International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:3, No:4, 2009

A Balanced Cost Cluster-Heads Selection Algorithm for Wireless Sensor Networks

Ouadoudi Zytoune, Youssef Fakhri and Driss Aboutajdine

Abstract—This paper focuses on reducing the power consumption of wireless sensor networks. Therefore, a communication protocol named LEACH (Low-Energy Adaptive Clustering Hierarchy) is modified. We extend LEACHs stochastic cluster-head selection algorithm by a modifying the probability of each node to become cluster-head based on its required energy to transmit to the sink. We present an efficient energy aware routing algorithm for the wireless sensor networks. Our contribution consists in rotation selection of cluster-heads considering the remoteness of the nodes to the sink, and then, the network nodes residual energy. This choice allows a best distribution of the transmission energy in the network. The cluster-heads selection algorithm is completely decentralized. Simulation results show that the energy is significantly reduced compared with the previous clustering based routing algorithm for the sensor networks.

Keywords—Wireless Sensor Networks, Energy efficiency, Wireless Communications, Clustering-based algorithm.

I. Introduction

WIRELESS Sensor Networks (WSNs) can offer unique benefits and versatility with respect to low-power and low-cost rapid deployment for many applications which do not need human supervision. The nodes in WSNs are usually batteryoperated sensing devices with limited energy resources and replacing or replenishing the batteries is usually not an option.Thus energy efficiency is one of the most important issues and designing power-efficient protocols is critical for prolonging the lifetime. The latest developments in time critical, low cost, long battery life, and low data rate wireless applications have led to work on wireless sensor networks (WSNs). These WSNs have been considered for work in certain applications with limited power, reliable data transfer, short communication range, and reasonably low cost such as industrial monitoring and control, home automation and security, and automotive sensing applications[1]. The WSNs consist of a set of sensors that communicate with each other to form a sensor field. These large numbers of nodes, which have the ability to communicate wirelessly, to perform limited computation, and to sense their surroundings, form the WSN[2]. Specific functions can be obtained through cooperation between these nodes; functions such as sensing, tracking, and alerting[3]. These functions make these wireless sensors very useful for monitoring natural phenomena, environmental changes, controlling security, estimating traffic flows, monitoring military application, and tracking friendly forces in the battle-fields[2]. In order to enhance the network life time by the period of a particular mission, many routing protocols have been devised. One of these is network clustering, in which network is partitioned into small clusters and each cluster is monitored and controlled by a node, called Cluster Head (CH). These cluster heads can communicate directly with the base station (BS). Other nodes send the data, sensed from the environment to these CHs. CHs first aggregates the data from the multiple sensor nodes, and then finally send it directly to the BS. Hence the CH should be powerful, closer to the cluster-centroid, less vulnerable [4] and has to have low mobility. Heinzelman et al. proposed LEACH [5] a protocol based on network clustering. Each cluster has a cluster-head that aggregates all the data received from the near nodes and send them to the base station. The cluster-head are selected following a distributed algorithm for each round. Every transmission round the node elects themselves to be a cluster-head. The decision is based on the suggested percentage of cluster-heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a calculated threshold, the node becomes a cluster-head for the current round. Zytoune et al. present a Stochastic Low Energy Adaptive Clustering Hierarchy protocol[6] which outperforms the LEACH when the interesting collected data is the minimum or the maximum value in an area. This protocol uses the same method proposed in LEACH for forming clusters. Once the clusters are formed, the cluster-head broadcasts in its cluster a data message containing its measurement assuming it the pertinent value. Only the nodes, having most significant data, send their messages towards the cluster-head. The [7] proposed an algorithm called TB-LEACH which is an improvement of the LEACH one. This algorithm permits to dominate the number of clusters heads to have at any transmission round, the optimal cluster-heads amount. that modifies the cluster-head selection algorithm to improve the partition of cluster. This algorithm assumes that all nodes receive the messages broadcasted by the nodes selected as cluster-heads. On one hand, if a node is not reachable by a cluster head it assumes that the number of clusters heads is insufficient, and elects them to be cluster head, and therefore the number of cluster-heads may be not dominated, on the other hand, this is not real with the large networks because the those messages can not reach all the network.

In this paper, we present a decentralized algorithm to select the cluster-heads based on the required energy to do the transmission to the sink. The rest of this paper is organized as follows. Section 2 gives the radio dissipation energy model used in this study. In Section 3, we detail the proposed

Ouadoudi Zytoune, Youssef Fakhri and Driss Aboutajdine are with GSCM_LRIT, Mohammed V University Agdal, Faculty of Sciences, Rabat, Morocco, zytoune@gmail.com, yousseffakhri@yahoo.fr, aboutaj@fsr.ac.ma

algorithm. Section 4 gives the simulation parameters and results and section 4 concludes the paper.

II. Radio Model

Recently, there is a significant amount of work in the area of building low-energy radios. We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics (this model is used in many works like [5, 6]), as shown in Fig.1. For the experiments described here, both the free space (d^2 power loss) and the multi path fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and the receiver. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used. Thus, to transmit an $l-bits$

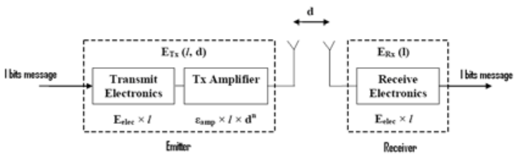

Fig. 1. Radio energy dissipation model.

message over a distance d, the radio expends(1):

$$E_{TX}(l,d) = E_{TX-elec}(l) + E_{TX-amp}(l,d) \quad (1)$$

$$E_{TX}(l,d) = \begin{cases} l.E_{elec} + l.\epsilon_{fs}.d^2 & \text{if } d < d_0 \\ l.E_{elec} + l.\epsilon_{mp}.d^4 & \text{if } d \geq d_0 \end{cases} \quad (2)$$

Where the threshold d_0 is (3):

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \quad (3)$$

The electronics energy (E_{elec}) depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal, whereas the amplifier energy, $\epsilon_{fs}.d^2$ or $\epsilon_{mp}.d^4$, depends on the distance to the receiver and the acceptable bit-error rate.

To receive an l-bit message, the radio expends(4):

$$E_{RX}(l) = E_{RX-elec}(l) = l.E_{elec} \quad (4)$$

It is also assumed that the radio channel is symmetric, which means the cost of transmitting a message from A to B is the same as the cost of transmitting a message from B to A. The used parameter values in our work are given in the following table:

TABLE I
Radio parameter values

Description	Symbol	Value
Energy consumed by the amplifier to transmit at a shorter distance	ϵ_{fs}	$10pJ/bit/m^2$
Energy consumed by the amplifier to transmit at a longer distance	ϵ_{mp}	$0.0013pJ/bit/m^4$
Energy consumed in the electronics circuit to transmit or receive the signal	E_{elec}	$50nJ/bit$
Energy consumed for beam forming	EDC	$5nJ/bit/signal$

III. The Balanced Cost Cluster-Heads Selection Algorithm for Wireless Sensor Networks: (BCSA)

Because of the cluster-head consumes higher energy than the normal nodes, the clustering algorithms used in the wireless sensors network attempt to balance the transmission energy cost over the network nodes by cluster-heads rotation selection. In the literature, no protocol was proposed to take in consideration the energy needed for the node to transmit to the sink when the node is elected for becoming cluster-head, to balance the energy consumption between nodes. Because of the nodes which are located near to the sink consume little energy compared to the far ones, due to the transmission range. For this raison, the nodes which are closer to the sink, must have more probability to become cluster-heads than the far ones. In this work, we propose a distributed algorithm to select the cluster-head nodes based on the node distance to the sink. In every transmission round, each node elect itself to become a cluster-head based on a determined percentage of cluster-heads for the network and the number of times the node has been a cluster-head so far. The percentage of cluster-heads determines the probability for nodes competition to become cluster-heads for each round. The CHs selection algorithm is the same that used in LEACH one. Each sensor elects itself to be a cluster head at the beginning of round r with probability $P_i(r)$. This probability is chosen such that the expected number of cluster head nodes for this round is k . So, the probability $P_i(r)$ must verifies the condition:

$$\sum_{i=1}^{N} P_i(r) = k; \quad (5)$$

Where, N is the network nodes number and k is the expected number of network clusters. To balance equitably the clusters heads role between network nodes, each node must be a cluster-head in each $\frac{1}{P} = N/k$ rounds on average.

$$P_i(r) = \begin{cases} \frac{P}{(1-P.(r \bmod (\frac{1}{P})))} & ; C_i(r) = 1 \\ 0 & ; C_i(r) = 0 \end{cases} \quad (6)$$

$C_i(t)$ indicates if the node i has been a cluster head in the most recent $(r\ mod(1/P))$ rounds ($C_i(t) = 0$ if node has been a cluster head and one otherwise). With this choice, we can demonstrates that the average of clusters heads every round is

$$\sum_{i=1}^{N} P_i(r) = k; \quad (7)$$

The work referred in [4] gives the average total energy consumed in the network, with $M \times M$ area, and having N

nodes uniformly distributed in this area, every transmission round. This energy is expressed in the equation (8):

$$E_{total} = l.(2N.E_{elec}+N.E_{DA}+k.\epsilon_{mp}.d^4_{toBS}+N.\epsilon_{fs}.\frac{M^2}{2.\pi.k}) \quad (8)$$

The E_{DA} is the energy consumed to perform the data aggregation in the cluster head.
The optimal number of clusters that minimizes the total energy consumed in the network can be found by (9):

$$\frac{\delta E_{total}}{\delta k} = 0. \quad (9)$$

Which means that the searched value of k is (10):

$$k_{opt} = \sqrt{\frac{N}{2\pi}}.\sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}.\frac{M}{d^2_{toBS}} \quad (10)$$

From this expression, we can see that the optimal number of clusters in the network is independent of the distance between any node to the base station. And the optimal value of P for this network is:

$$P_{opt} = k_{opt}/N. \quad (11)$$

We consider a network where, the base station is located far from the field. This network is represented in the figure 2. The nodes located in the sub-network $N4$ consumed more

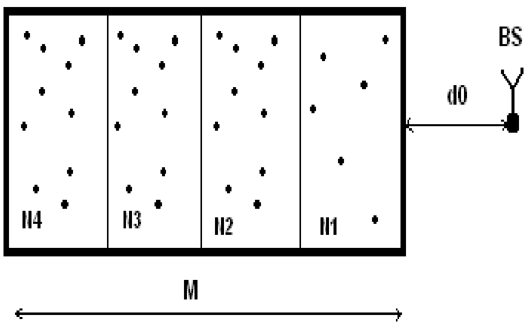

Fig. 2. Network mapping.

energy than the nodes located in the others subnetworks when there are selected for clusters heads. For permitting to extend the stable zone duration network service, the network nodes transmission energy cost must be different for the four subnetworks. So, the nodes in $N4$ have to become cluster head less frequently than the nodes in $N3$, the nodes in $N3$ have to become cluster head less frequently than the nodes in $N2$,and also for the nodes in $N2$ relatively the subnetwork $N1$ nodes . Assuming that the nodes in $N1$ become cluster head every P_1 transmission rounds, the nodes in $N2$ must become cluster head every P_2 transmission rounds to expend the same energy, where P_1 is greater than P_2. We define, so, four probabilities relatively to the node appurtenance to the sub-network $N1$, $N2$ $N3$ or $N4$. In the beginning of each

TABLE II
PROBABILITY VALUES

Description	Symbol	Value
Probability Associated for N1 nodes	P_1	0.0648
Probability Associated for N2 nodes	P_2	0.039
Probability Associated for N3 nodes	P_3	0.039
Probability Associated for N4 nodes	P_4	0.036

transmission round r, every node i uses its probability (P_1, P_2, P_3 or P_4 depending on its position in Ni where i=1, 2, 3,4) to elect itself to be cluster head. If a node is elected as cluster head, it broadcasts an advertisement message to the network indicating its state. The non-cluster head node determines its cluster for the current round by choosing the cluster head that requires the minimum communication energy, based on the received signal strength of the advertisement from each cluster head. After has selecting its cluster, each node transmits its data packet to its selected cluster head node that it will be a member of the cluster, transmitting a join-request message (Join-REQ) to it. The cluster head broadcasts another message in its cluster to indicate the termination of the cluster formation cycle. All transmissions use a CSMA/CA MAC protocol to do transmission. In this work, we assume the transmission free collision, because the data packet transmission duration is very small compared to the network sampling period. After the cluster formation, each node transmits its data packet to its cluster head. The cluster head, aggregates the received data in one message packet and transmits it to the base station.

IV. SIMULATIONS AND RESULTS

In this work, our main consideration is wireless sensor networks where the sensors are randomly distributed over an area of interest. The locations of sensors are fixed and a priori known by the base station. The sensors are in direct communication range of each other and can transmit to and receive from the base station. The nodes periodically sense the environment and have always data to send in each round (period) of communication. The nodes aggregate the data they receive from the others with their own data, and produce only one packet regardless of how the number of received packets. To validate the performance of our protocol, we simulate our algorithm and utilize a network with 100 nodes randomly deployed between (x=0, y=0) and (x=100, y=100). We choose to put the base station at (50,175). Each data message is 4000 bits long every round. The short message size is 200 bits long. The initial power of all nodes is considered to be $0.5J$ and $P_{opt} = 0.05$.
We take for the probablity P_i the values indicated in the table IV.

We carry out a comparison between the LEACH, TB-LEACH and the BCSA techniques using MATLAB. The simulation is done for 10 times and the represented results are an average. Figure 3 shows the number of nodes still alive in each transmission round.

We can see that the first node death in LEACH happens in the 589th round, in TB-LEACH it appears in 560th transmission round and in BCSA, it comes in the 621th round. Subsequently, in the last cited protocol, the lifetime of the

International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:3, No:4, 2009

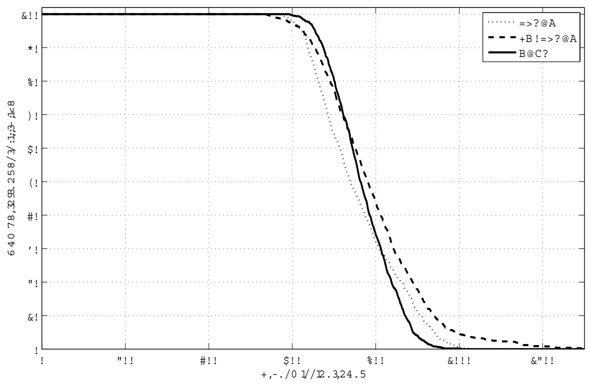

Fig. 3. Number of nodes still alive by transmission rounds.

whole network is increased by 5.43% compared to LEACH and 11% compared to TB-LEACH. As a result, for the application where keeping all the nodes working together is important, BCSA performs best among others, then BCSA find its applications in the situation where the network coverage is crucial.

V. Conclusions

In this paper, we present the characteristics of WSNs and the general routing models for protocols in WSNs.We discuss cluster-based routing protocols and their design criteria. And, we have proposed a routing based clustering protocol for WSNs. Through the simulation, we demonstrate that the proposed algorithm allows a large stable network lifetime compared to the most known clustering algorithms in this area and, so, the network coverage is extended.

Acknowledgements

This work was supported by the Academie Hassan II des Sciences et Techniques.

References

[1] F. Akyidiz, W. Su, Y. Sankarasubramaniam, E. Cayirci. Wireless Sensor Network: A Survey. *Computer Networks* **vol. 38, no. 4,** (2002) pp. 393–422.

[2] K. Romer, O. Kastin, F. Mattern: Middleware Challenges for Wireless Sensor Networks. *ACM SIGMOBILE Mobile Computing and Communications Review* **vol. 6, no. 4** (2002) 59–61.

[3] R. Shorey, A. Ananda, W. T. Ooi: Mobile , Wireless, and Sensor Networks. *1st Edition, IEEE press, John Wiley & Sons,* (2006).

[4] Khalid, Z., G. Ahmed, N. M. Khan, and P. Vigneras: A real-time energy-aware routing strategy for wireless sensor networks,. *accepted for presentation in The 2007 Asia-Pacific Conference on Communications, Bangkok , Thailand* (2007).

[5] W.R. Heinzelman, A.P. Chandrakasan, H. Balakrishnan: An application-specific protocol architecture for wireless microsensor networks, *IEEE Transactions on Wireless Communications* **1** (4) (2002) 660–670.

[6] O. Zytoune, M. El aroussi, M. Rziza, D. Aboutajdine: Stochastic Low Energy Adaptive Clustering Hierarchy, *ICGST- CNIR*, **Volume (8), Issue (1)**, (2008) pp 47–51.

[7] Hu Junping, Jin Yuhui, and Dou Liang: A Time-based Cluster-Head Selection Algorithm for LEACH, *In proceeding of IEEE Symposium on Computers and Communications 2008 (ISCC 2008)*, July 6 - 9, 2008, Marrakech, Morocco.