Energy saving solutions for WSNs based on energy models

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Abstract

In Wireless Sensor Networks (WSNs), minimizing energy consumption of a specific component may lead to increase the energy requirements of other components. The critical requirement is having models that it can show relationships among components in network. Through energy models, we see the functionalities and important energy parameters of each component. Therefore, this paper focuses on analyzing the energy models for WSNs. Motivated by this, we propose some solutions to save energy of network system. Finally, the paper also presents simulation results to demonstrate the efficiency of the energy saving solution.

Key word: wireless sensor networks, energy model, energy consumption.

1. Introduction

In WSNs, the sensor nodes are often provided limited energy capacity (<0.5Ah, 1.2V). Therefore, the lifetime of these nodes depends heavily on the lifetime of battery. If a node is out of energy, it stops working. The region around that node will not be monitored. Hence, energy consumption becomes an important problem for the success of deploying sensors in WSNs.

Most of proposals use the initial energy model [1] to estimate the efficiency of energy. However, the energy consumption [1] is considered in sending and receiving data. In fact, the WSNs consumes energy for other activities such as re-configure the network topology when node dies, surrounding environment, etc.

It is essential to study energy model for WSNs. Energy model gives the overall view of optimizing consumed energy of the network by considering the direct effects of its components. The clear architecture of energy model allows us to adjust the energy consumption of each its component.

The rest of this paper is organized as follows. Section 2 presents energy models. The methods of saving energy are analyzed in Section 3. Section 4 simulates and evaluates the efficiency of energy saving. Finally, Section 5 highlights the conclusion.

2. The energy model

The energy of WSNs is consumed by the operations of sensor nodes and used for maintaining the operations among nodes such as configure network. The two solutions for energy model: node-based and network-based approach, are presented in this section.

A. The node-based energy model

The energy of a sensor node is used for three basic tasks: processing, transferring and censoring [2]. H.Y. Zhou et al. propose the Node-Energy Model (NEM) based on three essential modules including Processor Energy Model (PEM), Transceiver Energy Model (TEM) and Sensor Energy Model (SEM).

Energy used for processing is

$$E_{cpu} = E_{cpu\text{-}state} + E_{cpu\text{-}change} \quad (1)$$

Similarly, the function of transferring energy of TEM.

$$E_{trans} = E_{\text{trans-}state} + E_{\text{trans-}change} \quad (2)$$

The energy consumed by sensors is

$$E_{sensor} = E_{\text{on-off}} + E_{off-on} + E_{sensor-run} \quad (3)$$

Finally, the total energy consumption of node

$$E_{node} = E_{cpu} + E_{trans} + E_{sensor} \quad (4)$$

It is clear that these three modules have strict relations about energy consumption.

B. The network-based energy model

The model of energy consuming in the overall network is proposed in [3]. Through this model, we have a better overall vision of optimizing energy consumption in WSNs.

The energy consumption in WSNs includes three major parts: the energy consumption for the node individually- $E_{individual}$, the energy consumption for collaboration with neighbor nodes - E_{local} and the energy consumption for global communication E_{global}. Eq.8 reveals these three components.

$$E_{individual,i}(\Delta t) = I(e_i(\text{alive}) + e_i(\text{sensor})) \quad (5)$$

$$E_{local,i}(\Delta t) = \sum_{j \in neighbour_i} L(e_{ij}(mon) + e_{ij}(local)) \quad (6)$$

$$E_{global,i}(\Delta t) = G(e_i(\text{topo}) + e_i(\text{router}) + e_i(\text{global})) \quad (7)$$

$$E_{total}(\Delta t) = \sum_{i=1}^{n} I_{individual,i} + \sum_{i=1}^{n} k_i L_{local,i} + \sum_{i=1}^{n} h_i G_{global,i} \quad (8)$$

The study of energy consuming model is necessary to evaluate the communication protocols, support for deploying WSNs.

3. The solutions using efficient energy based on energy model

Based on the Node-based Energy Model, the first solution is to adjust the sleeping time and active time property. The active state holds a lot of energy-consumption amount, so it affects the trend of changing energy significantly. The next states are idle state and sleeping state. In addition, the exchange state consumes not much energy. Hence, the efficient solutions are proper change between the three states.

Considering the effect of Processing Model (PM), Transmission Model (TM) and Sensor Model (SM) [4] on overall energy consumption of nodes, TM is ranked the first. The next two positions are PM and SM, respectively. Reducing energy consumption of TM is essential. This is done by focusing on the physical layer. Idle listening, overhearing, TDMA, ect are used to reduce packet collision.

With the network-based energy model, the larger the radius of transporting is, the more the neighbor nodes increase. And we need to reconstruct the neighbor nodes with larger distance. This leads to the expense for collaborating with new neighbors. As a results, E_{local} increases. However, the increasing of transporting radius will create new transmit lines which have a fewer relay nodes. This is suitable for reducing energy consumption in the network. The selected solution depends on the concrete application.

The solution, here, is the selection of routing algorithm. Because the efficient connecting architecture will reduce the transporting radius, the number of relay nodes. In addition, the good mechanism of routing will help each node “wake up” only when there is censoring requirement and fall into “sleep” during leisure time. This contributes to the network load balancing.

Some efficient routing protocol: GAF, CEC, SPIN, LEACH or PEGASIS are presented in [5]. The impact of those protocol on energy consumption will be presented in Section 4.

To evaluate the efficiency of WSNs, the relationships among components should be taken into discuss. Understanding the energy models help to us avoid the situation that reducing energy of one part may can be the increasing energy consumption of other part.

4. Simulation and Evaluation

In this section, we evaluate Direct, LEACH and PEGASIS protocols [1], [6] in the two models: Node-based Energy Model and Network-based Energy Model. The simulation software is OMNET++ [7]. The simulation parameters are shown in Table.1

Parameter	Value
Number of nodes	100
Simulation Area	600mx600m (scenario 1) 1200mx1200m (scenario 2)
Initial energy	0.25J

Table. 1. Simulation parameters.

Fig.1 shows the percentage of dead node according the number of rounds of data collection (scenario 1). In Fig.1, the time of first dead node of DIRECT, LEACH, and PEGASIS protocols occurs when the number of rounds is 29, 290 and 480, respectively. Besides, the ending time of all of the nodes is 116, 1208 and 1910 rounds for DIRECT, LEACH, and PEGASIS protocols. This shows that PEGASIS and LEACH save energy better than that of DIRECT. Both LEACH and PEGASIS protocols use the strategy of finding optimal route for transmitting data via relay nodes. Meanwhile, each node in DIRECT sends data directly to base station. LEACH and PEGASIS save more $e_i(\text{topo})$, $e_i(\text{route})$ than DIRECT.

Compared with LEACH, each leader node in PEGASIC receives only two messages at most, meanwhile, there are lots of messages in LEACH (equal number of nodes in each clusters). LEACH takes much energy to receiving data than PEGASIC. In addition, data-transmitting distance in PEGASIC is shorter than LEACH, so E_{trans} in PEGASIC is smaller than that of LEACH. In short, PEGASIC is more efficient energy than LEACH.

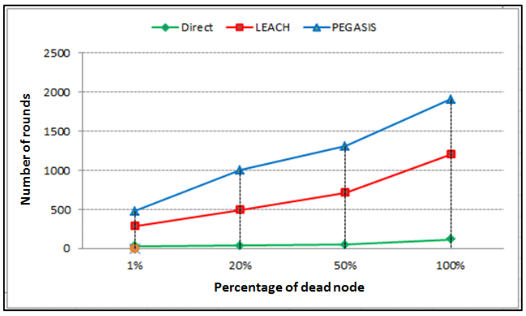

Fig.1.Performance results for a 600mx600m network

The next simulation is performed with 1200mx1200m network with scenario similar scenario 1.

The long distance requires much energy for transmit and receive data. Hence, with the same number of nodes and initial energy, the life of network is shorter than that of smaller area. Specifically, the lifetime of network is approximately 2000 rounds in scenario 1 while that is around 1200 rounds in scenario 2.

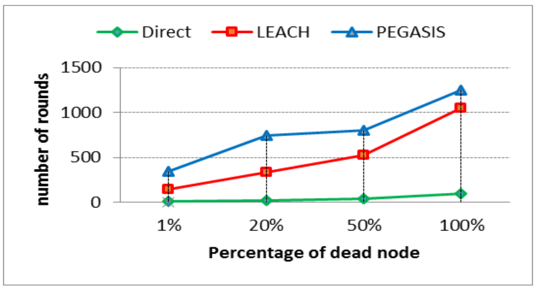

Fig.2.Performance results for a 1200mx1200m network

The distribution of sensor nodes, which is adequate for monitoring area, is important factor when considering the energy efficiency in WSNs.

5. Conclusion

The relationships among energy components and their interaction in a same application are important. The study of energy models may be used to analyze energy state of nodes, evaluate communication protocols, and help to deploy nodes as well as building WSN applications. Through energy models, we see the functionalities of component and important energy parameters. These parameters allow us to evaluate the performance of WSNs, optimize network operation, and design many efficient energy-consumed applications. In future, we continue studying model of energy consumption for overall applications and figure out the comprehensive map of energy consumption with concrete application.

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