency band. (See Editor for G.9960, "ITU-T Recommendation G.9960: Next generation wire-line based home networking transceivers—Foundation," ITU-T SG15/Q4, Jan. 2009) The default value of D is 1, but expanding it to 2 in some cases is under discussion. See, for example, "G.hn: PHY-Frame Header Extension," ITU Temporary Document ITU-T SG-15/Q4 09CC-046, Aug. 2009, and ITU Temporary Document ITU-T SG15/Q4 09XC-100 entitled "G.hn: Using Two Symbols for the Header of PHY Frame on Coax," Jul., 2009, filed in the priority application and incorporated herein by reference in their entirety.

The possibility of carrying more than PHY_H bits in the header (H=1 or 2) is also under discussion as disclosed in the "G.hn: PHY-Frame Header Extension" article and in "G.hn: Extended PHY Frame Header," ITU-T SG15/Q4 09XC-119, Jul. 2009, filed in the priority application and incorporated herein by reference in their entirety.

SUMMARY

One exemplary technique discussed herein is allowing different values of D in a single domain where nodes are operating in different portions of frequency bands. For the power-line medium, G.9960 has defined two overlapped baseband bandplans, 50 MHz-PB and 100 MHz-PB. The possibility of having narrower bandplans such as 25 MHz-PB and 12.5 MHz-PB are under discussion in order to support, for example, SmartGrid applications.

In this exemplary scenario, the level of frequency diversity is different depending on the bandplan, hence providing different header decodability if D is fixed to 1. If D is fixed to 2, then it increases reliability for the narrowband devices, but may also unnecessarily increase overhead for the wideband devices.

An exemplary aspect is therefore directed to techniques to accommodate different repetitions schemes (D=1, . . . , D_{MAX} and H=1, . . . , H_{MAX}) in a single domain, and still allow devices to communicate with one another. D_{MAX} and H_{MAX} can be 2 or larger than 2.

As illustrated in FIG. **1**, various header repetition schemes are illustrated where D, H=1 or 2. In FIG. **1**, the second instance of a block with the same label is a copy of the prior block. The modulation of the copied block may not be exactly the same as the original version. For example, the label "Header Ext" emphasizes the fact that it may contain different header information than the "Header." The payload after the header may be omitted in some cases (e.g., ACK, RTS/CTS, etc.).

The repetition scheme expands similarly with larger values of D_{MAX} and H_{MAX}. An exemplary aspect focuses on dealing with different values of D, with different values of H capable of being supported in a straightforward way as discussed in the paper G.hn: PHY-Frame Header Extension.

On exemplary aspect is directed toward receiver detection of D with variable repetition. More specifically, in accordance with this exemplary embodiment, the transmitter selects (or determines), the at least one D value. The selection may be at its own discretion, or may be based on information communicated between one or more receivers, or based on instruction(s) from one or more other receivers and/or a domain master. Selection may depend on the number of available sub-carriers (or the bandwidth) of the bandplan the transmitter operates on and/or the receiver(s) operates on. In accordance with this exemplary embodiment, a receiving node in the domain should be able to decode packets sent by the transmitter without knowing D a priori (i.e. prior to decoding the packet header).

Another exemplary aspect is for a transmitter to carry, insert or otherwise communicate the value of D in the header so that all nodes know how many OFDM symbols are carrying header information. The receiver(s) starts processing the header by decoding one OFDM header symbol. If the

receiver decodes it successfully, then the receiver knows how many more OFDM symbols (D−1) are carrying header information for a given frame. If the receiver fails to obtain the header information from the OFDM header symbol (i.e., the header decoding fails), then the receiver can try to decode two OFDM header symbols, and so on. The decoding of each additional OFDM header symbol provides additional diversity thereby increasing the likelihood of decoding the header information correctly.

Another exemplary aspect is directed to a fixed repetition scheme per domain. More specifically, a domain master can select (or determine) one or more fixed D values for at least one node in the domain. For example, the domain master may select one fixed value for all nodes in a domain. Selection may depend on the number of available sub-carriers (or the bandwidth) of the bandplans that the domain members operate on. The domain master may change the value of D dynamically. A node in the domain first needs to determine the D that the domain master has set (or selected/determined).

On exemplary aspect is for the domain master to carry, insert or otherwise communicate the selected value of D in the header of the MAP frame while also using this D value for the transmission of the MAP header as described above. In this case, a node will be able to determine the value of D using the methods described above. After this value is determined by a node, the node can use this value until it is changed or updated by, for example, a domain master, another transceiver, etc.

Another exemplary aspect is for the domain master to carry, insert or otherwise communicate the selected value of D in the MAP while using a fixed D for the header of the MAP frame (e.g., pre-defined per medium or D_{MAX}). The D value in the MAP will be used for non-MAP frames/packets. In this case, a node in the domain may not need multiple levels of header decode process as described in above. Also in this exemplary method, the MAP may be sent with a different D value than the D value used for other (non-MAP) frames/packets.

Another exemplary aspect is directed toward a fixed repetition scheme per TXOP.

More specifically, in addition, or alternatively, the domain master may select (or determine) a D value per TXOP. This selection may be at its own discretion, or based on information communicated between one or more transceivers or receivers, or based on instruction from one or more transceivers or receivers. Selection may depend on the number of available sub-carriers (and/or the bandwidth) of the bandplan the transmitter/transceiver operates on and/or the receiver(s) operates on.

An exemplary technique is to include D in the TXOP descriptor transmitted in the MAP so that all nodes know in advance what value of D is used for that TXOP. The TXOP descriptor is the part of the MAP message which can be communicated via the MAP frame as discussed above.

Any of the above aspects and further aspects may be located in a network management system or network operation device that is located inside or outside the network and/or the transceiver(s). The network operation or management device that is located inside or outside the network may be managed and/or operated by a user, consumer, service provider or power utility provider, a governmental entity, or the like.

BRIEF DESCRIPTION ON THE DRAWINGS

The exemplary embodiments of the invention will be described in detail, with reference to the following figures, wherein:

FIG. **1** illustrates exemplary header repetition schemes;

FIG. **2** illustrates an exemplary transceiver;

FIG. **3** illustrates an exemplary communications environment;

FIG. **4** is a flowchart outlining an exemplary method of a header repetition scheme;

FIG. **5** is a flowchart outlining another exemplary method for a header repetition scheme;

FIG. **6** is a flowchart outlining yet another exemplary method for a header repetition scheme;

FIG. **7** is a flowchart outlining another exemplary method for a header repetition scheme; and

FIG. **8** is a flowchart outlining another method of an exemplary header repetition scheme.

DETAILED DESCRIPTION

The exemplary embodiments of this invention will be described in relation to communications systems, as well as protocols, techniques and methods for header repetition, such as in a DSL or multimode multicarrier communications environment, a home network or an access network, or in general any communications network operating using any communications protocol(s). Examples of such home or access networks include home powerline networks, access powerline networks, home coaxial cable network, access coaxial cable network, wireless home networks, wireless corporate networks, home telephone networks and access telephone networks. However, it should be appreciated that in general, the systems, methods, and techniques of this invention will work equally well for other types of communications environments, networks, and/or protocols.

The exemplary systems and methods of this invention will also be described in relation to wired or wireless modems and/or a software and/or a hardware testing module, a telecommunications test device, or the like, such as a DSL modem, an ADSL modem, and xDSL modem, a VDSL modem, a line card, a G.hn transceiver, a MOCA transceiver, a Homeplug® transceiver, a power line modem, a wired or wireless modem, test equipment, a multicarrier transceiver, a wireless wide/local area network system, a satellite communications system, a network-based communications systems, such as an IP, Ethernet or ATM system, a modem equipped with diagnostic capabilities, or the like, or a separate programmed general purpose computer having a communications device that is capable of operating in conjunction with any one or more of the following communications protocols: MOCA, Homeplug, IEEE 802.11, IEEE 802.3, IEEE 802.16 (WiMAX), and ITU G.9960 (G.hn), or the like. However, to avoid unnecessarily obscuring the present invention, the following description omits well-known structures, operations and devices that may be shown in block diagram form or are otherwise summarized or known.

For purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the present invention. It should be appreciated however that the present invention may be practiced in a variety of ways beyond the specific details set forth herein. Furthermore, while the exemplary embodiments illustrated herein show various components of this system collocated, it is to be appreciated that the various components of the system can be located at distant portions of a distributed network, such as a communications network, node, within a Domain Master, and/or the internet, or within a dedicated secured, unsecured, and/or encrypted system and/or within a network operation or management device that is located inside or

outside the network. As an example, a Domain Master can also be used to refer to any device, system or module that manages and/or configures any one or more aspects of the network or communications environment.

Thus, it should be appreciated that the components of the system can be combined into one or more devices, or split between devices, such as a modem, a station, a Domain Master, a network operation or management device, a node or collocated on a particular node of a distributed network, such as a communications network. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the system can be arranged at any location within a distributed network without affecting the operation thereof. For example, the various components can be located in a Domain Master, a node, a domain management device, such as a MIB, a network operation or management device, or some combination thereof. Similarly, one or more of the functional portions of the system could be distributed between a modem and an associated computing device/system, and/or in a dedicated test and/or measurement device.

Furthermore, it should be appreciated that the various links **5**, including the communications channel(s) connecting the elements can be wired or wireless links or any combination thereof, or any other known or later developed element(s) capable of supplying and/or communicating data to and from the connected elements. The term module as used herein can refer to any known or later developed hardware, software, firmware, or combination thereof, that is capable of performing the functionality associated with that element. The terms determine, calculate, and compute and variations thereof, as used herein are used interchangeable and include any type of methodology, process, technique, mathematical operational or protocol. The terms transceiver and modem are also used interchangeably herein. The terms transmitting modem and transmitting transceiver as well as receiving modem and receiving transceiver are also used interchangeably herein.

The term management interface is related to any type of interface between a management entity and/or technician and/or user and a transceiver, such as, a CO-MIB or CPE-MIB as described, for example, in ITU standard G.997.1, which is incorporated herein by reference in its entirety.

Moreover, while some of the exemplary embodiments described herein are directed toward a transmitter portion of a transceiver performing certain functions, this disclosure is intended to include corresponding receiver-side functionality in both the same transceiver and/or another transceiver, and vice versa.

FIG. **1** illustrates four different header configurations where D, H=1 or 2. Even more specifically, in the first example, H=1 and D=1 with a preamble followed by a header followed by a payload. In a second example H=1 and D=2, with the preamble followed by header **2** that is repeated as header **4**, which is followed by the payload. As discussed, the repeated header can be repeated in full or in part. In the third example, H=2 and D=1, such that the preamble is followed by a header which is followed by an extended header and the payload. In the fourth example, H=2 and D=2 such that header **6** is repeated as header **8**, and the extended header **3** is repeated as extended header **5**, which is followed by the payload. As discussed, the repeated portions may be exact duplicates.

As a more specific example, consider the header configuration in the fifth example. In the fifth example, H is again equal to 2 and D is equal to 2 such that header **11** is repeated as header **12**, and the extended header **13** is repeated as extended header **14**, which is followed by the payload. For this example, the "Header" is limited to a certain number of bits (here arbitrarily illustrated as 10 bits), however, for this example, there are 15 bits of information that need to be included in the header. Thus, 10 bits are included in the "Header" and the remaining 5 bits are included in the "Header Ext." As will be appreciated, the number of information bits to be included in the header, the number of bits the header is capable of carrying and the number of bits the header extended is capable of carrying can be any value(s). The 10 bits in "Header" **11** are repeated in "Header" **12** and the 5 bits in "Header Ext" **13** and repeated in "Header Ext" **14**.

FIG. **2** illustrates an exemplary transceiver or Domain Master **200**. In addition to well known componentry, the transceiver or Domain Master **200** includes (for a Domain Master) a MAP determination module **210** and (for a transceiver) a MAP processing or relaying module **210**, a header assembly module **220**, modulation module **230**, demodulation module **240**, transmitter **250**, encoding module **260**, decoding module **270**, receiver **280**, and controller/processor **290**. In general, a Domain Master generally determines a MAP frame for transmission to one or more other transceivers while a transceiver is capable of one or more of receiving and/or relaying the received MAP frame to one or more other transceivers. For ease of discussion, in the following description, the determining and transmitting of a MAP frame will be performed by a Domain Master-type of transceiver and the receiving and/or relaying of a MAP frame will be performed by a non-domain master type of transceiver. However, the description also allows and enables any transceiver (Domain master or non-domain master) to determine, transmit, receiver and/or relay MAP messages.

In operation, the transceiver or Domain Master **200**, cooperating with the MAP determination module or MAP processing or relaying module **210**, transmitter **250**, and controller/processor **290** transmits a MAP frame that includes a TXOP descriptor. As discussed, this TXOP descriptor contains a bit field that indicates a value for an integer (D) where the integer D indicates a number of header OFDM symbols that carry header bits. Next, the transceiver or Domain Master **200**, cooperating with the header assembly module **220** and transmitter **250** prepares to transmit a second frame having a plurality of header bits using the D header OFDM symbols. Each OFDM symbol carries the plurality of header bits. Then, in cooperation with the modulation module **230**, the transceiver or Domain Master **200** modulates the header bit onto the D OFDM symbols. As discussed, this modulation of the header bits onto the D OFDM symbols can occur where the header bits are modulated onto the D OFDM symbols in the same order or can occur where the header bits are modulated onto the D OFDM symbols in a different order. In addition, the encoding module **260** may encode the value of D into a bit field on the header of the second frame. The second frame is then transmitted over the communications channel.

As discussed, the value of D can be updated based, for example, on information received from another transceiver, on information received from a domain master, can be initiated by the controller/processor **290**, or can in general be initiated and/or requested by any other device, wherein the value of D that is updated is different than the previous value of D. With the updated value of D, the above-described steps can be repeated utilizing this updated value of D.

In accordance with another exemplary operational embodiment, the transceiver or Domain Master **200** trans-

mits a MAP frame that includes the TXOP descriptor and then receives a second frame that has a plurality of header bits that use the D header OFDM symbols. This is followed by the demodulation module **240** demodulating the header bits from the D OFDM symbols that were received. Additionally, the decoding module **270** may decode the value of D from a bit field in the header of the received second frame. As with the previous embodiment, the value of D can be updated with the above steps being repeated.

In accordance with yet another exemplary operational embodiment, the transceiver **200** first receives the MAP frame that includes the TXOP descriptor with the cooperation of the receiver **280**. The transceiver **200**, with the cooperation of the header assembly module **220**, and transmitter **250**, transmits a second frame having a plurality of header bits using the D header OFDM symbols. As with the previous embodiments, the header bits are modulated onto the D OFDM symbols either the same or in a different order, and the value of D may be encoded in a bit field in the header of the second frame. Again, this can be followed by an updated value of D with the above steps being repeated.

In yet another exemplary operational embodiment, the transceiver **200** receives a MAP frame that includes the TXOP descriptor, which is followed by the receipt of a second frame that has a plurality of header bits that used the D header OFDM symbols. As with one of the above exemplary embodiments, this is done with the cooperation of the receiver **280**, the demodulation module **240** and decoding module **270**. Upon receipt, the header bits from the D OFDM symbols can be demodulated and the value of D from a bit field in the header of the second frame may be decoded.

FIG. **3** illustrates an exemplary communications environment that includes a first transceiver or domain master **310** and a second transceiver **320**. While not illustrated in FIG. **3**, there could be one or more additional transceivers that act as relays to pass the various informational messages and data exchanged between the transceivers to thereby facilitate communication between the first transceiver or domain master **310** and the second transceiver **320**.

In operation, the transceiver and/or domain master **310**, cooperating with the MAP determination module or MAP processing or relaying module **210**, transmitter **250**, and controller/processor **290** transmits a MAP frame that includes a TXOP descriptor over the communications channel to the second transceiver **320**. As discussed, this TXOP descriptor contains a bit field that indicates a value for an integer (D) where the integer D indicates a number of header OFDM symbols that carry header bits. Next, the transceiver/domain master **310**, cooperating with the header assembly module **220** and transmitter **250** prepares to transmit a second frame to transceiver **320** having a plurality of header bits using the D header OFDM symbols. Each OFDM symbol carries the plurality of header bits. Then, in cooperation with the modulation module **230**, the transceiver/domain master **310** modulates the header bit onto the D OFDM symbols. As discussed, this modulation of the header bits onto the D OFDM symbols can occur where the header bits are modulated onto the D OFDM symbols in the same order or can occur where the header bits are modulated onto the D OFDM symbols in a different order. In addition, the encoding module **260** may encode the value of D into a bit field on the header of the second frame. The second frame is then transmitted over the communications channel to the second transceiver **320**.

As discussed, the value of D can be updated based, for example, on information received from another transceiver, on information received from a domain master, can be initiated by the controller/processor **290**, or can in general be initiated and/or requested by any other device, wherein the value of D that is updated is different than a previous value of D. With the updated value of D, the above-described steps can be repeated utilizing this updated value of D.

In accordance with another exemplary operational embodiment, the transceiver/domain master **310** transmits a MAP frame that includes the TXOP descriptor to the second transceiver **320** and then receives from the second transceiver **320** a second frame that has a plurality of header bits that use the D header OFDM symbols. This is followed by the transceiver/domain master's **310** demodulation module **240** demodulating the header bits from the D OFDM symbols that were received. Additionally, the decoding module **270** of the transceiver/domain master **310** decodes the value of D from the bit in the header of the received second frame. As with the previous embodiment, the value of D can be updated with the above steps being repeated.

In accordance with yet another exemplary operational embodiment, the transceiver/domain master **310** first receives the MAP frame that includes the TXOP descriptor from the second transceiver **320** with the cooperation of the receiver **280** in the transceiver/domain master **310**. The transceiver/domain master **310**, with the cooperation of the header assembly module **220**, and transmitter **250**, transmits a second frame having a plurality of header bits using the D header OFDM symbols to the second transceiver **320**. As with the previous embodiments, the header bits are modulated onto the D OFDM symbols either the same or in a different order, and the value of D encoded in a bit field in the header of the second frame. Again, this can be followed by an updated value of D with the above steps being repeated.

In yet another exemplary operational embodiment, the transceiver/domain master **310** receives a MAP frame from the transceiver **320** that includes the TXOP descriptor, which is followed by the receipt of a second frame that has a plurality of header bits that used the D header OFDM symbols. As with one of the above embodiments, this is done with the cooperation of the receiver **280**, the demodulation module **240** and decoding module **270**. Upon receipt, the header bits from the D OFDM symbols can be demodulated and the value of D from a bit field in the header of the second frame decoded. Again, this can be followed by an updated value of D with the above steps being repeated.

FIG. **4** illustrates an exemplary method of packet transmission. In particular, control begins in step S**400** and continues to step S**410**. In step S**410**, a MAP frame is transmitted, with the MAP frame including a TXOP descriptor. As discussed, the TXOP descriptor can contain a bit field that indicates a value for an integer (D) wherein the integer D indicates a number of header OFDM symbols that carry header bits. The TXOP descriptor could contain multiple bit fields that indicate more than a value for the integer D as well. Next, in step S**420**, a second frame is prepared for transmission, the second frame having a plurality of header bits using D header OFDM symbols. Then, in step S**430**, the value of D is encoded into a bit field in the header of the second frame. Control then continues to step S**440**.

In step S**440**, the header bits are modulated onto the D OFDM symbols in either the same order or in a different order. Then, in step S**450**, the second frame is transmitted with control continuing to step S**460**.

In step S**460**, the value of D can optionally be updated with steps S**410**-S**450** being repeated. Control then continues to step S**470** where the control sequence ends.

FIG. **5** illustrates an exemplary method of packet reception. In particular, control begins in step S**500** and continues to step S**510**. In step S**510**, a MAP frame is received, with the MAP frame including a TXOP descriptor. As discussed, the TXOP descriptor contains a bit field that indicates a value for an integer (D) wherein the integer D indicates a number of header OFDM symbols that carry header bits. Next, in step S**520**, a second frame is received, the second frame having a plurality of header bits that used the D header OFDM symbols. Then, in step S**530**, the header bits are demodulated from the D OFDM symbols in the same order or in a different order. Control then continues to step S**540**.

In step S**540**, the value of D is decoded from a bit field in the header of the second frame. Then, in step S**550**, the value of D can optionally be updated with steps S**510**-S**540** being repeated. Control then continues to step S**560** where the control sequence ends.

FIG. **6** illustrates an exemplary method of packet communication. In particular, control begins in step S**600** in a first transceiver or Domain Master and continues to step S**610**. In step S**610**, a MAP frame is transmitted to a second transceiver, with the MAP frame including a TXOP descriptor. For the second transceiver, control begins in step S**602** and continues to step S**604** where the MAP frame including the TXOP descriptor is received.

Next, in step S**620**, a second frame is prepared for transmission and transmitted to the second transceiver, the second frame having a plurality of header bits using D header OFDM symbols. As discussed the header bits are modulated onto the D OFDM symbols with the TXOP descriptor containing a bit field that indicates a value for a integer (D) wherein the integer D indicates a number of header OFDM symbols that carry header bits. The TXOP descriptor could contain multiple bit fields that indicate more than a value for the integer D as well. Additionally, the header bits can be modulated onto the D OFDM symbols in the same order or in a different order and the value of D encoded into a bit field in the header of the second frame. Control for the first transceiver then continues to step S**630** where the control sequence ends.

In step S**606**, the second frame is received, the second frame having the plurality of header bits that used the D header OFDM symbols. Then, in step S**608**, the header bits are demodulated from the D OFDM symbols in the same order or in a different order with control continuing to step S**612**.

In step S**612**, the value of D is decoded from the bit field in the header of the second frame. Then, in step S**612**, the value of D can optionally be updated with steps S**610**, S**620** and S**604**-S**612** being repeated. Control then continues to step S**616** where the control sequence ends.

FIG. **7** illustrates an exemplary method of packet communication. In particular, control begins in step S**700** in a first transceiver or Domain Master and continues to step S**710**. In step S**710**, a MAP frame is transmitted to a second transceiver, with the MAP frame including a TXOP descriptor. Control then continues to step S**720** where the control sequence ends.

For the second transceiver, control begins in step S**702** and continues to step S**704** where after receipt of the MAP frame that includes the TXOP descriptor, a second frame is prepared by the second transceiver for transmission, the second frame having a plurality of header bits using D header OFDM symbols. Then, in step S**706**, the value of D is encoded into a bit field in the header of the second frame with control continuing to step S**708**.

In step S**708**, the header bits are modulated onto the D OFDM symbols in the same order or in a different order. Then, in step S**712**, the second frame is transmitted with control continuing to step S**714**.

In step S**714**, the value of D can optionally be updated with steps S**710** and S**704**-S**712** being repeated. Control then continues to step S**716** where the control sequence ends.

FIG. **8** illustrates another exemplary method of packet communication. In particular, control begins in step S**800** in a first transceiver or Domain Master and continues to step S**810**. In step S**810**, a MAP frame is transmitted to a second transceiver, optionally being relayed by one or more other transceivers, with the MAP frame including a TXOP descriptor. Control then continues to step S**820** where the control sequence ends. The relaying of one or more of the MAP frame and second frame as discussed herein is not limited to this specific embodiment, but could also occur in any of the other embodiments disclosed herein.

For the second transceiver, control begins in step S**802** and continues to step S**804** where the MAP frame that includes the TXOP descriptor is received. Next, in step S**806** a second frame is prepared by the second transceiver for transmission, the second frame having a plurality of header bits using D header OFDM symbols. Then, in step S**808**, the value of D is encoded into a bit field in the header of the second frame with control continuing to step S**812**.

In step S**812**, the header bits are modulated onto the D OFDM symbols in the same order or in a different order. Then, in step S**814**, the second frame is transmitted with control continuing to step S**816**.

In step S**816**, the value of D can optionally be updated with steps S**810** and S**804**-S**814** being repeated using the updated value of D. Control then continues to step S**818** where the control sequence ends.

As used herein the terms network and domain have the same meaning and are used interchangeably. Also, the terms receiver, receiving node and receiving transceiver have the same meaning and are used interchangeably. Similarly, the terms transmitter, transmitting node and transmitting transceiver have the same meaning and are used interchangeably. The terms transceiver and modem also have the same meaning and are used interchangeably. While the term home network has been used in this description, the description is not limited to home networks but in fact applies also to any network, such as enterprise networks, business networks, or any network with a plurality of connected nodes. The terms transceiver, node and modem have the same meaning and are used interchangeably in the description. The term frame and packet have the same meaning and are used interchangeably in the description. The term header and PHY-frame header have the same meaning and are used interchangeably in the description.

The terms network and home network have the same meaning and are used interchangeably in the description. While the term Home network has been used in this description, the description is not limited to home networks but in fact applies also to any network, such as enterprise networks, business networks, or any network with a plurality of connected nodes.

While the above-described methods and systems can be described with respect to a port (or endpoint) in a network, they can also be implemented in a dedicated module such as a test or network optimization module. This dedicated module could be plugged into the network and act as a Domain Master or with the cooperation of the Domain Master could initiate the various measurement techniques, gather the measurements from the port(s) in the network,

analyze the measurements and use the measured information to detect and diagnose problems in the network and/or to optimize or improve the performance of a network.

While the above-described flowcharts have been discussed in relation to a particular sequence of events, it should be appreciated that one or more changes to this sequence can occur without materially effecting the operation of the embodiments. Additionally, the exact sequence of events need not occur as set forth in the exemplary embodiments. The exemplary techniques illustrated herein are not limited to the specifically illustrated embodiments but can also be utilized with the other exemplary embodiments and each described feature is individually and separately claimable. Moreover, the steps in the flowcharts are optional, with some of or all of the steps being performed.

The above-described methods and systems and can be implemented in a software module, a software and/or hardware testing module, a telecommunications test device, a DSL modem, an ADSL modem, an xDSL modem, a VDSL modem, a linecard, a G.hn transceiver, a MOCA transceiver, a Homeplug transceiver, a powerline modem, a wired or wireless modem, test equipment, a multicarrier transceiver, a wired and/or wireless wide/local area network system, a satellite communication system, network-based communication systems, such as an IP, Ethernet or ATM system, a modem equipped with diagnostic capabilities, or the like, or on a separate programmed general purpose computer having a communications device or in conjunction with any of the following communications protocols: CDSL, ADSL2, ADSL2+, VDSL1, VDSL2, HDSL, DSL Lite, IDSL, RADSL, SDSL, UDSL, MOCA, G.hn, Homeplug® or the like.

Additionally, the systems, methods and protocols of this invention can be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a flashable device, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, a modem, a transmitter/receiver, any comparable means, or the like. In general, any device (or one or more equivalent means) capable of implementing a state machine that is in turn capable of implementing the methodology illustrated herein can be used to implement the various communication/measurement methods, protocols and techniques according to this invention.

Furthermore, the disclosed methods may be readily implemented in software stored on a non-transitory computer-readable storage media using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed system may be implemented partially or fully in hardware using standard logic circuits or VLSI design. Whether software or hardware is used to implement the systems in accordance with this invention is dependent on the speed and/or efficiency requirements of the system, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The communication systems, methods and protocols illustrated herein can be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods may be readily implemented in software that can be stored on a computer-readable storage medium, executed on programmed general-purpose computer with the cooperation of a controller and memory, a special purpose computer, a microprocessor, or the like. The systems and methods of this invention can be implemented as a program embedded on personal computer such as an applet, JAVA® or CGI script, as a resource residing on a server or computer workstation, as a routine embedded in a dedicated communication system or system component, or the like. The system can also be implemented by physically incorporating the system and/or method into a software and/or hardware system, such as the hardware and software systems of a test/modem device.

While the invention is described in terms of exemplary embodiments, it should be appreciated that any of the aspects of the invention described herein in connection with the exemplary embodiments could be separately and individually claimed and one or more of the features of the various embodiments can be combined with one or more features discussed in relation to one or more other embodiments.

While the exemplary embodiments illustrated herein discuss the various components collocated, it is to be appreciated that the various components of the system can be located a distant portions of a distributed network, such as a telecommunications network and/or the Internet or within a dedicated communications network. Thus, it should be appreciated that the components of the system can be combined into one or more devices or collocated on a particular node of a distributed network, such as a telecommunications network. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the communications network can be arranged at any location within the distributed network without affecting the operation of the system.

It is therefore apparent that there has been provided, in accordance with the present invention, systems and methods for header repetition in OFDM systems. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable arts. Accordingly, it is intended to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and scope of this invention.

The invention claimed is:

1. A wireless OFDM (Orthogonal Frequency Division Multiplexing) transceiver comprising:

a wireless OFDM communications receiver operable to receive, over a wireless communication channel, a first packet type in a first channel bandwidth, the first packet type comprising a first header field, wherein the first header field comprises two parts, a first part comprising a first set of header bits of the first header field and a second part comprising a second set of header bits of the first header field, wherein the first set of header bits of the first header field is different than the second set of header bits of the first header field; and

a demodulator operable to demodulate a first OFDM symbol followed by a second OFDM symbol, wherein the first OFDM symbol is used to receive the first part of the first header field and the second OFDM symbol is used to receive the second part of the first header field;

the wireless OFDM communications receiver further operable to receive, over the wireless communications channel, a second packet type in a second channel

bandwidth, the second packet type comprising a second header field, wherein the second header field comprises four parts, a first part comprising a first set of header bits of the second header field, a second part comprising a second set of header bits of the second header field, a third part comprising a third set of header bits of the second header field and a fourth part comprising a fourth set of header bits of the second header field,

wherein the first set of header bits of the second header field is the same as the second set of header bits of the second header field, wherein the third set of header bits of the second header field is the same as the fourth set of header bits of the second header field,

the demodulator further operable to demodulate a first OFDM symbol followed by a second OFDM symbol followed by a third OFDM symbol followed by a fourth OFDM symbol, wherein the first OFDM symbol is used to receive the first part of the second header field, the second OFDM symbol is used to receive the second part of the second header field, the third OFDM symbol is used to receive the third part of the second header field, the fourth OFDM symbol is used to receive the fourth part of the second header field,

wherein the second set of header bits of the second header field received using the second OFDM symbol are received in a different order than the first set of header bits of the second header field received using the first OFDM symbol,

wherein the fourth set of header bits of the second header field received using the fourth OFDM symbol are received in a different order than the third set of header bits of the second header field received using the third OFDM symbol, and

wherein the first channel bandwidth is at least two times wider than the second channel bandwidth.

2. The wireless transceiver of claim **1**, wherein the reception of the same header bits in the second OFDM symbol provides diversity to increase a likelihood of correctly receiving header information of the second packet type.

3. The wireless transceiver of claim **1**, wherein the reception of the same header bits in the fourth OFDM symbol provides diversity to increase a likelihood of correctly receiving header information of the second packet type.

4. The wireless transceiver of claim **1**, wherein the wireless transceiver supports SmartGrid applications.

5. The wireless transceiver of claim **1**, wherein the wireless transceiver supports one or more wireless standards.

6. The wireless transceiver of claim **1**, wherein a MAP (Media Access Plan) frame indicates whether two or four OFDM symbols are used to receive header bits.

7. The wireless transceiver of claim **1**, wherein the first header field indicates that the type of packet.

8. The wireless transceiver of claim **1**, wherein the second header field indicates that the type of packet.

9. A method of operating a wireless OFDM (Orthogonal Frequency Division Multiplexing) transceiver comprising:

receiving, by a wireless OFDM communications receiver over a wireless communication channel, a first packet type in a first channel bandwidth, the first packet type comprising a first header field, wherein the first header field comprises two parts, a first part comprising a first set of header bits of the first header field and a second part comprising a second set of header bits of the first header field, wherein the first set of header bits of the first header field is different than the second set of header bits of the first header field;

demodulating, by a demodulator, a first OFDM symbol followed by a second OFDM symbol, wherein the first OFDM symbol is used to receive the first part of the first header field and the second OFDM symbol is used to receive the second part of the first header field;

receiving, by the wireless OFDM communications receiver over the wireless communication channel, a second packet type in a second channel bandwidth, the second packet type comprising a second header field, wherein the second header field comprises four parts, a first part comprising a first set of header bits of the second header field, a second part comprising a second set of header bits of the second header field, a third part comprising a third set of header bits of the second header field and a fourth part comprising a fourth set of header bits of the second header field,

wherein the first set of header bits of the second header field is the same as the second set of header bits of the second header field, wherein the third set of header bits of the second header field is the same as the fourth set of header bits of the second header field;

and demodulating, by the demodulator, a first OFDM symbol followed by a second OFDM symbol followed by a third OFDM symbol followed by a fourth OFDM symbol, wherein the first OFDM symbol is used to receive the first part of the second header field, the second OFDM symbol is used to receive the second part of the second header field, the third OFDM symbol is used to receive the third part of the second header field, the fourth OFDM symbol is used to receive the fourth part of the second header field,

wherein the second set of header bits of the second header field received using the second OFDM symbol are received in a different order than the first set of header bits of the second header field received using the first OFDM symbol,

wherein the fourth set of header bits of the second header field received using the fourth OFDM symbol are received in a different order than the third set of header bits of the second header field received using the third OFDM symbol, and

wherein the first channel bandwidth is at least two times wider than the second channel bandwidth.

10. The method of claim **9**, wherein the reception of the same header bits in the second OFDM symbol provides diversity to increase a likelihood of correctly receiving header information of the second packet type.

11. The method of claim **9**, wherein the reception of the same header bits in the fourth OFDM symbol provides diversity to increase a likelihood of correctly receiving header information of the second packet type.

12. The method of claim **9**, wherein the wireless transceiver supports SmartGrid applications.

13. The method of claim **9**, wherein the wireless transceiver supports one or more wireless standards.

14. The method of claim **9**, wherein a MAP (Media Access Plan) frame indicates whether two or four OFDM symbols are used to receive header bits.

15. A wireless OFDM (Orthogonal Frequency Division Multiplexing) transceiver comprising:

means for receiving over a wireless communication channel a first packet type in a first channel bandwidth, the first packet type comprising a first header field, wherein the first header field comprises two parts, a first part comprising a first set of header bits of the first header field and a second part comprising a second set of header bits of the first header field, wherein the first set

of header bits of the first header field is different than the second set of header bits of the first header field;

means for demodulating a first OFDM symbol followed by a second OFDM symbol, wherein the first OFDM symbol is used to receive the first part of the first header field and the second OFDM symbol is used to receive the second part of the first header field;

means for receiving over the wireless communication channel a second packet type in a second channel bandwidth, the second packet type comprising a second header field, wherein the second header field comprises four parts, a first part comprising a first set of header bits of the second header field, a second part comprising a second set of header bits of the second header field, a third part comprising a third set of header bits of the second header field and a fourth part comprising a fourth set of header bits of the second header field,

wherein the first set of header bits of the second header field is the same as the second set of header bits of the second header field, wherein the third set of header bits of the second header field is the same as the fourth set of header bits of the second header field;

and means for demodulating a first OFDM symbol followed by a second OFDM symbol followed by a third OFDM symbol followed by a fourth OFDM symbol, wherein the first OFDM symbol is used to receive the first part of the second header field, the second OFDM symbol is used to receive the second part of the second header field, the third OFDM symbol is used to receive the third part of the second header field, the fourth OFDM symbol is used to receive the fourth part of the second header field,

wherein the second set of header bits of the second header field received using the second OFDM symbol are received in a different order than the first set of header bits of the second header field received using the first OFDM symbol,

wherein the fourth set of header bits of the second header field received using the fourth OFDM symbol are received in a different order than the third set of header bits of the second header field received using the third OFDM symbol, and

wherein the first channel bandwidth is at least two times wider than the second channel bandwidth.

16. The wireless transceiver of claim **15**, wherein the reception of the same header bits in the second OFDM symbol provides diversity to increase a likelihood of correctly receiving header information of the second packet type.

17. The wireless transceiver of claim **15**, wherein the reception of the same header bits in the fourth OFDM symbol provides diversity to increase a likelihood of correctly receiving header information of the second packet type.

18. The wireless transceiver of claim **15**, wherein the wireless transceiver supports SmartGrid applications.

19. The wireless transceiver of claim **15**, wherein the wireless transceiver supports one or more wireless standards.

20. The wireless transceiver of claim **15**, wherein a MAP (Media Access Plan) frame indicates whether two or four OFDM symbols are used to receive header bits.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,554,459 B2
APPLICATION NO. : 16/394490
DATED : February 4, 2020
INVENTOR(S) : Joon Bae Kim and Marcos C. Tzannes

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In Claim 7, at Column 13, Line 53, “that the” should be replaced with --the--.

In Claim 8, at Column 13, Line 55, “that the” should be replaced with --the--.

Signed and Sealed this
Tenth Day of January, 2023

Katherine Kelly Vidal

Katherine Kelly Vidal
Director of the United States Patent and Trademark Office