Balanced Energy Consumption Approach for Deployment of Clusters in a WSN

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***Abstract*— In this paper we aim to deploy the clusters of a Wireless Sensor Network in such a way so that it leads to a balanced energy consumption. First, we discuss about the radio energy dissipation model [1] that is already in place and the corresponding protocols which are used. Thereafter, we focus on the protocols which are already in practice in such a system, outlining their major disadvantages. Later on, we propose a methodology/algorithm that improves the overall energy consumption which is supported by the results of the experiments carried out by the simulations. Finally, a comparative analysis is done over the results obtained by our algorithm and those which existed previously.**

Keywords-wireless sensor networks; radio energy dissipation model; balanced energy consumption; cluster, hierarchial architecture

I. INTRODUCTION

Wireless sensor networks enable us to sense the environment, locally analyze the data and subsequently transmit the information through a wireless medium. Because sensor nodes are battery powered, they have limited resources. Thus energy efficiency is one of the most critical problems faced by any WSN. Hence, optimal energy utilization, thereby maximizing the network lifetime is of prime importance. A suitable network architecture in addition to energy aware protocols is very important in such cases. The most common architecture used by any WSN is the hierarchical cluster based architecture. Majority of the protocols used in WSN are designed keeping in mind such a hierarchical architecture. In Section II we briefly attempt a literature survey on the radio energy dissipation model [1] that is widely used in any hierarchical cluster based WSN. Section III discusses about the current state of the cluster organization process and states the problem definition. Section IV illustrates our approach for organization of the clusters taking into account balanced energy consumption for the entire system. Section V provides a sample test bed in which we carry out our simulation experiments and provide a comprehensive illustration between the various results obtained. Finally we conclude in Section VI.

II. LITERATURE SURVEY OF EXISTING HIERARCHIAL CLUSTER BASED WSN's

Energy consumption is very high for any WSN [2]. With the hierarchical approach any WSN can be represented by 2 layers in which layer 1 involves the sensor hardware and the control heads (cluster heads), while the second layer presents the protocols responsible for communicating between the cluster heads and the base station. Thus, layer 1 basically takes care of the intra-cluster communication whereas layer 2 takes care of the inter-cluster communication. This is shown in fig 1 below.

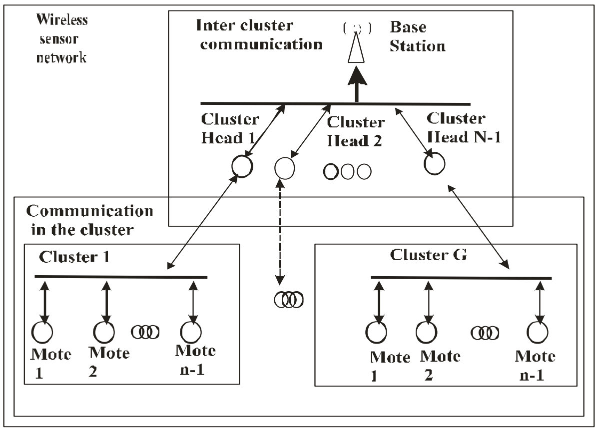

Figure 1

In order to depict the energy model of such architecture, we take the help of the radio energy dissipation model [2] as shown in fig 2 below.

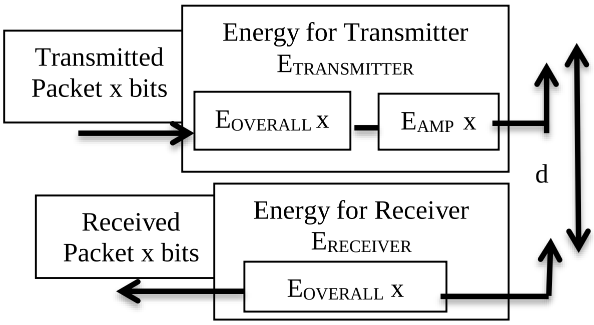

Figure 2

As per the model the amount of energy needed by the receiver ($E_{RECEIVER}$) is the amount of energy needed by the amplifier (E_{AMP}), whereas the amount of energy needed by the transmitter ($E_{TRANSMITTER}$) is equal to the amount of energy

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needed by the amplifier (E_{AMP}) and the amount of energy needed by the overall radio electronics ($E_{OVERALL}$). Thus, the amount of energy needed for transmission and reception of a packet of size x bits at a distance of d meters is given by:

$$E_{TRANSMITTER} = x\,(E_{OVERALL} + E_{AMP}\, d^{k}) \quad \text{-------------- (1)}$$

$$E_{RECEIVER} = x\, E_{OVERALL} \quad \text{-------------- (2)}$$

Where, k is a constant used to represent the signal strength loss [3]. For direct LOS we use k = 2 and for environments with severe interference we use k = 4.

If we assume that every individual cluster in the WSN consists of j nodes then as per equation (1) the amount of energy needed for transmission of a packet by any i[th] in a cluster ($E_{TRANSMITTERni}$) is given by:

$$E_{TRANSMITTERni} = x\,(E_{OVERALL} + E_{AMP}\, d^{k}_{CHEADni}) \quad \text{------(3)}$$

Where; $d_{CHEADni}$ is the distance between the cluster control head CH and the i[th] node.

Thus, the total amount of transmitted energy is given by:

$$E_{TRANSMITTERTOTAL} = \sum_{i=1}^{j} E_{TRANSMITTERni} \quad \text{------------ (4)}$$

Similarly, the total amount of energy needed by any control cluster head i for the purpose of packet reception is given by:

$$E_{RECEIVERCHEADi} = j \times E_{OVERALL} \quad \text{------------------------ (5)}$$

In the radio energy dissipation model since the base station is considered to be energy independent, thus the amount of energy needed for inter-cluster communication is equal to the summation of the energy requirements of all the control cluster heads. Assuming the total number of control cluster heads to be g, the total amount of received energy is given by:

$$E_{RECEIVERCHEADTOTAL} = \sum_{i=1}^{g} E_{RECEIVERCHEADi} \quad \text{-------- (6)}$$

Assuming that the sensor motes send their packets directly to the control cluster head and that they do not receive any packets, the total amount of energy needed by any cluster ($E_{CLUSTER}$) will be equal to:

$$E_{CLUSTER} = E_{TRANSMITTERTOTAL} + E_{RECEIVERCHEADTOTAL} \text{------ (7)}$$

III. CURRENT STATE OF CLUSTER ORGANISATION PROCESS AND PROBLEM DEFINITION

As the sensor nodes are battery powered, it means that they are in possession of a limited amount of energy. So, in order to minimize the overall energy requirement of such a system, most of the WSN protocols are energy sensitive and are deployed in a role based hierarchical environment [4] . In the previous section from equation 4 it is clear that the total amount of energy needed for packet transmission depends on the size of the packet and the distance of any sensor node form its respective cluster head. It is to be noted that we assume E_{ELECT} and E_A to be constants as they are determined by their respective sensor hardware. Hence, it is very easy to comprehend that for minimum energy consumption, we need to optimize either the size of data or the distance of the sensor nodes from their respective cluster heads i.e. the distance the data needs to travel. In this paper we do not go for optimization of data size [5], instead we focus on the second parameter. Several well-known protocols are already in use in hierarchical WSN's [1, 2, 6] using a distance based approach for cluster organization. The algorithm for such protocols in general is given below:

```
for i = 1 to N
CHead_i = 0; DistanceToCHead_i = ∞;
if n_i = = CHead
        relate n_i with base terminal
else
        for j  = 1 to N
        if n_j = = CHead
                calculate DistanceTon_j
        if DistanceTon_j <  DistanceToCHead_i
        DistanceToCHead_i = DistanceTon_j; CHead_i = n_j;
                end;
        end;
j++;
end;
end;
i++;
end
```

From the algorithm it is absolutely clear that any sensor node will automatically connect to the nearest available cluster head. Although the overall energy consumption is minimized in such a scheme, but it is associated with another severe drawback that is illustrated by figure 3 below.

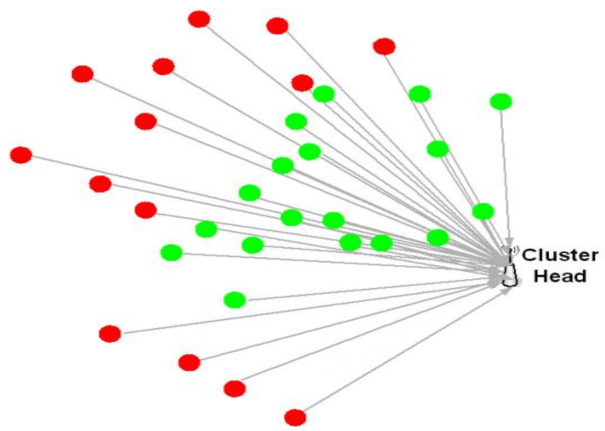

Figure 3

From the figure it is evident that the motes marked with red have already depleted their energy, and hence cannot take part in further communication. The distance based approach leads to unequal consumption of energy by the sensor motes, as a result of which all such motes with are furthest away from the cluster heads are depleted first. This can create serious problems in networks where the node density is medium to low, or from networks where accuracy is of prime importance.

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IV. CLUSTER ORGANIZATION TAKING INTO ACCOUNT BALANCED ENERGY CONSUMPTION

Strategies for balanced energy consumption must be incorporated to the protocols being implemented in the WSN's. The total amount of energy is determined entirely by the device battery characteristics [7]. Balanced energy consumption must be implemented out of the total energy available to ensure a uniform power loss across all the devices thereby increasing the lifetime of the entire network and also improving the overall network reliability. Hence, for every sensor mote selection of a proper cluster head is of prime importance.

In our paper we assume that each and every sensor mote uses a complex parameter for evaluating their respective cluster heads. This complex parameter that we select is a function of the amount of energy needed by the communication protocols and the total amount of energy available in the system. Thus we can ensure that the cluster head that would be selected is optimized from an overall balanced energy point of view. If we consider any two sensor motes say n_A and n_B, then the corresponding complex parameter for the two is given by $W(n_A, n_B)$. We define $W(n_A, n_B)$ as follows:

$$W(n_A, n_B) = E_{com}(n_A, n_B) / E_{nA} \quad \text{--------------------------(8)}$$

Where, E_{com} is a function that determines the amount of energy needed for data transmission between nodes A and B and E_{nA} represents the amount of energy initially possessed by node A before the beginning of the cluster organization process. The corresponding algorithm for the proposed protocol is given below:

```
for i = 1 to N
CHead_i = 0; W_CHead_i = ∞;
if n_i = = CHead
      relate n_i with base terminal
else
      for j = 1 to N
      if n_j = = CHead
                calculate W_n_j as per equation 8
      if W_n_j <  W_CHead_i
                W_CHead_i = W_n_j; CHead_i = n_j;
                end;
      end;
j++;
end;
end;
i++;
end
```

V. SIMULATION EXPERIMENT AND RESULT ANALYSIS

In this section we carry out simulation experiments for both the approaches that have been mentioned above. A denotes the standard cluster organization procedure whereas B denotes our proposed method. Simulations have been carried out in MATLAB. The simulation environment consists of a 10000 sq. m area over which the nodes have been dispersed. We have carried out the experiment corresponding to100 sensor motes per cluster assuming the base station to be at a fixed distance of 100 meters in both the cases. The amount of energy present in the sensor motes that have been shown in figures below is an average over 100 simulation runs and packet size of 64 bytes. As per the energy model discussed previously we have taken the following standard values:

E_A = 10 pJ/bit/m^2 for k = 2 and
E_A = 13.10^{-4} pJ/bit/m^2 for k = 4 and
E_{ELECT} = 50nJ/bit

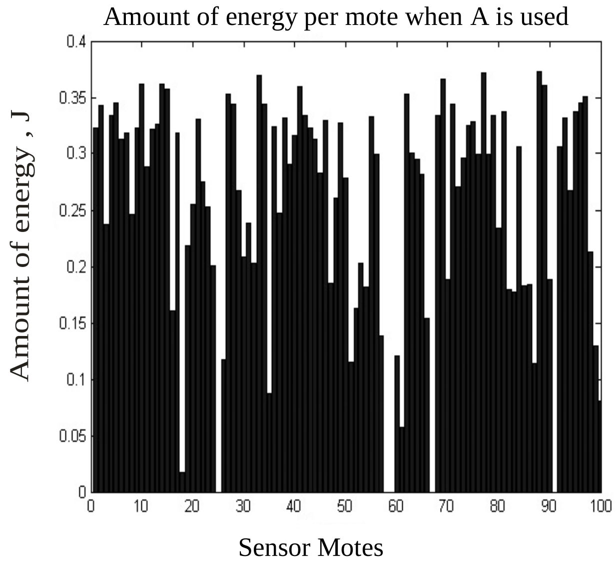

Figure 4

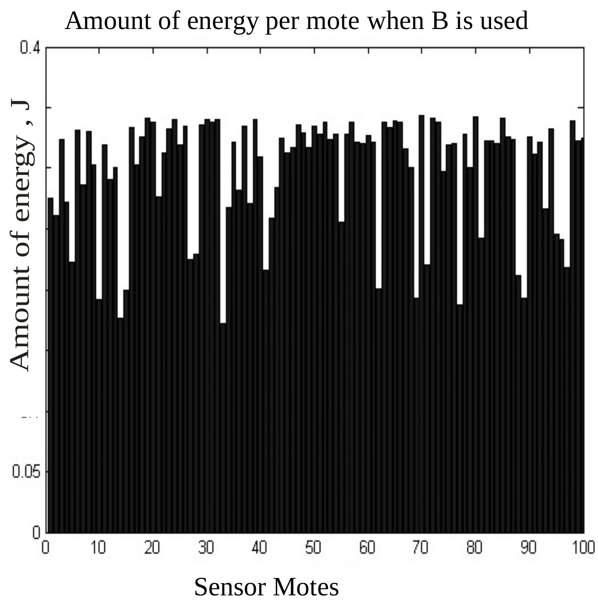

Figure 5

Figures 4 and 5 shown above represents the average amount of energy per mote for the tradition approach and our approach towards the formation of the cluster head respectively. From both the figures it is clear that the overall amount of energy

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when A is used is greater than that of B, but the energy is not uniformly distributed among the sensors in case of A and this leads to some of the nodes depleting their energy much faster than the rest.

Figure 6 below shows the average number of active sensor motes per cluster per communication round.

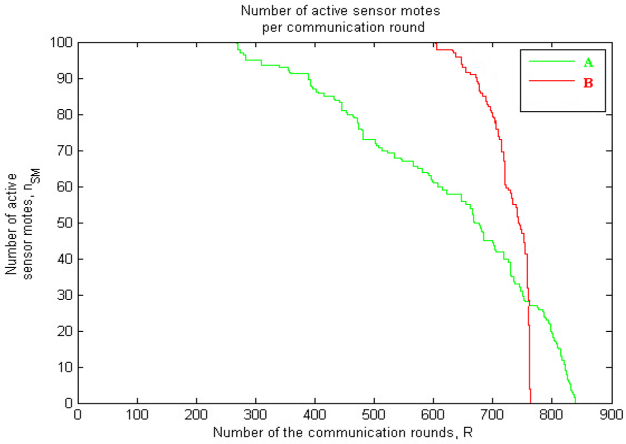

Figure 6

From figure 6 it is clear that although A provides the longest operational lifetime of the network but corresponding to any particular round the number of active nodes for B is far more greater that A. Thus, we can conclude that the overall energy balance in case of B is much better as compared to A, but at the expense of a somewhat decreased overall network operational time.

VI. CONCLUSION

Based on the results of the simulation experiments performed we can conclude that the process of cluster head organization keeping in mind the balanced energy constraints is suitable for systems where a greater degree for reliability is desired. Our proposed B approach much outperforms the classical A approach with respect to a balanced energy distribution for the entire system, though at a cost of somewhat decreased overall lifespan of the entire network as a whole.

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