Energy 114 (2016) 647–662

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

An adaptive clustering approach to dynamic load balancing and energy efficiency in wireless sensor networks

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A R T I C L E I N F O

Article history:
Received 3 April 2016
Received in revised form
28 July 2016
Accepted 3 August 2016

Keywords:
Energy efficiency
Life time duration
Cluster-heads distribution
Load balancing
Hierarchical clustering
Wireless sensor networks

A B S T R A C T

Clustering is a well known approach to cope with large nodes density and efficiently conserving energy in Wireless Sensor Networks (WSN). Load balancing is an effective approach for optimizing resources like channel bandwidth, the main objective of this paper is to combine these two valuable approaches in order to significantly improve the main WSN service such as information routing. So, our proposal is a routing protocol in which load traffic is shared among cluster members in order to reduce the dropping probability due to queue overflow at some nodes. To this end, a novel hierarchical approach, called Hierarchical Energy-Balancing Multipath routing protocol for Wireless Sensor Networks (HEBM) is proposed. The HEBM approach aims to fulfill the following purposes: decreasing the overall network energy consumption, balancing the energy dissipation among the sensor nodes and as direct consequence: extending the lifetime of the network. In fact, the cluster-heads are optimally determined and suitably distributed over the area of interest allowing the member nodes reaching them with adequate energy dissipation and appropriate load balancing utilization. In addition, nodes radio are turned off for fixed time duration according to sleeping control rules optimizing so their energy consumption. The performance evaluation of the proposed protocol is carried out through the well-known NS2 simulator and the exhibited results are convincing. Like this, the residual energy of sensor nodes was measured every 20 s throughout the duration of simulation, in order to calculate the total number of alive nodes. Based on the simulation results, we concluded that our proposed HEBM protocol increases the profit of energy, and prolongs the network lifetime duration from 32% to 40% compared to DEEAC reference protocol and from 25% to 28% compared to FEMCHRP protocol. The authors also note that the proposed protocol is 41.7% better than DEEAC with respect to FND (Fist node die), and 25.5% better than FEMCHRP with respect to LND (last node die) while maintaining the average data transmission delay. We found also that HEBM achieved 66.5% and 40.6% more rounds than DEEAC and FEMCHRP respectively.

1. Introduction

Networks of Wireless Sensor devices are being deployed to collectively monitor and disseminate information about a variety of phenomena of interest. A wireless sensor device is a compact battery-operated device, capable of sensing physical sizes of its surroundings, and sending out the related information to a base station. Advances in integrated circuit design are continually shrinking the size, weight and cost of sensor devices while simultaneously improving their resolution and accuracy [1]. At the same time, modern wireless networking technologies enable the coordination and networking of a large number of such devices [2]. A Wireless Sensor Network (WSN) consists of a large number of sensor nodes working collaboratively to achieve a common mission. One or more sinks (base stations) are dedicated to collect data from all sensor nodes and forward them to the end user. These sinks constitute the interface through which the WSN interacts with the outside world. Although nodes are able to self-organize and collaborate together in order to establish and maintain the network [3] they are battery powered, limited in terms of

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http://dx.doi.org/10.1016/j.energy.2016.08.012
0360-5442/

processing, storage, and communication capabilities. Challenges in WSN arise in the implementation of several services, there are so many controllable and uncontrollable parameters [4] by which the implementation of wireless sensor network can be seriously affected such as energy conservation. As it is known, the valuable small size of a sensor node imposes a small battery with a limited available energy budget. When the wireless sensor network replaced the single macro sensors, it gained an advantage in the extended range of sensing, fault tolerance, improved accuracy and lower cost than its predecessors.

But as the number of nodes increases in the WSN, to increase the coverage range and accuracy, energy management becomes a major constraint since all these nodes are battery powered. And in that situation recharging or replacing of the battery is impossible [5]. In this paper, we propose an Energy Efficient Adaptive Clustering Protocol with data gathering using intra-inter cluster multi-hop communication. The aimed goal is to achieve better cluster size balance offering a network topology dissipating minimum energy. A node clustering is admitted as an efficient way to reduce energy consumption and extend the lifetime of the network. This is doing through data aggregation and fusion in order to reduce the number of transmitted messages to the Base Station (*BS*) [6]. So, nodes of the network are organized into clusters for processing and forwarding the information whereas lower energy nodes can be used for sensing target events. *HEBM* makes no assumptions on the size and the density of the network. The number of levels depends on the cluster range and the minimum energy path to the head. The proposed protocol reduces the number of dead nodes, the energy consumption, and extends the network lifetime. Recent applications of exergy analysis wsn have been simulated by the quest for more sustainable industrial systems. However, the benefits and drawbacks of exergy analysis in comparison to energy analysis are less prevalent in wsn literature. One of the biggest disadvantages of the previous work is that, sensor nodes are randomly divided among clusters which leads to lack of balance. Thus, some clusters have more nodes while some others have lesser. Also, certain cluster heads are located at the center of the cluster and some cluster heads may be in the edge of the cluster; this situation can cause an increase in energy consumption and may have great impact on the performance of the entire network. Due to any reason when the Cluster head dies, the cluster will become useless because the data gathered by the cluster nodes would never reach the Base Station. Also, the load balancing scheme for optimization of the consumed energy in previous work has not been used for service oriented WSNs. The service oriented WSNs should resolve the energy optimization issue by considering the constraints of cluster head distribution for coverage preservation in the network and the implementation of load balancing among the sensor nodes. Hence, in this paper the author's have proposed (HEBM) approach to reach the following objectives: reducing the overall network energy consumption (Extending the network lifetime duration) through balancing the energy consumption among sensor nodes and developing an efficient hierarchical clustering scheme in WSN. The implementing of the load balancing among sensor nodes leads to avoid energy hole and to obtain clusters quasi completely distributed. The clustering scheme we used is efficient in complexity of messages and time and the cluster-heads are well-distributed across the network. Like this, the proposed protocol HEBM selects a cluster head node not only by considering residual energy of the node greater than the average residual energy level of nodes in network, but in this work, a new Cluster-Head selection mechanism was proposed. This way identifies a cluster head which covers the entire field with minimum communication distance, using a combination of four metrics: residual energy, communication distance between the sensor nodes, communication distance between the sensor and the base station, and the number of neighbors. And we consider the problem of conserving energy by turning off the node's radio for periods of a fixed time length. The aim is to design sleep control laws that minimize the expected value of a cost function representing both energy consumption cost and holding costs for backlogged packets.

2. Related work

The growing interest of wireless sensor networks and the increasing advancements in microelectronics and wireless communication technologies constantly intensify efforts in the design and development of wireless sensor network: design of low-power signal processing architectures, low-power sensing interfaces, energy efficient wireless media access control, adaptive routing protocols, quality of service etc. Smaragdakis et al. [7] proposed (SEP) Stable Election Protocol which is an extension to the pioneer LEACH protocol. SEP is a heterogeneous aware protocol, based on weighted election probabilities of each node to become cluster head according to their respective energy. This approach aims to ensure a uniform use of the nodes energy in order to prevent prematurely dead nodes. In Linked Cluster Algorithm LCA [8], the nodes with the smallest *ID* become cluster head. All the other nodes which are 1-hop to the heads become children of the cluster-heads. In Refs. [9], the nodes with the highest degree among their 1-hop neighbors become cluster heads. The authors propose two load balancing heuristics for mobile ad hoc networks, where one is similar to LCA and the other is a degree-based algorithm. PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [10], creates a near optimal nodes-chain in which each node communicates only with a close neighbor and takes turn transmitting to the base station, thus reducing the amount of energy spent per round. This is an improvement over LEACH. . The Weighted Clustering Algorithm (WCA) [11] elects cluster-heads based on the number of surrounding nodes, transmission power, and residual battery life duration and mobility rate of the node. WCA also restricts the number of nodes in a cluster so that the performance of the MAC protocol is not degraded. These weights are based on the application and the highest weight node among its one hop neighbor. All of the above algorithms generate 1-hop clusters and require synchronized clocks and have a complexity of O(n), where n is the number of sensor nodes. This makes them suitable only for networks with a small number of nodes (not scalable). Also, all the previous protocols require either knowledge of the network density or homogeneity of node dispersion in the network area. Hybrid Energy Efficient Distributed clustering (HEED) [12] does not make any assumptions about the network, such as, density and size. Every node runs HEED individually and at the end of the process, each node either becomes a cluster head or a child of a cluster head. Residual energy of a node is the first parameter in the election of a cluster head, and the proximity to its neighbors or node degree is the second. HEED generates a 1-level hierarchical clustering structure for intra-cluster communication. EAP (Energy Aware Routing Protocol) [13] clusters sensor nodes into groups and builds routing tree among cluster heads for energy saving communication. In addition, EAP introduces the idea of area coverage to reduce the number of working nodes within a cluster in order to prolong network lifetime. In Refs. [9], Sajjanhar et al. proposed a Distributive Energy Efficient Adaptive Clustering protocol. This protocol is adaptive in terms of data reporting rates and residual energy of each node within the network, which is having Spatio-temporal variations in data reporting rates across different regions. The proposed protocol selects a node to be a cluster head depending upon its hotness value and residual energy. In Refs. [14], authors proposed A cluster Based Energy Efficient Location Routing Protocol which uses hierarchically structured method, multihop and location based nodes.

Some of the proposed protocols consider the imprecise state information while determining the routes, Heping et al., [15], proposed a hybrid medium access control protocol (HMAC) with an embedded cross-layer optimization solution to provide routing-layer coarse-grained end to-end Quality-of-Service support for latency-sensitive traffic flows. They proposed a novel channel reservation technique to reduce end to end delay. Keming DU et al., proposed a bandwidth-aware routing protocol BARP [16], which is based on the existing Dynamic Source Routing protocol (DSR), maintaining the Integrity of the Specifications used to find a route in maximum bandwidth from a source node to a destination. Jasani et al. [17] proposed the QoS performance of MANETs by comparing the results of using AODV and DSR routing protocols. Using the OPNET Modeller, they have conducted an extensive set of performance experiments for those protocols with a wide variety of settings. Athreya et al. [18] proposed a routing mechanism that uses cross layer strategies. The cross-layer strategy involves incorporating feedback and information from layers below the network layer to make decisions at the network layer. It works well for small networks. In Xing et al. (2015) the authors proposed network coding condition with QoS constraint which provides proof for coding opportunity detection. To facilitate the evaluation of discovered routes, a novel routing metric, called CQRM (coding-aware QoS routing metric), is presented, which jointly considers link quality, node congestion, and coding opportunity. They proposed a path evaluation mechanism for the paths returned by multi-path routing mechanism. In Ref. [19] a new routing protocol called Fuzzy Based Energy Efficient Multiple Cluster Head Selection Routing Protocol (FEMCHRP) for Wireless Sensor Network is proposed. The routing process involves nodes clustering and the selection of Cluster Head nodes of these clusters which send all the information to the Cluster Head Leader (CHL). After that, the cluster head leaders send aggregated data to the Base Station (BS). Also, Sajjanhar et al. [20] proposed a Distributive Energy Efficient Adaptive Clustering (DEEAC) protocol. This protocol is adaptive in terms of data reporting rates and residual energy of each node within the network. DEEAC Protocol has Spatio-temporal variations in data reporting rates across different regions. DEEAC selects a node being cluster head depending upon its hotness value and residual energy.

However, although In this paper [21] the authors proposed an improved delay-aware and energy-efficient clustered protocol called Hamilton Energy-Efficient Routing Protocol (HEER). HEER forms clusters in the network initialization phase and links members in each cluster on a Hamilton Path constructed using a greedy algorithm, for data transmission purpose. No cluster reformation is required and the members on the path will take turns to become cluster head. The design allows HEER to save on network administration energy and also balance the load comparing to traditional cluster-based protocols. The authors in Ref. [22] proposed a sleep schedule with a service coverage guarantee in WSNs. Firstly, by considering the redundancy degree on both service and the node level, we can get an accurate redundancy degree of one sensor node. Then, we can adopt fuzzy logic to integrate the redundancy degree, reliability and energy to get a sleep factor. Based on the sleep factor, we furthermore propose the sleep mechanism. Clustering is commonly admitted as an approach aware of node energy conservation and complying with network scalability. Cluster heads uniformly distributed in sensing area and payload balancing have a great positive impact in prolonging nodes life time duration. In this paper [23], an improved nonlinear dynamic adaptive particle swarm optimization (NDAPSO) is applied for producing energy-aware clusters with a selection of optimal cluster heads. The fitness function used for evaluating the particles consider four features, such as energy consumption, intra-cluster distance, the proportion of cluster heads energy and degree of energy consumption equilibrium, and a new cluster head competition mechanism is introduced.

In the paper Eric Gamess et al., [24], the authors introduced a new algorithm for counting nodes equipped with a wireless interface; they proposed a local re-clustering mechanism to further mitigate the uneven energy load during the data transmission phase, that is, different layers reselect their CHs at different frequencies according to their relative distances to the BS. In this paper [25] the authors designed a low power consumption wireless sensor network node, and presented the structure and realization method. It is simple, reliable, and suitable for the situation in which transmission requirements is not too stringent. Its biggest advantage is super low energy consumption. In Refs. [26], the authors proposed network coding condition with QoS constraint which provides proof for coding opportunity detection. To facilitate the evaluation of discovered routes, a novel routing metric, called CQRM (coding-aware QoS routing metric), is presented, which jointly considers link quality, node congestion, and coding opportunity. In Refs. [27],a seaport terminal scenario is used to present a convergence network platform incorporating WSN sensor theory. The results of the simulation of the proposed network confirms the suitability of WSN to be used in the transmission of data traffic associated to meter readings which is required for effective energy consumption and management policies in industrial environments comprising equipment with high energy demands.

3. Hierarchical Energy-Balancing Multipath routing protocol for wireless sensor networks: HEBM

3.1. Proposal motivation

WSNs are actually facing various problems, such as: Coverage problem which reflects how well an area of interest is monitored or tracked by sensors; position estimation issue, which is related to the distance measures between sensor positions; sensors energy conservation problem which really impacts the WSN mission success; security information and vulnerability problem which may cause end user making wrong decision following corrupted received information, robustness which may incur network objective unreachable, etc. So, due to the actual technology advance in battery design supplying poor node energy budget, the paramount problem In WSN is the energy issue. Most of the node energy is consumed in sending and receiving of data as compared to sensing and data processing. In this paper, we propose HEBM protocol (Distributed Energy Efficient Adaptive Clustering Protocol with data gathering and QoS). Our goal is to achieve better cluster size balance for large scale WSNs and obtain clusters such that each has the minimum energy consuming topology and quality of service characteristics such as delay, error rate, and throughput data rate.

There are several requirements for our clustering algorithm:

(i) A clustering algorithm should be completely distributed because a centralized control manner is not practical in a large-scale WSN.
(ii) The cluster heads should be well distributed throughout the monitoring area to make energy consumption well-balanced among all sensor nodes.
(iii) The clustering algorithm itself should be energy efficient.
(iv) A clustering algorithm needs to support the heterogeneous energy circumstance. In fact, it is hard to guarantee that the battery capacity of all nodes will be the same.

The quality of service is based on routing algorithms for multi-hop wireless sensor networks. We propose a routing protocol that can provide QoS that appropriately reflects changes in network status regarding reliability and delay, even in circumstances with a deficiency in sensor node resources. Our algorithm has the advantage of minimizing the routing control messages and, therefore, can safely operate from an energy efficient perspective.

3.2. Network model

In the sequel, we consider a homogeneous WSN, where nodes are uniformly randomly dispersed throughout the area. The nodes in the network are scattered within a square area, where the length of the sides is represented by "*M*". We assume that all the nodes can communicate with the BS with enough energy, and also can use different power levels for communications. Nodes and the BS are stationary and no mobility is supported. Although the BS can be located farther from the monitoring field, we investigate a network that the BS is approximately located at the center of the field. All the nodes can communicate with their neighbors located within the cluster range of the nodes, in one single-hop. This is assumed that all the nodes are synchronized at least once at the beginning of each phase. For the sake of simplicity, wireless transmission channel is assumed to be secure; we assume that the entire network operational time is divided into some rounds, at the beginning, the clusters are formed, and in the remainder of the round, the data are gathered, aggregated and transmitted to the BS. In our clustered network, we assumed the cluster-head to be awake in all the time of a round, and the ordinary nodes (or cluster members) can go to sleep except in their time slots.

3.3. Radio model

We used the following equations for calculating the communication energy dissipation. The energy spent for the transmission of the k-bit packets over distance *d* is given by Equation (1):

$$E_{Tx}(K,d) = KE_{elc} + KE_{amp}d^2 \tag{1}$$

E_{elec} is required energy for activating the electronic circuits. E_{amp} is required energy for amplification of transmitted signals to transmit a one bit in open space and multi path models, respectively.

Energy consumption to receive a packet of *K* bits is calculated according to Equation (2).

$$E_{Rx}(K) = KE_{elc} \tag{2}$$

The residual energy of a node Ni, after transmitting a message of *k* bits at distance *d* from the receiver, is calculated by using Equation (3).

$$E_{ri} = E_{initial} - (E_{TX}(k,d) + E_{RX}(K)) \tag{3}$$

We can compute the total initial energy of the networks by using Equation (4):

$$E_{total} = NE_{initial} \tag{4}$$

$E_{average}$ denotes the average energy of all live sensor nodes, which is calculated as follows Equation (5):

$$E_{average} = \sum_{n=1}^{n} E_{residual}(i) \Big/ n \tag{5}$$

E_{round} is the total energy dissipated in the network during a round, which is given by Equation (6):

$$E_{round} = \lambda\left[NE_{DA} + 2NE_{elect} + NE_{fs}d_{neigh}^2 + E_{amp}d_{ChtoBs}^4\right] \tag{6}$$

where E_{DA} is the data aggregation cost spent in each node, d_{CHtoBS} is the average distance between the cluster head and the BS, d_{neigh} is the average distance to the next node in the chain, λ is the total size of transmitted data, E_{fs} and E_{amp} depend on the transmitter amplifier model used.

3.4. HEBM proposed protocol

One of the important factors that improve the lifetime of wireless sensor network is the design of the network. In this section, we describe the proposed HEBM approach. HEBM approach utilizes adaptive clustering scheme. A clustering scheme is called an adaptive scheme if over time, the number of clusters varies and the nodes membership evolves. In HEBM, the BS is assumed to have unlimited energy residues and communication power. It is also assumed that the BS is located at a fixed position, either inside or away from the sensor field [28]. Nodes with special high condition (*Pch*) can act as CH (Cluster-head) for bearing data transmission overload. In order to prevent early death due to excessive energy expenditure, all nodes should alternately take turns to become CH, so CH election needs to consider many factors. In *HEBM*, the following factors are considered: node-weight, residual energy, condition distance between nodes, and condition distance with BS. The HEBM protocol achieves a good distribution of clusters (unresolved problem with many protocols). As shown in Fig. 1, the HEBM protocol takes place in "rounds" that represent time intervals determined in advance. Each round is consisting of six phases, the initialization phase, neighbor discovery phase election Pch_{temp} phase, election final CH, cluster formation, transmission phase.

3.4.1. HEBM initialization phase

Initially, sensor nodes are randomly deployed in a capture zone. There are many techniques used to conserve WSN energy, in order to prevent its premature exhaustion. Longer distance transmission, involving a number of relaying nodes, increases energy consumption very fast. It is striven to receive messages from nodes located as close as possible to a Base Station. When nodes are deployed there is no possibility to change their locations.

- The initialization phase, illustrated in Fig. 2, is to broadcast an announcement message *BS-Msg*, by the base station, at a certain power level to all network sensor nodes. Thus, each node can calculate the approximate distance from the base station, according to the received signal strength. Then each node computes a parameter which is set as following: D (N, BS).

Received signal strength indicator can be used to estimate the distance between two nodes based on the strength of the signal received by another node. In HEBM a sender node sends out a signal with a determined strength that fades as the signal propagates Fig. 3. Theoretically, the signal strength is inversely proportional to squared distance, and a known radio propagation model can be used to convert the signal strength into distance.

3.4.2. Neighbors discovery phase

Neighbors Discovery (ND) plays an important role in the initialization phase of wireless sensor networks. In real deployments, sensor nodes may not always be awake due to limited power supply and energy conservation, which forms low-duty-cycle networks. Existing researches on the *ND* problem in low-

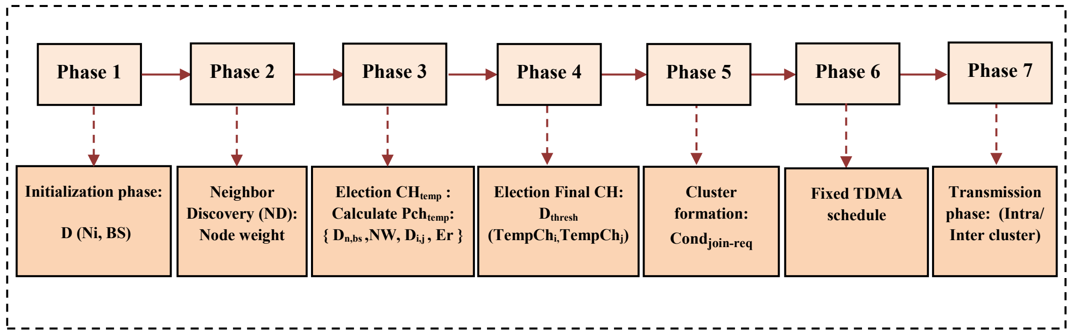

Fig. 1. *HEBM* phases.

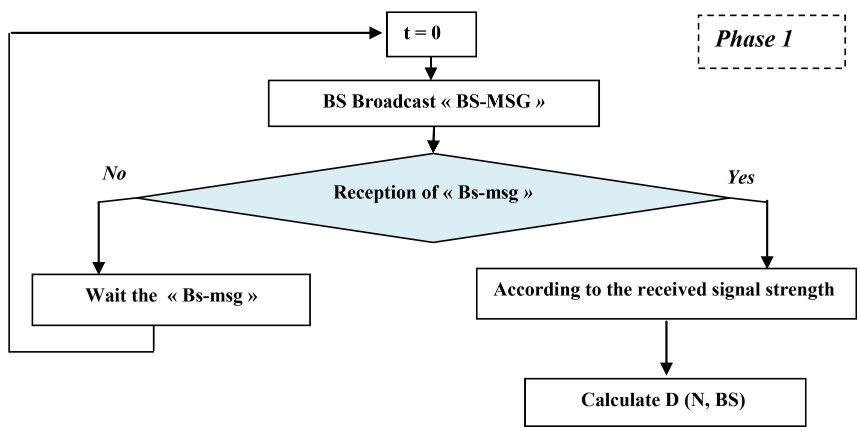

Fig. 2. Initialization phase D (Ni,BS).

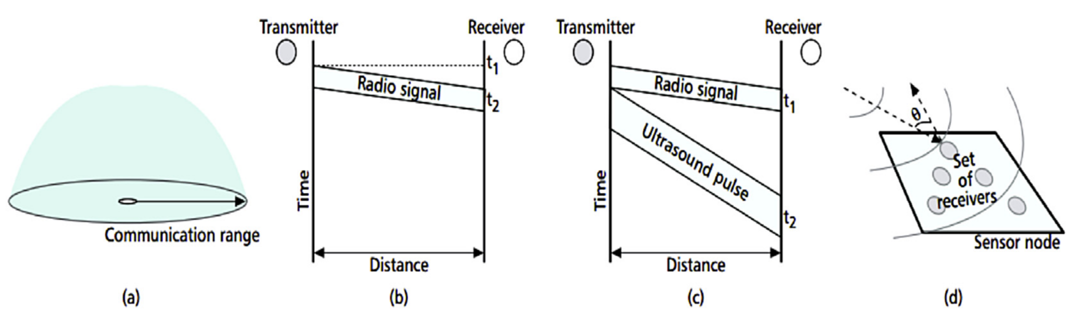

Fig. 3. a) Decrease in signal strength; b), c) methods to derive the distance from the signal's arrival time; d) Angle of arrival of the signal.

duty-cycle networks are all based on the assumption that a receiver can receive only one packet successfully at a time [29].

The neighborhood discovery is a component of the WSN Construct algorithm. During the WSN Construct, each node in the network performs at least one neighborhood discovery. The objective of this phase is to collect as much information as possible about other nodes in the vicinity in order to provide a good basis for decision-making in choosing neighbors. For that reason, messages of different types have to be exchanged between the discoverer and neighboring nodes to transmit information and to notify the chosen neighbors. Finally, the neighborhood discovery ends with the construction of a neighbor table as shown in Fig. 4. In our HEBM contribution, each node, in order to calculate the node-weight, sends a message *Discov-neigh-msg* which contains its identifier. Each node receiving the message sends immediately a *Discov-neigh-msg* message of same type, and then each member has its neighbors table, allowing it to know its cost (the size of the table).

The objective of the choose neighbors procedure is to make the best choice for the purpose of the whole wireless sensor network. In HEBM protocol, two aspects are crucial for the choice of the neighbors. On the one hand, neighbors with a good link quality are important. If messages to or from a neighbor are received only rarely and require many retransmissions because of a bad link quality, a lot of energy is wasted and the reliability of the network function is decreased. Thus, it is energy-efficient and more reliable for the network function to choose the nodes with the best link quality as neighbors.

Fig. 5 illustrates the neighborhood discovery. At the beginning, the discoverer transmits a *Discov-neigh-msg*, by the time the discoverer transmits the first broadcast, and a timer *ts-discov* is started simultaneously. While the timer is running, the node waits for broadcast received messages; a node receiving a notification

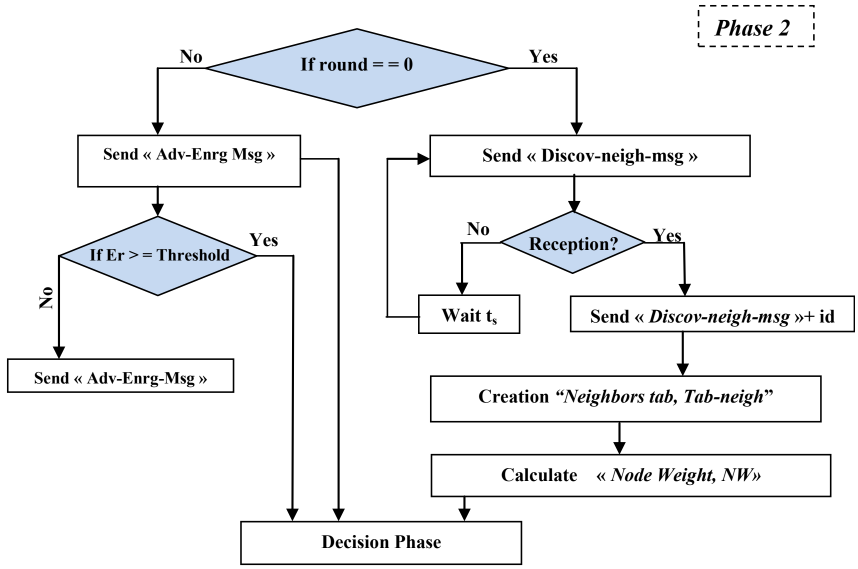

Fig. 4. Neighbor discovery (node weight).

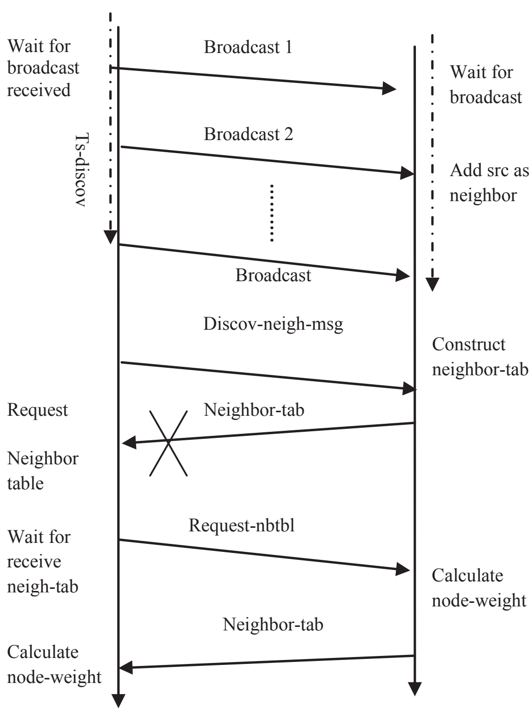

Fig. 5. Create neighbor table and calculate node weight.

adds the source as neighbor'(s) of the neighbor and transmits an *acknowledgment (ack)* notification back to the discoverer. As a reaction on receiving an *ack* notification, the discoverer adds the source as a neighbor as well. Upon having received all *ack* notifications, the discoverer constructs a neighbor table and thus the neighborhood discovery is completed.

The neighborhood discovery is completed with the construction of the neighbor table, whether it could be filled up with neighbors or remains empty. The choose neighbors procedure is a component of the neighborhood discovery. The procedure chooses neighbors among all nodes which are discovered during the neighbor discovery process.

3.4.3. Election of temporary CH phase

The most important part of each clustering scheme is the cluster-head election. In the clustering-based protocol, the nodes are arranged into local clusters. Each cluster consists of one cluster head and the number of member nodes which belongs to the same cluster. All non-cluster head nodes should transmit their data to the cluster head while the cluster head must forward the received data from all the cluster members to the remote Base Station (BS) after performing data aggregation. Therefore, being a cluster head is much more energy consuming than being a non-cluster-head (Standard) member node. For the cluster head election, the proposed HEBM uses a hybrid scheme of residual energy and distance among the cluster-heads, the distance between node and BS, node-weight. The cluster-head election phase is done in two steps: the local competition and the distance condition.

In our proposed method, the nodes compete in a competition scheme to be elected as the cluster head candidate. The CH election and cluster formation in HEBM protocol have four primary objectives: prolonging network lifetime by distributing energy consumption, minimizing control overhead (to be linear in the number of nodes), the clustering process within a constant number of iterations, and producing well-distributed cluster heads. At first, the condition of each node being selected as the cluster-head candidate is found, this condition "Pch", is determined proportionally using a combination of four metrics:

(i) The distance between the node and the Base Station.
(ii) Residual energy of node and its neighbors.
(iii) The distance between the nodes neighbors.
(iv) Weight-Node: number of node neighbors.

So we assumed these following equations (Eqns. 7–10) for calculating the temporary Cluster head:

$$\beta_1(i,j) = 1 - \alpha_1\left(1 - D_{Bs,i}/D_{Bs,j}\right) \tag{7}$$

DBs,i: the distance between the node "i" and the base station BS.
DBs,j: the distance between the node neighbor "j" and the base station BS.

$$\beta_2(i,j) = 1 - \alpha_2\left(1 - Nw_i/_{Nw_j}\right) \tag{8}$$

Nwi: Node-weight of node «i».
Nwj: Node-weight of node neighbor «j».

$$\beta_3(i,j) = 1 - \alpha_3\left(1 - E_i/_{E_j}\right) \tag{9}$$

Er,i: Residual energy of node « i ».
Er,j: Residual energy of node neighbor « j ».

$$Pch_{(i,j)} = Max\left[1 - \sum_{i,j=1}^{n} \beta_1(i,j), \beta_2(i,j), \beta_3(i,j))\right] \tag{10}$$

$Pch_{(i,j):}$ a condition to be cluster head for node « CH ». α1, α2, α3: constant coefficient «0» or «1»

Each sensor node (Ni) in the network calculates its condition *Pch* $_{(i,j),}$ and then broadcasts a message, called *CH-ADV*, to other nodes. This message includes the node *ID* and the value of condition *Pch*. In the proposed competition scheme, we define a competition range called *Rcomp* which represents the Cluster range (or cluster radius). The *Rcomp* parameter specifies the radius of a cluster, i.e., the farthest a node inside a cluster can be from the clusterhead. The cluster radius is a system parameter and is fixed for the entire network, this range should be reasonable, that is, it should not be too long to overload the network and should not be too short to increase the number of cluster-head candidate advertisements as shown in Fig. 6.

As indicated in Fig. 7, the node *Ni* wait for t_{wait} time units and receives the message *Pch*-msg from all its neighbors. Note that, the waiting time t_{wait} should not be too short as some nodes may not receive the message *Pch-msg*, and it should not be too long as it increases the time complexity. Then it compares its condition value *Pch* with that of its neighbors. If it found its condition *Pch* value greater than *Pch* value of all its neighbors, then it elects itself as cluster-head candidate. Else, it sends a join message to the neighbor that has the highest condition *Pch* to become a member of the cluster. The number of selected cluster heads varies according to the specified cluster radius. The smaller the radius, the larger the required number of cluster heads to fully cover the entire network.

3.4.4. Election of final cluster-heads phase

(Fig. 8 and Fig. 8a) illustrates the election of final CH. In the figures, each elected CH_i temporary should broadcast *CCH-ADV* message containing its node ID_i and the *Pch(i)* probability. When a *CHj* temporary receives this message, it calculates the distance between the sender CH_i and itself. If this distance is greater than or equal to a threshold distance, D_{thd}, it ignores the message, but if the distance (d_{chi}, d_{chj}) is less than D_{thd} and if it found *Pch (i)* value of sender greater than its own *Pch (j)*, then the receiver CH_j temporary becomes an ordinary node and sends a *Join-msg* message to the sender cluster head CH_i. if two temporary CH are on the same level, the distance between them is less than D-threshold and they have the same *Pch*, then the temporary *CH* with the higher *Pch* value is elected as a final cluster-head. The pseudo code of the cluster-head election phase of the proposed *HEBM* is presented in Fig. 11. The role of each CH is to carry out the following three tasks. The first task is to gather sensed data from the cluster nodes periodically and aggregates the data in an effort to remove redundancy among correlated values. The second task of the cluster head is to generate a Time Division Multiple Access (TDMA) schedule through which sensor nodes receive a time slot for data transmission. The third task is to transmit the aggregated data to nearby CH or directly to the base station. Hence, the lifetime of CH would be a very short span of time if the fixed node performs all the three tasks and it becomes essential to shift the cluster head periodically in a well-structured manner.

3.4.5. Cluster formation phase

After the election phase, follows the cluster formation one. In this phase, the CHs broadcast the *Adv_Msg* to neighbor nodes. Upon

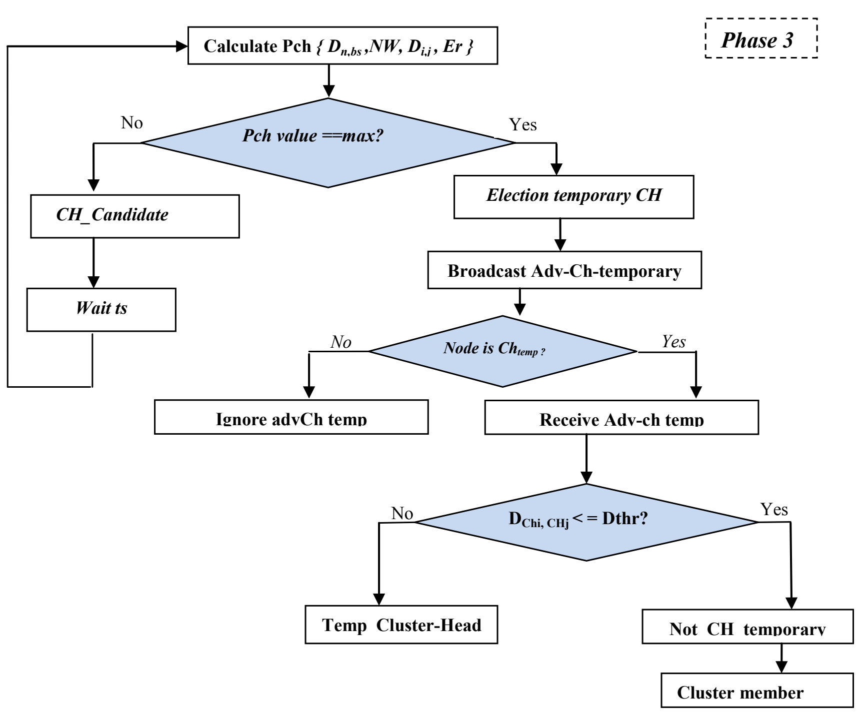

Fig. 6. Temporary cluster-head election.

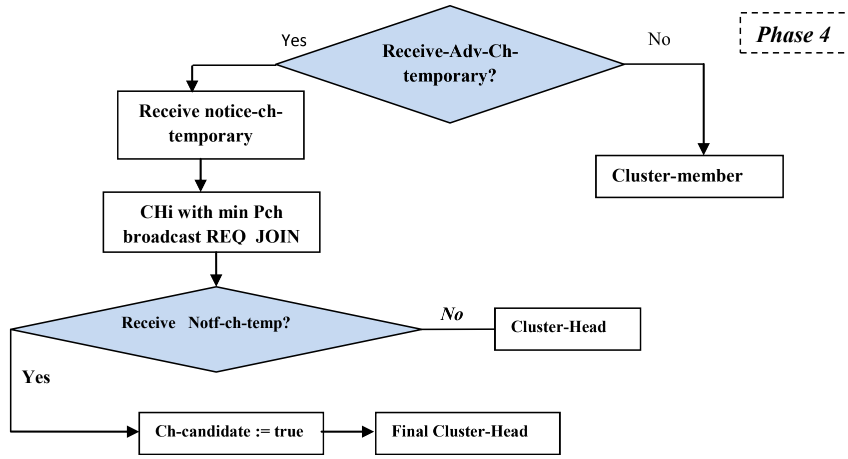

Fig. 7. Final cluster-head election.

receiving the *Adv_Msg*, other non-CH nodes have to estimate $Join_{cond\ (i,CHj)}$, and then join clusters by sending a *Join_ Msg* to their respective CH. By Equation (11).

$$Join_{cond(CH,j)} = Max\left(1 - \frac{Pchj}{D_{i,chj} + D_{chj,bs}}\right) \quad (11)$$

where: $D_{chj,bs}$ is the distance from ch_j to the Base Station.

$D_{i,\ chj}$ is the distance from node i to ch_j. $Join_{cond(CH,J)} \rightarrow$ Max, Pch_j $\rightarrow$ Max, and $D_{chj,\ bs} + D_{i,\ CHj} \rightarrow$ Min allows the node to choose the *CH* that has the greater *Pch* and that is closer to the *BS*.

Due to inherent resource constraints in communication and energy consumption, node clustering techniques have been widely utilized by Wireless Sensor Network applications to achieve energy efficiency and scalability. Clustering provides an efficient and scalable network structure for collaborating sensor nodes by grouping them into a hierarchy. Such hierarchical structures are constructed by various clustering approaches at different network layers such as the Data Link layer and the network layer [29]. Clustering offers many advantages in improving the performance of Wireless Sensor Network. Clustering keeps network traffic local and thus reduces energy dissipation of long-distance transmissions as well as the amount of routing information stored at each sensor node. *HEBM* Clustering can improve conserve energy by employing cluster heads (*CHs*) to perform local data aggregation and activity scheduling among local members. Inactive members can stay in the sleeping mode or low-power operations. Furthermore, clustering also helps in reducing the cost of topology maintenance as a reaction to dynamic topology changes [30]. To be responsive to dynamic phenomenon changes, a collaborative structure needs to be configurable and adaptable to phenomenon dynamics. With a clustered network, topology reconfiguration is only performed on the cluster head level and does not affect local cluster nodes. Thus, the overhead of dynamic topology adaptation can be greatly minimized [30].

- *HEBM* allows resource utilization optimizations and was successfully used for time and energy savings. These optimizations essentially reflect the usage of clustering algorithms for task and resource allocation.
- *HEBM* Improves also scalability: As clustering helps to organize large-scale unstructured ad hoc networks in well-defined groups according to application specific requirements, tasks and necessary resources can be distributed in this network in an optimized way.

3.4.6. Steady phase

In Fig. 9, after cluster formation phase, the cluster-heads adopt a *TDMA* (Time Division Multiple Access) protocol and send a time schedule to each of their members. In *HEBM* protocol, a transmission time slot is assigned to each node, during which the nodes can send their messages [31]. In wireless transmission, as the signal from a sender propagates over the channel, it attenuates with distance; it also suffers from physical propagation due to interactions with the physical environment (*e.g., passing through obstacles*). A receiver receives the signal after attenuation and other propagation effects, and it attempts to decode the signal. If the received signal strength is sufficiently higher than the sum of the noise and signal from interfering signals, the signal can be decoded successfully (*with low error rate*); otherwise, the transmission cannot be received [30]. Thus, interference from concurrently transmitting nodes plays an important effect in determining whether correct reception or a collision occurs. Ready-to-receive mode consumes nearly as much energy of the *HEBM* sensor node's resources as receive mode [32]. Thus, a way to set the node to a sleeping mode and determine the right time to wake it again is necessary to effectively save energy in idle time spans. The TDMA based scheduling protocols make the nodes to be in inactive mode until their allocated time slots. The TDMA based protocols [1] are designed such that the shortest path for communication will be found out and only a particular link will be in wake up mode for a transmission (see Fig. 9a).

3.4.7. HEBM network transmission time (NTT)

Once the clusters are formed, a *TDMA* schedule is fixed in all clusters of the network. In *NTT*, all nodes send their data to their *Pch*, during assigned time slots. Cluster-heads receive data from their clusters and aggregate them if necessary. Fig. 11 Data aggregation is a key technique for minimizing data amount being routed in the network. So, Cluster-heads have only to send meaningful information to *BS* in order to efficiently reduce packets to be transmitted and consequently prolong the battery lifetime [33]. One of the primary challenges in Multi-Hop Wireless Networks (*MHWNs*) is the routing problem; how to construct efficient routes for a network that is self-configuring. From a routing perspective, clustering allows to split data transmission into intra-cluster (within a cluster) and inter-cluster (between cluster-heads and

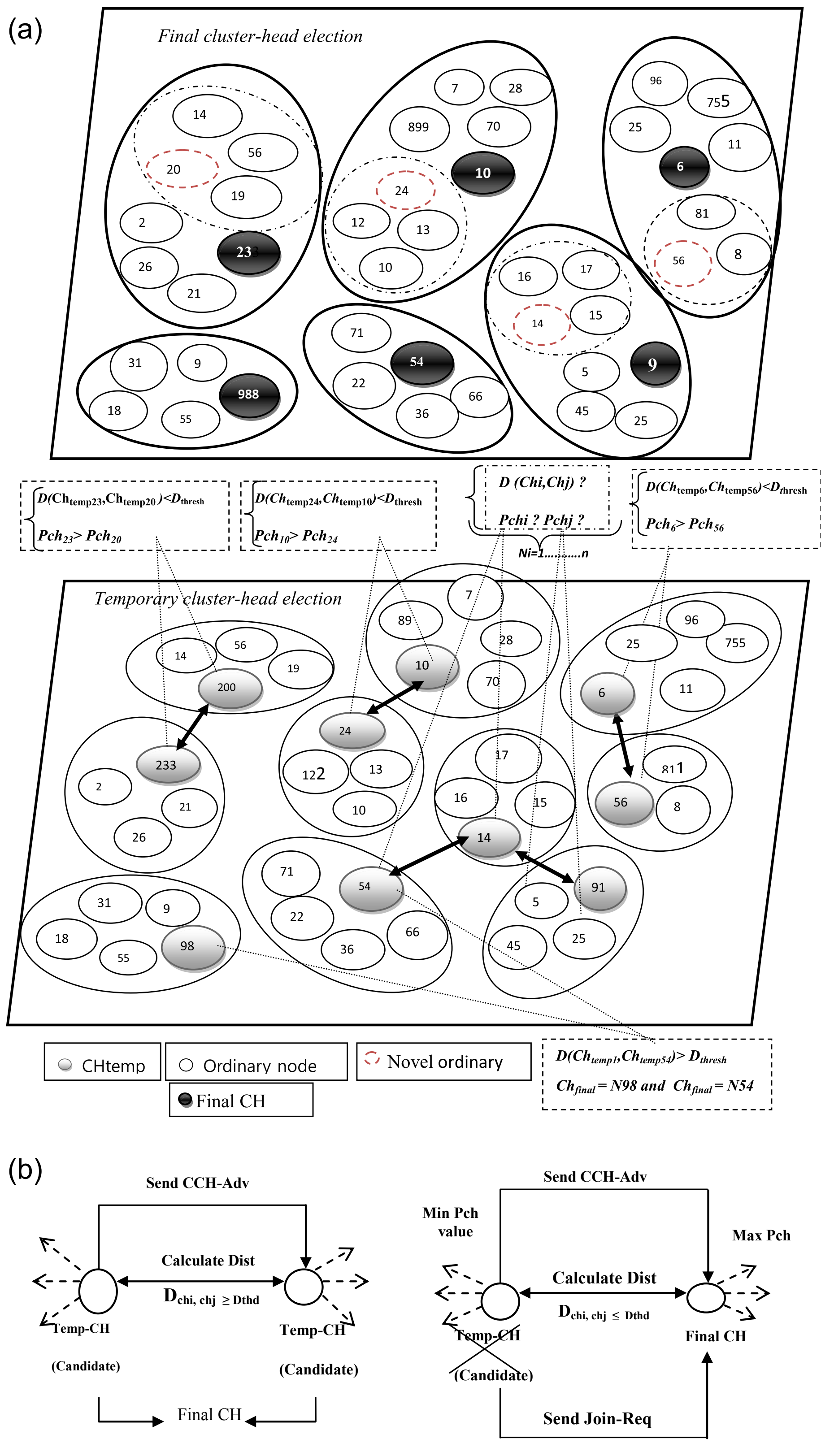

Fig. 8. HEBM re-clustering. a *HEBM* Final cluster-head Election.

every cluster-head and the sink) communication. This separation leads to significant energy saving since the radio unit is the major energy consumer component in a sensor node [34]. In fact, member nodes are only allowed to communicate with their respective cluster head, which is responsible for relaying the data to the BS with possible aggregation and fusion operations. Moreover, this

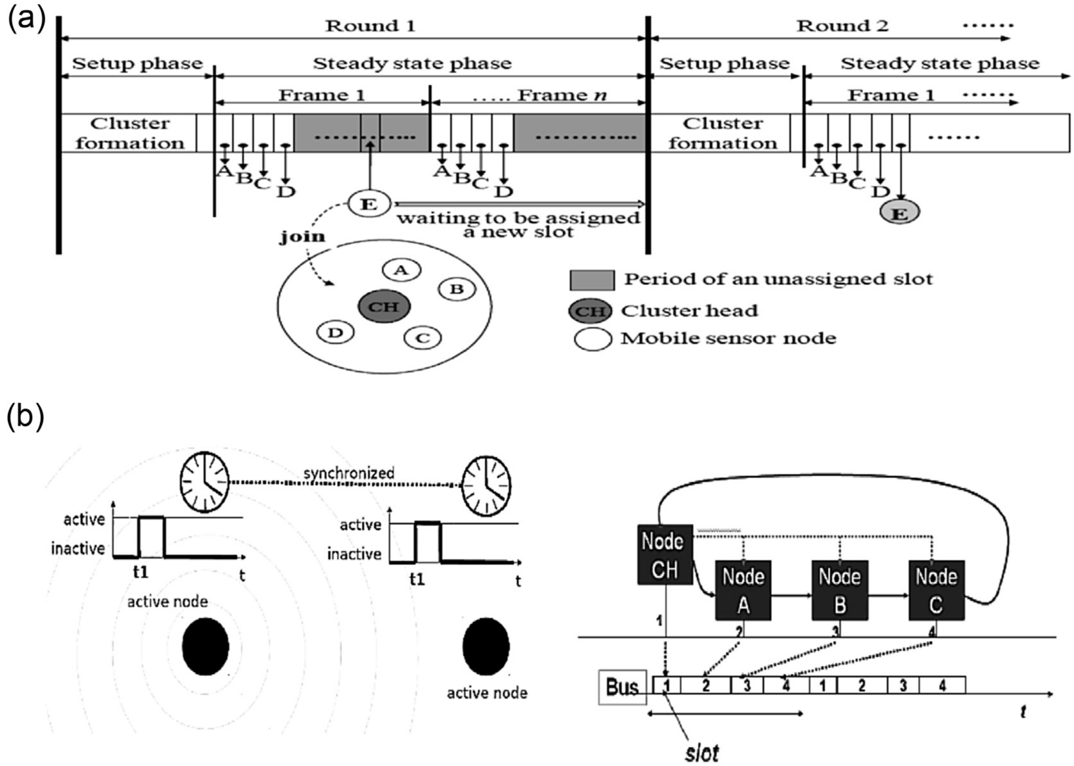

Fig. 9. Time Line showing HEBM based Clustering Protocol. a *HEBM* Time Division Multiple Access.

separation allows reducing routing tables at both member nodes and cluster-heads in addition to possible spatial reuse of communication bandwidth. The BS is usually located far away from the sensing area and is often not directly reachable to all nodes due to signal propagation problems. A more realistic approach is multi-hop inter-cluster routing that had shown to be more energy efficient. As indicated in Fig. 11, sensed data are relayed from one cluster to another until reaching the sink. Inter-cluster communication in several proposals is achieved through organizing the cluster-heads in a hierarchy allowing then better energy distribution and overall energy consumption [35]. However, maintaining the hierarchy could be costly in large and dynamic networks where nodes die as soon as their battery is coming to exhaustion. Fig. 10 *HEBM* network transmission.

4. Performance evaluation

In this section, we evaluate the performance of the proposed *HEBM* via several simulation experiments. At first, the simulation setup is explained and then the results are presented, a comparison between the simulation results in *HEBM, DEEAC*, and *FEMCHRP* algorithms is performed via *NS2* simulator. We use two scenarios for simulations. In the first scenario, 100 nodes are uniformly and randomly dispersed in a field of size 200 m_200 m. To study the effect of scale on the performance of HEBM, in the second scenario, 200 nodes are uniformly and randomly dispersed in a field of size 200 m_200 m.We assume that the BS is located at the center of the field. The other simulation parameters are summarized in Table 1.

4.1. Nodes energy consumption in HEBM proposal

Fig. 12 and Fig. 13 show the results for the energy consumed by sensor nodes in *HEBM, DEEAC* and *FEMCHRP* protocols. The energy consumed by sensor nodes for each round in *HEBM* is much lower than that in DEEAC and *FEMCHRP.* According to the data presented in these figures, *HEBM* has less energy consumption than the other two protocols, because this protocol periodically selects cluster heads according to a hybrid of their residual energy distance between node and *BS,* weight-node: number of neighbor nodes, such as node proximity to its neighbors or node degree. The main reason for this result is the suitable number and distribution of the clusters in the network. As expected, *FEMCHRP* has variable energy consumption, relevant to the pendulous number of its clusters in consecutive rounds. Although *DEEAC* has distributed clusters across the network properly, as the number of clusters in *DEEAC* is large, energy consumption in the whole network increases. Therefore, *HEBM* has the lowest energy consumption among the two protocols and has more energy consumption in contrast with the other protocols. Other main reason, *HEBM* uses a multihop communication inter-cluster and intra-cluster. Each parent node polls its direct ordinary node and forwards the data to its parent node until the data reaches the cluster head, and a multihop communication between cluster-head and base station. Fig. 11 depicts the total remaining energy per round and total remaining energy per round is more in HEBM as compared to *DEEAC.*

4.2. HEBM life time duration for wireless sensor network

The network lifetime for three protocols is depicted in Fig. 14 and Fig. 15. The result between the number of nodes alive and the number of rounds is shown by Fig. 13. The result obtained by measuring time until the first node dies to time until the last node dies exhibits *HEBM* ensuring a better lifetime than other protocols *DEEAC* and *FEMCHRP,* because *HEBM* method elects the nodes with the highest condition cluster head *Pch* Also, in this approach, the load balancing in the network is performed properly, which provides a longer time between the beginning of operations until the time the first node dies. Figs. 14 and 15 depict the total number of

Phase 1: "Initialization phase"

 # Distance D(Ni,Bs).

(1) The BS broadcasts "**BS-msg**".
(2) **IF** the message "**BS-msg**" is received from Ni ***THEN***
(3) The node Ni **Calculate** D(Ni,Bs)
(4) **ELSE**
(5) wait t_{wait} seconds to receive "**BS-msg**" message
(6) **EndIF**

 # Node weight.

(7) ∀i, N_i Broadcasts "**Disc-neigh-msg**" in R_{thd};
(8) **IF** the "**Disc-neigh-msg**" message is received from N_j
(9) **THEN**
(10) **Add** identifier "id" and send msg "**Disc-neigh msg**";
(11) **Create** table of neighbors "**neigh-tab**" ;
(12) **Weight-node**=length of **neigh-tab**;
(13) **ELSE**
(14) **wait** for t_{wait} seconds for the "**Disc-neigh-msg**";
(15) EndIF

Figure.a: Initialization phase

Phase 2: "Decision phase"

(1) ∀i, j " Ni" **send**s msg {**WN, Er, Dbs,D_{i-j}**};
(2) ∀i, "Ni " **calculates** the condition $P_{Cch(i)}$;
(3) **Evaluate** the condition cluster head Cch (i);
(4) **For** each **node neighbor**
(5) If ∀i, j ; $Pch(i) > Pch(j)$ THEN
(6) **Ni ← CCH(i);** // Ni is the cluster head
(7) broadcast the ***CCH-ADV*** messages to the higher power levels
(8) **Else**
(9) **Nj ← CCH(j);** // Nj is the cluster head
(10) **wait** t_{wait} seconds for the **CH-ADV message**
(11) **send** a Join-Req message to the cluster-head candidate
(12) **EndIF**

Figure.b: Decision phase

#Phase3: Condition distance

(1) **IF** the current node is a **cluster-head candidate** THEN
(2) Wait for t_{wait} seconds to **receive** the **CCH-ADV** message
(3) **IF** the **CCH-ADV** message **received** THEN
(4) **Evaluate** the received messages and **calculate** the distance
(5) **IF** ∀j , i $\sqrt{(Xcch(i) - Xcch(j))2 + (ycch(i) - ycch(j))2} \geq Dth$ THEN
(6) **Broadcas**t the **CH-ADV** message to all nodes in Rc
(7) **ELSE**
(8) **Send** the CH send a ***Join-Req*** message to the cluster-head candidate

Figure.c: Condition distance "temporary and final cluster-head"

Phase 3: "Steady phase"

(1) Cluster head node fixes and sends a ***TDMA*** to all its cluster members.
(2) Each cluster member sends its data ***packets*** in allocated ***TDMA*** slot
(3) CH ***collects*** the data from all the nodes in its cluster multihope ***communication*** inter-cluster.
(4) CH ***transmits*** the data with ***multihope*** communication inter-cluster to the BS node.
(5) **For** each (***level i***)
(6) **for** each **CH**
(7) **CH** receives the data from the ***cluster member***
(8) The ***CH*** Aggregates the data.
(9) **IF** (***i*** **==*1***) // ***level I***
(10) ***CH*** transmits data to the BS.
(11) ***Else***
(12) ***CH*** broadcasts data in the next level.
(13) **End If**
(14) **End For**
(15) **End For**

Figure .d: Steady phase

(1) **ChID** : CH identifier **bsID** :BS identifier
(2) **nexthopID_** : neighbor ID
(3) **clusterheadChoices_** : list containing all the **current CHs**
(4) **Begin**
(5) Specify the **max–dist** CH compared to BS in **clusterheadChoices_ list.**
(6) **Calculate** the rays of levels from the **maxCH**.
(7) **For** (each **ChId** belonging to **level N_**)
(8) **IF** (**ChId** has a nearest neighbor in **Level N**) **Then**
(9) Search (**nexthopID_**) in **level N.**
(10) **Else**
(11) Search (**nexthopID_**) in Level **N-1**.
(12) **EndIF**
(13) **EndFor**
(14) **IF** (**ChId** belongs to level 1) **Then**
(15) **IF** (**ChId** has a nearest neighbor in **Level 1**) **Then**
(16) **Search** (**nexthopID_**) in **Level 1**.
(17) **Else**
(18) **The nexthopID** : BsID
(19) **SendDataToBS**
(20) **EndIF**
(21) **EndIF**
(22) **End**

Figure.e: HEBM network transmission time

Fig. 10. HEBM pseudo algorithm.

nodes (100–200 devices) that remain alive over the simulation time. The result shows that HEBM performs better than *DEEAC* and *FEMCHRP.* In *DEEAC* (200 nodes), the first node death occurs after 210 rounds. And near to 800 rounds, almost all the nodes are dead in *FEMCHRP*. While in *HEBM*, the first node dies after 310 rounds. *So HEBM* performs best for 100 and 200 sensor devices.

In Fig. 16, we can observe that HEBM increases the profit of energy, and prolongs the network's lifetime duration because we used an adaptive clustering protocol. The cluster heads, and next cluster-heads are elected based on the residual energy of each node and the average energy of each cluster. Indeed, DEEAC based on dynamic chain clustering approach prolongs the network lifetime from 55% to 75% compared to FEMCHRP protocol, and from 40% to 50%. We also note that the network's lifetime obtained is very close to that provided with DEEAC algorithm (from 10% to 15%).

It can be observed from Fig. 17, that network lifetime duration obtained by HEBM is more than DEEAC as the last node dies in DEEAC for 500 nodes is after 11350 rounds and in DEEAC it dies after 6140 rounds. Thus, stability period of HEBM is more than DEEAC. This improvement is because the HEBM method elects the nodes with the highest residual energy as the cluster-heads and Pch election. Also, in this approach, the load balancing in the network is performed properly, which provides a longer time between the beginning of the operations until the time the first node dies.

Fig. 18 depicts the network lifetime of *HEBM, DEEAC, and FEMCHRP* with different *BS* node position, the increase of the

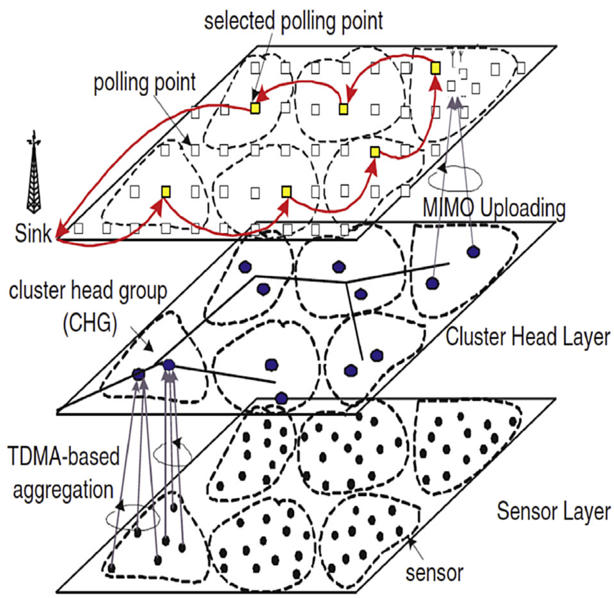

Fig. 11. *HEBM* network transmission.

Table 1
Parameters of simulation.

Parameter	Value
Area	200 m × 200 m
Data packet size	4000 bits
Control packet size	512 bits
Number of sensor nodes	100/200/ … /800
Initial energy	2 J
Base station location	(50,50)
Distance d_0	87 m
E_{elec}	50nj/bit

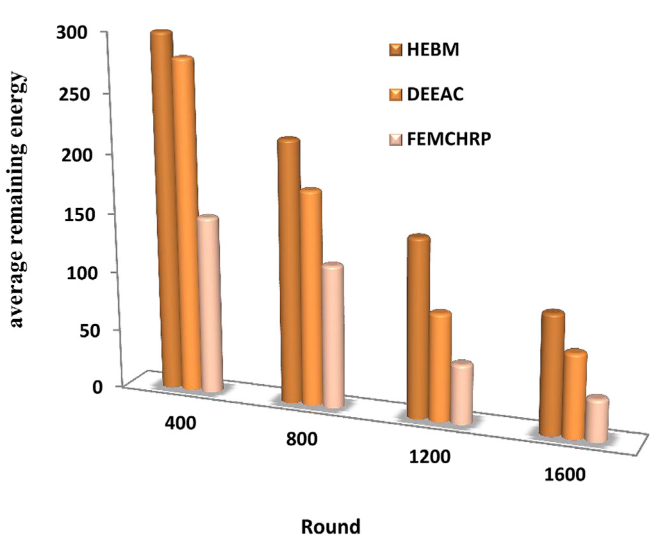

Fig. 12. Average remaining energy.

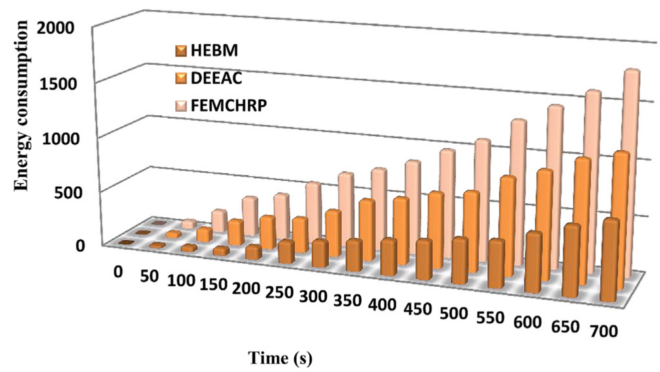

Fig. 13. Comparison of Energy consumption.

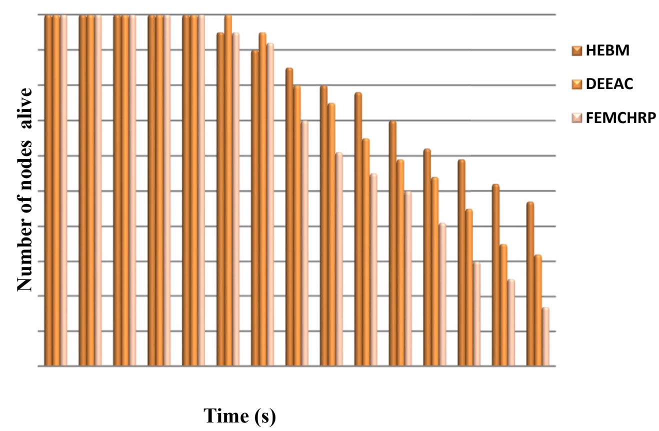

Fig. 14. Comparison of network life time duration with 100 nodes.

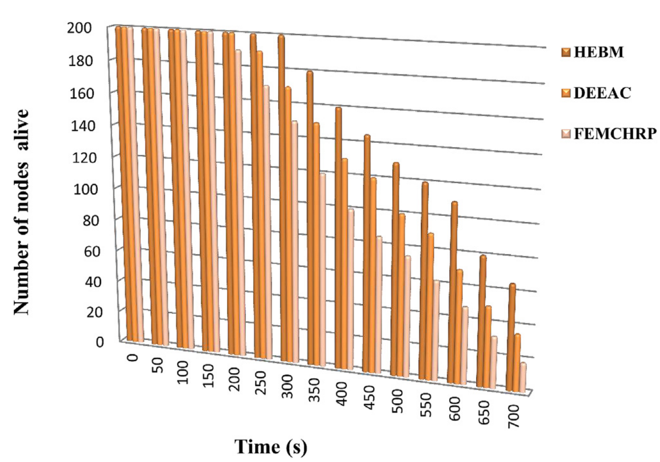

Fig. 15. Comparison of network life time duration with 100 nodes.

distance between the BS node and the network, the energy consumption of the nodes that can directly communicate with the BS node will increase remarkably. In this case, the number of the nodes that can directly communicate with the BS node is, the more rapidly the performance of protocols degenerates. Therefore, *HEBM* uses multihop communication to communicate with BS node, perform remarkably better than *DEEAC*. In *HEBM*, all nodes should take turns to be a cluster head to communicate with the BS node, and since the distance between each node and the BS node is different, the energy consumption for each node is different. As a result, some node with higher energy consumption will die soon. As Fig. 16 shows, the network lifetime of *HEBM* and *DEEAC* is over 200 rounds longer than that of *FEMCHRP*. Fig. 19 shows the average number of cluster over a number of nodes that means the total number of clusters that are formed in network space. The HEBM protocol provides

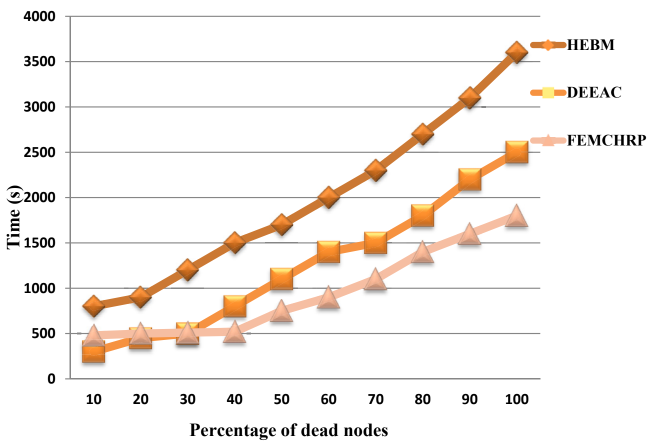

Fig. 16. Percentage of dead nodes in the network.

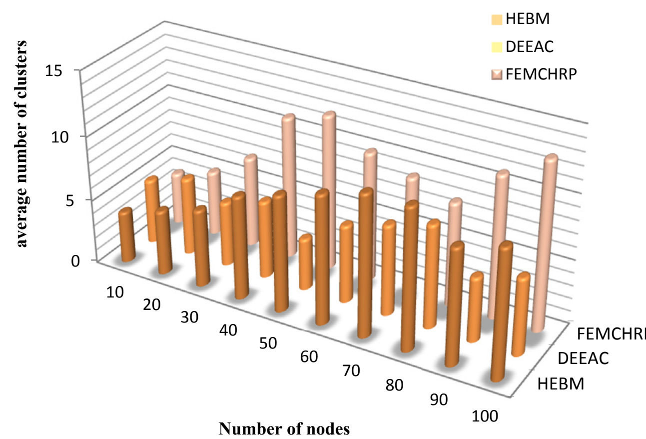

Fig. 19. Average number of clusters over number of nodes.

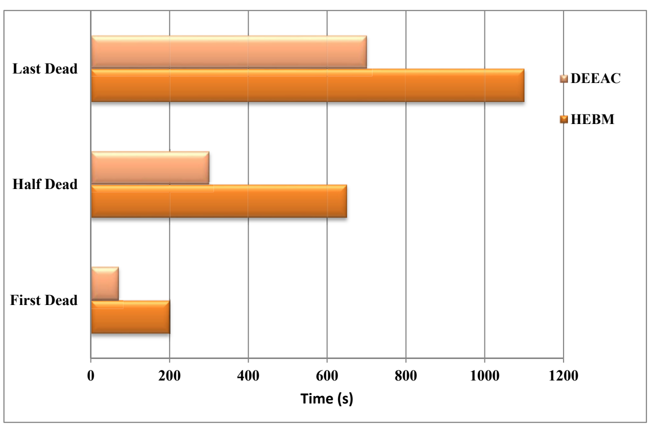

Fig. 17. Rounds for 1st, half and last node dead in HEBM & DEEAC.

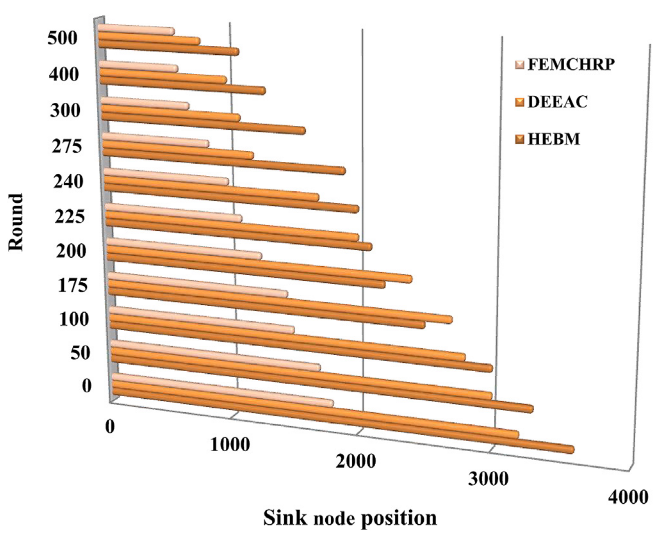

Fig. 18. Sink node position vs Network Life time.

about *32.81%* fewer clusters than *DEEAC* end *45.73%* than *FEMCHRP*. In *HEBM* protocol, we used also the load balancing, so for each cluster head can handle the same number of nodes at the same time.

The variation of the average number of clusters with respect to the transmission range is illustrated in Fig. 20. We found that there is opposite relationship between clusters and transmission range. This is on the grounds that a cluster head with a considerable transmission range will cover a large area. For example: in HEBM cluster formation, *for* $n = 800$, $Tr = 150$, *N. cluster* $= 4$, *for* $n = 600$, $Tr = 110$, *N. cluster* $= 8$, *for* $n = 200$, $Tr = 50$, *N. cluster* $= 12$. So, we conclude that when the transmission range increases, the average number of clusters decreases. The possible reason for this kind of behavior is that a cluster with a large transmission range will cover a larger area. Fig. 21 shows *HEBM* cluster-head distribution map, in area ($200\ m \times 200\ m$) *HEBM* clustering algorithm is completely distributed because a centralized control manner is not practical in a large-scale sensor network (*with* $n = 100$, $n = 200$, $n = 300$, $n = 400$) The cluster heads in *HEBM* are well distributed throughout the monitoring area to make energy consumption well-balanced among all sensor nodes. The load balancing is accomplished by determining a pre-defined threshold on the number of nodes that a cluster head can cover ideally. This ensures that none of the cluster heads are overloaded at any instance of time. In our algorithm, Load Balancing means that each cluster head can handle the same number of nodes at the same time.

Fig. 22 illustrates the latency per packet over the number of nodes; the simulation results show that HEBM protocol offers better results in terms of reduction of latency than other protocols like *DEEAC* and *FEMCHRP*.

In Fig. 23, *Number of packets* = *file size/packet size*.

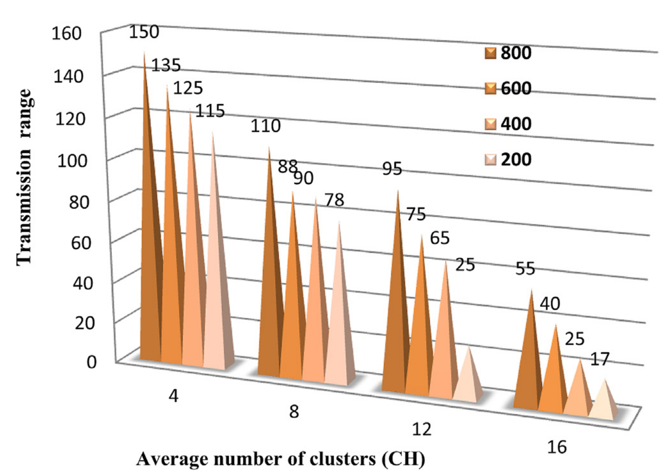

Fig. 20. Average number of clusters over transmission range.

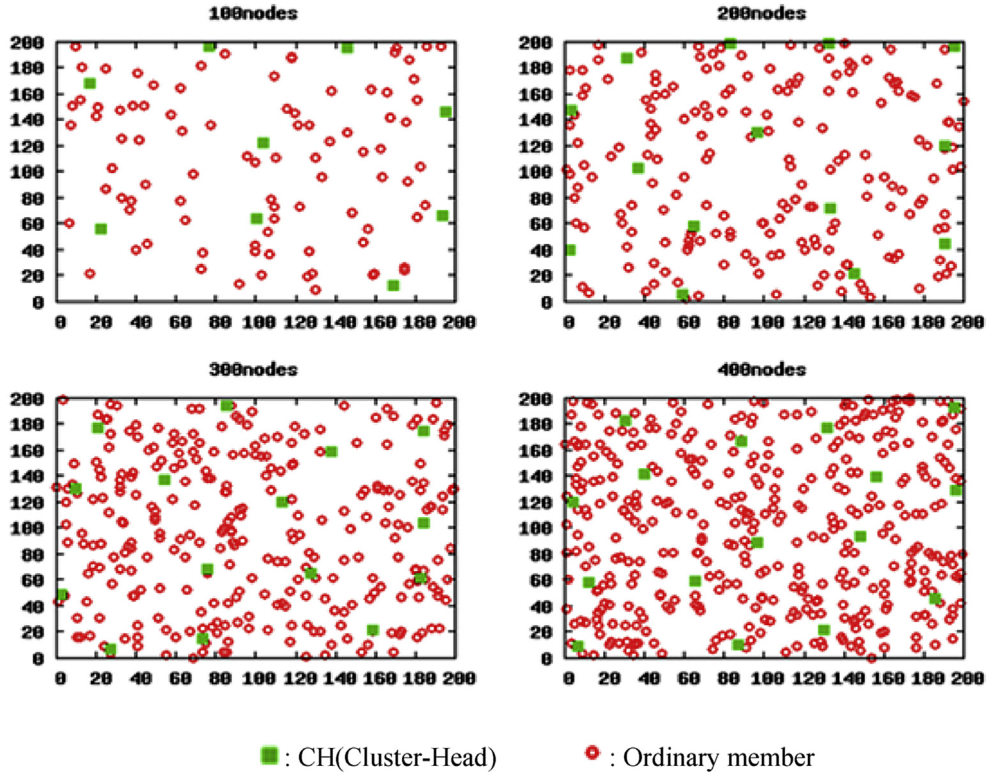

Fig. 21. HEBM Cluster Head distribution map.

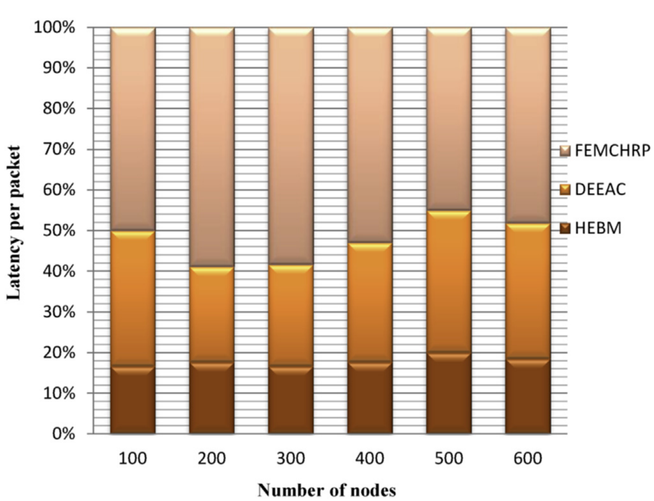

Fig. 22. Latency per packet over number of nodes.

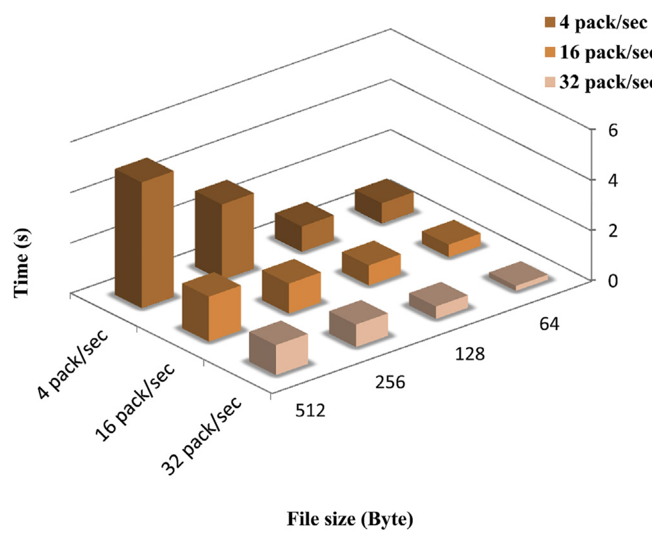

Fig. 23. Transmission time in different number of packets.

Time = function of number of packets, this figure illustrates HEBM protocol with number of packets sending (*4pack/s, 16 pack/s, 32 pack/s*). Fig. 24 shows the total number of data received at the base station as a function of time *(HEBM packet's sent, received and dropped).* The proposed protocol HEBM with the variable desirable number of cluster-heads sends more data to the base station than DEEAC, since the lifetime of the sensor networks is longer than in DEEAC which makes HEBM performance greater when the number of cluster heads is variable.

We used the following Equation (12) for calculating probability of packets sending.

$$Pqt - send_{DEACP} = \frac{Nb - succ - packet}{Tot - Nb - send - packets} \tag{12}$$

As shown in Table 2, our proposal outperforms the referenced protocols regarding the most important factors as energy efficiency, load balancing and scalability.

Wireless sensor networks basically consist of low cost sensor nodes which collect data from environment and relay them to a sink, where they will be subsequently processed. Since wireless nodes are severely power-constrained, the major concern is how to conserve the nodes energy so that network lifetime can be

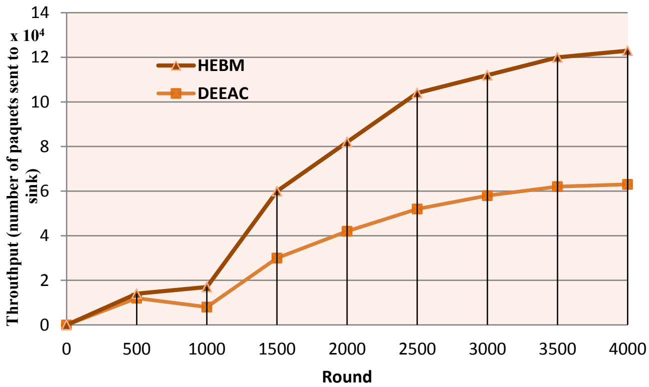

Fig. 24. Number of packets sent to Base station.

of paramount importance to get rid from node energy exhaustion. This undesirable energy lack situation may lead to the incapacity of successfully achieving the network mission. It is also the case when a sensor node sends erroneous data because of its residual energy below an acceptable threshold. Therefore, nodes energy is a vital factor greatly influencing the WSN mission outcome. So, energy issue increasingly attracts researchers attention in order to make sensor nodes saving their energy consumption for lasting as long as possible. This is what our proposal HEBM is aiming to. Thus, new useful metrics (assigning weight to a node, predefined threshold for the number of nodes to be created by a clusterhead, load balancing) and multi-hop intra inter clusters routing have been used guaranteeing an efficient node clustering repartition leading to improved node energy saving which involve network lifetime duration enhancement.

Table 2
Comparative Analysis of three clustering protocols (*FEMCHRP, DEEAC and HEBM*).

Characteristics	Protocol		
	FEMCHPR (Fuzzy Based Energy Efficient Multiple Cluster Head Selection Routing Protocol)	DEEAC (Distributive Energy Efficient Adaptive Clustering Protocol)	HEBM (Proposed protocol) (Hierarchical Energy-Balancing Multipath routing protocol for Wireless sensor networks)
Energy efficiency	Good	Good	High
Cluster stability	Medium	High	High
Load balancing	Poor	Good	High
Classification	Proactive/clustering	Proactive/clustering	Proactive/clustering
Delivery delay	Medium	Small	Small
Scalability	Low	Low	Good
Reliability	Good	Good	Good
Algorithm complexity	Medium	Medium	Medium
Routing structure	Both flat and hierarchical	Both flat and hierarchical	Both flat and hierarchical
Security	No	No	No (Future work)

extended significantly until reaching end mission. For this, the following criteria have to be considered:

- In order to save energy consumption in idle states, low duty-cycled operation is widely in WSNs, where each node periodically switches between sleeping mode and awake mode.
- Clustering is the process of dividing sensor nodes into groups based on some attributes. Generally based upon geographical location and remaining residual energy value, clusters are formed. Clustering is a well-known approach to cope with large nodes density and efficiently conserving energy in Wireless Sensor Networks.
- The metric of Cluster Head selection.
- Inter-cluster (and intra-cluster) communication in several proposals is achieved through organizing the cluster-heads in a hierarchy allowing then better energy distribution and overall energy consumption.
- Data aggregation has been put forward as an essential paradigm for wireless routing in sensor networks. The idea is to combine the data coming from different sources for eliminating redundancy, minimizing the number of transmissions and thus saving energy.

5. Conclusion and future work

In Wireless Sensor Networks, where nodes have at their disposal non rechargeable batteries with limited initial energy budget, it is

In HEBM, the distance among the cluster-heads has been utilized to reach a well-distributed clustered WSN with suitable size clusters. Several simulation scenarios have been carried out and the results showed by HEBM outperform those exhibited by protocols used as references.

Future work is focused on the adaptation of our proposal to a sensor deployment environments with mobile base station which is expected to gain further energy saving. As well, we envision providing our proposal with fault tolerance capabilities especially for vital nodes like base station and cluster heads.

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