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Abstract
An energy-efficient smart protocol design is a key challenging problem in Wireless Sensor Networks (WSNs). Some of the few existing energy-efficient routing protocols schemes always forward the packets through the minimum energy based optimal route to the sink to minimize energy consumption. It causes an unbalanced distribution of residual energy between sensor nodes, which leads to network partition. The prime goal of this approach is to forward packets to sink through the energy denser area to protect the nodes with less residual energy, which is maximizing the Sensor Networks Lifetime. The existing technique Energy Balanced Routing Protocol (EBRP) fails to achieve Throughput, End-to-End Delay, in order to improve the Network Performance. So the efficient routing protocol is needed with the capabilities of both the Energy Efficiency and Energy Balancing. To address these issues, we have proposed Delay Aware Energy Balanced Dynamic Routing Protocol (DA-EBDRP). The proposed routing technique achieves in terms of End-to-End Delay, Throughput, Portion of Living Node (PLN) and Network Lifetime. By simulation results the proposed algorithm achieves better performance than the existing methods.

Keywords - Wireless Sensor Networks, Delay Minimum, Balancing Energy Consumption and Potential Filed, Energy-Efficient Routing, End-to-End Delay, Throughput, Portion of Living Node (PLN) and Network Lifetime.

1. Introduction
   
A. Wireless Sensor Networks (WSNs)
Wireless Sensor Networks are a series of sensors randomly or evenly distributed across a vast area used to monitor disaster areas, terrorist attack areas, forest fires etc. The sensors are located at random locations and relay their information to a central base that is usually far from the region of sensor nodes. Sensors usually have a few basic properties that come along with them: one or more sensors, a radio transceiver for communication, a microcontroller for computation and decision making and a battery for energy.

The network should have the self-organizing capability because the positions of individual nodes are not known initially. Cooperation among the nodes is the main feature of this network. The group of nodes cooperates to distribute the gathered information to their neighbor users in this network. The important application areas of the sensor networks are the military areas, natural disaster and in health. In addition, this network is used to monitor the light, temperature, humidity and other environmental factors for the civil applications.

B. Energy Balancing in WSN

Wireless Sensor Networks (WSNs) are installed and deployed to carry out different applications, such as Environmental Monitoring, Targeting, Industrial Control, Disaster Recovery, Nuclear, Biological & Chemical attack Detection Reconnaissance and Battlefield Surveillance. This Wireless Sensor Networks are expected to play more important role in the future generation networks to sense the physical world [1,2,3,4,7]. It is very well known that the energy is the most serious and critical resource for battery-powered Sensor Networks. To extend the lifetime of this network as long as possible, the energy efficiency becomes the most important parameter during the Protocol design. In order to achieve and use the limited energy at sensor nodes effectively, the recently proposed routing schemes are attempting to find the minimum energy path to the sink, which is used to optimize the energy usage at nodes.

From the literature survey, however, it is observed that to focus on the efficiency of energy while designing protocols for WSNs is not sufficient. And also identified that the uneven energy depletion which is dramatically reduces the lifetime of networks and decreases the sensors coverage ratio. And Furthermore, these results in [4] point out that one hop away from the sink will exhaust their energy level, there still up to ninety three percent of initial energy left at these nodes beyond away. And this imbalance of energy consumption imbalance is certainly undesirable for the long-term strength and health of the sensor network. These sensor nodes itself consume their energy heavier evenly, then the connectivity between these sensors and the sink could be maintained for a
longer time and thus the network partition might be postponed. This beautiful degradation of the network connectivity could be obviously provided substantial gains. And hence, it should be rational to make a suitable trade-off between both the energy efficiency and the balanced energy consumption.

2. Related Work

From our literature survey, it is noted that numerous literatures focus on energy efficient routing protocols which aim is to find an optimal best path to minimize energy consumption either on local nodes or in the whole WSN [6, 7, and 8]. However, some existing routing protocols have facing the problem of energy imbalance.

A few Routing Protocols such as LEACH [9], EAD [10] and HEED [11] offer energy balance within clusters by arbitrarily choosing the cluster head, but however they are limited solutions.

M. Singh and V. Prasanna in [12], define the energy-balance property and then designed, proposed and evaluated an energy-balanced algorithm for single-hop Wireless Sensor Networks.

X. Wu, G. Chen and S.K. Das in [5] developed and proposed a non-uniform node distribution strategy which is achieving nearly balanced energy depletion.

The Energy-Aware Routing [13] was proposed by X. Wu and G. Chen, and S.K. Das which focuses multiple paths, which improves the network survivability. But from our literature survey, it is noted that it quite consume energy to exchange the routing information very frequently. Recently, the author Fengyuan Ren et al, proposed an efficient Energy Balanced Routing Protocol [4]. This scheme employs the steepest gradient search method to decide the route. In this Gradient-Based Routing, the gradient is a state demonstrating the direction toward neighboring nodes through which the destination could be reached. It could be established with different parameters such as Energy Consumption, Physical Distance, Hop Count, Residual Energy and Energy Density. The aim of this scheme is to forward the packets to the designated sink through the dense energy area in order to protect the nodes with comparatively less residual energy. They have proposed a novel routing scheme called Energy Balanced Routing Protocol which does overcome the problem of energy consumption imbalance is a serious issue in recently proposed energy-efficient routing techniques, and it does demonstrate the advantage of balanced energy consumption between the sensor networks. However, this schemes consumes more cost which leads End-to-End delay.

To address this type of routing loop problem, EBRP [1], efficient enhanced mechanisms have been proposed to find and eliminate loops. From our experimental results, it is observed that this Energy Balanced Routing Protocol (EBRP) improves Network Lifetime. But however, it is observed that this work fails to achieve End-to-End Delay and Throughput. This causes the Network Performance Degradation. To address this major issue, in this research work, we have proposed an efficient and effective mechanism called Delay-Aware Energy Balanced Dynamic Routing Protocol, which improves the Network performance in terms of End-to-End Delay and Throughput. At the same time, this proposed work holds all the positive features of Energy Balanced Routing Protocol.

Chang and Tassiulas [16] proposed an energy conserving routing protocol to maximize the system lifetime by balancing the energy consumption among the nodes in proportion to their energy reserves. These proposed schemes embedded the energy awareness into the protocol and were proposed for a homogenous ad hoc network, where all the nodes are treated identical in terms of functioning and available resources. In addition, those schemes are suitable for static networks because the benefits come from the even Distribution of traffic among different nodes. When the nodes are moving independently, the savings provided by these algorithms, if any, is negligible because of the difficulty of real-time re-configuration.

Sohrabi and Pottie [17] proposed a self-organization protocol for wireless sensor networks. Each node maintains a TDMA like frame, called super frame, in which the node schedules different time slots to communicate with its known neighbors. At each time slot, it only talks to one neighbor. To avoid interference between adjacent links, the protocol assigns different channels, i.e., frequency (FDMA) or spreading code (CDMA), to potentially interfering links. Although the super frame structure is similar to a TDMA frame, it does not prevent two interfering nodes from accessing the medium at the same time. The actual multiple access is accomplished by FDMA or CDMA. A drawback of the scheme is its low bandwidth utilization. For example, if a node only has packets to be sent to one neighbor, it cannot reuse the time slots scheduled to other neighbors.

Piconet [18] is an architecture designed for low-power ad hoc wireless networks. One interesting feature of Piconet is that it also puts nodes into periodic sleep for energy conservation. The scheme that Piconet uses to synchronize neighboring nodes is to let a node broadcast its address before it starts listening. If a node wants to talk to a neighboring node, it must wait until it receives the neighbor’s broadcast.

The paper is organized as follows. The Section 1 describes with overview of WSN and energy balancing in
WSN. Section 2 deals with the related works. Section 3 is devoted for the Existing Scheme EBRP. Section 4 describes the Proposed Algorithm Delay-Aware Energy Balanced Routing Protocol (DA-EBRP) Section 5 describes the performance analysis and the last section concludes the work.


While designing an efficient routing protocols in Wireless Sensor Networks, we need to focus on an important two major parameters namely energy balance and energy efficiency. These two parameters are different attributes of routing techniques design goal.

3.1 Design Models and Properties of Energy Balanced Routing Protocol (EBRP)

In this section, we are discussing the Design models and various properties. i.e. This section focuses how to construct potential fields through depth, energy density and residual energy on each and every node, and how to integrate them into a combined virtual potential field which will drive packets to sink and at the same time this system has to focus balanced energy consumption.

3.1.1 Design Models of Energy Balanced Routing Protocol (EBRP)

Here, we are discussing various design models such as Depth Potential Field, Energy Density Potential Field, Energy Potential Field, and Hybrid Potential Fields.

Depth Potential Field

To provide the routing function such as how to move packets toward the sink, an inverse proportional function of depth which is as the depth potential field $V_d$. i.e. $V_d(d) = 1/(d+1)$, where $d = D(i)$ represents the depth of node $i$. The depth potential difference $U_d(d_1, d_2)$ from depth $d_1$ to $d_2$ could be defined as

$$U_d(d_1, d_2) = V_d(d_2) - V_d(d_1) = (d_1 - d_2)/(d_2 + 1)((d_1 + 1)$$

Since the potential function $V_d(d)$ is monotonically decreasing, while the packets in depth potential field go along with the direction of the gradient, they can reach the sink finally. The Depth of potential field is illustrated in fig.2. The value of the depth difference between neighboring nodes will be 0, 1, or -1 due to the nodes two or more hops away from a node may not become its neighbors. Thus

![Fig. 2. Depth Potential Field](image-url)
3.1.2.2 Depth

The design and implementation details of this EBRP are discussed in this Section. This EBRP is designed with the various routing Control Message Signals such as Flag, Depth, Energy and Energy Density, Distance with Received Signal Strength Indicator (RSSI), Time to Update. The structure is shown in the Figure Fig. 3. The various control signals of this EBRP are discussed below.

3.1.2.1 Control Message

This is the format of the routing control message, which consists of five parts is shown in Fig. 1. The flag field has 6 bits which is reserved for extensions. This EBRP defines two types of control messages where the first message is the normal updated message and its type field is 00 and the second field carries the information which is used by EBRP, comprising energy density depth and residual energy. And the third is used to confirm routing loops which is called as Check Loop Packet (CLP) with the value of 01.

3.1.2.2 Depth

In this EBRP, initially, the depth of all nodes have been initialized to 0xff and sink default depth is 0. The sink first will send the update message, nodes which one hop away from the sink could get their own depth level by adding one “1” to the depth value to the update message. Similarly all the other nodes will get their own depth by receiving did update message from its neighbors. The procedure for depth calculation is shown below.

```
Select the Lowest Depth LD from the Routing Table
If (Lowest Depth LD > LD+1)
{
  setLocalDepth (LD+1)
}
```

3.1.2.3 Energy and Energy Density

The EBRP calculates residual energy of the local node with feasible software. Here a Smart System is introduced to measure and estimate the consumed energy while forwarding packets. The System could log the actions that the local node is being performed to evaluate the consumed energy through battery model [14] which is published by the authors R. Musunuri and J.A. Cobb. In this work, it is assumed that the value of residual energy could be easily obtained from the above identified method. This value will be forwarded to the update message, and thus each node does know all its neighbors residual energy and will be maintained them in the routing table. Energy density of the local node could be acquired by adding all residual energy of the neighbors in routing table. Then it is dividing this sum by the area of coverage disk.

3.1.2.4 Distance

The distance between two neighbors could be easily obtained by various techniques, like signal attenuation evaluation or estimation based on Received Signal Strength Indicator (RSSI) [15]. This is noted that the distance used by EBRP might be approximate.

3.1.2.5 Time to Update

The Energy Balanced Routing Protocol EBRP exchanges routing messages to its direct neighbors. To maintain the update pace, this EBRP states both the i. Least Updating Interval (LUI) and ii. Maximum Updating Interval (MUI) between the two consecutive update messages. The MUI is continuously larger than LUI. If no messages from a neighbor in two MUIs intervals, neighbor might be considered as dead node. Thus this EBRP will again calculating the depth and other values. And then this EBRP will send an updated message with the following conditions.

- If the Maximum Updating Interval (MUI) Timer Expires
- If the Elapsed Time exceeds Least Updating Interval (LUI)
- Energy consumption exceeds a certain threshold

4. Identified Problem of the Existing System EBRP

This Energy-Balanced Routing Protocol (EBRP) is designed which focused and monitored the Sensors Networks in terms of residual energy and energy density. The aim of this approach is to forward packets to sink via the dense energy area to protect the nodes with less residual energy, which is maximizing the Sensor Networks Lifetime. However, from our experimental results, it is noted that this scheme finds a best energy density based route between source and destination. But it doesn’t focus shortest path, which degrades network performance in terms of Throughput, End-to-End Delay, and Network Lifetime. That is if this Energy Balanced Routing Protocol (EBRP) calculates
route based on Energy Density and Shortest Path as well, the network performance could be improved in terms of Throughput, End-to-End Delay and Network Lifetime. Thus this research paper designed and proposed an efficient Delay-Aware Energy Balanced Dynamic Routing Protocol (DA EBDRP), which will improve the network performance in terms of Throughput, End-to-End Delay and Network Lifetime.

5. Proposed Delay-Aware Energy Balanced Dynamic Routing Protocol (DA-EBDRP)

In Wireless Sensor Networks, it is important to save sensors energy. Current research on routing in Wireless Sensor Networks generally and mostly focused on energy aware and energy balanced protocols like EBRP to maximize the lifetime of the network which is discussed in the previous section.

The design of a smart delay sensitive shortest path and Energy balanced routing protocol DA-EBDRP for WSNs should allow a flexible trade-off between packet delay, the corresponding energy consumption and energy density. The routing methodology in DA-EBDRP is designed to take advantage of the EBRP and it will focus the shortest path to find the shortest energy density based route.

This proposed DA-EBDRP consists of three Phases. They are

- Energy Balanced based Shortest Route Finding
- Alternate Next Energy Balanced based Shortest Route Finding
- Route Update

5.1 Energy Balanced based Shortest Route Finding

This is the first phase of the DA-EBDRP. The procedure to find the shortest path based Energy Balanced Route of the proposed DA-EBDRP is shown below. This procedure will discover the best energy balanced based Delay Minimum optimal route.

Shortest_Path(Short_Path ( )
Updating Message: u_Msg
Neighbouring Node: neighbor_ID
Packetdropratio: PDR_size
Link Capacity: Lin_Cap
CLK: ClkB
BW: Bandwidth
Select Parent according to max_d, max-U_p, max-U_v, min-u_Msg.DEPTH, MIN-cost, Random
Short_Path() which finds & returns the shortest path of local node
Distance() which returns the distance of the neighbor;
Calculate_Energy-Density() which calculates & returns the energy density of local node;
UpdateRoutingTable() which updates the routing table;
SetLocalDepth() which sets the depth of the local node
Local_Energy_Density= calculateLocalEnergyDensity ( ):
\[ \theta_d = (\text{Local\_Depth+1} + \text{PDR\_size})/u\_Msg\_Depth+1 \]
Short_Path(U_v, \theta_d >1 \ ? 1-I/\theta_d -1)
Lin_Cap = Short_Path(RERR+CLK size)
\[ \theta_{eq} = u\_Msg\_Energy\_Density/Local\_Energy\_Density \]

5.2 Alternate Next Energy Balanced based Shortest Route Finding

This is the second phase of the proposed work. In this phase, alternate shortest path Alternate_Sort_Path will be identified by the sub procedure Alternate_Sort_Path() and it will be updated in the Route Update Table. If any nodes under the current working path are reached the lowest energy threshold level, that route will be blocked and the Alternate_Short_Path will be activated and subsequently Alternate_Sort_Path() will be called and another Alternate_Sort_Path will be discovered. This procedure will improve the reliability of the Sensor Networks and it will improve the network lifetime also.

5.3 Route Update

This phase is used to update the new route if the working route is getting down. This improves reliability and Throughput without delay.

5.4 Pseudo code of Proposed Delay-Aware Energy Balanced Dynamic Routing Protocol (DA-EBDRP)

The above process is controlled by a novel and reliable route monitoring and selecting technique which is shown below.

CALL Short_Path (calculateLocalEnergyDensity ( ) )
Select optimal route
FOR there are sensing data to be sent DO
BEGIN
IF Route Functioning Well
CALL data delivery
ELSE IF
CALL Alternate_Short_Path (calculateLocalEnergyDensity ( ) )
Select Alternate optimal route
END

6. Performance Analysis and Discussions

The performance of our proposed DA-EBDRP is implemented with QualNet4.5 Simulator and DA-EBRP is thoroughly studied and evaluated in this section in terms of in terms of End-to-End Delay, Throughput, Portion of Living
Node (PLN) and Network Lifetime. It is also compared with the recently proposed Energy Balanced Routing Protocol (EBRP) and established that our proposed work is performing well as compared with the existing one in terms of Throughput and End-to-End Delay and this proposed work retains all the positive features of Portion of Living Node (PLN) and Network Lifetime.

This approach improves the throughput level of the system, which is shown in the Figure Fig. 6. But however, from the Figure Fig. 6, observed that as the sending packets are more, our work chooses route based on the energy dense nodes and hence the throughput of our work is almost equal to EBRP for higher volume of data communication.

As far as the Network Life Time is concerned, our proposed work couldn’t achieve higher performance for low density nodes. But however, from the Figure Fig. 7, it is established that our proposed work maintains the feature of EBRP when sensor network has more than 200 nodes.

From the Figure Fig. 8, it is observed that our proposed work utilizes all the nodes of Sensor Network and hence our work achieves more living nodes as compared with EBRP for long time simulation. But however, for short time of execution, it couldn’t retain more nodes like EBRP because our work focuses energy density and shortest path as well for communication.

From the Figure Fig. 8, it is observed that our proposed work utilizes all the nodes of Sensor Network and hence our work achieves more living nodes as compared with EBRP for long time simulation. But however, for short time of execution, it couldn’t retain more nodes like EBRP because our work focuses energy density and shortest path as well for communication.

Fig. 4. Route Discovery Delay DA-EBRP vs EBRP

From the Figure Fig. 4, it is noted that our proposed DA-EBRP discovers the shortest path earlier as compared with the EBRP. It is happening because, our work continuously pre-calculating the alternate best shortest path which is maintained by route update table, while communication takes place in the current shortest path. It is also observed that as density of nodes increases, the route discovery time approaches EBRP because considerable time is required to calculate the Energy Density in condensed nodes.

Our proposed work’s prime objective is to discover the best shortest path with sufficient energy density to forward packets to sink. That is the reason why, our method consumes less End-to-End Delay to forward the packets to destination as compared with EBRP, which is shown in the Figure Fig. 5.

Fig. 5. End-to-End Delay DA-EBRP vs EBRP
7. Conclusions

In Wireless Sensor Networks, recharge or replace the batteries of the nodes may not be possible. That is the energy is a very precious resource and hence energy-efficient protocol design is a major challenging issue. We have discussed various energy-efficient routing protocols and discussed their issues. To overcome these major issues, an efficient Energy-Balanced Routing Protocol (EBRP) is designed. In this work, we were analysed its pros and cons. From our experimental results, we established that the EBRP fails to achieve Throughput and End-to-End Delay. To achieve these major issues, we have developed Delay-Aware Energy Balanced Routing Protocol (DA-EBRP). We have thoroughly studied and investigated this proposed routing technique and compared with EBRP in terms of End-to-End Delay, Throughput, Portion of Living Node (PLN) and Network Lifetime. From our experimental results it is established that this proposed work outperforms Energy Balanced Routing Protocol (EBRP) in terms of End-to-End Delay and Throughput, which improves the Network Performance. Further, we revealed that this proposed work retains all the qualities of EBRP in terms of Portion of Living Node (PLN) and Network Lifetime.

References


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N. Kaleeswari received her B.Sc degree in Electronics from Bharathiar University, India in 2000, M.Sc degree in Applied Electronics from Bharathiar University, India in 2002, M.E. degree in Electronics and Communication Engineering (Applied Electronics) from Anna University of Technology – Coimbatore, India in 2010 and she is currently pursuing full time Ph.D. degree in Electronics and Communication Engineering from Anna University of Technology – Coimbatore, India. Her research interests include Wireless Sensor Networks, System Networking, Digital Communication, Adhoc Networks and Pervasive Computing.