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(54) MINIMAL CONTROL OVERHEAD AVALANCHE RELAY

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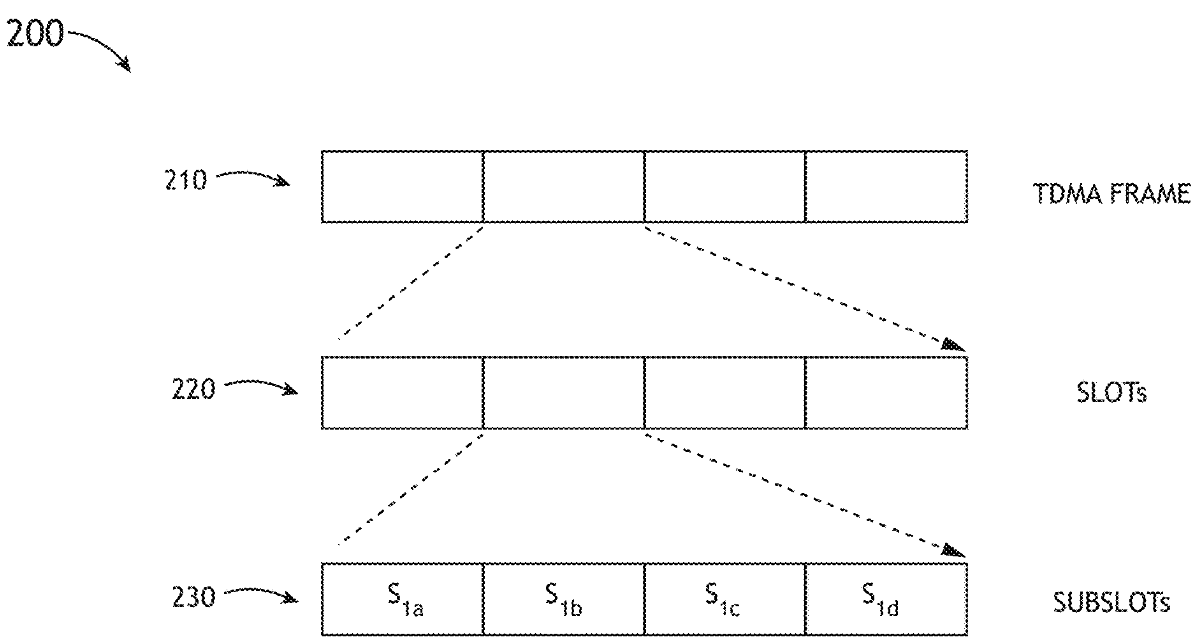
CPC ***H04L 5/0053*** (2013.01); ***H04B 7/2656*** (2013.01)

(57) **ABSTRACT**

A method of routing a first signal in a telecommunication network is disclosed. The telecommunication network comprises plural nodes and uses time-division multiple access (TDMA) frames, with each TDMA frame divided into time slots and each time slot is divided into subslots. The method includes the telecommunication network being configured as either a mixed network or a reduced overhead node only network.



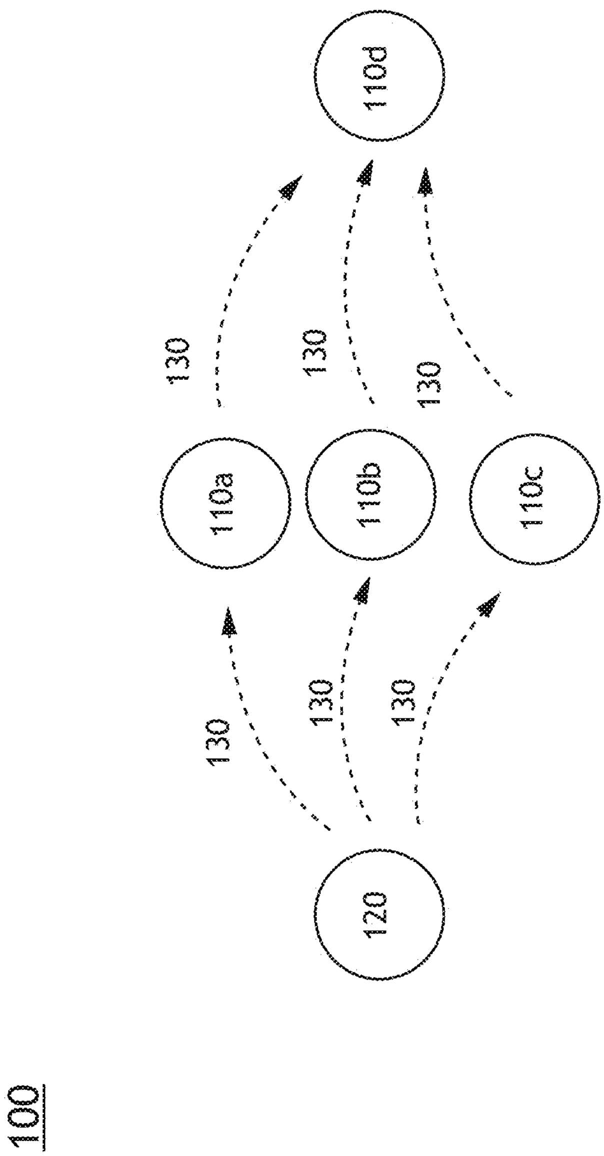


FIG. 1

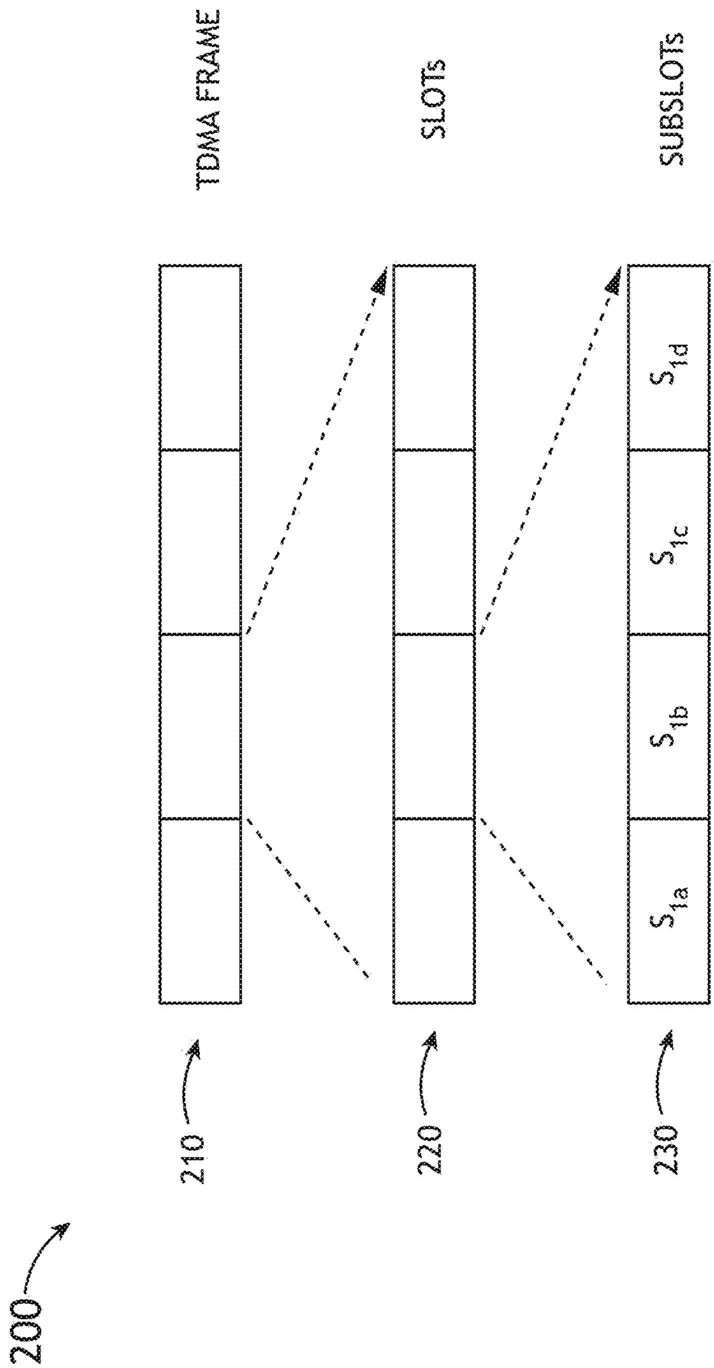


FIG. 2

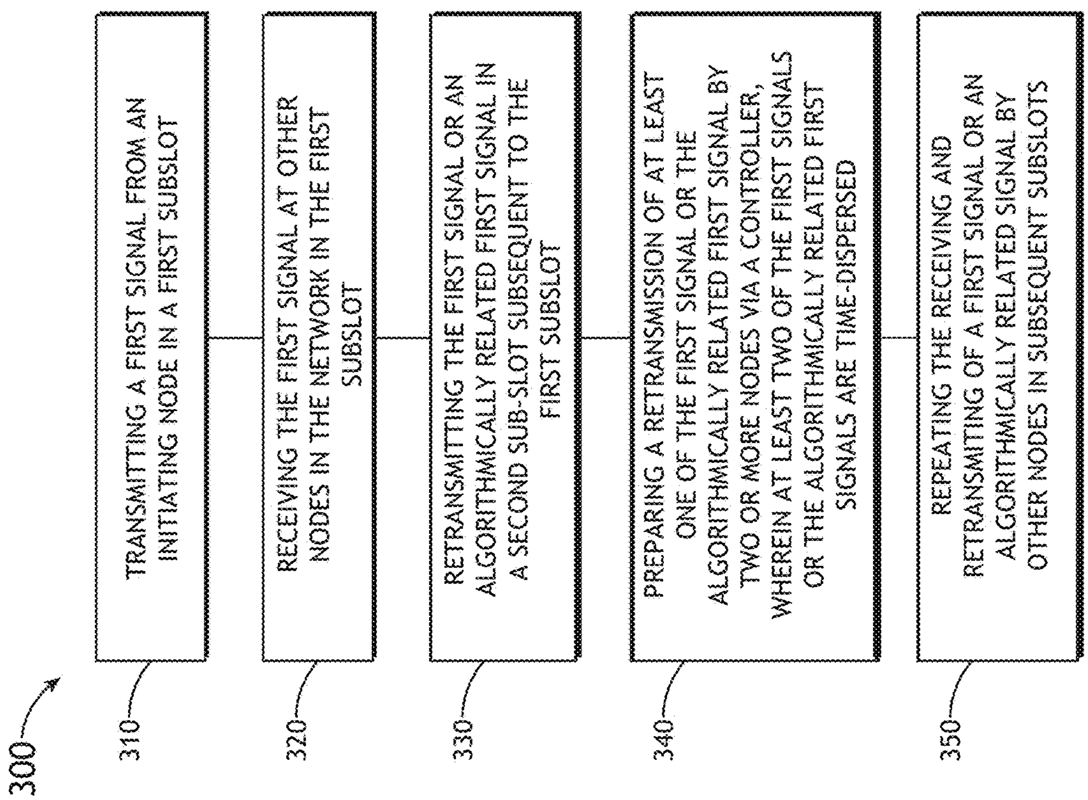

300
310
TRANSMITTING A FIRST SIGNAL FROM AN INITIATING NODE IN A FIRST SUBSLOT
320
RECEIVING THE FIRST SIGNAL AT OTHER NODES IN THE NETWORK IN THE FIRST SUBSLOT
330
RETRANSMITTING THE FIRST SIGNAL OR AN ALGORITHMICALLY RELATED FIRST SIGNAL IN A SECOND SUB-SLOT SUBSEQUENT TO THE FIRST SUBSLOT
340
PREPARING A RETRANSMISSION OF AT LEAST ONE OF THE FIRST SIGNAL OR THE ALGORITHMICALLY RELATED FIRST SIGNAL BY TWO OR MORE NODES VIA A CONTROLLER, WHEREIN AT LEAST TWO OF THE FIRST SIGNALS OR THE ALGORITHMICALLY RELATED FIRST SIGNALS ARE TIME-DISPERSED
350
REPEATING THE RECEIVING AND RETRANSMITTING OF A FIRST SIGNAL OR AN ALGORITHMICALLY RELATED SIGNAL BY OTHER NODES IN SUBSEQUENT SUBSLOTS

FIG. 3

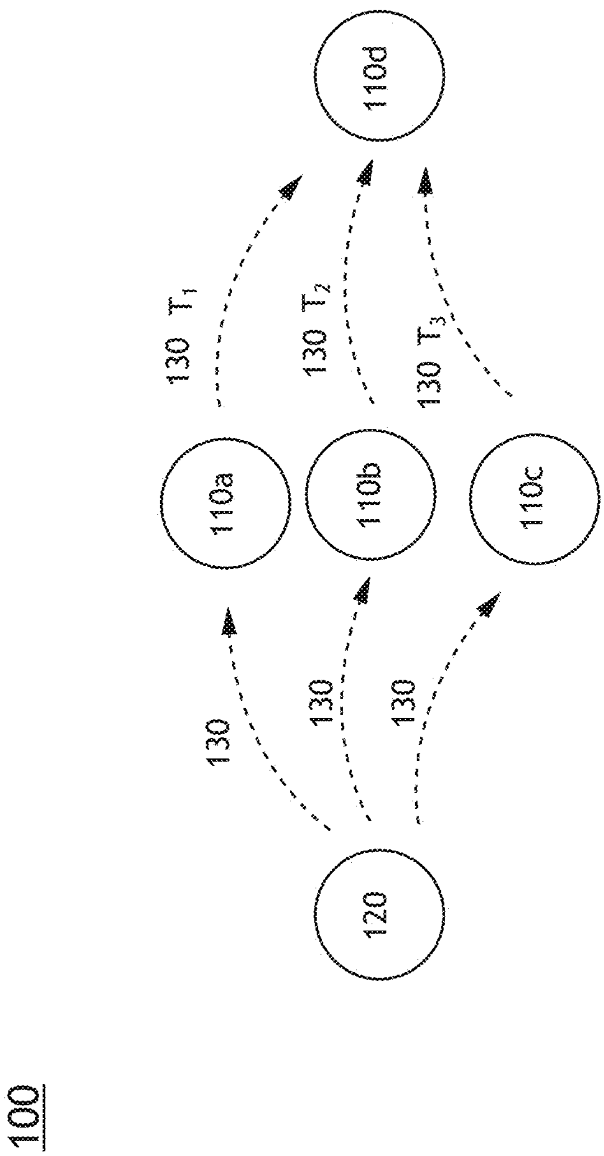


FIG. 4

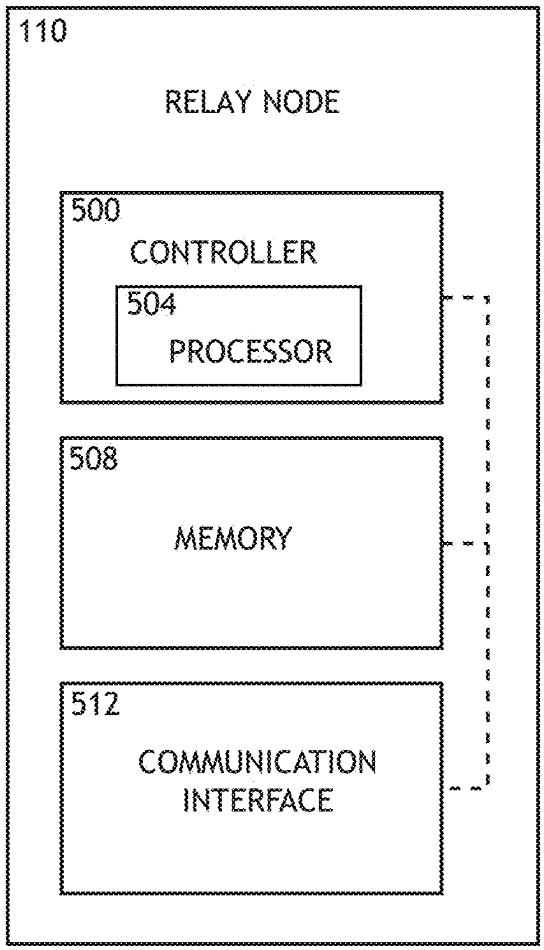

110
RELAY NODE
500
CONTROLLER
504
PROCESSOR
508
MEMORY
512
COMMUNICATION
INTERFACE

FIG.5

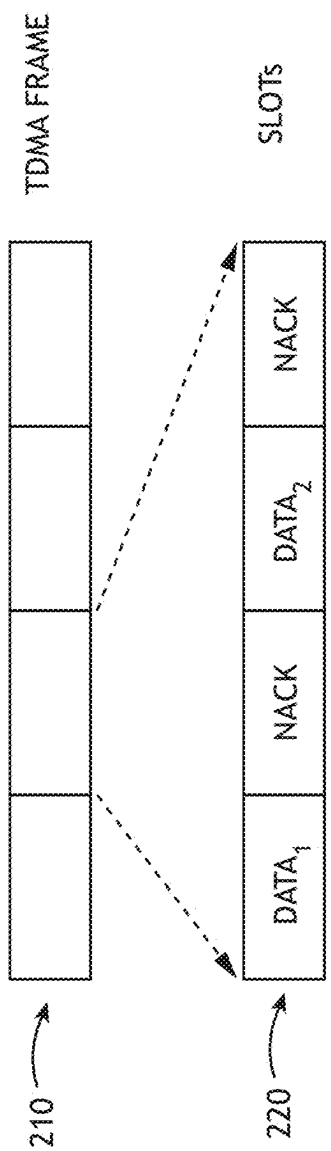


FIG. 6

700

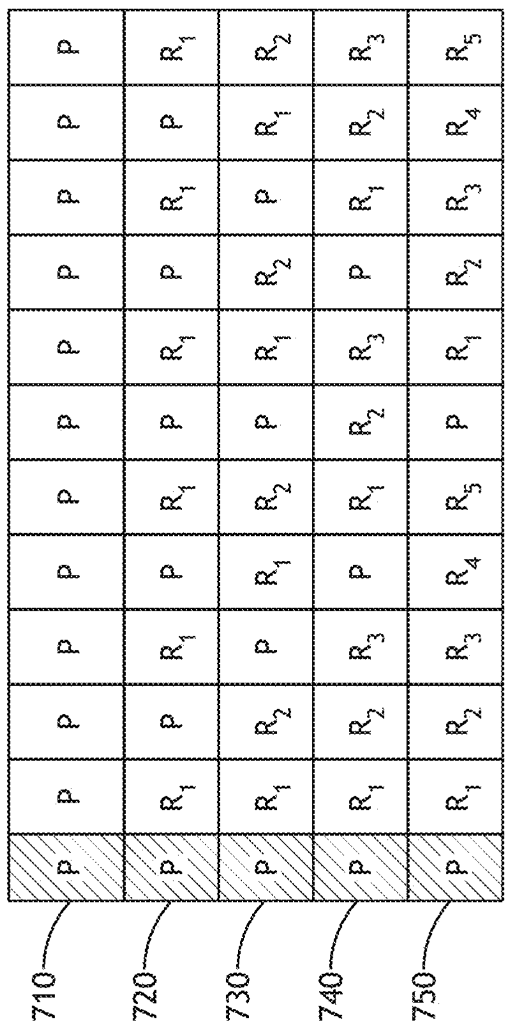

710
720
730
740
750
P P P P P P P P P P P P
P R1 P R1 P R1 P R1 P R1 P R1
P R1 R2 P R1 R2 P R1 R2 P R1 R2
P R1 R2 R3 P R1 R2 R3 P R1 R2 R3
P R1 R2 R3 R4 R5 P R1 R2 R3 R4 R5

FIG. 7

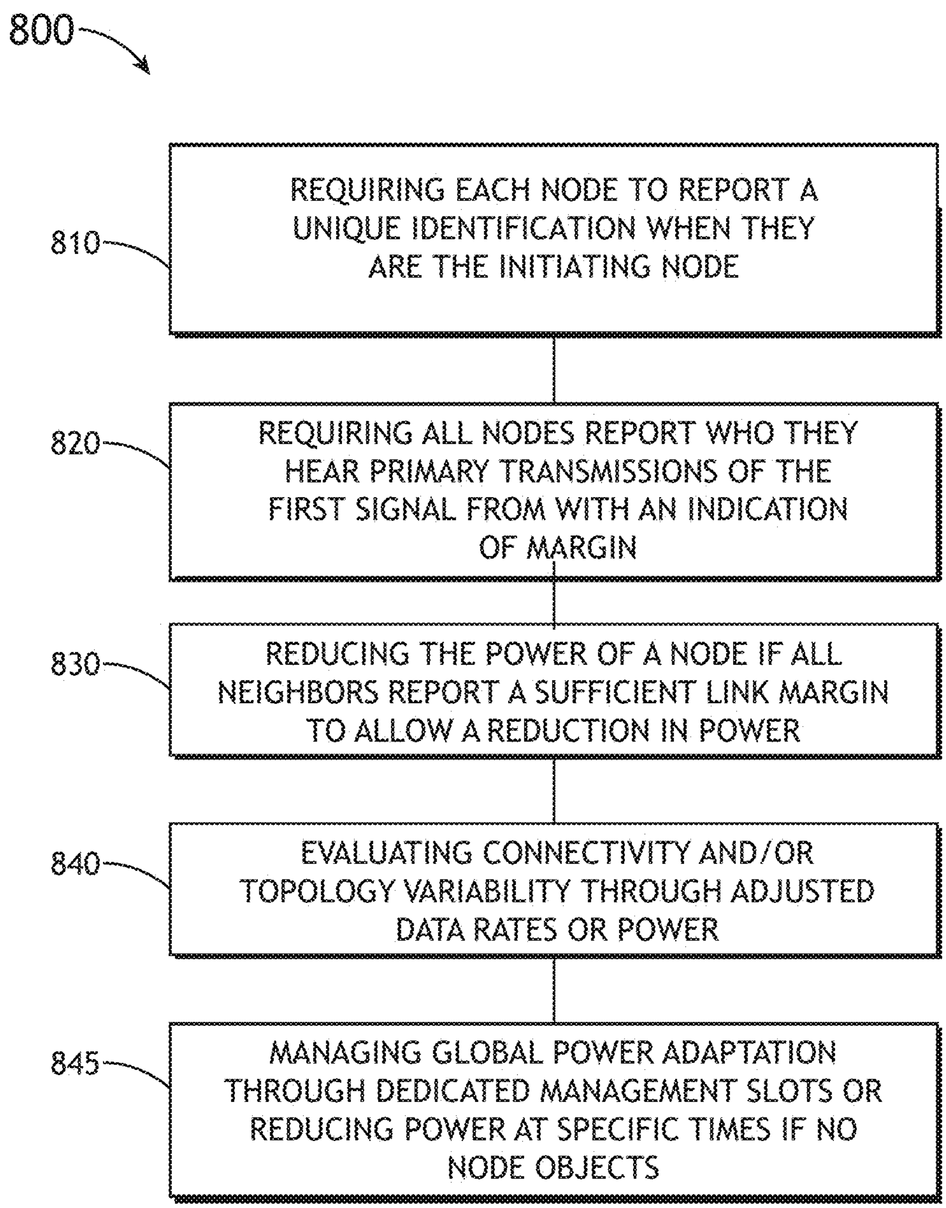

800
810
REQUIRING EACH NODE TO REPORT A UNIQUE IDENTIFICATION WHEN THEY ARE THE INITIATING NODE
820
REQUIRING ALL NODES REPORT WHO THEY HEAR PRIMARY TRANSMISSIONS OF THE FIRST SIGNAL FROM WITH AN INDICATION OF MARGIN
830
REDUCING THE POWER OF A NODE IF ALL NEIGHBORS REPORT A SUFFICIENT LINK MARGIN TO ALLOW A REDUCTION IN POWER
840
EVALUATING CONNECTIVITY AND/OR TOPOLOGY VARIABILITY THROUGH ADJUSTED DATA RATES OR POWER
845
MANAGING GLOBAL POWER ADAPTATION THROUGH DEDICATED MANAGEMENT SLOTS OR REDUCING POWER AT SPECIFIC TIMES IF NO NODE OBJECTS

FIG.8

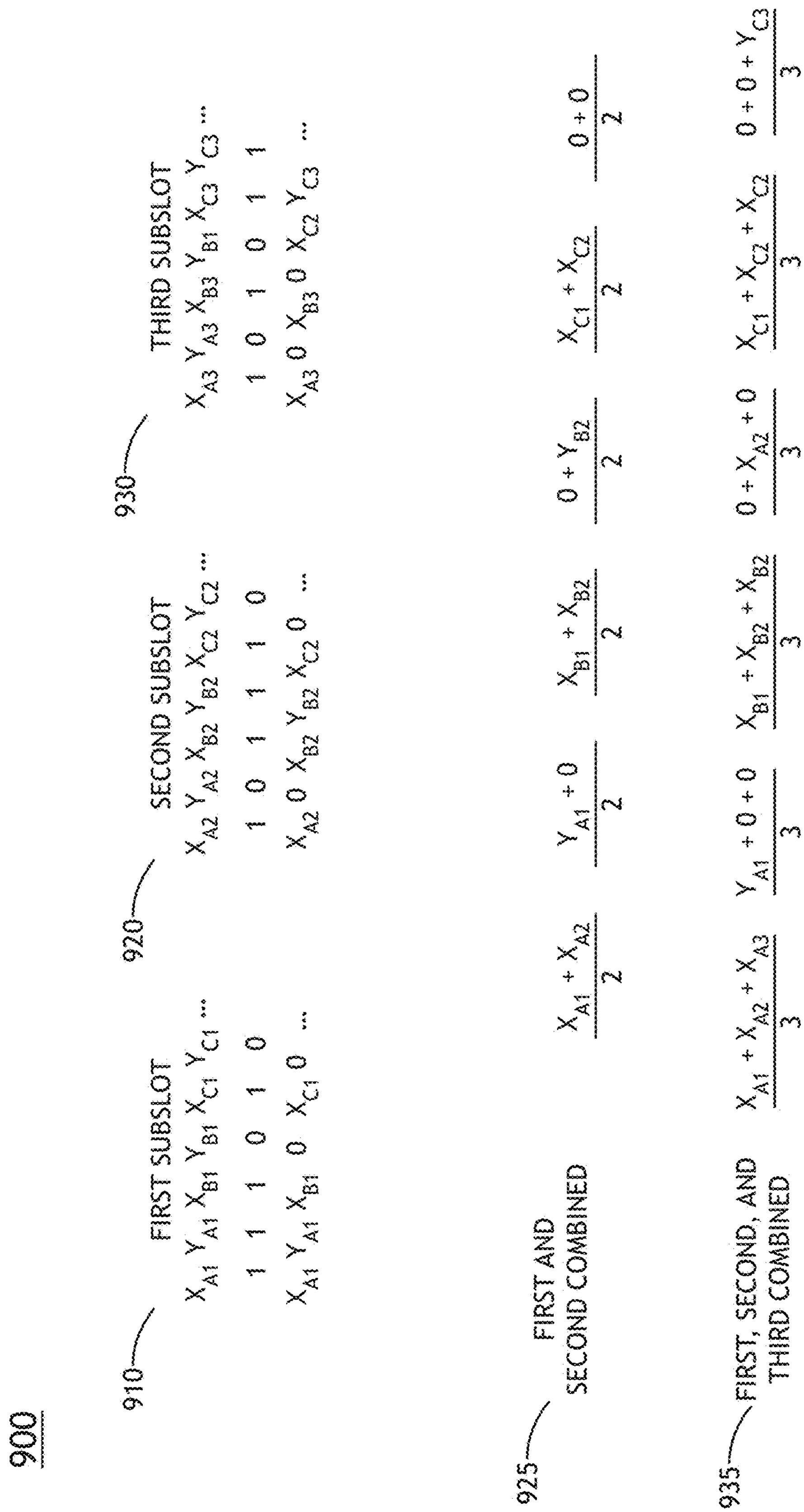

900
910
FIRST SUBSLOT
X_{A1} Y_{A1} X_{B1} Y_{B1} X_{C1} Y_{C1} ...
1 1 1 0 1 0
X_{A1} Y_{A1} X_{B1} 0 X_{C1} 0 ...
920
SECOND SUBSLOT
X_{A2} Y_{A2} X_{B2} Y_{B2} X_{C2} Y_{C2} ...
1 0 1 1 1 0
X_{A2} 0 X_{B2} Y_{B2} X_{C2} 0 ...
930
THIRD SUBSLOT
X_{A3} Y_{A3} X_{B3} Y_{B3} X_{C3} Y_{C3} ...
1 0 1 0 1 1
X_{A3} 0 X_{B3} 0 X_{C2} Y_{C3} ...
925
FIRST AND SECOND COMBINED
$\frac{X_{A1}+X_{A2}}{2}$ $\frac{Y_{A1}+0}{2}$ $\frac{X_{B1}+X_{B2}}{2}$ $\frac{0+Y_{B2}}{2}$ $\frac{X_{C1}+X_{C2}}{2}$ $\frac{0+0}{2}$
935
FIRST, SECOND, AND THIRD COMBINED
$\frac{X_{A1}+X_{A2}+X_{A3}}{3}$ $\frac{Y_{A1}+0+0}{3}$ $\frac{X_{B1}+X_{B2}+X_{B2}}{3}$ $\frac{0+X_{A2}+0}{3}$ $\frac{X_{C1}+X_{C2}+X_{C2}}{3}$ $\frac{0+0+Y_{C3}}{3}$

FIG. 9

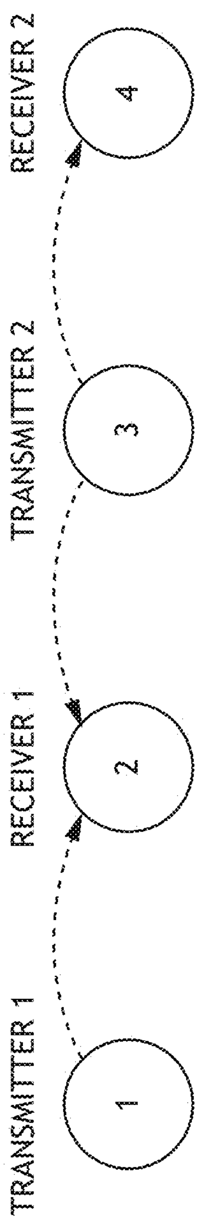


FIG. 10A

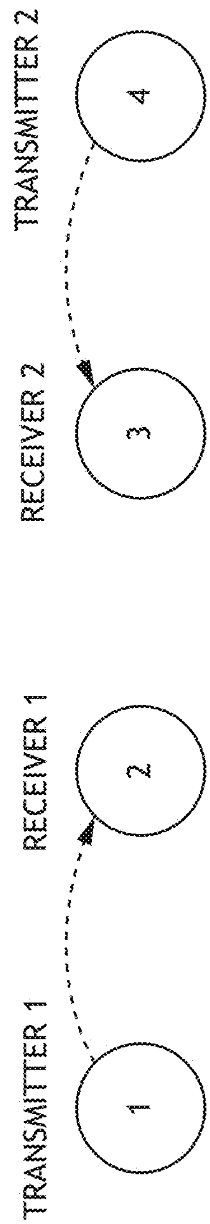


FIG. 10B

FIG.11A

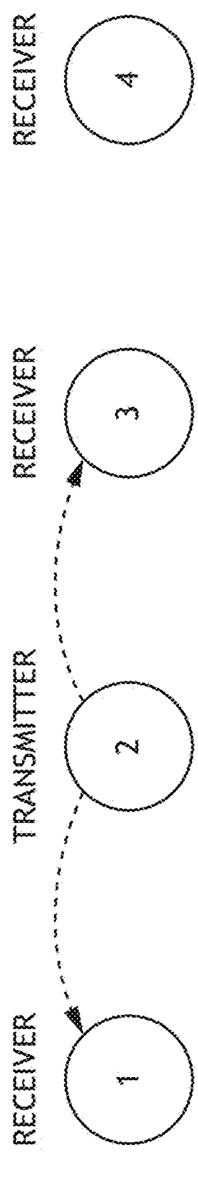


FIG.11B

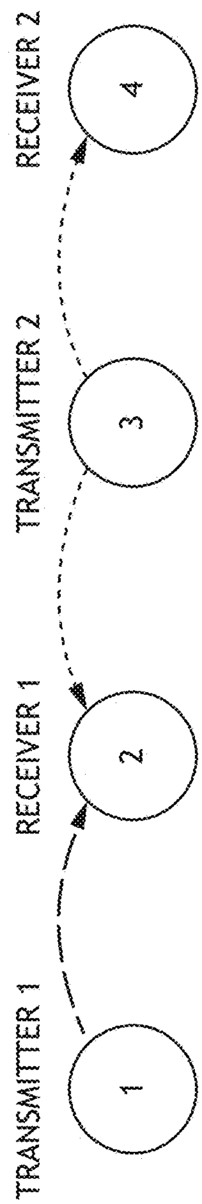


FIG.11C

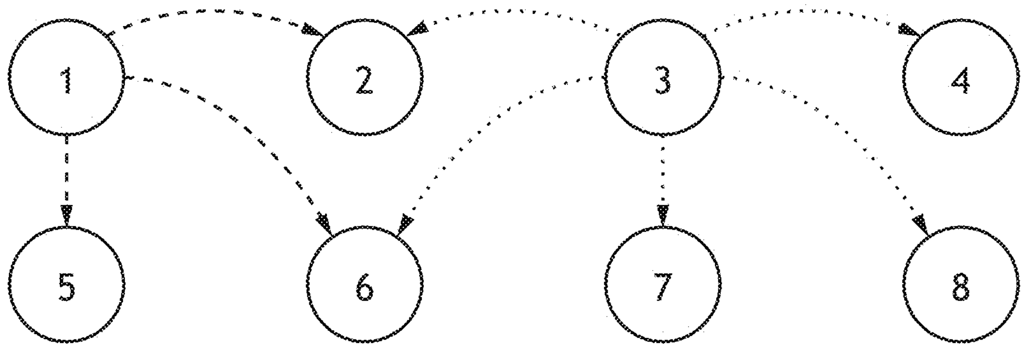


FIG. 12A

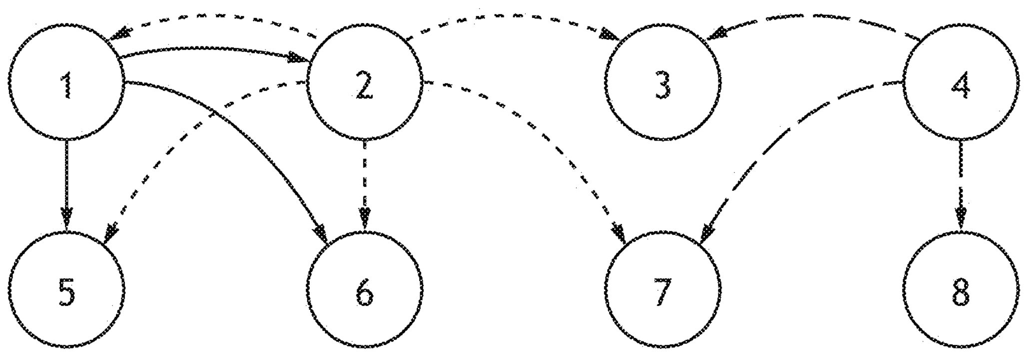


FIG. 12B

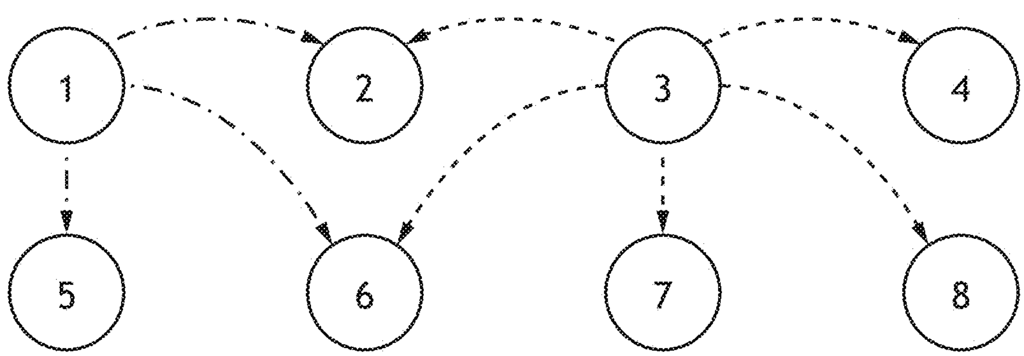


FIG. 12C

MINIMAL CONTROL OVERHEAD AVALANCHE RELAY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit under 35 U.S.C. § 120 of U.S. application Ser. No. 18/581,627, filed Feb. 20, 2024, which is incorporated herein by reference in the entirety.

BACKGROUND

[0002] Previously, methods for managing relays within a network were proposed using a synchronized time-division multiple access (TDMA) scheme in a wideband channel. The general approach is to divide a TDMA slot into subslots and arrange for every node that heard a transmission in a subslot to retransmit exactly the same message in the next subslot. An initial transmission would be relayed by all of its neighbors, then relayed by neighbors of neighbors and so on for as many subslots as were provisioned.

SUMMARY

[0003] A method of routing first signals in a telecommunication network is disclosed in accordance with one or more illustrative embodiments of the present disclosure. In one illustrative embodiment, the method includes transmitting a first signal from an initiating node in a first subslot and receiving the first signal at other nodes in the network in the first subslot. In another illustrative embodiment, the method includes retransmitting the first signal or an algorithmically related first signal in a second subslot different and non-overlapping from the first subslot. The retransmitting includes preparing a retransmission of at least one of the first signal or the algorithmically related first signal by one or more nodes via one or more respective controllers and transmitting the first signal or the algorithmically related first signal via the one or more nodes.

[0004] In another aspect, the first subslot of the TDMA frame may be allocated by at least one method: randomly, deterministically such that one or more particular nodes are allocated the first subslot and one or more non-allocated nodes are configured to know that they are not allocated the first subslot, or the first subslot may comprise multiple timeslots and the multiple timeslots are configured to be allocated via a mix of at least one of randomly or deterministically. In another aspect, the telecommunication network may include a reduced overhead node only network comprising only reduced overhead nodes or a mixed network comprising a combination of reduced overhead nodes and normal nodes configured to transmit both traffic and control data. In further aspects, the reduced overhead node only network may be configured such that a TDMA frame is defined asynchronously based on a transmission of the signals by a transmitter of the first subslot in a TDMA frame or predefined synchronously based on known synchronized timing between nodes.

[0005] In another aspect, the mixed network may be configured such that a TDMA frame is defined asynchronously based on a transmission of signals by a transmitter of the first subslot in a TDMA frame or predefined synchronously based on known synchronized timing between nodes, and the reduced overhead nodes are configured to receive transmissions from the normal nodes. A subset of the reduced overhead nodes may be configured to transmit relatively-low-rate control overhead signals configured to inform the normal nodes that one or more timeslots are allocated to be used by the reduced overhead nodes, where the relatively-low-rate control overhead signals are defined as being at a rate of time that is less frequent than a control overhead rate of control overhead signals configured to be transmitted by the normal nodes. The normal nodes may be configured to perform relays of control data on behalf of a subset of the reduced overhead nodes and configured to not transmit relatively-low-rate control overhead signals, ensuring timeslots are allocated for the reduced overhead nodes.

[0006] In another aspect, at least one normal node may be configured to un-allocate one or more nodes based on one or more timeout thresholds, where the at least one normal node is configured to use an overhead node timeout threshold for reduced overhead nodes that is longer in time relative to a normal timeout threshold for normal nodes. The at least one normal node may include a Network Control Node (NCN) configured to determine the control data for an entirety of the telecommunication network. A reduced overhead node timeout measurement, against which a breach of an overhead node timeout threshold is configured to be determined, may be reset to zero based on a receiving of either one of: a transmission comprising the control data; or a transmission comprising traffic without control data.

[0007] In another aspect, one or more nodes may be further configured to repeat the receiving and retransmitting of the first signal or the algorithmically related first signal by other nodes in subsequent subslots. A first signal of at least one subslot may be combined with a replica or an algorithmically related first signal of at least one other subslot to increase a probability of reception. The initiating node may be further configured to transmit a second signal or an algorithmically related second signal in a subslot subsequent to the first subslot on a different frequency than the retransmitted first signal or the algorithmically related first signal. At least one node not within range of the initiating node may be configured to transmit at least one of a second signal or an algorithmically related second signal in at least one of a first subslot or a second subslot subsequent to a first subslot on a different frequency than the transmitted first signal or algorithmically related first signal.

[0008] A system for routing first signals in a telecommunication network is disclosed in accordance with one or more illustrative embodiments of the present disclosure. In one illustrative embodiment, the system may include at least one controller of a node configured to transmit a first signal from an initiating node in a first subslot and receive the first signal at other nodes in the network in the first subslot. In another illustrative embodiment, the system may be configured to retransmit the first signal or an algorithmically related first signal in a second subslot different and non-overlapping from the first subslot. The retransmitting includes preparing a retransmission of at least one of the first signal or the algorithmically related first signal by one or more nodes via one or more respective controllers and transmitting the first signal or the algorithmically related first signal via the one or more nodes.

[0009] In another aspect, the first subslot of the TDMA frame may be allocated by at least one method: randomly, deterministically such that one or more particular nodes are allocated the first subslot and one or more non-allocated nodes are configured to know that they are not allocated the first subslot, or the first subslot may comprise multiple timeslots and the multiple timeslots are configured to be allocated via a mix of at least one of randomly or deterministically. In another aspect, the telecommunication network may include a reduced overhead node only network comprising only reduced overhead nodes or a mixed network comprising a combination of reduced overhead nodes and normal nodes configured to transmit both traffic and control data.

[0010] This Summary is provided solely as an introduction to subject matter that is fully described in the Detailed Description and Drawings. The Summary should not be considered to describe essential features nor be used to determine the scope of the Claims. Moreover, it is to be understood that both the foregoing Summary and the following Detailed Description are example and explanatory only and are not necessarily restrictive of the subject matter claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The detailed description is described with reference to the accompanying figures. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items. Various embodiments or examples ("examples") of the present disclosure are disclosed in the following detailed description and the accompanying drawings. The drawings are not necessarily to scale. In general, operations of disclosed processes may be performed in an arbitrary order, unless otherwise provided in the claims.

[0012] FIG. **1** is a diagram illustrating a communication system wherein an initiating node transmits a first signal or an algorithmically related first signal to three nodes, all which relay the transmission to a single node, in accordance with one or more embodiments of this disclosure.

[0013] FIG. **2** is a diagram illustrating a TDMA frame arrangement, in accordance with one or more embodiments of this disclosure.

[0014] FIG. **3** is a flow diagram illustrating a method of modeling transmitting a first signal or an algorithmically related first signal to nodes using multiple subslots, in accordance with one or more embodiments of this disclosure.

[0015] FIG. **4** is a diagram illustrating a communication system containing nodes used as relays in a time-diverse multipath arrangement, in accordance with one or more embodiments of this disclosure.

[0016] FIG. **5** is a block diagram illustrating a node used for relaying a first signal or an algorithmically related first signal, in accordance with one or more embodiments of this disclosure.

[0017] FIG. **6** is a diagram illustrating the incorporation of a NACK signal into a slot, in accordance with one or more embodiments of this disclosure.

[0018] FIG. **7** is a diagram illustrating a series of possible arrangements of subslots, in accordance with one or more embodiments of this disclosure.

[0019] FIG. **8** is a flow diagram illustrating a method for managing power within a network, in accordance with one or more embodiments of this disclosure.

[0020] FIG. **9** is a diagram illustrating signal conversion using puncture rate expansion within a subslot, in accordance with one or more embodiments of this disclosure.

[0021] FIG. **10**A is a diagram illustrating two transmitters operating in a telecommunication network with on-air collisions, in accordance with one or more embodiments of this disclosure.

[0022] FIG. **10**B is a diagram illustrating two transmitters operating in a network without on-air collisions, in accordance with one or more embodiments of this disclosure.

[0023] FIG. **11**A-C are diagrams illustrating a method for relaying transmissions without collisions in a multiple subslot and multiple frequency telecommunication network, in accordance with one or more embodiments of this disclosure.

[0024] FIG. **12**A-C are diagrams illustrating the use of frequency diversity in an eight-node mesh TDMA network, in accordance with one or more embodiments of this disclosure.

DETAILED DESCRIPTION

[0025] Before explaining one or more embodiments of the disclosure in detail, it is to be understood that the embodiments are not limited in their application to the details of construction and the arrangement of the components or steps or methodologies set forth in the following description or illustrated in the drawings. In the following detailed description of embodiments, numerous specific details may be set forth in order to provide a more thorough understanding of the disclosure. However, it will be apparent to one of ordinary skill in the art having the benefit of the instant disclosure that the embodiments disclosed herein may be practiced without some of these specific details. In other instances, well-known features may not be described in detail to avoid unnecessarily complicating the instant disclosure.

[0026] Avalanche Relay is a media access control (MAC) technology that uses cooperative broadcasting for robust communications in decentralized, ad hoc wireless networks. Typically, one node transmits and all receiving neighbor nodes then rebroadcast the transmission at the same time cooperatively, so that the multiple receptions look like multipath at receivers. In multihop networks, the two hop neighbors receive these cooperative transmissions and then rebroadcast the transmission on at the same time cooperatively again to reach nodes that are two hops away from the original transmitter. This cooperative rebroadcast allows data to be robustly flooded through a network without requiring routing or acknowledgements.

[0027] In general, an Avalanche Relay communication network typically includes one or more Coordinated Transmissions (CTs), usually in allocated time slots in a Time Division Multiple Access (TDMA) MAC, with one time slot allocated to the initial transmitting node (i.e., a node that has original data that is sent through the network), and one or more time slots allocated to the cooperative rebroadcast transmissions of the data. The CT, e.g., transmissions in time slots, may be contiguous (back-to-back, bordering each other in time) or non-contiguous (with gaps of known time between transmissions). For example, non-contiguous may mean that there are other time slots in between the CT transmissions.

[0028] Typically, there is Avalanche Relay control coordination data sent between nodes to coordinate time (and time slots) and to coordinate which nodes can transmit in which time slots.

[0029] For purposes of the present disclosure, this control coordination data may be referred to as control data, control overhead, control traffic, and/or the like.

[0030] Further, one Network Control Node (NCN) is often selected, usually dynamically elected by one or more nodes, to be the network coordinator for time and time slot allocations. In other words, the NCN may determine and coordinate time (and time slots) and determine which nodes can transmit in which time slots and communicate this information to other nodes in the network.

[0031] Some CTs are allocated to be in contention, so that nodes may contend for the first transmission in a CT set of time slots. For example, a node may be configured to sense that a contention timeslot is available (e.g., not in use) and attempt to use that timeslot to enter a network and request transmit time slots from the NCN. In addition, the first timeslot might be used for bursty traffic, such as push-to-talk voice data.

[0032] Other CTs may have the first transmission allocated to a particular node for contention-free communications. In other words, a particular node may have the first transmission allocated solely to itself. For example, the first timeslot may be allocated to one or more particular nodes to transmit reliable data (e.g., critical data) or for the NCN to broadcast time slots and time synchronization information.

[0033] Avalanche Relay may generally be used for commercial as well as military applications, such as commercial Internet of Things (IoT), public safety voice and data, commercial Mobile Ad hoc Networks (MANETs) as well as military MANETs such as Warrior Robust Enhanced Network (WREN) waveforms. An example of an Avalanche Relay implementation is TrellisWare's Barrage Relay network (BRn) used in TrellisWare Secure Mobile (TSM) Network.

[0034] An Avalanche Relay node may include a Controller node, either statically assigned or dynamically elected, and configured to coordinate network-wide characteristics such as time synchronization and TDMA frames with timeslot and subset allocations.

[0035] One disadvantage of typical Avalanche Relay networks is the amount of control traffic overhead that is used to coordinate time and time slot allocation. Typically, Avalanche Relay has (a)periodic transmissions by nodes to synchronize time, time slot allocations, and other parameters such as power.

[0036] These control traffic transmissions: consume battery life in battery powered radios, such as handheld radios; increase interference with other nearby systems, especially in unlicensed spectrum shared with other radio systems, like WiFi; and allow spectrum sensing systems to know that an Avalanche Relay network or nodes is in the area, where the more often nodes transmit, the easier it is for detect, interfere, and geolocate the network and nodes.

[0037] The use of ad hoc relays in a TDMA communication network are described in U.S. Pat. No. 6,594,273, filed Jul. 9, 1999 and U.S. Pat. No. 4,639,937, filed Dec. 7, 1983, the entirety of which are both hereby incorporated by reference in their entirety. In some embodiments, the waveform may be a time division multiple access (TDMA) based waveform that supports frames, time slots and subslots. Data streams may be divided into frames, which are then divided into time slots. The time slots may be allocated to users statically and/or dynamically for different purposes, including transmitting data, voice, relaying data, and performing network management. Time slots may be further divided into subslots, allowing the transmission of a variety of one or more signals into one or more subslots within a time slot.

[0038] Broadly speaking, embodiments of the concepts here are directed to improvements of a system and method for routing signals using relays in an ad hoc TDMA communication network, wherein the system and method are configured to utilize reduced control overhead nodes for improved efficiency.

[0039] In embodiments, one or more nodes may be configured to operate in a "minimal (node) control overhead" mode, or reduced overhead nodes with less node control overhead data than regular nodes. In some embodiments, nodes in "minimal control overhead" mode may at least one or more of: only receive traffic, e.g., never transmit; only initiate transmissions (e.g. transmit data in first subslot) but not relay traffic; initiate transmissions and only relay for other "minimal control overhead" mode nodes. Another example, is one of the last two cases above, and furthermore using low rate control transmissions as part of a mixed network.

[0040] In some embodiments, all nodes are reduced overhead nodes. In other embodiments, in a mixed node case, some are reduced overhead nodes, and some are normal nodes (e.g., non-reduced overhead nodes). Reduced may simply mean less node control overhead data (e.g., referred to as "control data" or the like) transmitted than the normal nodes. The network may be configured use no (or little) time synchronization with the first subslot, or some time synchronization for the first subslot. Using time synchronization may mean that the first subslot transmissions are on time boundaries but may be in contention or contention free. For example, contention based may mean similar to random Aloha methodologies for using subslots. For instance, random Aloha may mean that two nodes may randomly attempt to use a subslot, but that may cause interference and the transmission to fail if two nodes happen to attempt at the same time. Slotted Aloha, means some TDMA frame synchronization information is known the nodes. For example, the nodes may be synched in time to know when the start of the frame is and how many subslots there are, or the like. For instance, in slotted Aloha, the nodes of the network may know (based on previous syncing operations) that the first subslot is to be allocated to a particular set of nodes.

[0041] In some embodiments, all nodes in the network may be operating in "minimal control overhead" mode or it may be a mixed network with some nodes in "minimal control overhead" and other nodes operating with higher control overhead. This latter case may include an Avalanche Networks with Network Control Nodes (NCNs) that may configured to coordinate time synchronization, and TDMA slot assignments.

[0042] Note that, for purposes of the present disclosure, unless noted otherwise, that phrases such as first and second timeslot or subslot, initial and secondary, and/or the like as applied to timeslots or subslots is for distinguishing purposes only and is not meant to mean the timeslots or subslots share a boundary and are contiguous, rather that they are different. For example, there may exist any number or size of gaps between a first and second subslot.

[0043] Furthermore, it is noted that some figures of the present disclosure are used in or may be related to U.S. patent application Ser. No. 16/810,542, filed Mar. 5, 2020, issued as U.S. Pat. No. 11,464,009 on Oct. 4, 2022, which are both hereby incorporated by reference in their entirety. However, note that any element, limitations, or concept such as networks, nodes, communication protocols may be defined, configured, and/or limited differently herein than in U.S. Pat. No. 11,464,009, and therefore U.S. Pat. No. 11,464,009 is not necessarily limiting to any aspect of the present disclosure. For example, concepts herein may further extend, modify, replace, remove, and/or the like concepts from U.S. Pat. No. 11,464,009. For instance, some embodiments herein may utilize reduced (control) overhead nodes configured to be allocated to a first timeslot, where the first timeslot is configured to be in contention and/or contention free, without necessarily allocating particular slots to negative-acknowledgement of data, or control data for adjusting power, FEC, and/or changes to number of timeslots.

[0044] At least some embodiments herein may be classified into two categories: configured for only reduced overhead nodes, or a mixed network for a mix of reduced overhead nodes and normal nodes.

[0045] For purposes of the present disclosure, "normal nodes" may be referred to as non-reduced overhead nodes, higher control overhead nodes, other nodes, secondary nodes, or the like. For example, normal nodes may be configured to receive relatively higher (i.e., more) control data that reduced overhead nodes. For example, normal nodes may be standard nodes of an avalanche telecommunication network. For example, normal nodes may typically be configured to relay any data they receive. For example, normal nodes may relay traffic (i.e., non-node-control data such as voice data or other media data) as well as relaying (node) control data.

[0046] Reduced overhead nodes may be nodes that are configured to transmit (e.g., relay) less node control data than normal nodes. For example, the reduced overhead nodes may typically transmit less (or no) node control data. For instance, the reduced overhead nodes may, in a sense, have less functionality in this regard, but with the benefit of improved efficiency, less battery drain, and the like.

[0047] In at least some embodiments, a method is disclosed. The method may be performed via a relay node **110**, a set of relay nodes **110** and/or the like. For example, nodes may include any limitations herein such as being reduced overhead nodes as described. The method may be performed all or in part by the nodes or the like. The method may be performed via a system (e.g., one or more nodes) configured to perform the method, or parts thereof. For example, the method may be performed via a telecommunication network **100** including nodes.

[0048] The method may involve routing first signals in a telecommunication network **100**. The telecommunication network **100** may include a plurality of nodes. The telecommunication network may use time-division multiple access (TDMA) frames. Each TDMA frame may be divided into a series of time slots. Each time slot may be divided into subslots. The method (e.g., method **1300** of FIG. **13** not shown) may include the steps of step **1302**) transmitting a first signal from an initiating node in a first subslot, step **1304**) and receiving the first signal at other nodes in the network in the first subslot. The method **1300** may also include the step **1306**) retransmitting the first signal or an algorithmically related first signal in a second subslot different and nonoverlapping from the first subslot. The retransmitting may include preparing a retransmission of at least one of the first signal or the algorithmically related first signal by one or more nodes via one or more respective controllers and transmitting the first signal or the algorithmically related first signal via the one or more nodes.

[0049] The telecommunication network may include at least one of: a reduced overhead node only network comprising only reduced overhead nodes; or a mixed network comprising a combination of reduced overhead nodes and normal nodes configured to transmit both traffic and control data.

[0050] The first subslot of the TDMA frame may be configured to be allocated by at least one of: randomly; deterministically such that one or more particular nodes are allocated the first subslot and one or more non-allocated nodes are configured to know that they are not allocated the first subslot; or wherein the first subslot comprises multiple timeslots and the multiple timeslots are configured to be allocated via a mix of at least one of randomly or deterministically.

[0051] The telecommunication network may include the reduced overhead node only network comprising only the reduced overhead nodes.

[0052] The reduced overhead node only network may be configured such that a TDMA frame is defined asynchronously based on a transmission of the signals by a transmitter of the first subslot in a TDMA frame.

[0053] The reduced overhead node only network may be configured such that a TDMA frame is predefined synchronously based on known synchronized timing between nodes.

[0054] The telecommunication network may include the mixed network comprising the combination of reduced overhead nodes and the normal nodes.

[0055] The mixed network may be configured such that a TDMA frame is defined asynchronously based on a transmission of signals by a transmitter of the first subslot in a TDMA frame.

[0056] The mixed network may be configured such that a TDMA frame is predefined synchronously based on known synchronized timing between nodes. The reduced overhead nodes may be configured to receive transmissions from the normal nodes.

[0057] A subset of the reduced overhead nodes may be configured to transmit relatively-low-rate control overhead signals configured to inform the normal nodes that one or more timeslots are allocated to be used by the reduced overhead nodes. The relatively-low-rate control overhead signals may be defined as being at a rate of time that is less frequent than a control overhead rate of control overhead signals configured to be transmitted by the normal nodes.

[0058] The normal nodes may be configured to perform relays of control data on behalf of a subset of the reduced overhead nodes and may be configured to not transmit (e.g., not relay, receive only) relatively-low-rate control overhead signals. The normal nodes may be configured to ensure timeslots are allocated for the reduced overhead nodes.

[0059] At least one normal node may be configured to un-allocate one or more nodes based on one or more timeout thresholds. The at least one normal node may be configured to use an overhead node timeout threshold (e.g., more than 10 minutes) (e.g., more than 1 hour) for reduced overhead nodes that is longer in time relative to a normal timeout threshold (e.g., less than 1 minute) for normal nodes.

[0060] The at least one normal node may include a Network Control Node (NCN) configured to determine the control data for an entirety of the telecommunication network. For example, the NCN may be centralized and determined to determine most (e..g, more than half) and/or all of the control data. For instance, the NCN may aggregate, and analyze data to determine the number of each type of node and based on that, determine an allocation of time slots and/or number of timeslots and/or (any other control data).

[0061] A reduced overhead node timeout measurement, against which a breach of an overhead node timeout threshold is configured to be determined, may be configured to be reset to zero based on receiving either one of: a transmission comprising the control data; or a transmission comprising traffic without control data. For example, a subslot allocate to a particular reduced overhead node or set of reduced overhead nodes may be timedout (i.e., un-allocated) based on a transmission received from the reduced overhead node. For instance, that transmission doesn't necessarily need to be, nor required to be, control data, but it may be configured to be inferred that the reduced overhead node still exists and needs the allocated subslot simply by any transmission sent by the reduced overhead node. For instance, the reduced overhead node timeout measurement (e.g., timer stored on memory **508**) may be reset (e.g., to zero) based on a transmission to allow the allocation to last longer.

[0062] The reduced overhead nodes may be characterized in that each reduced overhead node is configured to, in terms of transmissions comprising control data, at least one of: 1) receive (control data) transmissions only, without transmitting the control data; 2a) receive transmissions only, except for originating transmissions in the first subslot; 3a) receive transmissions only, except for: originating transmissions in the first subslot; and retransmissions for other reduced overhead nodes in later timeslots; 2b) receive transmissions only, except for: originating transmissions in the first subslot; and relatively low-rate control transmissions when part of a mixed network; or 3b) receive transmissions only, except for: originating transmissions in the first subslot; retransmissions for other reduced overhead nodes in later timeslots; and relatively low-rate control (data) transmissions when part of a mixed network.

[0063] One or more nodes may be further configured to repeat the receiving and retransmitting of the first signal or the algorithmically related first signal by other nodes in subsequent subslots.

[0064] A first signal of at least one subslot may be combined with a replica or an algorithmically related first signal of at least one other subslot to increase a probability of reception.

[0065] The initiating node may be further configured to transmit a second signal or an algorithmically related second signal in a subslot subsequent to the first subslot on a different frequency than the retransmitted first signal or the algorithmically related first signal.

[0066] At least one node not within range of the initiating node may be configured to transmit at least one of a second signal or an algorithmically related second signal in at least one of a first subslot or a second subslot subsequent to a first subslot on a different frequency than the transmitted first signal or algorithmically related first signal.

[0067] Now, various figures of U.S. patent application Ser. No. 16/810,542, filed Mar. 5, 2020, are described in a nonlimiting way. Note that the embodiments, language, and figures described below may be used in, but are not necessarily limiting to the embodiments above. For example, U.S. patent application Ser. No. 16/810,542 may, in a sense, by incorporated all or in part below.

[0068] In some embodiments, subslots are dedicated to the same message or specific parts of the same message. For example, an initiating node may send an initial portion of a signal on an initial subslot. The receiving node that receives the initial portion of the signal on the initial subslot may then retransmit the signal on a second subslot to another node. In another example, the initiating node may send multiple portions of a signal in multiple subslots. The receiving node may receive these multiple portions of a signal on multiple subslots, then retransmit one or more portions of these signals on subsequent subslots. A node may have multiple uses for a subslot within a slot. For example, a node may reuse a subslot for traffic management on an opportunistic basis. Several uses and combination of uses of subslots by nodes are possible. Alternatively, a node may be excluded from using a subslot, and vice-versa. Therefore, the description of nodes and subslots herein should not be interpreted as a limitation, but merely as an illustration.

[0069] For example, a TDMA slot may be split into six subslots, wherein three of the subslots may be dedicated to a single channel, with one subslot dedicated to a first signal (i.e., the transmission of a signal by the initiating node **120**), and two subslots dedicated to relay purposes. It is noted that a TDMA based waveform is different from a conventional point to point contention-based waveform, which does not depend on the knowledge of time. It is contemplated that a TDMA based waveform may be better suited to support a large number of nodes, and that many of these nodes may be used to receive and retransmit data as a relay node, provide improved efficiency, efficacy, and resource allocation compared to a conventional contention-based waveform. It should also be noted that the terms slots, time slots and subslots may at times be used interchangeably

[0070] It is noted that the first signal, once transmitted by the initiating node **120**, retains the status as the first signal after retransmission through another node **110**, as the message encoded by the signal does not change. It is also noted that a first signal that is encoded (e.g., to produce an algorithmically related first signal) by a node **110** and transmitted is may still referred to as a first signal or may be referred to as an algorithmically related first signal (i.e., the first signal retains the same message, whether or not a retransmission of the first signal has been encoded). In the interest of clarity, a subsequent signal transmitted by an initiating node that contains a message different that the first signal is referred to as a second signal.

[0071] FIG. **1** is a diagram depicting a telecommunication network **100** in accordance with one or more embodiments of this disclosure. In some embodiments, the telecommunication network **100** includes a plurality of nodes **110**. A node **110** is a connection point that can receive, create, modify, store, or send data along a telecommunication network **100**. For example, the majority of nodes **110** in the telecommunication network **100** may be configured to receive and send data in the telecommunication network **100**. In another example, a node **110** may be able to receive and send data as well as modify the signal. For instance, the node **110** may be able to send or retransmit data at a different frequency than another node **110**. In another instance, the node **110** may be able to retransmit the data with a variable time delay. In another instance, the node **110** may be able to retransmit the data with a different modulation.

[0072] In some embodiments, the retransmitted first signal is exactly the same signal (e.g., a replica) as the initial transmission of the first signal by the initiating node **120**. In some embodiments, the retransmission is a signal different from initial transmission of the first signal by the initiating node **120** that carries the same message. For example, the retransmission may be a transmission algorithmically related to the first signal that would improve the probability of receivers to recover the information encoded in the initial transmission of the first signal by the initiating node **120**, while still allowing the message of the initial transmission of the first signal by the initiating node **120** to stay intact. This replication of the original transmission of the first signal by the initiating node **120** may be repeated through several iterations as the message is transmitted and retransmitted though different relays. The use of multiple transmissions of first signals, algorithmically related first signals, and replica signals of first signals and algorithmically first signals is intended to increase the probability of reception.

[0073] A node **110** may take the form of any communication device capable of receiving or sending a signal. For example, a node **110** may take the form of a mobile device (e.g., a cellular phone or mobile military radio). In another example, a node **110** may be a fixed-site node. The node **110** may have differing power capabilities within the network. For example, the telecommunication network **100** may contain both a fixed-site transmitting node **110** with greater than 1 kW capabilities, and a mobile node **110** with constrained power usage and transmitting capabilities.

[0074] The nodes **110** or the telecommunication network **100** may be arranged by any method or topology that allow nodes **110** to receive and send data from other nodes **110**. For example, the nodes **110** may be arranged in an ad hoc telecommunication network **100**.

[0075] In embodiments, the telecommunication network **100** includes an initiating node **120**. The initiating node **120** initiates the sending of a first signal **130** through the telecommunication network **100**. For example, the initiating node may transmit the first signal **130** to nodes **110** within range (e.g., nodes **110***a-c*). Nodes **110***a-c* receiving the first signal **130** may then retransmit the first signal **130** to other nodes (e.g., node **110***d* that are in range. In some embodiments, a node **110** that received the transmission from the initiating node **120** may retransmit the first signal **130** back to the initiating node. The initiating node **120** may have similar characteristics to the other nodes **110** within the telecommunication system. For example, the initiating node **120** may be a mobile radio unit, with the plurality of nodes within the telecommunication network **100** also being mobile radio units. In some embodiments, the initiating node **120** may have different characteristics than other nodes **110** in the telecommunication network **100**. For example, the initiating node **120** may be a fixed-site transceiver, with the other nodes **110** being mobile radio units.

[0076] FIG. **2** is a diagram illustrating a TDMA data stream **200**, in accordance with one or more embodiments of this disclosure. TDMA allows multiple users to transmit on a single frequency, with each user given one or more portions of time within a longer time period to transmit a signal. TDMA time periods are commonly divided into frames **210**, with each frame **210** divided into time slots **220**. Time slots **220** are defined periods in time that a user may transmit a signal using the TDMA architecture. The data transmitted from the node **110** within a time slot **220** may include not only the payload data that the user wants to send (e.g., voice data) but also control data that assists in signal synchronization and propagation. This control data is often included in a preamble of the data stream.

[0077] In some embodiments time slots **220** are further divided into subslots **230**. As previously stated herein, subslots **230** may be utilized to support relay node utilization within the ad hoc communication network **100**. Nodes **110** acting as relays may relay the same signal (e.g., data) or signals that have been algorithmically derived from the data received from the first signal **130**. In some embodiments, nodes **110** may retransmit once within the slot (e.g., a subsequent subslot **230**). In some embodiments, nodes **110** may retransmit more than once within the slot. In some embodiments, nodes **110** may transmit at every opportunity within the time slot **220**. It should be noted that initiating nodes **120** or other transmitting nodes **110** that determine that they are the sole connection to other nodes **110** may transmit their signal more than once. In some embodiments, the TDMA structure only contains subslots **230** (e.g., with time slots **220** and/or frames **210** omitted). In some embodiments, the subslots **230** may start asynchronously or synchronously, depending on the structure and need of the network. In some embodiments, an initial TDMA frame starts asynchronously on the transmission of a first signal **130** by a primary transmitter. In some embodiments, the telecommunication network **100** does not have a TDMA structure.

[0078] FIG. **3** is a flow chart illustrating the steps for the method **300** for using subslot **230** in the telecommunication network **100**. In some embodiments, the method **300** includes the step **310** of transmitting a first signal **130** from an initiating node **120** in a first subslot **230**. An illustration of the first signal **130** being transmitted from an initiating node **120** is shown in FIG. **1**. FIG. **2** illustrates the designation of the first subslot **230** as subslot S_{1A}.

[0079] In some embodiments, the method includes the step **320** of receiving the first signal **130** at other nodes **110** in the network in the first subslot. For example, in FIG. **1**, the first signal **130** is received by the node **110***a* in the first subslot S_{1a} after being sent from the initiating node **120**. The first signal **130** may also be received by other nodes **110***b-c* in the first subslot S_{1a} if they are in range of the initiating node **120**.

[0080] In some embodiments, the method **300** includes the step **330** of retransmitting the first signal **130** or an algorithmically related first signal **130** in a second subslot **230** subsequent to the first subslot. For example, in FIG. **1**, node **110***a* retransmits the first signal **130** to other nodes **110***b-c* in the telecommunication network in a subsequent subslot **230** (e.g., subslot S_{1b} in FIG. **2**).

[0081] In some embodiments, the method **300** further includes the improvement step **340** of preparing a retransmission of at least one of the first signal or the algorithmically related first signal by two or more nodes via a controller, wherein at least two of the first signals or the algorithmically related first signals are time-dispersed. Time-dispersion of multiple signals (e.g., also referred to as multipath or relay diversity) creates a robust signal, allowing a receiver to resolve the signal in separate paths. For example, if time-dispersed signal (e.g., two or more signals with slightly different delays) are transmitted from multiple transmitter and received by a single receiver fading of the signal from each separate transmitter is likely to be uncorrelated resulting in a higher likelihood of the receiver recovering the message when the signals are dispersed in time sufficiently to allow the receiver to resolve the individual paths. In still another example, the first signal **130** or an algorithmically related first signal may be retransmitted by multiple nodes simultaneously multiple times. With every time a node then hears a transmission and/or retransmission, the node has a better chance of correctly receiving the transmission. Methods and devices for creating a time-dispersed signal are described herein.

[0082] The step **340** of preparing a time-dispersed transmission or retransmission of at least one of the first signal **130** or a time-dispersed algorithmically related first signal by two or more nodes via a controller may occur at any point within the method **300**. Step **340** may occur before the transmission of the first signal **130** or the algorithmically related first signal. In the case of coordinated NACKs, a controlling element prepares a coordinated transmission of replica signals by all nodes transmitting in that slot. As another example, the step **340** may occur after the reception of a first signal **130** from an initiating node **120** to a receiving node **110** and before the retransmission of the first signal **130** or the algorithmically related first signal by the receiving node. The retransmission (e.g., time-dispersed) may be prepared in response to a previous reception or receptions, where the controlling elements at individual nodes ensure that signals transmitted by multiple nodes that overlap in time and frequency are all replicas of the same signal. In the case of the NACK slot, there is no transmission to relay, but the NACK is in response to previous reception(s), or lack thereof (e.g., missed data). It should be known that the time-diverse retransmission may be transmitted in response to the signal to be relayed (e.g., as in a TDMA network), or in response to an asynchronous first signal that may or may not eventually organize within an ad hoc network to form a TDMA relay structure.

[0083] In some embodiments, the method **300** further includes the step **350** of repeating the receiving and retransmitting of a first signal **130** or an algorithmically related first signal by other nodes in subsequent subslots. The step **350** may be repeated a number of times, with each set of repeated steps adding data from the first signal **130** or an algorithmically related first signal to subsequent subslots (e.g., slots S_{1c} and S_{1d} in FIG. **2**). Contacting every node **110** in the network ensures that the first signal **130** or an algorithmically related first signal **130** will reach the intended node **110**. It should be noted that as the number of relays required to allow a signal to propagate across an entire network increases, the number of subslots required to manage the relaying of signal increases as well. Therefore, the number of subslots utilized in the telecommunication network **100** may need to be adjusted according to the topography and number of the relay nodes **110**. The method **300** does not require routing tables, simplifying the routing process. Signals that return to nodes **110** that have already transmitted or received the first signal **130** or an algorithmically related first signal **130** will convey to the node **110** information regarding the structure, status or other characteristic about the communication network **100**. However, these signals may not be retransmitted.

[0084] In some embodiments, one or more nodes **110** of the telecommunication network **100** is further configured to control multipath spreading by varying transmission delay with respect to a time reference (start of a subslot or time of reception of the signal to be relayed for example). Diversity relay is a multipath-controlling method for ensuring that a transmitted signal reaches its destination, as the higher number of paths that the signal takes, the greater probability that the signal will be received by the intended node **110**.

[0085] Multipath time relay provides greatest benefit when the time dispersion at the node **110** is sufficient to allow the node **110** to resolve separate paths, but not so great as to exceed the multipath delay spread capabilities of the node **110** (e.g., such as when using an equalizer or rake receiver). It is also desirable to create a time diverse path in the event that the physical geometry doesn't provide sufficient delay separation between individual relay transmissions. In some embodiments a time diverse path is accomplished by having nodes stagger or dither their transmission (i.e., control multipath spreading by dithering retransmission delay) with respect to the nominal slot start, either deterministically, or in a pseudo random fashion. In some embodiments, the node **110** may determine multipath spreading by self-assessment. In some embodiments, the node **110** may determine multipath spreading through the reception of control data form another node.

[0086] FIG. **4** is a diagram illustrating a communication system containing nodes **110** that relay the first signal **130** or the algorithmically related first signal **130** in a time-diverse multipath arrangement, in accordance with one or more embodiments of this disclosure. Here, a first signal **130** is transmitted from an initiating node **120** to other nodes **110***a-c* in the telecommunication network **100**. Upon receiving the first signal **130**, the receiving nodes **110***a-c* retransmits the first signal **130** or the algorithmically related first signal **130** to a node **110***d* that is an intended destination of the first signal **130**. It should be noted that one, more than one, or all nodes **110** of the communication network **100** may be targeted to receive the first signal **130** or the algorithmically related first signal. One or more retransmissions from the retransmission nodes **110***a-c* may be time delayed (e.g., T**1**, T**2** or T**3** in FIG. **4**) so that the receiving node **110***d* receives the first signal **130** or the algorithmically related first signal as a time-diverse spread signal. For example, if nodes **110***a-c* transmit precisely on the start of the subslot, the signals are received at **110***d* at the respective time of propagation from each node to **110***d* following the start of the subslot. If the distance from **110***a-c* to **110***d* is the same for all three paths, the signals would be received at exactly the same time. Introducing a variable time delay between **110***a-c* retransmissions can spread the reception time at **110***d* out to optimize the time dispersion for reception.

[0087] In some embodiments, the decision to control multipath spreading can be taken locally or globally. The key limitation is that the delay dither should not result in received multipath that exceeds the design capability of the node **110** or telecommunication network **100**. At the global level, a node **110** may determine multipath spreading through self-assessment. All nodes **110***a-c* have the ability to monitor the delay spread that they are seeing and if any of them detect delay spread approaching their limit, the nodes **110***a-c* would transmit a signal to reduce spread in a slot **220** or subslot **230** designated for signal-spreading control data. If nothing is heard in that slot **220** or subslot **230** for a period of time, time-delay of the signal may be increased by some modest amount. If a node **110** indicates that it is approaching its multipath delay spread capability by transmitting the agreed upon signal, the multipath delay spread would be decreased and maintained at the lower level for a longer period (e.g., hysteresis) before allowing a future increase.

[0088] At a local level, multipath delay can be managed between neighbors. Fundamentally, the only transmissions that matter to a node **110** are transmission to and from neighboring nodes **110**, and not transmissions to and from nodes **110** not within range. With that in mind, each node **110** is able to assess locally what delay spread it is seeing and could report that metric when it transmits (e.g., the node **110** may receive control data from other neighboring nodes **110**). If all of a node's neighbors report low delay spread, a node **110** may increase the time delay that it retransmits the signal. Alternatively, at the cost of additional overhead, nodes can explicitly report which nodes that they are hearing (e.g., when they transmit in the first subslot and include a node identifier field, but not in a subsequent subslot) and signal characteristics such as received SNR and delay.

[0089] FIG. **5** is a block diagram illustrating a node **110** used for relaying a first signal **130** or the algorithmically related first signal **130**, in accordance with one or more embodiments of this disclosure. As mentioned herein, the nodes **110** are configured to opportunistically receive a first signal **130** from the initiating node **120**, and retransmit the first signal **130** or the algorithmically related first signal to another node **110**.

[0090] In some embodiments, the relay nodes **110** include a controller **500**. The controller **500** provides processing functionality for the relay node **110** and can include any number of processors **504**. The one or more processors **504** may include any processors **504** used in the art including, but not limited to, field programmable gate arrays (FPGA), and application-specific integrated circuits (ASIC). The controller **500** may utilize the one or more processors **504** to receive and decode incoming transmissions and recode and retransmit the relayed transmissions. The controller **500** may also include resident or external memory **508** for storing data, executable code, and other information accessed or generated by the relay node **110**. The controller **500** can execute one or more software programs embodied in a non-transitory computer readable medium (e.g., a memory **508**) that implements techniques described herein. The controller **500** is not limited by the materials from which it is formed or the processing mechanisms employed therein.

[0091] The memory **508** can be an example of a tangible, computer-readable storage medium that provides storage functionality to store various data and/or program code associated with operation of the relay node **110** and or controller **500**, such as software programs and/or code segments, or other data to instruct the controller **500**, and possibly other components of the relay node **110**. The memory **508** can store data, such as a program of instructions for operating the relay node **110** and/or incoming data from the first signal **130** or the algorithmically related first signal **130**. It should be noted that while a single memory **508** is described, a wide variety of types and combinations of memory **508** (e.g., tangible, non-transitory memory) can be employed. The memory **508** can be integral with the controller **104**, can comprise stand-alone memory, or can be a combination of both. Some examples of the memory **508** can include removable and non-removable memory components, such as random-access memory (RAM), read-only memory (ROM), flash memory (e.g., a secure digital (SD) memory card, a mini-SD memory card, and/or a micro-SD memory card), solid-state drive (SSD) memory, magnetic memory, optical memory, universal serial bus (USB) memory devices, hard disk memory, external memory, and so forth.

[0092] In embodiments the relay node **110** includes a communication interface **512**. The communication interface **512** can be operatively configured to communicate with the components of the relay node **110** and the controller **500**. For example, the communication interface **512** can be configured to retrieve data from the controller **500** or other devices, transmit data for storage in memory **508**, retrieve data from storage in memory, **508** and so forth. The communication interface **512** can also be communicatively coupled with the controller **500** to facilitate data transfer between components of the relay node **110** and the controller **500**. It should be noted that while the communication interface **512** is described as a component of the relay node **110**, one or more components of the communication interface **512** can be implemented as external components communicatively coupled to the relay node **110** via a wire and/or wireless connection. The relay node **110** may also include and/or connect to one or more input/output (I/O) devices. In embodiments, the communication interface **512** includes or is coupled to a transmitter, receiver, transceiver, physical connection interface, or any combination thereof.

[0093] In some embodiments, the first signal **130** or the algorithmically related first signal **130** of at least one subslot **230** is combined with a replica or algorithmically related first signal or the algorithmically related first signal **130** of at least one other subslot **230**. When exactly the same signal is used for more than one subslot **230**, nodes **110** receiving the first signal **130** or the algorithmically related first signal **130** can combine information obtained in the two subslots **230** to improve the received first signal or the algorithmically related first signal **130** to the point where it can be successfully decoded. Subslots **230** may be combined using soft decisions, which uses metrics for the quality of received bits or symbols to weight the contribution from each copy of the same bit or symbol in the detection process. If the initial detection is insufficient to recover the message, possibly as indicated by failing a cyclic redundancy check (CRC), incorporation of soft-decision information (e.g., at the bit level) from subsequent subslots **230** may suffice to recover the message without error. Alternatively, analogous first signals **130** may be captured, retained, and the subslots **230** combined by any of the commonly used diversity receive combining techniques. By combining subsequent slots in this manner, the subsequent impulse response may be assessed and used to determine if artificial delay may be added to increase multipath capabilities (e.g., an enhancement in diversity gain).

[0094] In some embodiments, the telecommunication network **100** further comprises a feedback protocol. Feedback protocols are necessary in networks to resolve or prevent errors in data transmissions. In some embodiments, the feedback protocol is generated by designating a slot **220** following a data transmission slot **220** as a negative-acknowledgement (NACK) slot **220**, as shown in FIG. **6**. Any nodes **110** that require retransmission transmit the identical retransmission request in the slot **220**, which could then be relayed in subslots **230**. A single node **110** or multiple nodes **110** requiring retransmission will provide the same NACK when multiple nodes send a NACK simultaneously, the result is beneficial rather than destructive because the receiving nodes **110** see the same kind of artificial multipath as in McGibney diversity relay. In some embodiments, the feedback protocol includes an automatic repeat request (ARQ) protocol. It should be noted that NACK requests are prepared before the coordinated retransmission of first signals or algorithmically related first signals by all nodes **110** transmitting in a slot (i.e., the NACK is not a rebroadcast of the first signal **130**).

[0095] Adaptation of global dithering of timing to improve received time dispersion of relayed signals may also be accomplished in a fashion similar to negative acknowledgment based ARQ protocols. In some embodiments, data slots **220** are designated to allow a receiving node **110** to at least one of object to an increase in dither or request an increase in dither. The global dither can therefore be managed by the telecommunication network **100** at the node **110** level with low overhead. It should be noted that dedicated management slots **220** should be far enough apart as to not adversely impact overheads and balanced for adaptability.

[0096] Efficiency in telecommunication networks **100** may be increased through optimization of the number of subslots **230** utilized within a data slot **220** of a frame **210**. In some embodiments, the telecommunication network **100** is further configured to at least one of increase the number of subslots **230** in a slot **220** depending on one or more data signals sent from one or more nodes or decrease the number of subslots **230** in a slot **220** depending on one or more data signals sent from one or more nodes. In the following two examples, one or more subslots **230** have been designated as subslots one, two and three, and one or more nodes **110** have been designated as nodes A, B, C, D, and E. In one example, the number of subslots **230** in a slot **220** may be reduced if one or more subslots **230** are not utilized. For instance, if node A transmits in subslot one, nodes B and C relay in subslot two, and nodes D and E relay in subslot three, if there are no nodes beyond D and E, that would mean that three subslots **230** were not required and that the message propagated to all nodes **110** within the network within two subslots **230**. If all nodes **110** initiating the transmission are found to only require two subslots **230** to propagate the signal to all nodes **110**, then the number of subslots **230** may be reduced. In another example, the number of subslots **230** may be increased. For instance, if a node **110** only hears transmissions in the last subslot **230**, then the node **110** may object to any reduction in the number of subslots **230**. In another instance, if a node **110** detects that there are other active nodes **110** that do not receive a signal, the node **110** may request that the number of subslots **230** increase.

[0097] In telecommunication networks **100** where subslot **230** or node **110** reducing protocols are used, conditions may arise where subslot **230** or node **110** numbers should remain the same or even expand. For example, subslot/node expansion may be prioritized as the result of adversarial action or adverse propagation conditions, making the telecommunication network **100** more robust. In some embodiments, the telecommunication network **100** further comprises a slot **220** dedicated to at least one of vetoing a change in subslot **230** number or request an increase in subslot **230** number. For example, a mechanism for vetoing (e.g., NACKing) may be a dedicated slot **220** in which all nodes **110** that wish to maintain the current number of relay opportunities based on the number of subslots **230** transmit an agreed upon message. In another example, a second dedicated slot **220** may be assigned to allow any node **110** requiring more subslots **230** for relaying to transmit an agreed upon message to increase the number of subslots **230**.

[0098] FIG. **7** is a diagram illustrating a series **700** of slots (e.g., slots **710-750**) with possible arrangements of subslots **230**, in accordance with one or more embodiments of this disclosure. In each row, a slot **710-750** begins with a primary subslot **230**, designated by a 'P' (e.g., hatched background). Subslots **230** used in a relay context are shown with an 'R' with a subscript indicating which relay level they represent. Aligned primary slots **220** across rows permit adaptation within the slots/subslots between the aligned primary slots to occur with some degree of robustness possible because the aligned primary slots can be consistent across all possible subslot **230** arrangements. Thus, even if a misconfiguration does occur where some elements of the telecommunication network **100** do not receive a change notice, it can be corrected quickly with the aligned primary slots **220**. For example, as shown in FIG. **7**, an adaptation within the slot structure could include slots with zero, one, two, three, or five relay subslots (e.g., in slots **710-750**). In this example, the adaptation rules are modified for a three to five, or five to three, transition as the adaptation is a transformation by two subslots **230**, rather than a change by one subslot **230**. If less than the maximum number of relay subslots **230** are being used, then an opportunity exists for signals other than the first signal **130** or the algorithmically related first signal **130** to be transmitted. For instance, using the example above, if the most critical service is voice, and voice can be supported by five subslots (e.g., using four relays), the ability to support other services (e.g., chat or file transfer) can be added as the capacity improves (e.g., when the number of relay nodes needed is reduced).

[0099] The interconnectivity of nodes **110** within a telecommunication network **100** may also allow the telecommunication network **100** to adjust transmitted power levels for each node **110**, optimizing power usage for the entire telecommunication network **100**. FIG. **8** is a flow diagram illustrating a method **800** for managing power within the telecommunication network **100**, in accordance with one or more embodiments of this disclosure.

[0100] In some embodiments, the method **800** includes the step **810** of requiring each node to report a unique identification when they are the initiating node. Node **110** usage data may then be used for local power optimization of the telecommunication network **100**. In some embodiments, the method **800** includes the step **820** of requiring all nodes **110** report who they hear primary transmissions of the first signal **130** or the algorithmically related first signal from with an indication of margin. Primary transmission denotes the first time that a node **110** has received the first signal **130** or the algorithmically related first signal. Node **110** reception data may then also be used in local power optimization.

[0101] In some embodiments, the method **800** further includes the step **830** of reducing the power of a node **110** if all neighboring nodes **110** report a sufficient link margin to allow a reduction in power. For example, the power of a transmitting node **110** may be reduced if a neighboring node **110** determines that the transmitting node **110** could reasonably operate at half transmission power. In some embodiments, the method **800** further includes the step **840** of evaluating connectivity and/or topology variability through adjusted data rates or power. For example, using a higher data rate may decrease the transmission time of a transmitting node **110**, which may decrease power consumption. In another example, using a lower data rate may allow a longer transmission distance, reducing the number of subslot **230** used to relay the signal, thereby reducing the overhead and increasing the data capacity of the telecommunication network **100**. In another example, the use of more efficient data transmission waveform may reduce power consumption. For instance, a binary phase shift keying (BPSK) signal may be converted to a quadrature phase shift keying (QPSK) signal, resulting in a doubling of the data rate for the signal and increased power efficiency. In some embodiments, the data rate is set by the node sending the first signal **130** or the algorithmically related first signal. Alternatively, the data rate may be changed by nodes acting as relays along the signal path. However, changes in the data rate must be coordinated with other nodes within the communication network **100** to ensure that all overlapping transmissions are replicas.

[0102] In some embodiments, the method **800** further includes the step **845** of managing global power adaptation through dedicated management slots **220** or reducing power at specific times if no node **110** objects. For example, if any node **110** sends the defined agreed upon signal (e.g., or packet) requesting increased power in a management slot **220** designated for power management, then the entire telecommunication network **100** would increase power.

[0103] In some embodiments, data rates and/or power management within a communication network **100** may be modified (e.g., optimized) according to changes in network topography. In another example, a lower data rate would be considered if the signal strength dropped because the distance between nodes increased or the power of the nodes had been reduced. In still another example, an overall reduction in the area covered by the communication network **100** (e.g., a communication network **100** that has reduced from covering 10000 square kilometers to 1000 square kilometers, comprising one or more mobile nodes **110**) may require fewer subslots to support the necessary number of relays.

[0104] In some embodiments, the method **300** further includes the step of operating a coding scheme. In an ad hoc communication network, all nodes **110** acting as a relay need to send a signal that encodes exactly the same message sent from the initiating node **120**. However, the signals transmitted by the initiating node and relay node for the same message may differ due to coding schemes (e.g., error correction codes such as convolutional codes), which are then algorithmically derived back into the same message. As the message is sent through the communication network **100**, each retransmission improves the error correction coding available to nodes **110** that hear more than one transmission or retransmission.

[0105] Subslots used to relay data do not necessarily have to be a direct copy of the first signal **130** or the algorithmically related first signal in all cases. All relays need to send exactly the same signal in response to a received signal, but that does not need to be identical to the received first signal, the constraint is only that signals that overlap at a receiver on a frequency in time must be replicas of one another so that they can be combined. That replica signal can be derived algorithmically from the first signal **130**. For example, nodes **110** can compute parity bits from the first signal **130** and send those. If the method for generating the parity bits changes from subslot to subslot but is predefined so all relays do the same thing for every subslot, nodes that are not able to detect a message from a single subslot can improve their likelihood of detecting a message using multiple received subslots, each of which carries different parity bits. The method is general, but specific examples can be given: Reed Solomon codes could be used in one instance, convolutional codes in another, Turbo-codes or LDPC codes in still others.

[0106] In some embodiments, the first signal **130** or algorithmically related first signal includes a forward error correction code with a rate equal to or less than 1. Convolutional codes are a type of error-correcting codes that generate parity symbols through a sliding application of a Boolean polynomial function to a data stream, which can then be decoded using the Viterbi algorithm. Convolutional codes are of particular use with fading channels, as they can be used to determine probabilities correctness of bits for signals within transmissions where errors are present (e.g., through soft decision decoding). Convolutional codes may be systematic, where the encoded message includes the original data bits, potentially interleaved or permuted, as well as parity bits derived from the original data bits. Non-systematic codes do not send the original data bits, but only bits derived from the polynomial functions. In general, non-systematic codes are preferable when convolutional codes are employed with a traditional Viterbi maximum likelihood decoder. When convolutional codes are used to form a code that is decoded by with a turbo-code approach, systematic convolutional codes are preferred. In either case, so long as the code rate is 1 or less, the original message can be recovered if there are no errors in the transmission. Lowering the rate of the code improves the ability to recover the original message in the presence of errors.

[0107] In some embodiments, the coding scheme may include the step of recovering the data in the first signal **130** or algorithmically related first signal and validating the integrity of the data. An illustrative example, a non-systematic convolutional code could use a rate ⅓ convolutional code, using 3 polynomials to generate the encoded message. If the output of the first polynomial were sent as the primary message, with a CRC appended, the original message could be recovered if there were no errors in the reception. In the first subsequent subslot, all transmissions could use the output of the second polynomial, again with a CRC appended. Retransmissions by nodes that received the primary message would be made by detecting the first signal **130** or the algorithmically related first signal, confirming from the CRC that it was not corrupted, recovering the original message bits, encoding them with the rate ⅓ encoder and using the bits from the second polynomial as the basis of the re-transmission. Similarly, for the second subsequent subslot, the message would be based on the bits encoded by the third polynomial. A receiver can attempt to decode the message with any individual slot as a rate ⅓ code, punctured to rate 1. If it receives any two subslots, it can attempt the decoding as a rate ⅓ code punctured to rate ½. If it receives all three subslots, the decoding can use the full power of the rate ⅓ code. An obvious extension to this includes sending encoded messages which have some amount of redundancy to allow for error correction, for example, by basing the messages on a rate ¼ convolutional code, with the primary message consisting of the output of the first polynomial and the first ⅓ of the bits output from the fourth polynomial. The second subslot would use the encoded bits from the second polynomial and the second ⅓ of the bits from the fourth polynomial and the third sub-slot would use the output of the third polynomial and the last ⅓ of the bits from the fourth polynomial. There are many possible variations on this basic approach.

[0108] In some embodiments, the coding scheme may include evaluating the data from at least one of the algorithmically related first signal or a combination of the first signal **130** and the algorithmically related first signal. For example, the evaluation of the first signal **130** and the algorithmically related first signal may be performed through the use of turbo codes. Turbo codes are a type of convolutional code that combines two convolutional codes to achieve better performance than a convolutional code by itself. Signals are run through two or more encoding steps, transmitted, and the signals are decoded at the receiving node. The process of turbo coding can be expanded to an additional splitting step and combining step, resulting in an increased code rate without having to change on-air bandwidth or modulation. In some embodiments, the retransmission of the first signal **130** or algorithmically related first signal in the subsequent subslot is further prepared to contain parity bits derived from the data of the first signal **130** or algorithmically related first signal. For example, the data from the first signal **130** or the algorithmically-derived first signal may be encoded into data bits and parity bits. The convolutional codes used in the coding scheme are systematic convolutional codes, or are codes where the original message bits can be recovered by reordering the sequence of the bits. In some embodiments, the coding scheme and the convolutional codes used in the coding scheme are associated within STANAG 4538 data link protocols or other code combining automatic repeat request (ARQ) protocols.

[0109] For example, the coding scheme may include combining the convolutional codes into a turbo code. For instance, the turbo code may be encoded by sending the data through a convolutional encoder, then sending an interleaved copy of the data through the same convolutional encoder. The original data, checksum 1, and checksum 2 are combined into one data stream. In another example, for an n-bit input of $X_1X_2X_3 \ldots X_n$, the encoded sequence will be $X_1\ Y_1\ Z_1\ X_2\ Y_2\ Z_2\ X_3\ Y_3\ Z_3 \ldots X_n\ Y_n\ Z_n$, where $X_1 \ldots X_n$ are the data bits, $Y_1 \ldots Y_n$ are the checksum bits, and $Z_1 \ldots Z_n$ are the checksum bits from an interleaved convolutional encoder.

[0110] In some embodiments, the coding scheme may include splitting the turbo code into two or more data streams, wherein a first data stream comprises checksum bits from the first convolutional encoder and data bits, and a second data stream comprises checksum bits from the interleaved convolutional encoder and interleaved data bits. For example, the encoded sequence $X_1\ Y_1\ Z_1\ X_2\ Y_2\ Z_2\ X_3\ Y_3\ Z_3 \ldots X_n\ Y_n\ Z_n$ may be further split into two signals: $X_1Y_1X_2Y_2X_3Y_3 \ldots X_nY_n$ and $I_1Z_1I_2Z_2I_3Z_3 \ldots I_nZ_n$, where $X_1 \ldots X_n$ are the data bits, $Y_1 \ldots Y_n$ are the checksum bits from the convolutional encoder, $Z_1 \ldots Z_n$ are the checksum bits from the interleaved convolutional encoder, and $I_1 \ldots I_n$ are the interleaved data bits.

[0111] In some embodiments, the coding scheme may include preparing and retransmitting the algorithmically related first signal in a subsequent subslot. Once separated into two or more signals, the data streams may be transmitted independently from each other. For example, the data stream containing checksum bits from the convolutional encoder may be transmitted in a first subslot, wherein the data stream containing checksum bits from the first interleaved convolutional encoder may be transmitted in a second subsequent subslot. It should be noted that the independent data streams may also be sent within different subslots within the same time slot. In some embodiments, the coding scheme may include receiving the transmitted data stream (e.g., by a receiver on a node **110**). In some embodiments, the coding scheme may include at least one of combining the data streams into a turbo code and decoding the data stream with a turbo code decoder, or decoding one or more data streams with a Viterbi decoder. For example, a node **110** may receive the two data streams from the transmitted split signal, each from separate slots, and combine them. The interleaver may be different on both slots **220**, as the reception of any two slots **220** may be decoded with a turbo code decoder. When transmitted in subsequent slots **220**, with a high enough SNR either reception can be received independently. For example, if both transmissions were received, but both receptions have errors, the data can be combined and decoded with a turbo code decoder. In another example, a Viterbi decoder may be used to decode the received signals, particularly if at high SNR values (i.e., the coded signals may be decoded through different iterations of decoders until one decoder is found with the fewest errors or zero errors. In some embodiments, three or more convolutional codes (e.g., a "super turbo code") may be utilized to encode and decode first signals or algorithmically related first signals.

[0112] In some embodiments, the first signal **130** or algorithmically related first signal is further prepared to contains parity bits derived from the data of the first signal **130** or algorithmically related that are different from the parity bits of one or more preceding retransmissions. In some embodiments, the data from one or more combinations of a first signal **130** and subsequent algorithmically related signals are evaluated, and a retransmission of the first signal **130** or algorithmically related first signal if prepared based on the evaluation.

[0113] In some embodiments, the combination of the received first signal or algorithmically related first signal can at least one of increase the number of decoding algorithms that can recover the data or decrease the code rate.

[0114] In some embodiments the coding scheme may be identical for any retransmission. In some embodiments, the coding scheme may be different for any retransmission.

[0115] In some embodiments, the decoding scheme can decode any retransmission independently. In some embodiments, the decoding scheme can be improved by the reception of multiple retransmissions. In some embodiments, multiple decoding schemes can be used to decode a single transmission. In some embodiments, multiple decoding schemes can be used to decode receptions improved by the reception of multiple retransmissions. It should be known that one slot, multiple slots, or a combination of slots may be used in association with the coding scheme. For example, multiple subslots may be used for redundant messaging (e.g., in case that an initial signal is missed). It should be noted that the method **850** allows the encoding of a first signal **130** into two coded signals with differing coding properties, and allows the reception of either of the two coded signals to be received in order to recover data from the first signal **130** with a Viterbi decoder, or reception of both signals (with errors) to be decoded by a Turbocode decoder.

[0116] In some embodiments, the coding scheme further includes a code puncturing scheme, wherein data streams within two or more subslots coding redundant first signals are punctured with a unique puncture pattern. Data puncturing is the process of removing some parity bits from an encoded signal after encoding with an error-correction code, and is commonly associated with convolutional or turbo codes. Puncturing reduces the number of transmitted bits, which increased the overall data transmission rate. For example, the turbo convoluted code $X_1Y_1X_2Y_2X_3Y_3$ . . . may be punctured and transmitted as the code $X_1Y_1X_2$_ X_3Y_3 . . . , with the punctured 'X' to be expanded when decoded upon reception to read as $X_1Y_1X_2$ 0 X_3Y_3 . . . The nature of the punctured turbo code (e.g., or other punctured, convolutionally encoded code) is that the payload data is still intact once the transmission is decoded.

[0117] In embodiments, first signals or algorithmically related first signals in multipath or subslot-repeated transmissions may be punctured multiple times and expanded. This puncture rate expansion works with both systematic and non-systematic convolutional codes as long as the transmitted data is the same underlying sequence that has been punctured differently.

[0118] FIG. **9** is a diagram illustrating a setup **900** for puncture rate expansion within a slot, in accordance with one or more embodiments of this disclosure. For example, for the first subslot **910**, the convoluted data X_{A1} Y_{A1} X_{B1} Y_{B1} X_{C1} Y_{C1} . . . is punctured using the puncture pattern 111010. On reception, if the CRC passes, then the reception was satisfactory and the data can be retransmitted. If the CRC fails, the data is not satisfactory and the soft decisions are stored for the next slot. The data after the first reception is expanded after the first reception to produce X_{A1} Y_{A1} X_{B1} 0 X_{C1} 0 . . . .

[0119] Continuing this example, before transmitting on the second slot **920**, the data is reencoded and punctured with a second distinct pattern, 101110, a pattern capable of converting a signal of X_{A2} Y_{A2} X_{B2} Y_{B2} X_{C2} Y_{C2} . . . to X_{A2} 0 X_{B2} Y_{B2} X_{C2} 0 . . . that may be transmitted. On reception, the soft decisions are combined in such a way that there are fewer expanded bits, using the first and second combined equation **925**.

[0120] Continuing this example, before transmitting on the third slot **930**, the data is reencoded and punctured with a third distinct pattern, 101011, a pattern capable of converting a signal of X_{A3} Y_{A3} X_{B3} Y_{B1} X_{C3} Y_{C3} . . . to X_{A3} 0 X_{B3} 0 X_{C3} Y_{C3} . . . that is transmitted. On reception, the soft decisions are combined in such a way that all checksum bits have been transmitted at least once, using the first, second, and third combined equation **935**.

[0121] In some embodiments, the code puncturing scheme is adjusted to optimize the number of times that the bits are punctured. For example, it may be more suitable to puncture a non-systematic convolutional code with retransmissions set up to minimize the number of times the same unique bit is analyzed, and maximizing the number of different bits that are analyzed. For instance, if two of six bits are punctured using a non-systematic convolutional code, each bit will be analyzed twice after three transmissions, whereas a systematic convolutional code may analyze some bits three times, and other bits only once.

[0122] Both the expanded use of turbo codes and puncture rates may modify the code rate without having to change the on-air bandwidth or modulation, which allows either a longer range, or a lower transmit power for the same probability of correct reception. Lower transmit power will increase the battery life of power constrained nodes (e.g., battery powered radios) and reduce the range in which adversaries can detect radio transmitters. Each expansion method has its own advantage and disadvantage. Puncture rate expansion has a lower complexity receiver and can be used with higher data rates or with less processing power. Puncturing also reduces redundancy, which increases the code rate i.e., from rate ½ to rate ¾) making the transmission less robust. Turbo code expansion has a more complex receiver but can operate with poorer signal quality.

[0123] In order for a telecommunication network **100** to dynamically reconfigure itself, all of the nodes **110** need to know as much as possible about the topology of the telecommunication network **100**. The management data of the telecommunication network **100** is all overhead data as far as the user is concerned and ideally would be transmitted in a way that doesn't impact the user (e.g., through transmitting in a different frequency).

[0124] When two nodes **110** that are in range of each other transmit on the same frequency, their transmissions interfere with each other. If the nodes **110** are transmitting identical data, the interference can be constructive and improve the reception at a receiver node **110**. If the data is different the interference is destructive and can prevent reception of either transmission at the receiving node **110**.

[0125] FIG. **10**A is a diagram illustrating two transmitting nodes **110** operating in a telecommunication network **100** with on-air collisions. Here, the transmitting nodes are only two hops away from each other. Signals transmitted by transmitting nodes one and three collide at node two, whereas node four only receives one signal from node three. With only two nodes **110** acting as a relay node, transmitting nodes can never be far enough apart that there will not be on air collisions. FIG. **10**B is a diagram illustrating two transmitting nodes **110** operating in a telecommunication network **100** without on-air collisions (e.g., the transmitters are three hops apart.

[0126] A potential for interference in transmitting with relay nodes **110** arises from signals retransmitted from relay nodes **110** interfering with new signals sent from initiating nodes **120**. For example, after sending a first signal **130** to a relay node **110**, in the first subslot **230**, an initiating node **120** may then transmit overhead data (e.g., a second signal) to other nodes **110** in a subsequent subslot **230**. If the node **110** receiving the initial signal retransmits the first signal **130** or algorithmically related first signal in the second subslot **230**, the first signal **130** and the overhead data will interfere with each other. In this scenario, additional frequencies may be utilized. For example, in some embodiments, the initiating node **120** is further configured to transmit a second signal in the second subslot **230** (e.g., subsequent subslot) or a third subslot **230** subsequent to the third subslot in a different frequency than the retransmitted first signal or algorithmically related first signal **130**. It is important to note that one or more nodes **110** of the communication network **100** may comprise half duplex devices that communicate with other half-duplex devices, but not simultaneously. For example, for these half-duplex devices, the relay will receive in the first subslot **230**, transmit in the second subslot **230** and will not be able to receive another signal until the third subslot.

[0127] FIG. **11**A-C is a diagram illustrating a method for relaying transmissions without collisions in a three-relay telecommunication network **100**. In this example, a first signal **130** from node one is initially transmitted to node two in subslot one (e.g., FIG. **11**A). Node two then transmits the first signal **130** to node three in subslot two (e.g., FIG. **11**B). Node one also receives a retransmitted first signal or algorithmically related first signal **130** from node two, but disregards it with respect to retransmitting the first signal **130** or algorithmically related first signal. However, node one may also take note of other aspects of the received transmission (e.g., whether no other retransmission is heard, or whether the retransmission is transmitted on the same frequency, either in the next subslot or in a later first subslot). When the transmission to node three has completed, and before node one transmits overhead data, both node one and node two will switch to a secondary frequency. In FIG. **11**C, node three is shown transmitting the first signal **130** or algorithmically related first signal to nodes two and four, while node one is transmitting overhead data to node two using the secondary frequency (e.g., in a second subslot **230** subsequent to the first subslot **230**). The two signals reaching node two do not interfere with each other, as the frequencies of the two transmissions are different.

[0128] Relay networks using frequency diversity along with multiple relay subslots can greatly reduce collisions in more complex networks where there are multiple concurrent transmissions. FIG. **12**A-C are diagrams illustrating the use of frequency diversity in an eight-node mesh TDMA network using a first, a second, and a third subslot, respectively. Transmissions with similar frequencies are shown with identical arrow patterns in FIGS. **12**A-C.

[0129] In some embodiments, at least one node **110** that is not within the range of the initiating node **120** (e.g., nodes three, four, seven, and eight are not in range of initiating node one in FIG. **12**A) is configured to transmit a second signal or algorithmically related second signal in at a first subslot **230** and/or a second subslot **230** subsequent to the first subslot **230** in a different frequency than initiating node one. For example, node three in FIG. **12**A, out of range of the initiating node **120** (e.g., node one), has been elected to transmit a second signal or algorithmically related second signal to neighboring node **110** using a different frequency that that used by the initiating node **120** to send a first signal **130** to nodes two, five and six. However, nodes two and six will not receive the second signal or algorithmically related second signal if they are only capable of receiving on a single channel and are configured to listen for the signal from node one in this subslot. The second signal or algorithmically related second signal may contain data similar or dissimilar to the first signal **130** or algorithmically related first signal.

[0130] It is important to note that all nodes within the communication network **100** may act as relays when they are capable of doing so. By having all nodes **110** always acting as relay nodes when possible, no overhead is needed to assign specific nodes for relaying, reducing resource needs required to operate the communication network **100**. In FIG. **12**B, one of the nodes **110** that received the first signal **130** from node one (e.g., node two) retransmits the first signal **130** or algorithmically related first signal **130** in the second subslot to nodes **110** in range using the same frequency as the initial transmission of the first signal **130** from node one to node two. At the same time, the node that initially transmitted the first signal **130**, node one, is transmitting another signal (e.g., a secondary signal) to the second subslot **230** using a secondary frequency. Also, at the same time, a node not in range of node two, node four is transmitting a third signal within the second subslot **230** using a secondary frequency. Nodes five and six receive both signals from nodes one and two if they are capable of receiving signals on multiple frequencies. If nodes five and six are only capable of receiving a single frequency, then they will only receive transmissions from node one or node two. Node two, acting as a transceiver, would not be able to receive the transmission from node one at the same time that it is transmitting to nodes one, three, five, six and seven. It should be noted that some transmissions in FIG. **12**B (e.g., from nodes five and six) were removed for clarity. All nodes that receive a transmission would then automatically retransmit the signal. It should also be noted that the nodes **110** in FIG. **12**B have full duplex capability, and can transmit on a different frequency than the frequency for which they are receiving transmissions. Communication networks **100** operating with one or more nodes **110** with half duplex capability may have different relay capabilities or patterns, as half duplex nodes are not capable of transmitting on different frequencies that the frequency for which they are receiving transmissions. For example, a node sending a first signal **130** may wait until after its neighbors have had an opportunity to retransmit the first signal **130** or algorithmically related first signal before sending a second signal in a subsequent subslot on the same or different frequency.

[0131] In FIG. **12**C, one of the nodes **110** that received the first signal **130** or algorithmically related first signal from node two (e.g., node three) retransmits the first signal **130** or algorithmically related first signal using a third subslot **230** to all neighboring nodes. When this transmission occurs, all nodes within the network have received the first signal **130** or algorithmically related first signal at which time the first signal **130** or algorithmically related first signal will no longer propagate. At the same time, other nodes **110** have transmitted, and may continue to transmit, signals through the telecommunication network **100**. Through the use of nodes **110** as relays, frequency diversity, and multiple subslots **230**, a signal intending to reach all nodes **110** will do so while still allowing multi-signal communication between sets of nodes **110**. As in FIG. **12**B, some transmissions in FIG. **12**C were removed for clarity (e.g., all nodes that receive a transmission automatically retransmit the signal).

[0132] In some embodiments, the method of routing signals in a telecommunication network **100** further includes adjusting the power level of a node based upon at least one characteristic of the reception of the first signal **130** or algorithmically related first signal, or the condition of the neighboring nodes **110**. For example, overhead data could be transmitted globally at a high power and a low data rate, which will allow the node to transmit at maximum range. The data waveforms may then adjust the power rate and/or the data rate according to one or more qualities of the link. For instance, the data rate which can impact the topology of the network, and the number of subslots, which affects the overhead, may be jointly optimized to maximize the capacity of the network. Power levels may also be adapted on a node-by-node basis. For example, a node acting only as a relay may be turned off if it is determined that another node may provide the same action (i.e., a reduction of redundant nodes). Also, as mentioned herein, data may also be modulated to increase data rates. For example, switching from a QPSK modulation to an eight-phase shift keying (8PSK) modulation could increase data rate with a compensatory decrease in power usage. By adjusting power locally or globally within the telecommunication network **100**, data may be efficiently managed without overextending the data capacity of the telecommunication network **100**. Other characteristics of the first signal **130**, algorithmically related first signal, or condition of the neighboring nodes may be used as a basis for adjusting the power level of a node. Therefore, the above description should not be interpreted as a limitation of the present disclosure, but merely an illustration.

[0133] It should be noted the methods described herein for modifying, delaying, otherwise adapting signals received and/or transmitted by the nodes may be performed by the components operating within the node including but not limited to the controller **500**, memory **508**, processors **504**, or the communication interface **512**.

[0134] As used herein a letter following a reference numeral is intended to reference an embodiment of the feature or element that may be similar, but not necessarily identical, to a previously described element or feature bearing the same reference numeral (e.g., 1, 1a, 1b). Such shorthand notations are used for purposes of convenience only and should not be construed to limit the disclosure in any way unless expressly stated to the contrary.

[0135] Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by anyone of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0136] In addition, use of "a" or "an" may be employed to describe elements and components of embodiments disclosed herein. This is done merely for convenience and "a" and "an" are intended to include "one" or "at least one," and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0137] Finally, as used herein any reference to "one embodiment", "in embodiments", or "some embodiments" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment disclosed herein. The appearances of the phrase "in some embodiments" in various places in the specification are not necessarily all referring to the same embodiment, and embodiments may include one or more of the features expressly described or inherently present herein, or any combination or subcombination of two or more such features, along with any other features which may not necessarily be expressly described or inherently present in the instant disclosure.

[0138] It is to be understood that embodiments of the methods disclosed herein may include one or more of the steps described herein. Further, such steps may be carried out in any desired order and two or more of the steps may be carried out simultaneously with one another. Two or more of the steps disclosed herein may be combined in a single step, and in some embodiments, one or more of the steps may be carried out as two or more substeps. Further, other steps or substeps may be carried in addition to, or as substitutes to one or more of the steps disclosed herein.

[0139] Although inventive concepts have been described with reference to the embodiments illustrated in the attached drawing figures, equivalents may be employed and substitutions made herein without departing from the scope of the claims. Components illustrated and described herein are merely examples of a system/device and components that may be used to implement embodiments of the inventive concepts and may be replaced with other devices and components without departing from the scope of the claims. Furthermore, any dimensions, degrees, and/or numerical ranges provided herein are to be understood as non-limiting examples unless otherwise specified in the claims.

What is claimed is:

1. A method of routing first signals in a telecommunication network, wherein the telecommunications network comprises a plurality of nodes, wherein the telecommunications network uses time-division multiple access (TDMA) frames, each TDMA frame being divided into a series of time slots, and each time slot being divided into subslots,

wherein at least one of: the telecommunication network comprises a reduced overhead node only network comprising only reduced overhead nodes; or the telecommunication network comprises a mixed network comprising a combination of reduced overhead nodes, and normal nodes configured to transmit both traffic and control data,

the method comprising steps of:

transmitting a first signal from an initiating node in a first subslot; and

receiving the first signal at other nodes in the network in the first subslot; and

retransmitting the first signal or an algorithmically related first signal in a second subslot different and nonoverlapping from the first subslot, wherein the retransmitting comprises:

preparing a retransmission of at least one of the first signal or the algorithmically related first signal by one or more nodes via one or more respective controllers; and

transmitting the first signal or the algorithmically related first signal via the one or more nodes.

2. The method of claim **1**, wherein the first subslot of the TDMA frame is configured to be allocated by at least one:

randomly;

deterministically such that one or more particular nodes are allocated the first subslot and one or more non-allocated nodes are configured to know that they are not allocated the first subslot; or

wherein the first subslot comprises multiple timeslots and the multiple timeslots are configured to be allocated via a mix of at least one of randomly or deterministically.

3. The method of claims **2**, wherein the the telecommunication network comprises the reduced overhead node only network comprising only the reduced overhead nodes.

4. The method of claim **3**, wherein the reduced overhead node only network is configured such a TDMA frames is defined asynchronously based on a transmission of the signals by a transmitter of the first subslot in a TDMA frame.

5. The method of claim **3**, wherein the reduced overhead node only network is configured such that an TDMA frame is predefined synchronously based on known synchronized timing between nodes.

6. The method of claim **1**, wherein the telecommunication network comprises the mixed network comprising the combination of reduced overhead nodes, and the normal nodes.

7. The method of claim **6**, wherein the mixed network is configured such that a TDMA frames is defined asynchronously based on a transmission of signals by a transmitter of the first subslot in a TDMA frame.

8. The method of claim **6**, wherein the mixed network is configured such that an TDMA frame is predefined synchronously based on known synchronized timing between nodes, and, further, in that the reduced overhead nodes are configured to receive transmissions from the normal nodes.

9. The method of claim **6**, wherein a subset of the reduced overhead nodes are configured to transmit relatively-low-rate control overhead signals configured to inform the normal nodes that of one or more timeslots are allocated to be used by the reduced overhead nodes, wherein the relatively-low-rate control overhead signals are defined as being at a rate of time that is less frequent than a control overhead rate of control overhead signals configured to be transmitted by the normal nodes.

10. The method of claim **6**, wherein the normal nodes are configured to perform relays of control data on behalf of a subset of the reduced overhead nodes and configured to not transmit relatively-low-rate control overhead signals, wherein the normal nodes are configured to ensure timeslots are allocated for the reduced overhead nodes.

11. The method of claim **10**, wherein at least one normal node is configured to un-allocate one or more node based on one or more timeout thresholds, wherein the at least one normal node is configured to use an overhead node timeout threshold for reduced overhead nodes that is longer in time relative to a normal timeout threshold for normal nodes.

12. The method of claim **10**, wherein the at least one normal node comprises a Network Control Node (NCN) configured to determine the control data for an entirety of the telecommunication network.

13. The method of claim **10**, wherein a reduced overhead node timeout measurement, against which a breach of an overhead node timeout threshold is configured to be determined, is configured to be reset to zero based on a receiving of either one of: a transmission comprising the control data; or a transmission comprising traffic without control data.

14. The method of claim **1**, wherein the reduced overhead nodes are characterized in that each reduced overhead node is configured to, in terms of transmissions comprising control data, at least one of:

1) receive transmissions only, without transmitting of the control data;

2a) receive transmissions only, except for originating transmissions in the first subslot;

3a) receive transmissions only, except for: originating transmissions in the first subslot; and retransmissions for other reduced overhead nodes in later timeslots;

2b) receive transmissions only, except for: originating transmissions in the first subslot; and relatively low-rate control transmissions when part of a mixed network; or

3b) receive transmissions only, except for: originating transmissions in the first subslot; retransmissions for other reduced overhead nodes in later timeslots; and relatively low-rate control transmissions when part of a mixed network.

15. The method of claim **1**, wherein one or more nodes are further configured to repeat the receiving and retransmitting of the first signal or the algorithmically related first signal by other nodes in subsequent subslots.

16. The method of claim **1**, wherein a first signal of at least one subslot is combined with a replica or an algorithmically related first signal of at least one other subslot to increase a probability of reception.

17. The method of claim **1**, wherein the initiating node is further configured to transmit a second signal or a algorithmically related second signal in a subslot subsequent to the first subslot on a different frequency than the retransmitted first signal or the algorithmically related first signal.

18. The method of claim **1**, wherein at least one node not within range of the initiating node is configured to transmit at least one of a second signal or an algorithmically related second signal in at least one of a first subslot or a second subslot subsequent to a first subslot on a different frequency than the transmitted first signal or algorithmically related first signal.

19. A system of routing first signals in a telecommunication network, wherein the system is configured to, utilizing at least one controller of a node:

transmit a first signal from an initiating node in a first subslot; and

receive the first signal at other nodes in the network in the first subslot; and

retransmit the first signal or an algorithmically related first signal in a second subslot different and nonoverlapping from the first subslot, wherein the retransmitting comprises:

preparing a retransmission of at least one of the first signal or the algorithmically related first signal by one or more nodes via one or more respective controllers; and

transmitting the first signal or the algorithmically related first signal via the one or more nodes,

wherein the telecommunications network comprises a plurality of nodes, wherein the telecommunications network uses time-division multiple access (TDMA) frames, each TDMA frame being divided into a series of time slots, and each time slot being divided into subslots,

wherein at least one of: the telecommunication network comprises a reduced overhead node only network comprising only reduced overhead nodes; or the telecommunication network comprises a mixed network comprising a combination of reduced overhead nodes, and normal nodes configured to transmit both traffic and control data.

20. The system of claim **19**, wherein the first subslot of the TDMA frame is configured to be allocated by at least one:

randomly;

deterministically such that one or more particular nodes are allocated the first subslot and one or more non-allocated nodes are configured to know that they are not allocated the first subslot; or

wherein the first subslot comprises multiple timeslots and the multiple timeslots are configured to be allocated via a mix of at least one of randomly or deterministically.

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