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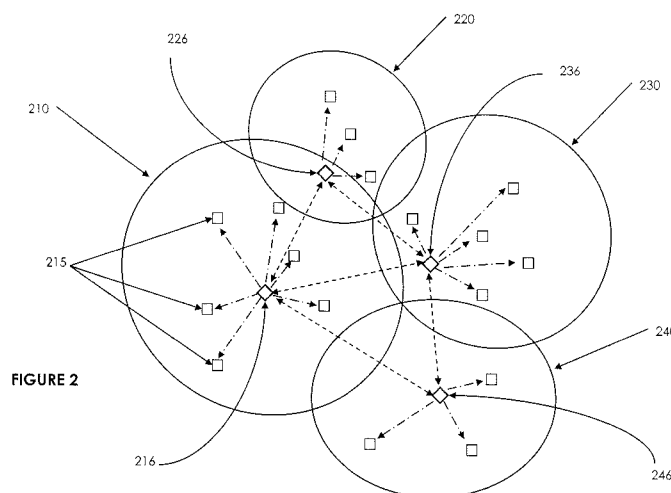
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(57) Abstract: The invention relates to a method for self organizing a plurality of nodes of a communication network into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head, and being able to communicate within the communication network over a plurality of broadcast communication channels, said method comprising for said at least one potential cluster head the act of broadcasting an advertisement message over a first communication channel, said advertisement message comprising a first information related to the capacities of the potential cluster head with regards to a given application, and second information related to a second communication channel over which the plurality of nodes can exchange messages with said potential cluster head, and the act of receiving over the second communication channel a response message if any from a node, said response message comprising an indication that the node, based on the first information, has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.

DYNAMIC CLUSTERING MANAGEMENT

FIELD OF THE PRESENT INVENTION:

5 The present invention generally relates to communication networks and more specifically to the formation and management of plurality of nodes of a communication system into self organized clusters.

BACKGROUND OF THE PRESENT INVENTION:

10 Today, in the communication field, element management within a group comprising a large number of such elements is critical. For example, for Peer to Peer (P2P) or Ad-hoc networks, such as sensor networks, or meshed WIFI networks, one basic technology is to regroup a large number of these elements into one or more groups, also called here after clusters. Clustering contributes to performance
15 enhancement of the elements as a group, and service quality improvement for one or more applications carried out by the elements.

 An example of such a network is a network comprising fire probes disseminated throughout a forest. Such probes may work as cooperative nodes in a wireless network for fire prevention by organizing themselves into clusters of nodes.
20 Whenever one of the fire probes fails due to a battery failure or some other reasons, the related cluster needs to reorganize. Keep alive messages are constantly exchanged between nodes of a same cluster for the organization and management of said cluster. Another example may be insects monitoring through a network of probes disseminated in a forest.

25 One possible scenario for such networks is that there is no pre-existing network infrastructure. The elements have therefore to establish communication links within the network to exchange information among themselves when carrying out a network application. A clustering method is thus needed to organize the network of nodes.

30 Initial management methods included manually defined clustering or static

clustering. These methods were limited in efficiency as the cluster could not adapt easily to dynamic change.

Self organized clustering implies that the nodes can reorganize themselves following a triggering event with limited if no external intervention, the resultant cluster infrastructure evolving overtime as a consequence. Nodes use exchanges of messages and follow clustering methods to (re)organize the clusters of the network. Self organized cluster management methods are known e.g. from US 7,171,476 B2 or from US 6,876,643 B1. One major problem with the known management methods is that a large number of message exchange (message overhead) is needed to manage the clusters in a network. Furthermore, most methods are not scalable, i.e. whenever more nodes join the same cluster, the dynamic management is no longer efficient.

Another issue is that the cluster management needs to be robust to dynamic changes, such as the change of a cluster head, whatever the size of the cluster is.

There is still a need today for an improved self organized cluster management, that is robust to dynamic changes in the nodes characteristics, and scalable in that the message overhead may be controlled as the number of nodes grows. There is also a need for improved self organized clusters in a network of nodes.

SUMMARY OF THE PRESENT METHOD AND SYSTEM:

It is an objective of the present method and system to overcome disadvantages and/or make improvements in the prior art.

To that extend, the present method relates to a method for self organizing a plurality of nodes of a communication network into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head, and being able to communicate within the communication network over a plurality of broadcast communication channels, said method comprising for said at least one potential cluster head the acts of:

- broadcasting an advertisement message over a first communication channel, said advertisement message comprising:

- first information related to the capacities of the potential cluster head with regards to a given application,

5 - second information related to a second communication channel over which the plurality of nodes can exchange messages with said potential cluster head,

- receiving over the second communication channel a response message if any from a node, said response message comprising an indication that the node, based on the first information, has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.

10 In order to establish a cluster, only one response message is needed. Since the response message is broadcasted, other nodes which have also selected the potential cluster head based on the first information do not need to send a similar message. All nodes having selected the potential cluster head will have the knowledge of the elected cluster head through the first node that sent a response message.

15 The present method also relates to a method for self organizing a plurality of nodes of a communication network into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head, and being able to communicate within the communication network over a plurality of broadcast communication channels, said method comprising for one node of said plurality of nodes the acts of:

20 - receiving from the at least one potential cluster head an advertisement message over a first communication channel, said advertisement message comprising:

- first information related to the capacities of the potential cluster head with regards to a given application,

25 - second information related to a second communication channel over which the node can exchange messages with said potential cluster head,

30

- selecting, based on said first information, the potential cluster head as the head to a cluster comprising said potential cluster head and said node,

- broadcasting over the second communication channel a response message comprising an indication that said node has selected the potential cluster head as the head to the cluster.

The present system relates to a system for self organizing a plurality of nodes of a communication network into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head and being able to communicate within the communication network over a plurality of broadcast communication channels, said potential cluster head being arranged to:

- broadcast an advertisement message over a first communication channel, said advertisement message comprising:

- first information related to the capacities of the potential cluster head with regards to a given application,

- second information related to a second communication channel over which the plurality of nodes can exchange messages with said potential cluster head,

at least one node being arranged to:

- send over the second communication channel a response message, said response message comprising an indication that said node, based on the first information, has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.

BRIEF DESCRIPTION OF THE DRAWINGS:

The present system and method are explained in further detail, and by way of example, with reference to the accompanying drawings wherein:

FIG. 1 shows an exemplary embodiment of the present system,

FIG. 2 shows an illustration of the message flows among nodes and cluster heads in accordance with an embodiment of the present system,

FIG. 3 shows a flow diagram illustrating an embodiment of the present method,

FIG. 4 shows a flow diagram illustrating another embodiment of the present method, and:

5 FIG. 5 shows an illustration of a change of status of a node in the network.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS:

The following are descriptions of exemplary embodiments that when taken in conjunction with the drawings will demonstrate the above noted features and
10 advantages, and introduce further ones.

In the following description, for purposes of explanation rather than limitation, specific details are set forth such as architecture, interfaces, techniques, etc., for illustration. However, it will be apparent to those of ordinary skill in the art that other
15 embodiments that depart from these details would still be understood to be within the scope of the appended claims.

For example, the invention allows an improved self organized management of nodes in a communication network. The man skilled in the art will notice that this is not the sole embodiment possible, and that the present system and method may be
20 implemented other content such as a wireless network, a Local Area Network (LAN) or more generally any type of network, wireless or wired line, over which a plurality of nodes may exchange messages.

Moreover, for the purpose of clarity, detailed descriptions of well-known devices, systems, and methods are omitted so as not to obscure the description of the present system. In addition, it should be expressly understood that the drawings
25 are included for illustrative purposes and do not represent the scope of the present system.

By node or element, one may understand any electronic device capable of exchanging messages and data over a communication network. Such device may be a portable or mobile device, or a fixed one. The messages may be exchanged
30 over a wireless network or not, or a combination of both. Bluetooth®, Infrared,

WiMAX or WIFI technologies may be used e.g. for exchanging messages between nodes in the example a wireless network. The man skilled in the art may readily apply the teachings of the present method and system to any existing communication networks.

5 The nodes are also capable of broadcasting messages over a plurality of channels within the communication network.

 The nodes are also capable of carrying a given application, which is the reason behind the clustering. An example of such application may be data transfer, physical parameter monitoring, ... Some nodes may have higher capacities, i.e. abilities, in regards to such an application, when compared to other nodes in the network. These nodes will be described later on as potential master nodes or potential cluster head. Once elected as the head to a cluster, these nodes will be referred to as cluster heads. The other nodes will be called here after regular nodes or member nodes once the cluster has been formed or once they have joined a cluster.

15 For simplification purposes, the method will be illustrated here after for one given application. The method may be readily transposed to clustering involving two or more applications. Nodes which are potential master nodes for a first application could be regular nodes for a second or third application.

20 FIG. 1 shows an illustration of an embodiment of the present system. A group of network nodes 115 have self-organized into a cluster 110. Other nodes 125 and 135 have self organized into clusters 120 and 130 respectively. Each cluster will have a cluster head, respectively 116, 126, and 136.

 The nodes from a communication network as seen in FIG. 1 may be of three types:

25 - a "regular" node 145 which have not joined a cluster yet and which is bound to become a cluster member. It may become a cluster member when electing a potential cluster head 146 as cluster head. The formed cluster, like clusters 110, 120 and 130 in the illustration of FIG. 1, then comprises at least said regular node and the potential cluster head which have become respectively a cluster member and a

30

cluster head. Regular nodes 145 may also become a cluster member when joining an already existing cluster. The election mechanism, as described later on, is based on advertisement messages (AM) sent by the potential cluster heads and/or the existing cluster heads throughout the network,

5 - potential cluster heads 146. Potential cluster heads are determined upon their specific capacities in relation to the given application. How these capacities are established is external to the present clustering mechanism. These capacities may be seen as having a direct consequence on the performance of such a node with regards to the given application. For nodes such as electronic portable or
10 mobile devices, the capacities may be for instance the battery reserve that will allow the device to carry the application over a period of time longer than other nodes. The capacity may also be, but not limited to, the data transfer the device is capable of, its processor characteristics, ...

 - cluster heads 116, 126 or 136. These cluster heads correspond to potential
15 cluster heads which have been elected previously. They are the head or master nodes to clusters (respectively 110, 120 and 130 in FIG. 1) comprising the cluster head and at least one cluster member such as cluster member 115, 125 and 135 respectively.

When the clustering mechanism is initiated, all nodes are either regular nodes
20 or potential cluster heads. All nodes will exchange periodical Advertisement Messages (AM) and Response Messages (RM) to form and maintain clusters using different broadcasting channels, as explained here after.

A first communication channel, called here after the network channel or
25 global channel, is used to exchange messages between all nodes during the clusters formation. This channel is also used by the cluster heads and potential cluster heads to exchange messages.

More specifically, the global channel for the whole group is used by:

1. cluster heads and potential cluster heads to communicate information, including the advertising about their capacities in respect to the application,
- 30 2. new nodes coming to the network and which want to join a cluster (regular

nodes) or start a new one (potential cluster heads), and;

3. former cluster members from a cluster and which have lost their cluster head. Such nodes may indeed be seen as new nodes.

The communication at each cluster level will use a dedicated
5 communication channel, called here after the cluster channel. In other words, each cluster is further characterized by a distinct cluster channel which is defined by each potential cluster head prior to being elected as cluster head. To do so, a potential cluster head will select its own cluster channel, distinct from the global channel or the cluster channels already in use. The potential cluster head will advertise
10 information related to this cluster channel over the global channel and will listen to response messages if any on this cluster channel. The global channel and cluster channels, all of them broadcast channels, are control channel for the purpose of cluster formation and maintenance.

Regular nodes wishing to either join an existing cluster or elect a potential
15 cluster head to form a new cluster, will listen to advertisements on the global channel, will elect an appropriate (potential) cluster head and respond using the cluster channel corresponding to the appropriate (potential) cluster head. These nodes will then become members of the corresponding cluster.

The cluster formation and maintenance will now be illustrated in relation to
20 FIGs. 2 and 3.

In a preliminary act 300, the cluster formation is initiated. In this exemplary embodiment of the present method, it is assumed that no cluster exists already, and the nodes in the network are either regular nodes 215 or potential cluster head 216 as seen in FIG. 2. Other scenarios, such as a regular node joining an existing cluster,
25 or a cluster head sending maintenance messages, will be illustrated later on.

A parameter, here after called the Cluster Member Index (CMI), may be defined to keep track of a node current status. The CMI may be a number with three values to represent the three types of members, for instance CLUSTER_MEMBER, POTENTIAL_CLUSTER_HEAD and CLUSTER_HEAD. The CMI of each node, whether at
30 the initial act 300, or at any later stage of the cluster maintenance, may be set as

follows:

- for a potential cluster head: any member which "wishes" to become a cluster head, based e.g. on its capacities with regard to the given application, will set its CMI to a value corresponding to `POTENTIAL_CLUSTER_HEAD`,

5 - for a regular node: a regular node may set its CMI as `CLUSTER_MEMBER` if it does not wish to be a potential cluster head, e.g. its capacities with regards to the given application are limited. This may be the case if the battery is reaching a low level threshold, or its data transfer rate is limited,

10 - for cluster head: a potential cluster head will become a cluster head only when elected by regular nodes. From that point on, a potential cluster head will change its CMI to the `CLUSTER_HEAD` value. When a cluster head is no longer sought by its cluster members, e.g. it no longer receives response messages from any cluster member, it will switch back to potential cluster head, and change its CMI back to the value `POTENTIAL_CLUSTER_HEAD`.

15 In a further act 310, a potential cluster head 216 will send an advertisement message (AM) over the global channel as seen in FIG. 2. In order to advertise the other nodes 215 about its capacities in relation to the given application, in other words to enable regular nodes 215 to elect it as cluster head, the potential cluster head 216 will send in the AM:

20 - a first information related to the capacities of this potential cluster head 216 with regards to the given application. The first information may be a direct or indirect indication of the potential cluster head capacities. For instance, the first information may be limited to an indication that the node sending the message declares itself as a potential cluster head. The first information may also correspond to more detailed
25 indications of the capacities, like data transfer, battery charge left, ...

- a second information related to a cluster communication channel over which the nodes may exchange messages with this potential cluster head.

The second information may correspond for instance to a Channel ID (identification) that indicates the cluster channel over which cluster members can
30 communicate with the potential cluster head once it is chosen as the cluster head.

As mentioned before, the cluster channel is chosen by the potential cluster head among available channels. The cluster channel may be chosen e.g. randomly to avoid duplicated channels among clusters.

FIG. 2 illustrates the advertisement messages AM sent out over the global channel by a plurality of potential cluster heads 216, 226, 236 and 246.

In an additional embodiment of the present method, further information may be included in the AM:

- the scope D_G of the AM. The scope defines how far away from the potential cluster head the AM is valid. Beyond that distance D_G the AM may no longer be read by a node. The distance may be measured in number of hops from the potential cluster head. Initially, when the cluster is not formed yet, the scope of the AM may be set to a large number and will be adjusted once the cluster head received one or more response messages from cluster members, as explained later on,

- an advertisement cycle T_{ADV} that is the time period between two advertisement messages AM. The advertisement cycle may be adjusted based on the overhead control as explained later in an additional embodiment of the present method. Other parameters such as remaining life of battery for instance may be taken into account in the definition of T_{ADV} .

Once act 310 has been carried out, the potential cluster head will wait for response messages (RM) from regular nodes, which will signal through the RM that they have elected the potential cluster head as cluster head.

In a further act 320, the potential cluster head 216 receives over the second communication channel, i.e. the cluster channel, a response message RM from a regular node 215 in the network. This response message comprises an indication that this node, based on the first information in the AM of the potential cluster head has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.

Indeed, upon receiving the AM from the potential cluster head, any regular nodes 215 may elect this potential cluster head as cluster head, using the first information in the AM of the potential cluster head and its own set of election rules.

The set of rules for election of a cluster head may vary from one regular node to the other. The distance from the potential cluster head may be for instance of importance to some nodes, on top of the first information of the AM.

In an additional embodiment of the present method, the response message
5 may include the distance from the elected cluster head. The distance from the cluster head can be obtained from the AM received by the regular node sending the RM using for instance a TTL (Time To Live) parameter in the AM, i.e. a distance parameter indicating the distance from the potential cluster head. From the RMs, a cluster head may determine the cluster size `CLUSTER_SIZE`, i.e. the distance from said
10 cluster head to its farthest cluster member. This distance may be seen as an uplink distance from the potential cluster head to the cluster member.

In an alternative embodiment of the present method, a downlink distance may be defined from the cluster head to the potential cluster head using a TTL in the RM.

15 Upon choosing the cluster head, a regular node about to become a cluster member will respond to the cluster channel indicated in the AM from the potential cluster head. The newly cluster member may then switch from listening to the global channel to listening to the cluster channel, and thus may respond only to that cluster channel. The cluster member will thus receive all AMs sent by the cluster head on the
20 cluster channel as well as other response messages sent by cluster members from the same cluster, as the cluster channel is a broadcast channel.

In a further embodiment of the present invention, a selective suppression of the response messages may be carried out to reduce the message overhead. Every regular node which has elected the potential cluster head may schedule its
25 response message with a random delay. The delay may be randomized based on the advertisement cycle T_{ADV} from the advertisement message so that all these nodes get a chance to send a RM before the next AM from the potential cluster head.

As all response messages from the nodes in the same cluster are sent on the cluster channel, and will be received by all members from this same cluster. The
30 selective suppression may be applied as follows: upon receiving a RM from any

fellow cluster member (which have also elected the same potential cluster head) and whose distance to the elected cluster head is larger than its own distance to said elected cluster head, the scheduled RM will be simply suppressed or cancelled. CLUSTER_SIZE will then be determined from the distance parameter in the RM which
 5 reports the largest distance from the elected cluster head to the furthest cluster member.

In order to facilitate the choice of a cluster head, any regular node may store a "AM table" for all the potential cluster heads it has received an AM from. That table may for example comprise the following data for each of these potential
 10 cluster heads:

- potential cluster head ID,
- first information in the AM related to the capacity of said potential cluster head,
- distance from the potential cluster head to itself.

15 In a further act 330, once a response message has been received by the potential cluster head, it changes its status to cluster head. This may be carried out through the CMI which is switched to the CLUSTER_HEAD value.

In a further embodiment of the present method, the newly elected cluster head may start to send in an act 340 two advertisement messages both to the
 20 global channel and its own cluster channel every advertisement cycle T_{ADV} :

1. a cluster advertisement message to its own cluster channel with a scope D_c set to CLUSTER_SIZE, the scope defining how far from the cluster head the message may go. This message may be seen as a keep alive message, to inform the cluster nodes that it is still an active cluster head,

25 2. A cluster head will send the cluster advertisement message to the global channel with a large scope D_g . The use of the global channel allows communication with other cluster heads, as well as with any other regular nodes wishing to join the existing cluster. This message comprises the same information as the AM sent in act 310 and may use the same large scope as the one from the AM in act 310.

30 The two AMs on the cluster and global channel respectively are illustrated as

being sent simultaneously and with the same periodicity. The AM on the global channel may be sent every multiple of the advertisement time T_{ADV} , as this AM is used for any nodes wishing to join the existing cluster. These two AMs may also be sent asynchronously in an alternative embodiment.

5 The present method allows a simple and straightforward maintenance of a cluster. Cluster members will response to the keep alive AM on the cluster channel in the same way they replied to the AM on the cluster channel during the cluster formation. These acts may be seen as acts 310 and 320. In other words, cluster members will reply to a cluster head for cluster maintenance in the same way
10 regular nodes respond to a potential cluster head once they have elected it during the cluster formation.

When a regular node, referred to here after as new comer, wishes to join an existing cluster, it will listen to the global channel for any AM. The advertisement messages on the global channel may come from:

- 15 - cluster heads to existing clusters, which keep on advertising on the global channel, as explained here before,
- potential cluster heads advertising to create a new cluster.

In both instances, this new comer will elect a cluster head, whether potential or not, based on the first information in the AM and its own election rules and send a
20 response message on the cluster channel corresponding to the second information in the AM. This response message will be one of the response messages the cluster head may receive as in act 320 on the cluster channel. The additional embodiment of the suppression may also be carried out in the same way, as the new comer will listen to the cluster channel once a cluster head elected.

25 New potential cluster head will start with advertising to the global channel with their own predetermined time period, as described in relation to acts 300 to 330. Regular nodes, which are not cluster members, will listen to the new potential cluster heads as well as other AMs from existing potential cluster heads and cluster heads and may chose to elect said potential cluster head as cluster head.

30 Cluster members, having hopped out of a cluster for any given reason, may

also listen on the global channel to the AMs of potential cluster heads as well as other AMs from existing potential cluster heads and cluster heads, just like a regular node looking to join a cluster.

For some reasons, there may be instances when a cluster member no longer receives any AM from its cluster channel for a predetermined time period (e.g. two or more advertisement cycles), in an additional embodiment of the present method, it will then switch to the global channel to elect a new potential cluster head or cluster head and join a cluster consequently, just like the new comer illustrated here above.

When a cluster head no longer receives any RM on its cluster channel for a predetermined time period (e.g. two or more advertisement cycles), it will switch back to potential cluster head, e.g. change its CMI to POTENTIAL_CLUSTER_HEAD. It will stop sending AM on its cluster channel, and will continue sending AM only to the global channel with the same or a longer time period, just like any new potential cluster head.

In an additional embodiment of the present method, the advertisement period may vary for a potential cluster head depending on the reception or not of RMs. For instance, a potential cluster head may start to send one AM to the global channel every advertisement cycle for a predetermined time period T_{NIT} (e.g. three advertisement cycles, $3 T_{ADV}$). The potential cluster head will listen to its own cluster channel for any response from cluster members. If no response is received after T_{NIT} , it will remain as a potential cluster head and will send one advertisement message to global channel at a second predetermined time period T_P larger than the initial one T_{NIT} (e.g. every two advertisement cycles $2 T_{ADV}$).

In a further embodiment of the present method, the potential cluster head may change its status to regular node if no RM is received after a third predetermined time T_I . This node may nevertheless, beyond T_I , switch back to the status of potential cluster head at regular intervals to check if it can form a cluster. The change may also happen through external means and/or following a change in its capacities (e.g. remaining battery life below a given level).

In a further embodiment of the present method, the first information in the AM may be limited to the CMI. The CMI may be seen as an indication of the capacities of potential cluster head and cluster heads with regard to the application.

A regular node, the CMI of which is set to CLUSTER_MEMBER, may select from the AMs received on the global channel, for example using the AM table, the potential cluster head or cluster head which is the closest.

As mentioned before with regard to the capacities with regards to the application, the CMI is set external to the present clustering mechanism.

The advertisement and response messages, AM and RM respectively, are considered as overhead traffic for cluster formation and maintenance. Measurements may be defined to evaluate the overhead of the present cluster formation, one example being the number of messages $N_{RECEIVED}$ received by any node in the network during a given period of time $T_{PREDETERMINED}$. This number of messages takes into account the facts that:

- each cluster member will receive on the cluster channel AM from its cluster head, and some RM from fellow cluster members,
- potential cluster heads receive on the global channel only AM from all other potential cluster heads and cluster heads,
- a cluster head will receive AM from all potential cluster heads, other cluster heads, and RM from its own cluster members.

To control overhead, each cluster head and potential cluster head may monitor the number of message $N_{RECEIVED}$ received during $T_{PREDETERMINED}$. A predetermined threshold may be set. Once this threshold is reached, the advertisement cycle T_{ADV} may be adjusted to bring down the number of messages $N_{RECEIVED}$ to below the threshold level. Once the $N_{RECEIVED}$ of a potential cluster head or cluster head has reached the predetermined threshold, such potential cluster head or cluster head may increase its advertisement cycle T_{ADV} to decrease the overhead. The adjustment of the advertisement cycle may alternatively be carried out independently among the potential cluster heads and cluster heads.

As explained earlier, the status of a network node, as defined by the CMI

parameter, is set external to the clustering mechanism, e.g. based on the node capacities with regards to the given application. The CMI of potential cluster heads and cluster members may be set and changed by external means based on the given application requirements.

5 In a further embodiment of the present method, a (potential) cluster head may be allowed to be both a (potential) cluster head and a cluster member of another cluster at the same time. In order to do so, a fourth status may be defined through an additional CMI value CLUSTER_DUPLEX.

Such a member may:

- 10 - advertise to both global channel (as in act 310) and cluster channel (as in act 340 for the keep alive message) as a (potential) cluster head,
- listen to its own cluster channel for response message, and
- listen to another cluster channel and send RM to that cluster channel of the cluster head it has chosen from its AM table as explained before.

15 FIG. 4 shows an additional embodiment of the present method and corresponds to the act carried out by a regular node or cluster member.

In a preliminary act 400, the cluster formation is initiated. In this exemplary embodiment of the present method, it is assumed that no cluster exists already, and the nodes in the network are either regular nodes 215 or potential cluster head 216 as seen
20 in FIG. 2.

In a further act 410, a regular node receives from the at least one potential cluster head an advertisement message over a first communication channel, i.e. the global channel, said advertisement message comprising the first and second information as described in relation to FIG. 3.

25 In an additional act 420, the regular node will select, based on the first information comprised in the one or more AM it has received, a potential cluster head as the head to a cluster comprising said potential cluster head and said node.

In a further act 430, the regular node will broadcast over the cluster channel (as indicated from the second information) a response message RM to the elected cluster
30 head. The regular node becomes a cluster member to the cluster comprising at least

itself and the elected cluster head. The newly cluster member will also switch to listening to the cluster channel.

In a further act 440, the cluster member may reply to further AM (keep alive messages) from the cluster head during cluster maintenance.

5 Other cases, like a cluster member leaving its cluster, or a new regular node available to join a new cluster or an existing cluster have been illustrated before.

A cluster member may decide to change cluster affiliation as its election rules will lead to the decision of hopping out of its current cluster. The "ex"-cluster member will resume its listening of the global channel, as all potential cluster heads and
10 cluster heads keep on sending AM at regular intervals on the global channel. In an alternative embodiment, it may select a potential cluster head based on its AM table (selecting for example the next in line) even if the table has not been updated since the regular node, while a cluster member, was not listening to the global channel.

15 FIG. 5 shows an illustration of a change of status of a node in the network. A potential cluster head 510, once elected by at least one regular node, will switch its status to cluster head 520. A cluster head 520, which no longer receives RM from cluster members, will switch back to the potential cluster head status after a predetermined time.

20 In an additional embodiment of the present method, a potential cluster head 510 may choose to stay as potential cluster head status as wished, or may choose to switch to the status of a regular node 530 (and may become a cluster member) if its capacities has changed so as not being able to serve as potential cluster head, or may choose to leave the system completely at will.

25 A regular node 530, once its capacities improved to having the potential and will to be a potential cluster head, may change its status to potential cluster head through external means.

The nodes of the communication network comprise one or more processors with portions to carry out the present method. The plurality of nodes of the present

communication network forms a system wherein the present method may be carried out.

Obviously, readily discernible modifications and variations of the present system are possible in light of the above teachings. It is therefore to be understood that within
5 the scope of the appended claims, the present invention may be practiced otherwise than as specifically described herein. For example, while described in terms of hardware/software components interactively cooperating, it is contemplated that the invention described herein may be practiced entirely in software. The software may be embodied in a carrier such as magnetic or optical disks, or a radio frequency or
10 audio frequency carrier wave.

Thus, the foregoing discussion discloses and describes merely exemplary embodiments of the present invention. As will be understood by those skilled in the art, the present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Accordingly, the disclosure of the present
15 invention is intended to be illustrative, but not limiting of the scope of the present invention, as well as other claims. The disclosure, including any readily discernible variants of the teachings herein, defines, in part, the scope of the foregoing claim terminology such that no inventive subject matter is dedicated to the public.

For example, several parallel clustering may be carried out when the nodes from
20 the communication network are capable of running more than one application. Furthermore, the nodes may be various electronic devices, even within the same cluster. A node may change status through the action of external means, such as a network operator, or based on itself, e.g. when the monitoring of a node parameter triggers a status change. A low battery may force a cluster head to lower its activity,
25 and switch to cluster member for the rest of the battery life. In case of a mobile cluster head, the cluster head, showing a lower data transfer as a consequence to lower network coverage, may change its status to cluster member. Conversely, any improved network coverage may change the status back to potential cluster head.

The section headings included herein are intended to facilitate a review but
30 are not intended to limit the scope of the present system. Accordingly, the

specification and drawings are to be regarded in an illustrative manner and are not intended to limit the scope of the appended claims.

In interpreting the appended claims, it should be understood that:

a) the word "comprising" does not exclude the presence of other elements or
5 acts than those listed in a given claim;

b) the word "a" or "an" preceding an element does not exclude the presence
of a plurality of such elements;

c) any reference signs in the claims do not limit their scope;

d) several "means" may be represented by the same item or hardware or
10 software implemented structure or function;

e) any of the disclosed elements may be comprised of hardware portions
(e.g., including discrete and integrated electronic circuitry), software portions (e.g.,
computer programming), and any combination thereof;

f) hardware portions may be comprised of one or both of analog and digital
15 portions;

g) any of the disclosed devices or portions thereof may be combined together
or separated into further portions unless specifically stated otherwise;

h) no specific sequence of acts or steps is intended to be required unless
specifically indicated; and

20 i) the term "plurality of" an element includes two or more of the claimed
element, and does not imply any particular range of number of elements; that is, a
plurality of elements can be as few as two elements, and can include an
immeasurable number of elements.

CLAIMS

What is claimed is:

1. A method for self organizing a plurality of nodes of a communication network
5 into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head, and being able to communicate within the communication network over a plurality of broadcast communication channels, said method comprising for said at least one potential cluster head the acts of:
 - broadcasting an advertisement message over a first communication channel,
10 said advertisement message comprising:
 - first information related to the capacities of the potential cluster head with regards to a given application,
 - second information related to a second communication channel over
15 which the plurality of nodes can exchange messages with said potential cluster head,
 - receiving over the second communication channel a response message if any from a node, said response message comprising an indication that the node, based on the first information, has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.
- 20 2. The method of claim 1, further comprising an act of sending an additional advertisement message over the second communication channel after reception of a response message.
- 25 3. The method of claim 2, wherein the additional advertisement message comprises a scope defining how far from the potential cluster head said additional advertisement message is valid, said scope corresponding to the cluster size.
4. The method of claim 1, wherein the response message comprises a distance
30 parameter indicating the distance from the potential cluster head to the node, said

method further comprising an act of receiving an additional response message from another node with a distance parameter indicating a distance larger than with the previous response message.

5 5. The method of claim 1, further comprising the act of sending further advertisement messages over the first communication channel, whether a response message has been received or not, at regular intervals.

10 6. The method of claim 5, further comprising the act of sending additional advertisement messages at larger intervals of time when no response message has been received after a predetermined time.

7. The method of claim 5, further comprising the acts of:
- calculating the number of messages received by the head to the cluster over a
15 given period of time
- increasing the regular intervals if the number of messages is larger than a threshold.

8. A processor for a potential cluster head in a communication network, said
20 communication network comprising a plurality of nodes, said plurality of nodes being able to self organize into clusters and communicate within the communication network over a plurality of broadcast communication channels, said processor comprising:

25 - a portion to broadcast an advertisement message over a first communication channel, said advertisement message comprising:

- first information related to the capacities of the potential cluster head with regards to a given application,
- second information related to a second communication channel over which the plurality of nodes can exchange messages with said potential cluster
30 head,

- a portion to receive over the second communication channel a response message if any from a node of the plurality of nodes, said response message comprising an indication that said node, based on the first information, has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.

9. The processor of claim 8, further comprising a portion to send an additional advertisement message over the second communication channel after reception of a response message.

10. The processor of claim 9, wherein the additional advertisement message comprises a scope defining how far from the potential cluster head said additional advertisement message is valid, said scope corresponding to the cluster size.

11. The processor of claim 8, wherein the response message comprises a distance parameter indicating the distance from the potential cluster head to the node, said processor further comprising a portion to receive an additional response message from another node with a distance parameter indicating a distance larger than that from the previous response message.

12. The processor of claim 8, further comprising a portion to send further advertisement messages over the first communication channel, whether a response message has been received or not, at regular intervals.

13. The processor of claim 12, further comprising a portion to send additional advertisement messages at larger intervals of time when no response message has been received after a predetermined time.

14. The method of claim 12, further comprising the acts of:

- calculating the number of messages received by the head to the cluster over a given period of time

- increasing the regular intervals if the number of messages is larger than a threshold.

5

15. A method for self organizing a plurality of nodes of a communication network into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head, and being able to communicate within the communication network over a plurality of broadcast communication channels, said method comprising for one node of said plurality of nodes the acts of:

10

- receiving from the at least one potential cluster head an advertisement message over a first communication channel, said advertisement message comprising:

15

- first information related to the capacities of the potential cluster head with regards to a given application,

- second information related to a second communication channel over which the node can exchange messages with said potential cluster head,

- selecting, based on said first information, the potential cluster head as the head to a cluster comprising said potential cluster head and said node,

20

- broadcasting over the second communication channel a response message comprising an indication that said node has selected the potential cluster head as the head to the cluster.

16. The method of claim 15, further comprising the act of:

25

- listening to the second communication channel for other response messages from other nodes having selected the same potential cluster head,

17. The method of claim 16, wherein the response message comprising a distance parameter indicating the distance from the potential cluster head to the node, said distance parameter being calculated from the received advertisement message.

30

18. The method of claim 17, further comprising the act of:

- deleting the response message if another response message comprises a distance parameter indicating a larger distance from the selected potential cluster head.

19. The method of claim 15, further comprising the act of:

- listening no longer to the second communication channel,
- resuming the listening of the first communication channel for further advertisement message.

20. A processor for a node in a communication network comprising a plurality of nodes, said plurality of nodes being able to self organize into clusters and communicate within the communication network over a plurality of broadcast communication channels, said processor comprising:

- a portion to receive from the at least one potential cluster head an advertisement message over a first communication channel, said advertisement message comprising:

- first information related to the capacities of the potential cluster head with regards to a given application,

- second information related to a second communication channel over which the node can exchange messages with said potential cluster head,

- a portion to select, based on said first information, the potential cluster head as the head to a cluster comprising said potential cluster head and said node,

- a portion to broadcast over the second communication channel a response message comprising an indication that said node has selected the potential cluster head as the head to the cluster.

21. The processor of claim 20, further comprising a portion to:

- listen to the second communication channel for other response messages from other nodes having selected the same potential cluster head,

22. The processor of claim 20, wherein the response message comprising a distance parameter indicating the distance from the potential cluster head to the node, said distance parameter being calculated from the received advertisement message.

23. The processor of claim 22, further comprising a portion to:

- delete the response message if another response message comprises a distance parameter indicating a larger distance from the selected potential cluster head.

24. The processor of claim 20, further comprising a portion to:

- listen no longer to the second communication channel,
- resume the listening of the first communication channel for further advertisement message.

25. A system for self organizing a plurality of nodes of a communication network into at least one cluster of nodes, the plurality of nodes comprising at least one potential cluster head and being able to communicate within the communication network over a plurality of broadcast communication channels, said potential cluster head being arranged to:

- broadcast an advertisement message over a first communication channel, said advertisement message comprising:

- first information related to the capacities of the potential cluster head with regards to a given application,

- second information related to a second communication channel over which the plurality of nodes can exchange messages with said potential cluster head,

at least one node being arranged to:

- send over the second communication channel a response message, said response message comprising an indication that said node, based on the first information, has selected the potential cluster head as the head to a cluster comprising at least said potential cluster head and said node.

5

26. The system of claim 25, wherein the potential cluster head is further arranged to send an additional advertisement message over the second communication channel after reception of a response message.

10 27. The system of claim 25, wherein the potential cluster head is further arranged to sending further advertisement messages over the first communication channel, whether a response message has been received or not, at regular intervals.

28. The method of claim 27, further comprising the acts of:

15 - calculating the number of messages received by the head to the cluster over a given period of time

- increasing the regular intervals if the number of messages is larger than a threshold.

20 29. The system of claim 25, wherein the node is further arranged to listen to the second communication channel for other response messages from other nodes having selected the potential cluster head,

25 30. The system of claim 29, wherein the response message comprises a distance parameter indicating the distance from the potential cluster head to the node, said distance parameter being calculated from the received advertisement message.

31. The system of claim 30, wherein the node is further arranged to:

- delete the response message if another response message comprises a distance parameter indicating a larger distance from the selected potential cluster head.

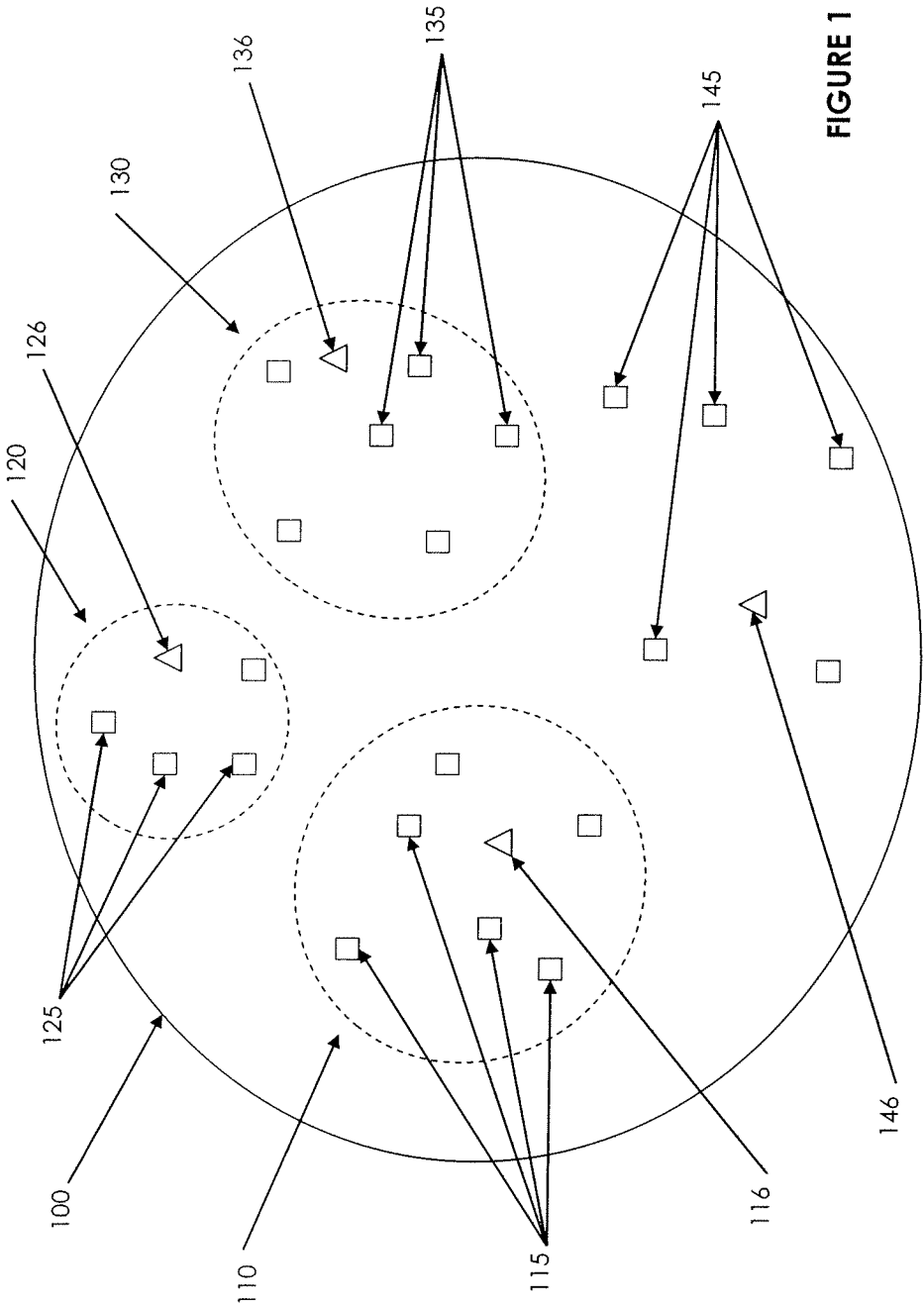


FIGURE 1

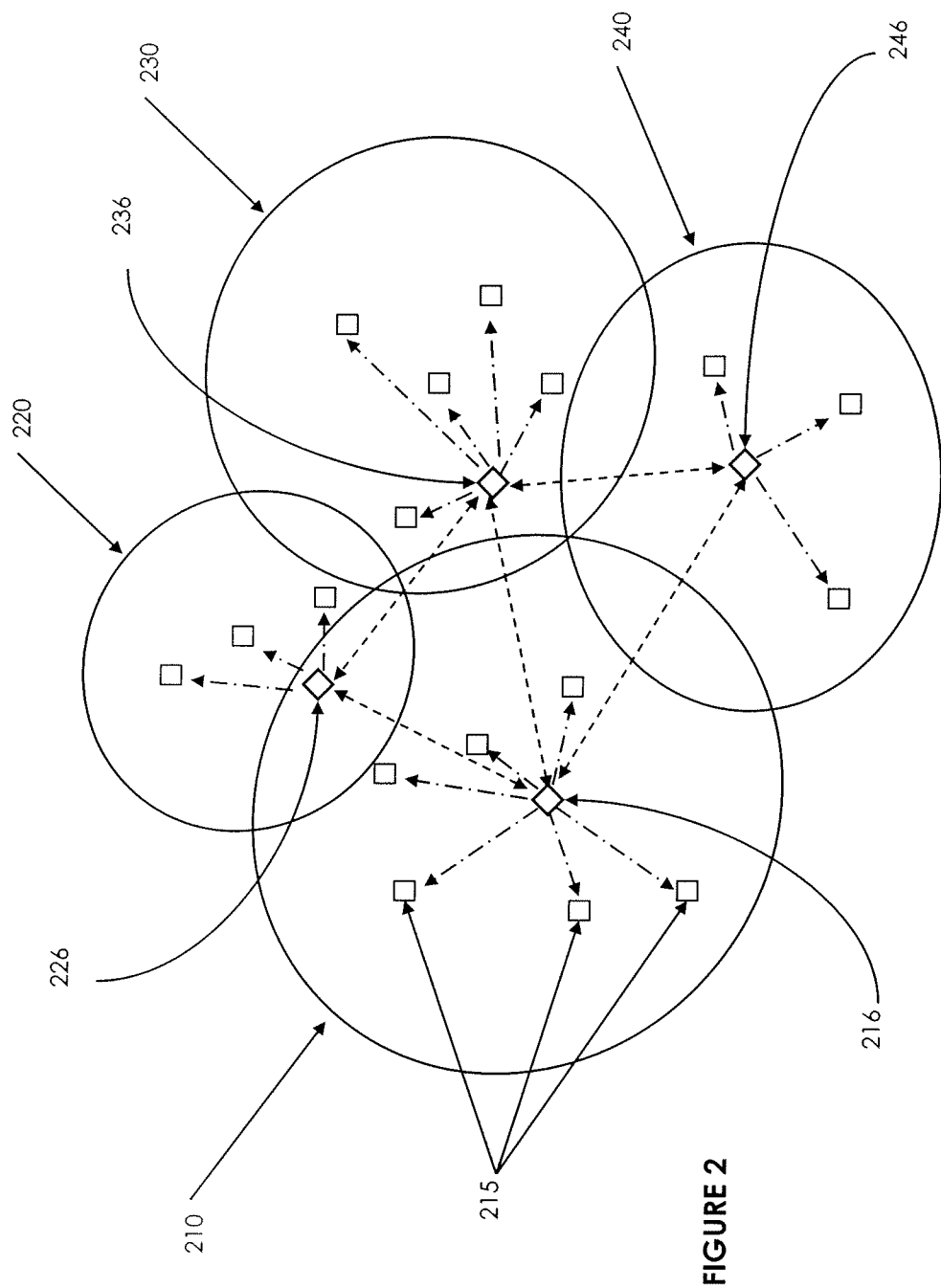
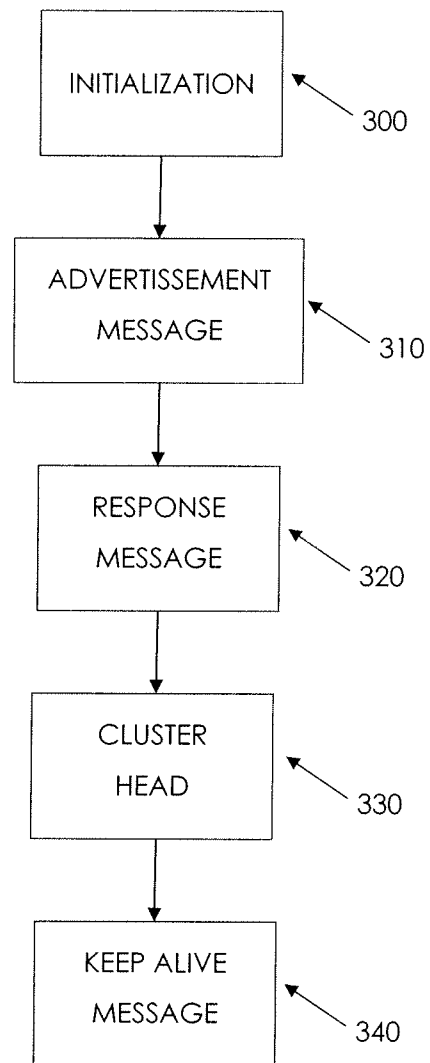
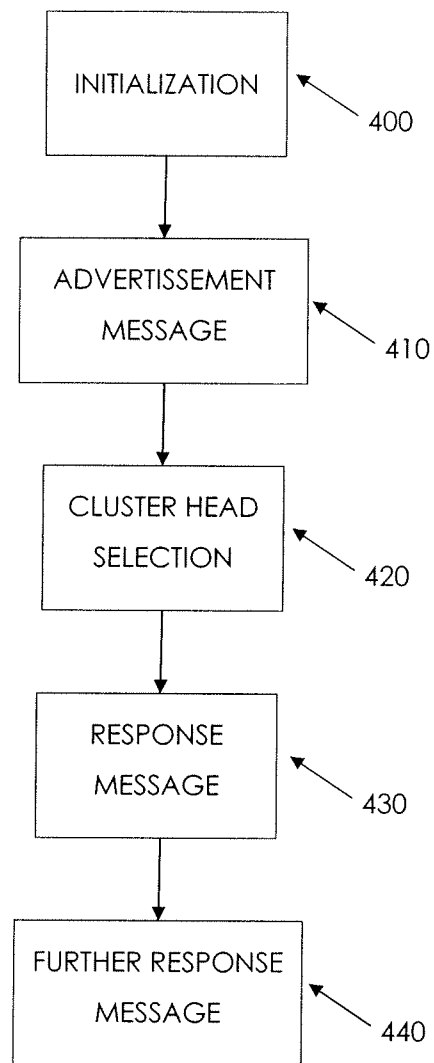


FIGURE 2

3/5

**FIGURE 3**

4/5

**FIGURE 4**

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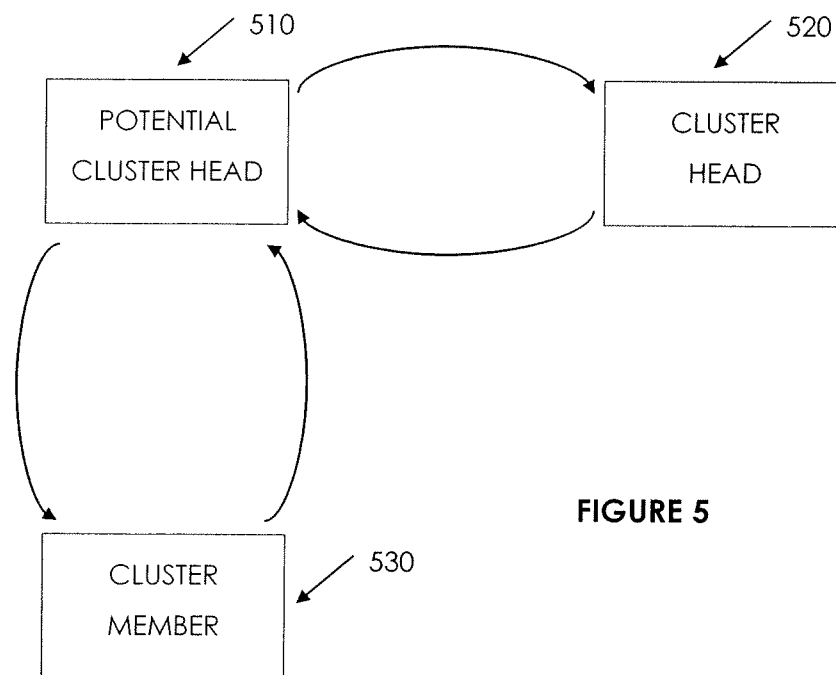


FIGURE 5