Cluster-Based Sleep Scheduling Protocol for Mobile Wireless Sensors Network

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ABSTRACT:
Mobile Wireless Sensors Networks (MWSNs) are used in several applications presenting difficult/dangerous environment and/or requiring the movement of sensors after initial deployment. Optimizing the use of the limited energy resource in a MWSN is a key challenge for researchers to maintain longer network survival. This paper attempts to provide an energy-efficient data routing solution for large MWSNs. The aim of this work is to propose a cluster-based scheduling protocol for MWSN. The network is firstly divided into an optimal number of clusters according to sensors connectivity. Secondly, a sleep scheduling algorithm is proposed to save the energy consumption by turning off the overlapped nodes in the sensing field. This method is distributed among sensor nodes in each cluster. It is based on the perimeter coverage level of mobile sensor nodes to schedule their activities according to their weights. The weight is used to balance the energy consumption for all sensor nodes in a cluster. The proposed approach ranges from sensors deployment and their organization to their operational mode. Experimental results demonstrate that the proposed cluster-based scheduling algorithm, based on the perimeter coverage of sensors, provides higher energy efficiency and longer lifetime coverage for MWSNs as compared to other protocols.

KEYWORDS: Mobile WSN, Energy Consumption, Clustering, Sleep-Scheduling, Perimeter Coverage.

1. INTRODUCTION

A Wireless Sensors Network (WSN) contains a large number of small devices interconnected by wireless communication channels. Each sensor node cooperates with other sensors to supervise or to monitor various phenomena in its surrounding environment and uses a battery as energy resource. A mobile WSN consists of mobile sensors which can change their positions frequently after initial deployment. They are deployed in various environments including remote, dangerous and hostile regions. In fact, mobile WSNs are used in a variety of applications such as environmental monitoring, seismic monitoring, health care applications, infrastructure protection, acoustic detection, undersea navigation, smart city and military surveillance [1]-4]. Since mobile sensors are intended to operate in a hostile environment, to be deployed unpredictably and typically to have a limited and irreplaceable energy resource, minimizing the energy consumption is a primary objective while ensuring that the network performs its task properly [5]. Consequently, efficient and rigorous management of the energetic resource is of paramount importance. One of the proposed solutions to save sensor energy in WSNs is hierarchical routing protocols. The Hierarchical protocols have demonstrated an energy efficiency and scalability. It dynamically organizes sensor nodes into clusters according to some criteria. Then, the cluster head collects, aggregates and transmits data toward the sink to reduce data transmission and to save energy [6]-[8]. Another important used solution to save sensor energy is sensor scheduling i.e., to switch to sleep mode the overlapped nodes alternately. The key assumption is that mobile WSN are densely deployed where close nodes provide redundant measurements [9].

In this paper, we make the following contributions: The mobile WSN is organized into clusters according to sensor nodes position and inter-connectivity before scheduling nodes activities. This organization have demonstrated an energy efficiency and scalability [10]. Then, mobile sensors communicate and cooperate together to elect a CH for each period of time.

An optimized sleep scheduling algorithm is proposed where a minimum number of mobile nodes will be set into the active mode while other overlapped nodes will be put in the sleeping mode. A distributed approach

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based on k-perimeter coverage algorithm is proposed. Our solution consists of checking that every sensor perimeter is covered. Precisely, we focused on solving the sensor activities scheduling problem for k-coverage in a sensing model incorporating a large number of mobile sensor nodes.

We conducted various simulation experiments into the discrete event simulator OMNeT++ to show the efficiency of the proposed protocol.

The rest of this paper is organized as follows. Section 2 reviews related work, section 3 is devoted to the proposed approach description and focuses on the k-coverage model characterization which is used to schedule sensor nodes activities in mobile WSN. Section 4 presents simulation results of our proposed protocol. Section 5 concludes the paper and gives some suggestions for future work.

2. RELATED WORK

In the literature, there are many research papers treating the coverage problem in a WSN. In this section, we briefly highlight some existing approaches on this topic.

The Energy-Efficient Wake-Up Scheduling protocol reduces the dissipated energy by sensors modules for synchronization and state transition. It uses the Time Division Multiple Access (TDMA) protocol to schedule sensor nodes. In a scheduling period, a sensor node wakes up at most two times: when transmitting data for its parent or receiving packets from its child node [11]. But this method causes a significant delay.

Two delay-efficient aggregation scheduling algorithms, with Signal to Interference-plus Noise Ratio (SINR) constraints of WSNs, are proposed. For data aggregation, this approach generates a routing tree and propose two scheduling algorithms which can produce collision-free link schedules. In a Wireless Sensor Networks, nodes are distributed in a plane. For each node having data to be delivered, the goal is to conceive the routing scheme and the node transmission scheduling for data aggregation under SINR constraints. The proposed algorithms have a remarkable effect on the data aggregation delays. They are asymptotically optimum in random Wireless Sensor Networks [12]. But, the data aggregation method is not efficient.

The Adaptive Sleep Scheduling algorithm for Cluster Based WSNs is proposed to schedule sensor nodes activities based on the remaining energy. The WSN is divided into clusters with adaptive clustering algorithm where the CH is elected according to its remaining energy. The CH calculates the average of the available energy in its cluster and the sensor nodes with less remaining energy go to sleep state [13]. This adaptive sleep scheduling approach reduces the energy consumption. But, the traffic controlling is very difficult and the data lost packets rate is important in large networks.

The distributed Coverage-Preserving Clustering Protocol (CPCP) uses the weight coverage cost and the remaining energy metrics to decide the becoming of a sensor. Sensor nodes with minimum-weight coverage cost and higher remaining energy deployed in dense network areas are likely to be elected as CHs and/or to be in active mode. According to this decision, each sensor node keeps its status until the end of an activation time which it determines based on its coverage cost. If the sensing area of a sensor is full covered by other sensors, it turns to inactive mode during the current round [14]. However, this sleep-scheduling approach is not efficient; because, in each round, it cannot guarantee the found of all redundant nodes. Therefore, running the CPCP algorithm by sensor nodes depends on the defined activation times. So, instead of the beginning, the decision of becoming an active or inactive node can occur anytime during the round. This leads to more energy consumption since redundant sensor nodes must wait the end of their activation times to change their status.

The centralized NSGA-CCP-3D protocol is proposed to cope with cluster based and full area coverage challenges in a 3D WSN. The network is divided into equal cubes. The goal of this protocol is to propose a common solution by setting the adequate and optimal status for every sensor node (CH, active or sleep). This solution have to insure energy efficiency by minimizing the number of active sensors while providing full connectivity and coverage in 3D WSNs. For that, a new chromosome encoding scheme is given as a single multi-objective optimization solution . The full area coverage is ensured as each cube in the network is covered by at least one sensor [15]. However, NSGA-CCP-3D assumes that all the CHs can communicate with the BS which cannot be used in large networks.

A genetic algorithm-based methods for clustering and scheduling sensor nodes is proposed to optimize sensors energy consumption. The GA operates in 2 steps. In the first one, sensors are organized into clusters in 2-D space according to sensors position. Clusters number is fixed in advance. In the second step, sensor nodes are scheduled depending on their remaining energy. So, sensors with maximum energy level are more likely to be set in active mode. The main objective of the GA is to select minimum number of sensors while ensuring full coverage [16]. However, this approach is proposed for fixed WSN and is unsuitable for mobile networks. In fact, mobile WSNs are characterized by a frequent topology change. But, the GA forms the clusters according to sensors position and cluster centers which are defined in the initialization phase.

The Mobile Sampling Protocol (MSP) is proposed to define a distributed sleep scheduling strategy for mobile nodes in a WSN. It is an application layer protocol with adaptive scheme that is based on the detection of similarities between sensor measurements to discover the redundancy. The main assumption is that the nearby sensor nodes give the same measurements.

The WSN is divided into two-node clusters. For each cycle, one of the two nodes still is sleeping, while the second is awaken to receive/transmit data packets. This role is reversed between these cluster members in order to balance the energy consumption [17]. This approach reduces the energy consumption. But, the two nodes' clusters organization is not an efficient solution in term of data delivery especially under high mobility rate.

In order to reduce energy consumption, an Energy Efficient Sleep-Scheduling for Cluster Based Aggregation in a mobile WSN is proposed to schedule nodes data gathering activities. Each sensor node wakes up only twice: for receiving data from its neighbor and then for transmitting data to the sink. To maintain the synchronization between sensor nodes, this algorithm uses an efficient time allocation for all the scheduling states. Therefore, it uses the Probability-based Prediction and Sleep Scheduling (PPSS) protocol to reduce the energy consumption [18]. However, it is a centralized scheduling algorithm which could not be used in a large WSN.

According to the literature survey, it does not exist a solution that meets all the requirements of a mobile WSN. Most of the existing works are based on static networks, non-adaptive methods and do not consider nodes mobility. Therefore, nodes mobility factor is not well addressed whether for nodes organization or for nodes activities scheduling.

In this paper, we propose an adaptive sleep scheduling algorithm for a large mobile WSN that cope with such network dynamic aspect. As an extension to the previous work [10], we develop a power aware sleep scheduling algorithm for a cluster based mobile WSN that provides higher energy conservation and longer network lifetime.

3. PROPOSED APPROACH FOR K-COVERAGE IN A MOBILE WSN

In this section, we present our solution to resolve the coverage overlap problem of mobile sensors in a large clustered WSN. For that, we describe our proposed algorithm based on sleep scheduling to dynamically find the optimal number of active nodes and to put the overlapped nodes in the sleeping state ensuring a k-covered region. This scheme reduces the energy consumption, balances the dissipated energy by mobile sensors and improves the network lifetime.

3.1. Network Model

In this paper, we consider a mobile WSN containing a large number of mobile sensor nodes randomly deployed. These sensors have the same sensing range and can move freely in the sensing field. They are used to continuously supervise the area of interest and to provide a maximum covering rate. All nodes are supposed to initially have the same energy level and the same sensing range denoted R. The proposed WSN contains also some anchor nodes knowing their positions in advance. Thus, a mobile sensor can estimate its position and approximate the distance from any anchor in its sensing area using the trapezoidal GOMASHIO approach combined with the ToA, RSSI and its sensing range [19]. It is also assumed that the sink is stationary.

3.2. Network Organization

The considered WSN contains a large number of randomly deployed mobile sensors. These sensors are grouped into clusters according to their position and the connectivity between them. Since mobile sensor nodes change their position over the time, sensors repartition in a sensing field changes frequently and cannot be predicted in every region at every instant. So, fixing the number of clusters in advance, as used in several proposed clustering algorithms, is not suitable for mobile networks. In this context, we were based on a clustering algorithm, proposed in a previous work, that optimizes the number of groups and forms compact clusters [10]. In that approach, we proposed the stochastic method for modeling and dimensioning a mobile WSN. In fact, when considering V: the set of vertices, W: the edges and a graph G (V,W); a random walk on this graph is a stochastic process. Therefore, a random movement from one node to another is defined by the stochastic matrix. After that, by altering the processes of the MCL algorithm on the stochastic matrix, we could interpret distinct clusters. Finally, in the previous work, we succeeded to organize mobile sensors into compact and well separated clusters basing on a clustering method by reference to the stochastic matrix and the MCL algorithm as described in Fig. 1. once the clusters are formed, a CH is elected for each one depending on three criteria: sensors residual energy, position and degrees.

3.3. Radio Energy Consumption Model

The radio module is responsible to ensure communication between sensor nodes. It is the most energy consuming component. For that, many protocols are developed for the network and MAC layers to reduce the energy dissipation during the communication phase.

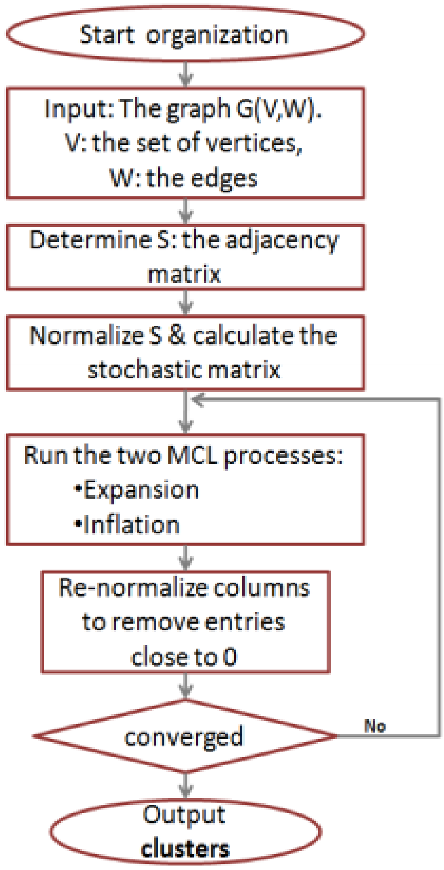

Fig. 1. Mobile sensors organization: proposed clustering method.

To transmit k-bits message at a distance d, the transmitter consumes:

$$E_{Tx}(k,d) = k * E_{elec} + k * E_{amp} * d^2 \quad (1)$$

Where Eelec is the dissipated energy by the sensor node transmitter circuit per bit, Eamp is the energy of amplification, d is the distance from the sender to the receiver.

To receive a message of k-bits, the receiver consumes:

$$E_{Rx}(k,d) = k * E_{elec} \quad (2)$$

In this paper, we assumed that sensor nodes are organized into clusters using the stochastic matrix and the MCL algorithm.

• To transmit k-bits packet to the CH, member nodes consume:

$$E_{toCH} = \sigma \int_{dCH}^{0} 2\pi x \times \rho \times (kE_{elec} + kE_{amp}x^2)dx \quad (3)$$

$$= \sigma k\pi\rho \times (E_{elec}d_{CH}^2 + \frac{1}{2}E_{amp}d_{toBS}^4) \quad (4)$$

Where, $2\pi x \times \rho \times dx$ represents the number of sensor nodes that can communicate with the CH i.e. located at a position $x \leq r_i$ (range of the CH) and σ represents the percentage of active nodes in the cluster.

• To receive a data packet from member nodes, each CH consumes:

$$E_{re} = k \times (\pi r_i^2 \rho - 1) \times E_{elec} \quad (5)$$

• To send a data packet toward the BS, a CH consumes:

$$E_{toBS} = kE_{elec} + kE_{amp}d_{toBS}^4 \quad (6)$$

• Then, the total consumed energy in each cluster is given by:

$$E_{cluster} = E_{toCH} + E_{toBS} + E_{re} \quad (7)$$

$$= k\pi\rho r_i^2 \left(\sigma + \frac{1}{2}\sigma\alpha r_i^2 + E_{elec}\right) + kE_{amp}d_{toBS}^4 \quad (8)$$

where $\propto$ represents the amplifier energy factor in free space.

• So, a node member of each cluster consumes on average:

$$E_{member} = \frac{E_{cluster}}{\pi r_i^2 \rho} \quad (9)$$

3.4. Sleep Scheduling Approach

Reducing the energy consumption and improving the network lifetime are fundamental tasks in mobile WSNs. Several strategies have been proposed in the literature to schedule sensors activities by turning a maximum number of sensor nodes into the sleep state while ensuring a full coverage in the area of interest. But, it has been proven that minimizing the number of active sensors while ensuring a certain coverage rate is an NP-hard problem [20].

In this article, we propose a generic framework for k-perimeter coverage in a mobile WSN that implements a large number of mobile nodes and few anchors. Precisely, we propose a distributed approach where each anchor runs a k-perimeter coverage algorithm to determinate for each member if it should turn to active or inactive state.

Our work mainly focuses on the perimeter-coverage model. In fact, a sensor node n is perimeter-covered if for every point p in its detection area is covered by at least one sensor node. Therefore, it is said k-covered if every point p in its perimeter is covered by at least k sensors (k > 1). Our solution consists of checking how each sensor perimeter is covered instead of determining the coverage of each region in the network.

- **Sensor perimeter-covered calculation**

In this approach, we proceed to calculate the perimeter-covered of a sensor c_i by every neighbor

c_j where $d(c_i, c_j) \leq 2 * R_S$ as shown in Fig. 2.

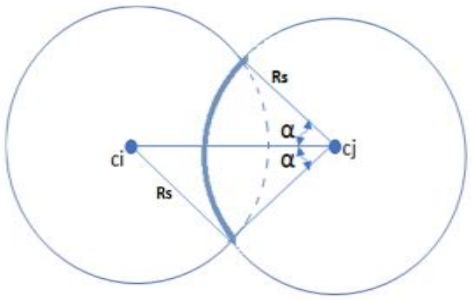

Fig. 2. c_i sensor perimeter-covered by c_j sensor.

Thus, to determine the c_i perimeter-covered by the other sensors, we calculate the Euclidean distance $d(c_i, c_j)$ between c_i and c_j. Then, we determine the half angle αj which covers a half arc of the perimeter covered by c_j : $\propto_j = \cos^{-1}(\frac{d(c_i,c_j)}{2R_S})$.

Finally, we place the arc covered by c_j on a segment [0, 2π]. If the segment [0, 2π] is fully covered, the perimeter of ci is covered, otherwise there are some points in the detection area of c_i that are not covered by other sensors.

- **Proposed Protocol Algorithm**

In this section, we describe our node's sleep scheduling strategy to solve the problems of data redundancy, to reduce the energy consumption and to extend the mobile WSN lifetime. Sensor nodes, which provide the coverage of the area, are chosen by the anchor in a distributed way according to their weight. The randomly deployed mobile sensors are, in the first step, organized into clusters using an efficient clustering protocol based on stochastic Matrix and MCL algorithm [10]. In a second step, the proposed sleep scheduling protocol is periodically executed by the anchor to schedule sensors activities in each cluster. Let's recall that periodic protocols have proven their effectiveness against unexpected sensors failure. In fact, if a sensor has failed before running the sleep scheduling algorithm, it will not be considered in the next step. Therefore, the failure persists only temporarily if a sensor node fails after running the sleep scheduling algorithm for a new period [21]. In order to determinate which node go to sleep mode, the proposed protocol is based on the residual energy, the proximity to the anchor and the number of neighbors. We give a brief description of the proposed sleep scheduling mechanism in Fig. 3.

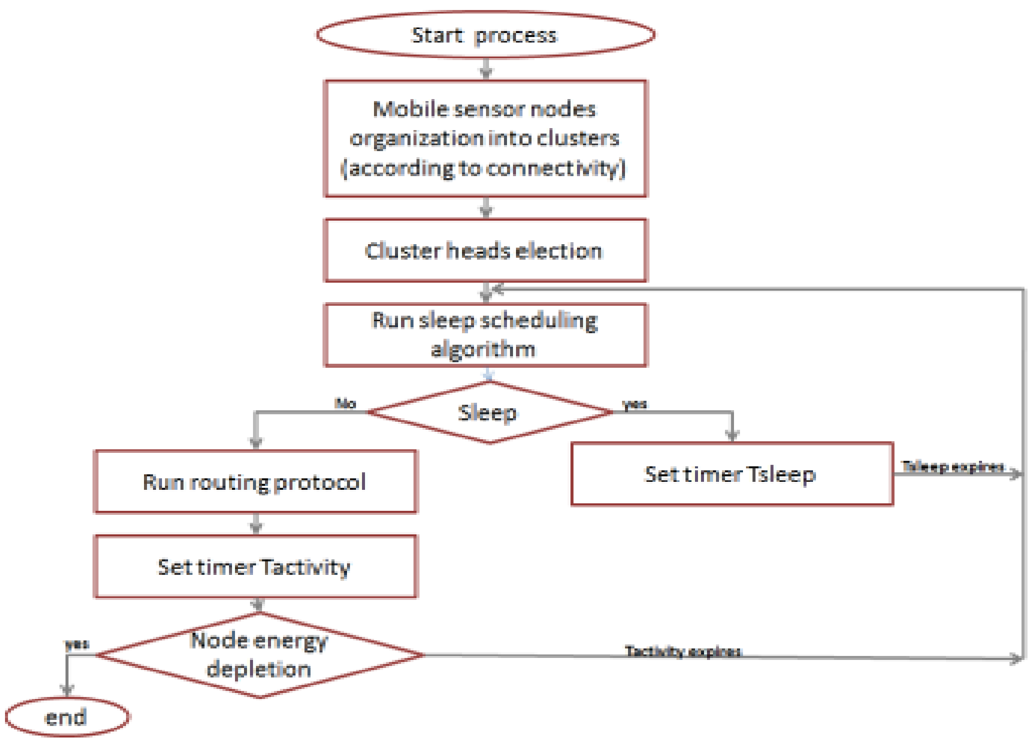

Fig. 3. Proposed Sensors Activities Scheduling Model.

Once mobile nodes are organized into clusters, the anchor collects information about sensor members to make the adequate decision and to set the optimal number of sensors on active mode satisfying the coverage requirement. For each period, the anchor broadcasts the INFO message to the adjacent mobile nodes to announce the new scheduling period. On receiving the INFO packet, each mobile node sends an INFO rep message. The rep message contains the sensor ID, its cluster ID, its residual energy, its degree and its position. Each mobile sensor node determines its coordinate using the localization algorithm proposed in [19]. The anchor calculates the weight of member nodes in each cluster and sorts them into a list CL in a descending order according to the following equation:

$$W_{ej} = deg_j^{\frac{1}{2}} + e_{rj}^{\frac{1}{4}} + \left(\frac{1}{d_{ja_i}}\right)^{\frac{1}{4}} \tag{10}$$

Where deg_j is the degree of the node j, e_{rj} is the residual energy and d_{ja_i} is the distance that separates node j to the anchor i in its range.

Then, this anchor traverses the list CL and checks if each entry, i.e. sensor node, is perimeter covered. If it is the case, it turns off the sensor S_j, sets its neighbors to the active state and removes them from the list CL. In fact, a sensor node with the least number of neighbors, the least remaining energy and more far away from the anchor is more likely to go on sleep mode. Finally, the anchor broadcasts a message containing the ID and the new status of the sensor S_j.

Algorithm 1 illustrates the main steps of the proposed Sleep scheduling mechanism. The following notations are used in the proposed algorithm.

CL: a list that an anchor creates for its mobile member nodes in each cluster. It calculates the weight of each member node according to the residual energy, the position and the degree. Then, this list is sorted in a descending order.

$\boldsymbol{S_j}$**:** mobile node j.

INFO packet: sent by the anchor to all the member nodes to announce the new scheduling period and ask for information exchange.

INFO_rep: sent by a sensor node as a reply to the INFO message. It contains the status information of a node, such as the residual energy, the cluster ID, the position and the number of neighbors.

Algorithm 1: Scheduling algorithm

```
Initialization;
CL ← Null
i, j ← 0
for each cluster do
    for each scheduling period do
        Send INFO Packet to other member nodes;
        Wait INFO_rep from other nodes in a cluster;
        //Anchor collects status information of each sensor
        if Anchor receive INFO_rep packet then
            CL[i] ⟵ info;
            i + +;
        end
    end
    for each entry in CL do
        //calculate the weight of each sensor i
            W_i = deg_i^(1/2) + e_ri^(1/4) + (1/d_ia_i)^(1/4);
    end
    Sort CL in descending order according to Wi;
    CH.status=on; //Set the CH node on active mode;
    while j < size of sensors list do
        if S_j <> CH then
            //Check if sensor Sj is covered if S_j <> CH then
                if S_j is covered then
                    S_j is redundant;
                    S_j .status=idle;
                    CH broadcasts a msg containing the status and ID of S_j;
                    Turn on the corresponding neighbors covering S_j;
                    remove these neighbors from the list;
                end
            end
        end
        j + +;
    end
end
```

4. EXPERIMENTAL RESULTS AND DISCUSSION

In this section, we present the simulation results that we obtained by the implementation of the proposed sleep scheduling technique into the OMNet++ simulator. We conducted many experiments to evaluate and to compare its performance with the EESSCBA [22] and the Efficient Clustering Protocol based on stochastic matrix & MCL (ECP) [10]. In the simulation, we considered a network containing 100 randomly distributed mobile nodes moving in a 1000m × 1000m sensing field. The considered metrics in the evaluations are energy consumption, loss packets rate and data packets delivery ratio. The simulation parameters are summarized in Table 1.

Table 1. Simulation Parameters.

Parameters	Values
Field dimension	1000×1000
Initial energy in each node	10 J
Number of nodes	25, 50, 75, 100 and 125
Nodes speed	5 m/s
Transmission range	100 m

4.1. Remaining Energy

The overall remaining energy is compared between ECP, EESSCBA and our proposed approach considering the sensing and communication energies.

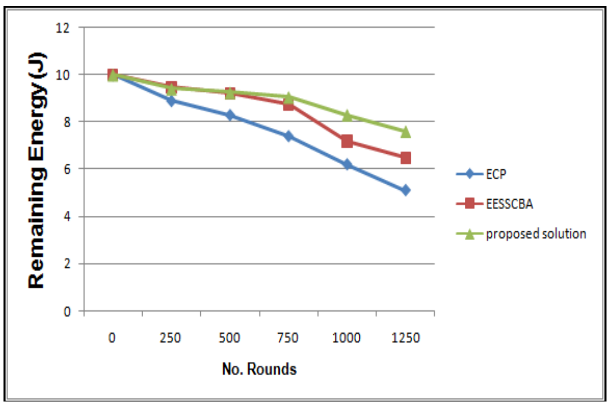

Fig. 4. Average remaining energy in sensor nodes.

As illustrated in Fig. 4, the energy consumption is more marked in ECP and EESSCBA than in the proposed protocol. After 500 rounds, the remaining energy was 9.21J in ECP, 7.98J in EESSCBA and 9.25J in the proposed algorithm. After 1000 rounds, it decreased rapidly by EESSCBA and ECP until reaching respectively 5.5J and 7.2J; whereas it reached 8.3J by the proposed approach. It can be noticed from Fig. 4 that the proposed solution optimizes the energy consumption and provides more remaining energy in sensor batteries as compared to the ECP and EESSCBA protocols. This is achieved by the combination of a good cluster-based organization and a periodic scheduling approach. Therefore, the proposed scheduling algorithm promotes sensor nodes with less energy to switch to sleep mode according to equation (10). On the other hand, this is due to the centralized EESSCBA scheduling algorithm which requires an additive data flow exchange between the BS and sensor nodes as opposed to the distributed proposed algorithm. Let's recall that the energy dissipation depends on the traveled distance. Thus, sensor nodes, which are far away from the BS, have to dissipate a significant amount of energy to communicate with the BS and to be scheduled.

4.2. Number of Alive Nodes

We simulated the number of alive nodes in a WSN containing 200 nodes at node speed of 5 m/s. As shown in Fig. 5, the number of alive nodes over time is more important when using our proposed approach. The obtained rate of alive nodes, after 1250 rounds, by our approach is 70%, by ECP is 10% and by EESSCBA is 37.5%. It can be noticed from Fig. 5 that the proposed solution maintains more alive sensors as compared to the ECP and EESSCBA protocols. This is because: First, referring to the Fig. 4, it was noted that nodes, implementing the EESSCBA and the ECP, run out their energetic resources before the sensors that implement the proposed sleep scheduling scheme. Second, when it is a centralized protocol (as in the case of EESSCBA protocol), the distance factor will lead to more energy consumption in the region far away from the BS. Indeed, in one hop mode, sensor nodes far away from the BS will die quickly. So, it is clear that our approach ameliorates the number of remaining nodes in the network. Therefore, as compared to the ECP, it has successfully extended the network lifetime by the sensors activities scheduling.

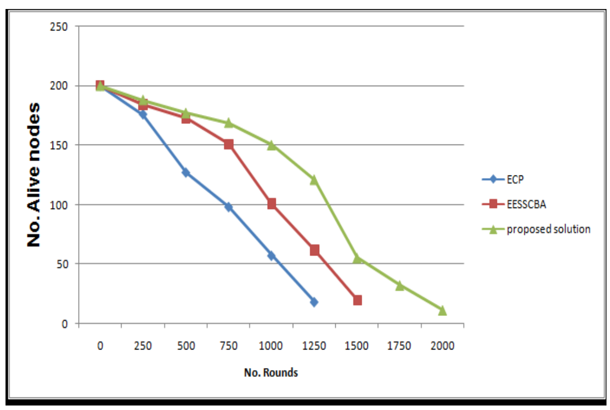

Fig. 5. Number of alive nodes.

4.3. Packet Delivery Ratio

Fig. 6 illustrates the data delivery ratio of ECP, EESSCBA and the proposed protocol with different number of sensor nodes. From the results, we can observe that the proposed protocol demonstrates better performance in term of data delivery ratio than EESSCBA. This is due to two reasons. First, it is due to the proposed clustering protocol which is designed to compromise the number of CHs in the network and reduce the communication costs. As opposed to the EESSCBA protocol, our algorithm do not fix the number of clusters in advance. It takes appropriate decisions related to nodes dispersion to optimize the number of clusters, to reduce the energy consumption and to improve the data delivery ratio. Second, the redundant nodes are selected to go to inactive status where the rest of active nodes are sufficient to provide the same coverage rate. In fact, a sensor node is selected to switch to sleep mode only if it is perimeter covered by other sensors. In this case, sensors are able to monitor the sensing field with less energy consumption. And by doing so, active nodes can perform their missions for long periods. Hence, it is unnecessary to set all sensors in the active mode which provide an energy conservation with the requested delivery ratio.

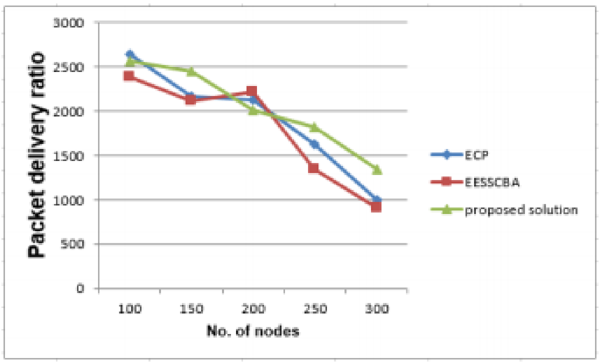

Fig. 6. Nodes vs Packet delivery ratio.

4.4. Coverage Duration

Initially, all sensor nodes have the same amount of energy (10 J) and they stop working when their batteries are exhausted. The network lifetime depends on the coverage rate of the sensing area. Thus, the simulations are running until the coverage rate falls below a certain threshold. In this case, the network fails to accomplish its missions. For these simulations, the threshold was set at 90%. Fig. 7 shows the link between node density and network lifetime. Obviously, network lifetime increases as nodes density increases. In fact, sensor nodes can remain in sleep mode for a long period in a dense network as compared to a less dense one. Therefore, the quasi-local aspect of the proposed algorithm and the periodic selection of active sensors, according to their capabilities, allow it to more extend the network lifetime as compared to the EESSCBA.

Fig. 7 shows that our approach extends the coverage duration by 34% and 17% compared to EESSCBA and ECP with 300 nodes respectively.

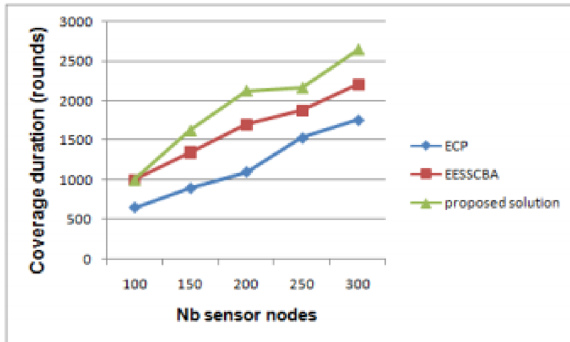

Fig. 7. Coverage duration comparison.

5. CONCLUSION

This paper proposes an energy efficient solution for mobile WSNs. It is based on a distributed clustering and sleep scheduling algorithms for MWSNs. The mobile nodes in the network organize themselves into clusters, dynamically elect a CH among them and send to sleep the overlapped nodes. The proposed sleep scheduling algorithm is based on sensors perimeter covered. It promotes the transition to the off state, the nodes having a minimum weight. This weight is a function of the remaining energy, the neighbors' number and the proximity to the anchor. The proposed protocol is designed to support mobile environments. In this context, a full and robust solution improving the network lifetime while maintaining a good coverage rate can easily cope with large mobile WSNs. Several simulations have been carried out into OMNet++ simulator to evaluate the performance of the proposed protocol. The obtained results show that the proposed algorithm is more efficient than other approaches in terms of lifetime, active sensors rate, coverage rate and packet delivery ratio. Finally, it is interesting to implement the proposed solution using a testbed to check it in real world applications.

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