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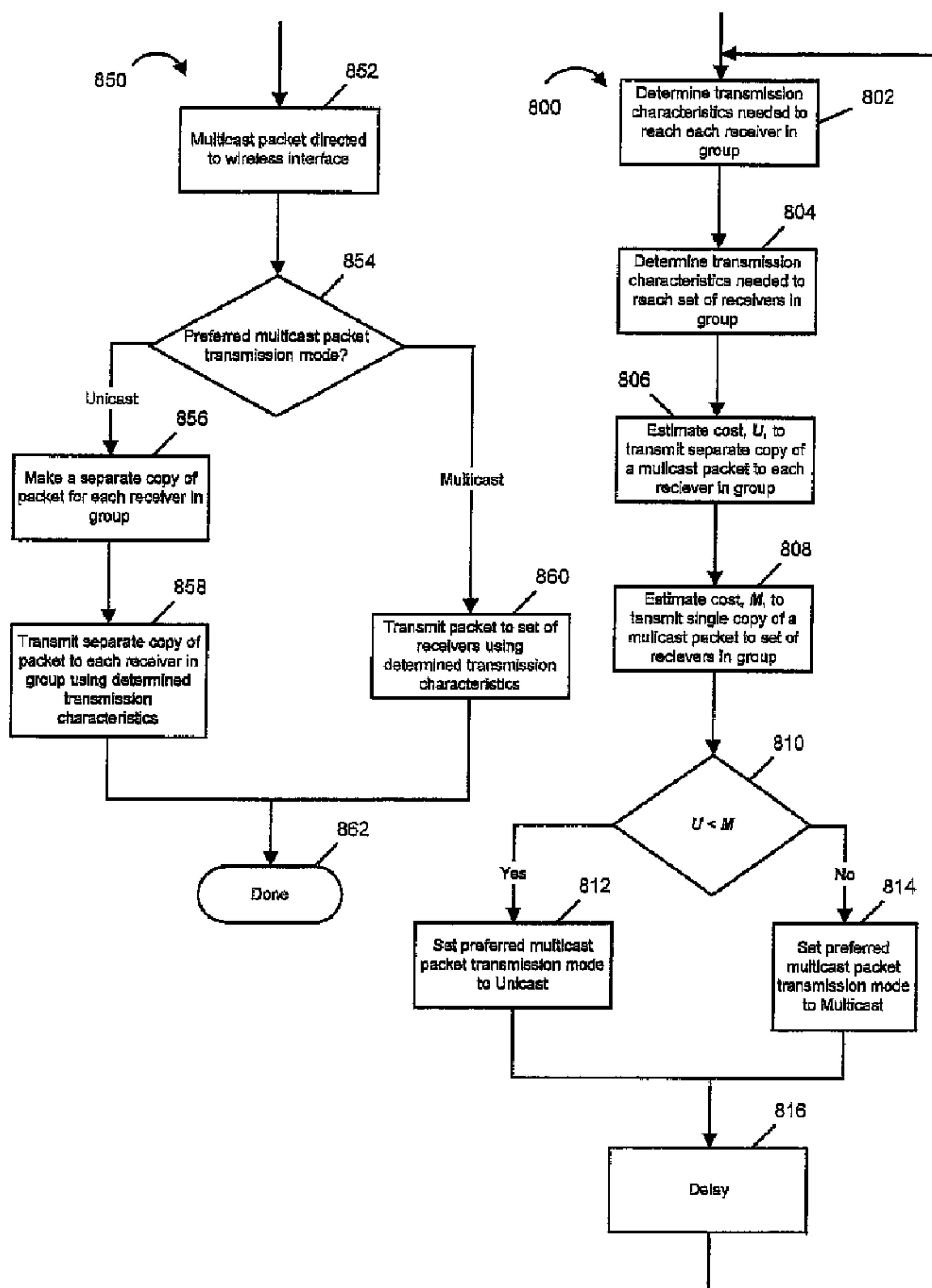
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(54) Titre : PROCEDES ET APPAREIL DE SIGNALISATION DE COMMUNICATIONS DE GROUPE  
(54) Title: GROUP COMMUNICATION SIGNAL METHODS AND APPARATUS



(57) Abrégé/Abstract:

Group communications methods and apparatus are described. Multicast operation is supported with the transmission characteristics (1003, 1052), e.g., transmission power level, coding rate, and/or modulation method being selected to reliably

**(57) Abrégé(suite)/Abstract(continued):**

communicate information to the end nodes (134, 136, 144, 146, 154, 156) in the group but not necessarily to all end nodes within the cell or sector (138, 148, 158). Thus resources can be conserved by matching transmission requirements with information on the requirements of one or more group members. The requirements for reliably reaching the end node with the worst channel conditions can, and in some embodiments is, used to determine the group transmission requirements. Power level and other transmission resource allocations can change in response to changes in group membership and/or conditions corresponding to existing group members.

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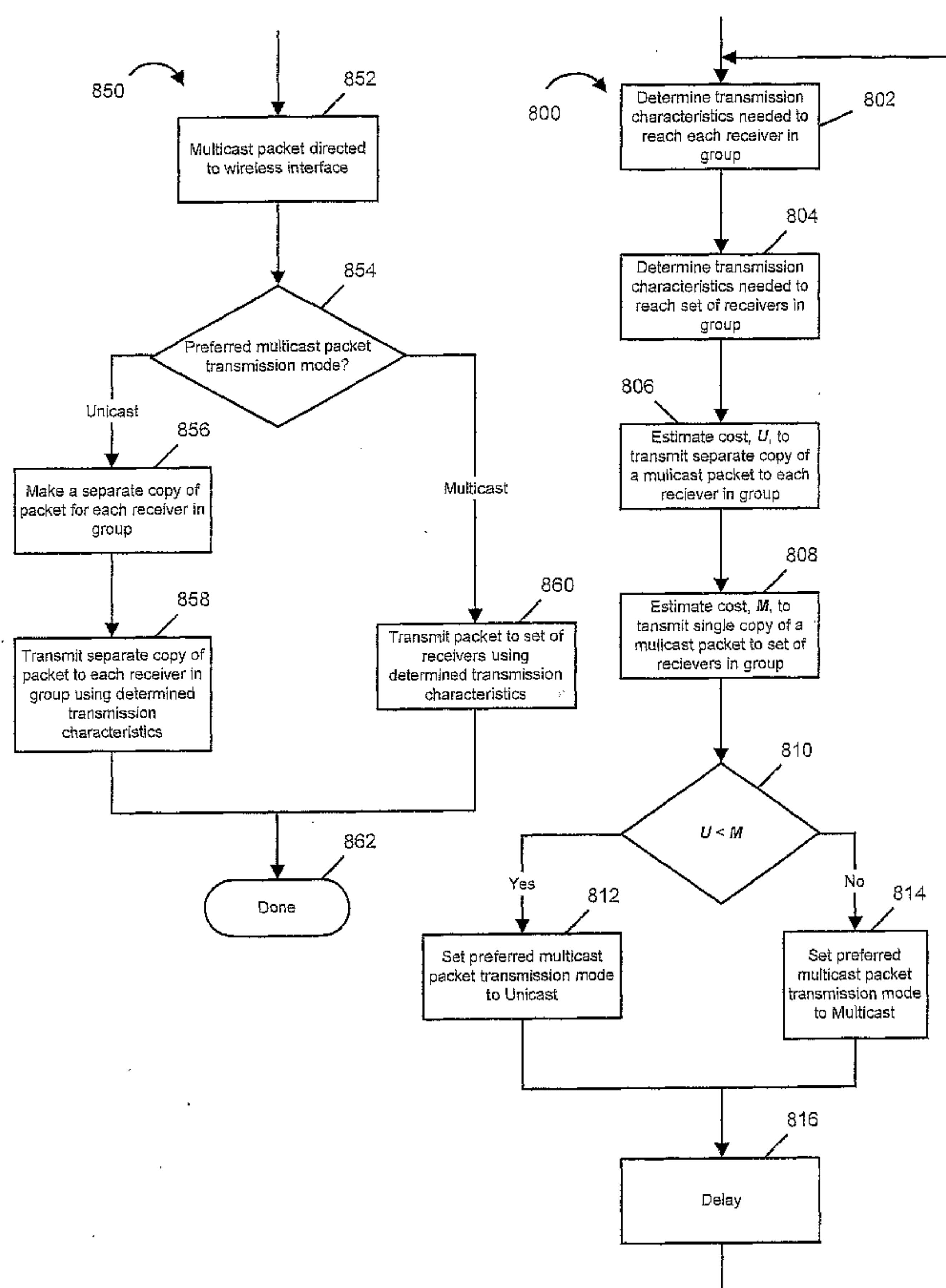
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(54) Title: GROUP COMMUNICATION SIGNAL METHODS AND APPARATUS



**(57) Abstract:** Group communications methods and apparatus are described. Multicast operation is supported with the transmission characteristics (1003, 1052), e.g., transmission power level, coding rate, and/or modulation method being selected to reliably communicate information to the end nodes (134, 136, 144, 146, 154, 156) in the group but not necessarily to all end nodes within the cell or sector (138, 148, 158). Thus resources can be conserved by matching transmission requirements with information on the requirements of one or more group members. The requirements for reliably reaching the end node with the worst channel conditions can, and in some embodiments is, used to determine the group transmission requirements. Power level and other transmission resource allocations can change in response to changes in group membership and/or conditions corresponding to existing group members.

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## GROUP COMMUNICATION SIGNAL METHODS AND APPARATUS

### FIELD OF THE INVENTION:

5 This invention relates to communications systems and, more particularly, to methods and apparatus for implementing group communications and/or controlling transmission of group communication signals.

### BACKGROUND:

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In a typical cellular communication network, a set of geographically dispersed base stations provide wireless access to a communications infrastructure. Users with wireless communication devices, or terminals, are able to establish a direct communication link with a suitable base station and then exchange information with other users and/or end systems 15 throughout the communication network.

IP multicast technology provides an efficient packet delivery service for group communications (e.g., one-to-many or many-to-many). The use of IP multicast reduces the bandwidth utilization for group communications. This is especially important for supporting 20 group communications over wireless media, where bandwidth is a scarce resource.

When using IP multicast, a group of recipients is associated with an IP multicast address. A data source addresses and sends a single copy of each IP datagram intended for the group of recipients to the IP multicast group address. The routed network will replicate and forward each 25 datagram as needed to deliver it to the routers interconnecting all of the group members. Specialized IP multicast routing protocols are used to form the delivery trees needed for copying and forwarding multicast datagrams.

IP multicast is a receiver-oriented service, in that receivers join a given multicast group 30 to receive datagrams sent to the corresponding IP multicast group address. End systems and access routers communicate with each other via a group membership protocol, e.g., Internet Group Management Protocol (IGMP), to enable the access router to maintain information on active multicast group membership necessary for building the delivery trees.

**BRIEF DESCRIPTION OF THE FIGURES:**

Fig. 1 illustrates a network diagram of an exemplary communications system of the present invention.

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Fig. 2 illustrates an exemplary access node implemented in accordance with the present invention.

Fig. 3 illustrates transmission of a separate copy of a multicast packet to each member in  
10 a group in accordance with the present invention.

Fig. 4 illustrates transmission of a copy of a multicast packet to a plurality of members in a group in accordance with the present invention.

15 Fig. 5 illustrate transmission of a copy of a multicast packet to a plurality of members in a group using a first set of transmission characteristics to enable reception by the set of receivers in the group in accordance with the present invention.

20 Fig. 6 illustrate transmission of a copy of a multicast packet to a plurality of members in a group using a second set of transmission characteristics to enable reception by the set of receivers in the group in accordance with the present invention.

25 Fig. 7 illustrates a flowchart that shows an exemplary procedure to adaptively control the mode and characteristics of transmitting multicast packets in accordance with the present invention.

30 Fig. 8 illustrates flowcharts that show exemplary procedures to adaptively determine the preferred mode and characteristics of transmitting multicast packets and to transmit multicast packets based on the determined mode and characteristics in accordance with the present invention.

Figs. 9, 10, 11 and 12 illustrate exemplary information stored by an access node in accordance with various embodiments of the present invention.

**SUMMARY OF THE INVENTION:**

The present invention is directed to methods and apparatus for implementing group communications, e.g., multicast communications methods and apparatus. The methods and apparatus of the present invention are particularly well suited for use in wireless communications systems. In such systems different end nodes, which may be wireless terminals used by different individual users, have different communications requirements, e.g., power, timing coding rate, modulation method and/or other signal requirements. These differing signal requirements are often a function of differences in channel conditions and/or end node location which exist between different end nodes and an access node. The conditions, including channel condition and location, can change over time as an end node moves within the coverage area of an access node. Each end node may be a member of zero, one, or more multicast groups at any point in time. Access nodes serve as the end node's point of attachment, e.g., via a wireless communications link, to a communication system, e.g., cellular network. Group membership may vary with time.

Different multicast applications can be executing on different end nodes with each end node being a member of one, multiple or no multicast groups at any point in time. Within an area serviced by a transmitter, e.g., access node's sector or cell transmitter, group membership may change due to actions by the group member(s), e.g., as a user of an end node decides to enter or exit a group, e.g., by signaling a multicast application to make the desired group membership change or by terminating the multicast application. Membership can also change as the result of an end node dynamics, e.g., a mobile node, entering or leaving a cell.

The methods and apparatus of the invention are directed to the subject matter claimed in the present application.

In accordance with the present invention, transmission requirements for one or more individual group members may be determined and, in the case of a signal directed at the same time to multiple group members, the transmission requirements for the group are primarily determined from the requirements of the group member with the poorest channel conditions. In such cases, the transmission power, coding rate and/or other characteristics of the multicast signal transmitted over the wireless communications link are determined by information relating to at least one group member and the signal is not necessarily intended to reach the transmitter's

full coverage area. Thus, assuming the full set of group members are close to the transmitter and experiencing good channel conditions, the transmission power may be much lower than would be required to reach the full transmitter coverage area, e.g., the full sector or cell.

5 While determining transmission characteristics such as power, coding rate, and/or modulation method as a function of channel condition information related to group members can be used with systems which support the two modes of operation as discussed above, this feature of the invention can be used in embodiments where a single mode of multicast transmissions is supported and each transmission is directed to multiple end nodes in a group, when the group  
10 includes more than one end node in the access node's coverage area.

The transmissions implemented by the access node may be OFDM signal transmissions. However, CDMA and other implementations are also supported and possible.

15 Numerous variations on the above described methods and apparatus of the present invention are possible. The detailed description which follows provides additional description of the invention as well as discussing additional exemplary embodiments, features and benefits of the invention.

## 20 DETAILED DESCRIPTION OF THE FIGURES AND THE INVENTION:

Fig. 1 illustrates an exemplary communication system 100, e.g., a cellular communication network, which comprises a plurality of nodes interconnected by communications links. Nodes in the exemplary communication system 100 may exchange information using signals, e.g., messages, based on communication protocols, e.g., the Internet Protocol (IP). The communications links of the system 100 may be implemented, for example, using wires, fiber optic cables, and/or wireless communications techniques. The exemplary communication system 100 includes a plurality of end nodes 134, 136, 144, 146, 154, 156, which access the communication system via a plurality of access nodes 130, 140, 150. The end  
25 nodes 134, 136, 144, 146, 154, 156 may be, e.g., wireless communication devices or terminals, and the access nodes 130, 140, 150 may be, e.g., wireless access routers or base stations. The exemplary communication system 100 also includes a number of other nodes as may be needed to provide interconnectivity or to provide specific services or functions. Specifically, the  
30 exemplary communication system 100 includes a mobility agent node 108, e.g., Mobile IP home

agent node, as may be needed to support mobility of end nodes between access nodes, a session signaling server node 106, e.g., Session Initiation Protocol (SIP) proxy server, as may be needed to support establishment and maintenance of communication sessions between end nodes, and an application server node 104, e.g., multimedia server, as may be needed to support specific 5 application layer services.

The Fig. 1 exemplary system 100 depicts a network 102 that includes the application server node 104, the session signaling server node 106, and the mobility agent node 108, each of which is connected to an intermediate network node 110 by a corresponding network link 105, 10 107, 109, respectively. The intermediate network node 110 in the network 102 also provides interconnectivity to network nodes that are external from the perspective of the network 102 via network link 111. Network link 111 is connected to another intermediate network node 112, which provides further connectivity to a plurality of access nodes 130, 140, 150 via network links 131, 141, 151, respectively.

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Each access node 130, 140, 150 is depicted as providing connectivity to a plurality of N end nodes (134, 136), (144, 146), (154, 156), respectively, via corresponding access links (135, 137), (145, 147), (155, 157), respectively. In the exemplary communication system 100, each access node 130, 140, 150 is depicted as using wireless technology, e.g., wireless access links, to 20 provide access. A radio coverage area, e.g., communications cell, 138, 148, 158 of each access node 130, 140, 150, respectively, is illustrated as a circle surrounding the corresponding access node.

The exemplary communication system 100 is subsequently used as a basis for the 25 description of an embodiment of the invention. Alternative embodiments of the invention include various network topologies, where the number and type of network nodes, the number and type of links, and the interconnectivity between nodes may differ from that of the exemplary communication system 100 depicted in Fig. 1.

30 Fig. 2 provides a detailed illustration of an exemplary access node 300 implemented in accordance with the present invention. The exemplary access node 300, depicted in Fig. 2, is a detailed representation of an apparatus that may be used as any one of the access nodes 130, 140, 150, depicted in Fig. 1. In the Fig. 2 embodiment, the access node 300 includes a processor 304, a network/internetwork interface 320, a wireless communication interface 330 and memory

310, coupled together by bus 306. Accordingly, via bus 306 the various components of the access node 300 can exchange information, signals and data. The components 304, 306, 310, 320, 330 of the access node 300 are located inside a housing 302.

5        The processor 304 under control of various modules, e.g., routines, included in memory 310 controls operation of the access node 300 to perform various signaling and processing, as discussed below. The modules included in memory 310 are executed on startup or as called by other modules. Modules may exchange data, information, and signals when executed. Modules may also share data and information when executed.

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      The network/internetwork interface 320 provides a mechanism by which the internal components of the access node 300 can send and receive signals to/from external devices and network nodes. The network/internetwork interface 320 includes, a receiver circuit 322 and a transmitter circuit 324 used for coupling the node 300 to other network nodes, e.g., via copper wires or fiber optic lines. The wireless communication interface 330 also provides a mechanism by which the internal components of the access node 300 can send and receive signals to/from external devices and network nodes, e.g., end nodes. The wireless communication interface 330 includes, e.g., a receiver circuit 332 with a corresponding receiving antenna 336 and a transmitter circuit 334 with a corresponding transmitting antenna 338 used for coupling the access node 300 to other network nodes, e.g., via wireless communication channels.

      In the Fig. 2 embodiment, the memory 310 of the access node 300 includes a multicast routing/forwarding module 311, multicast routing/forwarding information 312, a group membership module 313, group information 314, member information 315, a transmission cost estimation module 316, a multicast transmission mode determination module 317 and a multicast control module 318. Transmission cost estimation module 316 includes a transmission control module 319 for determining at least one of a transmission power level, coding rate and modulation method to be used for transmitting packets to the end nodes which are indicated by said first set of group membership information to be members of said first group, said at least one of a transmission power level and coding rate being determined as a function of information relating to a condition associated with at least one group member. Various modulations methods which may be selected include, e.g., QPSK, QAM 16, QAM 64, etc. The transmission control module includes logic, circuits and/or sub-modules for adjusting the determined transmission power level, coding rate and/or modulation method in response to changes in channel condition

information, as a channel condition associated with the end node in said first group having the worst channel conditions changes over time.

The multicast routing/forwarding module 311 controls the operation of the access node 5 300 to support routing/forwarding of multicast traffic packets. The multicast routing/forwarding module 311 may use any one of a variety of multicast routing protocols, e.g., Distance Vector Multicast Routing Protocol (DVMRP), Protocol Independent Multicast (PIM), etc. The multicast routing/forwarding information 312 includes, e.g., the multicast routing and/or forwarding tables indicating the interfaces between which multicast packets corresponding to specific groups 10 should be copied and forwarded. The group membership module 313 controls the operation of the access node 300 to support managing group membership information on interfaces of the access node 300. The group information 314 includes, e.g., the set of groups for which there are active members connected to the access node 300 via the wireless interface 330 and specific information pertaining to each such group. The member information 315 includes, e.g., specific 15 information pertaining to each group member connected to the access node 300 via the wireless interface 330. Both the group information 314 and member information 315 are more fully described subsequently.

The transmission cost estimation module 316 computes a cost estimate corresponding to 20 the transmission of multicast information (e.g., packets or a fixed number of information bits) to one or more members in a group. In some embodiments of the invention the estimated cost is a function of one or more determined transmission characteristics, e.g., power, bandwidth, time, code rate. In some embodiments of the invention, the determined transmission characteristics are a function of the channel condition and or channel variation (e.g., signal to noise ratio, error 25 rate). In accordance with some embodiments, information used for cost estimation as well as the results are included in the group information 314 and member information 315 stores.

The multicast transmission mode determination module 317 determines the preferred mode for transmission of multicast information (e.g., packets) for a particular multicast group. In 30 some embodiments, the preferred multicast packet transmission mode is determined based on the number of group members. For example, if the number of group members is less than or equal to some threshold  $N$ , a separate copy of each multicast packet is transmitted to each group member, while if the number of group members is greater than the threshold  $N$ , a single copy of each multicast packet is transmitted to the set of group member. In some embodiments, the

preferred multicast packet transmission mode is determined based on the relative estimated costs for transmitting information separately to each member (e.g., unicast directed transmissions) versus transmitting information simultaneously to the set of group members (e.g., multicast directed transmissions). In accordance with some embodiments, information used for multicast transmission mode determination as well as the results are included in the group information 314 and member information 315 stores.

5 The multicast control module 318 controls the overall operation of the access node 300 to support adaptively controlling the mode and/or characteristics of transmitting multicast 10 information (e.g., packets) via the wireless interface 330.

10 Thus, the multicast control module 318 exchanges signals and/or information with other modules included in memory 310, e.g., group information 314, member information 315, transmission cost estimation module 316, and multicast transmission mode determination 15 module 317. The multicast control module 318 implements switching between modes of operation, transmission power levels, modulation methods and coding rates based on determinations and/or information provided by the various other modules including the transmission control module 319 and multicast transmission mode determination module 317.

20 Figs. 3 and 4 illustrate transmission of a multicast packet from an access node 300 implemented in accordance with the invention during two different modes of operation. Fig. 3 illustrates a scenario 900 where the access node 300 transmits a separate copy of each multicast packet to each group member using individually allocated transmission resources, while Fig. 4 illustrates a scenario 400 where the access node 300 transmits a single copy of each multicast 25 packet to the set of group members using shared transmission resources. The transmission resources may include a transmission unit, said transmission unit being, e.g., one of a frame and a time slot. The transmission resources may also include other things such as segments and spreading codes. Determination of the preferred mode for transmission of multicast packets is a function of the set of group members (e.g., the number of group members) and/or the specific 30 information associated with each group member (e.g., channel condition and/or channel variation).

Fig. 3 depicts an access node 300 and a plurality of end nodes (910, 911, 912, 913, 914, 915, 916, 917) within the radio coverage area 901 of the access node 300. A first end node 912

and a second end node 915 are each marked with an *M* to indicate that they are members of a particular multicast group. The dotted-dashed line 930 between the access node 300 and the first end node 912 represents transmission of a copy of a multicast packet to said first end node 912. A corresponding dotted-dashed circle 931 represents the characteristics (e.g., power and code rate) of the transmission directed to said first end node 912. The dashed line 920 between the access node 300 and the second end node 915 represents transmission of a separate copy of the same multicast packet to said second end node 915. A corresponding dashed circle 921 represents the characteristics (e.g., power and code rate) of the transmission directed to said second end node 915. The transmissions to the first end node 912 and the second end node 915 may occur either simultaneously or at different points in time, but in either case they are separate transmissions using transmission resources specifically assigned, allocated, or associated with the respective end nodes.

Fig. 4 depicts an access node 300 and a plurality of end nodes (410, 411, 412, 413, 414, 15 415, 416, 417) within the radio coverage area 401 of the access node 300. A first end node 410, a second end node 412, and a third end node 415 are each marked with an *M* to indicate that they are members of a particular multicast group. The dashed lines 420 between the access node 300 and the group of end node 410, 412, 415 represent transmission of a multicast packet to the group of end node 410, 412, 415. A corresponding dashed circle 421 represents the 20 characteristics (e.g., power and code rate) of the transmission directed to said group of end node 410, 412, 415. Transmission of the multicast packet to the group of end nodes 410, 412, 415 uses shared transmission resources that are monitored by the individual end nodes 410, 412, 415 in parallel. The shared transmission resources may include a transmission unit, transmission segment, spreading code and/or other transmission resources of the type described above.

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Figs. 5 and 6 illustrate transmission of a multicast packet during the second mode of operation (e.g., the mode illustrated in Fig. 4) from an access node 300 implemented in accordance with the invention using two different sets of transmission characteristics. Fig. 5 illustrates a scenario 500 where the access node 300 transmits single copy of each multicast 30 packet to the set of group members using shared transmission resources and a first set of transmission characteristics (e.g., power and code rate), while Fig. 6 illustrates a scenario 600 where the access node 300 transmits a single copy of each multicast packet to the set of group members using shared transmission resources and a second set of transmission characteristics (e.g., power and code rate). Determination of the transmission characteristics is a function of the

set of group members (e.g., the number of group members) and/or the specific information associated with each group member (e.g., channel condition and/or channel variation). Changes in group membership, e.g., adding or deleting end nodes from a group, or changes in conditions corresponding to an end node which is a group member such as channel conditions and/or channel variations may trigger transition from transmitting as shown in Fig. 5 to transmitting as shown in Fig. 6. The location of the end node, e.g., mobile node, 610 within the cell and the channel condition to the end node 610 are both conditions which correspond to the end node 610. In Fig. 6 the channel corresponding to the end node identified by reference 610 is likely to be worse than the worst channel to a group member in Fig. 5 since node 610 is further away from the base station 300 than any of the group members in the Fig. 5 example.

Fig. 5 depicts an access node 300 and a plurality of end nodes (510, 511, 512, 513, 514, 515, 516, 517) within the radio coverage area 501 of the access node 300. A first end node 512, a second end node 514, and a third end node 515 are each marked with an *M* to indicate that they are members of a particular multicast group. The dashed lines 520 between the access node 300 and the group of end nodes 512, 514, 515 represent transmission of a multicast packet to the group of end nodes 512, 514, 515. A corresponding dashed circle 521 represents the characteristics (e.g., power and code rate) of the transmission directed to said group of end nodes 512, 514, 515. Transmission of the multicast packet to the group of end nodes 512, 514, 515 uses shared transmission resources that are monitored by the individual end nodes 512, 514, 515 in parallel. The dashed circle 521 is shown to minimally encompass said group of end nodes 512, 514, 515 to indicate the transmission characteristics are determined to efficiently transmit the multicast packet to the group of end nodes 512, 514, 515, e.g., using minimum power, bandwidth, and/or time needed to reliably transmit the multicast packet to the group members.

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Fig. 6 depicts an access node 300 and a plurality of end nodes (610, 611, 612, 613, 614, 615, 616, 617) within the radio coverage area 601 of the access node 300. A first end node 610, a second end node 612, and a third end node 615 are each marked with an *M* to indicate that they are members of a particular multicast group. The dashed lines 620 between the access node 300 and the group of end nodes 610, 612, 615 represent transmission of a multicast packet to the group of end nodes 610, 612, 615. A corresponding dashed circle 621 represents the characteristics (e.g., power and code rate) of the transmission directed to said group of end nodes 610, 612, 615. Transmission of the multicast packet to the group of end nodes 610, 612, 615 uses shared transmission resources that are monitored by the individual end nodes 610, 612, 615

in parallel. The dashed circle 621 is shown to minimally encompass said group of end nodes 610, 612, 615 to indicate the transmission characteristics are determined to efficiently transmit the multicast packet to the group of end nodes 610, 612, 615, e.g., using minimum power, bandwidth, and/or time needed to reliably transmit the multicast packet to the group members.

5 The dashed circle 621 in Fig. 6 is depicted with a larger radius than the dashed circle 521 in Fig. 5 to indicate that the transmission characteristics are different (e.g., 621 may correspond to a higher power transmission than 521).

Fig. 7 illustrates a flowchart 700 defining an exemplary procedure used in some 10 embodiments of the present invention to adaptively control the transmission of multicast packets, via the wireless interface 330 of an access node 300 implemented in accordance with the invention. The procedure is executed for each multicast packet directed to the wireless interface for transmission to a set of group members associated with the wireless interface. The 15 first step 702 of the procedure corresponds to the event of a multicast packet being directed to the wireless interface for transmission to a set of group members associated with the wireless interface. In the second step 704, a determination is made as to whether the number of group members is greater than a pre-determined threshold  $N$ .

If the number of group members does not exceed the pre-determined threshold  $N$ , a 20 separate copy of the multicast packet is transmitted to each group member, steps 706, 708, 710. Thus, in step 706 a separate copy of the multicast packet is made for each member of the group, in step 708 transmission characteristics for sending a copy to each member of the group are determined, and in step 710 the individual copies are separately transmitted to each group member using transmission resources specifically assigned, allocated, or associated with each 25 group member.

Alternatively, if the number of group members does exceed the pre-determined threshold  $N$ , a single copy is transmitted to the set of members in the group, steps 712, 714. Thus, in step 30 712 transmission characteristics for sending a copy to the set of members in the group are determined, and in step 714 a copy of the multicast packet is transmitted to the set of members in the group using shared transmission resources that are monitored by each group member. In either case, processing ends in step 716.

Fig. 8 illustrates a first flowchart 800 defining an exemplary procedure used in some embodiments of the present invention to adaptively determine a preferred multicast packet transmission mode for multicast packets corresponding to a particular group that are directed for transmission via the wireless interface 330 of an access node 300 implemented in accordance with the invention. Fig. 8 also illustrates a second flowchart 850 defining an exemplary procedure used in some embodiments of the present invention to adaptively control the transmission of multicast packets, via the wireless interface 330 of an access node 300 implemented in accordance with the invention, based on the preferred multicast packet transmission mode, e.g., as determined by the procedure defined by said first flowchart 800 in Fig. 8.

The procedure defined by the first flowchart 800 in Fig. 8 executes repeatedly for a particular multicast group (e.g., as a background process) irrespective of multicast packet arrivals for said group. The first step 802 determines the transmission characteristics (e.g., power, code rate) for separately transmitting information to each member in the group (e.g., as a function of individual member channel condition and variation). The next step 804 determines the transmission characteristics (e.g., power, code rate) for transmitting information to the set of members in the group using shared transmission resources (e.g., as a function of group channel condition and variation). The next step 806 estimates the cost  $U$  of separately transmitting the same information to each member in the group (e.g., as a function of the transmission characteristics associated with each member determined in step 802). The next step 808 estimates the cost  $M$  of transmitting information to the set of members in the group using shared transmission resources (e.g., as a function of the transmission characteristics determined in step 804).

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In step 810, the estimated costs,  $U$  and  $M$ , corresponding to the two modes of operation, are compared. If the estimated cost  $U$  is less than the estimated cost  $M$ , then the preferred multicast packet transmission mode is set to *Unicast* in step 812, otherwise the preferred multicast packet transmission mode is set to *Multicast* in step 814. Step 816 optionally adds a delay, before returning to step 802 and repeating the procedure, to control the frequency of the computations.

The procedure defined by the second flowchart 850 in Fig. 8 is executed for each multicast packet directed to the wireless interface for transmission to a set of group members

associated with the wireless interface. The first step 852 of the procedure corresponds to the event of a multicast packet being directed to the wireless interface for transmission to a set of group members associated with the wireless interface. In the second step 854, a determination is made as to whether the preferred multicast packet transmission mode (e.g., as set by the procedure defined by the first flowchart 800 in Fig 8) is presently set to *Unicast* or *Multicast*.

If the preferred multicast packet transmission mode is *Unicast*, a separate copy of the multicast packet is transmitted to each group member, steps 856, 858. Thus, in step 856 a separate copy of the multicast packet is made for each member of the group and in step 858 the individual copies are separately transmitted to each group member using transmission resources specifically assigned, allocated, or associated with each group member and using transmission characteristics as determined during the last execution of step 802.

Alternatively, if the preferred multicast packet transmission mode is *Multicast*, a single copy is transmitted to the set of members in the group, step 860. Thus, in step 860 a copy of the multicast packet is transmitted to set of members in the group using shared transmission resources that are monitored by each group member and using transmission characteristics as determined during the last execution of step 804. In either case, processing ends in step 862.

Fig. 9 illustrates exemplary group information 314 and exemplary member information 315 (both in tabular form) that may be stored in memory 310 of an access node 300 implemented in accordance with the invention. The group information 314 table includes columns (a) 1001 identifying a group, (b) 1002 identifying the end nodes that are members of the group, (c) 1006 the channel condition and/or location information corresponding to the end node in the group to which the row corresponds having the worst channel conditions and/or which is located furthest away from the access node, (d) 1003 indicating the determined transmission characteristics for transmitting information using shared resources to the set of members in the group, (e) 1004 indicating the estimated cost for transmitting information using shared resources to the set of members in the group, (f) indicating the estimated cost for separately transmitting information to each member of the group using individually allocated resources, and (g) 1005 indicating the preferred multicast transmission mode for the group. The group information 314 may be, and in some embodiments is, updated from time to time, e.g., as changes in group membership, channel conditions and/or location occur. Portions of the information show in table 314 may be, and in some embodiments is, stored elsewhere in

memory. Each row 1021, 1022 of the group information 314 table, represents the information associated with a particular multicast group. Exemplary information is presented for two multicast groups. The first group (224.225.1.6) includes two members (10.2.1.2 and 10.2.1.10) and indicates that the preferred multicast packet transmission mode is *Unicast*. The second 5 group (224.225.1.9) includes four members (10.2.1.5, 10.2.1.10, 10.2.1.27, and 10.2.1.43) and indicates that the preferred multicast packet transmission mode is *Multicast*. Note that in column 1003 the power and coding rate for the group is selected to correspond to the coding rate/power level combination needed to reach the end node in the group with the worst channel 10 conditions. This will normally correspond to a lower power level and a higher coding rate than that which would be required to reach all areas of the transmission coverage region. This is particularly beneficial in terms of conserving resources when group members are located well within the boundary of the transmission coverage region. In some embodiments of the present invention, the coding rate may be lower and/or the power level used may be higher for the group than the minimum required to reach the end node in the group with the worst channel conditions, 15 e.g., to improve robustness of in the absence of ARQ.

In the exemplary group information 314 table, the estimated multicast mode transmission cost in column 1004 may be, and in some embodiments is, a function of the determined multicast transmission characteristics in column 1003. Note however, that the estimated unicast 20 mode transmission cost in column 1007 of the group information 314 table may be, and in some embodiments is, a function of the individual estimated unicast transmission cost corresponding to each group member listed in column 1002, where the individual estimated unicast transmission cost corresponding to each group member is shown in column 1053 of the member information 315 table. For each group, e.g., row, the preferred multicast transmission mode in 25 column 1005 is set to *Multicast* if the estimated multicast mode transmission cost in column 1004 is lower than the estimated unicast mode transmission cost in column 1007, and is set to *Unicast* otherwise. Note that alternative cost estimation and mode determination functions are used in various embodiments of the present invention.

30 The member information 315 table includes columns (a) 1051 identifying a group member/end node, (b) 1055 channel condition and/or location information for the individual end node, (c) 1052 indicating the determined transmission characteristics for separately transmitting information to the end node, and (c) 1053 indicating the estimated cost for separately transmitting information to the end node. Each row (1061, 1062, 1063, 1064, 1065) of the

member information 315 table, represents the information associated with a particular end node (A, B, C, D or E). The member information 315 may be, and in some embodiments is, updated as the conditions/location corresponding to the end node changes. Note that an end node may be a member of multiple groups, but need not be listed in the member table more than once. For 5 example, end node 10.2.1.10 (row 1063 of the member information 315 table) is indicated as a member of group 224.225.1.6 (row 1021 and column 1002 of the group information 314 table) and group 224.225.1.9 (row 1022 and column 1002 of the group information 314 table).

Fig. 10 illustrates exemplary group information 314' and exemplary member information 10 315' as may be stored in memory 310 of an access node at a second point in time (e.g., a time other than the time at which the information shown in Fig. 9 is stored). The group information and 314' and member information 315' are shown with the same rows and columns, but the 15 row/column reference numbers have been augmented with a prime symbol, ', to indicate that the information corresponding to a particular row/column may be different at said second point in time. The group information 314' shown in Fig. 10, indicates that end node 10.2.1.43 is a member of the first group 224.225.1.6 (see row 1021' and column 1002'), where said end node is not shown as a member in Fig. 9 (see row 1021 and column 1002). Correspondingly, the group 20 information 314' table in Fig. 10 indicates that the estimated unicast transmission cost (row 1021' and column 1007') is higher than that shown in Fig. 9 (see row 1021 and column 1007), and that the preferred multicast transmission mode is set to *Multicast* (see row 1021' and column 1005').

Fig. 11 illustrates exemplary group information 314" and exemplary member information 25 315" comparable to that shown in Fig. 10, but wherein the determined multicast transmission characteristics 1003" and estimated multicast mode transmission costs in column 1004" are computed differently. In particular, in accordance with the Fig. 11 example, for a particular group, e.g., row of the group information 314" table, the determined multicast transmission characteristics in column 1003" are set equal to the determined unicast transmission characteristics of the worst node in the group, where the worst node is indicated in column 30 1006" and the corresponding unicast transmission characteristics is indicated in column 1052" of the member information 315" table. Similarly, the estimated multicast mode transmission cost in column 1004" is set equal to the estimated unicast transmission cost corresponding to the worst node, where the worst node is indicated in column 1006" and the corresponding estimated unicast transmission cost is indicated in column 1053" of the member information 315" table.

Fig. 12 illustrates exemplary group information 314"" and exemplary member information 315"" based on the same computations as used in Fig. 11, but as may be stored in memory 310 of an access node at a second point in time (e.g., a time other than the time at 5 which the information shown in Fig. 11 is stored). In accordance with the Fig. 12 example, changes are indicated for both groups 224.225.1.6, row 1021"", and 224.225.1.9, row 1022"".

For group 224.225.1.6, row 1021"", note that there are changes to the determined multicast transmission characteristics in column 1003"", the estimated multicast mode transmission cost in column 1004", and the estimated unicast mode transmission cost in column 1007", as compared to the same row/columns in Fig. 11. Each of these changes corresponds to 10 changes related to the group member 10.2.1.2 identified as the worst node, node A. With respect to this member, changes in channel conditions and/or location affect the unicast transmission characteristics resulting in higher power requirement and higher cost than in the 15 case of the Fig. 11 example. This change results higher power requirement and costs for the group than in the case of the Fig. 11 example, despite the fact that the membership of the group 224.225.1.9 remains the same from the time of the Fig. 11 example to the time of the Fig. 12 example.

For group 224.225.1.9, row 1022", note that there are changes to group membership in column 1002" and other columns, as compared to the same row/columns in Fig. 11. The group 20 information 314"" indicates that end node 10.2.1.5 is not a member of the second group 224.225.1.9 (see row 1022" and column 1002"). Correspondingly, the worst node indicated in column 1006" is different than in the case of Fig. 11 example and that the determined multicast 25 transmission characteristics in column 1003", the estimated multicast mode transmission cost in column 1004", and the estimated unicast mode transmission cost in column 1007" have all been changed accordingly, as compared to the same row/columns in Fig. 11.

Thus, Fig. 12 when compared to Fig. 11, shows that changes in group membership 30 and/or conditions corresponding to a member of a group which has the same group membership, can trigger changes in the allocation of transmission resources such as power, and coding rate. The same changes could, and in some embodiments do, result in changes in the modulation method selected to be used.

In some embodiments of the present invention, communications between nodes is based all, or in part, on the Internet Protocol (IP). Thus, communication of both data and/or control signaling between the network nodes may use IP packets, e.g., datagrams.

5 Various features of the present invention are implemented using modules. Such modules may be implemented using software, hardware or a combination of software and hardware. Many of the above described methods or method steps can be implemented using machine executable instructions, such as software, included in a machine readable medium such as a memory device, e.g., RAM, floppy disk, etc. to control a machine, e.g., general purpose 10 computer with or without additional hardware, to implement all or portions of the above described methods. Accordingly, among other things, the present invention is directed to a machine-readable medium including machine executable instructions for causing a machine, e.g., processor and associated hardware, to perform one or more of the steps of the above-described method(s).

15

Numerous additional variations on the methods and apparatus of the present invention described above will be apparent to those skilled in the art in view of the above description of the invention. Such variations are to be considered within the scope of the invention. The methods and apparatus of the present invention may be, and in various embodiments are, used 20 with code division multiple access (CDMA), orthogonal frequency division multiplexing (OFDM), or various other types of communications techniques which may be used to provide wireless communications links between access nodes and mobile nodes. In some embodiments the access nodes are implemented as base stations which establish communications links with mobile nodes using OFDM and/or CDMA. In various embodiments the mobile nodes are 25 implemented as notebook computers, personal data assistants (PDAs), or other portable devices including receiver/transmitter circuits and logic and/or routines, for implementing the methods of the present invention.

**What is claimed is:**

1 1. A method of operating an access node servicing a transmission area, the method  
2 comprising:

3       storing, at a first point in time, a first set of group membership information including a  
4 first group identifier corresponding to a first group and a first set of end node identifiers  
5 corresponding to a first set of end nodes which are members of said first group at said first point  
6 in time;

7       receiving a first set of packets including said first group identifier corresponding to said  
8 first group;

9       determining at least one of a transmission power level, coding rate, and modulation  
10 method to be used for transmitting packets to the end nodes which are indicated by said first set  
11 of group membership information to be members of said first group, said at least one of a  
12 transmission power level, coding rate, and modulation method being determined as a function of  
13 information relating to a condition associated with at least one group member; and

14       transmitting, using said determined at least one of a transmission power level, coding  
15 rate, and modulation method a copy of said first set of packets, said transmitted copy of the first  
16 set of packets being directed to a plurality of said group members.

1 2. The multicast communications method of claim 1, wherein said determined at least one  
2 of a transmission power level, coding rate, and modulation method is a power level which is  
3 lower than a power level which would be required to reach all end nodes in said serviced  
4 transmission area but is sufficient to reach all the end nodes in said first group.

1 3. The method of claim 2,

2       wherein said condition is a channel condition;

3       wherein said transmission area is a cell; and

4       wherein said determined transmission power level is insufficient to reach all end nodes in  
5 said serviced transmission area at a given coding rate but is sufficient to reach all end nodes in  
6 said first group.

1 4. The method of claim 2,

2       wherein said condition is a channel condition; and

3       wherein said transmission area is a sector.

1 5. The method of claim 4, wherein said condition is a location condition.

1 6. The multicast communications method of claim 1, wherein said determined at least one  
2 of a transmission power level, coding rate, and modulation method is a power level and wherein  
3 said determining step is dynamically performed to adjust the transmission power level as a  
4 function of a channel condition associated with the end node in said first group having the worst  
5 estimated channel conditions over a period of time.

1 7. The multicast communications method of claim 1, wherein said determined at least one  
2 of a transmission power level, coding rate, and modulation method is a coding rate which is  
3 higher than a lower coding rate which would be required to reach all end nodes in said serviced  
4 transmission area at a given transmission power level but is sufficient to reach all end nodes in  
5 said first group.

1 8. The multicast communications method of claim 1, further comprising:

2 storing, at a second point in time, updated group membership information, said updated  
3 group membership information including the first group identifier corresponding to the first  
4 group and a second set of end node identifiers corresponding to a second set of end nodes which  
5 are members of said first group at said second point in time;

6 receiving a second set of packets including said first group identifier corresponding to  
7 said first group;

8 determining at least one of a transmission power level and coding rate to be used for  
9 transmitting a copy of said second set of packets to the end nodes which are indicated by said  
10 updated set of group membership information to be members of said first group, said at least one  
11 of a transmission power level and coding rate being determined as a function of information  
12 relating to a condition associated with at least one group member; and

13 transmitting a copy of said second set of packets to the end nodes indicated by said  
14 updated set of group membership information to be members of said first group.

1 9. The method of claim 8, wherein the first group includes different end node at said first  
2 and second times.

1 10. The method of claim 8, wherein the first group has the same end nodes in said first group

2 at said first and second times but there has been a change in the channel condition associated  
3 with the at least one group member, said at least one group member being the end node in said  
4 first group with the worst channel conditions.

1 11. The method of claim 8, wherein the power level used to transmit said copy of said  
2 second set of packets is different from the power level used to transmit said copy of said first set  
3 of packets.

1 12. The multicast communications method of claim 8,  
2 wherein said determined at least one of a transmission power level and coding rate to be  
3 used for transmitting a copy of said second set of packets is a power level; and  
4 wherein said determining step is performed to select the transmission power level so that  
5 the transmitted copy of said second set of packets will be transmitted with sufficient power to  
6 reach each of the end nodes indicated to be members of said first group by said updated set of  
7 group membership information.

1 13. The multicast communications method of claim 11,  
2 wherein said determined at least one of a transmission power level and coding rate to be  
3 used for transmitting a copy of said second set of packets is a coding rate; and  
4 and wherein said determining step is performed to select the coding rate so that the  
5 transmitted copy of said second set of packets will be transmitted with a coding rate sufficient to  
6 reach each of the end nodes indicated to be members of said first group by said updated set of  
7 group membership information, the determined coding rate being higher than a lower coding  
8 rate which would be required to reach all end nodes in said serviced transmission area given a  
9 transmission power level which is used to transmit said copy of said second set of packets.

1 14. The method of claim 1, further comprising:  
2 storing, at said first point in time, a second set of group membership information  
3 including a second group identifier corresponding to a second group and a second set of end  
4 node identifiers corresponding to a second set of end nodes which are members of said second  
5 group at said first point in time;  
6 receiving a second set of packets including said second group identifier corresponding to  
7 said second group;  
8 determining at least one of a transmission power level and coding rate to be used for

9 transmitting packets to the end nodes which are indicated by said second set of group  
10 membership information to be members of said second group, said at least one of a transmission  
11 power level and coding rate being determined as a function of information relating to a condition  
12 associated with at least one member of said second group; and

13 transmitting a copy of said second set of packets using said determined at least one of a  
14 transmission power level and coding rate, said transmitted copy of the second set of packets  
15 being directed to a plurality of said group members.

1 15. An apparatus for servicing a transmission area, comprising:

2 memory including, at a first point in time, a first stored set of group membership  
3 information including a first group identifier corresponding to a first group and a first set of end  
4 node identifiers corresponding to a first set of end nodes which are members of said first group  
5 at said first point in time;

6 a receiver for receiving a first set of packets including said first group identifier  
7 corresponding to said first group;

8 a transmission control module for determining at least one of a transmission power level  
9 and coding rate to be used for transmitting packets to the end nodes which are indicated by said  
10 first set of group membership information to be members of said first group, said at least one of  
11 a transmission power level and coding rate being determined as a function of information  
12 relating to a condition associated with at least one group member; and

13 a transmitter coupled to said transmission control module for transmitting, using said  
14 determined at least one of a transmission power level and coding rate, a copy of said first set of  
15 packets, said transmitted copy of the first set of packets being directed to a plurality of said  
16 group members.

1 16. The apparatus of claim 15, wherein said determined at least one of a transmission power  
2 level and coding rate is a power level which is lower than a power level which would be  
3 required to reach all end nodes in said serviced transmission area but is sufficient to reach all the  
4 end nodes in said first group.

1 17. The apparatus of claim 16,

2 wherein said condition is a channel condition; and

3 wherein said transmission area is a cell.

1 18. The apparatus of claim 16,  
2 wherein said condition is a channel condition; and  
3 wherein said transmission area is a sector.

1 19. The apparatus of claim 16, wherein said condition is a location condition.

1 20. The apparatus of claim 15, wherein said determined at least one of a transmission power  
2 level and coding rate is a power level and wherein said transmission control module includes:  
3 means for adjusting the determined transmission power level in response to changes in  
4 channel condition information, as a channel condition associated with the end node in said first  
5 group having the worst channel conditions changes over time.

1 21. The apparatus of claim 15, wherein said determined at least one of a transmission power  
2 level and coding rate is a coding rate which is higher than a lower coding rate which would be  
3 required to reach all end nodes in said serviced transmission area given a transmission power  
4 level which is used but is sufficient to reach all end nodes in said first group.

1 22. The apparatus of claim 21, further comprising:  
2 a group membership control module for updating group membership information;  
3 within said memory, at a second point in time, a stored set of updated group membership  
4 information, said updated group membership information including the first group identifier  
5 corresponding to the first group and a second set of end node identifiers corresponding to a  
6 second set of end nodes which are members of said first group at said second point in time, the  
7 first group having different end node membership at said first and second times;  
8 wherein said receiver includes means for receiving a second set of packets including said  
9 first group identifier corresponding to said first group; and  
10 wherein said transmission control module includes means for determining at least one of  
11 a transmission power level and coding rate to be used for transmitting a copy of said second set  
12 of packets to the end nodes which are indicated by said updated set of group membership  
13 information to be members of said first group, said at least one of a transmission power level  
14 and coding rate being determined as a function of information relating to a condition associated  
15 with at least one group member.

1 23. The apparatus of claim 22, wherein the power level determined to be used to transmit

2 said copy of said second set of packets is different from the power level used to transmit said  
3 copy of said first set of packets.

1 24. The apparatus of claim 22,  
2 wherein said determined at least one of a transmission power level and coding rate to be  
3 used for transmitting a copy of said second set of packets is a power level; and  
4 wherein said transmission control module includes:  
5 means for selecting the transmission power level so that the transmitted copy of said  
6 second set of packets will be transmitted with sufficient power to reach each of the end nodes  
7 indicated to be members of said first group by said updated set of group membership  
8 information.

1 25. The apparatus of claim 23,  
2 wherein said determined at least one of a transmission power level and coding rate to be  
3 used for transmitting a copy of said second set of packets is a coding rate;  
4 and wherein said transmission control module includes:  
5 means for selecting the coding rate so that the transmitted copy of said second  
6 set of packets will be transmitted with a coding rate sufficient to reach each of the end  
7 nodes indicated to be members of said first group by said updated set of group  
8 membership information, the determined coding rate being higher than a lower coding  
9 rate which would be required to reach all end nodes in said serviced transmission area  
10 given a transmission power level which is used to transmit said copy of said second set  
11 of packets.

1 26. The apparatus of claim 15,  
2 wherein at said first point in time said memory further includes a stored second set of  
3 group membership information including a second group identifier corresponding to a second  
4 group and a second set of end node identifiers corresponding to a second set of end nodes which  
5 are members of said second group at said first point in time; and  
6 wherein said transmission control module further includes:  
7 means for determining at least one of a transmission power level and coding rate  
8 to be used for transmitting packets to the end nodes which are indicated by said second  
9 set of group membership information to be members of said second group, said at least  
10 one of a transmission power level and coding rate being determined as a function of

11 information relating to a condition associated with at least one member of said second  
12 group.

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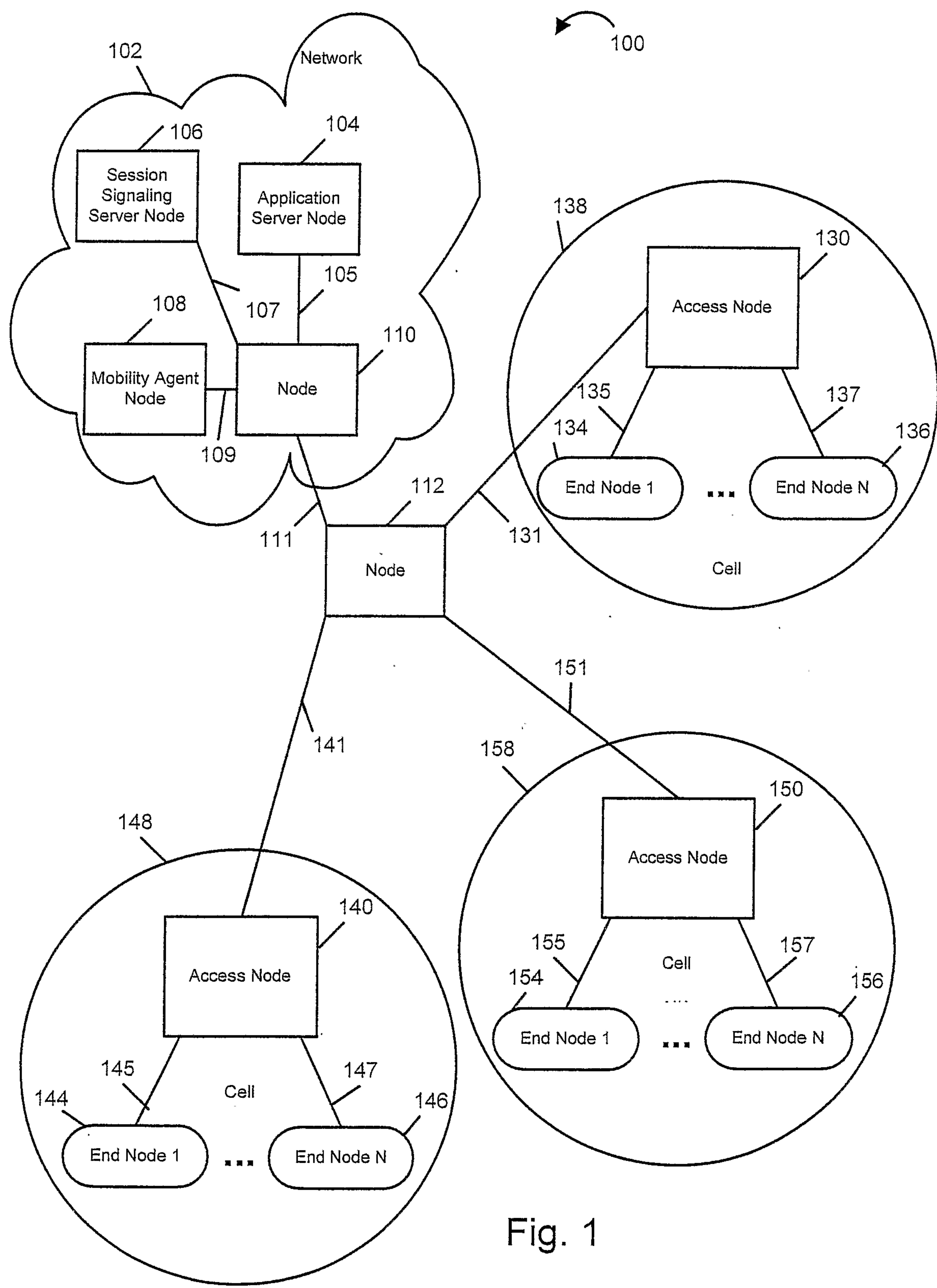


Fig. 1

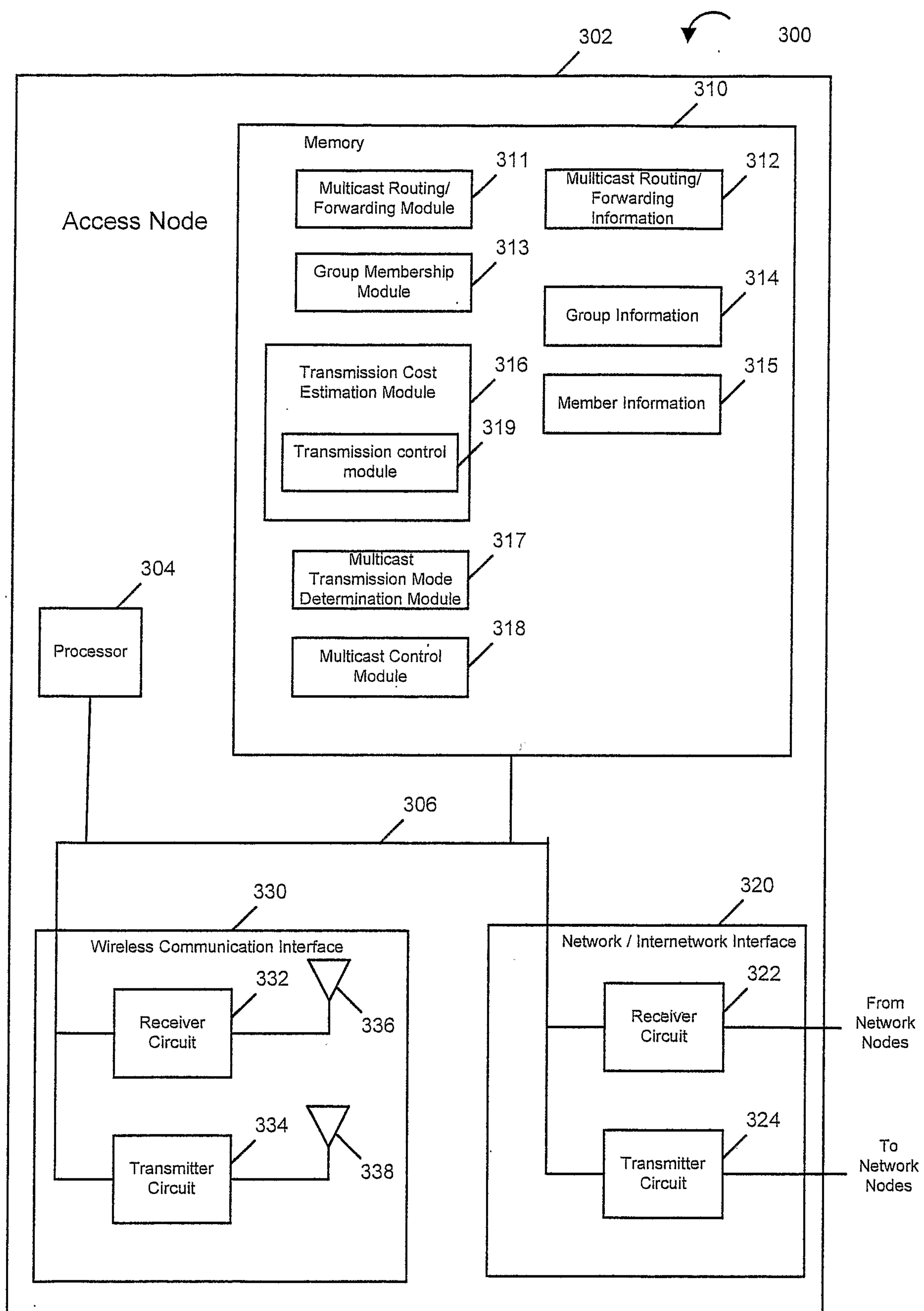
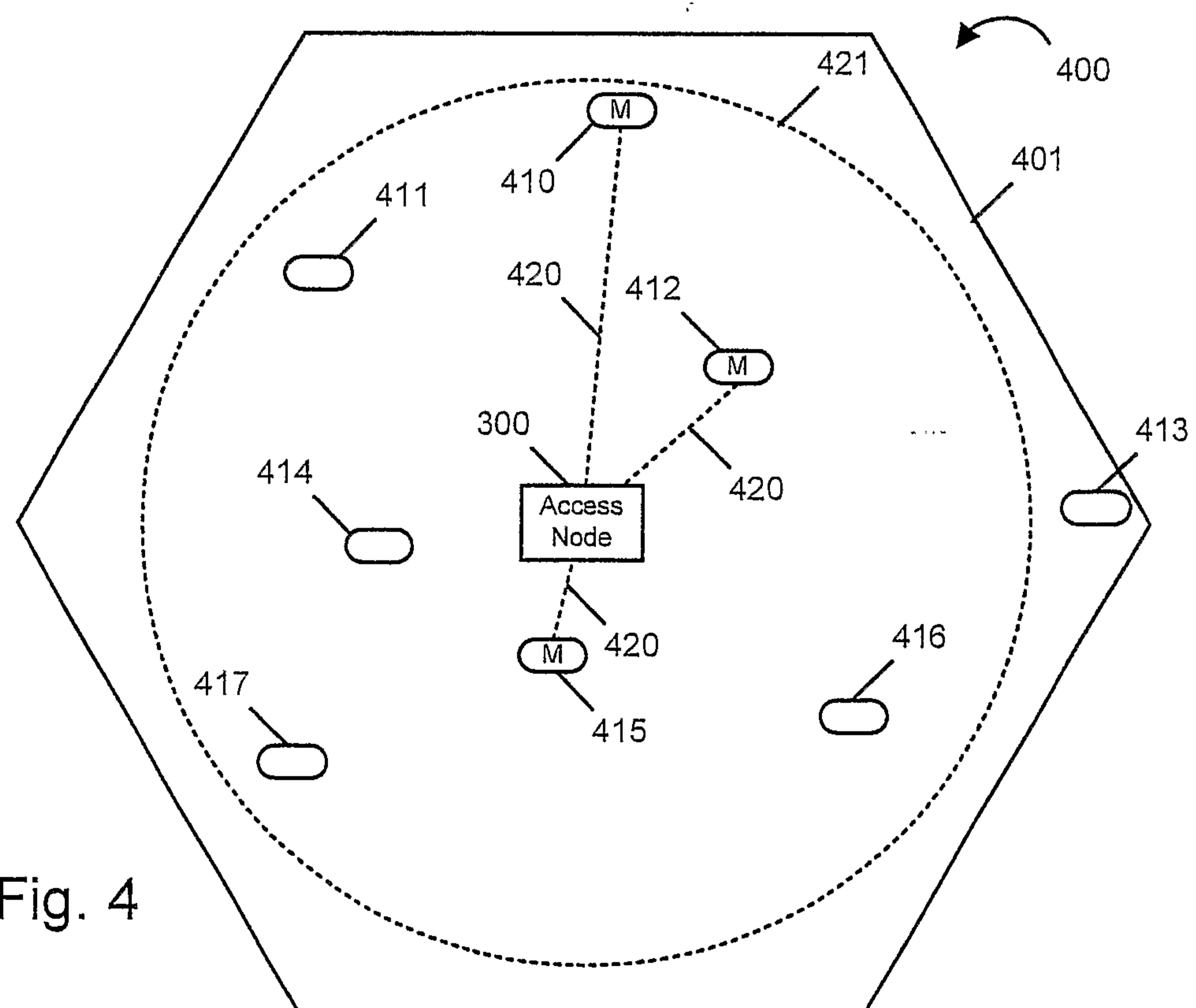
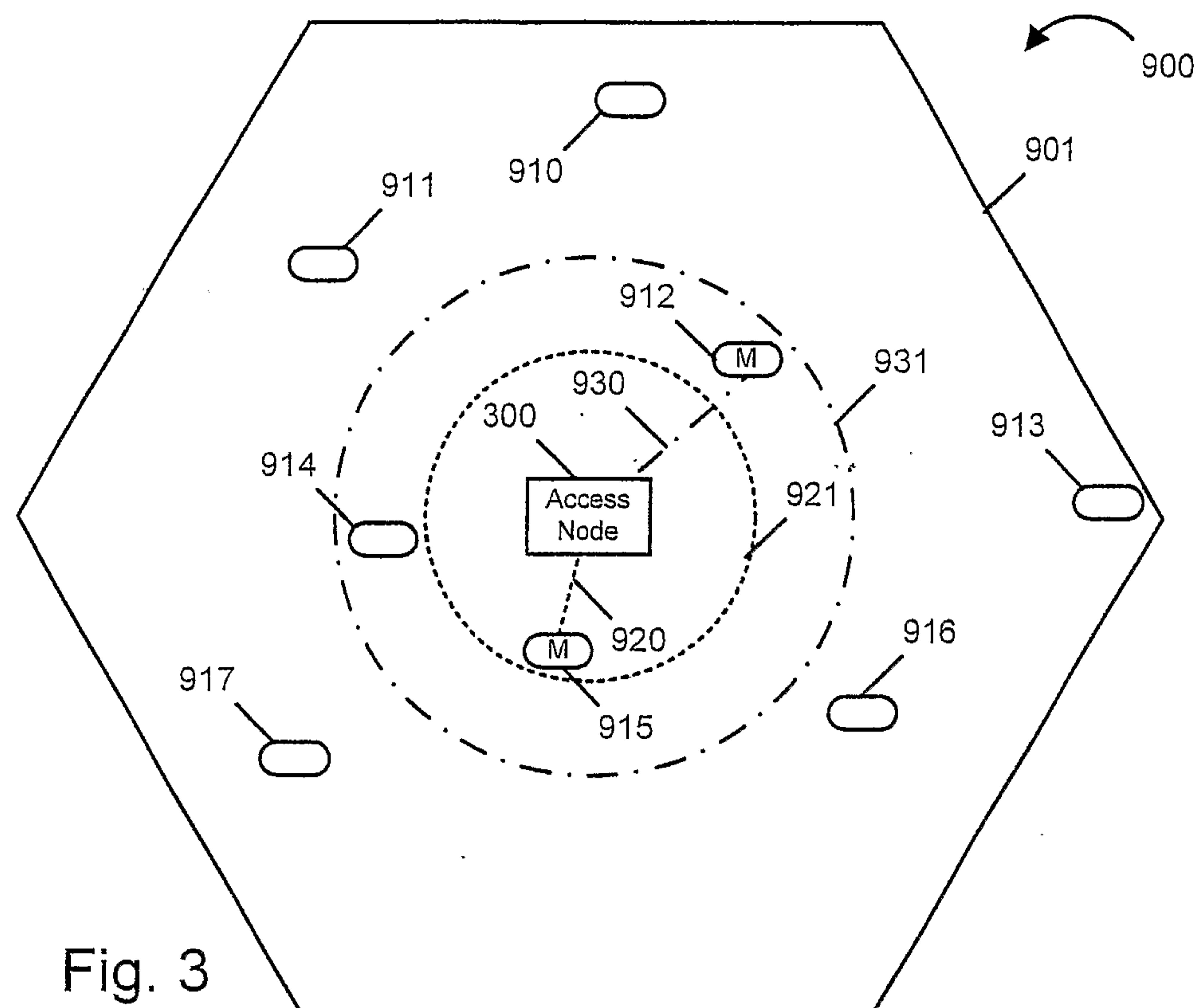


Fig. 2

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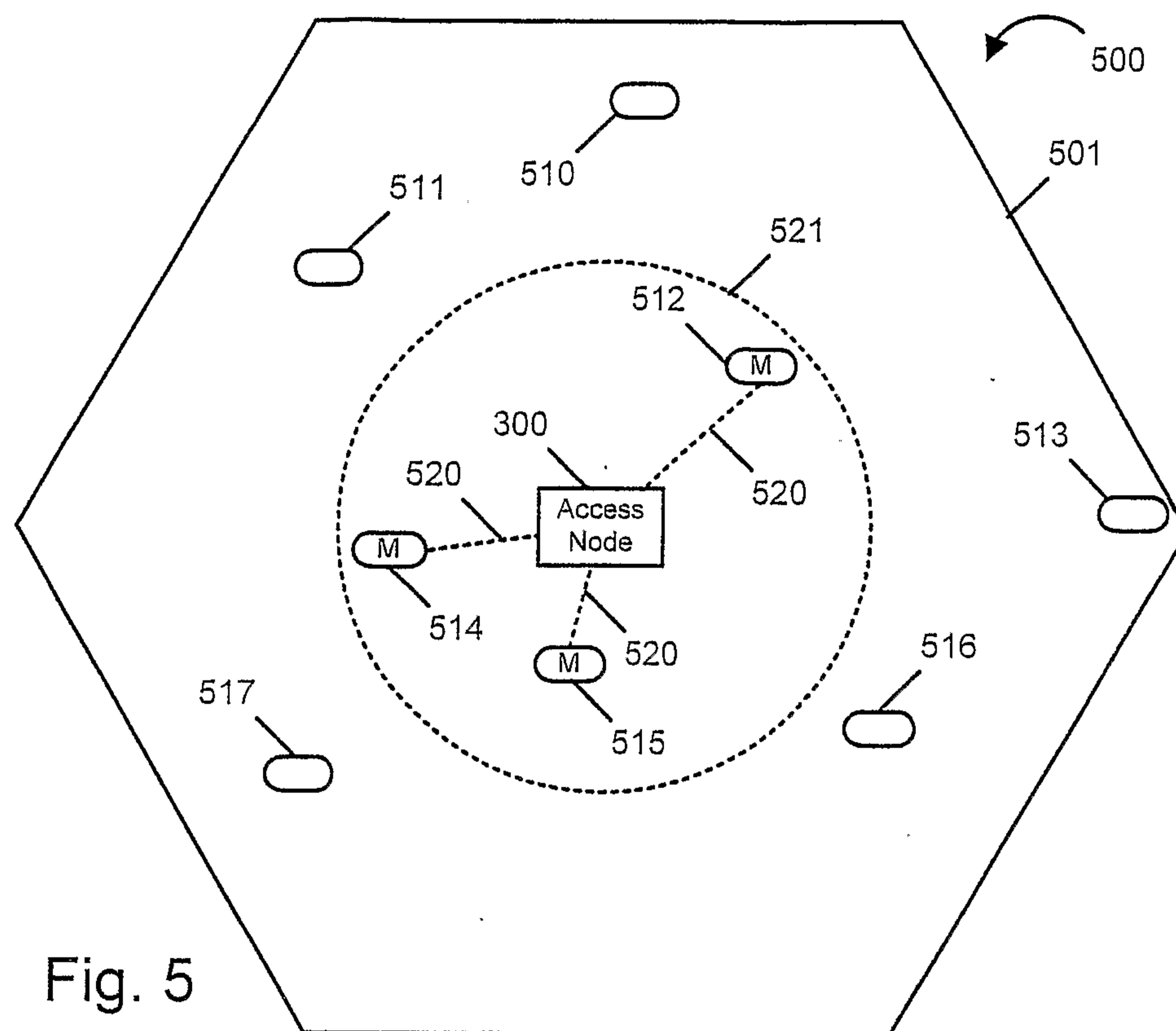


Fig. 5

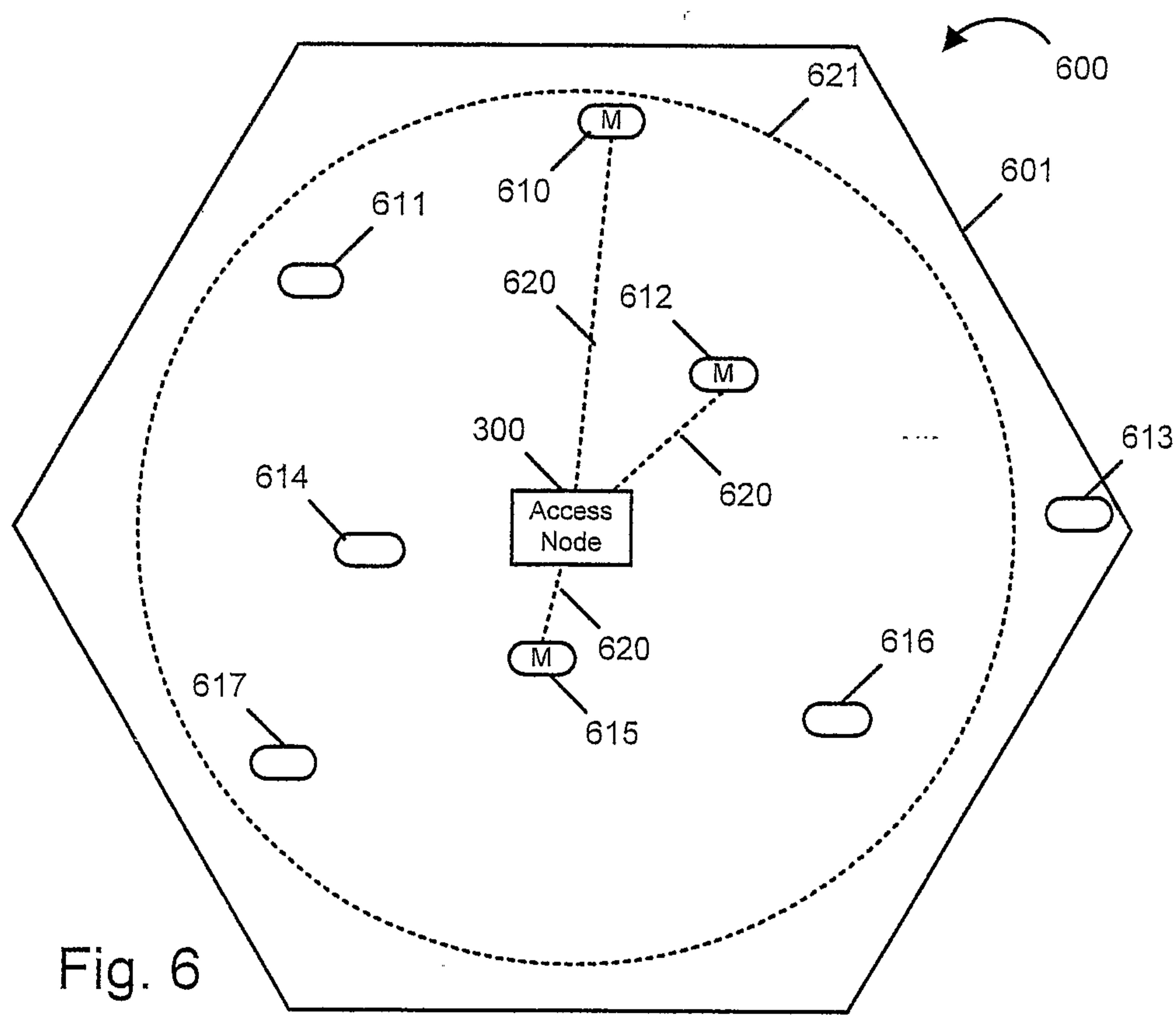


Fig. 6

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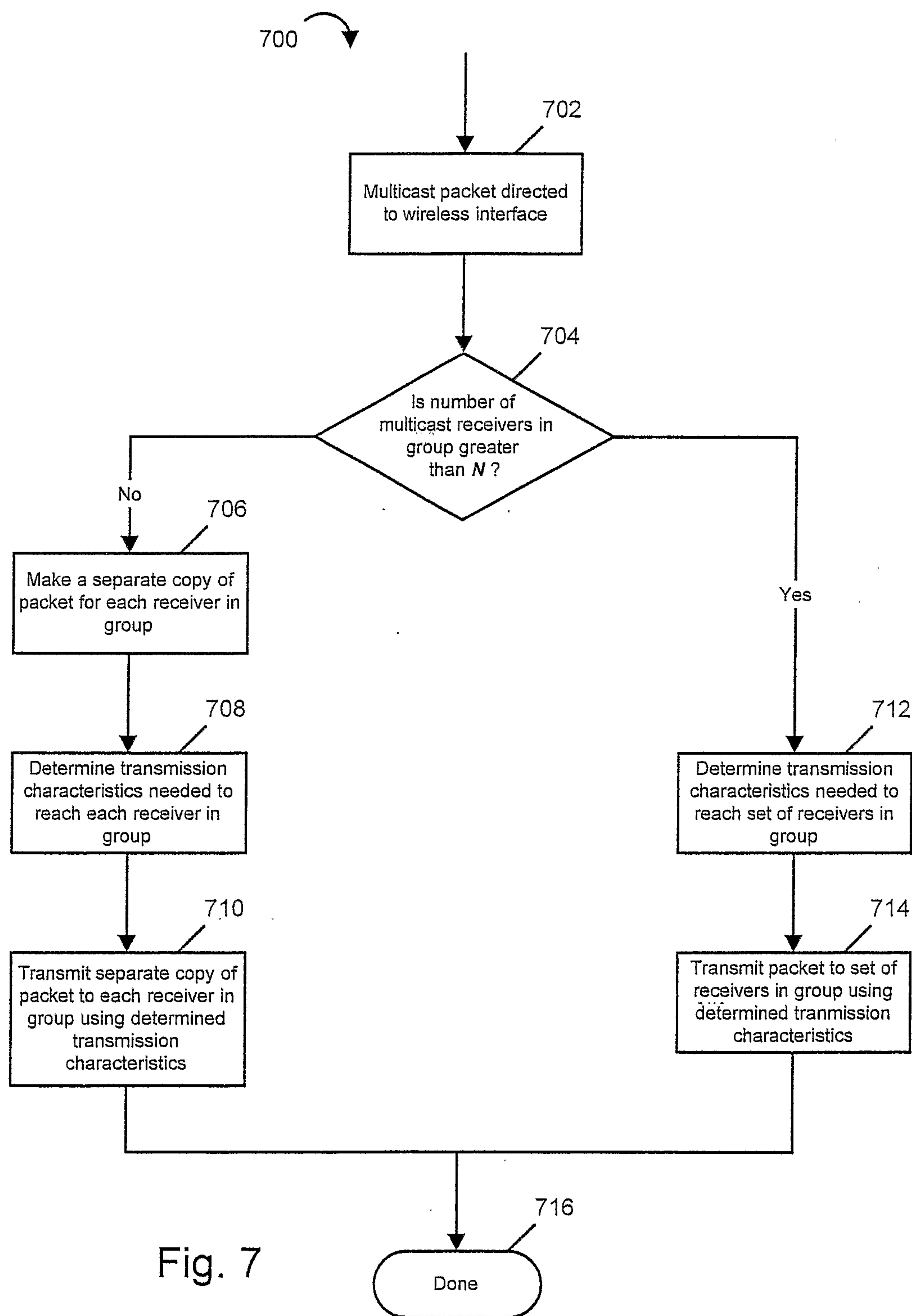


Fig. 7

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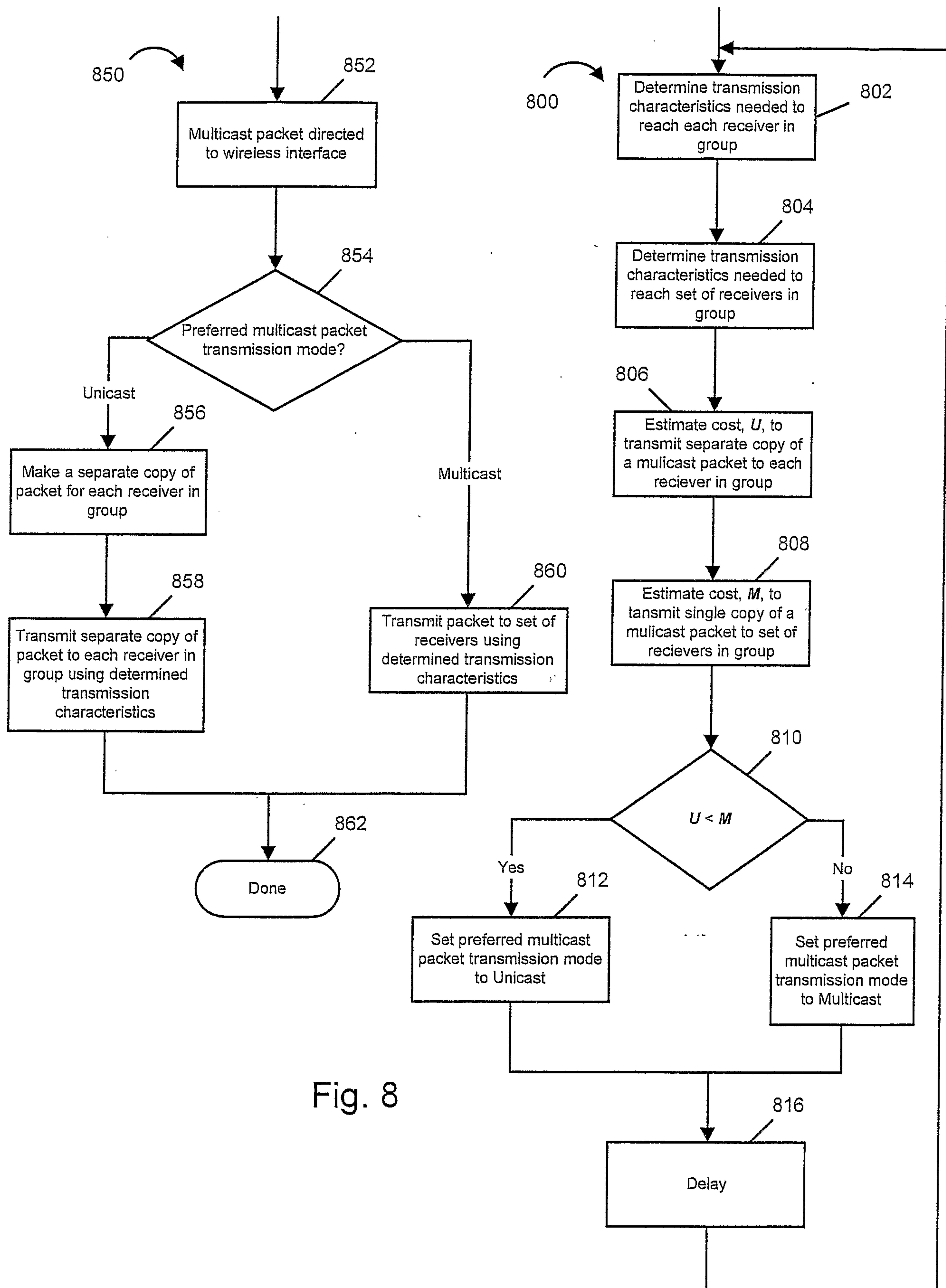


Fig. 8

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314

1001	1002	1006	1003	1004	1007	1005
Group ID	Group Member List	Worst Node Channel Condition and/or Location Information	Determined Multicast Transmission Characteristics	Estimated MM Tx Cost	Estimated UM Tx Cost	Preferred Multicast Tx Mode
1021	224.225.1.6 10.2.1.2 10.2.1.10	SNR/Location of End Node with Worst Condition (Node A)	Power = 6 Code rate = 1/3	7	6	Unicast
1022	224.225.1.9 10.2.1.5 10.2.1.10 10.2.1.27 10.2.1.43	SNR/Location of End Node with Worst Condition (Node B)	Power = 7 Code rate = 1/6	9	18	Multicast

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1051	1055	1052	1053
Group Member / End Node	Node Channel Condition and/or Location Information	Determined Unicast Transmission Characteristics	Estimated Unicast Transmission Cost
1061	10.2.1.2	Power = 4 Coderate = 1/3	5
1062	10.2.1.5	Power = 5 Coderate = 1/6	7
1063	10.2.1.10	Power = 1 Coderate = 1/2	1
1064	10.2.1.27	Power = 5 Coderate = 1/3	6
1065	10.2.1.43	Power = 3 Coderate = 1/3	4

Fig. 9

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314'

Group ID	Group Member List	Worst Node Channel Condition and/or Location Information	Determined Multicast Transmission Characteristics	Estimated MM Tx Cost	Estimated UM Tx Cost	Preferred Multicast Tx Mode
1021'	224.225.1.6	10.2.1.2 10.2.1.10 10.2.1.43	SNR/Location of End Node with Worst Condition (Node A)	Power = 6 Code rate = 1/3	7	10
1022'	224.225.1.9	10.2.1.5 10.2.1.10 10.2.1.27 10.2.1.43	SNR/Location of End Node with Worst Condition (Node B)	Power = 7 Code rate = 1/6	9	18

315'

Group Member / End Node	Node Channel Condition and/or Location Information	Determined Unicast Transmission Characteristics	Estimated Unicast Transmission Cost
1061'	10.2.1.2	SNR/Location End NodeA	Power = 4 Coderate = 1/3
1062'	10.2.1.5	SNR/Location End NodeB	Power = 5 Coderate = 1/6
1063'	10.2.1.10	SNR/Location End NodeC	Power = 1 Coderate = 1/2
1064'	10.2.1.27	SNR/Location End NodeD	Power = 5 Coderate = 1/3
1065'	10.2.1.43	SNR/Location End NodeE	Power = 3 Coderate = 1/3

Fig. 10

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314"

Group ID	Group Member List	Worst Node Channel Condition and/or Location Information	Determined Multicast Transmission Characteristics	Estimated MM Tx Cost	Estimated UM Tx Cost	Preferred Multicast Tx Mode
1021"	224.225.1.6 10.2.1.2 10.2.1.10 10.2.1.43	SNR/Location of End Node with Worst Condition (Node A)	Power = 4 Code rate = 1/3	5	10	Multicast
1022"	224.225.1.9 10.2.1.5 10.2.1.10 10.2.1.27 10.2.1.43	SNR/Location of End Node with Worst Condition (Node B)	Power = 5 Code rate = 1/6	7	18	Multicast

315"

Group Member / End Node	Node Channel Condition and/or Location Information	Determined Unicast Transmission Characteristics	Estimated Unicast Transmission Cost
1051"	SNR/Location End NodeA	Power = 4 Coderate = 1/3	5
1055"	SNR/Location End NodeB	Power = 5 Coderate = 1/6	7
1052"	SNR/Location End NodeC	Power = 1 Coderate = 1/2	1
1053"	SNR/Location End NodeD	Power = 5 Coderate = 1/3	6
1061"	SNR/Location End NodeE	Power = 3 Coderate = 1/3	4
1062"			
1063"			
1064"			
1065"			

Fig. 11

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314<sup>'''</sup>

Group ID	Group Member List	Worst Node Channel Condition and/or Location Information	Determined Multicast Transmission Characteristics	Estimated MM Tx Cost	Estimated UM Tx Cost	Preferred Multicast Tx Mode
1021 <sup>'''</sup>	224.225.1.6 10.2.1.2 10.2.1.10 10.2.1.43	SNR/Location of End Node with Worst Condition (Node A)	Power = 5 Code rate = 1/3	6	11	Multicast
1022 <sup>'''</sup>	224.225.1.9 10.2.1.10 10.2.1.27 10.2.1.43	SNR/Location of End Node with Worst Condition (Node D)	Power = 5 Code rate = 1/3	6	11	Multicast

315<sup>'''</sup>

Group Member / End Node	Node Channel Condition and/or Location Information	Determined Unicast Transmission Characteristics	Estimated Unicast Transmission Cost
1061 <sup>'''</sup>	10.2.1.2	Power = 5 Coderate = 1/3	6
1062 <sup>'''</sup>	10.2.1.5	Power = 5 Coderate = 1/6	7
1063 <sup>'''</sup>	10.2.1.10	Power = 1 Coderate = 1/2	1
1064 <sup>'''</sup>	10.2.1.27	Power = 5 Coderate = 1/3	6
1065 <sup>'''</sup>	10.2.1.43	Power = 3 Coderate = 1/3	4

Fig. 12

