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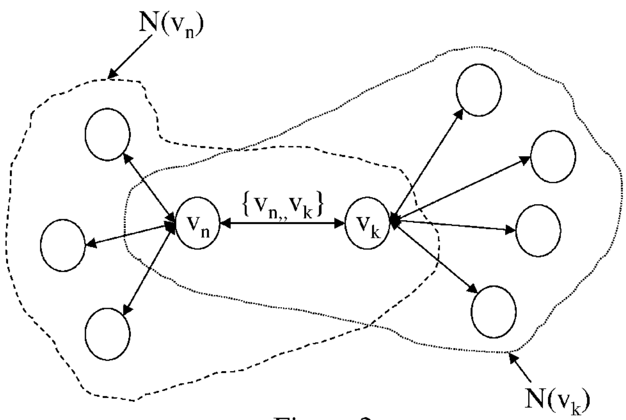

Figure 2

(57) Abstract: A distributed method for determining whether a node can represent or be represented by other nodes within a network comprises receiving at a node (v_n), respective sets of observations (k_l) for each neighbour node ($N(v_n)$) of the node across respective links ($\{v_n,v_k\}$) within the network. For each link, a measure ($D_{n,k}$) of dis-similarly between the observations for a neighbour node (k_l) and the corresponding observations (n_l) for the node is determined. Respective inequality measures (E_k) for each neighbour node ($N(v_n)$) of the node are determined, each inequality measure being a function of respective dissimilarity measures ($D_{n,k}$) and weights ($p_{n,k}$) for each link between a neighbour node (v_k) and its neighbour nodes. For each link ($\{v_n, v_k\}$) between the node and a respective neighbour node, a weight ($p_{n,k}$) is updated as a function of the dissimilarity measure ($D_{n,k}$) and a previous weight for the link. For each link between the node and a respective neighbour node, the node determines as a function of an inequality measure for the node (E_n) and the determined inequality measure for the neighbour node (E_k) whether a link between the node and the neighbour node should be maintained. The node then determines, based on the links maintained by the node, if the node can represent neighbour nodes within the network.

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Method and apparatus for determining whether a node can represent or be represented by other nodes within a network

This invention relates to a method and apparatus for determining whether a node can represent or be represented by other nodes within a network.

Referring now to Figure 1, in networks comprising a number of nodes $v_1, v_2, v_3, v_4, v_n, v_k$, M interconnected by communication links, it is often desirable to provide information across the network between various nodes and one or more management nodes (M). It will be appreciated, however, that as an increasing number of nodes need to report and/or be controlled across an increasing number of links particularly connecting remote nodes to a management node, the network traffic caused by such reporting/control could easily congest the network.

It is appreciated that it would be useful to elect a sub-set of leader nodes, in this case say v_1, v_2, v_3, v_4, v_k which would report to the management node M on behalf of follower nodes in the neighbourhood of the leader nodes. The selection of leader nodes involves balancing the disparity introduced by selecting leaders who do not perfectly reflect the particular observations of their surrounding nodes against the overhead gains that can be achieved by selecting leaders for greater numbers of follower nodes.

For example, if a management node wished to observe interference conditions being experienced by nodes within a network, it would be desirable to obtain reports in relation to interference from the smallest number of leaders which best approximated the noise conditions of their neighbours around the network. Then any control messages that a management node sent back to the leader node(s) could in turn be relayed to their follower node(s) and on balance this control should be as appropriate to the followers as their leaders.

It is also appreciated that the burden for determining which nodes report back to or are directly controlled by a management node should be delegated to the nodes of the network rather than determined by a management node.

In "A-GAP: An Adaptive Protocol for Continuous Network Monitoring with Accuracy Objectives", A Gonzalez Prieto and R Stadler, IEEE Transactions on Network and Service Management (TNSM), Vol. 4, No. 1, June 2007; and "H-GAP: estimating histograms of local variables with accuracy objectives for distributed real-time monitoring" D Jurca and R Stadler, IEEE Transactions on Network and Service Management (TNSM), Vol. 7, No. 2, pp. 83-95, 2010 methods are proposed for configuring local filters within nodes that control whether an update is sent towards a management node at a root of a spanning tree within the network including balancing accuracy of information reported against reporting overhead.

It is an object of the present invention to provide a method and apparatus for determining whether a node can represent or be represented by other nodes within a network.

According to the present invention there is provided a method for determining whether a node can represent or be represented by other nodes within a network according to claim 1.

In a further aspect, there is provided a node arranged to operate the method of claim 1.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a mesh network including a number of interconnected nodes and a management node;

Figure 2 is a detailed view of a portion of the network of Figure 1; and

Figure 3 is a flow diagram illustrating the operation of a node within the network of Figures 1 and 2.

Referring now to Figure 2, which shows a portion of the network of Figure 1 around the link 10 (which is marked in Figure 1). According to the invention, each node runs an agent (or comprises a distributed component of management overlay) which is arranged to obtain from and provide to the nodes of a partition comprising at least some of its direct neighbours, certain information to enable an individual agent to determine whether the node can represent or be represented by nodes in the network partition. Once an agent has determined a sub-set of nodes within its network partition with which it shares relatively similar observations at a given time, the various agents within the sub-set can then readily determine whether or not they are to act as a leader node or a follower node.

Table 1 illustrates the basic terminology used in describing the preferred embodiment; other terms are introduced and defined later in the description:

Table 1

Notation	Description
v_n	n[th] node in the network
$\{v_n, v_k\}$	Denotes an edge starting at node v_n and terminating at node v_k and across which the nodes can communicate.
$N(v_n)$	Set of nodes in the same partition as node v_n
k'	For a node v_n having a set of neighbours $N(v_n)$, k' is used to index the set of neighbours.
n'	For a node v_k having a set of neighbours $N(v_k)$, n' is used to index the set of neighbours.
$\lvert N(v_n) \rvert$	Number of nodes in the same partition as the node v_n
$p_{n,k}$	A weight learned for link $\{v_n, v_k\}$, which is a member of the entire set of all possible communicating pairs of nodes.
$D_{n,k}$	Measure of dis-similarity between observations at nodes v_n and v_k
a_n	Mean Dis-similarity at v_n,
b_n	Weighted Mean Dis-similarity at v_n,
c_n	Weighted Dispersion at v_n.
E_n	Inequality measure for node v_n based on given weights for the links of the partition around the node.
$\mathbf{n}_l$	A vector of observations drawn at node v_n where each

	element of the vector is indexed by the index l.
$\mathbf{k}_l$	A vector of observations drawn at node v_k where each element of the vector is indexed by the index l.
$\Delta C_1(n,k)$	The sum of the scaled changes in the pair of inequality measures across each link $\{v_n, v_k\}$ for $p_{n,k} = 1$ and $p_{k,n} = 1$.
$\Delta C_0(n,k)$	The sum of the scaled changes in the pair of inequality measures across each link $\{v_n, v_k\}$ for $p_{n,k} = 0$ and $p_{k,n} = 0$.

The dis-similarly measure $D_{n,k}$ can be as simple or complex as required by any given application. Preferably, $D_{n,k}$ comprises a symmetric measure of dis-similarity between two nodes that are in communication range of each other, i.e. $D_{n,k} \equiv D_{k,n}$, thus, dis-similarity between two nodes connected by a link is the same. One measure of dis-similarity is the symmetric KullbackLeibler Divergence (KLD) taking the form:

$$D_{n,k} = D_{k,n} = \sum_l (\mathbf{n}_l - \mathbf{k}_l)\log\frac{\mathbf{n}_l}{\mathbf{k}_l} \qquad \textbf{Eq1}$$

where $\mathbf{n}_l$ is the vector of $l > 0$ observations at node v_n and $\mathbf{k}_l$ is the corresponding set of l observations at node v_k. In the described embodiment, the dis-similarity variable, $D_{n,k}$ is restricted to being non-negative and is only equal to zero when $\mathbf{n}_l \equiv \mathbf{k}_l$.

The dis-similarity measure above is based on observation values being non-negative, or, if they are negative, some function transforming the observations should be used to ensure that the dis-similarity measure works within the present embodiment. So, for some observations, an absolute value function of the form $D_{n,k} = D_{k,n} = \sum_l (|\mathbf{n}_l| - |\mathbf{k}_l|)\log\frac{|\mathbf{n}_l|}{|\mathbf{k}_l|}$ or a square function of the form $D_{n,k} = D_{k,n} = \sum_l (\mathbf{n}_l^2 - \mathbf{k}_l^2)\log\frac{\mathbf{n}_l^2}{\mathbf{k}_l^2}$ could be used. These functions work well where it makes sense to compare positive with negative values, however, it would still not make sense to use these functions to compare Celsius temperature values.

In this case a measure based on Squared Euclidian Distance (SED) using a function of the form: $D_{n,k} = D_{k,n} = \sum_l (\mathbf{n}_l - \mathbf{k}_l)^2$ would be more appropriate. This can take both positive and negative observation values, it is only zero when the two values are the same, it is symmetric, and it is non-negative.

Still other dis-similarity functions are:

$$D_{\alpha(n,k)} = \frac{1}{\alpha(\alpha-1)} \sum_l (\mathbf{n}_l^{\alpha} \mathbf{k}_l^{1-\alpha} - \alpha \mathbf{n}_l + (\alpha-1)\mathbf{k}_l) \quad \alpha \in \Re \setminus \{0,1\};$$ and

$$D_{\beta(n,k)} = \sum_l \mathbf{n}_l \frac{\mathbf{n}_l^{\beta-1} - \mathbf{k}_l^{\beta-1}}{\beta-1} - \frac{\mathbf{n}_l^{\beta} - \mathbf{k}_l^{\beta}}{\beta} \quad \beta \in \Re \setminus \{0,1\}$$

Using the above notation, the following terms can be defined:

$$a_n = \frac{1}{|N(v_n)|} \left(\sum_{k' \in N(v_n)} D_{n,k'} \right) \quad \textbf{Eq2}$$

$$b_n = \frac{1}{|N(v_n)|} \left(\sum_{k' \in N(v_n)} p_{n,k'} D_{n,k'} \right) \quad \textbf{Eq3}$$

$$c_n = \sqrt{\frac{1}{|N(v_n)|} \sum_{k' \in N(v_n)} (p_{n,k'} D_{n,k'})^2} \quad \textbf{Eq4}$$

$$p_{n,k} \Leftarrow p_{n,k} \cdot \left(\frac{a_n c_n}{b_n^2} + \frac{a_k D_{n,k}(1 - p_{n,k})}{c_k b_k} \right) \div \left(\frac{a_k c_k}{b_k^2} + \frac{a_n D_{n,k} p_{n,k}}{c_n b_n} \right) \quad \textbf{Eq5}$$

It can be seen from the above equations that once initialized for example at 0.5, $p_{n,k}$ is updated based explicitly on local parameters, the weight of the links $\{v_n, v_{k'}\}$ for all nodes $k' \in N(v_n)$ in the same partition as v_n, $p_{n,k}$, the dis-similarity measure between observations drawn at nodes v_n and all v_k where $k' \in N(v_n)$, $D_{n,k}$, and, the number of nodes in the same partition as v_n, $|N(v_n)|$.

The update function of equation (5) has the following properties:

- The update is a function of local parameters that are available to each node.
- This update is non-negative in both the numerator and the denominator, thus, when $p_{n,k}$ is initialized non-negatively, it remains non-negative.

- This update involves no tuning parameters which means that the embodiment is self-tuning and self-configuring.

Preferably, a linear combination of the update weight resulting from Eqn. 5 with the previous value of the updated weight is taken:

$$p_{n,k}^{new} = (1-\gamma)p_{n,k}^{old} + \gamma p_{n,k}^{fromEqn5}$$

The value, γ is a positive number between zero and one. Preferably, the value of, γ in this linear combination is set to:

$$\gamma = \max\left\{1/3, \frac{E_k}{\sqrt[3]{1+\frac{D_{n,k}{}^{2}(2p_{n,k}-1)}{\sum_{n'\in N(v_k)}\left(p_{k,n'}D_{k,n'}\right)^2}}}\right\}$$

Thus, it will be seen that Equation 5 represents the particular case where $\gamma = 1$.

Preferably, each updated weight is normalized to ensure that is still a probability, that is, the relationship $p_{n,k} + p_{k,n} = 1$ holds.

The update function can be triggered regularly, synchronously, or asynchronously, e.g. when one of the nodes starts to behave differently or out of its usual regime.

Thus, the update function and subsequent steps can be performed when changes occur between the current observations at a node and observations at the node at a previous time, in a periodic manner, or, in a synchronized manner triggered using a global clock or stimulus from the management node.

The update function can also be run iteratively until the calculated weight begins to converge for the given observations and weights.

So, referring to Figure 3, in response to a signal to update node leadership at least in a given vicinity of a network, nodes within a partition exchange their current observation values

$\mathbf{n}_l$, $\mathbf{k}_l$ as well as the vector of weights $p_{n,k}$ $p_{k,n}$ for all edges terminating at nodes v_n, v_k respectively , steps 30, 31.

Parameters $D_{n,k}$, a_n, b_n and c_n are then calculated by the node, step 32 and these can be used to update the weights $p_{n,k}$, for each link around a node, step 34.

Once a node has run its update function and determined the weights $p_{n,k}$ for each link surrounding the node, it can now move to determine whether or not each link should be maintained, step 36. (This need only be done if the weights around a node have changed by a given amount.) This making or breaking of links is only for the purpose of determining whether the node should act as a leader within a group of nodes of a partition and does not otherwise affect their communication.

In the embodiment, the maintenance test determines the effect of setting the weight for each of $p_{n,k}$ and $p_{k,n}$ for a given link $\{v_n, v_k\}$ around a node to each of 0 or 1 on the sum of the scaled absolute changes in the pair of inequality measures across each link. In the preferred embodiment, the inequality measure at node v_n is defined as:

$$\mathrm{E_n} = \mathrm{c_n}/(\mathrm{b_n}\sqrt{|\mathrm{N(v_n)}|}) \quad \textbf{Eq6}$$

Table 2 provides a series of some alternative inequality measures for the weighted observations at node v_n some being more useful, for example, the Hoyer or Gini measure, than others. To simplify the notation, within the table $c_{k'} = p_{n,k'}D_{n,k'}$ and $\mathbf{c}$ (in the Gini measure) is the vector of $p_{n,k'}D_{n,k'}$ for all $k' \in N(v_n)$. The convention adopted here is that an increase in the score from any of these functions implies that the inequality of the observed vector is bigger.

Measure	Definition
ℓ^0, ℓ^0_ϵ	$\#\{k', c_{k'} = 0\}$ or $\#\{k', c_{k'} \le \epsilon\}$
$-\ell^1$	$-\left(\sum_{k' \in N(v_n)} c_{k'}\right)$
$-\ell^p$	$-\left(\sum_{k' \in N(v_n)} c_{k'}^p\right)^{1/p}$, $0 < p < 1$
$\frac{\ell^2}{\ell^1}$	$\frac{\sqrt{\sum_{k' \; inN(v_n)} c_{k'}^2}}{\sum_{k' \in N(v_n)} c_{k'}}$
$-\tanh_{a,b}$	$-\sum_{k' \in N(v_n)} \tanh\left((ac_{k'})^b\right)$
$-\log$	$-\sum_{k' \in N(v_n)} \log\left(1 + c_{k'}^2\right)$
K_4	$\frac{\sum_{k' \in N(v_n)} c_{k'}^4}{\left(\sum_{k' \in N(v_n)} c_{k'}^2\right)^2}$
$-\ell^p_-$	$-\sum_{k' \in N(v_n), c_{k'} \neq 0} c_{k'}^p$, $p < 0$
H_G	$-\sum_{k' \in N(v_n)} \log c_{k'}^2$
H_S	$-\sum_{k' \in N(v_n)} \hat{c}_{k'} \log \hat{c}_{k'}^2$ where $\hat{c}_{k'} = \frac{c_{k'}^2}{\|\boldsymbol{c}\|_2^2}$
H'_S	$-\sum_{k' \in N(v_n)} c_{k'} \log c_{k'}^2$
Hoyer	$\left(\sqrt{\lvert N(v_n)\rvert} - \frac{\sum_{k' \in N(v_n)} c_{k'}}{\sqrt{\sum_{k' \in N(v_n)} c_{k'}^2}}\right)\left(\sqrt{\lvert N(v_n)\rvert} - 1\right)^{-1}$
pq-mean	$-\left(\frac{1}{\lvert N(v_n)\rvert} \sum_{k' \in N(v_n)} c_{k'}^p\right)^{\frac{1}{p}} \left(\frac{1}{\lvert N(v_n)\rvert} \sum_{k' \in N(v_n)} c_{k'}^q\right)^{-\frac{1}{q}}$, $p < q$
Gini	$1 - 2\sum_{j=1}^{\lvert N(v_n)\rvert} \frac{c_{(j)}}{\|\boldsymbol{c}\|_1} \left(\frac{\lvert N(v_n)\rvert - j + \frac{1}{2}}{\lvert N(v_n)\rvert}\right)$ for ordered data, $c_{(1)} \le c_{(2)} \le \cdots \le c_{(\lvert N(v_n)\rvert)}$

Table 2

While each of these inequality measures can be used in the maintenance test of step 36 described below, some may require adjustments to the update function of equation (5) for example including a weighting to ensure that measures from one node would not necessarily dominate another.

It will be appreciated that in variants of the above described embodiment, calculations of the inequality measures could be performed at various nodes and these calculated inequality measures could be exchanged between nodes, rather than exchanging only the observations and weights as described above.

For the maintenance step 36, the sum of the scaled changes in the pair of inequality measures across each link $\{v_n, v_k\}$ for $p_{n,k} = 1$ and $p_{k,n} = 1$ is calculated as follows:

$$\Delta C_1(n,k) = f\left(\frac{E_n(p_n^*) - E_n(p_n^1)}{E_n(p_n^*)}\right) + f\left(\frac{E_k(p_k^*) - E_k(p_k^1)}{E_k(p_k^*)}\right) \textbf{Eq7}$$

The sum of the scaled changes in the pair of inequality measures across each link $\{v_n, v_k\}$ for $p_{n,k} = 0$ and $p_{k,n} = 0$ is:

$$\Delta C_0(n,k) = f\left(\frac{E_n(p_n^*) - E_n(p_n^0)}{E_n(p_n^*)}\right) + f\left(\frac{E_k(p_k^*) - E_k(p_k^0)}{E_k(p_k^*)}\right) \textbf{Eq8}$$

where $p_n^* = p_{n,k}$ is a vector comprising the updated weights for the links around a node v_n after Eq 5 has been applied; and $p_n^x = \begin{cases} p_{n,k} \, where \; n \neq k \\ x \; where \; n = k \end{cases}$ is a vector in which the weight x for a given link $\{v_n, v_k\}$ is set to 0 or 1 when calculating the inequality measure for a node v_n.

In the preferred embodiment, the function f(·) of equations (7) and (8) comprises the absolute value function |·|, but equally a squared function such as $(\cdot)^2$ could be used.

The maintenance test comprises determining if $\Delta C_1(n,k) \prec \Delta C_0(n,k)$. If so, then the logical link $\{v_n, v_k\}$ is broken i.e. if the effect of maintaining the link on the inequality measure is less than the effect of breaking the link, the link is broken, otherwise it is maintained.

Once the maintenance test is complete, each node in a network will now have an integer number W_n of connections to surrounding nodes and each node communicates its number W_n to each of its neighbours (or just its remaining connected nodes), step 38.

One exemplary and simple mechanism for selecting which of these is to act as leader (and so continue to report or be controlled from a management node), is to determine which node has the highest number of connections W_{max}, step 40. Thus, if any given node has a highest number of maintained links in the partition of nodes that it is a member of, it will continue to report to the management node – otherwise, the link will cease to or not act as a leader.

Another scheme which could be employed among a group of nodes between which links have been maintained after step 36 is to determine which of the nodes has the best capacity for reporting back to a management node. For example, if only one node within a group of nodes within a femtocell network has spare capacity on its DSL backhaul, this node could act as leader among connected nodes.

Using the above schemes, it will be seen that leaders can be chosen within a group of interconnected nodes. In order to further aggregate nodes, it is possible to extend the scheme to have leaders communicate with one another in a similar fashion to the scheme above to go through a second round of aggregation (or partitioning). Alternatively, the neighbourhood for a node v_n could be extended to include not alone nodes directly connected to the node v_n, but perhaps nodes connected via two or more communication links to the node.

Regardless, it will be seen that using the scheme described above, the aggregation and error provided are quantized in that for any given set of observations at any given time, a set number of leaders will be determined i.e. it is not possible to vary the permitted error against the desired aggregation. However, it will be appreciated that the scheme could be adjusted to allow for such tuning.

It will be set that using the above scheme different leaders could be chosen for different sets of observations and also that different management nodes could be chosen for handling reports from different sets of leaders of different observations.

The embodiment has been described in terms of a mesh network most typically involving a network of wireless nodes, possibly base stations which could serve wireless network devices. The invention is equally applicable to an ad hoc network of wireless network devices communicating on a peer-to-peer basis. Equally the invention is applicable to networks in which some or all of the nodes have wired interconnections.

As mentioned above, the dis-similarity measure $D_{n,k}$ can be based on any one or more variables pertaining at nodes of the network at any given time, for example, noise, interference, packet loss, packet delay, jitter, (absolute) temperature.

The invention is not limited to the embodiment(s) described herein but can be amended or modified without departing from the scope of the present invention.

Claims:

1. A method for determining whether a node can represent or be represented by other nodes within a network comprising:

a) receiving (31) at a node (v_n), respective sets of observations ($\mathbf{k}_l$) for each node of a partition comprising at least some of the neighbour nodes ($N(v_n)$) of said node across respective links ($\{v_n, v_{k'}\}$)) within said network;

b) for each link, determining (32) a measure ($D_{n,k'}$) of dissimilarly between said sets of observations for a node ($\mathbf{k}_l$) of said partition and a set of corresponding observations ($\mathbf{n}_l$) for said node;

c) determining (31) at said node (v_n), respective inequality measures ($E_{k'}$) for each node (N(v_n)) of said partition, each inequality measure being a function of respective dissimilarity measures ($D_{n,k'}$) and weights ($p_{n,k'}$) for each link between a node (v_k) of said partition and its neighbour nodes;

d) for each link ($\{v_n, v_{k'}\}$) between said node and a respective node of said partition, updating (34) a weight ($p_{n,k'}$) as a function of said dissimilarity measure ($D_{n,k'}$) and a previous weight for the link;

e) for each link between said node and a respective node of said partition, determining (36) as a function of an inequality measure for said node (E_n) and said determined inequality measure for said node (E_k) of said partition whether a link between said node and said node of said partition should be maintained; and

f) determining (40) based on the links maintained by said node, if said node can represent nodes of said partition within said network.

2. A method according to claim 1 further comprising:

sending (30) said current set of observations ($\mathbf{n}_l$) for said node to each node of said partition.

3. A method according to claim 1 wherein said dissimilarity measure $D_{n,k}$ for a link $\{v_n, v_k\}$ comprises: $D_{n,k} = D_{k,n} = \sum_l (\mathbf{n}_l - \mathbf{k}_l)\log\frac{\mathbf{n}_l}{\mathbf{k}_l}$ where $\mathbf{n}_l$ and $\mathbf{k}_l$ are the respective sets of observations for each node of a link.

4. A method according to claim 1 wherein said updated weight for a link $p_{n,k}$ comprises:

$$p_{n,k} \Leftarrow p_{n,k} \cdot \left(\frac{a_n c_n}{b_n^2} + \frac{a_k D_{n,k}(1 - p_{n,k})}{c_k b_k} \right) \div \left(\frac{a_k c_k}{b_k^2} + \frac{a_n D_{n,k} p_{n,k}}{c_n b_n} \right)$$

where

$$a_n = \frac{1}{|N(v_n)|}\left(\sum\nolimits_{k' \in N(v_n)} D_{n,k'}\right)$$

$$b_n = \frac{1}{|N(v_n)|}\left(\sum\nolimits_{k' \in N(v_n)} p_{n,k'} D_{n,k'}\right)$$

$$c_n = \sqrt{\frac{1}{|N(v_n)|}\sum\nolimits_{k' \in N(v_n)} \left(p_{n,k'} D_{n,k'}\right)^2} \; .$$

5. A method according to claim 4 comprising the step of providing said updated weight for a link $p_{n,k}$ as a linear combination of the updated weight value and the previous value of the updated weight.

6. A method according to claim 1 wherein said determining whether a link should be maintained includes comparing a first value ($\Delta C_0(n,k)$) on decreasing a weight ($p_{n,k}$) for a link to a minimum value and a second value ($\Delta C_1(n,k)$) for increasing a weight for a link to a maximum value to determine the effect of not maintaining said link from said node.

7. A method according to claim 1 wherein said inequality measure (E_n) for a node is a function of the number of neighbours of a node and a weighted mean (b_n) or variation (c_n) in said dissimilarity measures.

8. A method according to claim 1 wherein said inequality measure (E_n) for a node is a function of the number of neighbours of a node, the dissimilarity measures between the node and each of its neighbour nodes and the weights for each link between the node and each of its neighbour nodes.

9. A method according to claim 7 or 8 wherein said inequality measure E_n for a node comprises: $\mathrm{E_n = c_n/(b_n \sqrt{|N(v_n)|})}$

where
$$b_n = \frac{1}{|N(v_n)|}\left(\sum_{k'\in N(v_n)} p_{n,k'} D_{n,k'}\right)$$
$$c_n = \sqrt{\frac{1}{|N(v_n)|}\sum_{k'\in N(v_n)} \left(p_{n,k'} D_{n,k'}\right)^2} .$$

10. A method according to claim 6 wherein said first value comprises:
$$\Delta C_0(n,k) = \left|\frac{E_n(p_n^*) - E_n(p_n^0)}{E_n(p_n^*)}\right| + \left|\frac{E_k(p_k^*) - E_k(p_k^0)}{E_k(p_k^*)}\right|$$

and said second value comprises:
$$\Delta C_1(n,k) = \left|\frac{E_n(p_n^*) - E_n(p_n^1)}{E_n(p_n^*)}\right| + \left|\frac{E_k(p_k^*) - E_k(p_k^1)}{E_k(p_k^*)}\right|$$

where $p_n^* = p_{n,k}$; and $p_n^x = \begin{cases} p_{n,k} \, where \; n \neq k \\ x \; where \; n = k \end{cases}$.

11. A method according to claim 1 wherein step d) is performed only in response to said observations changing by more than a given amount.

12. A method according to claim 1 wherein steps d) is performed iteratively until said weight for a link begins to converge to a given value.

13. A method according to claim 1 further comprising the step of: g) responsive to said node determining it can represent nodes of said partition, communicating with other

representative nodes of said network to determine if said node can represent other representative nodes of said network.

14. A method according to claim 13 wherein said determining if said node can represent other representative nodes of said network comprises performing steps a) to f) with neighbouring representative nodes.

15. A method according to claim 1 wherein said step of determining said inequality measures comprises one of receiving or calculating at said node (v_n), respective inequality measures (E_k) for each neighbour node ($N(v_n)$) of said node within said network.

16. A method according to claim 1 wherein said weights for each link have a value ranging from 0-1.

17. A method according to claim 1 comprising: responsive to the number of links maintained by said node being greater than the number of links maintained by any node of said partition to which said node maintains a link, determining said node can represent said nodes of said partition.

18. A node within a network operable to communicate with at least one neighbouring node and arranged to operate the method of any previous claim.

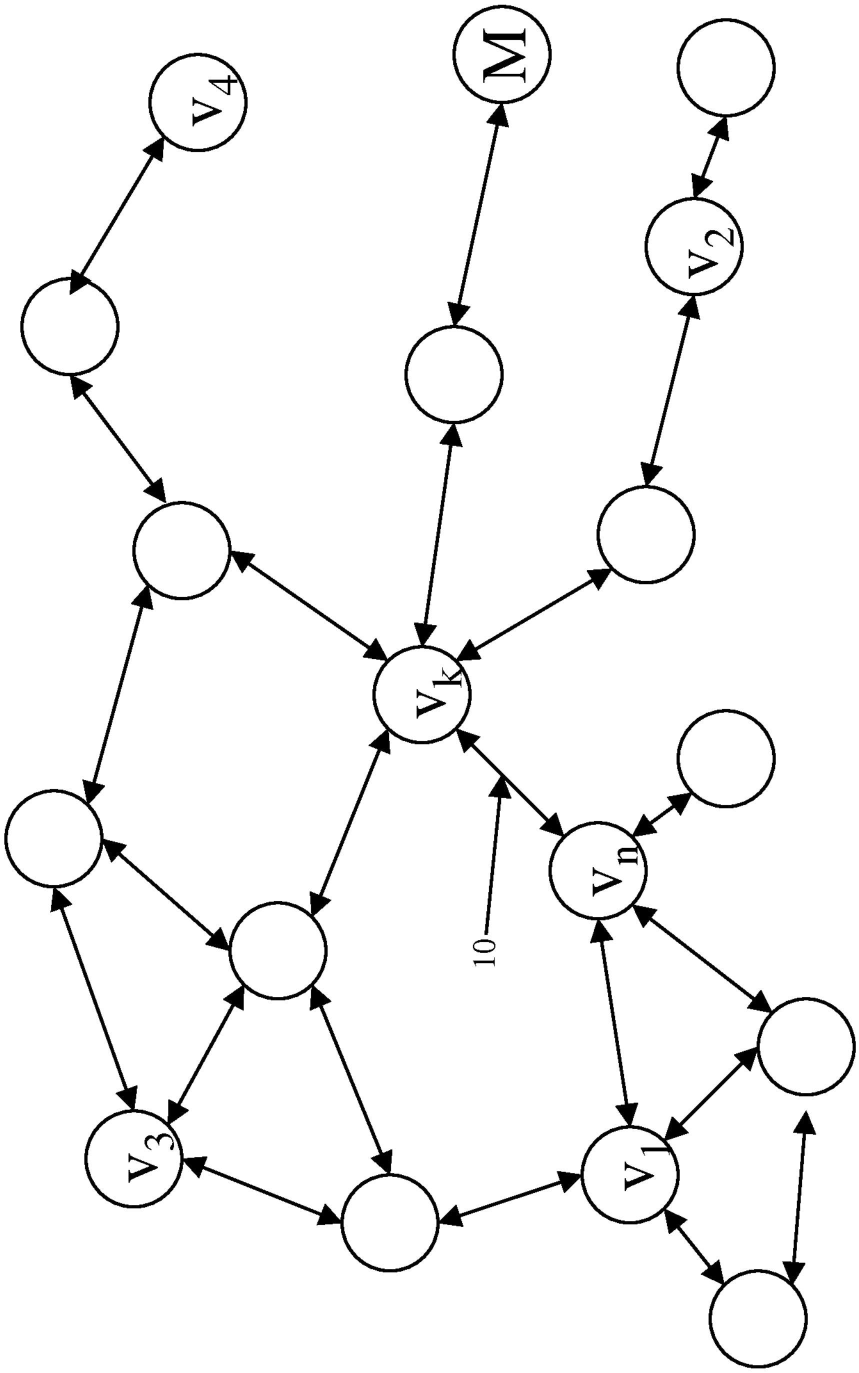

Figure 1

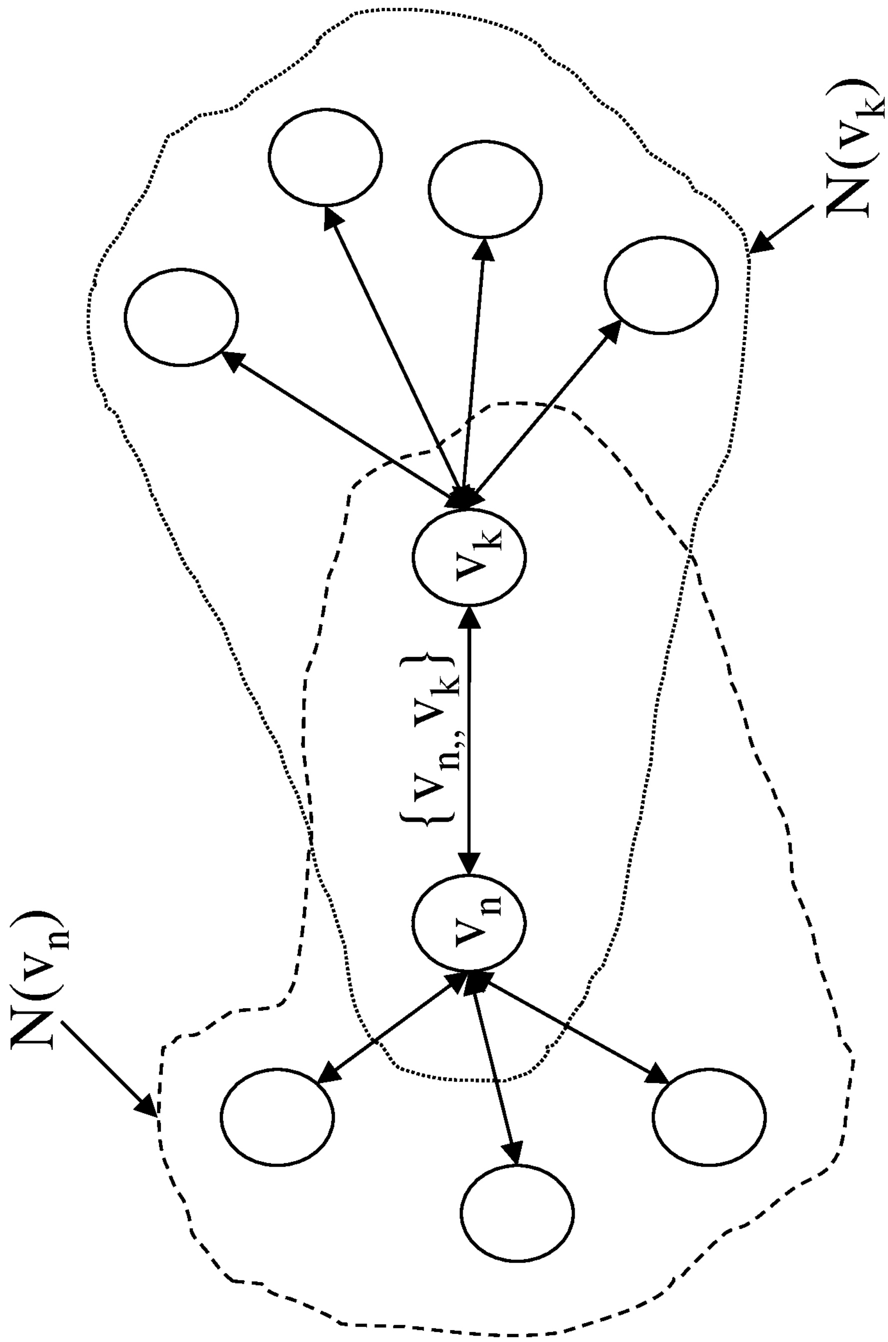

Figure 2

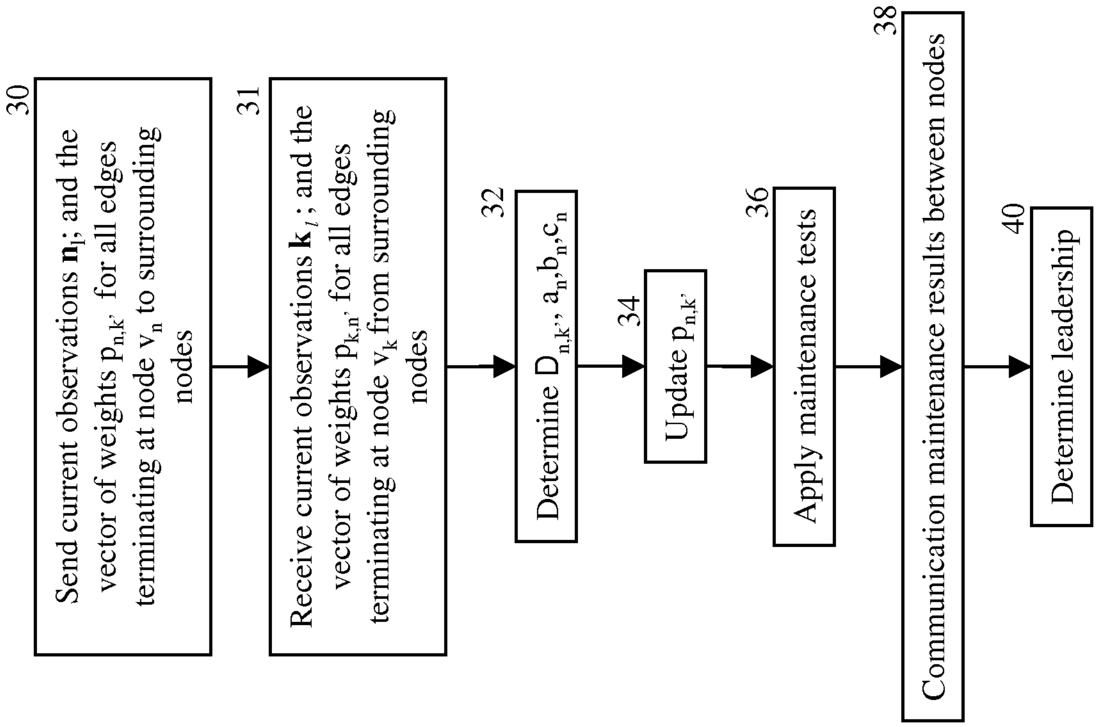
30
Send current observations $\mathbf{n}_l$; and the vector of weights $p_{n,k'}$ for all edges terminating at node v_n to surrounding nodes
31
Receive current observations $\mathbf{k}_l$; and the vector of weights $p_{k,n'}$ for all edges terminating at node v_k from surrounding nodes
32
Determine $D_{n,k'}$, a_n,b_n,c_n
34
Update $p_{n,k'}$
36
Apply maintenance tests
38
Communication maintenance results between nodes
40
Determine leadership

Figure 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/062464

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F17/10 H04L29/08 H04W40/32 H04L12/56
ADD.

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)
G06F H04L H04W

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SAEED EBADI ET AL: "A new Multi-Hop and Hierarchical Clustering algorithm for energy saving in wireless sensor network", BROADBAND NETWORK AND MULTIMEDIA TECHNOLOGY (IC-BNMT), 2010 3RD IEEE INTERNATIONAL CONFERENCE ON, IEEE, 26 October 2010 (2010-10-26), pages 1102-1105, XP031889271, DOI: 10.1109/ICBNMT.2010.5705260 ISBN: 978-1-4244-6769-3 section 5; abstract -----	1-18

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[X] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 August 2012	17/08/2012

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DAWEI XIA ET AL: "Near-Optimal Node Clustering in Wireless sensor Networks for Environment Monitoring", ADVANCED NETWORKING AND APPLICATIONS, 2007. AINA '07. 21ST INTERNATIONAL CONFERENCE ON, IEEE, PI, 1 May 2007 (2007-05-01), pages 632-641, XP031095356, ISBN: 978-0-7695-2846-5 section 4; abstract -----	1-18
X	IMBRIGLIO L ET AL: "DSVCA: A novel distributed clustering algorithm for Wireless Sensor Networks based on statistical data correlation", ULTRA MODERN TELECOMMUNICATIONS&WORKSHOPS, 2009. ICUMT '09. INTERNATIONAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 12 October 2009 (2009-10-12), pages 1-6, XP031574399, ISBN: 978-1-4244-3942-3 sections I.D, III and IV -----	1-18