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Energy Balanced Heuristic Approach for Path Selection using Graph Theory

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Abstract

One of the challenging tasks in Wireless Sensor Network is to route data efficiently from source to destination. Data is routed to the destination using single path, resulting in failure of nodes In this mechanism, A fault tolerant system is required that can switch from an inaccessible path with broken links to available candidate paths. In this paper, a new graph theory approach for multiple path selection based on quality of service parameters is proposed .Results of the proposed approach are compared with existing approach and it has been found that this methods enhances network lifetime and improves path stability.

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Keywords: Graph theory; BFS; Fault; reliability;WSN

1. Introduction

A number of energy-aware routing algorithms for WSNs have been presented in recent years. These routing algorithms can be classified into clustering or hierarchical routing algorithms that group sensor nodes into clusters based on different criteria. In a cluster routing algorithm, a node is selected as cluster head based on different selection parameters [1, 2, 3]. The cluster head aggregates data from its member nodes and transmits aggregated data to sink node. The other type is the centralized routing, which uses probabilistic

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forwarding[4] or an optimization strategy, such as ant colony optimization or heuristic approaches to find stable routes based on the global information on the network topology and energy consumption [5, 6, 7].

A heuristic algorithm based on geographical routing is proposed in[8]. In this, global positioning system is used to find out locations of source and destination. A multi hop technique is adopted for establishing the shortest path based on greedy approach and on minimum overlapping area coverage with the predecessor node. This approach is capable of routing data with minimum number of hops to the destined node and thus improves network performance in terms of routing overhead and average end-to-end delay.

In[9], the author proposes an energy aware routing algorithm that uses minimum number of hops for transmission of data. By varying the transmission distance, the interconnections between the nodes can be changed and different network topologies can be obtained. For different values of transmission distances an improvement over different performance metrics can be achieved.

Krishnaveni and Saumaya[10] addresses the problem of routing loop and propose a loop elimination mechanism by integrating it with energy balanced routing .A shortest path algorithm is used to find the optimized path with high energy. Authors were able to improve lifetime of the network, throughput and coverage ratio as compared to the commonly used energy-efficient routing algorithm.

Another energy balanced robust scheme based on swarm intelligence that chooses the next node based upon node's local information was suggested by Zhang and Shen in 2009[11]. This method balances load evenly among the nodes and was able to achieve longer lifetime.

In our previous work[12], an energy efficient path determination method is proposed that finds the shortest path from source to destination node using improved BFS approach. In an improved BFS (IBFS) approach , nodes are added in the queue based on the minimum distance from the source node. Though existing approach helps to find the optimal path from source to destination but still it has certain limitations;

- It does not take it account parameters like energy, packet delivery ratio for selecting next candidate node.
- Nodes with same distance are added into the queue randomly i.e. no priority like energy factor is considered while insertion.
- This approach fails to find faulty nodes.

Enriched Breadth First Search (EBFS) approach takes care of all the limitations of IBFS approach and thus results obtained are better in terms of network lifetime and energy consumption.

2. **Enriched breadth first search approach**

BFS is a graph traversal algorithm that begins at source node and explores all its neighbouring nodes. Then for each of its neighbouring node; it explores all the unexplored nodes that are in its communication range. It has been proved through induction that BFS always results in shortest path tree from its root (provided all the nodes are separated by same distance) and no path can skip a level. Nodes consume energy while communicating with neighbouring nodes. Therefore, optimization of energy resources in a network becomes essential with each network operation. One of such critical network operation is the route identification. An effective route is generally considered as the shortest path between the source and the destination. Using same path again and again for transmission of data over the network results in over usage of resources of nodes. EBFS is an enhancement over IBFS approach as it selects the route from source to destination based upon residual energy of the sensor nodes, distance between the neighbours and node packet loss rate.

3. Proposed algorithm:

3.1. Design philosophy:

Selecting a reliable path from source to destination that yields low delay and enhanced network lifetime is a challenging problem. Transmission of data over a single selected path over time consumes more energy as nodes die due to over usage which leads to uneven consumption of energy. Thus, link reliability over the path is an important area of concern. EBFS approach takes care of the faulty nodes by selecting new nodes in case of failure. The formation of new path over rounds prolongs the lifetime of the network.

In EBFS, 'N' heterogeneous sensors are distributed randomly in the sensing field. Sensor nodes are stationary for the lifetime. Every node has an ability to transmit to any other node or Sink directly. All the nodes have same transmission range and have enough power to carry their sensing and communication activity.

For better understanding, EBFS has been divided into number of phases.

3.2. Level assignment phase

Network area is divided into number of concentric levels based on the Sink's sensing range. Sink node is located at (97,100). The level assignment starts from sink node, as it can be clearly seen in Figure 1. Nodes are deployed randomly in the network area.

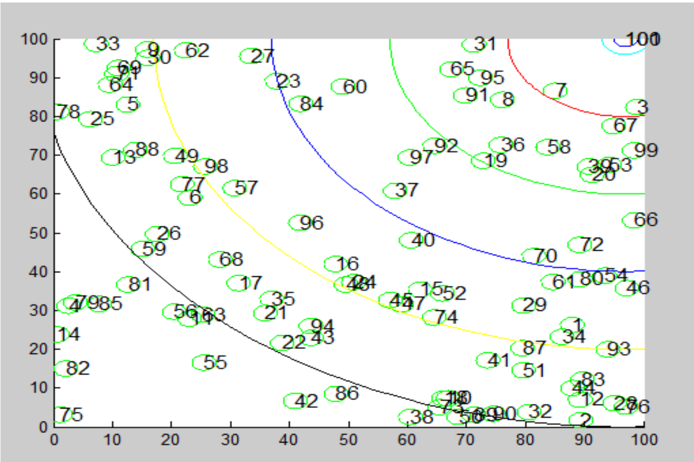

Fig.1. level assignment phase.

3.3. Route discovery phase

Route discovery process is initiated from the sink node. A route discovery message is broadcasted by the sink (source) node. The source node then waits for the route reply. If the reply is received with in the allotted time frame; node is said to be active. In order to keep track of all the neighbouring nodes, each node maintains a routing table. Various fields maintain by each node are described below. The algorithm uses timestamp =1 to find out nodes which are one hop away.

Source ID: Source node ID
Destination ID: Neighbour's node ID
Node Status: Node can be in active or in dead state.
Energy: It is the adjacent node's remaining energy.
Distance: It is the distance between the source node and the adjacent node, calculated using Euclidean distance formula.
Packet Drop Rate (PDR) : It is the number of packets received by a node(p_{Ri}) to the total number of packets transmitted (p_{Ti}).It is calculated using

$$p = \left(p_{Ri} - p_{Ti}\right) / p_{Ri} \tag{1}$$

.

If the value p >0.05, then there may be a link failure due to collision, congestion or node failure. It is assumed that a node is considered to be erroneous if a node packet loss >0.05 i.e. a node is considered to be faulty if it loses more than 5 packets out of 100 packets.

Fault: A faulty node does not take part in a route construction phase. Each node in the network will calculate its fault value. A node may be considered faulty if there is packet loss or node's residual energy becomes less than threshold value or if the node does not receive or transmit data in permissible timestamp.

$$ff\left(node\_fault\right) = IF(nodepacketloss > 0.05) \text{ OR } IF(ResidualEnergy > \theta) \text{ OR } IF(t > 1) \tag{2}$$

If any of the above condition holds true, the node is assumed to be dead and it no longer takes part in route formation process.

3.4. Link formation phase

Once all the nodes update their routing table, link formation starts from the sink node. From every level, a node based on the selection Criteria (M) will be selected to form a route from source to destination .

$$M = \max\left(\frac{Energy}{distance}\right) \tag{3}$$

Definitions

n: Total number of sensors
d_{ij}: Distance of node i to node j
ff: Detection of Faulty node.
P: Packer drop rate
E: Remaining Energy of a node.
θ1, θ2: Pre defined threshold values for Energy and Fault.
t: Timestamp
Δt: Timestamp for a sensor node to be active i.e. Δt = ti+1-ti
dtij : Distance matrix created for active nodes.
R: Sensing range of a sensor

Algorithm

Begin

Formation of sensor network

$$\forall i, i \in s_i : s_i = s_1, s_2, s_3, s_4 ...... s_n$$

For each si , compute the distance d_{ij}^{t} for a particular timestamp t

$$\left|d_{si,sj}{}^{t}\right| = \sqrt{\left(x_{si} - x_{sj}\right) - \left(y_{si} - y_{sj}\right)}$$

Calculate packet drop rate, Pi

$$Ps_i = Ps_{iT} - Ps_{iR}$$

F Psi>0 , Then si is faulty.

Calculate residual energy of a node, Esi

$$E_{si} = E_{initial(si)} - E_{consumed(si)}$$

/* Only nodes which are in sensing range of each other can be communication neighbor*/
IF $|d^t_{si,sj}|$ > R THEN set $|d^t_{si,sj}|$=0 End if
/* Only a high energy node can be the communication neighbor*/
If (E(sj) < θ1) Then set $|d^t_{si,sj}|$=0 Endif
/* Only a node with no packet loss can be a communication neighbor*/
If (Psi >0) Then set $|d^t_{si,sj}|$=0 End if
Set Source Node and destination node for the communication

$$\forall s_i, i \in n : s_{dest} = s_n$$
$$\forall s_{i,} s_j, i,j \in n : s_{src} = \max(dist_{i,j}) \wedge d^t_{si,sj} = 1$$

If $s^t_i = \Delta t$ /*If communication is performed on current time stamp, the node will be active*/
THEN s^t_i =Active OTHERWISE s^t_i=FAULTY
End if
If $d^t_{si,sj}=1$
Calculate, $M_{si} = E_{si} / d^t_{si,sj}$
A node with maximum M_{si} will be selected
End if
Call BFS (M_{si}) /*Generate Path on Fault Effective Matrix*/
Perform Communication over Path generated from BFS
Perform Network Analysis under different Parameters
End
BFS(M_{si})
/* M_{si} is the actual metric between connected nodes under the distance, fault and energy vector */
Path = [] /* Initialize an empty array*/
Initialize all nodes to ready state (status = 1). // Here n can be defined as the active nodes. Initially,
For i:=1 to n step 1
Set visit[v] =0 // visit=0, for unvisited nodes.
//Initialize starting node say v and make visit[v] =1
// Add on to queue [v], initialize to pointers to keep track front and rear element of queue
Front=Rear=-1 // initially
Rear=Front=0 // increment Rear++, front++
Queue [Rear] = v
Repeat step 4 and 5 until queue is empty
// Check
While (Front<=Rear)
Remove the front node n of queue and process n
// Deleting element from the queue
v=queue [Front]
Front++ //incrementing front by one
Add to the rear of the queue all the neighbors of n that are active
End while
//find out all the nodes adjacent to v
For i=0 to n step 1

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                                   d[v][i]!==1 and visit[i]==0
                                        Rear++
                                     Queue[Rear]=i
                                        End for
                                        End for
   Call Travelnode (v)
    RETURN
    TravelNode (v,d)
 // v is the current node to process for BFS based node visit
     If (v==Active)    // If communication is performed on same time stamp
     Set status (v) = V;
     Path=Path U { V }
     End if
 // Process all nodes
    For  i=1 to n step 1
    If (d(v(i),i)<>0)
// Identify the adjacent of current Nodes
    If (status(v(i)) == NV )        //  NV=not visited
 //  If adjacent node is not visited*/
        Parent(v(i)) = v
       TravelNode (v(i))
//  Repeat process on all adjacent nodes
     End if
     End if
   End for
```

4. Simulation analysis

In this section, several simulation results have been provided to evaluate the performance benefits of EBFS. For this purpose, MATLAB has been used to compare the results of conventional BFS approach (IBFS) with proposed Enriched BFS method. Our simulation environment consists of 100 sensor nodes randomly deployed in a field of 100 x100 m. All the nodes are identical with transmission range set to 25m. The Sink is situated at the upper right corner of the field. Table 1 shows the simulation parameters.

Table 1. Simulation parameters.

Parameter	Value
Network Area	100x100m
Number of nodes (n)	100
Sink node	(97,100)
Transmission Energy	50*0.000000001J
Receiving Energy	50*0.000000001J
Forwarding Energy	10*0.000000001J
Topology	Random
Energy of nodes	Fixed (Heterogeneous)
Packet Size	2000
Sensing Range	20m

The proposed and the existing approach are compared on energy consumption pattern .In this, x axis represents rounds and y axis represents energy consumed in the network. As shown in the figure 2, initially nodes are having maximum energy but with each communication round, some energy are consumed by each participating node. After 200 rounds, the node starts to die. EBFS shows significant improvement over IBFS approach across rounds. As nodes start to die in IBFS, the link distance to form connected path between the nodes will increase, which doubles the energy factor whereas EBFS shows balanced energy consumption since alternate nodes are selected having less distance for data transfer.

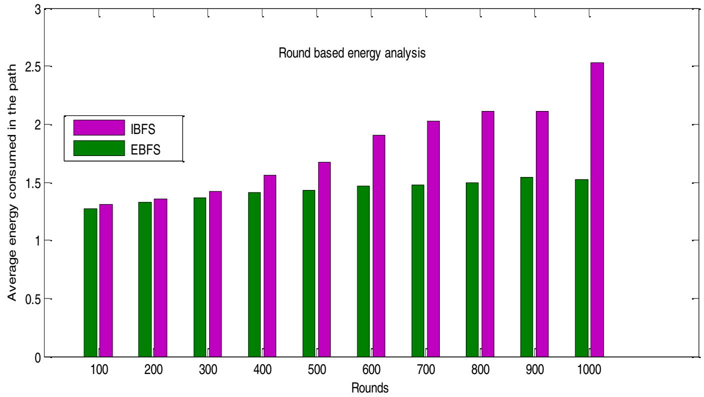

Fig. 2. Energy analysis.

IBFS increases link distance between the participating active nodes with time. As nodes began to lose their energies during data transfer IBFS always increases link distance to form connected path with left over nodes but EBFS searches for next closest neighbor to generate a new path. The path length in EBFS varies with the next node selection as shown in figure 3.

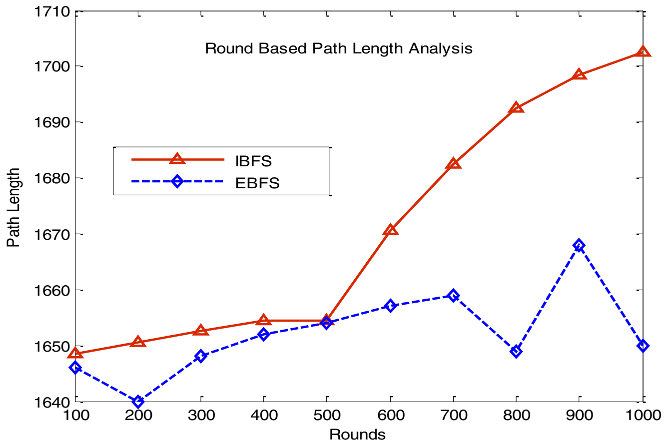

Fig.3. Path length analysis.

Network lifetime comparison of proposed and existing approach is shown in figure 4. Lifetime of EBFS is enhanced by 37% as compared to IBFS since the death of first node is delayed in EBFS. Selection of the node is done on the basis of energy and distance parameter whereas in IBFS no weightage is given to node's residual energy and selection is purely based on distance criteria Thus method adopted for selection of next node in EBFS is better when compared to IBFS.

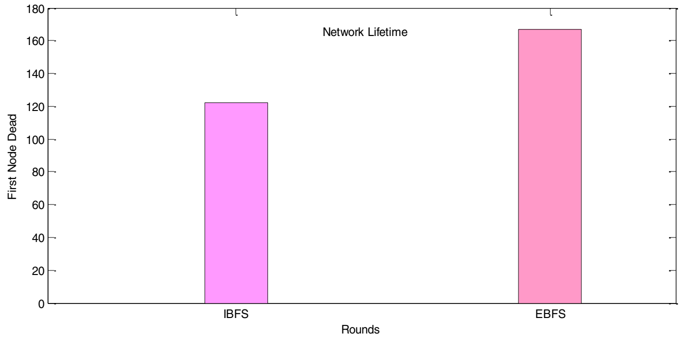

Fig. 4. Network lifetime.

5. Conclusion

In this paper, an adaptive Enriched BFS based fault tolerant approach is proposed in a level based network. Nodes for path selection are selected on the basis of selection value metric for enhancing lifetime of the network. It is a reliable route discovery approach that finds alternate nodes to avoid link failure from source to destination. The obtained results clearly show the improved network reliability and energy using EBFS as compared to IBFS.

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