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Energy Efficient Rule based intelligent routing using Fitness Functions in Wireless Sensor Networks

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Abstract*: Wireless Sensor Networks (WSNs) is a distributed collection of tiny wireless nodes which forms an ad hoc network dynamically to sense the natural phenomenon and sent it to the control station. Due to the resource constrained nature of WSN, maximizing the nodes life time is main and challenging issue. In this paper, Fitness Function based Routing Protocol (FFBRP) is proposed which provides the optimal routing to increase the life time of nodes in a network. The proposed protocol selects the fitness functions based on the important routing parameters like nodes energy consumption, nodes life time, packet Delivery ratio of nodes, distance between nodes, end to end delay of nodes and routing overhead of nodes. Based on the combination of selected fitness function parameters, the intelligent rules are generated and the optimal routes are discovered to perform energy efficient effective routing in WSN. By doing so, the proposed protocol provides better performance in terms of network life time and has better Quality of Service (QoS) than other existing techniques. The implementation of the proposed scheme is carried out using Network Simulator (NS2) with mannasim framework. Simulation results justifies that, proposed protocol outperforms the existing techniques and has better Packet Delivery Ratio, throughput , network life time, energy consumption, end to end delay and routing overhead .

***Keywords* : Wireless Sensor Network, fitness function, energy optimization, life time, efficient routing**

I. INTRODUCTION

WSNs is a distributed collection of tiny nodes which are used to sense the events in deployed environment and transmit the sensed information [1] to Base Station (BS) or Control station for the further processing. The nodes in WSN are self-organizing and can establish the ad hoc network connection on the fly, regardless of how many number of nodes that are malfunctioned in the network. Another important feature of WSN is in network processing.

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In network processing is a technique, where all the nodes in the network collaborate and transmit the sensed data using multi hop communication using effective routing technique in order to[2] [3] conserve the nodes energy. In WSN, energy efficient routing is an important and challenging issue to be addressed to enhance the life time of the nodes in WSN. Since nodes of WSN are resource constrained devices, if the energy spent during the routing is not taken care, the life and the performance of the network decreases and finally sensor nodes will not perform intended services. Therefore, energy efficient routing protocol is needed to prolong the network connectivity and extend the life time of the network. The main aim of energy efficient routing protocol is to optimize [4][5] the spend energy of nodes during routing operation. Most of the energy efficient routing protocols forward the routing packets to the nodes which have high residual energy. From the literature, there are various routing protocols that have been proposed to perform energy efficient effective routing [10] [17] in WSN. In most of the existing routing protocols, some part of the energy is wasted on discovering the optimal routes between source node and destination nodes and another part of energy is wasted on flooding of control packets and data packets. Motivated from all these observations, in this paper an energy efficient intelligent rules based routing using fitness function is proposed which employs fitness functions to optimize the energy during routing. The proposed protocol selects the fitness functions based on the important routing parameters like nodes energy consumption, nodes life time, packet Delivery ratio of nodes, distance between nodes, end to end delay of nodes and routing overhead of nodes. Based on the combination of selected fitness function parameters, the intelligent rules are generated and from them. Based on the rules, the optimal routes are discovered to perform energy efficient effective routing in WSN.

II. LITERATURE SURVEY

In WSN, energy efficient routing is an important and main challenge issue to be addressed. Energy efficient and effective routing can be achieved by selecting the more relevant effective fitness functions [20] and generates the effective intelligent rules to discover the optimal routing path between source nodes and destination nodes. The main aim of the fitness function is to figure out most important parameters for optimization in energy and effectiveness in routing in WSN.

There are many energy efficient routing protocols that have been proposed in literature. Among them Ad hoc On demand Multi path routing protocol (AOMR-LM) [23] is proposed to provide energy efficient multi path routing to maximizes the nodes life time during routing operation. n this protocol, the nodes residual energy is used to calculate their energy level. The advantage of this protocol is that , it improves the life time of the network by forwarding the routing packets to the nodes which have high residual energy.

Manickavelu et al has proposed [24] a protocol, which focuses on route discovery process. In this protocol, a Particle Based Swarm Optimization (PSO) based life time prediction algorithm is proposed, that is used to predict the route nodes life time and bandwidth that are required for routing of packets. Based on the above prediction, the fuzzy based rules are formed to discover the optimal route to reach their neighbors. The advantages of this protocol are that it minimizes the packet loss and communication overhead. Sharma et al [25] has proposed Received Signal Strength Identifier (RSSI) based energy efficient protocol to identify the nodes energy status. In this scheme, the Link Failure Perdition (LEP) algorithm is used to get link layer feedback and to update the active nodes. The advantages of this protocol are it reduces the energy consumption and decreases end to end delay. Santhosh kumar SVN [22] et al proposed a protocol by name Secured – Selective Design Relay Inquiry Protocol (S-SEL DRIP) which provides the efficient data dissemination in WSN by using energy efficient rule based routing. The efficient rules are formed based on the nodes residual energy and hop distance of the nodes between their neighbors. The advantages of this protocol are that it improves the network life time and increases the dissemination ratio.

Logaambigai et al has proposed a protocol namely Fuzzy Logic Based Unequal Clustering (FBUC) [8] to perform energy efficient routing in WSN. They use mamdami fuzzy triangular membership function, which is used for efficient generation of fuzzy rules for routing. The advantages of this protocol are that it reduces the time delay and maximizes the network life time. Selvi M et al has proposed energy efficient routing protocol which is based on fuzzy temporal logic for performing energy[16] efficient routing in WSN. The advantages of this protocol are it increases the packet delivery ratio and decreases the end to end delay. Selvi et al proposed a protocol namely Delay Constrained Energy efficient multi hop routing Algorithm (DCEMRA) [21] to perform energy efficient routing in WSN. This scheme introduces the delay constrained based reliable routing without increasing end to end delay. The advantages of this approach are it maximizes the life time of the network and have better throughput, energy efficiency, link quality and scaliblity. Selvi M et al proposed an intelligent agent [15] based routing algorithm for energy efficient routing in WSN. In this protocol, they make use of intelligent agents that are used to make decisions during route discovery process. The advantages of this scheme are, it has better energy consumption and reduces end to end delay during routing. From the literature, many energy efficient clustering based routing protocols are proposed [12] [19]. Among them, kulothangan et al proposed adaptive fault tolerant routing protocol [7] for energy efficient routing in WSN with error reporting. The advantages of this protocol are it provides best path selection during routing and extends the nodes life time. Men Yoo et al proposed an energy and delay minimization [9] cluster head based routing protocol. The advantages of this protocol are that it provides better routing overhead and conserves the nodes energy during routing. Tomoya Enokidio[19] et al has proposed a routing protocol which employs extended delay based algorithm to minimize end to end delay and response time during routing process. Mohamed [11] et al proposed an energy efficient adaptive fuzzy clustering protocol for energy efficient routing in WSN. In this protocol, it uses fuzzy C-means algorithm to discover the optimal route for energy efficient routing in WSN. Ru Huang et al has proposed an energy efficient effective routing [13] in WSN. Among all the works in the literature, for energy efficient routing in WSN LEACH and PEGASIS [18] are the state of art protocols for energy efficient routing in WSN. The observation from the literature survey is that most of the existing routing protocols fail to provide life time maximization of nodes and provide better Quality of Service (QoS) with reliability in data delivery during routing. Hence, there is need to design a novel protocol, which provides energy efficient routing with effectiveness in QoS during routing in WSN.

III. SYSTEM AND ENERGY MODEL

The following assumptions are made for designing the Fitness Function Based Routing Protocol (FFBRP)

1. Base Station (BS) is not resource constrained device it is trustworthy and cannot be compromised.BS
2. N number of sensor nodes is deployed randomly in 2D plain.
3. All the deployed sensor nodes are static in nature
4. After the deployment, the transmission range of each sensor nodes can be adjusted based on the position of its neighbor nodes.
5. All the deployed sensor nodes have same initial energy of 100J
6. The energy consumption by the sensor nodes is not uniform.
7. Based on Received Signal Strength identifier (RSSI), the distance between deployed sensor nodes are calculated.
8. Each sensor nodes are intelligent enough to follow rules based routing and select the optimal routing path based on generated intelligent rules.

IV. FITNESS FUNCTION BASED ROUTING PROTOCOL

A novel light weight protocol by name Fitness Function Based Routing Protocol (FFBRP) has been proposed to parameters like nodes energy consumption, nodes life time, packet Delivery ratio of nodes, distance between nodes, provide energy efficient optimal routing in WSN. The proposed protocol selects the fitness functions based on the important routing end to end delay of nodes and routing overhead of nodes. Based on the combination of selected fitness function parameters, the intelligent rules are generated and from them the optimal routes are discovered to perform energy efficient effective routing in WSN.

A. Fitness Function based Intelligent Rules Generation Phase

In fitness function based intelligent rules generation phase,

the intelligent rules are generated from the selected fitness function parameters. The selected fitness function parameters are nodes energy consumption, nodes life time, packet delivery ratio, nodes distance, end to end delay and routing overhead.

In the proposed protocol, the combinations of most relevant fitness function parameters are chosen and intelligent rules are generated from those selected parameters. The procedures for generating intelligent rules base are explained as follows.

Proposed Intelligent Rule base 1 :

Input : Node energy consumption, node life time
Output : Intelligent rules for discovering path for optimal routing
1. Base Station (BS) selects the source nodes and destination nodes to initialize the routing process.
2. For all destination nodes, source nodes initialize the route discovery process by using beacon message to detect the active nodes in a route and gets update on nodes energy consumption and nodes life time.
End for
3. For all paths present in route R_i between source nodes and destination nodes.
Do
4. BS calculates the nodes energy consumption using the equation (3)
Nodes energy consumption =
$\sum_{i=1}^{n} Intial\ enery - Current\ energy$
(3)
5. BS calculate the node life time by using the equation (4)
Nodes life time = $\sum_{i=1}^{n} energy\ (i) = 0$
(4)
End for
6. Based on above calculation, BS categorizes nodes energy consumption and nodes network life time as low and high
7. For all the possible paths present in route R_i between source and destination nodes
Check
7 .If (Nodes energy consumption > = low && node life time = high)
Then
Select the path for communication as optimal route 1
Else if (node energy consumption > = low && node life time > = low)
Then
Select the path for communication as optimal route 2
Else if ((node energy consumption > = high && node life time > = low)
Then
Select the path for communication as optimal route 3
Else if ((node energy consumption > = high && node life time > = low)
Then
Select the path for communication as optimal route 4
8. BS selects the optimal route based on acceding order to route the packets to the destination nodes.

Proposed Intelligent Rule base 2 :

Input : Node energy consumption, packet delivery ratio
Output : Intelligent rules for discovering path for optimal routing
1. Base Station (BS) selects the source nodes and destination nodes to initialize the routing process.
2. For all destination nodes, source nodes initialize the route discovery process by using beacon message to detect the active nodes in a route and gets the update on nodes energy and packet delivery ratio
End for
3. For all paths present in route Ri between source nodes and destination nodes.
Do
4. BS calculates the nodes energy consumption using the equation (3)
5. BS calculate the packet delivery ratio by using the equation (5)
PDR = (number of packets recieved)/(number of packets transmitted)*100 (5)
End for
6. Based on above calculation, categorize nodes energy consumption and packet delivery ratio as low and high
7. For all the possible paths present in route Ri between source and destination nodes
Check
7 .If (Nodes energy consumption > = low && PDR = high)
Then
Select the path for communication as optimal route 1
Else if (node energy consumption > = low && PDR > = low)
Then
Select the path for communication as optimal route 2
Else if ((node energy consumption > = high && PDR > = high)
Then
Select the path for communication as optimal route 3
Else if ((node energy consumption > = high && PDR > = low)
Then
Select the path for communication as optimal route 4
8. BS selects the optimal route based on acceding order to route the packets to the destination nodes

Proposed Intelligent Rule base 3 :

Input : Node energy consumption, hop distance
Output : Intelligent rules for discovering path for optimal routing
1. Base Station (BS) selects the source nodes and destination nodes to initialize the routing process.
2. For all destination nodes, source nodes initialize the route discovery process by using beacon message to detect the active nodes in a route and gets the update on nodes energy and hop distance.
End for
3. For all paths present in route Ri between source nodes and destination nodes.
Do
4. BS calculates the nodes energy consumption using the equation (3)
5. BS calculate the hop distance of the nodes by using the equation (6)
Hop distance = (Node(i) . X – BS . X)2 + (node(i) . Y – BS.Y)2
(6)
End for

6. Based on above calculation, categorize nodes energy consumption as high and low and hop distance as near and far
7. For all the possible paths present in route Ri between source and destination nodes
Check
7 .If (Nodes energy consumption > = low && hop distance = near)
Then
Select the path for communication as optimal route 1
Else if (node energy consumption > = low && hop distance > = far
Then
Select the path for communication as optimal route 2
Else if ((node energy consumption > = high && hop distance > = near)
Then
Select the path for communication as optimal route 3
Else if ((node energy consumption > = high && PDR > = far)
Then
Select the path for communication as optimal route 4
8. BS selects the optimal route based on acceding order to route the packets to the destination nodes.

Proposed Intelligent Rule base 4 :

Input : Node energy consumption, routing overhead
Output : Intelligent rules for discovering path for optimal routing
1. Base Station (BS) selects the source nodes and destination nodes to initialize the routing process.
2. For all destination nodes, source nodes initialize the route discovery process by using beacon message to detect the active nodes in a route and get the update on nodes energy and routing overhead.
End for
3. For all paths present in route Ri between source nodes and destination nodes.
Do
4. BS calculates the nodes energy consumption using the equation (3)
5. BS calculate the routing overhead of the nodes by using the equation (7)
Routing overhead = (Number of transmitted routing packets)/(number of routing packets+number of data packets sent*100) (7)
End for
6. Based on above calculation, categorize nodes energy consumption and routing overhead as high and low
7. For all the possible paths present in route Ri between source and destination nodes
Check
7 .If (Nodes energy consumption > = low && routing overhead = low)
Then
Select the path for communication as optimal route 1
Else if (node energy consumption > = low && routing overhead > = high)
Then
Select the path for communication as optimal route 2
Else if ((node energy consumption > = high && routing overhead > = low)
Then
Select the path for communication as optimal route 3
Else if ((node energy consumption > = high && routing overhead > = high)
Then
Select the path for communication as optimal route 4
8. BS selects the optimal route based on acceding order to route the packets to the destination nodes.

Proposed Intelligent Rule base 5 :

Input : Node energy consumption, routing overhead
Output : Intelligent rules for discovering path for optimal routing
1. Base Station (BS) selects the source nodes and destination nodes to initialize the routing process.
2. For all destination nodes, source nodes initialize the route discovery process by using beacon message to detect the active nodes in a route and get the update on nodes network life time and routing overhead.
End for
3. For all paths present in route Ri between source nodes and destination nodes.
Do
4. BS calculates the nodes energy life time using the equation (4)
5. BS calculate the routing overhead of the nodes by using the equation (7)
End for
6. Based on above calculation, categorize nodes life time and routing overhead as high and low
7. For all the possible paths present in route Ri between source and destination nodes
Check
7 .If (Node life time > = high && routing overhead = low)
Then
Select the path for communication as optimal route 1
Else if (node life time > = high && routing overhead > = high)
Then
Select the path for communication as optimal route 2
Else if ((node life time > = low && routing overhead > = low)
Then
Select the path for communication as optimal route 3
Else if ((node life time > = low && routing overhead > = high)
Then
Select the path for communication as optimal route 4
8. BS selects the optimal route based on acceding order to route the packets to the destination nodes.
Input : end to end delay and hop distance
Output : Intelligent rules for discovering path for optimal routing
1. Base Station (BS) selects the source nodes and destination nodes to initialize the routing process.
2. For all destination nodes, source nodes initialize the route discovery process by using beacon message to detect the active nodes in a route and get the update on end to end delay and hop distance.
End for
3. For all paths present in route Ri between source nodes and destination nodes.

Do
4. BS calculates the end to end delay using the equation (8)
End to end delay ⟦ Ri-Si)/n ⟧ (8)

5. BS calculate the hop distance of the nodes by using the equation (6)
End for
6. Based on above calculation, categorize end to end delay as high and low and hop distance as near and far
7. For all the possible paths present in route Ri between source and destination nodes
Check
7 .If (end to end delay > = low && hop distance > = near)
Then
Select the path for communication as optimal route 1
Else if (end to end delay > = low && hop distance > = far)
Then
Select the path for communication as optimal route 2
Else if ((end to end delay > = high && routing overhead > = near)
Then
Select the path for communication as optimal route 3
Else if ((end to end delay > = high && hop distance > = far)
Then
Select the path for communication as optimal route 4
8. BS selects the optimal route based on acceding order to route the packets to the destination nodes.
In the proposed protocol, the six set of intelligent rules are generated to provide the energy efficient optimal routing in WSN. Depending upon the situation, the BS selects the optimal route from above generated rules set and provides energy optimal efficient routing in WSN.

V. EXPERIMENTAL SETUP AND SIMULATION PARAMETERS

The feasibility of proposed protocol is implemented by using network simulator using mannasim framework. For efficient evaluation of proposed protocol, we consider simulation area as 1000m * 1000m. Table 1 gives simulation parameters of the proposed system.

Table 1. Simulation Parameters

Network simulator	NS2 version (2.33) Mannasim framework
Simulation area	1000m*1000m
Density of nodes	150-500
Transmission range	20-30m
Physical layer	Phy/wirelessphy-mica2
Radio Propagation model	Two ray model
Environment	Urban
Node initial energy	100J
Transmission power (tx)	1.2J per packet at maximum power
Receiving power (rx)	0.36J per packet at maximum power
Simulation duration	70 minutes
No of trails	100
Packet size	50 - 500 bytes

VI. RESULTS AND DISCUSSIONS

The performance of FFBRP is evaluated by using the performance metrics like node energy consumption, node life time, packet delivery ratio.

A. Node Energy Consumption

From our simulation, we observe that average energy spent by the nodes for varying packet size varies from 3.8J to 11.9J. Figure 1 gives the node energy consumption with varying packet size for FFBRP, DCEMRA and FBUC.

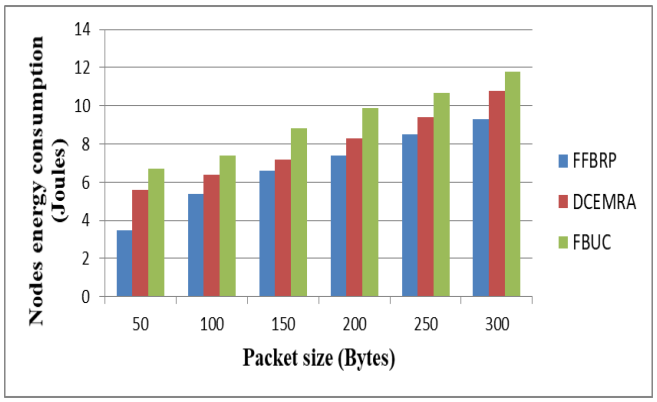

Figure 1 Node Energy consumption

From the graph, we can observe that the average energy consumption of the nodes in proposed FFBRP is better than other existing protocols because, FFBRP employs fitness function based intelligent rule based routing to discover the optimal routing path to perform energy efficient routing. By doing so, FFBRP reduces the energy spend on route discovery process and controls the flooding. Whereas other existing protocols consumes more energy and floods both routing packets and data packets to nodes of WSN. Hence, the proposed FFBRP has better average nodes energy consumption compared with other existing routing protocols.

B. Node Life time

Figure 2 gives the node life time with varying packet size for FFBRP, DCEMRA and FBUC. From the graph, it can be observed that the proposed FFBRP increases the node life time when it compared with other existing protocols.

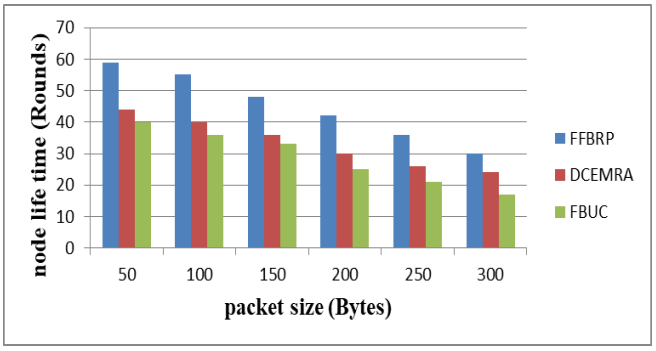

Figure 2 Node life time

FFBRP selects the efficient fitness function parameters and generate the intelligent rules to discover the optimal path. By doing so, the proposed protocol discover the optimal route and reduce overhead in the routing process. Proposed protocol there by reduces the flooding of both routing packets and data packets. Hence, the it has the better life time compared with other existing protocols. The proposed protocol outperforms the rest and has better node life time even at maximum packet size of 300 bytes.

C. Packet delivery ratio

Figure 3 gives the comparison of FFBRP with other existing protocols in terms of packet delivery ratio. Packet delivery ratio is measured with varying packet sizes.

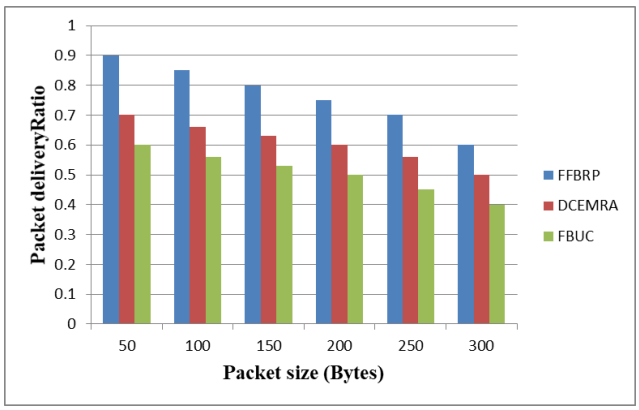

Figure 3 Packet delivery ratio

From the graph, it is clear that packet delivery ratio of FFBRP is better than other existing protocols because FFBRP uses fitness function based intelligent rules to discover the optimal path to perform energy efficient routing. FFBRP outperforms the rest because the number of packets drop is considerably less when it compared with other existing protocols.

VII. Conclusion and Future Work

In this paper, a Fitness Function based Routing Protocol (FFBRP) is proposed for discovering the best optimal path among all the possible routes. The proposed protocol identifies the best optimal path by using fitness functions and generates the intelligent rules from those fitness functions to perform energy efficient reliable routing in WSN. The proposed protocol is implemented using NS2 simulators and evaluated with the performance metrics like node energy consumption, node life time, end to end delay, throughput and routing overhead with other existing protocols like DCEMRA, FBUC. Simulation results justify that proposed protocol outperforms rest in each and every performance metrics and exhibits better performance in terms of life time and QoS than other existing protocols. Future work of the proposed system can be done by enhancing this protocol for mobile nodes.

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