Energy Optimisation using Distance and Hop-based Transmission (DHBT) in Wireless Sensor Networks
Scheme and Simulation Analysis

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Abstract: Wireless Sensor networks operate in a low energy mode and consume less power. The ultimate challenge of a sensor node is to make the lifetime of the node increase by which the energy consumption is so minimal. This paper addresses a mechanism by which the distance between any source and destination nodes is used by the source nodes to decide whether transmission of the message to destination node must be multi-hop or direct transmission by simply boosting the node power. The network size and the topology are considered for determining the threshold value for the distance based on which the decision is made. The simulation results have shown that the proposed method, DHBT, can increase the lifetime of the sensor network by at least 130% when compared to the legacy systems.

1 INTRODUCTION

Wireless sensor networks play a major role in applications like surveillance, animal habitat, agricultural monitoring and observation, nuclear radiation observation, location tracking, smart homes and industrial automation (Obaidat and Misra, 2014). Usually small sized nodes are deployed in an environment. These nodes are used to monitor the environment, collect the data and report to the gateway node or base station nodes. All this work is done autonomously (Lee et al., 2009).

One of the greatest challenges is to increase the lifetime of sensor network due to adversarial conditions of deployment environments that limits battery power of sensor nodes, as they are not rechargeable easily.

As of now, many routing algorithms, data aggregation, location tracking, and clustering have been proposed and most of these minimize energy consumption due to delay in routing; optimize the nodes to go to sleep mode and thereby increasing the network lifetime. The nodes in a network will consume more power if a single node dies that determines the lifetime of a network (Obaidat and Misra, 2014, Jurdak et al., 2010).

Metrics like energy consumption, and latency, routing issues are being directly affected by the number of hops and distance of hops. If the hop count is too large, the energy consumption can be minimized by adopting multi-hop transmission, but at the cost of increase in end-to-end delay and overhead. If the hop count is small (in case of direct transmission), the latency and end-to-end delay will be very small and hence the energy consumption is high at the source node as the hoping is avoided. Having said this, both methods should exist in a network to increase the lifetime of the sensor network (Anastasi et al., 2009). An optimal schedule should be formulated to optimize energy, thereby increasing the lifetime of the network of dynamic and static topology.

This paper addresses this issue to handle both the multi-hop and direct transmissions. Based on the hop count number and hop distance, the source node either bypasses intermediate nodes or uses direct transmission. Since either of the techniques is selected at runtime, the lifetime of the network will be increased at least by 130%. A strategy is used to

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find the Hop count threshold and distance of the hops in the case of multi-hop transmission.

The objective of this paper is to increase the lifetime of the sensor network via distance based transmission. The contributions of this paper are listed below:

1. The source node determines all the possible paths along with their corresponding hop count and distance before starting the transmission.
2. If the destination is within a threshold distance or minimum hop count threshold, then the source node bypasses the hops and sends the information to destination node by slightly increasing its power. With this, the lifetime of the network is increased as source node uses minimal power rather than awakening the intermediate nodes. This method will not be effective large-scale deployments of sensor nodes with huge number of intermediate nodes exist between source and destination nodes.

The rest of the paper is organized as follows. Section 2 presents the previous related research and introduces the problem statement. In Section 3, relevant network, traffic and energy models are presented. Performance evaluation using simulation analysis and comparison are given in Section 5 and Section 6 concludes the paper.

2 RELATED WORK

The researchers have proposed many methods to reduce the energy utilization of node in sensors. They have taken solar power and combined many routing protocols to increase the life span of battery and this technique is named as Enhancement of energy conservation technology (EECT). This EECT method is used in large organization to monitor the air conditioners, which use heat energy and sunlight. So, heat energy is utilized to make the environment pollutant free and the battery usage is reduced (Thayananthan and Alzranhi, 2014). The performance is also affected by latency, energy and reliability. Data aggregation approach is used to reduce the redundancy and cost. ACO (Ant Colony Optimization) is used to reduce the energy utilization and also help to improve the life of sensor node. This is only used when the channel is secured (Ye and Mohamadian, 2014). The MEB (Minimum Energy Broadcast) is used to reduce the consumption of energy. POS based hybrid algorithm and local search is used in this method. To decrease the transmission power, POS is applied. The r-shrink method is modified to re-establish the network again (Hsiao et al., 2013).

The other methods using POS is either non-linear programming or linear programming in order to minimize the battery usage (Akyildiz et al., 2002; Zeng and Pei, 2009). Development of routing protocol is done using multi-objective fitness function and encoding. These all use clustering algorithm to minimize the energy consumption. Physical to network layer optimization is done to increase lifespan of network and reduce battery consumption. The important applications and its requirements are gathered to overcome this problem (Pazzi and Boukerche, 2008).

Clustering is used to improve scalability, lifetime of network and to reduce traffic load (Alla et al., 2012). Due to extra load of receiving and transmitting data to base station, cluster heads utilize more energy. When overhead is more, cluster heads are destroyed and stop working. Thus, this will reduce the overall performance of a network. To overcome this problem, Differential Evaluation based algorithm is used which will reduce the load and enhance the lifetime of network. This will also increase the efficiency of data transfer from source sensor node to its destination (Kuila and Jana, 2014).

These all are the techniques, which were used to optimize the energy utilization during transferring data from a particular source sensor node to the destination sensor node (Akkaya and Younis, 2005; Beyme and Leung, 2014; Saleem et al., 2012). These techniques when applied to any protocol in the sensor network will increase the lifespan of our network and the battery lifetime. But it is not optimized more than 20%. Many other methods are there on which researchers work to reduce more and more power consumption during the data transfer in sensor networks.

Jeong-Hun Lee designs a network through an energy efficient protocol based on the resource constraints available between the BS and the source node (Lee and Moon, 2014).

3 RADIO MODEL AND PROBLEM STATEMENT

The energy consumption model of a typical sensor network is shown in Figure 1. Energy is being consumed by the radio of the sending and receiving node through its processor, transceiver and the amplifier. Amplifier consumes energy only when

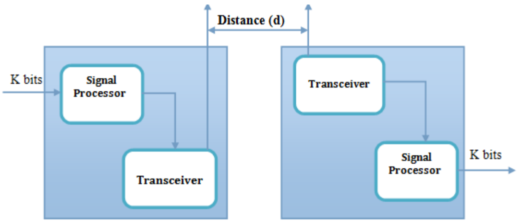

Figure 1: Energy Model of Typical Sensor network.

transmitting a packet while the radio consumes power during the reception of a packet.

The aim of this paper is to design an algorithm that uses distance and hop as a metric that optimizes the energy based on the dynamic selection of any of the metric during the data transmission and also to reduce the battery consumption, which increases the lifetime of the sensor nodes.

In the proposed algorithm, DHBT, the distance and hop are two metrics that are selected dynamically during each data transmission. If a source node decides to send a packet or data to a destination node, the source node computes the path to the destination node. The number of hops in each path, the distance along each path and the residual energy of all the nodes within the path are determined. Firstly, the source node selects the path that requires minimum energy. Based on the hop count and the path length the packet transmission between the source and destination nodes happens either through multi-hop transmission or direct transmission. The Hop count threshold will be computed based on an algorithm, which also depends on the network size and the topology.

3.1 Assumptions

1. The nodes are static or stationary
2. All the nodes are homogenous (same energy level while transmitting or receiving a packet)
3. The distance between the nodes is not constant.
4. Nodes are placed on a plane (X and Y axis)
5. Power usage during sleep mode is negligible
6. A boundary is considered while evaluating the sensor energy model. (This model may not work for a larger boundary with huge distance constraints).
7. Minimal number of intermediate nodes (δ)

Table 1: Variables Used.

Variables and their purpose	
Pi	Paths, i ε 1….m, n<m
E_T	Energy Consumption while transmitting a message, Joules
E_R	Energy consumed while receiving a message, joules
E_F	Energy consumed while forwarding a message, joules
N	Number of Hops
N_t	Hop count threshold
D	Minimum distance threshold by which the source node send info to destination node directly, m
E_e	Energy consumed by the radio, joules
L	Message length
d_0	Distance threshold, m
D[n]	Distance matrix
C[n]	Energy Matrix
E[n][m]	Stores all the paths and its optimal energy value

3.2 DHBT Algorithm

```
Initialize  number of nodes → Sn.
Identify two corner nodes of the
topology and compute all the paths
between the two nodes
fori=1 to n
        Find all path→[A]
D[i] → distance(Pm)
Discard N = 1
Compute (fix) Nt, L
Return(Pm)
If N >Nt: Goto HOP
Elseif N <Nt: Transmit with N=1
Elseif N<Nt and distance > d0; Goto
ENERGY
end for
HOP: fori=1 to m
C[i]→hop(Pm)  //find number of hop
in all paths and store in array C
Return Pk
end for
ENERGY: fori=1 to m
for j=I to m
E[i][1] →min(C[ i])
E[i][2] →min(D[i])
Return(E[i][j])
end for
endfor
```

The algorithm explains the computation of energy of the path, hop count and paths between the corner nodes. Then, the average path length L or the characteristic path length of a graph G, denoted L, is the average distance between vertices, where the average is taken over all pairs of distinct vertices. In any graph of order n, there are |E(Kn)| distinct pairs of vertices. So, for a graph G of order n,

$$L = \frac{2}{n(n-1)} \sum_{v1,v2 \in V(G)} d(v1, v2) \quad (1)$$

Complexity analysis:

a. The problem belongs to NP-Hard class to compute the output of this problem as it takes infinite time complexity. Mean time complexity is O (n^n).
b. This NP-hard problem is reduced to NP complete problem, which can be solvable in real time.
c. Brute force attack is used to compute the path as all the paths between a source and destination has to be computed. Also, the intermediate nodes should be minimal, otherwise it will take infinite time to compute optimal path and the algorithm becomes complex.

4 MATHEMATICAL MODEL

The energy consumed during the transmission and reception of packets is:

$$k.E_e + k.\varepsilon_f.d^2, if d < d_0$$
$$k.E_e + k.\varepsilon_m.d^4, if.d \geq d_0 \quad (2)$$
$$E_R = k.E_e \quad (3)$$
$$E_F = E_R + E_T \quad (4)$$

For 1 bit message the total energy consumed by the N hop is given as:

$$E(N) = \left[(2N-1)E_e + \sum_{i=1}^{N} \varepsilon_m.d_{i^\alpha} \right] \quad (5)$$

If N <**N$_t$**, there will be a direct transmission, in that case the equation boils down to:

$$E(N) = 2E_e + \varepsilon_m d^4 \quad (6)$$

Since the E (N) here depends on the distanced, which is to the power of 4, it proves that when the distance is huge, the energy occupation will also be more. Here in this case, the intermediate nodes are not transmitting anything and they may be in sleep mode as the source node decides to use direct transmission.
However, DHBT algorithm also uses distance as one of the metrics in reducing the energy level.

If N <N$_t$ and if the distance is greater than the threshold distance, then normal multi hop transmission will be occurring, thereby minimizes the energy that will be wasted in direct transmission.

4.1 Analysis of Graph Model

Let the network shown in Figure 2 is as a graph G. The figure shows only one edge, but the graph we consider is a multi-graph (A loopless graph that has multiple edges between two nodes). Here, we model this as multi-graph as our algorithm proposes three metrics: distance, hop and energy. In each edge, hop, energy and distance will be considered as weight.

The multi-graph will be solved based on the algorithm and is shown in Table. 2

Let G = {V, E, r} where:

- V is the vertices
- E is the number of edges
- r:E; Assigning to each edge an unordered pair of end nodes

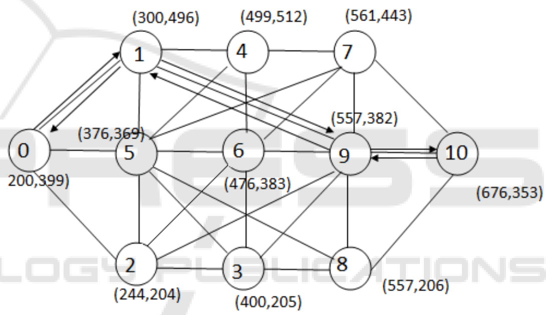

Figure 2: Path taken by DHBT.

Let Aij will be the adjacency matrix and Iij will be the incident matrix to find whether the given nodes are incident on the edges or not.

Iij = 1 if Ej is incident with Vi; else 0.

Let Eij represents the weighted matrix for Energy, Dij represents the weighted matrix for distance and Hij be the weighted matrix for Hop count.

$$Eij = \begin{matrix} E11 & E12 & ... & E1M \\ E21 & E22 & ... & E2M \\ .... & ... & ... & ... \\ EN1 & EN2 & ... & ENM \end{matrix}$$

$$Dij = \begin{matrix} D11 & D12 & ... & D1M \\ D21 & D22 & ... & D2M \\ .... & ... & ... & ... \\ DN1 & DN2 & ... & DNM \end{matrix}$$

2. Find path using brute force from matrix Dij
All path -> [Dij]
check all the combinations v0-v1, v0-v2,…… , v0-v1,……..,v0-v1-v2-….v10.
3. Find path having shortest path using maximum [Eij]
Min path-> [Eij]
4. Take the path having minmum distance and min energy.

5 IMPLEMENTATION AND RESULTS

The network is tested using Network Simulator 2 (NS2) and mannasim where the simulations were carried out. Here are the parameters that were used during the simulation as shown in Table 2. For comparison of DHBT protocol, the nearer resemblence protocol is DSR, so DSR is taken for comparison. DSR also computes all the paths between the source and destination. The path taken by the DHBT and DSR protocol is shown in Figures 2 and 3, respectively.

Table 2: Simulation Parameters.

Parameter	Description
MAC layer	802.11
Protocol	DSR, DHBT, LEACH
Propogation method	TwoRayGround
Transport Agents	TCP with 1500 bytes
Number of nodes	11,50,100 (LEACH protocol handles the Cluster head automatically, whereas DSR and DHBT handles clutser head separately)
Topology	Random with X=776 and Y=612)
Tranmission Power	18mW
Forwarding Power	17mW
Receving Power	19.7mW
Idle Power	5 µA/0.005mW
Sleep Power	2µA/0.002mW (Negligible)
Sensed parameters	Temperature and pressure
Data dissemination interval	0.1 seconds
Sensing type	On Demand/Programmed

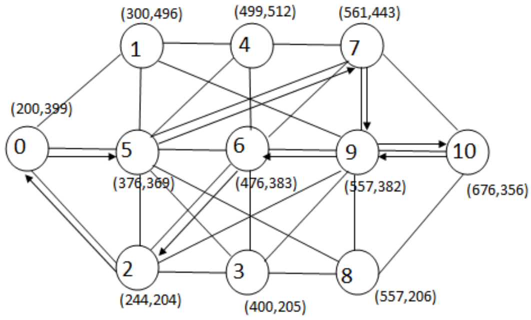

Figure 3: Path taken by DSR Protocol.

Experimental Setup:

The nodes were deployed as shown in the Fig 3 with x and y locations so that for all the protocols under comparison we will have the same topology. Since a simulator is used for validating the protocol, the sensing happens through Gaussian distribution. Pressure and temperature sensors were modelled and sensed.

Energy Consumption:

In DHBT, the path taken by the protocol is 0->1->9->10, whereas the DSR handles it 0->5->7->9->10. So DHBT is optimising the power consumed at least by one hop and hence the energy occupied by DHBT is less compared to DSR. The number of nodes is tested from small to huge nodes (11, 50,100). In most of the cases the energy compared by the DHBT is lower by at least 25% compared to DSR protocol. Since DHBT directly computes all the paths related to hop, distance and energy, AODV is not preferred for comparison as AODV selects the path based on the network topology on an on-demand basis.

Throughput:

When we take the case of transmission of data from source to destination, then the average rate of successful transmission is taken as throughput. Hence, we have analysed throughput of DSR and DHBT protocols. Throughput of DHBT protocol is comparatively high as compared to DSR.

Route Selection:

DSR protocol considers hop count to find the path for forwarding packets and also takes another path to send the acknowledgment of the packet received.

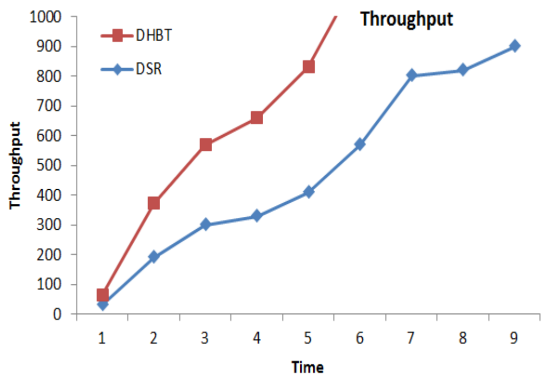

Figure 4: Throughput vs. time.

But DHBT protocol will first consider the paths having less number of hops then will consider the distance and energy. And the acknowledgment of the data received is also sent by the same path. Therefore, DHBT is more effective if we consider all the conditions as compared to DSR protocol. Figure 4 shows this difference between them.

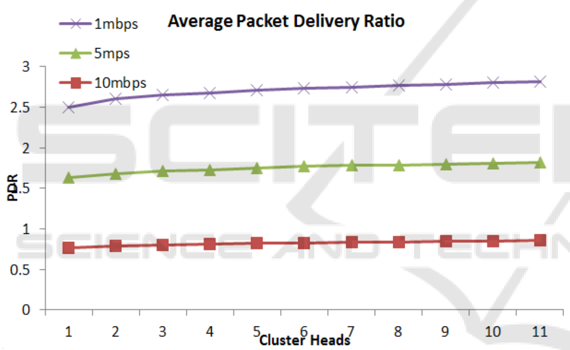

Figure 5: Average packet delivery Ratio vs. number of cluster heads.

The packet delivery ratio, and the lifetime of the network are shown in Figures 5 and Figure 6, respectively. Both are normalized and the PDR is relatively constant for various bandwidth increases. This predicts the stability of the network during the increase in the bandwidth. Moreover, the lifetime of the network is good for LEACH and DHBT, but DHBT has slightly 10% more lifetime over LEACH and network with DSR lifetime is too low compared to other protocols.

Figures 7 and 8 show the energy consumed and dissipated by DSR and DHBT protocols for 50 nodes by varying the number of cluster heads. Figure 9 shows the dissipation of energy for a long time by DHBT whereas the energy depleted fast by the other protocols.

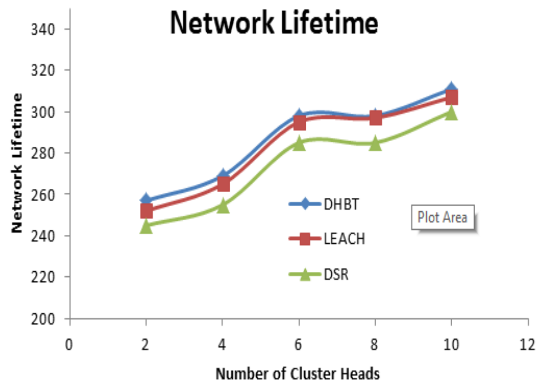

Figure 6: Network Lifetime vs. nuber of cluster heads.

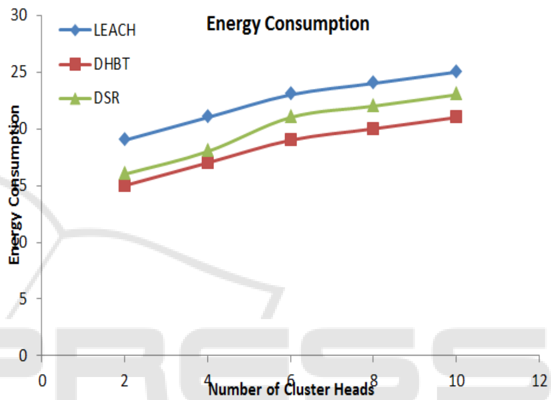

Figure 7: Energy consumption vs. number of cluster heads.

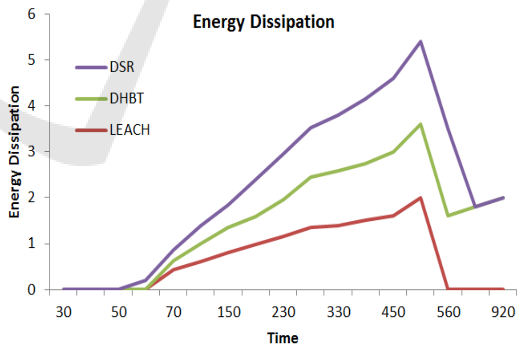

Figure 8: Energy dissipation vs. time.

6 CONCLUSIONS

In this paper, we derived a new algorithm called DHBT by which the distance between any source and destination nodes is used by the source nodes to decide whether transmission of the message to destination node must be multi-hop or direct transmission by simply boosting the node power. DHBT scheme has reduced the overall energy utilization for each transfer of data in a sensor network. Energy and hop count is working well with DHBT whereas the distance calculation depends on the transmitter and the receiver, so this work does not handles distance calculation. However, distance can be accurately calculated in the future work. Also, distance can be computed using a localization algorithm for sensor networks and thus the nearest location of the sensor node could be found out and can be solved for energy calculation. Simulation analysis was used to predict the performance of our proposed schema and to compare its performance with competing schemes. We found out that DHBT has excellent performance. As future work, we plan to conduct more simulation experiments on DHBT under different scenarios in order to check further the performance under different conditions and environments.

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