A Fair Routing Protocol Using Generic Utility Based Approach in Wireless Sensor Networks

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***Abstract*— Wireless Sensor Networks (WSN) have been noticed and researched nowadays. These new type of networks have unique characteristics. These characteristics make them different rather than other networks. WSNs composed of set of nodes that collect and transmit information about their environment. They have different constraints such as computational power, storage capacity, energy and etc. Of course the main constraint in wireless sensor networks is energy. Nodes energy source is limited and in most cases not rechargeable. Fairness in node's energy consumption can increase network lifetime. In this paper problem of data transport in WSN as an optimization problem is formulated. Objective function is to maximize performing fairness in network nodes subject to flow and energy constraints. Out put of optimization problem is a vector which consists of all links portion. Output is investigated via Opnet simulator.**

Keywords; Fairness, Routing Protocol, Utility Based, Wireless Sensor Networks.

I. Introduction

In the recent years, many researches have been conducted on Wireless Sensor Networks (WSNs). These networks are composed of hundreds or thousands of sensor nodes that sense their environment. Communications are done in ad hoc manner in these networks [1, 2]. In other words, nodes in addition to their routine tasks forward other node's traffic. Nodes collect information about environment and send useful one to determined node called sink using other nodes. Sink is individual node that process collected data. Sink can be normal node, but in many networks, sink has more resources rather than normal nodes [3].

In wireless sensor networks, all nodes collaborate to route packets between source and sink using routing protocol which is implemented in all nodes. Routing is the process of finding route from source to destination using intermediate nodes. WSNs are a subset of ad hoc networks [4]. In ad hoc networks all the nodes are able to forward other node's data.

Wireless sensor networks have unique characteristics [1]. Because of these characteristics, WSN's protocols are different from other networks protocols. Resources constraint is the most important characteristic of WSNs. Nodes of wireless sensor networks have limited resources such as computational power, storage space, energy and etc. Energy constraint is the most important one, because, primitive energy source of network nodes is limited and it is not rechargeable [5]. Network lifetime of these networks is depended on their nodes energy. If node energy is finished, it will drop. Communications consume the most energy in nodes. Routing protocols determine the volume of communications; therefore they are the most important factor of energy consumption. With respect to all above mentioned points, routing protocols in wireless sensor networks should consider energy constraint in all network's layers [6].

To perform fairness in network nodes energy consumption is another factor which has influence on network lifetime. If fairness is not considered, some nodes consume more energy rather than others. Therefore their energy is so sooner depleted. When lots of network nodes are dropped, the network will be partitioned. This leads to Increase network energy consumption increasingly. Partitioned network can not perform its tasks perfectly. Many nodes with high available energy exist in partitioned networks [7].

In this paper, we formulate the problem of data transport in sensor networks as an optimization problem whose objective function is to maximize performing fairness in network node's energy consumption, subject to flow and energy constraints. In particular, we consider providing fairness as optimization problem objective. We know when fairness is provided efficient, network lifetime will be prolonged. Flow and energy as two important parameters in wireless sensor networks are considered as subject. We consider optimization problem topology specific. The traffic which every node should forward is output of optimization problem.

To the best of our knowledge, in previous researches, providing fairness in node's energy consumption did not considered as optimization problem objective. Different papers solve optimization problem for wireless sensor networks by considering different objectives. In [8], they formulated optimization problem whose objective function is to maximize the amount of information collected at the sinks, subject to the flow, energy and channel bandwidth constraints. They introduce energy constrains and the notion of quality of data into the formulation. Also based on a markov model extended from [9], they derive the link delay and the node capacity in both the single and multi hop environment and future them in the problem formulation. In [10] similar optimization problems are considered for wireless sensor networks.

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In the rest of this paper, following sections are discussed. In section 2, problem formulations are presented. Section 3, describes the proposed protocol in details. Section 4 is dedicated to the simulation results. Finally section 5 concludes the paper.

II. Problem Formulation

In this section, we formulate a utility based optimization problem that can be tailored to fulfill various goals and requirements for different applications in wireless sensor networks. Here we consider following optimization problem:

Objective max F (1)

Subject to

For each network nodes j: $\sum_i X_{ij} = \sum_k X_{jk}$ (2)

For each network nodes j:

$$\left[\left(\sum_i X_{ij} \times e_r\right) + \left(\sum_k X_{jk} \times e_s\right)\right] \times T < e_j \quad (3)$$

For all i,j: $X_{i,j} \leq B$ (4)

Variables and constants which used in above optimization problem are described as follows:

- $\sum_i X_{ij}$ in formula 2 expresses the input traffic to node j.

- $\sum_j X_{jk}$ in formula 2 expresses the output traffic from node j.

- X_{ij} describes traffic transmitted from node i to node j via direct link between them.

- e_r expresses the energy needed for receiving packets.

- e_s expresses the energy needed for sending packets.

- T expresses time.

- e_j expresses the primary energy of node j.

- B is maximum bandwidth of link.

Function F is calculated as follows:

- $F = \sum_{i=1}^{p} F_i$

- For each network nodes i: $F_i = \sum_{j=1}^{n} \sum_{k=1}^{m} \left| e_{ij-} e_{kj} \right|$

- e_{ij} expresses the remaining energy of node j in i^{th} time slice.

- $T = n \times timeslice$

e_{ij} is calculated as follows:

$$e_{ij} = j \times \left[\left(\sum_i X_{ij} \times e_r\right) + \left(\sum_k X_{jk} \times e_s\right)\right] \times timeslice$$

By solving formula (1), vector X is achieved. Vector X expresses each link portion in traffic transmission.

III. Proposed Protocol

Proposed protocol can be used for intra cluster routing in wireless sensor networks. As discussed in section 1, cluster head or sink should know topology of cluster or network respectively. Afterward, cluster head can solve optimization problem simply, then floods vector X to all cluster nodes. For example see figure 1.

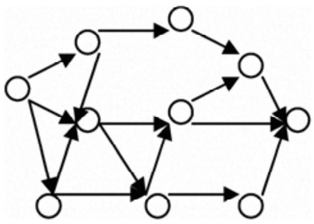

Figure 1 – Network topology

As observable in figure 1, nodes select nodes with lower distance to cluster head as next hop. In topology depicted in figure 1, there are 18 links between nodes. We stamp each link by a number. In vector X each link portion in forwarding packets is determined. When a node receives vector X, it creates a routing table. In mentioned routing table for each record, its portion in forwarding node's traffic is determined.

When a node receives a packet, it can forward incoming packet to next hop using routing table. For example in figure 1, sender has 3 neighbors; based on vector X, portion of each link between sender and its neighbor in forwarding packets is determined. Table 1 presents vector X for topology which is depicted in figure 1.

3.27	3.36	3.33	3.11	3.4	3.294
2.62	2.78	3.5	3.36	3.47	3.146
4.1	3.85	3.15	3.52	3.11	3.546
4.1	2.9	2.41	2.5	2.12	2.806
0	0.94	0.74	0.99	0.99	0.732
0.49	1.06	0.76	0.53	0.83	0.734
2.78	2.3	2.577	2.57	2.57	2.5594
0	1.28	1.65	1.93	1.94	1.36
3.11	3.5	3.35	2.95	3.34	3.25
4.1	2.9	2.41	2.52	2.12	2.81
0.57	0.77	1.08	0.94	1.13	0.898
4.67	3.6	3.49	3.47	3.25	3.696
2.18	3.33	3.96	3.77	3.64	3.376
0.35	0.6	1.69	1.75	1.42	1.162
3.14	2.98	2.53	2.75	3.09	2.898
3.14	2.98	2.53	2.75	3.09	2.898
10	10	10	10	10	10
0	0	0	0	0	0

Table 1 – Vector X

Columns 1, 2, 3, 4 and 5 present different vector X. We have solved optimization problem many times and finally in column 6 average of performed experiments are presented.

IV. Simulation Results

In this section, using computer simulation we evaluate the performance of the proposed protocol. We simulate our protocol using Opnet [11]. We use topology which is depicted in figure 1.

In figure 2, network nodes residual energy is depicted versus time.

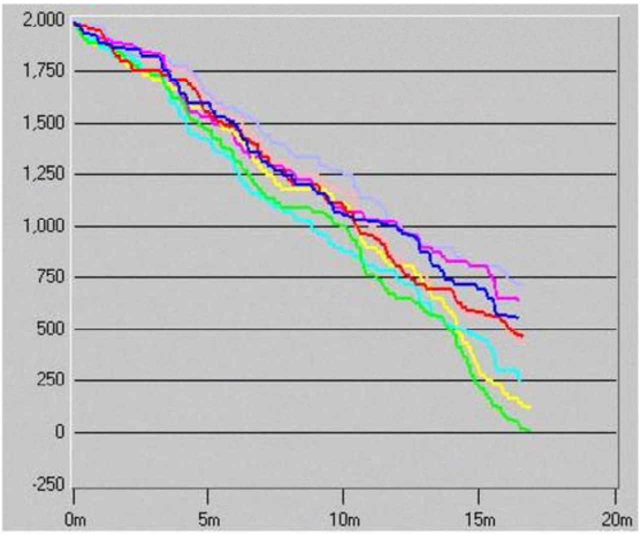

Figure 2 – network nodes' residual energy versus time

As observable in figure 2, network lifetime is about 17 minutes. In performed simulation network lifetime is considered as difference between beginning of simulation and the time which first node dies.

We can see in figure 2 that the maximum difference between every two node is about 740.

We change one the entries of vector X manually. We change X(2) from 21 to 60. Figure 3 presents residual energy versus time for new vector X. Figures 4 and 5 present residual energy versus time for similar changes in other entries of vector X.

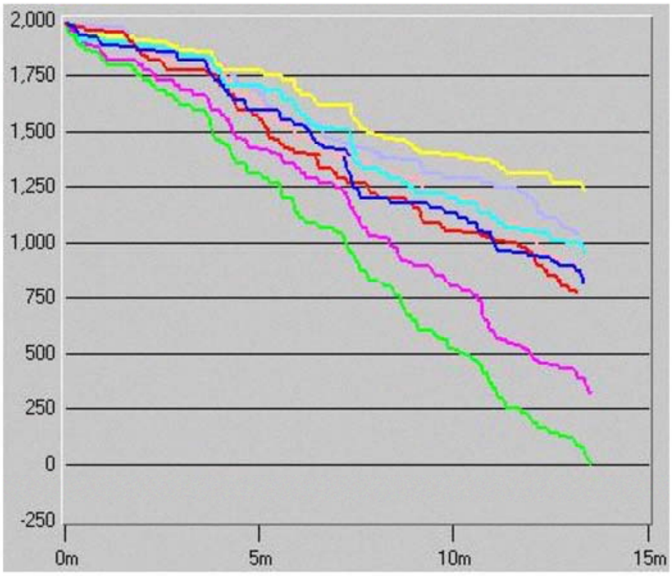

Figure 3 – network nodes' residual energy versus time

It is observable in figure 3, by changing entries of vector X manually network lifetime is shortened. For example in figure 2, network lifetime is 17 minute, but in figure 3 network lifetime is about 14 minute.

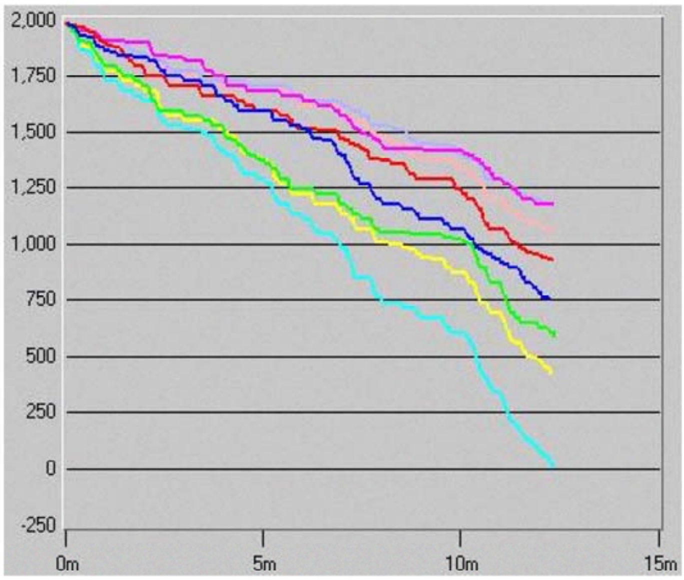

Figure 4 – network nodes' residual energy versus time

Another parameter that makes our protocol efficiency clear is fairness. Difference between every two node is in figure 2 is about 740, but in figure 3 difference between ever two node is 1250.

We also implement random algorithm in Opnet. Random algorithm selects next hop randomly. When a node receives a packet, it will send it to one of its neighbors randomly. Of course the next hop node should have lower distance to sink in comparison to sender node. Figure 6 presents the result of random algorithm.

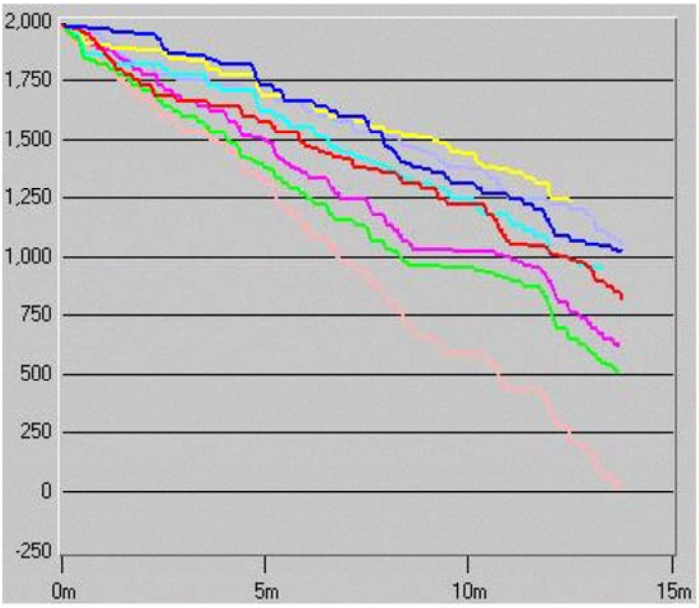

Figure 5 – network nodes' residual energy versus time

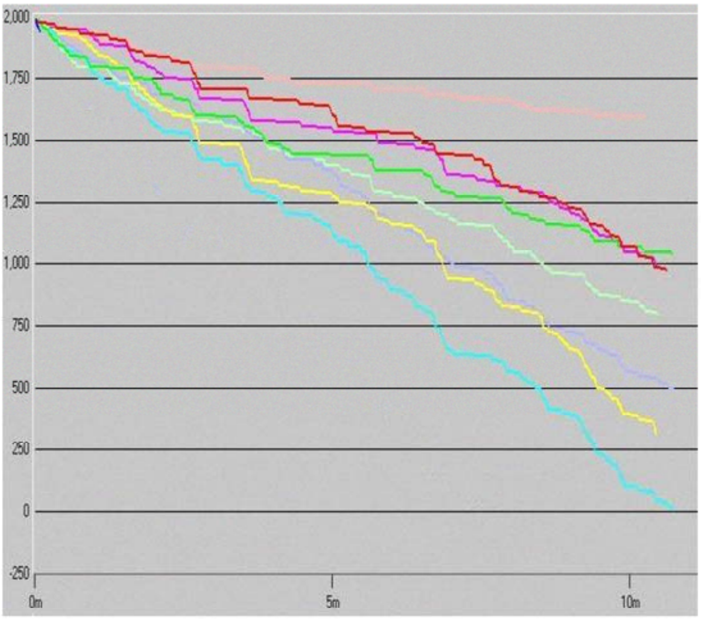

Figure 6 – network nodes' residual energy versus time

As observable in figure 6, network lifetime is about 11 minute, and difference between every two node is about 1600. When network use proposed protocol, network lifetime is about 17 (47% improvement) and difference between every two node is about 740 (less than half).

V. CONCLUSION AND FUTURE WORKS

Power consumption is a fundamental concern in wireless sensor networks. In fact, sensors are battery-constrained devices which have a limited power sources. The energy consumption of traditional sensor nodes is known to be dominated by the communication functionalities. So to use node's energy more efficiently, the energy aware routing protocols are very important. In this paper we proposed a new energy aware routing protocol in wireless sensor networks. The proposed protocol is designed based on generic utility approach. Based on simulation results, it is obvious that the two main goals of the proposed protocol have been achieved. Increasing network lifetime and improving performing fairness in network energy consumption. We can consider different parameters as objective function in optimization problem in future works.

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