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(71) Applicant *(for all designated States except US)*: **MOTOROLA, INC.** [US/US]; 1303 East Algonquin Road, Schaumburg, Illinois 60196 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CHIOU, Wayne,** [US/US]; 3091 Nw 123 Avenue, Sunrise, Florida 33323 (US). **ALLEN, Vernon A.,** [US/US]; 700 Se 14th Street, #m, Fort Lauderdale, Florida 33316 (US). **ANDRIC, Oleg,** [US/US]; 2017 Tigris Drive, West Palm Beach, Florida 33411 (US). **D'SOUZA, Ralph L.,** [US/US]; 13826 Nw 22nd Court, Sunrise, Florida 33323 (US). **PHAM, Minh T.,** [US/US]; 10687 Kasmir Court, Boynton Beach, Florida 33437 (US).

(74) Agents: **HAAS, Kenneth A.** et al.; 1303 East Algonquin Road, Schaumburg, Illinois 60196 (US).

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(54) Title: METHOD AND APPARATUS FOR NETWORK FORMATION

(57) Abstract: When a requesting node (402) has routing capabilities and attempts to join a network and there are no association slots available, the requesting node (402) will send an association message to a potential root node (401). If the root node (401) has reached the maximum number of links, and has a non-routing capable node (403) associated with it, the root node (401) will send a message to the non-routing capable node (403), instructing it to disassociate and attempt to re-associate at a later time. A message is then sent to the requesting node (402) for it to associate with the root node (401).

METHOD AND APPARATUS FOR NETWORK FORMATION

Field of the Invention

The present invention relates generally to network formation and in particular, to a method and apparatus for ad-hoc network formation.

Background of the Invention

In a wireless network with routing capable and non-routing capable nodes, it is possible that non-routing capable nodes will prevent additional nodes from joining the network. More particularly, since nodes within an ad-hoc communication system may have a maximum number of connections to other nodes, if non-routing nodes join the network before the routing nodes, then the maximum number of nodes capable of joining the network may be limited. This is illustrated in FIG. 1.

As shown in FIG. 1 network 100 has formed with two non-routing nodes 102 connected to routing node 101. As is evident, if all routing capable nodes can only support 2 associated nodes and two non-routing capable nodes join first to the root node, then this network can only support a maximum of 3 nodes. On the other hand, if two routing capable nodes join the root node then this network can support at least 7 nodes (FIG. 2). Therefore a need exists for a method and apparatus for forming a network that prevents non-routing nodes from limiting the number of nodes that can join a network.

Brief Description of the Drawings

FIG. 1 is a block diagram illustrating network formation.

FIG. 2 is a block diagram illustrating network formation.

FIG. 3 is a block diagram of an ad-hoc network.

FIG. 4 is a block diagram of an ad-hoc network illustrating network formation.

FIG. 5 is a block diagram of a node.

FIG. 6 is a flow chart showing operation of the node of FIG. 5.

Detailed Description of the Drawings

In order to address the above-mentioned need, a method and apparatus for network formation is provided herein. When a requesting node has routing capabilities and attempts to join a network and there are no association slots available, the requesting node will send an association message to a potential root node. If the root node has reached the maximum number of links, and has a non-routing capable node associated with it, the root node will send a message to the non-routing capable node, instructing it to disassociate and attempt to re-associate at a later time. A message is then sent to the requesting node for it to associate with the root node. This will result in a net increase of available association slots for the other nodes to associate to the network. If the root node does not have non-routing capable nodes associated to it, a refusal message is sent to the requesting node. The requesting node will then repeat the query with other potential root nodes until it can associate with the network.

The present invention encompasses a method for network formation. The method comprises the steps of receiving a request to form a communication link with a requesting node and determining if a maximum number of links has been achieved. In response to the request to form the link and the determination, communication to a non-routing node is broken and a communication link is formed with the requesting node.

The present invention additionally encompasses a method for network formation. The method comprises the steps of receiving a request to form a communication link with a requesting node, determining if a maximum number of links has been achieved, determining if the requesting node is a routing node, and determining if any associated nodes are non-routing nodes. In response to the determinations, communication to a non-routing node is broken and a communication link with the requesting node is formed.

The present invention additionally encompasses an apparatus comprising a receiver receiving a request to form a communication link with a requesting node, and logic circuitry determining if a maximum number of links has been achieved and in

response to the request to form the association link and the determination, disassociating communication with a non-routing node and forming a communication link with the requesting node.

Turning now to the drawings, wherein like numerals designate like components, FIG. 3 is a block diagram of network 300. Network 300 preferably utilizes a communication system protocol defined by the 802.15.3 Wireless Personal Area Networks for High Data Rates standard, or the IEEE 802.15.4 Low Rate Wireless Personal Area Networks standard. One of ordinary skill in the art will recognize that other communication system protocols may be utilized without varying from the scope of the invention. For example, communication system 100 may utilize communication system protocols such as, but not limited to, Ad-hoc On Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), Temporally-Ordered Routing Algorithm (TORA), Bluetooth™ standard (IEEE Standard 802.15.1), . . . , etc.

As shown, network 300 includes a number of routing nodes 301 and non-routing nodes 302. Nodes 301-302 represent devices that communicate with each other through wireless communication, and can be transportable (mobile) or they can be fixed in a given place. Nodes 301-302 can include, for example, transceiver security tags attached to valuable assets such as lap top computers, or be embedded in wireless communication devices including cellular telephones.

During operation of network 300, nodes become associated with each other for routing purposes, with transmissions between two nodes generally taking place through intervening nodes. The intervening nodes receive a source transmission, and "repeat" the source transmission until the source transmission reaches its destination node. As discussed above, many networks comprise nodes that are incapable of routing data. If a non-routing node 302 joins network 300 before a routing node 301, then the maximum number of nodes capable of joining the network may be limited. In order to address this issue, when a node receives a request for association, the node will attempt to associate the requesting node. If, however, the node has reached a maximum number of links, the node will be unable to associate the requesting node. In this situation, the node will determine if the requesting node is a routing node and if any associated node is a non-routing node. If both conditions are true, the non-routing node will be disassociated and replaced by the requesting node. This procedure is illustrated in FIG. 4.

As shown in FIG. 4, node 402 requests an association with node 401 at time period 404. If the maximum number of links for this network is two, then the association cannot be completed since node 401 has two existing links. If node 401 determines that node 402 is capable of routing, and that an associated node (e.g., node 403) is a non-routing node, then a non-routing node is forced to disassociate with node 401. This is accomplished by node 401 sending a disassociation message to non-routing node 403 at time period 405. In response, node 403 disassociates with node 401 at time period 406, and an "OK to associate" message is sent to node 402 at time period 407. At time period 408 node 402 associates with node 401. Finally at time period 409, node 403 tries to join the network again, and associates with node 402.

FIG. 5 is a block diagram of node 500. In a preferred embodiment of the present invention node 500 comprises antenna 503 coupled to transmitter/receiver (transceiver) 504, in turn, coupled to logic circuitry 505. Although various forms for antenna 503, transceiver 504, and logic circuitry 505 are envisioned, in a preferred embodiment of the present invention node 500 is formed from a Freescale Inc. MC13192 transceiver 504 coupled to a Motorola HC08 8-bit processor 505. When node 500 wishes to communicate with any other network node, it does so via over-the-air communication signal 506. Node 500 may serve as a routing or non-routing node. Additionally, when acting as a routing node, node 500 may serve to relay data among network nodes.

FIG. 6 is a flow chart showing operation of the node 500 when acting as a routing node. The logic flow begins at step 601 where transceiver 504 receives an association message (e.g., 802.15.4 Association Message) from a requesting node. The association message is a request from the requesting node to form a communication link (e.g., an ad-hoc communication link) with node 500. As discussed, the request is received via an over-the-air communication. At step 603, logic circuitry 505 determines if a maximum number of links has been obtained, and if not, the logic flow continues to step 613 where a link is established to the requesting node. If, however, at step 603 it is determined that the maximum number of links exist for node 500, the logic flow continues to step 605 where logic circuitry 505 determines if the requesting node is capable of routing. This determination is accomplished by analyzing capability information received with the association message. If, at step 605 it is determined that the requesting node is not capable of routing, the logic flow ends at step 615. However, if at step 605 it is determined that the requesting node is capable of routing, the logic

flow continues to step 607 where logic circuitry 505 determines if any associated node is a non-routing node. If, at step 607 it is determined that there exists no non-routing node associated with node 500, the logic flow ends at step 615, otherwise the logic flow continues to step 609.

At step 609 logic circuitry 505 instructs transmitter 504 to transmit a disassociation message to the associated non-routing node, resulting in the non-routing node to disassociate (break communication) with node 500. Next, at step 611, logic circuitry instructs transmitter 504 to transmit an association message to the requesting node, causing the requesting node to form a communication link with node 500.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. For example, it is possible that when a routing capable node attempts to join the network and there are no association slots available, the routing capable node will first scan for a potential routing node and any non-routing nodes. If a non-routing node is found and the node which it is associated with is also found then the requesting node can directly request the non-routing node to leave the current association and join the requesting node after the requesting node takes the non-routing nodes association slot. The benefit of this is to insure that the non-routing node can rejoin the network and the requesting node will not have to query for multiple nodes to associate with. It is intended that such changes come within the scope of the following claims.

Claims

1. A method for network formation, the method comprising the steps of:

receiving a request to form a communication link with a requesting node;

determining if a maximum number of links has been achieved;

in response to the request to form the link and the determination, disassociating communication to a non-routing node; and

forming a communication link with the requesting node.

2. The method of claim 1 wherein the step of receiving the request to form the communication link comprises the step of receiving a request to form an ad-hoc communication link.

3. The method of claim 1 wherein the step of disassociating communication to the non-routing node comprises the step of transmitting a disassociation message to the non-routing node.

4. The method of claim 1 wherein the step of forming the communication link with the requesting node comprises the step of transmitting a message to the requesting node, instructing the requesting node to form the link.

5. The method of claim 1 further comprising the steps of:

determining if the requesting node is a routing node.

6. An apparatus comprising:

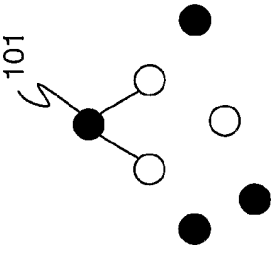
a receiver receiving a request to form a communication link with a requesting node; and

logic circuitry determining if a maximum number of links has been achieved and in response to the request to form the association link and the determination, disassociating communication with a non-routing node and forming a communication link with the requesting node.

7. The apparatus of claim 6 wherein the request to form the communication link comprises a request to form an ad-hoc communication link.

8. The apparatus of claim 6 wherein the disassociation with the non-routing node takes place by the logic circuitry instructing a transmitter to transmit a disassociation message to the non-routing node.

9. The apparatus of claim 6 wherein the communication link is formed with the requesting node by transmitting a message to the requesting node.



Routing Node
Non-Routing Node

FIG. 1
100

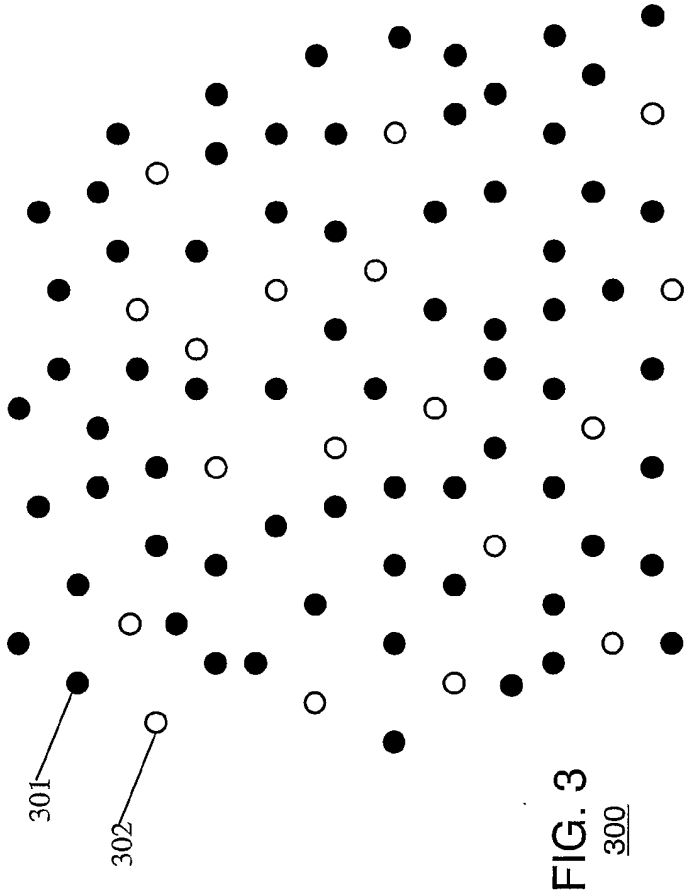


FIG. 3
300

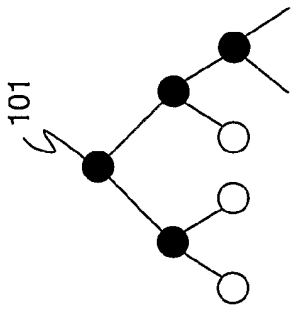


FIG. 2
100

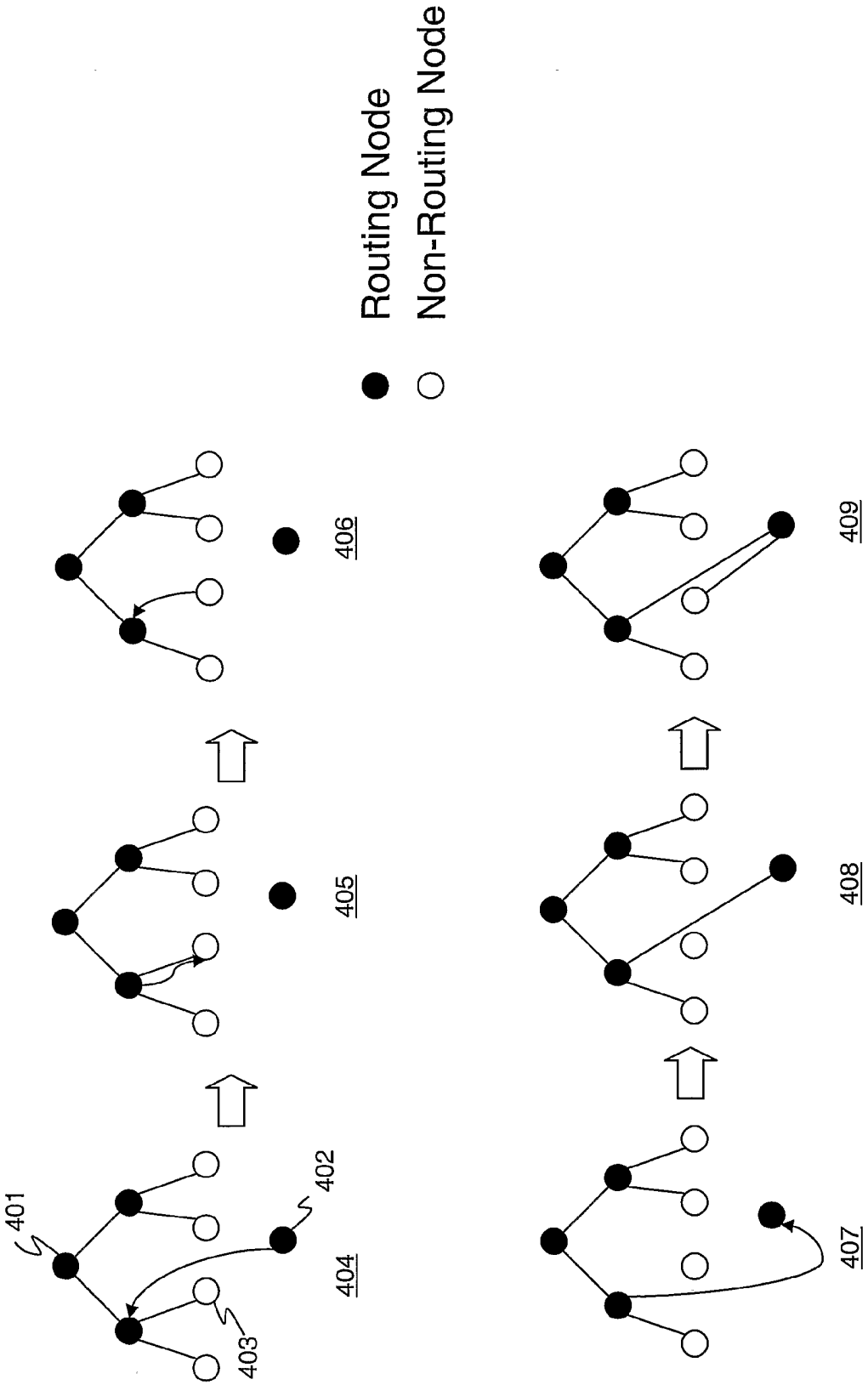

Routing Node
Non-Routing Node
401
402
403
404
405
406
407
408
409

FIG. 4

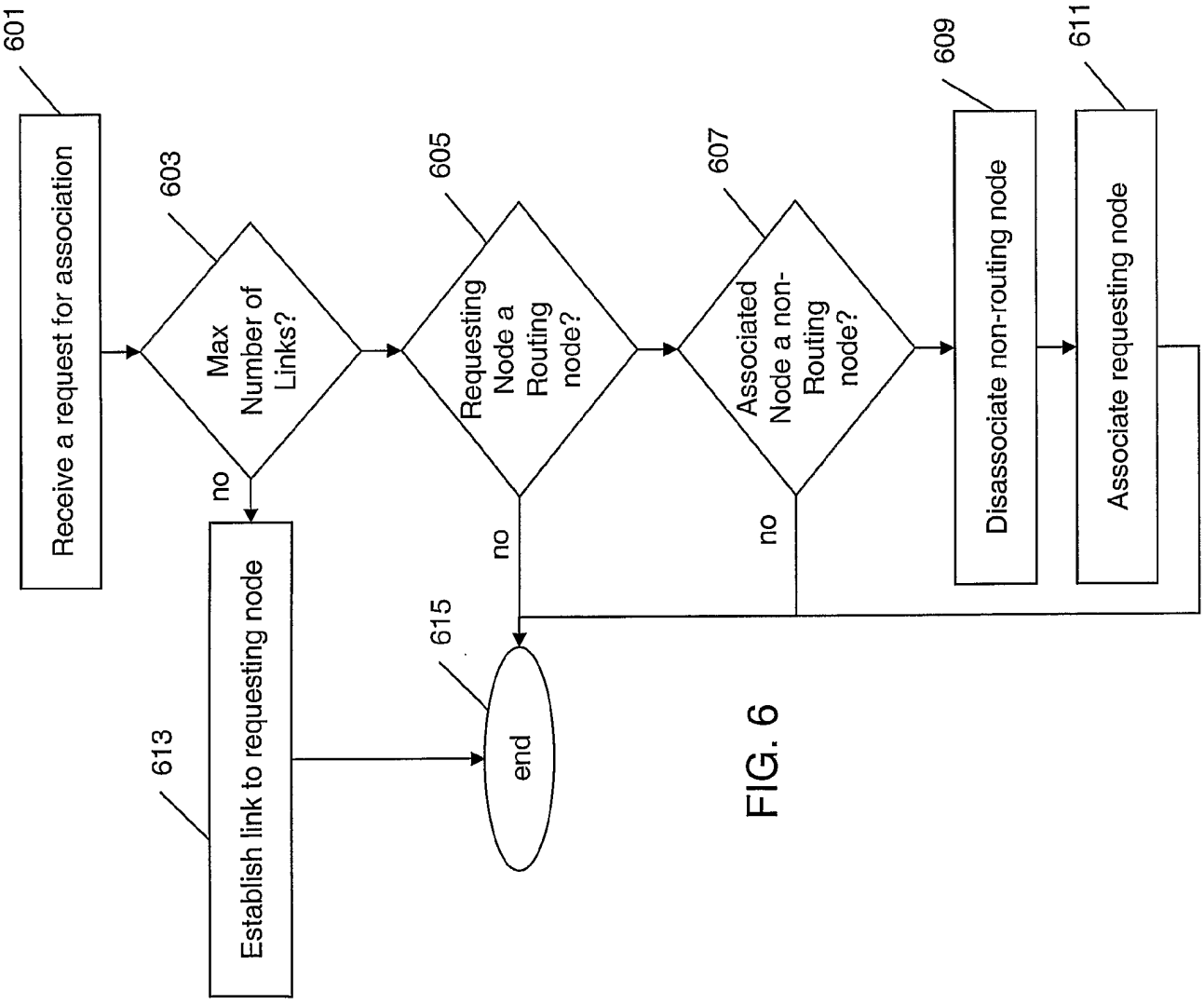

601
Receive a request for association
603
Max Number of Links?
no
613
Establish link to requesting node
605
Requesting Node a Routing node?
no
607
Associated Node a non-Routing node?
no
609
Disassociate non-routing node
611
Associate requesting node
615
end

FIG. 6

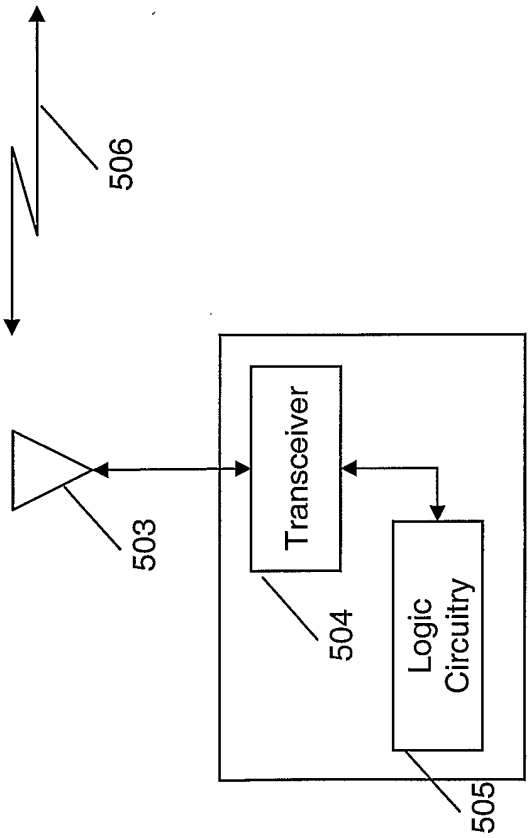


FIG. 5
500

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US06/05574

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **H04Q 7/20**(2006.01)

USPC: 455/445,452.1,453,41.2,502;370/238,254,400
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/445,452.1,453,41.2,502; 370/238,254,400

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2004/0192221 A1 (MATSUNAGA) 30 September 2004 (30.09.2004), paragraphs [0116], [0117].	1-2, 4-7, 9 --- 3, 8
Y,P	US 2005/0086384 A1 (ERNST) 21 April 2005, paragraph [0261].	3, 8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 May 2006 (26.05.2006)	22 JUN 2006
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Joseph H. Feild Telephone No. 703-305-6750

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