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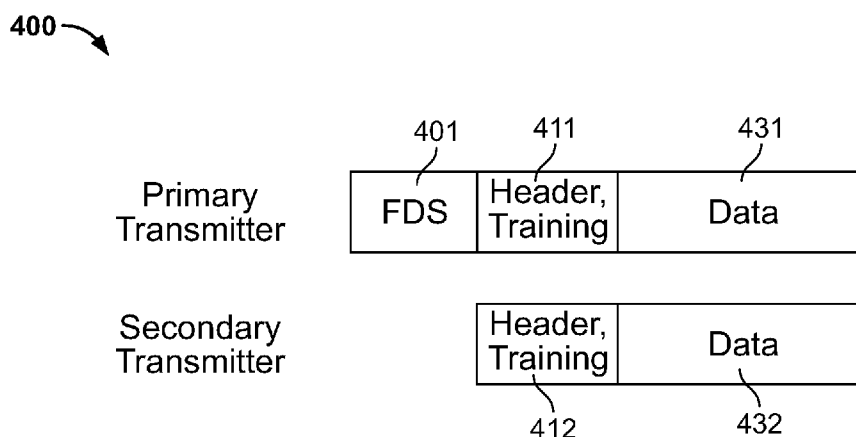


FIG. 4

(57) Abstract: A method of conducting full-duplex transmission between first and second nodes in a communications system having more than two nodes includes the issuing of a start signal on a channel by the first node, wherein the start signal signals that full-duplex transmission is to begin, and identifies the second node as a node with which full-duplex communication is to occur. The method also includes, following the issuing of the start signal, the beginning of full-duplex transmission by the first and second nodes. A node, for use in a network including at least two nodes, is configured to initiate full-duplex communication with any other node by issuing a start signal, where the start signal signals that full-duplex transmission is to begin, and identifies a second node as a node with which full-duplex communication is to occur, and by, following the issuing of the start signal, beginning full-duplex communication.

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METHOD AND APPARATUS FOR FULL-DUPLEX OPERATION
IN A MULTIPOINT-TO-MULTIPOINT NETWORK

Cross Reference to Related Application

[0001] This claims the benefit of copending, commonly-
5 assigned United States Provisional Patent Applications
Nos. 62/382,908 and 62/382,913, both filed September 2,
2016, each of which is hereby incorporated by reference
herein in its respective entirety.

Field of Use

10 **[0002]** This disclosure relates to a method and
apparatus for providing full-duplex operation in a
multipoint-to-multipoint network.

Background

[0003] The background description provided herein is
15 for the purpose of generally presenting the context of the
disclosure. Work of the inventors hereof, to the extent
the work is described in this background section, as well
as aspects of the description that may not otherwise
qualify as prior art at the time of filing, are neither
20 expressly nor impliedly admitted to be prior art against
the present disclosure.

[0004] Many full-duplex systems operate in a point-to-
point mode in which two nodes communicate between
themselves. In such a case, Medium Access Control (MAC) is
25 not required given that each of the two nodes can always
transmit while simultaneously receiving from the other

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node. Examples of full-duplex point-to-point systems are Ethernet 1000BASE-T and 10GBASE-T systems.

[0005] Some full-duplex systems operate in a point-to-multipoint mode in which one node (sometimes referred to
5 as a "master node" or "access point") transmits to multiple other nodes and receives transmission from the other nodes. There is no direct communication between the other nodes. The master node or access point transmits in the downstream direction, and the other nodes share the
10 upstream transmissions. The master node or access point is thus the only node that can initiate a full-duplex transmission.

Summary

[0006] A method of conducting full-duplex transmission
15 between first and second nodes in a communications system having more than two nodes includes the issuing of a start signal on a channel by the first node, wherein the start signal signals that full-duplex transmission is to begin, and identifies the second node as a node with which full-
20 duplex communication is to occur. The method also includes, following the issuing of the start signal, beginning full-duplex transmission by the first node and by the second node.

[0007] In such a method, each node of the first and
25 second nodes signals a respective duration of its respective transmission, and duration of the full-duplex transmission between the first and second nodes is determined by whichever respective duration is longer.

[0008] The method further includes the one of the first
30 and second nodes whose respective transmission has a shorter duration transmitting additional symbols to extend its transmission to match the duration of the transmission of the other of the first and second nodes. Alternatively, the method includes the first node signaling a required
35 transmission duration based on its data to be transmitted, and the second node adjusting its transmission to fit the required transmission duration. In such a method, the

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second node adjusting its transmission includes the second node shortening its transmission by decreasing the amount of data to be sent, or the second node adjusting its transmission includes the second node transmitting
5 additional symbols to extend its transmission to match the duration of the transmission of first a node.

[0009] The method further includes performing echo cancellation on the full-duplex transmission to remove, from a transmission in one direction, an echo of a
10 transmission in another direction.

[0010] In the method, the full-duplex transmission may be performed using orthogonal frequency division modulation (OFDM), the first node transmits on a first set of OFDM subcarriers, and the second node transmits on a
15 second set of OFDM subcarriers.

[0011] In the method, the full-duplex transmission is performed using orthogonal frequency division modulation (OFDM), and at least one of the first node and the second node transmits a signal on at least one OFDM subcarrier to
20 signal other nodes that the channel is in use.

[0012] A method of conducting full-duplex transmission between nodes in a communications system having more than two nodes includes establishing a medium access plan assigning respective temporal slots to respective pairs of
25 nodes, and
on opening of a respective temporal slot, initiating full-duplex transmission between nodes in the respective pair of nodes to which the respective temporal slot is assigned, wherein any node in the communications system is capable
30 of full-duplex communication with any other node according to the medium access plan.

[0013] In the method, the initiating full-duplex transmission includes issuing of a start signal on a channel by one of the nodes in the respective pair of
35 nodes, signaling that full-duplex transmission is to begin, and following the issuing of the start signal, beginning full-duplex transmission by both of the nodes in the respective pair of nodes.

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[0014] In the method, each node in the respective pair of nodes signals a respective duration of its respective transmission, and duration of the full-duplex transmission between the nodes in the respective pair of nodes is
5 determined by whichever respective duration is longer. The one of the nodes in the respective pair of nodes whose respective transmission has a shorter duration may transmit additional symbols to extend its transmission to match the duration of the transmission of the other of the
10 first and second nodes.

[0015] The method also includes a first one of the nodes in the respective pair of nodes signaling a required transmission duration based on its data to be transmitted, and a second one of the nodes in the respective pair of
15 nodes adjusting its transmission to fit the required transmission duration.

[0016] The method also includes performing echo cancellation on the full-duplex transmission to remove, from a transmission in one direction, an echo of a
20 transmission in another direction.

[0017] In the method, the full-duplex transmission is performed using orthogonal frequency division modulation, a first set of subcarriers is used for transmission by a first node in the respective pair of nodes, and a second
25 set of subcarriers is used for transmission by a second node in the respective pair of nodes.

[0018] A node, for use in a communications network including at least two nodes, is configured to initiate full-duplex communication with any other node by issuing a
30 start signal on a channel, wherein the start signal signals that full-duplex transmission is to begin, and identifies a second node as a node with which full-duplex communication is to occur, and following the issuing of the start signal, beginning full-duplex communication. A
35 communications system includes a plurality of that node.

[0019] In such a communications system, each node signals a respective duration of its respective

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transmission, and duration of the full-duplex transmission is determined by whichever respective duration is longer.

[0020] The communications system further includes the node whose respective transmission has shorter duration
5 transmitting additional symbols to extend its transmission to match the duration of the transmission of the node whose respective transmission has a longer duration.

[0021] The communications system further includes one node signaling a required transmission duration based on
10 its data to be transmitted, and the other node adjusting its transmission to fit the required transmission duration.

[0022] In the communications system, the full-duplex transmission is performed using orthogonal frequency division modulation (OFDM), one node transmits on a first
15 set of OFDM subcarriers, and the other node transmits on a second set of OFDM subcarriers.

[0023] In the communications system, the full-duplex transmission is performed using orthogonal frequency division modulation (OFDM), and at least one of the nodes
20 transmits a signal on at least one OFDM subcarrier to signal other nodes that the channel is in use.

Brief Description of the Drawings

[0024] Further features of the disclosure, its nature and various advantages, will be apparent upon
25 consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which like reference characters refer to like parts throughout, and in which:

[0025] FIG. 1 is a schematic representation of a system
30 operating in accordance with an implementation of the subject matter of this disclosure;

[0026] FIG. 2 is a flow diagram of an implementation of a first method according to the subject matter of this disclosure;

35 **[0027]** FIG. 3 is a representation of one variant of a signaling format used in accordance with the subject matter of this disclosure;

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[0028] FIG. 4 is a representation of another variant of a signaling format used in accordance with the subject matter of this disclosure;

5 [0029] FIG. 5 is a flow diagram of an implementation of a second method according to the subject matter of this disclosure;

[0030] FIG. 6 is a schematic representation of a node used in implementations of the subject matter of this disclosure.

10 Detailed Description

[0031] For purposes of this disclosure, "full-duplex" communication should be considered to mean communication in which nodes transmit and receive at the same time, using at least some overlapping frequencies. Because
15 there is usually some residual echo of the transmit signal in the receive path, each node has to perform echo cancellation. The received signal is:

$$r(t)=y(t)+a(t)+n(t)$$

where $r(t)$ is the received signal, $y(t)$ is the desired
20 signal received from a distant transmitter, $a(t)$ is the echo of the node's own transmit signal, and $n(t)$ is noise. In receive mode, the node estimates $a(t)$ and subtracts it from $r(t)$. The echo signal is obtained via the convolution of the echo channel with the transmitted
25 signal:

$$a(t)=x(t)*h(t)$$

where $x(t)$ is the transmitted signal and $h(t)$ is the echo channel. The echo channel may be estimated by the node by using a sounding signal and/or adaptive filtering
30 techniques.

[0032] As noted above, many full-duplex systems operate in a point-to-point mode in which two nodes communicate between themselves. In such a case, Medium Access Control (MAC) is not required given that each of the two nodes can
35 always transmit while simultaneously receiving from the other node. Examples of full-duplex point-to-point systems are Ethernet 1000BASE-T and 10GBASE-T systems.

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[0033] Some full-duplex systems operate in a point-to-multipoint mode in which one node (sometimes referred to as a "master node" or "access point") transmits to the other nodes and receives transmission from the other nodes.

5 There is no direct communication between the other nodes. The master node or access point transmits in the downstream direction, and the other nodes share the upstream transmissions. The master node or access point is thus the only node that can initiate a full-duplex
10 transmission.

[0034] In accordance with implementations of the subject matter of this disclosure, in a full-duplex system, each node in a plurality of nodes (which may include all nodes) is configured to initiate full-duplex communication
15 with each other node. In effect, each node in the plurality of nodes can be a master node. A system in accordance with the subject matter of this disclosure typically includes up to 32 nodes. Such a system may be a home network, a small office network, or an access system.

20 **[0035]** As seen in FIG. 1, a system 100 operating in accordance with an implementation of the subject matter of this disclosure, includes at least four nodes A, B, C, D. In this implementation, the aforementioned plurality of nodes includes all nodes in system 100. Either of nodes A
25 and B can initiate full-duplex communication with the other of nodes A and B over path 101. Either of nodes A and C can initiate full-duplex communication with the other of nodes A and C over path 102. Either of nodes A and D can initiate full-duplex communication with the
30 other of nodes A and D over path 103. Either of nodes B and C can initiate full-duplex communication with the other of nodes B and C over path 104. Either of nodes B and D can initiate full-duplex communication with the other of nodes B and D over path 105. Either of nodes C
35 and D can initiate full-duplex communication with the other of nodes C and D over path 106. If there are additional nodes in system 100, then any one of those

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other nodes can initiate full-duplex communication with any other node in system 100 over a path between them.

[0036] Although paths 101-106 are shown in FIG. 1 as being individual paths, paths 101-106 are only logical
5 representations of communication paths. System 100 could be a wired system in which paths 101-106 are actual physical paths, or a wired system in which paths 101-106 are logical paths on a single multi-channel physical path (e.g., a bus to which all nodes are connected).
10 Alternatively, system 100 could be a wireless system in which paths 101-106 are wireless connections.

[0037] In order to avoid collisions, and to allow each node to estimate the echo channel for echo cancellation (i.e., as noted above, to cancel from a transmission in
15 one direction echoes remaining from a transmission in the other direction), a control protocol, such as a Medium Access Control (MAC) protocol, for system 100 should control when and how a node may initiate full-duplex communication on a channel. In one implementation, a MAC
20 protocol such as, e.g., a CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) protocol is used to access a channel. A node, which may be referred to as a "primary transmitter," that is initiating a full-duplex communication broadcasts a signal to access the
25 communications medium. This signal, which may be referred to as a Full-Duplex Start (FDS) signal, reserves the channel and identifies the other node that will form the full-duplex pair. All other nodes in system 100 also receive this signal.

[0038] Once the other node that is identified in the FDS (also referred to as the "secondary transmitter")
30 receives the FDS, the secondary transmitter knows that it is the other member of the full-duplex pair and can also transmit. From that point on, the other nodes in
35 system 100, which also process the FDS (see below in connection with FIG. 6), refrain from attempting to access the channel being used by the primary transmitter node and the secondary transmitter node. Both the primary

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transmitter node and the secondary transmitter node can start a full-duplex communication (with both nodes transmitting and receiving simultaneously) once a predetermined time, as discussed below, has elapsed from the transmission of the FDS by the primary transmitter.

5 [0039] In a variation, a similar scheme could be used to implement three-way full-duplex communication among three nodes, in which Node A transmits to node B, and node C transmits back to node A. This is a less common case than two-way full duplex, but it is possible in some scenarios. In such a scheme, the FDS identifies node C as the secondary transmitter, but the header of messages transmitted by the primary transmitter indicates that node B is the intended receiver of data transmitted by node A. In order for such an arrangement to work, node B must not receive the signal transmitted by node C. That is, node B and node C must be selected and configured so that they do not interfere each other. For example, in a frequency-division multiplexing environment, they could be configured to use different subcarriers.

15 [0040] A method 200 for initiating a full-duplex transmission between nodes in a network system, according to an implementation of the subject matter of this disclosure using an FDS signal, is diagrammed in FIG. 2. At 201, a primary transmitter node sends an FDS signal. At 202, all other nodes in system 100 receive the FDS signal. At 203, nodes other than the secondary transmitter node designated in the FDS signal remove themselves from the channel (by refraining from attempting to access the channel) for a duration derived from a signal from the primary transmitter (see below). At 204, both the primary transmitter node and the secondary transmitter node wait for a predetermined duration. Normally the predetermined duration is of zero length. However, there may be a short wait, such as the time needed for the secondary node to change from receive mode to transmit mode, which may be, e.g., one or a small number of clock cycles. At 205, both the primary

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transmitter node and the secondary transmitter node begin full-duplex transmission, ending the initiation phase.

[0041] In one variant of a signaling format 300 used in accordance with the subject matter of this disclosure, shown in FIG. 3, after sending the FDS 301, the primary transmitter node sends a header signal portion 311 specifying the total duration of the full-duplex transmission. Following header signal portion 311, the primary transmitter node sends a training signal portion 321 and one or more data symbols 331. At the same time, following header signal portion 311, the secondary transmitter node, advised of the total duration of the full-duplex transmission, sends a header/training signal portion 322, followed by one or more data symbols 332. The amount of data sent in data symbols 332 is adjusted by the secondary transmitter node to fit the duration set by the primary transmitter node in header signal portion 311.

[0042] In another variant of a signaling format 400 used in accordance with the subject matter of this disclosure, shown in FIG. 4, after the primary transmitter node sends the FDS 401, both the primary transmitter node and the secondary transmitter node wait for the aforementioned predetermined duration (which normally is of zero length, as discussed above) to elapse. Both the primary transmitter node and the secondary transmitter node then send a respective header/training signal portion 411, 412 specifying the respective duration required to send the total amount of data that the respective node has to send in one or more symbols 431, 432. Because those durations could be, and likely are, different for each node, the total duration will be the longer of the two durations. The node with the shorter duration will extend its frame with dummy or silence symbols. In any case the node with the shorter duration may transmit acknowledgments for the data it receives from the other node.

[0043] In a second implementation of the subject matter of this disclosure, based on time-division multiplexing,

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different nodes are assigned temporal slots during which they can engage in full-duplex communication. The assignments may be referred to as a "Medium Access Plan" (MAP), which may be promulgated by one of the nodes that is tasked with that function. In one variant of such an implementation, nodes are assigned to slots by pairs, and in each slot, the pairs assigned to that slot engage in full-duplex communication (unless neither node has information to transmit, in which case the slot remains unused). The assigning of temporal slots is made according to an analysis of which nodes are likely to need to transmit to which other nodes. Such an analysis may include review of previous resource reservation requests.

[0044] Normally, the MAP remains in effect until a new MAP is sent. Therefore, in order to ensure that every possible pair of nodes that may need to communicate can communicate, then unless the system includes a resource request mechanism, the MAP should include a slot for all possible pairings. However, in all but the smallest systems, assigning a temporal slot for every possible pair of nodes is impractical. One solution may be for the MAP to include a repeating pattern of slots that does not include every possible pairing, but on every n th repetition, where n is determined by the system design, the pattern is expanded to include all possible pairings.

[0045] In a second variant of a time-division multiplexing implementation, the MAP assigns temporal slots to individual nodes as primary transmitters. Upon the opening of any temporal slot, the primary transmitter assigned to that temporal slot begins full-duplex communication with a desired other node by sending an FDS identifying that other node. The full-duplex communication session lasts only until the temporal slot closes, unless both of the participating nodes require less than the full duration of the temporal slot to transmit whatever information they have to transmit. If the full-duplex communication session does not occupy the

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full duration of the temporal slot, the channel remains inactive for the balance of the temporal slot.

[0046] Returning to the first variant of a time-division multiplexing implementation in which each
5 temporal slot is assigned to a particular pair of nodes, in one version of such a variant of a time-division multiplexing implementation, the two nodes assigned to a temporal slot begin transmitting immediately upon opening of that temporal slot. In a second version of such a
10 variant of a time-division multiplexing implementation, upon opening of a temporal slot, even though the temporal slot is assigned exclusively to a particular pair of nodes, no transmission occurs until one of the nodes assigned to that temporal slot sends an FDS signal as in the first
15 implementation, as discussed above. In this version of such a variant, if no FDS signal is sent by either node in a particular temporal slot, no transmission occurs during that temporal slot.

[0047] A method 500 for initiating a full-duplex
20 transmission according to a time-division multiplexing implementation of the subject matter of this disclosure is diagrammed in FIG. 5. At 501, a MAP is promulgated from one of the nodes to all nodes. At 502 a next temporal slot is opened (i.e., a system clock reaches that temporal
25 slot). At 503 it is determined whether FDS signaling is in use. If FDS signaling is not in use, then at 504 the two nodes assigned to that temporal slot begin transmitting for the duration of the temporal slot. At the conclusion of the temporal slot at 505, the two nodes
30 stop transmitting and flow returns to 502 for the next temporal slot.

[0048] If at 503 it is determined that FDS signaling is in use, then at 506, one of the nodes assigned to the temporal slot, which has been designated "primary," sends
35 an FDS signal. At 507, both the primary node assigned to the temporal slot and the other node with which the primary nodes is communicating (the other node may or may not also be assigned to the temporal slot, depending on

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the particular variant that is implemented as discussed above) wait for a predetermined duration. At 508, both of the nodes that are communicating in the temporal slot node begin full-duplex transmission for a duration determined
5 by signaling. At the conclusion of the temporal slot at 505, the two nodes stop transmitting (if the transmission has not concluded earlier) and flow returns to 502 for the next temporal slot.

[0049] In some variants of the first implementation
10 based on FDS signaling, nodes not participating in the full-duplex transmission also need to know its duration, so they can contend for access to the channel when the full-duplex transmission is finished. Where transmission duration is not known ahead of time, because it is based
15 on the duration of the longest of both transmissions, each of the two nodes that are participating in the full-duplex transmission has to signal the duration in an orthogonal way that can be understood by all nodes, including nodes that cannot separate the two transmitted signals.
20 According to one mechanism, where the communication uses orthogonal frequency-division multiplexing (OFDM), each of the two nodes involved in a full-duplex transmission could transmit the duration information in a subcarrier that is not used by the other of the two nodes. If duration is
25 determined solely by one of the nodes, then only that one node need signal the duration to other nodes. The use of such orthogonal transmissions to signal channel availability allows any half-duplex nodes (not shown) that may be present in the system to participate in the same
30 MAC scheme along with full-duplex nodes.

[0050] Another situation that may be addressed by the use of OFDM signaling is a situation where echo cancellation cannot be performed, either because of low signal strength or where one node does not have much or
35 any data to transmit to the other node. If OFDM is used, then rather than assigning all subcarriers in a channel to both nodes using the channel, the subcarriers in the channel can be divided up between the two nodes, so that

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there is no echo of transmissions by one node in the transmissions of the other node. Although such an arrangement would not be in-band full-duplex, it is still full-duplex in the sense defined above. Specifically, it is full duplex, in the sense of simultaneous bidirectional communication. And although different frequencies are used, in an OFDM context, and the gap between the subcarriers used in the different directions would not be large enough to allow use of external filters (e.g., duplexers). Therefore, there still should be precise time synchronization and coordination of transmissions between primary and secondary nodes, as provided using the FDS signaling described above.

[0051] G.hn OFDM communication implementations of the subject matter of this disclosure are described in concurrently-filed, commonly-assigned United States Patent Application No. _____, entitled "METHODS AND APPARATUS FOR PERFORMING FULL DUPLEX COMMUNICATIONS USING A G.hn PROTOCOL" (Attorney Docket No. MP10138/004048-0477-101), which is hereby incorporated by reference herein in its entirety.

[0052] As shown in FIG. 6, a node 600 that may be used in a system implemented according to the subject matter of this disclosure includes transceiver circuitry 601, memory 602 for storing parameters of a MAC scheme, possibly including a MAP, and a controller 603 configured to operate transceiver circuitry 601 in accordance the MAC scheme and/or MAP stored in memory 602. Controller 603 may include detection hardware (not shown) that determines whether a signal is intended for node 600 by computing the phase difference between consecutively-received carriers, and compares that phase difference with the phase difference that would be expected if the signal was formed with a known sequence of phases. When there is a good match of the expected phase differences across a sufficient number of preamble carriers, controller 603 declares that it has found a signal that matches the known sequence of phases it was looking for.

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[0053] Thus it is seen that a MAC scheme, and a system implementing that scheme, in which any node can initiate full-duplex transmission with any other node, have been provided.

5 **[0054]** As used herein and in the claims which follow, the construction "one of A and B" shall mean "A or B."

[0055] It is noted that the foregoing is only illustrative of the principles of the invention, and that the invention can be practiced by other than the described
10 embodiments, which are presented for purposes of illustration and not of limitation, and the present invention is limited only by the claims which follow.

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WHAT IS CLAIMED IS:

1. A method of conducting full-duplex transmission between first and second nodes in a communications system having more than two nodes, the
5 method comprising:
issuing of a start signal on a channel by the first node, wherein the start signal signals that full-duplex transmission is to begin, and identifies the second node as a node with which full-duplex communication
10 is to occur; and
following the issuing of the start signal, beginning full-duplex transmission by the first node and by the second node.
2. The method of claim 1 wherein:
15 each node of the first and second nodes signals a respective duration of its respective transmission; and
duration of the full-duplex transmission between the first and second nodes is determined by
20 whichever respective duration is longer.
3. The method of claim 2 further comprising the one of the first and second nodes whose respective transmission has a shorter duration transmitting additional symbols to extend its transmission to match the
25 duration of the transmission of the other of the first and second nodes.
4. The method of claim 1 further comprising:
the first node signaling a required transmission duration based on its data to be transmitted;
30 and
the second node adjusting its transmission to fit the required transmission duration.
5. The method of claim 4 wherein the second node adjusting its transmission comprises the second node

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shortening its transmission by decreasing the amount of data to be sent.

6. The method of claim 4 wherein the second node adjusting its transmission comprises the second node
5 transmitting additional symbols to extend its transmission to match the duration of the transmission of first a node.

7. The method of claim 1 further comprising performing echo cancellation on the full-duplex
transmission to remove, from a transmission in one
10 direction, an echo of a transmission in another direction.

8. The method of claim 1 wherein:
the full-duplex transmission is performed
using orthogonal frequency division modulation (OFDM);
the first node transmits on a first set of
15 OFDM subcarriers; and
the second node transmits on a second set
of OFDM subcarriers.

9. The method of claim 1 wherein:
the full-duplex transmission is performed
20 using orthogonal frequency division modulation (OFDM); and
at least one of the first node and the
second node transmits a signal on at least one OFDM
subcarrier to signal other nodes that the channel is in
use.

25 10. A method of conducting full-duplex
transmission between nodes in a communications system
having more than two nodes, the method comprising:
establishing a medium access plan assigning
respective temporal slots to respective pairs of nodes;
30 and
on opening of a respective temporal slot,
initiating full-duplex transmission between nodes in the
respective pair of nodes to which the respective temporal
slot is assigned; wherein:

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any node in the communications system is capable of full-duplex communication with any other node according to the medium access plan.

11. The method of claim 10 wherein the
5 initiating full-duplex transmission comprises:

issuing of a start signal on a channel by one of the nodes in the respective pair of nodes, signaling that full-duplex transmission is to begin; and
10 following the issuing of the start signal, beginning full-duplex transmission by both of the nodes in the respective pair of nodes.

12. The method of claim 10 wherein:
each node in the respective pair of nodes signals a respective duration of its respective
15 transmission; and

duration of the full-duplex transmission between the nodes in the respective pair of nodes is determined by whichever respective duration is longer.

13. The method of claim 12 wherein the one of
20 the nodes in the respective pair of nodes whose respective transmission has a shorter duration transmits additional symbols to extend its transmission to match the duration of the transmission of the other of the first and second nodes.

25 14. The method of claim 10 further comprising:
a first one of the nodes in the respective pair of nodes signaling a required transmission duration based on its data to be transmitted; and

a second one of the nodes in the respective
30 pair of nodes adjusting its transmission to fit the required transmission duration.

15. The method of claim 10 further comprising performing echo cancellation on the full-duplex

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transmission to remove, from a transmission in one direction, an echo of a transmission in another direction.

16. The method of claim 10 wherein:
the full-duplex transmission is performed
5 using orthogonal frequency division modulation;
a first set of subcarriers is used for
transmission by a first node in the respective pair of
nodes; and
a second set of subcarriers is used for
10 transmission by a second node in the respective pair of
nodes.

17. A node for use in a communications
network including at least two nodes; wherein:
the node is configured to initiate full-
15 duplex communication with any other node by:
issuing a start signal on a channel,
wherein the start signal signals that full-duplex
transmission is to begin, and identifies a second node as
a node with which full-duplex communication is to occur;
20 and
following the issuing of the start signal,
beginning full-duplex communication.

18. A communications system comprising a
plurality of the node of claim 17.

25 19. The communications system of claim 18
wherein:
each node signals a respective duration of
its respective transmission; and
duration of the full-duplex transmission is
30 determined by whichever respective duration is longer.

20. The communications system of claim 19
further comprising the node whose respective transmission
has shorter duration transmitting additional symbols to
extend its transmission to match the duration of the

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transmission of the node whose respective transmission has a longer duration.

21. The communications system of claim 18 further comprising:

5 one node signaling a required transmission duration based on its data to be transmitted; and
 the other node adjusting its transmission to fit the required transmission duration.

22. The communications system of claim 18
10 wherein:

 the full-duplex transmission is performed using orthogonal frequency division modulation (OFDM);
 one node transmits on a first set of OFDM subcarriers; and
15 the other node transmits on a second set of OFDM subcarriers.

23. The communications system of claim 18 wherein:

 the full-duplex transmission is performed
20 using orthogonal frequency division modulation (OFDM); and
 at least one of the nodes transmits a signal on at least one OFDM subcarrier to signal other nodes that the channel is in use.

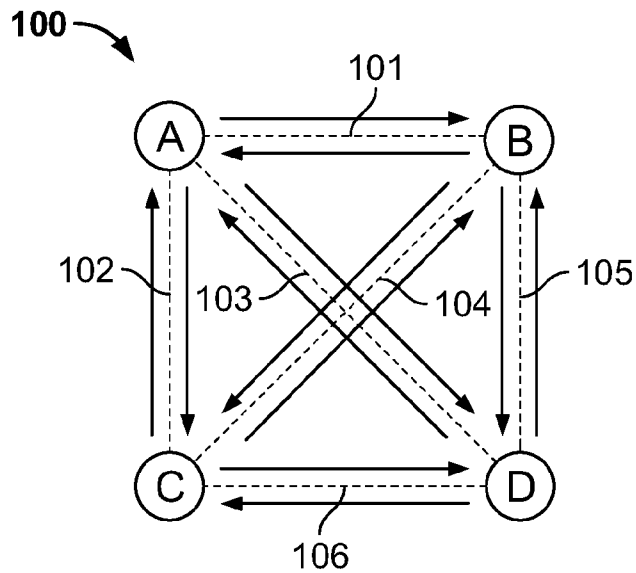


FIG. 1

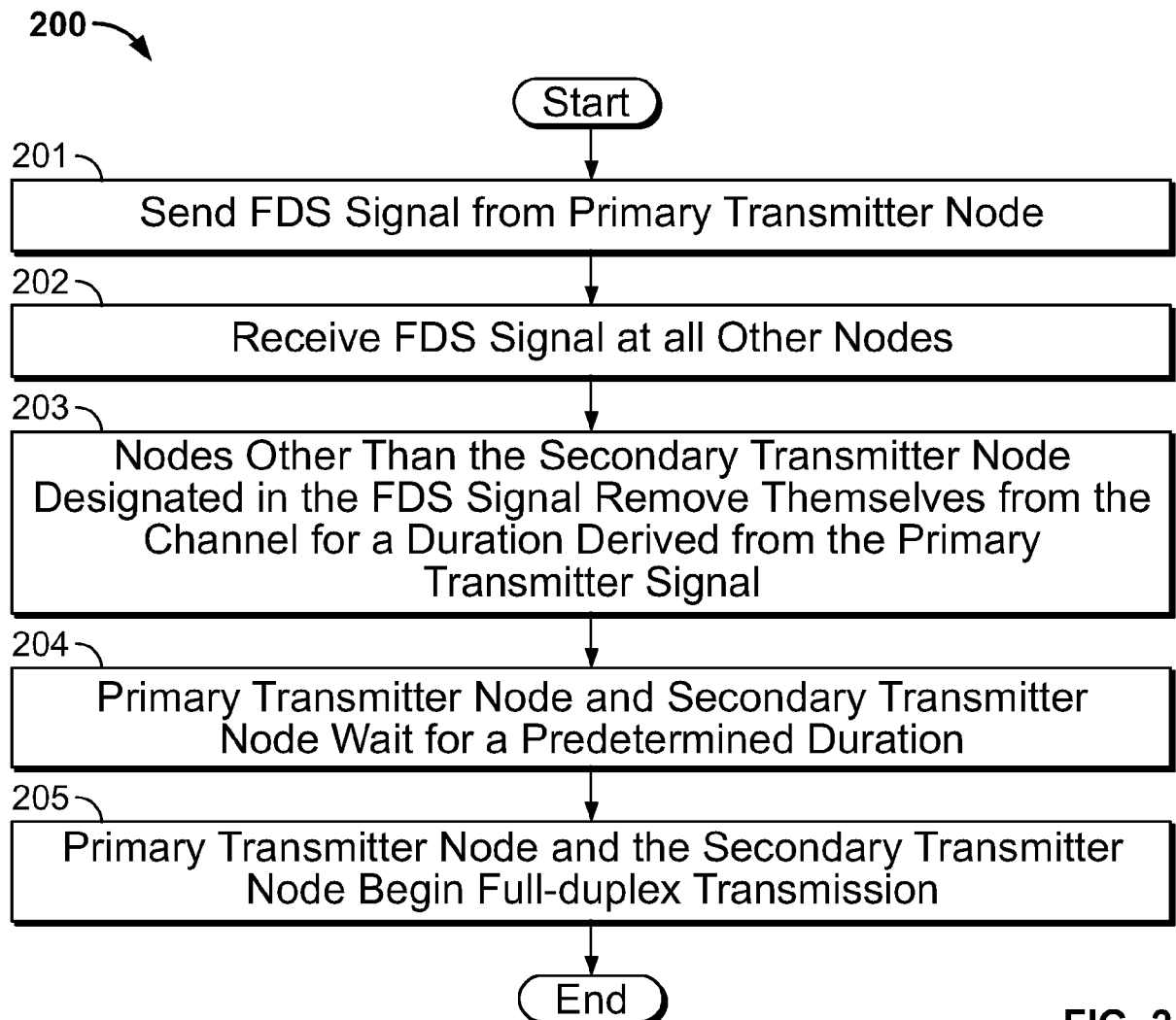


FIG. 2

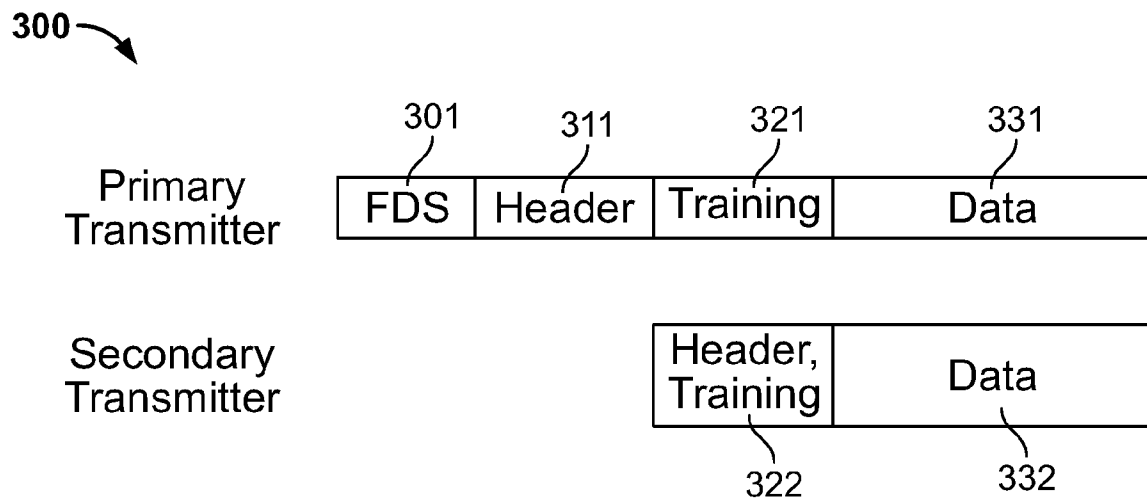


FIG. 3

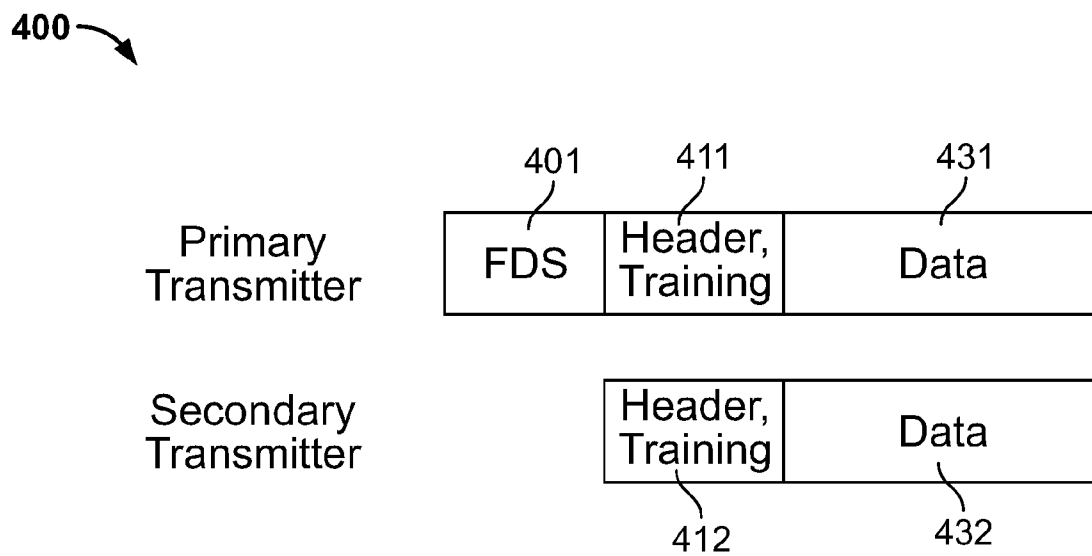
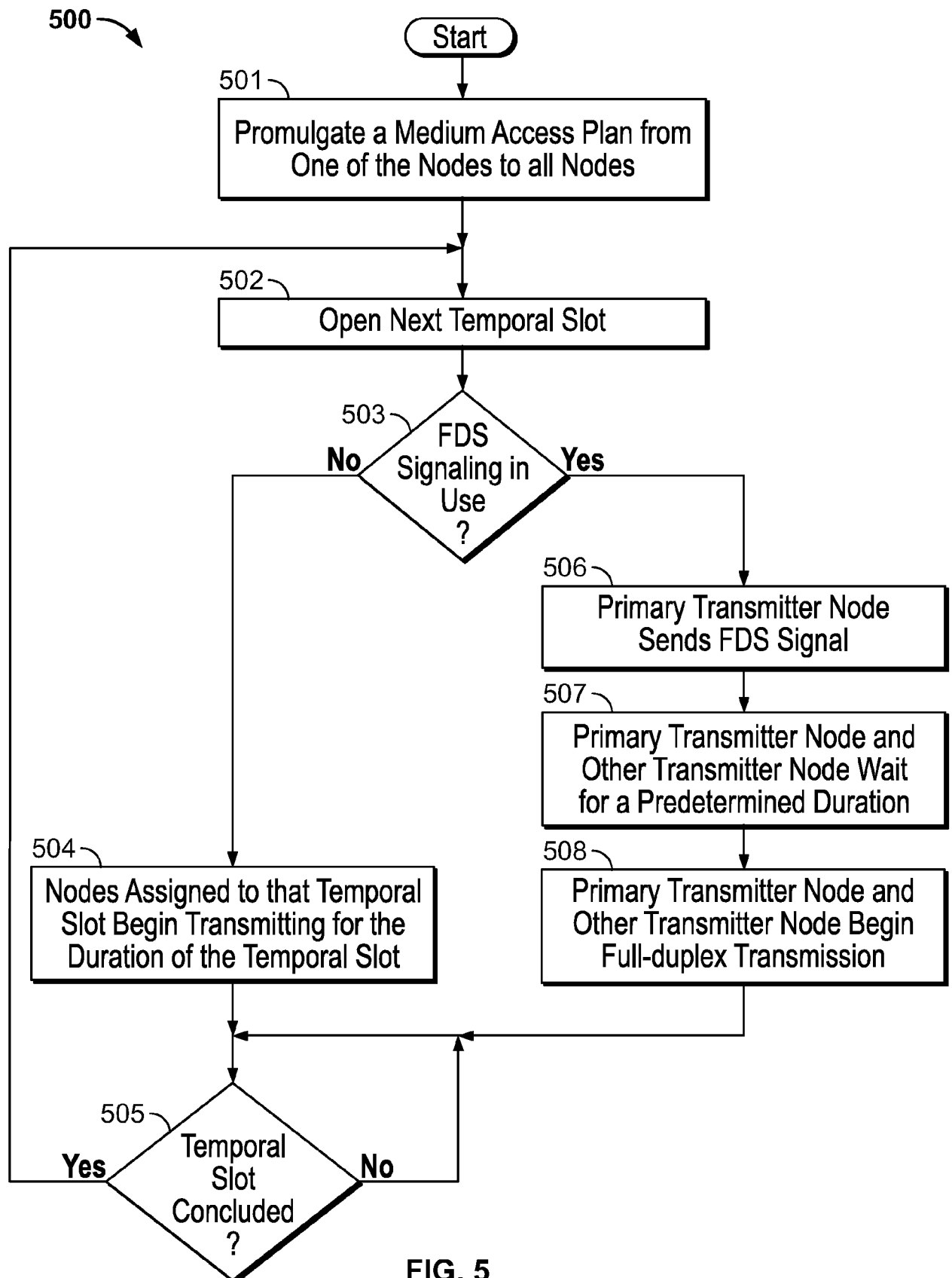


FIG. 4



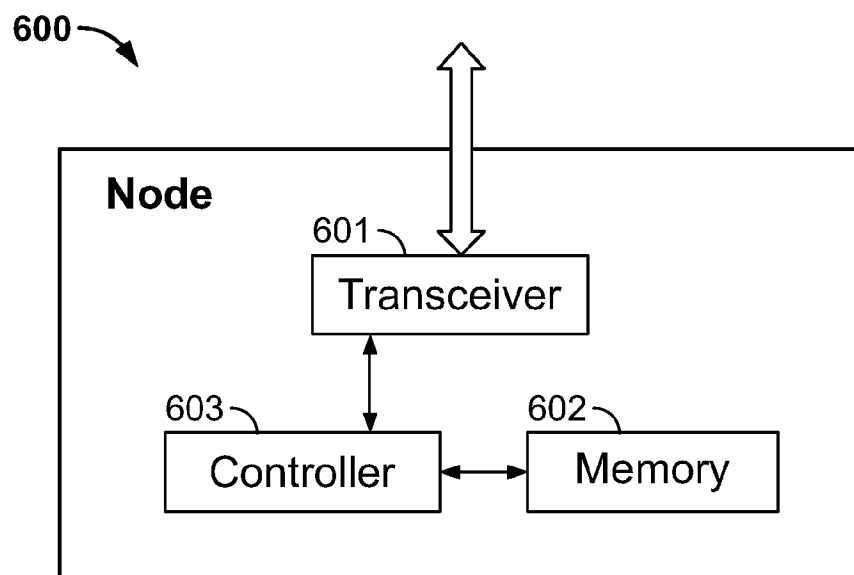


FIG. 6