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Enhancing Energy Efficiency in WSN using Energy Potential and Energy Balancing Concepts

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ABSTRACT
There are much different energy aware routing protocols proposed in the literature, most of them focus only on energy efficiency by finding the optimal path to minimize energy consumption. These protocols should not only aim for energy efficiency but also for energy balance consumption. In this work, energy balanced data gathering routing algorithm is developed using the concepts of potential in classical physics [16]. Our scheme called energy balanced routing protocol, forwards data packets toward the sink through dense energy areas so as to protect the nodes with relatively low residual energy. This is to construct three independent virtual potential fields in terms of depth, energy density and residual energy. The depth field is used to establish a basic routing paradigm which helps in moving the packets towards the sink. The energy density field ensures that packets are always forwarded along the high energy areas. Finally, the residual energy field aims to protect the low energy nodes. An energy-efficient routing protocol, tries to extend the network lifetime through minimizing the energy consumption whereas energy balanced with efficiency routing protocol intends to prolong the network lifetime through uniform energy consumption with efficiently.

Keywords
Sensor networks, energy efficient routing, potential fields, low energy nodes.

1. INTRODUCTION
Recent development in wireless technology has enabled the development of low power, multifunctional sensor nodes that are in small size and communicate in small distances. This tiny sensor node, which consists of sensing, data processing and communicating components, leverage the idea of sensor networks. A sensor network is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or very close to it. The positions of these sensor nodes can be easily engineered to be either fixed to a particular location or have certain amount of mobility in a predefined area. [24][25]

2. BACKGROUND STUDY

The sensing or monitoring of for example temperature, humidity etc., constitutes one of the two main tasks of each sensor. The other main task is packet forwarding using the equipped wireless technology. Whichever way data is transmitted the network must provide a way of transporting information from different sensors to wherever this information is needed. Sensor networks could be deployed in a wide variety of application domains such as military intelligence, commercial inventory tracking and agricultural monitoring [22][23][24].

Each node stores the identity of one or more nodes through which it heard an announcement that another group exists. That node may have itself heard the information second-hand, so every node within a group will end up with a next-hop path to every other group, as in distance-vector. Topology discovery proceeds in this manner until all network nodes are members of a single group. By the end of topology discovery, each node learns every other node's virtual address, public key, and certificate, since every group members knows the identities of all other group members and the network converges to a single group.

3. EXISTING SYSTEM

The existing system focus on energy efficient routing whose target is to find an optimal path to minimize energy consumption on local nodes or in the whole WSN [17][18][19]. The energy aware routing maintains multiple paths and properly chooses one for each packet delivery to improve network survivability. It may be quite costly since indeed to exchange routing information very frequently and may result in energy burden and traffic overload for the nodes.

4. PROBLEM IDENTIFICATION

Energy is an important resource for battery-powered wireless sensor networks (WSN) that makes energy-efficient protocol design a key challenging problem. The three main reasons that can cause an imbalance in energy distribution:

- **Topology:** The topology of the initial deployment limits the number of paths along which the data packets can flow. For example, if there is only a single path to the sink, nodes along this path would deplete their energy rather quickly. In this extreme case, there are no ways to reach an overall energy balance.

- **Application:** The applications themselves will determine the location and the rate at which the nodes generate data. The area generating more data and the path forwarding more packets may suffer faster energy depletion.

- **Routing:** Most energy-efficient routing protocols always choose a static optimal path to minimize energy consumption which results in energy imbalance since the energy at the nodes on the optimal path is quickly depleted.

5. SYSTEM DESIGN DESCRIPTION

5.1 *EBERP: Energy Balanced with Efficiency Routing Protocol:*

The goal of Energy Balanced with Efficiency Routing Protocol is to force the packets to move towards the sink so that the nodes with relatively low residual energy are protected. The Energy Balanced with Efficiency Routing Protocol is designed by constructing a mixed virtual potential field. It forces packets to move towards the sink through dense energy area. It protects the sensor nodes with low residual energy. Successfully delivers the sensed packet to the sink. Result shows significant improvement in network lifetime, coverage ratio and throughput.

This article focuses on routing that balances the energy consumption with efficiency. Its main contributions are:

- The concept of potential in classical physics is referred to build a virtual hybrid potential field to drive packets to move towards the sink through the high energy area and steer clear of the nodes with low residual energy so that the energy is consumed as evenly as possible in any given arbitrary network deployment.
- Classify the routing loops and devise an enhanced mechanism to detect and eliminate loops. The simulation results reflect that the proposed solution for EBERP makes significant improvements in energy consumption balance, network lifetime and throughput when compared to the other commonly used energy efficient routing algorithm.

An energy-efficient routing protocol, tries to extend the network lifetime through minimizing the energy consumption whereas energy balanced with efficiency routing protocol intends to prolong the network lifetime through uniform and efficient energy consumption. The former readily results in the premature network partition that disables the network functioning, although there may be much residual energy left. On the other hand, the latter may not be optimal with respect to energy efficiency as it can burn energy evenly to keep network connectivity and maintain network functioning as long as possible. Let us use a simple example to demonstrate what uneven energy depletion results in and how the proposed scheme Energy Balanced with

Efficiency Routing Protocol (EBERP) works to balance energy consumption with efficiently.

In this system, energy balanced data gathering routing algorithm is developed using the concepts of potential in classical physics. Our scheme called energy balanced routing protocol, forwards data packets toward the sink through dense energy areas so the nodes with relatively low residual energy can be protected. The cornerstone of the EBERP is to construct three independent virtual potential fields in terms of energy density, depth and residual energy. The depth field is used to establish a basic routing paradigm which helps in moving the packets towards the sink. The energy density field ensures that packets are always forwarded along the high energy areas. Finally, the residual energy field aims to protect the low energy nodes and the energy is balanced efficiently.

5.2 Depth of Potential Field

To provide the basic routing function, namely to instruct packets move toward the sink, we define the inverse proportional function of depth as the depth potential field Vd(d) as shown in Eq. 5.1:

$$Vd(d) = \frac{1}{d+1} \text{- -} Eq\ 5.1$$

Where d =D (i) denotes the depth of node i. Then, the depth potential difference Ud (d1; d2) from depth d1 to depth d2 is given by Eq 5.2

$$Ud(d1,d2) = Vd(d2) - Vd(d1) = \frac{d1-d2}{(d2+1)(d1+1)} \text{- - - - - - - - - - -} Eq\ 5.2$$

Since the potential function Vd(d) is monotonically decreasing, when the packets in this depth potential field move along the direction of the gradient, they could reach the sink eventually and the basic routing function can be achieved. For a given network topology, Vd(d) is definite and time invariant. Moreover, when the data packets move closer to the sink, the centrality should be larger, where the centrality denotes the trend that a node in depth d forwards the packets to the neighbors in depth d-1.

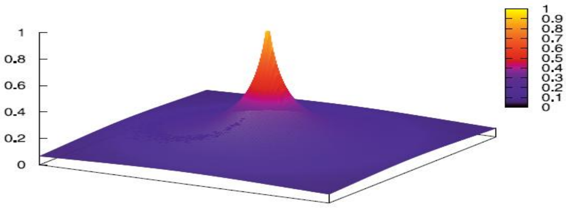

Figure 1. Depth potential field

- Energy Density Potential Field

A node adds up the energy values of all its neighbors, which can be obtained through messages exchanged among nodes and calculates the area of the radio coverage disk, so that the corresponding energy density can be readily obtained using the aforementioned definition. EBERP defines the energy density potential field as shown in Eq. 5.3 as follows:

$$Ved(i,t) = ED(i,t) ----------------------- Eq\ 5.3$$

Where Ved(i; t) is the energy density potential of node i at time t, and ED(i; t) is the energy density on the position of node i at time t. Thus, the potential difference Ued(i; j; t)from node i to node j is given by Eq. 5.4

$$Ued(i,j,t) = Ved(j,t) - Ved\ (i,t) = ED(j,t) - ED(i,t) ------- Eq\ 5.4$$

Driven by this potential field, the data packets will always flow toward the dense energy areas. However, with only this energy density field, the routing algorithm is not practical since it would suffer from the serious problem of routing loops. This fact will be clarified in the subsequent simulation experiments.

- Energy Potential Field

EBERP defines an energy potential field as shown in Eq. 5.5 using the residual energy on the nodes in order to protect the nodes with low energy:

$$Ve(i,t) = E(i,t) ------------------------- Eq\ 5.5$$

Where Ve (i; t) is the energy potential of node i at time t, and E(i; t) is the residual energy of node i at time t. Then potential difference Ue (i; j; t) from node i to j is derived as shown in Eq 5.6.

$$Ue(i,j,t) = Ve(j,t) - Ve(i,t) = E(j,t) - ED(i,t) ---------- Eq\ 5.6$$

The two latter potential fields are constructed using the linear functions of energy density and residual energy, respectively. Although the properties of the linear potential fields are straightforward, both of them are time varying, which will result in the routing loop.

6. PERFORMANCE EVALUATION

In this section protocols are evaluated by simulation. It illustrates the advantages of our protocol along with Mint Route protocol which uses the shortest path for transfer of packets from source to sink.

6.1 Performance Metrics

To make a performance evaluation, several measurable metrics has to be defined.

- Network Lifetime

The network lifetime [16] of a sensor network is defined as the time when the first energy exhausted node (First Dead Node, FDN) appears. The network lifetime is closely related to the network partition and network coverage ratio. When a node begins to die, the probability of network partition increases and the network coverage ratio might reduce.

- Functional lifetime

The functional lifetime of a task is defined as the amount of time that the task is perfectly carried out. Different tasks have different requirements. Some tasks may require no node failure while some others just need a portion of nodes to be alive, therefore the function lifetime may vary much according to task requirements. In simulation experiments, requirements are based on the application by making all the sampling nodes alive, functional lifetime is defined as the interval between the beginning of task and the appearance of the First Dead Sampling Node (FDSN).

- Functional Throughput (FT)

Functional throughput is defined as the number of packets thatthe sink receives during the functional lifetime. For a given application, FT is mainly influenced by the length of the functional lifetime

6.2 Simulation Setup

The simulation experiments in wireless sensor networks are conducted and evaluated to get the performance of our EBERP and compare them with Mint Route algorithm. In this special topology, a node can only communicate with its direct neighbors. The node can act as either a sampling node or a relaying node depending on the requirements. The nodes in the event areas can execute sampling and relaying tasks. The same simulation is repeated by deploy in n number of nodes with a maximum of 1000 nodes, the average values of the performance metrics are calculated.

6.3 Performance Results.

In order to evaluate the relative performance of proposed protocol, the protocol is compared with the existing Mint Route protocol. The graph shown in the fig 3 will give a comparison result of how well the energy is balanced for routing in our proposed scheme.

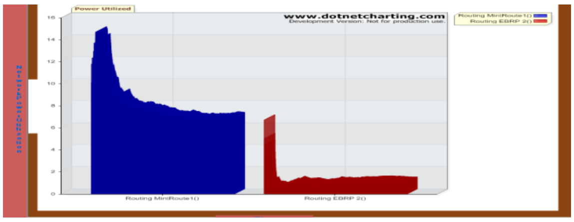

Figure 2. Comparison results for EBERP and Mint Route routing

- Network Lifetime and Network Throughput

Mint Route always chooses the shortest path, thus it will burn out the energy of nodes on that path quickly. However, EBERP will choose another path through other areas with more energy once it finds out that the energy density in this area is lower than that in other areas nearby. Therefore, EBERP can improve the energy consumption balance across the network and prolong the network lifetime as well as the functional lifetime. The statistical results are listed in table 8.1 shows the network throughput. The EBERP prolongs the time of FDN. The functional throughput is and network lifetime is also improved. The statistics listed in the table 8.2 show the results of network lifetime. From these results, conclusion can be drawn that more gain can be obtained through the EBERP's energy consumption balance and the integrity of the data received in EBERP is much better than that in Mint Route since there is fewer packets loss in EBERP.

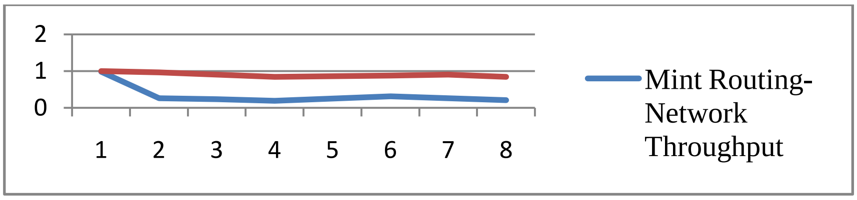

Figure 3. Network Throughput

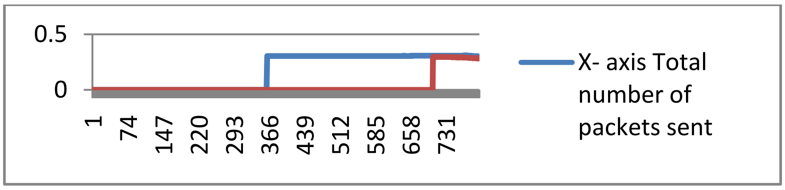

Figure 4. Network Lifetime

6.4 Summary

The performance evaluation chapter discusses about the simulation results drawn by considering all the performance metrics parameters like functional lifetime, network lifetime and network throughput. The comparison performance graph along with the network throughput and network lifetime graph gives a clear overview of the existing and proposed protocols being implemented.

7. CONCLUSION AND FUTURE ENHANCEMENT

7.1 Conclusion

Energy is an important resource for battery-powered wireless sensor networks (WSN) that makes a key challenging problem for designing energy-efficient protocol. Most of the existing energy efficient routing protocols usually forward packets through the minimum energy path to the sink that merely minimizes energy consumption which leads unbalanced distribution of residual energy amongst sensor nodes. Only, saving energy is not enough to effectively prolong the network lifetime. The uneven energy depletion often results in network partition and low coverage ratio which decrease the performance. This article focuses on routing that balances the energy consumption with efficiently. Its main contributions are firstly, referring the concept of potential in classical physics to build a virtual hybrid potential field to drive packets to move towards the sink through the high energy area and steer clear of the nodes with low residual energy so that the energy is consumed as evenly as possible in any given arbitrary network deployment. Then, classify the routing loops and devise an enhanced mechanism to detect and eliminate loops. The simulation results reflect that the proposed solution for EBERP makes significant improvements in energy consumption balance, network lifetime and throughput when compared to the other commonly used energy efficient routing algorithm.

7.2 Future Enhancement

In this project the routing loops: one hop - loop, origin - loop and queue - loop are being detected and eliminated by cutting the loop. Hence, future enhancement can be done in detecting and eliminating the loops and transmitting packets by avoiding the loops. It will further help in improving the overall system performance.

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