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Load Balancing Routing Protocol for considering Energy Efficiency in Wireless Sensor Network

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Abstract. A WSN is composed of a large number of sensor nodes, which are the finite energy resources. Therefore, extending the life of the sensor nodes and minimization in overall power consumption is very important. In this paper, we propose the LBRP that supports to balance the traffic throughout the WSN. In LBPR, the traffics passed by each node are distributed through multiple paths instead of a single path. It allows significant energy saving and makes long-lived sensor nodes. Simulation results show that significant energy savings can be achieved compared to the multi-hop routing protocols.

Keywords: Wireless Sensor Network, Load balancing, Routing Table, *(m,k)-firm* scheduling

1 Introduction

Wireless Sensor Networks (WSNs) are highly distributed networks of small, lightweight wireless nodes. Sensors have limited sensing region, processing power and energy. They consume energy in sensing the object, processing and transmitting the data. Energy in WSNs is very scarce resource due to limited battery power. In order to minimize the energy consumption in WSNs, several energy-efficient MAC protocols and energy-efficient routing protocols have been proposed in the literature. These schemes aim to decrease the energy consumption by using sleep schedules.

As the nodes spend substantial energy in sending and receiving data, a robust and power-aware routing protocol can maximize the network lifetime. Typically, an ideal routing protocol would avoid the fast drain of sensor nodes with high energy consumption. Also, the load balancing is valuable in a sensor network where the density of nodes is high and the communication bandwidth is scarce and shared. It also balances the power consumption inside the sensor networks to prevent some nodes from dying faster than others[1,2,3,4].

In this paper, a load balancing routing protocol (LBRP) for wireless sensor networks is proposed in order to consider energy efficiency and extend the network lifetime. Each node maintains a flow table to choose the next hop node to relay the data, and after transmission it updates the (m,k)-firm field in the flow table. LBRP divides the neighbor nodes into two groups. One group contains the nodes that meet their deadline with (m,k)-firm constraint, the other contains the nodes that miss their

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deadline. The forwarding candidate is chosen from the second group, and the neighbor node with highest priority has a higher probability to be chosen as the forwarding node. Computer simulation of LBRP has been done and a better outcome has been observed compared to one of the multi-hop routing strategies.

2 Load Balancing Routing Protocol to consider energy efficiency

2.1 DBP

DBP(Distance Based priority) was a dynamic priority assignment mechanism for jobs under (m,k)-firm constraint[5]. The basic idea of DBP algorithm is as follows : the closer the stream to a failure state, the higher its priority is. A failure state occurs when the stream's (m,k)-firm requirement is violated. That is, the deadlines of at least m out of any consecutive *k* packets must be met. The term "any consecutive *k* packets" implies a sliding window guarantee for a flow.

For each stream source, which requires an (m,k)-firm, the priority is assigned based on the number of consecutive deadline misses that leads the stream to violate its (m,k)-firm requirement. This number of deadline misses is referred to as distance to failure state from current state.

The k-sequence is a word of k bits ordered from the most recent to the oldest job in which each bit keeps memory of whether the deadline is missed (bit = 0) or met (bit=1). Each new job causes a leftward shift of all the bits, the leftmost exists from the word and is no longer considered, while the rightmost will be a 1 if the job has met its deadline or a 0 otherwise

The priority of its job at a given instant can be assigned with the distance of the current k-sequence to a failure state. Evolving the k-sequence can determine the violating distance of the job. That is left shift the k-sequence and adding in the right side 0s until the evolved k-sequence violates (m,k)-firm of the job, and the number of added 0s is the priority. If a job stream is already in failure state, the highest priority 0 is assigned. Normally, for a job τ with constraint β = (m,k)-firm, let priority $VD^{\beta}(\tau)$ denote its violating distance, we get

$$VD^{\beta}(\tau) = \begin{cases} k - l(m,s) + 1 & if \ \sum_{i=1}^{k} k_i\,(\tau) \geq m \\ 0 & if \ \sum_{i=1}^{k} k_i\,(\tau) < m \end{cases} \quad \textbf{(1)}$$

where *s* denote the state of the previous k sequence jobs of τ, *l(m,s)* denote the position (from the right) of the n^{th} meet (or 1) in the *s*.

However, DBP chooses the priority based on the history of the stream's k-sequence, and doesn't take into account any specific information on the actual attributes of the stream like jitter, congestion. To overcome these problem, we assign not only the priority based on $VD^{\beta}(\tau)$ but also the priority with the network state information to the flow.

2.2 Load Balancing Routing Protocol (LBRP)

LBRP divides the neighbor nodes into two groups. The first group, G1 contains the nodes that meet the (m,k)-firm constraint, the other, G2 contains the nodes that miss. The selection process of the forwarding candidate is as follows.

In LBRP, each node keeps a flow table to store information passed by beaconing. Each entry inside the table has the following fields : (Neighbor Node ID, Speed, $VD^{\beta}(\tau)$, End-to-end Delay(EED), Group). Speed is calculated by dividing the advance in distance from the next hop node j by the estimated delay to forward a packet to node j. Formally,

$$\text{Speed} = \textit{Distance from node i to next hop j} \,/\, \textit{HopDelay} \quad (2)$$

First, each node investigates the speed in flow table to choose the forwarding candidate. After choosing the node with lowest speed to the neighbor node, the chosen node is checked whether it belongs to G1 or not. If it belongs to group G1, it means that the node transmits *m* out of its last *k* consecutive packets to chosen node, it is excluded the forwarding candidate. If the chosen node is in group G2, it means that it didn't receive *m* out of its last *k* consecutive packets from previous node, so it has more energy than nodes that belong to G1, Therefore, the forwarding node is chosen from the nodes that belong to G2 to balance the consumption of the energy and packets are forwarded only to it.

The sink periodically sends back the value of EED to the corresponding source nodes, to inform them with the end-to-end delay of the streams they generated. So, when the node choose next node, it considers the network state information together as follows.

$$\text{NextHop} = \alpha VD^{\beta}(\tau) + (1 - \alpha)\, EED \quad (3)$$

After a source node receives the feedback of EED, it adds the value to the header of the packets it generates and then forwards them to the intermediate nodes.

3 Evaluation

Performance of the LBRP is proven by simulation. We chose ns-2 as the simulator and a uniform topology that includes 100 nodes in an area of 200 x 200 m. Table 1 describes the detailed setup for our simulator.

Table 1. Simulation settings

Routing	DSDV, LBRP
Bandwidth	200Kb/s
Transmission power	24mW
Receive power	10mW
Idle power	10mW

Figure 2 shows the comparison of the energy consumption with LBRP to DSDV. It shows that the gain achieved by LBRP increases with the rate of traffic generated by each sensor node. In the case of the DSDV that determines the best path only, once the path is determined, each node sends packets in the direction of the determined path. However, LBRP sends packets to the node capable of maintaining much energy and can balance traffic and reduce congestion by dispersing packets into the node that belongs to the groups, so to prolong the network lifetime is achieved.

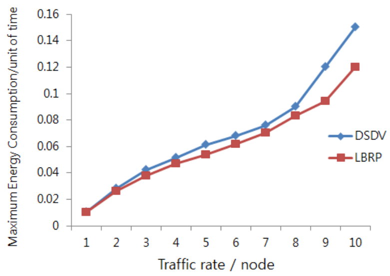

Fig. 2. Comparison of the energy consumption between LBRP and DSDV

4 Conclusion

WSNs require the energy-efficient protocols that make use of the finite energy resources of the sensor nodes. In this paper, we showed that the routes used in LBRP are more spread out than those of the basic routing. The LBRP must take advantage of the total available energy resources in the network before its death.

To achieve this, we proposed the balancing the energy consumption throughout the network by sending the packet generated by each sensor node through multiple paths instead of forwarding always through the same path. Simulations show that significant energy saving can be achieved compared to the basic routing protocols.

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