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Improving WSN Lifetime Using Q-Routing Technique

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Abstract: ***Wireless Sensor Networks having many number of small sensor nodes, having limited energy, memory and computing power. Among these limitations, energy consumption is the most important criteria of Wireless Sensor Networks. Routing in wireless sensor networks is a challenging issue because the system lifetime should be increased through efficient energy aware routing schemes. Recently, many routing schemes are taking this energy consumption as the main design factor. This paper shows the use of Q-Routing technique for reducing the energy consumption and to improve the Wireless Sensor Network Lifetime.***

Keywords: Wireless Sensor Network, Energy Aware Routing, Q-Routing, Network Lifetime**.**

1. Introduction

Wireless Sensor Networks consists hundreds or thousands of sensor nodes. The sensor nodes will be deployed inside some environmental areas such as dense forest or inaccessible terrain or a disaster area to obtain the information about the environmental changes like temperature, pressure and vehicle tracking. The sensor nodes are capable of monitoring and collecting the environmental changes called events. These events are then send to a main location through the wireless Networks. The main location is called sink or base station which has no limitation on its energy, processing power or memory. The sink node collects this information from sensors and takes appropriate decision. There may have some gateways which performs aggregation of sensed data from a group of sensors and collectively send this towards sink. Each sensor node has limited by energy, memory, and power computation, the design techniques of sensor nodes should be innovative and are required to use the available energy and bandwidth efficiently under the limitations.

Multi-hop communication among the sensor nodes is more efficient than single–hop communication. Wireless Sensor Networks has wide range of applications such as Forest fire Detection, Area Monitoring, Health care Monitoring etc. Due to these reasons, while designing the routing algorithm for Wireless Sensor networks, the main concern should be its energy efficiency.

One important issue regarding Wireless Sensor Networks is the hot spot problem. The energy of some nodes may exhaust faster than other nodes in the network. It is a main problem associated with gateways since they have an additional overhead of aggregating collective data from a group of sensors. If that node is a part of some rout, the data cannot even send to the sink. So it is important to have a balance between energy levels of every node in the entire network. We can achieve this by using multipath routing.

Routing algorithm is the strategy to find a path from a specific node to the base station. This must consider the nodes features in order to optimize the network lifetime and latency in data transmission [1]. Q-Routing makes use of Q-learning technique in the routing algorithm, which was first introduced by Boyan and Littman in 1994 [2]. This paper aimed to improve the wireless network lifetime by applying Q-learning technique in the routing algorithm.

The rest of the paper is organized as follows. In Section II we describe about energy efficient routing. Section III describes the study about various energy efficient routing schemes. And the paper is concluded in section IV.

2. Related Work

Many researchers are already there in the field of reinforcement learning and also energy aware routing algorithm. Many of the researchers are not using this reinforcement learning technique for energy aware routing. The authors of [7] say that some of the Q-learning algorithms can achieve optimal results without introducing much overhead to the system.

The Q-Routing algorithm was originally proposed by Boyan and Littman [2] for dynamic load balancing in packet switched network. Consider a node x whose neighbor node is y and destination node is d. Let $Q_x(d,y)$ be the time (including delay time which may experience at x) for a packet to arrive at destination, through y. Each node store a local table which have entries for each and every neighbor – destination pairs. When a node receives a packet, it will immediately respond to the node x, with its own estimated remaining time τ to the destination node. The value for τ can be calculated as

$$\tau = \min_{z \in neighbours\ of\ y} Q_y(d,z) \tag{1}$$

For updating the local estimates, it uses some other variables also. Those include q- the time for sender to process the message and s- time for the message to reach the next node. A learning factor η is applied in the update rule of local estimate. The neighbor's local estimate for every node will update using the rule given below:

Update rule:

$$Q_x(d,y) = Q_x(d,y) + \Delta Q_x(d,y)$$

With:

$$\Delta Q_x(d,y) = \eta\left(q + s + \tau - Q_x(d,y)\right) \quad (2)$$

In some situations, the original Q-Routing algorithm has some exploration behavior. For example, the original Q-Routing algorithm is unable to recover its routing policy when a high traffic load ends and the network returns a low traffic load. Instead of routing policy, it will keep the load balancing policy. Many Q-Routing algorithms tried different approaches to overcome this problem.

3. Proposed Work

The problem in the original Q-Routing algorithm can be overcome using the concept of feedback signals. It can be used to find the lowest energy on path and the aim of this approach is to find the nodes having lowest energy on each path. These nodes from different paths can then compare with the energy performance of these paths. The comparison is done by using the Q-value associated with every neighbor in the routing table. Appending a node's energy level to the feedback message is known as parent energy feedback. When a node receives feedback it will use the received energy level to modify the neighbors Q-value in its routing table. It does this by generating a multiplier for the value stored in the routing table. This multiplier is generated depending on the amount of energy available at the node. The less energy available at a node, the higher a multiplier will be used to discourage further usage of nodes with lower power levels. A multiplier for a neighbor's value in the routing table is obtained by weighing the neighbor's energy level by a weighing function. It will help for faster propagation of weakest node information throughout the network. And it results in significance improvement of Wireless Sensor Network Lifetime.

4. Simulation Environment

The simulation environment has been created with the help of network simulator version 2. The design of the proposed system is done as follows. A large wireless sensor network is created by deploying many number of sensor nodes. The protocol depends on Q-values, each node has to be initializing the potential value and trust value. This values may be get updated in the future. While transmitting a data, these values can be used to find the next hop with highest Q-value.

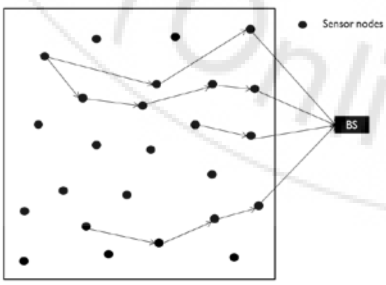

Figure 1: Proposed multipath routing scheme

Initialization Phase: The neighbors are first discovered using HELLO protocol. After the neighbor discovery, the routing table corresponding to every neighbor nodes will be initialized with an initial Q-value. The nature of Q-Routing algorithm allows as initializing the Q-values with a random constant value.

Learning Phase: In this phase, every node will send many dummy packets to its neighbors for having some learning experience. When a node receives a dummy packet, it will send the feedback to the sender node. It uses piggybacking which aims to reduce the communication overhead in the system. The received feedback value is used to update the routing table with a new Q-value of its neighbor. After a predetermined time interval, the network will reaches some stable state, and then it allows normal event transmission. That is, the nodes can now sense the environment and can send it to the base station. The Q-value update rule is given below.

$$Q(i,j) = \alpha[r + \gamma * Q(i,j)$$

where $j \in N_i$, the neighboring nodes of node i, α is the learning rate and γ is the discount factor.

During the learning phase, a token acquisition policy has been used to avoid congestion in the network. When a node wants to send dummy packets, it will acquire a token from the base station and can send the dummy packets. After the allotted time interval, it can release the token, and other nodes can now make use of the token for sending dummy packets. It significantly reduces network congestion and hence it helps to improve network lifetime.

5. Simulation Results

The developed routing algorithm has been evaluated by creating multiple simulations in the simulation environment. Different topology with different number of nodes is created for testing and the average lifetime was calculated using an energy function. The XGRAPH is used to plot the obtained average energy level and then it compared with some existing WSN routing protocol. The newly developed algorithm consumes less energy when comparing with the old one.

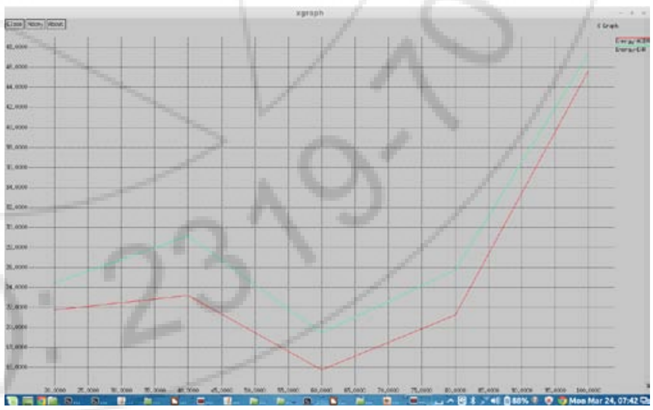

Figure 2: Comparison of Average network lifetime for different topologies

The routing algorithm uses piggybacking of feedback information which helps to reduce network overhead. The past experience of a node is used to come up with its best Q-value. The algorithm has been tested and found to be efficient for different topologies.

6. Conclusion and Future Work

The wide range of applications for wireless sensor networks has significantly increased the importance of WSN routing schemes. In this work we propose an energy aware routing scheme which is based on dynamic multi hop routing for the WSN. The newly designed scheme aims to build a more energy efficient network. Piggybacking of feedback information is used to reduce the communication overhead.
The proposed routing scheme does not consider the security issues during communication. It is possible to provide secure communication by incorporating trust management in the routing decision, which is the future scope of this paper.

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