Efficient Energy Consumption Protocol in SN

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Abstract: *It is crucial in sensor networks to design and employ energy-efficient communication protocols, since nodes are battery-powered and thus their lifetimes are limited. The power management plane manages how a sensor node uses its power. In our work, we develop Simple and Efficient Energy consumption protocol in Sensor Networks (EECP), in which, packet queuing as well as routing are considered. This scheme efficiently utilizes the limited energy and available memory resources of sensor nodes and also has a significant impact on the success of real-time sensor data dissemination. We compare new protocol with other protocols for energy efficiency in real-time communication over sensor networks by NS2. Simulation experiments show that the new proposed scheme outperforms traditional schemes and improve performance efficiency.*

Keywords: *Energy Efficiency, Real-Time Communication, Sensor Networks, Braided Routing, Multi-paths Routing.*

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1. Introduction

The power management plane in sensor networks manages how a sensor node uses its power. For example, the sensor node may turn off its receiver after receiving a packet from one of its neighbors. This is to avoid getting duplicated packets. Also, when the power level of the sensor node is low, the sensor node broadcasts to its neighbors that it is low in power and cannot participate in routing packets. The remaining power is reserved for sensing. The management plane detects and registers the movement of sensor nodes, so a route back to the user is always maintained, and the sensor nodes can keep track of who are their neighbor sensor nodes. By knowing who the neighbor sensor nodes are, the sensor nodes can balance their power and task usage. The task management plane balances and schedules the sensing tasks given to a specific region. Not all sensor nodes in that region are required to perform the sensing task at the same time. As a result, some sensor nodes perform the task more than the others depending on their power level. These management planes are needed, so that sensor nodes can work together in a power efficient way, route data in a wireless sensor network, and share resources between sensor nodes. Without them, each sensor node will just work individually. The objective is to extend the lifetime of the network by reducing the energy use in the routing phase while maintaining a similar level of resilience to node failures.

New protocol offers significant advantages over existing real-time sensor data communication schemes. It reduces contentions to improve real-time performance by providing the flexibility of the nonlinear slack allocation. EECP delays data packet transmission nonlinearly during forwarding for a duration that correlates with their remaining deadline and distance to the destination. Also we implement the EECP algorithm with a multi-path routing protocol that is intended to provide a reliable transmission environment for data packet delivery and improve real-time performance. The braided multi-path routing which we use in our protocol, choose the best path and shortest one without exceed the delayed time makes more efficient used for the bandwidth and so decrease the packet miss ratio, drop ratio and overall delay.

It also has a significant impact on the success of real-time sensor data communication and avoids collision. Simulation experiments show that the used scheme outperforms traditional schemes by establishing a reliable path from the source to the sink by distributing the traffic load more evenly in the network. Moreover, delaying the data packets before reaching the sink also helps the data aggregation/fusion and therefore energy efficiency. The primary contribution of our work is more effective communication; and avoiding the contention in bursty traffic by using braided multi-path routing.

2. Related Works

In the recent years, numerous articles have been published describing new algorithms, routing protocols and architectures aiming at WSN lifetime maximization, through energy awareness.

Already proposed routing techniques [1, 3] for WSNs aiming at energy conservation, employ routing tactics such as data aggregation, in-network processing, clustering, different node role assignment and data-centric methods. There are several ways of categorizing these protocols and algorithms. For example, they can be discriminated depending on the network structure to Flat Networks Routing (Data-centric routing [1]), Hierarchical Networks Routing and Location based Routing [3]. In tanagonwiwat et al. [9] proposed Directed Diffusion a data-centric (i.e. all communication is for named-data) and application-aware paradigm aiming at avoiding unnecessary operations of network layer routing in order to save energy by selecting empirically good paths and by caching and processing data within the network. Yao and Gehrke [16] proposed another data-centric protocol, namely, COUGAR, for an architecture which treats the network as a huge distributed database system. Energy Aware Routing, a protocol proposed by Shah and Rabaey [13], although similar to Directed Diffusion, it differs in the sense that it uses occasionally sub-optimal paths to obtain energy benefits. This protocol can achieve longer network lifetime as energy is dissipated more equally among all nodes. TEEN and APTEEN, two hierarchical routing protocols are proposed by Manjeshwar and Agarwal [12]. TEEN (Threshold-sensitive Energy Efficient sensor Network protocol) and APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol) are suitable for time-critical applications. In both protocols the key factor is the measured attribute’s value. The additional feature of APTEEN is the capability of changing the periodicity and the parameters of TEEN according to user and application needs. The concept of generic, utility-based decision making in WSN is described in [5], where Byers and Nasser try to quantify the cost of each action performed by a sensor, by adopting heuristic assessments. Apart from routing protocols, Power TOSSIM [14], a WSN simulation tool has been developed. Power TOSSIM provides an accurate, per-node estimate of power consumption. Power TOSSIM is an extension of TOSSIM [10, 11, 15]), the event-driven simulation for TinyOS [16] applications. Also AODV is improved to be an energy consumption efficient routing algorithm and we will compare it with our new protocol.

3. Braided Multiple Path Routing

We introduce the (EECP) protocol with a localized braided multipath routing protocol. Multipath routing is intended to provide a reliable transmission environment for data packet delivery and improve real-time performance. The braided multi-path routing which we use in our protocol choose the best path and shortest one without exceed the delayed time. It makes more efficient used for the bandwidth. We explore the Energy efficiency of braided multi-path routing algorithm and illustrate it by using probabilities in EECP equations. We first overview the localized braided multi-path and then illustrate EECP protocol.

The braided multi-path chooses the shortest path from source to sink. The braided multi-path relaxes the requirement for node disjointedness. Alternate paths in a braid are partially disjoint from the primary path, not completely node-disjoint.

A constructive definition for our braided multi-path is (Figure 1): For each node on the primary path, find the best path from source to sink that does not contain that node. This alternate best path need not necessarily be completely node-disjoint with the primary path.

The localized technique for constructing braids is described below. Like the idealized algorithm for disjoint multi-path, this technique also utilizes two types of reinforcements. However, its local rules are slightly different, resulting in an entirely different multi-path structure. The sink sends out primary path reinforcement to its most preferred neighbor A. In addition, the sink sends alternate path reinforcement to its next preferred neighbor B. Again, as before, A propagates the primary path reinforcement to its most preferred neighbor and so on. In addition, A (and recursively each other node on the primary path) originates an alternate path reinforcement to its next most preferred neighbor. By doing this, each node thus tries to route around its immediate neighbor on the primary path towards the source. When a node, such as B, not on the primary path receives alternate path reinforcement, it propagates it towards its most preferred neighbor. When a node already on the primary path receives alternate path reinforcement, it does not propagate the received alternate path reinforcement any further.

Figure 2 illustrates a localized braid obtained by using the above mechanism. In this figure, nk+1 sends an alternate reinforcement to route around nk that passes through ai and ai-1 before rejoining the primary path at nk-2. In practice, though, local rules cannot always ensure this perfect detour around nk. Alternate path reinforcement sent out by nk+1 can follow any sequence of nodes, possibly completely disjoint from the rest of the primary path, towards the source. Equally, an alternate path reinforcement sent by nk+1 can rejoin the primary path at nk. These effects vary with node density and other factors, and arise due to the incomplete information that the local rules base their decisions upon.

On the contrary, an alternate path on the braid that routes around nk is constrained to either use the links on the primary path, or other links in the braid, between sink and nk+1 [50].

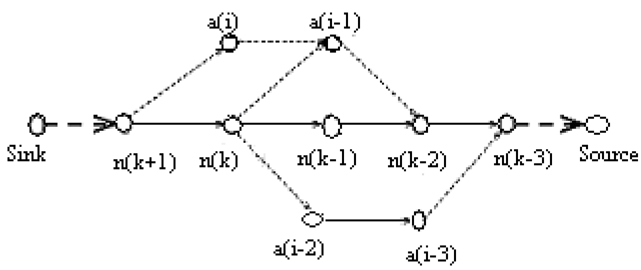

Figure 1. Idealized braid.

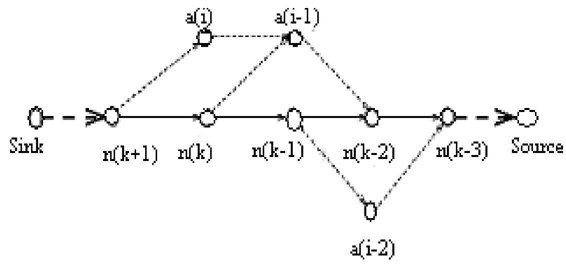

Figure 2. Localized braid.

4. Data Splitting Across Multiple Paths

In this section, we present some considerations on how to predict the number of paths that will successfully deliver a packet among the multiple disjoint paths obtained from the route discovery process. The increase of the probability for this successful delivery comes at the trade-off of added redundancy.

The entire data package to be sent from the source to the destination over the available k disjoint paths will be split up into smaller sub-packets of equal size. The number of created sub-packets corresponds to the number of available paths. Only a smaller number of these sub-packets will then be needed at the destination to reconstruct the original packet. There exist several fast and simple (i.e. linear) forward error correcting codes (or erasure codes) that allow the reconstruction of an original packet that has been split up and of which not all parts arrive at the destination. In the following, we will focus on approximating a value Ek that gives, with high probability, the number of successful paths. This value will then be used to determine the amount of redundancy to be added for the split packet transmission.

The total number of sub-packets is a function dependent on the multi-path degree and on the failing probabilities of the available paths. As these values change according to the positions of the source and the destination in the network, each source must be able to decide on the parameters for the error correcting codes before the transmission of the actual data sub-packets.

We want to send a data packet from a source to a destination and the process of route construction is finished, resulting in k different paths that are to be used. Each path has some rate pi (i = 1, . . . , k) that corresponds to the probability of successfully delivering a packet to the destination. This setting corresponds to a repeated experiment, the i-th sub-run corresponding to the packet transmission along the i-th path. Note that we consider node-disjoint paths and therefore can assume these experiments to be independent of each other. Let Sk : {0, 1}k $\rightarrow$ N be the random variable corresponding to the number of successfully delivering paths. (For Sk, each sub-run is assigned a 1 if the transmission was a success along the respective path, and 0 if it failed. Then, Sk represents the sum of these for the sub-runs, and clearly Sk $\leq$ k.)

Then, the expectation for the total number of successful paths is given by

$$E(S_k) = \sum_{i=1}^{k} p_i.$$

The distribution of the above repeated experiment can be approximated by normal distribution. This will be used to obtain a good estimator for Ek for a given bound α, the overall probability of successfully reconstructing the original packet at the destination. More formal, we want to deliver a good estimation for the value of Ek for a desired bound α such that P (Sk > Ek) > α holds.

In order to approximate by normal distribution N (μ,σ), the mean μ and the standard deviation σ are needed. In our case, μ will be given by the expectation for Sk, i.e. by the sum of the probabilities of successful delivery along each path, and thus we set

$$\mu := E(S_k) = \sum_{i=1}^{k} p_i.$$

Accordingly, we obtain the standard deviation by setting

$$\sigma^2 := \sum_{i=1}^{k} p_i(1 - p_i).$$

Obviously, each combination of the multi-path degree k and different probabilities p1, . . . , pk will yield a different normal distribution. To overcome this problem, we transform to the standard normal distribution N (0, 1).

$$S_k^* := \frac{S_k - \mu}{\sigma}$$

Table 1: Some values for the bound α

α	95%	90%	85%	80%	50%
x_α	-1.65	-1.28	-1.03	-0.85	0

The random variable is N (0, 1)-distributed. Now, consider a given bound α for the desired probability of being able to reconstruct the original packet at the destination after being sent along the different paths. For the standard normal distribution, the values of the bound xα for any given α such that the probability holds are known. Some value-pairs are presented in table 1.

$$P(S_k^* \geq x_\alpha) \geq \alpha$$

Note that these values are independent from the number of paths k used to send data. Using the above estimations, we transform the argument and obtain the following probability

$$S_k^* = \frac{S_k - \mu}{\sigma} \geq x_\alpha$$

$$P(S_k \geq x_\alpha \cdot \sigma + \mu) \geq \alpha.$$

We can therefore use $x_\alpha \cdot \sigma + \mu$ as Ek for the forward error correction code and set

$$E_k := \max\{\lfloor x_\alpha \cdot \sigma + \mu \rfloor, 1\}.$$

In terms of the input for the decision algorithm, the value for Ek is given by the following expression which gives the number of successfully delivering paths with the overall success probability of α.

$$E_k = \max\{\lfloor x_\alpha \cdot \sqrt{\sum_{i=1}^{k} p_i(1-p_i)} + \sum_{i=1}^{k} p_i \rfloor, 1\},$$

5. Protocol Framework

Simple and Efficient Energy consumption protocol in Sensor Networks is the primary contribution of this paper. EECP delays data packet transmission during forwarding for a duration that correlates with their remaining deadline and distance to the destination. Intuitively, this helps in heavy-traffic communication environment by making sure that priority inversion does not occur. Inversion occurs due to a node with only low priority packets sending and preventing a node with high priority packets from doing so. In summary, the following information is needed to schedule packets in the protocol:

- End-to-end deadline information: this information is provided by the application in the data packet as required by any real-time data communication application. For those applications where the header of data packet does not include this information, an alternative way for EECP to obtain the end-to-end deadline information is needed.
- End-to-end distance information: this information is obtained from the routing protocol. For example, this information is maintained in the routing tables of traditional distance vector based or link-state based routing protocols. This maintenance is to keep track of the cost of the path. Furthermore, in geographic routing, Euclidian distance measured as the distance from the current node to the destination. It can be used as the distance metric. End-to-end distance which can be measured either in numbers of hops like in Shortest Path Routing or by the difference between the average length of an alternate path and the length of the primary path as in Braid multi-path routing.

The energy Protocol is possible to allocate the available slack time non-uniformly among the intermediate hops along the path to the sink. For example, we may desire to provide the packets with additional time as it gets closer to the sink. The intuition is that in a gathering application, the contention is higher as the packet moves closer to the sink. More generally, we may want to allocate the slack time proportionately to the degree of contention along the path. We explore an Exponential increasing delaying policy with multi-path routing to break down the available time. We used multi-path routing that choose the best path in the case of congestion and apply heuristic scheme that attempts to pick the lowest latency path in network without collision.

Delay is used to decide how long a data packet can be queued locally. If the Delay is zero, the packet is forwarded at once. A single priority queue is used to queue all incoming data packets. In fact the Delay is the priority of the packets. We consider new protocol vs.AODV.

The Energy Efficient Protocol involves the architecture design of the whole system. The typical architecture of a system that EECP works on is shown in Figure3 and Figure 4 will illustrate the processing in the Protocol. This protocol resides above (or within) the routing layer. The EECP protocol and the MAC layer protocol are not aware of each other. It uses routing level information such as the end-to-end distance in making its decisions.

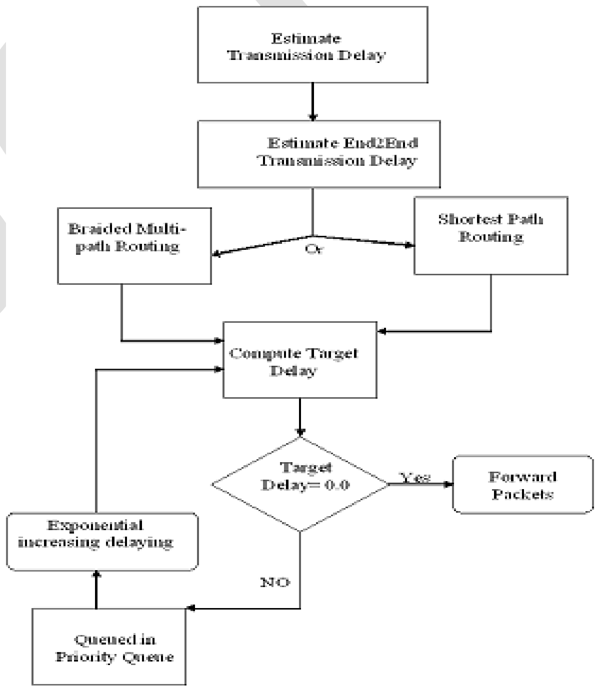

Figure 4. The proposed Protocol.

5.1. Energy Efficiency in Protocol

Keep-alive packets are used to keep the alternate paths in a ready state, rather than in the low energy use sleep state. Therefore, when a failure is detected in the primary path, an alternate path can be reinforced quickly, instead of using flooding based path discovery. The routing sequence used in this method is analogous to dealing cards.

In our multi-path schemes, the source periodically floods low-rate data over all alternate paths in the multi-path in order to keep alive those paths, thereby permitting fast recovery from failures on the primary path.

We describe the failure models for which we evaluated the resilience of our multi-path mechanisms. The failure probabilities that affect the multi-path schemes which we evaluated with our energy protocol are: The failure probability for isolated failures Pi, the arrival rate of patterned failures λp, and the radius of patterned failures Rp.

Braided multi-path routing alternates which path it sends a packet down. Since the paths are braided, each node may have multiple paths. If there are two or more reinforced paths from the given node, it will send the first data packet down one of them, the second data packet down another and so on, in an established order, until each reinforced path has received a data packet as shown in Figure 5. Each of these nodes behaves by the same rules. By doing so, each path is kept alive by the data packets because each path is periodically used. The data packets perform double duty as keep-alive packets. As a data packet passes through a node, the routing information contained at the node is updated. This eliminates the need for sending the low-rate keep-alive packets.

The amount of time that a node will stay awake without receiving a packet is dictated by a timer. The time-to sleep period should be as short as possible so that unused nodes will turn off. However, it should be long enough so that the nodes in the multi-path receive a packet before they go to sleep. Braided multi-path routing assumes that the requested data rate is high enough to keep all of the nodes in the path set from going to sleep. It enables the data packets to update the node routing information at least as frequently as the low-rate data packets would have. The low-rate data frequency is matched to the internal timing mechanism of the sensor nodes. However, in the event that the magnitude of the data packet frequency is insufficient to entirely satisfy this requirement, it ensures that the routing path set is maintainable. This situation was chosen in order to test the algorithms under a more difficult scenario. This led to the development of our protocol which terminates the path discovery in a way that creates a fairly constant path from source to sink.

This termination strategy is an improvement in resilience and energy use over braided multi-path routing because it creates a more consistent path set width between the source and the sink. This reduces the data rate required to keep the path nodes alive. This strategy also creates a braid-like path set consisting of a primary path and a wider, much intertwined series of alternate paths as shown in Figure 5. The objective is to further increase resilience by creating more ways to route around failures. This method uses additional nodes and therefore more energy. However, the termination strategy behaves in a constrained way. The reinforcements generally converge towards the primary path, reducing the number of extra nodes that are used while greatly increasing the number of interconnections.

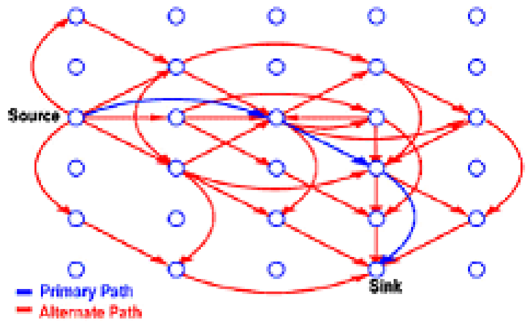

Figure 5. Reinforced paths in Braided multi-path routing.

6. Performance Evaluations

Designing energy-efficient systems has critical importance for a variety of networking domains, including sensor networks and mobile ad hoc networks. Based on this observation, we study how does delaying the data packets before reaching the sink and using braided multi-path routing help in efficient use of energy.

Our protocol showed some positive and interesting performance characteristics. It demonstrated significant universally lower energy use than the other algorithm. Sine AODV is improved to be an energy efficient routing algorithm, SO, we compare between our algorithm and AODV. The simulation results measured the energy efficiency of our algorithm is higher than the energy efficiency of the AODV routing algorithm. The results are due to the modest data rate and short time-to-sleep used, which tests the algorithms under unfavorable conditions. Tables 2 and 3 show the average residual energy of nodes in the network after simulation. It is clear that braided multi-path leaves the network with much higher residual energy than other traditional protocols does. This result demonstrates that braided multi-path has lower total energy consumption in communication than other protocol does. This benefit is achieved thanks to two braided multi-path properties. First, braided multi-path transmits data using the minimum power needed to reach the next hop. Second, it also restricts the route request procedure in the route discovery phase, which can be very costly in terms of energy used.

Table 2. The average residual energy in AODV.

Connection nodes	10	20	30
average residual energy in AODV	10.5 Joule	7.5 Joule	5 Joule

Table 3. The average residual energy in DMT.

Connection nodes	10	20	30
Average Residual energy in DMT	20 Joule	11 Joule	8 Joule

We also compared the number of nodes alive at the end of execution for these two protocols. -s 8&9 show the result for one instance of simulation under certain network topology. Obviously, our protocol can prolong the network connectivity longer than AODV. There are two reasons for this outcome. First, the total energy consumption is reduced in braided multi-path. Second, braided multi-path distributes the traffic load to multiple paths. See tables 4 and 5.

Table 4. An instance of the number of nodes alive in AODV.

Time	0	100	200
Number of nodes alive in AODV	100 nodes	100 nodes	60-50-45 nodes

Table 5. An instance of the number of nodes alive in BMP.

Time	0	100	200
number of nodes alive in BMP	100 nodes	100 nodes	100-60-48 nodes

The Route discovery frequency of the proposed approach is smaller than the other approach. This can imply that the multi-path can provide the path to the destination better than the one-path. The proposed approach has storages routes to change before the path break occurs. EECP can achieve the energy efficiency because the congestion change is detected within the network timely.

7. Conclusions and Future Work

A sensor network is a tool for distributed sensing of one or more phenomena, and reporting the sensed data to one or more observers. Real-time data communication is a service of great interest to many sensor network applications. Designing energy-efficient system has critical importance for real time applications in a variety of networking domains, including sensor networks and mobile ad hoc networks. Based on this observation, we study how does delaying the data packets before reaching the sink help in efficient use of energy. In this paper, we study the impact of exponential policy in communication processing on sensor networks; try to explore the effects of multi-paths routing on the energy consumption in the WSN. We develop protocol (EECP) that offers significant advantages over existing energy efficient protocol. The new protocol outperforms AODV in both the average residual energy and the number of nodes alive.

(EECP) utilizes multiple routes and distributes the data to multiple candidate neighbors. We noticed that the scheme efficiently utilizes the limited energy and available memory resources of sensor nodes. Further, EECP is a routing layer solution and does not require changes to lower level protocols. This makes it easier to deploy it independently of the underlying sensor network hardware capabilities.

It will be useful in the future to focus on: Develop energy efficient protocol by using sensitive real time routing protocol in routing layer.

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