AN ENTROPY-BASED THROUGHPUT METRIC FOR FAIRLY EVALUATING WSN ROUTING PROTOCOLS

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ABSTRACT
The level of information conveyed to the sink in a wireless sensor network is very vital to the correct operation of the ongoing application. In WSN, Using the absolute throughput, the number of data packets delivered to the sink, is not accurate. Since many packets are resulted from the aggregation process of many "raw" packets collected from the concerned sensed area. In this paper, we propose an entropy-based throughput metric to measure the performance of the hierarchal routing protocols for WSN. In the proposed metric, the information delivered to the sink is calculated instead of the number of data packets delivered to the sink. This method will lead to fair comparison and evaluatation of different routing protocols as well as more informative decision by the sink. We use the proposed metric to compare the performance of two well-known routing protocols; LEACH and EAD.

Categories and Subject Descriptors
C.2.2 [**Network Protocol**]: Routing protocols

General Terms
Performance

Keywords
Routing Protocols, WSN, Information Theory

1. INTRODUCTION
Throughput, which is the number of data packets delivered to the sink, is one of the important metrics used to evaluate different routing protocols. However, it is a misleading metric in hierarchal routing protocols. For hierarchal routing protocol, a packet delivered to the sink is resulted from aggregating many packets. Two different packets delivered to the sink may be resulted from the aggregation of different number of packets. These two packets may carry different amount of information. In this paper, we will propose Information-Entropy based metric to measure the throughput. The throughput is then defined as the amount of information delivered to the sink instead of the absolute number of data packets delivered to the sink.

To the best of our knowledge, there is no published work that uses the information theory to evaluate and compare the expected performance among MAC protocols or routing protocols for WSN. Nevertheless, [1] proposed an entropy-based sensor selection heuristic for localization problem.

This method of measuring the throughput will yield a better understanding of the operation of the WSN application under consideration. Moreover, it fairly compares different hierarchical routing protocols in which the clusters are formed using different techniques. In this paper and as a proof of concept, we will use the proposed metric to make a comparison between two different well-known routing protocols, EAD [2]and LEACH [3].

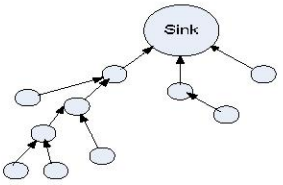

Figure 1: A network with different Clusters

2. AN ENTROPY-BASED THROUGHPUT METRIC FOR WSN ROUTING PROTOCOLS:
In the hierarchal routing protocols in WSN, clusters are usually formed. In each cluster, a set of nodes are connected to a head as shown in Figure 1. The head collects the data packets from the nodes and aggregates them into one packet. The resulted packets are then transmitted to the sink. In each routing protocol, different techniques are used to form the clusters. The number of nodes in each cluster is different. To calculate the throughput, it is not accurate to consider that all packets delivered to the sink have the same amount of information. For example, in Figure 1 the packet delivered through the most left branch is aggregated from 7 distinct

packets while the one delivered through the most right branch is resulted from just one packet. To distinguish between these two packets, we can measure the information entropy in each delivered packet.

In general, for a discrete random variable X that takes values from χ, the Shannon entropy of X is defined by

$$H(x) = -\sum_{x \in X} p(x) \log_2 p(x) \quad (1)$$

To apply the above concept to WSN, we will consider the packet that is aggregated from more "raw" packets (i.e. original sensed information) to be more informative. Therefore, for a cluster x composed of C nodes, we assumed that $p(x) = \frac{1}{C}$. The Information delivered to the sink can then be defined as

$$I = \sum_{x \in X} -\frac{1}{C_x} \log_2 \frac{1}{C_x} \quad (2)$$

where χ is the set of clusters and C_x is the number of nodes in cluster x.

3. PERFORMANCE RESULTS

We use the proposed metric to compare between two well-known routing protocols EAD and LEACH. We select these two protocols because they use a different mechanism to build the clusters. In EAD protocol, multiple trees rooted at the sink are built. Each tree can be considered as a separate cluster. In LEACH protocol, heads are identified in each round; each node will attach itself to one of the heads. The number of heads is not fixed in all rounds.

A grid network with 100 sensors distributed in an area of 50X50 m^2 is simulated to evaluate the two protocols. We assume different number of data transmission period (1, 5 and 10) in each round. We measure the absolute number of data packets delivered to the sink and the information delivered to the sink according to (2). Figure 2 and Figure 3 show the comparison between the two protocols using the absolute throughput, and the information delivered to the sink, respectively. It is interesting to notice that for 1 data transmission period, assuming the absolute throughput, EAD is improved by 51%, while using the proposed information-based throughput metric EAD is improved by only 8.6%. For 5 data transmissions, the improvement in the leach using absolute throughput is 39.4% while it is 55.5% using information based throughput.

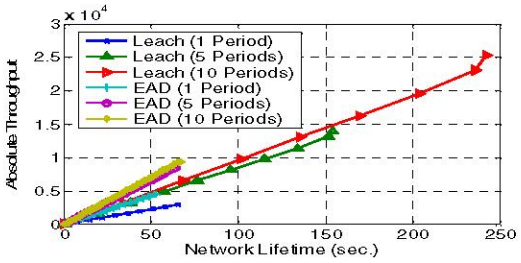

Figure 2: A Comparison between EAD and LEACH using absolute throughput

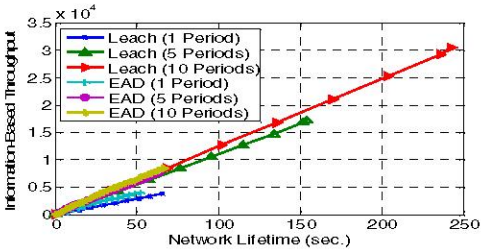

Figure 3: A Comparison between EAD and LEACH using information-based throughput

4. CONCLUSION

In this paper, we propose an entropy-based throughput metric to measure the performance of the hierarchal routing protocols for WSN. In the proposed metric, the information delivered to the sink is calculated. The proposed metric was used to compare the performance of LEACH and EAD. The obtained results using the new metric have shown that the improvement obtained by using EAD is incremental compared to LEACH as opposed to the old metric.

5. ACKNOWLEDGMENT

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