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Multi-Criteria Analysis and Advanced Comparative Study of Self-Organization Protocols in Wireless Sensor Network

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Abstract: Nowadays, Wireless Sensor Networks (WSN) play a crucial role in various fields such as the army, health, the environment and so on. Emerging technologies such as the internet of things, smart applications and smart grids stimulate the deployment of autonomous, self-configuring, large-scale Wireless Sensor Networks (WSNs). These sensors which are small nodes, collect data in a wellfield and transfer it to a new sink where all data waiting to be exploited by applications (web, mobiles, ...,) are stored. These new sensors have limitations which must be taken into consideration when deploying a WSN network, especially their strictly limited energy. Thus, in order to efficiently use the energy of these nodes to improve and increase the lifetime of the entire network and reduce the energy consumed during data transmission and processing, several self-organization algorithms have been proposed to create different network architectures based on required applications. In this research, we will study and examine the various WSN-based self-organization algorithms, highlighting their principles in order to compare them according to different metrics and on multiple requirements such as load balancing, energy efficiency, complexity of the algorithm, ..., etc. To perform this multi-criteria comparison, we will use the ROC (Rank Order Centroid) multicriteria analysis method to make the decision when designing and implementing a new efficient and effective self-organization algorithm that will meet all metrics and to all criteria in order to create a performant and sustainable WSN network.

Key words: Wireless sensor networks, network architecture, self-organization, energy efficiency, load balancing, multi-criteria analysis method (ROC)

INTRODUCTION

Micro Electromechanical Systems technology (MEMS) and wireless communication have recently seen tremendous progress and growth which has allowed the development of small-scale wireless sensors with limited energy resources, low storage capacity and low power communication (Kalantary and Taghipour, 2014; Lan and Mehmet, 2010; Akyildiz *et al*., 2002). These wireless sensor nodes are deployed in an area of interest by forming WSN wireless sensor arrays which detect and collect the information to be transferred to the Base Station (BS or sink) as illustrated in Fig. 1. This information will then be sent to the user via external networks (ethernet, WiFi, 3G/4G, satellite, ...,). The wireless sensor nodes are composed of different units which themselves are composed of different modules as illustrated in Fig. 2.

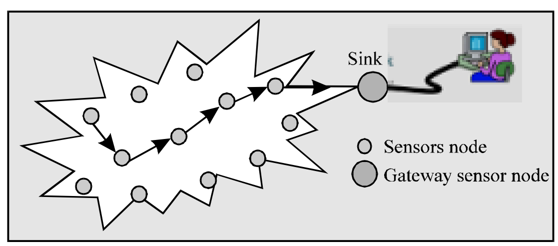

Fig. 1: General architecture of a WSN

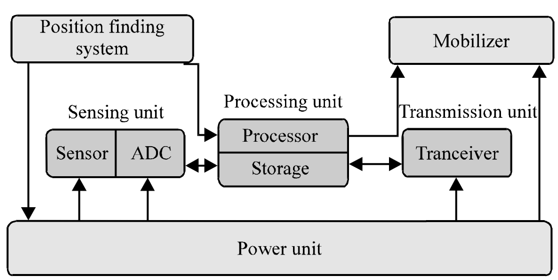

Fig. 2: Internal architecture of a sensor

The detection or sensing unit which consists of two modules: a sensor which makes it possible to detect the information in the field according to the phenomenon to be monitored and the characteristic of the sensor

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(Ex: the presence of an object, temperature, humidity, pressure, ...,) and an Analog-Digital Converter (ADC) which communicates with the processing unit to transfer the detected information:

- The processing unit for saving and processing the data collected from the field
- The communication unit which transmits and receives data from the outside
- The energy unit which is responsible for feeding the node

Sensor nodes are individual nodes that know nothing about the network and do not have an existing fixed infrastructure, they are often totally decentralized. Then, these nodes have to organize themselves, unlike traditional wired networks in an autonomous way to form a network topology, so that, they can communicate and transfer the detected data to the sink (Sirsikar *et al*., 2014). That is to say, before starting to transfer the detected data, all the sensor nodes that are in the capture zone will self-organize themselves in an autonomous and efficient way to build a solid topology which considers their limits in energy, storage capacity, processing and transmission power (a short radio range) and ensures the reception of data by the sink.

For this reason, several algorithms have been developed in recent times which allow the sensor nodes to self-organize and adopt a topology that will be the basis on which the data will be transferred to the base station and also an optimal structure to increase the life of these nodes and at the same time of the network.

These topologies and network architectures are divided into three types of categories (Al-Karaki and Kamal, 2004) flat architecture, location architecture and hierarchical architecture (Fig. 2). In a flat architecture and location, all nodes have the same role in the network and they have the same resources whereas in a hierarchical architecture, the network is divided into several levels of responsibility and the nodes do therefore not play the same role. The main techniques used in the hierarchical architecture are the construction of clusters or clustering, chains and trees (tree structure).

The algorithms based on the hierarchical architecture are more efficient than those based on the flat architecture on the location architecture in terms of energy consumption since they make, it possible to minimize the total aggregate transmit power on the nodes in the selected path and to balance the load between the nodes to extend the service life of the network (Walters *et al*., 2007).

The main objective of this study is to examine the different hierarchical algorithms used to form and construct network architectures and topologies in the form of clusters or chains or trees for WSN based on different criteria and metrics while considering the constraints of the sensor nodes to provide a long service life for the network and to balance the energy consumption and the load between these nodes.

MATERIALS AND METHODS

Chain-based algorithms: The chain-based algorithms are based on the construction of a string from all the nodes scattered in the zone of interest in order to transmit all the detected information to the base station. Among these algorithms the most common are PEGASIS (Lindsey and Raghavendra, 2002; Tan and Korpeoglu, 2003) is a protocol based on the construction of the chain. In each round, a leader is elected to lead the construction of this chain (Fig. 3). The construction of the chain begins with the node furthest from the base station.

The global knowledge of the network by the nodes begins with the node furthest from the base station and it is done with the choice of the nearest neighbors by transferring the distance and information of the neighboring node until covering all the nodes. This procedure is also carried out in the opposite direction so that all the nodes will have a global vision on the whole network (Fig. 4).

The data transmission begins with the leader which sends a token to both ends to send it their detected data (Fig. 5). In each round, a new leader is chosen to rebuild a chain and collect the detected data.

EECB (Yu and Song, 2010) is a protocol based on the construction of a chain of nodes which uses the same algorithm as PEGASIS except that they avoid the formation of the long links between the nodes (Fig. 6) and it chooses the leader on the basis of a residual energy formula and the distance between the base station and each sensor node in the network (Eq. 1):

$$d_i = \sqrt{(x_i - x_{BS})^2 + (y_i - y_{BS})^2}$$
$$Q_i = \frac{E_{residual\text{-}i}}{d_i} \quad (1)$$

PDCH (Linping *et al*., 2010), PEGASIS double cluster head is a new protocol that uses the same notions as PEGASIS. It proceeds in two phases. In the first phase, it creates several levels in the form of concentric circles whose center is the base station. In the second phase, it elects at each level two leader (or two cluster heads) to build the chain at the level. The red circles show the

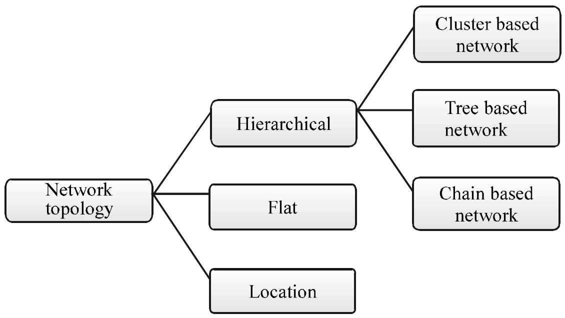

Fig. 3: Classification of network topologies

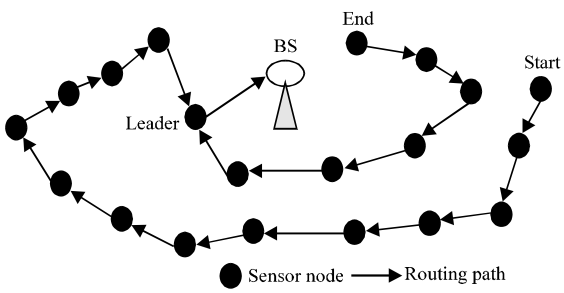

Fig. 4: Illustration of the PEGASIS protocol

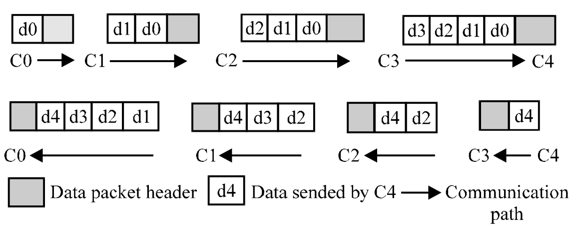

Fig. 5: Global network knowledge procedure

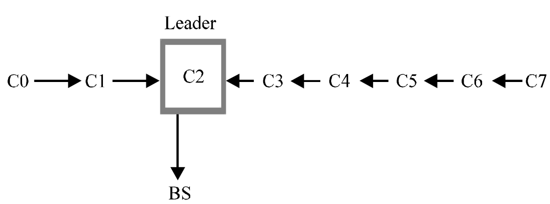

Fig. 6: Transmission of data to the leading node

nodes whose number of branches is >2. These notes are therefore more likely to be selected to be a group leader than the other notes of each level.

The selection of cluster heads is based on the same Eq. 1 to choose two cluster heads (main cluster head and secondary cluster head) in each level among the possible cluster heads available (red circles). One of the two CHs collects data of the chain in its level and sends it to the other CH which merges the chain of its level with the one it receives from the level to which it is

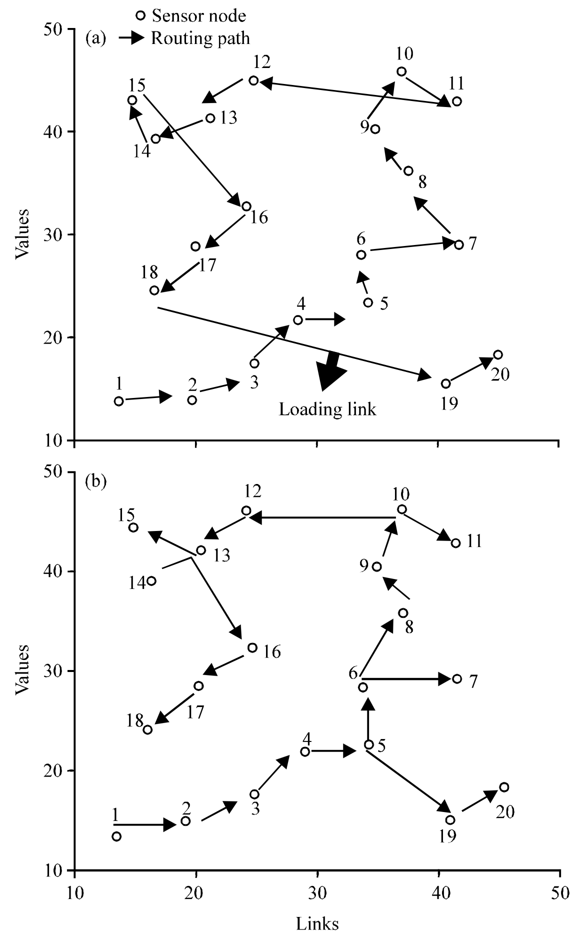

Fig. 7: a) PEGASIS with Long Link (LL) and b) EECB without Long Link (Ll)

adjacent if it exists. The latter then sends the result chain to the other adjacent level but closer to the base station. This process is initiated at the furthest level and is repeated until the global chain arrives at the base station (Fig. 7).

CCM is a new algorithm applied in an organized and well distributed network where each node has uniform coordinates (i, j) (i = the number of the string and j is the number of the node in this chain) (Tang *et al*., 2012).

This protocol is based on the construction of the chains whose leaders form a cluster. In each round, chain leaders are chosen and among them, a cluster head is elected to transmit to the base station his chain and all other chains received from other leaders.

ECCP is a hybrid hierarchical protocol based on the formation of chains in clusters. The selection of CH is based on the calculation of the weight of each node in a radius r and the node with the highest weight is elected a CH. Each CH forms its own cluster and the farthest node begins constructing the chain in the latter using the same processes as PEGASIS (Sheikhpour *et al*., 2012).

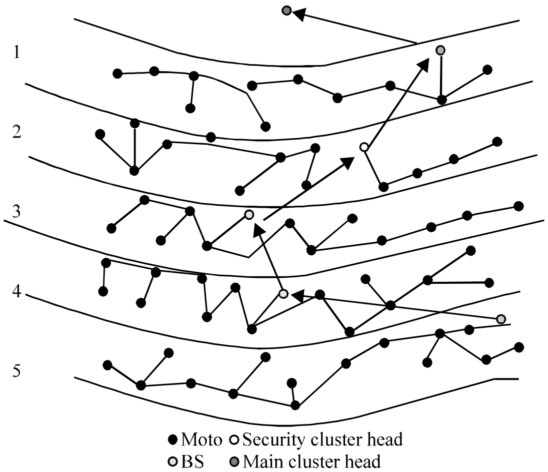

Fig. 8: Process of chain construction in PDCH

The construction of clusters is composed of two stages, the first is the selection of CHs and the second is the formation of clusters. In the step of selecting the CHs, each node broadcasts a message in a radio that contains its location and its residual energy. Each node that receives this message, it realizes the update of its table of neighborhood which contains the distance to its neighbors and it calculates its weight. After calculating the weight, each node sends its weight broadcast to all the nodes that are found in its radio r. The node with the bigger weight is elected a CH in his radio:

$$\text{Weight}_i = \text{RE}_{i*} \sum_{j=1}^{\text{number of neighbours}} \frac{1}{\text{dist}^2(v_i, v_j)} \qquad (2)$$

Where:

RE_i = The residual energy of the node i

dist (v_i,v_j) = The distance between the node i and the node j (for all the neighbors of the node i in his radio r)

SCBC is a protocol that is based on the creation of clusters in the surveillance zone and in each cluster a chain is constructed that contains a leader which is a CH or SCH (Secondary CH) (Tan and Viet, 2015). The division of the cluster surveillance zone is carried out by applying an algorithm which calculates the angular value of each cluster and also the angular angles of each node and after it decides the nodes that belong to each cluster. The number of nodes of each cluster is fair whose clusters have the same number of sensor nodes (Fig. 8).

Once the clusters are formed, the CHs selection step in each cluster begins. This step is based on the residual energy of each node in a cluster and a value of the cost that has a relation to the distance of the base station. If a node has a residual energy higher than Eavg and has a maximum cost then this node is elected as a CH. The

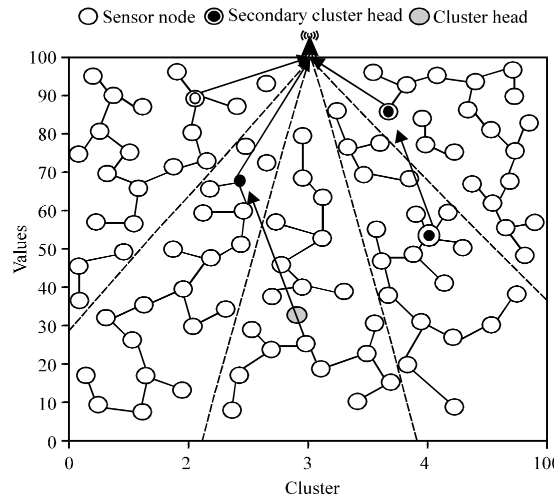

Fig. 9: Network topology with SCBC

selection of the secondary CH in each cluster is carried out in each round and is based on the average distance between the CHs selected in the previous step and the base station with the base station (R/2) range and Also with the number of SCHs which must not exceed k/2 (k is the cluster number). With these conditions, the CHs will be far from the base station and the SCHs will be closer to the base station and will work as much routers for these remote CHs (in a cluster there must not be a CH and SCH in the same round).

Pegasis multi-chain is a protocol based on the construction of chains in 4 regions of the surveillance zone (Patel and Munjani, 2016). In a area 100×100 with 100 nodes, each zone will contain 25 nodes in a dimension 50×50 and a base station. In each region, a node farthest from the BS of its region begins to create a chain whose leader is chosen in each round in a random manner (Fig. 9).

Tree-based algorithms: In this part, we will study some of the most used algorithms which are based on the self-organization of all the nodes that exists in the capture area to form a more suitable tree topology to transfer the collected data to the base station.

PEDAP is a hierarchical protocol based on tree construction using the prim spanning tree minimal algorithm which performs the branch cost calculation to know the optimal parent node of each node (Tan and Korpeoglu, 2003) (Fig. 10). The calculation is carried out by the base station.

The base station sends to each node in the network information such as: the parent node, the child nodes and the time slot number to send the data to the root node.

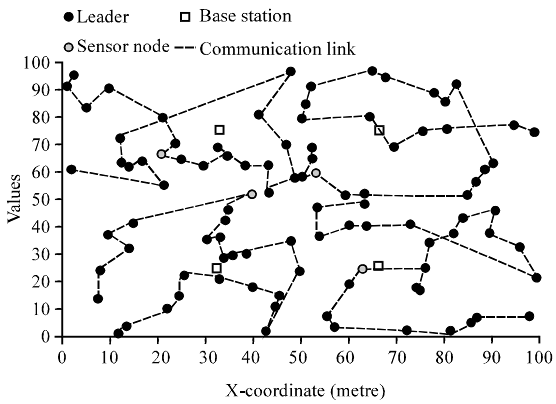

Fig. 10: PEGASIS multi-chain architecture

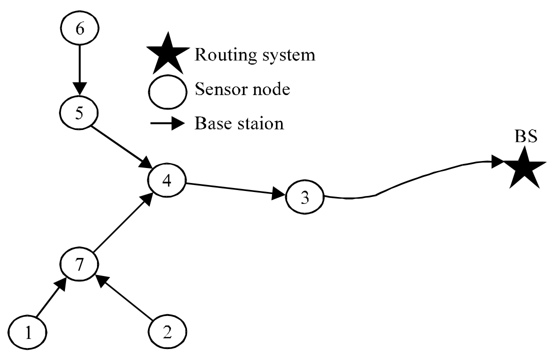

Fig. 11: The tree of a minimum spanning tree

TREEPSI is a protocol that works with rounds (Satapathy and Sarma, 2006). The construction of the tree begins with a node i which is the root and from this root the procedure of building the tree begins (Fig. 11). All the nodes in the monitoring zone have uniform initial energy, they have the location information and also have the ability to adapt the transmission power according to the distance at which the destination is located. The selection of node i as a root node is random (such as PEGASIS in turn) but this node must have a residual energy sufficient to transmit the data to the base station (the nodes know the location of the base station).

TBC is a protocol based on the construction of trees in clusters (Kim *et al*., 2010). In each round, nodes are elected as CHs (root nodes) and trees will be built in each cluster from these nodes.

Once the CHs form the clusters using the same procedure as LEACH, these CHs have become roots in each cluster. Each root detects the member node farthest from its cluster and its distance is named dmax. Once the value dmax is determined, then divide the cluster to levels

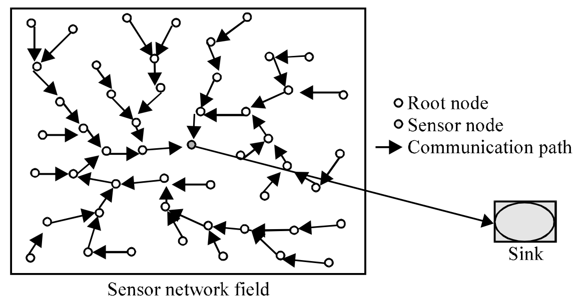

Fig. 12: Construction of the tree in TREEPSI

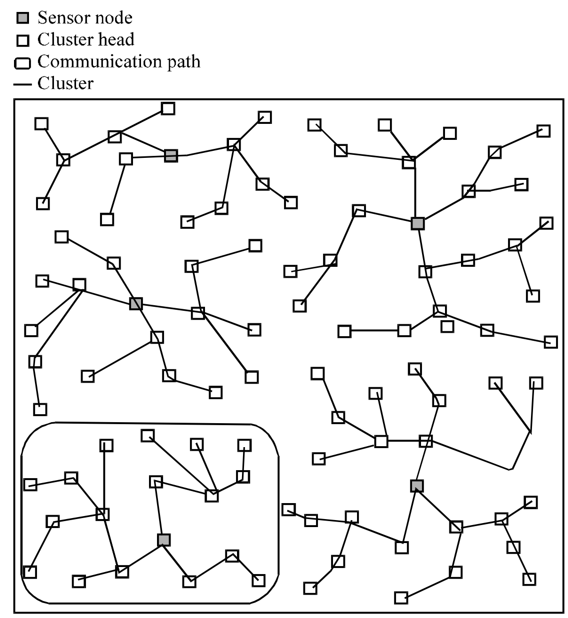

Fig. 13: The network topology with TBC

according to the alpha value, the number of levels in a cluster is dmax/alpha. These levels are circles around the root node. Each node in a level i detects the nearest neighbors and which are in level i-1 (Fig. 12).

Each node sends this detected data to its parent node, this node receives data from the child nodes, fusions them and passes them to the parent node in the cluster. When the data of all nodes that are members of the cluster are received by the CH (root node), it sends them to the BS.

TRP is a protocol based on the construction of a tree where the base station is the root node (Gong and Jiang, 2011). In each round tree formation begins with each node that searches for a parent node closer to the base station. This procedure is performed by all nodes in the network to build the desired structure before to begin transferring data from the most remote nodes to the root node (Fig. 13).

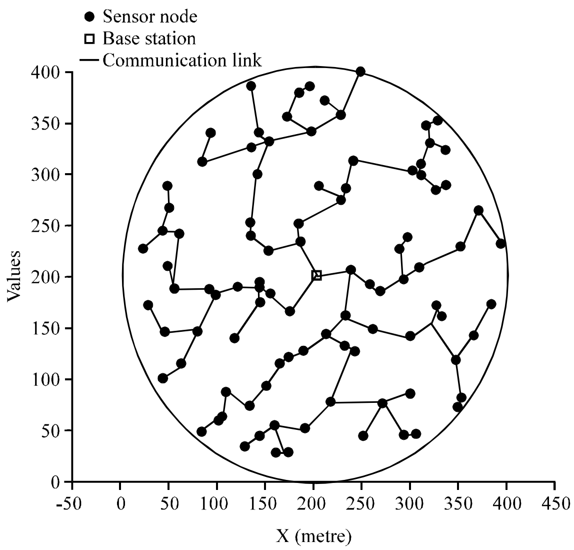

Fig. 14: Tree construction with TRP

GSTEB is a protocol based on the same procedures as TRP except that the base station does not play the role of the root node (Han *et al*., 2014). In this protocol, the root node is chosen in each round by the base station based on the highest residual energy of the nodes and this information is broadcast to all nodes of the network so that each node selects its parent node according to the distance with the root node (Fig. 14).

There is another case in the GSTEB protocol where the base station plays the role of the root node. In this case, all nodes in the network know that the root node is the base station. Then, each node looks for a relay node that is a neighbor node closer to the root than itself and that has a higher residual energy of all these neighbors (which will cause minimal consumption between all neighbors, one of these consumption is the sum of the consumption of the sensor node towards a relay node and that of the relay node to BS), this node will be selected as the parent node. If the sensor node can not find an appropriate parent node, it will transmit its data directly to BS (Fig. 15).

SSTBC is a protocol based on the creation of clusters in the zone of interest and in each cluster, it will have a node CH which will play the role of the root to form a minimum spanning tree using the prim algorithm (Tan and Viet, 2015). This protocol also uses a process to minimize the energy for nodes that relies on disabling the radio from a number of unnecessary nodes that can detect the same information to suppress the redundant data. In this protocol, the base station is responsible for the formation of clusters, sleep planning and the construction of minimum spanning trees.

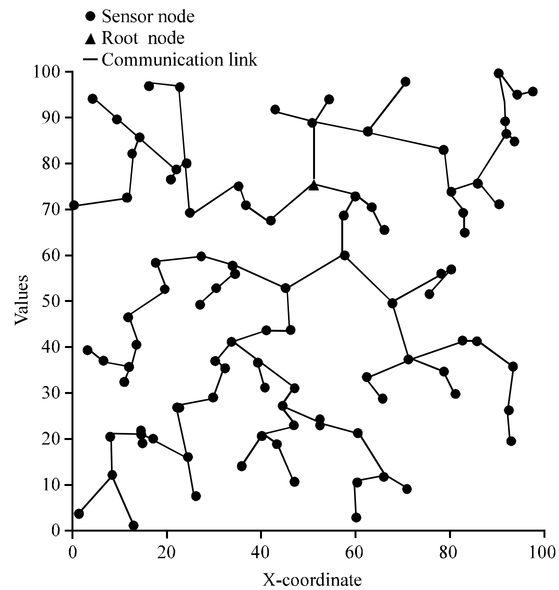

Fig. 15: Network topology in GSTEB with a different root node than the base station (bs located at (50, 175 m)

In each round, all nodes send a message to the base station to inform them of their locations and residual energies. The base station divides the zone of interest into 5 clusters, only in the first round. After each round, the base station partitions the nodes detection area to virtual square grids whose size is less than a distance threshold value. The candidate node with the highest residual energy will be in active mode and other nodes will be in standby mode in the same grid for the current round. In each round, the base station selects a CH in each cluster (Fig. 16). The selection is based on the calculation of the average energy and also of a cost, the node in a cluster that has a residual energy higher than that of the average energy and also has the highest cost, this node is elected like a CH in this round. Once the zone of interest is divided into grids and 5 clusters and in each cluster a CH is selected. So, the node CH will play the role of the root to build minimum spanning tree.

Cluster-based algorithms: In this family of algorithms, sensor nodes self-organize to form clusters. Each cluster has a cluster head which is responsible to transmit all data from its cluster to the base station. The most used algorithms of this family are:

LEACH (Heinzelman *et al*., 2000) is the first algorithm based on hierarchical clustering whose CHs Cluster Heads) is are selected randomly and in turn according to the threshold T(n) given by:

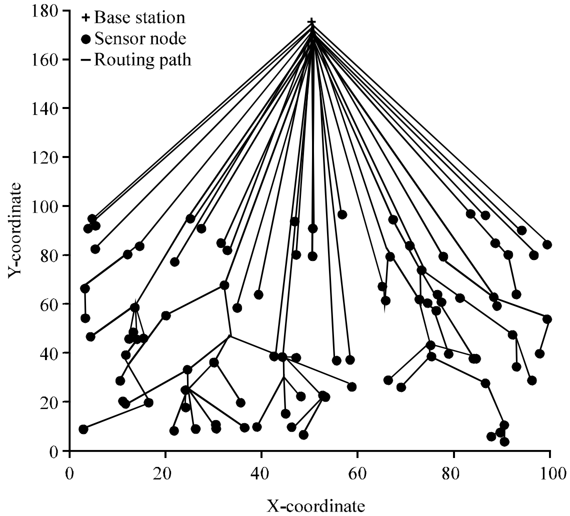

Fig. 16: Network topology in GSTEB with base station as root

$$T(n) = \frac{P}{1-P\times(r \bmod \frac{1}{P})} \forall n \in G$$

$$T(n) = 0 \forall n \notin G$$

Where:

P = Desired percentage of cluster heads (p = 0.05)
r = Current round
G = Set of nodes that have not been cluster-heads in the last 1/P rounds

Once the CHs are chosen, they start sending advertising messages to build the clusters. Each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement (Fig. 17).

EECS is a protocol based on the formation of clusters using almost the same procedures as LEACH, except that the selection of CHs is different (Ye *et al*., 2005). The choice of the CH is based on the residual energy of all the candidate nodes in the network. This energy is calculated by the base station when it receives the message "Hello" from the different nodes.

DAIC is a protocol that uses two zones to build clusters in the network (Gautam and Pyun, 2010). The zones are created based on the vertical distances between each sensor node in the network and the base station. These distances are computed by the base station. The zones are divided into primary zone which contains CHs and CH gateway and the secondary zone contains only

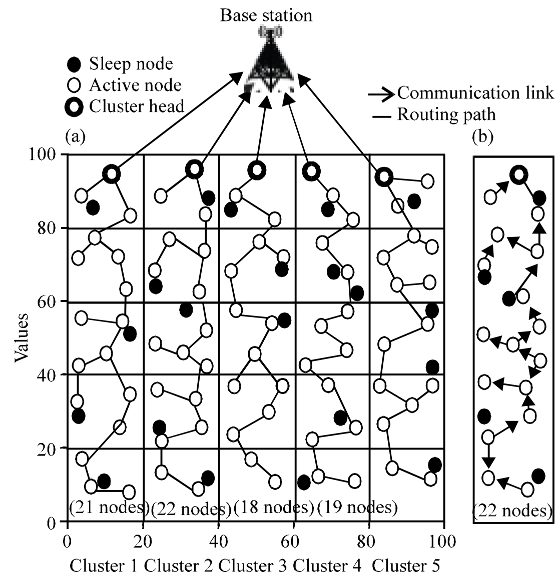

Fig. 17: a) The 100-node in 100×100 m network with virtual grid 5×5 m and b) An example for minimum spanning tree

Chs. The Chs of the primary and secondary zones form clusters in their zones and the gateway CHs make connections between them to the base station (Fig. 18).

CBRP is a protocol based on the construction o f clusters using the CHs selected with the same procedure as LEACH (Zarei *et al*., 2010). To transmit the data collected by the CHs to the base station, a tree is created by them using the minimum spanning tree.

EADUC is a hierarchical protocol that uses the same algorithm as LEACH to select CHs and clustering and also uses the concept of tree mapping between CHs to transmit data to the base station (Yu *et al*., 2011). The transmission of data from the CH to the base station is based on calculating the distance between the CH and the BS and the distance DIST_TH (this algorithm defines an appropriate TH DIST to ensure that all CH can find their next hop). In the case where the distance from CH to BS is smaller than DIST TH, then the CH communicates directly with the BS and defines the BS as its next jump. Otherwise, it communicates with the BS using another CH.

EADC is a protocol based on the construction of clusters with the same algorithms and procedures as the EADUC protocol (Yu *et al*., 2011). The only difference is that the CH selects the next CH with a higher relay value and closer to the BS than its next hop. If several neighboring Chs have the same "Relay" value, CH

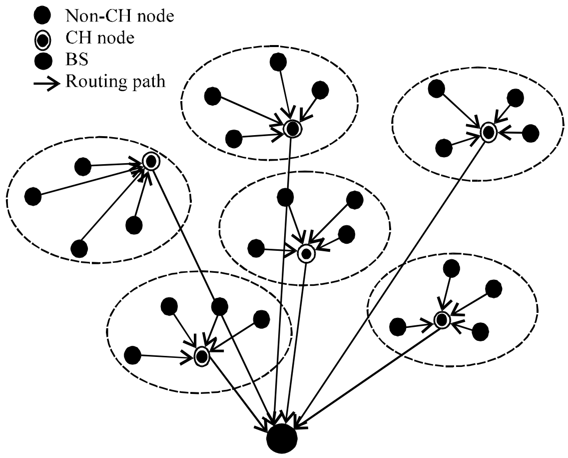

Fig. 18: Architecture LEACH

chooses the one with the larger d (sj, BS) value to avoid premature death of CHs close to the BS due to the excessive transfer of data.

MH-LEACH (Neto *et al*., 2014; Wang *et al*., 2009): The principle of this protocol is based on the selection of the CHs to form clusters according to the following threshold T (n):

$$T(n) = \frac{p}{1\text{-}P\times(r \bmod \frac{1}{p})}Q$$

$$\left\{Q = \{\frac{E_{residual}}{E_{intial}} + (1\text{-}\frac{E_{residual}}{E_{intial}})\frac{N\_num/P}{H\_times+1}\right\}$$

Where:

$E_{residual}$ = The node current energy
$E_{initial}$ = The maximal energy of the node
N_num = The number of adjacent nodes
H_times = Represents the times of the node has been selected as cluster head

Once the CHs are selected and the clusters are formed, the transmission of the data to the base station uses the creation of the initial and final routing tables according to the RSSI power received by the closest neighbors on the one hand and on the other hand according to the distance of the base station to ensure the sense of data transmission (Fig. 20a, b).

NEAHC (Ke *et al*., 2016) is a protocol based on the formation of clusters by the selection of CHs in each round using the threshold Th which is based on the residual energy:

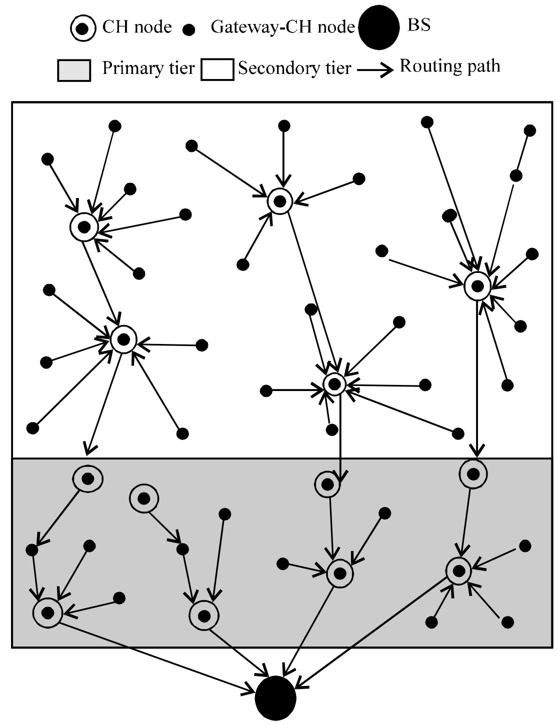

Fig. 19: The network topology in DAIC

$$T_h = \left\{\frac{P}{1\text{-}P\left[r \bmod (\frac{1}{p})\right]}\frac{1}{1+e^{-\alpha E_i}};\ n \in G\right.$$

Where:

p = The desired percentage of cluster heads
r = The current round
G = The set of nodes that have not become the cluster head in last 1/p rounds

">0 is a constant, 1/(1+e-"E_i) is a monotone increasing function about E_i: If the chosen random number less than Th, then n becomes the cluster head for the current round r. This function of threshold makes the nodes with more residual energy have a better chance to become the cluster heads, thus, balancing the energy consumption of the network.

After the cluster formation, each CH selects the data transmission path to the base station using the residual energy of all neighboring CHs and also the transmission cost. The chosen CH is either the direct communication to the BS or the communication to an optimal neighboring CH according to the residual energy and the cost of communication (Fig. 19).

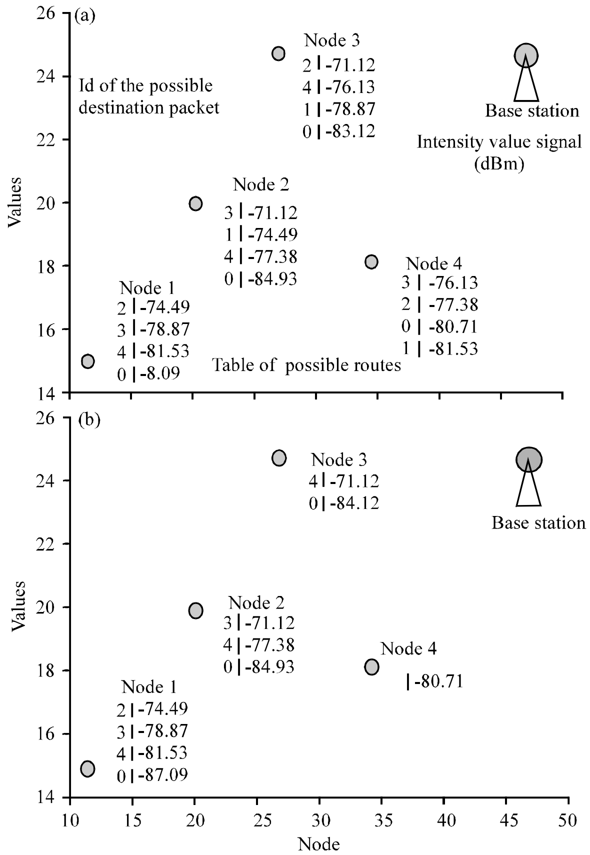

Fig. 20: Initial and final routing tables

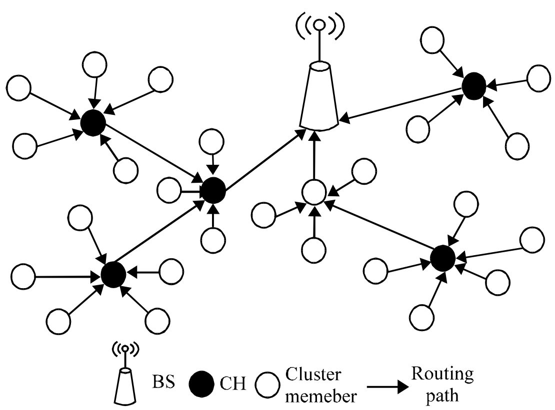

Fig. 21: Multi-hop network topology in NEAHC

Figure 20 and 21 the NEAHC protocol consumes a lot of energy resources in the calculations made to look for the optimal neighbor for each CH knowing that these CHs remain the most of the times turn on to collect data from their cluster which will cause their depletion to abruptly and also cause a decrease in the lifetime of the network. On the other hand, this protocol uses an adequate and efficient formula for the selection of the CHs in each round which improved the balance of the load between the different nodes of the network and also increases the stability of the system.

RESULTS AND DISCUSSION

Comparative study: In this study, we will carry out a comparison study based on the ROC multi criteria analysis method between the different algorithms studied in this study according to different metrics and performance criteria.

Comparison between the different algorithms studied according to their families on the basis of different metrics: In order to compare the different types of self-organization algorithms studied in the study, we propose some criteria and metrics that describe the behavior and architecture of wireless sensor networks and also affect their limitations and deployments as load balancing, energy efficiency, scalability, stability, delivery time and complexity of the algorithm (Liu, 2012; Abbasi and Younis, 2007; Boyinbode *et al*., 2011; Haneef and Zhongliang, 2012).

Table 1 shows the comparison between the different algorithms studied according to their families on the basis of different criteria using a conventional notation system.

This system is used for the purpose of a better and an easy understanding of the study and does not provide a standardized notation for the comparison.

Compariso between the different self-organization algorithms studied using the ROC multicriteria analysis method: In this comparative study, we will compare the different self-organization algorithms studied according to the most used criteria and metrics (load balancing, scalability, delivery time, complexity of the algorithm energy efficiency, stability) using the ROC multicriteria analysis method. This method is based on the calculation of the score of each self-organization algorithm studied according to the criteria and the chosen metrics. To perform this calculation, we first have to determine the weight associated with each metric for this reason we used a multicriteria analysis method (Roy, 2005). Multi-Criteria Decision Analysis (MCDA) is a powerful and critical tool and method that can be applied to many complex decisions. It allows in delicate and complex cases to properly analyze the phenomena or the systems in order to take a definitive decision to implement an action or a change by obtaining solutions that meet the criteria chosen in principle.

Table 1: Comparative table of different algorithms studied according to their families on the basis of different metrics

	The performance metrics					
Algorithms by family	Load balancing	Energy efficiency	Scalability	Stability	The delivery time	The complexity of the algorithm
Chain-based algorithm						
PEGASIS	Moderate	Low	Very Low	Moderate	Very long	High
EECB	Moderate	Moderate	Very Low	Moderate	Very long	High
PDCH	Moderate	Moderate	Long	Low	Long	High
CCM	Low	Moderate	Moderate	Moderate	Moderate	Low
ECCP	Low	Low	Moderate	Low	Long	High
SCBC	High	High	Moderate	Low	Long	High
PEGSIS multi chain	Low	Low	Moderate	Low	Moderate	Moderate
Tree-based algorithms						
PEDAP	Moderate	High	High	High	Very long	Low
TREEPSI	Low	Moderate	Moderate	Low	Very long	Moderate
TBC	Moderate	Moderate	Moderate	Moderate	Short	Moderate
TRP	High	Moderate	Low	Low	Long	High
GSTEB	Low	Moderate	Moderate	Low	Long	Moderate
SSTBC	Low	Low	Moderate	Moderate	Moderate	Very high
Cluster-based algorithms						
LEACH	Moderate	Moderate	Low	Moderate	Very short	Low
EECS	Moderate	Low	Low	Moderate	Short	Moderate
DAIC	Low	Moderate	Moderate	Moderate	Moderate	High
CBRP	Moderate	Moderate	Low	Moderate	Moderate	High
EADUC	Low	Low	Low	Low	Short	High
EADC	Moderate	Low	Low	Moderate	Moderate	High
MH-LEACH	High	Moderate	Moderate	Moderate	Moderate	High
NEAHC	High	Moderate	Moderate	Moderate	Moderate	Very high

Table 2: Calculation of criteria weights

Variables	Load balancing	Energy efficiency	Scalability	Stability	The delivery time	The complexity of the algorithm	Control
R1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.00
R2	0.7500	0.2500	0.0000	0.0000	0.0000	0.0000	1.00
R3	0.6111	0.2778	0.1111	0.0000	0.0000	0.0000	1.00
R4	0.5208	0.2708	0.1458	0.0625	0.0000	0.0000	1.00
R5	0.4567	0.2567	0.1567	0.0900	0.0400	0.0000	1.00
R6	0.4083	0.2417	0.1583	0.1028	0.0611	0.0278	1.00
Average	0.6245	0.2162	0.0953	0.0426	0.0169	0.0046	1.00

The score is calculated according to a number of criteria according to which the list is not exhaustive. The overall score is obtained by adding the partial scores (criteria) affected by relative weights. In the analysis of decisions, this operation is called additive synthesis or aggregation. As regards the evaluation of the relative weight of the criteria, there are several methods of multicriteria decision analysis. We have selected (ROC) (Barron, 1992; Danielson and Ekenberg, 2016; Hajoui *et al*., 2015) for its simplicity and proven effectiveness. Several methods of weight selection including Equal Weights (EW) and Rank-Order Centroid (ROC) weights have been proposed and evaluated (Butler and Olson, 1999). A common finding of these studies is that ROC weights appear to be better than other strategic patterns in terms ofchoice accuracy.

This method is a simple way to give weight to a number of items classified according to their importance. Policy makers can generally classify items much more easily than giving them weight. The centroid method affects the following weights where W_1 is the largest weight of the objective, W_2 is the weight of the second most important objective and so on:

$$D = \left\{ W_1 \geq W_2 \geq, ..., W_m \geq 0 \text{and} \sum_{j=1}^{m} W_j = 1 \right\}$$

This method takes these rows as inputs and converts them into weights for each of the elements. The conversion is based on the following equation:

$$W_j = \frac{1}{m}\left(\frac{1}{j} + \frac{1}{j+1} +, ..., + \frac{1}{m}\right)$$

To begin the comparative study. First, the criteria must be ordered in descending order according to the importance of the latter: load balancing <energy efficiency> <scalability> <stability> <the delivery time> the complexity of the algorithm (Table 2). Table 3 shows the result of the weight calculation of each criterain using the following equation:

Table 3: Criteria weights

Variables	Load balancing	Energy efficiency	Scalability	Stability	The delivery time	The complexity of the algorithm	Control
Weights	0.6245	0.2162	0.0953	0.0426	0.0169	0.0046	1.00

Table 4: The score of each self-organization algorithm according to the associated criteria using the indicated notation system

			The performance metrics					
Algorithms by family	Load balancing	Energy efficiency	Scalability	Stability	The delivery time	The complexity of the algorithm	Global score	Average per family
Chain-based algorithms								
PEGASIS	5	3	1	5	1	3	4.1101	4.2962
EECB	5	5	1	5	1	3	4.5425	
PDCH	5	5	3	3	3	3	4.6817	
CCM	3	5	5	5	5	7	3.3283	
ECCP	3	3	5	3	3	3	2.9153	
SCBC	7	7	5	3	3	3	6.1551	
PEGSIS multi chain	3	3	5	3	5	5	3.0433	
Tree-based algorithms								
PEDAP	5	7	7	7	1	7	4.5967	4.5245
TREEPSI	3	5	5	3	1	5	3.4081	
TBC	5	5	5	5	7	5	4.8775	
TRP	7	5	3	3	3	3	5.9307	
GSTEB	3	5	5	3	3	5	3.6663	
SSTBC	3	3	5	5	5	1	3.4913	
Cluster-based algorithms								
LEACH	5	5	3	5	9	7	4.6961	4.7185
EECS	5	3	3	5	7	5	3.7883	
DAIC	3	5	5	5	5	3	3.7423	
CBRP	5	5	3	5	5	3	4.8007	
EADUC	3	3	3	3	7	3	3.5003	
EADC	5	3	3	5	5	3	4.3683	
MH-LEACH	7	5	5	5	5	3	6.0497	
NEAHC	7	5	5	5	5	1	6.2311	

$$W_i^{ROC} = \frac{1}{N}\sum_{J=1}^{N}\frac{1}{j}$$

The control column ensures that all weights are normalized (sum of weights = 1). Consequently, we have the weight of each criterion as shown in Table 3.

Table 4 shows the notation attributed to each self-organization algorithm according to the criteria and metrics studied. The scoring system adopted is as follows:

- Less important
- Equally important
- Moderately important
- Much more important
- Considerably more important

Table 4 also shows the overall score calculated using the following formula: global score = (0.6245*load balancing)+(0.2162*energy efficiency)+(0.0953* scalability)+(0.0426*stability)+(0.0169* the delivery time y)+(0.0046* the complexity of the algorithm). Figure 22 llustrates the results of the overall score in the form of a graph.

According to the comparative study carried out in this study is based on the study of the different types of self-organization algorithms in the WSNs using some criteria and metrics based on the multicriteria analysis method ROC, we can notice that the family which best meets performance and metric criteria is the family of clustering algorithms that allow better management of energy efficiency and also for the improvement of network life.

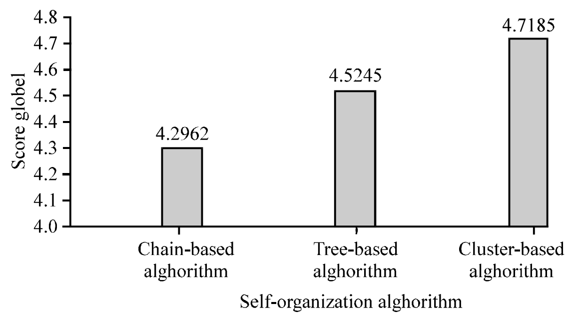

Fig. 22: The overall score as a graph

CONCLUSION

In recent years, Wireless Sensor Networks (WSNs) have achieved tremendous feat in various fields for better collaboration, deployment and efficiency in data detection by sensor nodes according to the service requested by applications. There is not a predefined infrastructure for network deployment, they use an efficient self-organization algorithm that help the sensor nodes to form an appropriate topology and transmit the sensed data to a base station.

In this study, we have carried out an in-depth study on the different types of self-organization algorithms most common in WSNs. During the analysis, we have found that several algorithms have been developed for improving energy efficiency and also increasing network lifetime by using clustering and the other algorithms have been focused in load balancing and the improvement of energy consumption in multi-hop communication using chains or trees. But the choice between protocols depends on the desired application, i.e., there can be an algorithm of a specific family (cluster, tree or chain) works very widely in a given application on the other hand another algorithm of another family can give poor results despite these better performances and these better criteria. For this reason, we will develop an approach based on self-organization algorithm that adapts to the most applications and which will give better performances.

SUGGESTIONS

This approach will be applied in the management of an intelligent parking system in order to improve the system and also facilitate the task for users to find a vacant parking space remotely in an efficient and practical way.

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