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Energy Conservative Opportunistic Routing(ECOR) in Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) are large collection of sensing nodes with processing and communication capabilities. The major issue in sensor network is limited battery power. Batteries cannot be recharged or replaced once deployed. Research on wireless sensor network has recently received much attention as they offer an advantage of monitoring various kinds of environment by sensing physical phenomenon. Recently Opportunistic Routing has emerged as a novel routing scheme that effectively improves the capacity of a multi hop wireless sensor networks. It takes the advantage of broadcast nature of wireless communication. In contrast to traditional unicast routing, where the next hop forwarder is formed before the transmission of data. Opportunistic Routing chooses its forwarder list dynamically with poor energy management. The performance of Opportunistic Routing is enhanced with energy conservation algorithms and higher throughput and thus network lifetime is increased.

Keywords: Energy Conservation Protocol, Opportunistic Routing, Wireless Sensor Network.

I. INTRODUCTION

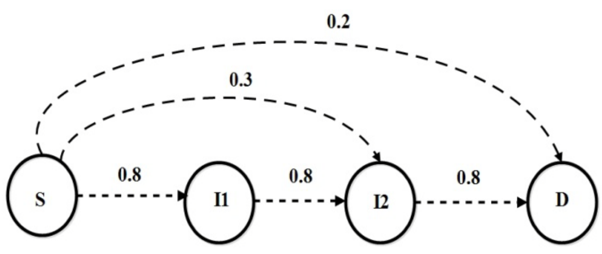
Wireless Sensor Networks (WSNs) consist of spatially distributed sensor nodes to monitor environmental conditions. It is used for various applications such as healthcare, habitat monitoring, home automation and traffic control. Sensor nodes are activated by limited energy battery and hence energy consumption is taken into account during network operations.

Traditional routing protocol, selects shortest path from the source to destination and it does not use the benefit of broadcast nature of the sensor nodes. Opportunistic Routing is more popular in the field of WSN since it increases the performance of mobile wireless networks. Opportunistic routing takes advantage of broadcast nature of the sensor nodes and allows any nodes that overhear the transmission to participate in forwarding the packet. In Opportunistic Routing, set of nodes is selected as the potential forwarder and referred as candidate set.

Opportunistic routing depends on the network conditions and link quality. While source node transmits a packet which is heard by all nodes in the communication range and nodes tend to transmit the same packet towards the destination. Extensible Opportunistic Routing (ExOR) follows scheduler to transmit the packet. Here, at any point of time only one forwarder node transmits a packets Each packet dynamically selects the route to reach the destination according to the strength of the wireless links. Node selects potential forwarders from the candidate list. After selecting the potential forwarder it coordinates with the other nodes and transmits the packet. This process is referred as candidate coordination. In case of failure of data transmission it is managed by broadcast advantage of WSN; data can be transmitted from the other node in the forwarder list and thus Opportunistic Routing reduces the retransmission. Further the packet transmission is managed by virtual link as it has higher delivery probability than any other link present in the path.

Recent studies show that traditional routing faces difficulties in coping with unreliable and unpredictable wireless medium. Opportunistic routing exploits the broadcast nature of the wireless medium and does not commit to a particular route before data transmission. Instead, the sender broadcasts its data; among the nodes that hear the transmission, the node closest to the destination is selected to forward the data.

Figure 1: Example of Opportunistic Routing



Assume a simple network with series of nodes S, I_1, I_2 and D as shown in Figure.1.There exist different routes available from the source node S to destination node D. The probability of successful transmission is reduced as distance between two nodes increases. Time-division-multiplexing TDM is applied in this simple network. In one time slot, node S broadcasts a packet to the whole network, and nodes I_1, I_2 and D overhear it simultaneously. The nature of broadcasting in the wireless network improves the transmission efficiency in two ways.

Firstly, when node S transmits the packet, nodes I_1, I_2 and D

receives it successfully. They can necessarily store and forward the packet in an opportunistic way, i.e., node A may send directly to node D in one hop rather than send each packet in a sequential time slots from node S to nodes I_1, I_2 and D separately. The other aspect is that if node S tries to send directly to node D, however, node D may not receive the packet correctly due to low probability of successful transmission is resolved through broadcast advantage. During the transmission from node S to node D, the nodeI_1, a neighboring node to node S, may simultaneously over hear the packet, and through the one-hop transmission from node S to I_1 node can achieve successful reception with a higher probability. Thus, the node I_1forwards the packet to node D in the next time slot, since a shorter distance from node I_1 to node D as it results in a higher successful transmission probability.

The ECOR aims at finding the optimal path from a source to a destination by selecting and prioritizing the forwarding list (list of forwarder nodes) to minimize the total energy consumed by considering hearing cost, transmission cost and forwarding cost to the sink node. It computes the expected cost to each node from a source, to select the forwarding nodes which in turn form an optimal forwarding list.

The rest of the paper is organized as Related Work and Background work are discussed in Section 2 and Section 3 respectively. System and Mathematical Model is explained in Section 4. Algorithm is developed in Section 5. Simulation and Performance Parameters are analyzed in section 6. Conclusions are presented in Section 7.

II. RELATED WORK

The major issue related to wireless sensor network is increasing the network lifetime, Yick *et al*., [1] have surveyed on energy issues related to internal platform and underlying operating system, communication protocol stack, network services and provisioning. Sarika *et al*., [2] have analyzed the possible energy efficient protocols related to data aggregation and energy loss in the network. While selecting the cluster head among the nodes near the base station. Routing protocol [2] minimizes total energy spent in the network by reducing the number of data transmissions and increasing the number of alive nodes over time or balancing the energy dissipation among the sensor nodes.

As the current major field of WSN application is Internet-of-Things [IOT], Machado *et al*.,, [3] have proposed Routing protocol based on Energy and Link quality [REL]. REL is implemented on smaller test bed to analyze the link quality based on load balancing, packet loss and energy consumption at nodes. REL is compared with existing protocols like Ad-hoc on Demand Distance Vector[AODV] and Link Quality-Based Lexical routing [LABILE]. Comparison concludes that REL protocol is more reliable for small scale networks than larger networks.

Lee *et al*., [4] developed an Energy Efficient Co-operative method for a Commercial[EECC] sensor networks. EECC select appropriate relay nodes within a cluster. The relay node helps CH and cluster nodes to communicate cooperatively. Relay node enables with less number of transmissions over the CH and helps in increasing the network lifetime. Niu *et al*., [5] developed an Reliable Reactive Routing Enhancement (R3E) protocol to handle the channel fading issue. R3E uses bias-back of scheme that discovers robust path to communicate with the neighbors to cooperate while forwarding the data.R3E in combination with AODV improves the performance by increasing the packet delivery ratio.

For selecting better relay node many researchers used opportunistic routing. Similarly Juan *et al*., [6] designed an Energy Saving via Opportunistic Routing (ENS-OR) algorithm. ENS-OR deals with the issue of power cost during data transmission over relay node. To increase the network lifetime Juan used 1-D queue network for creating forwarder table with sensor node location as entries, using this opportunistic routing is implemented. ENS-OR fails to address the energy consumption when nodes are in sleep mode.

Creating forwarder table is a challenge in opportunistic routing. To handle this issue, Daibo *et al*., [7] proposed a Duplicate Detectable Opportunistic Forwarding (DOF) scheme to eliminate duplication of packets. DOF enables sender to obtain the information of all potential forwarders via a slotted acknowledgement scheme. During this period packets has to wait until its slot to come, otherwise it reduces the duplication ratio and enhances the lifetime.

Zhu *et al*., [8] developed a tree based cluster protocol to avoid hotspot problem. The weight of the graph is calculated using residual energy at the node, distance to the BS and local node density. This protocol use rendezvous and sub-rendezvous point for communication between the root and the leaf nodes. The results are compared with SPT-DGA protocol and showed a better increase in network lifetime.

Euhana *et al*., [9] have developed an Opportunistic Routing scheme for WSN (ORW). ORW uses Expected number of Duty–Cycled wakeup (EDC) enables successful delivery of packets from source to destination.ORW reduces duty cycle on an average of 50% and reduces 30% of delay when being compared with the state-of-art protocols. EDC uses any-cast routing metric to reflect. The multi-path nature of opportunistic routing.EDC failed when multiple forwarders began to communicate concurrently.

This high wakeup rate demands more co-ordinations and increases the risk of duplication and increase in forwarding cost of each packet. The EDC design is not suitable for mesh based routing and bulk packet transfer. Yousaf *et al*., [10] proposed a Heuristic Approach to select Opportunistic Routing Forwarders (HASORF) to increase the throughput in wireless sensor network. HASORF is an bio inspired routing protocol and finds least number of hops to deliver the data destination. Through performance analysis HASORF achieves the best throughput as it transmits more number of bytes in less time period. HASORF failed to address the NP-hard problem of the given network.

Long *et al*., [11] analyzed a Geographical Opportunistic Routing (GOR) for providing better end-to-end reliable communication and reduced delay in the network.QOS enable GOR (EQGOR) priorities the forwarding candidate set by considering time complexity, latency and cost of energy required. EQGOR shows better Performance with respect to lowtime complexity and increase in network lifetime.

Jungmin *et al*., [12] has proposed an Opportunistic Routing within network aggregation to handle asynchronous Duty-cycle (ORD) in the Medium Access Control (MAC) protocol. ORD calculates multiple candidate forwarders and their random wakeup times that helps packet to wait at the intermediate node and executes data aggregation methods to reduce the number of transmission. Packets at node on forwarder list stores the status of network and the updates the feedback about the residual energy levels and maximum hop distance to control Packet Hold Time (PHT) so that the network lifetime is maximized.

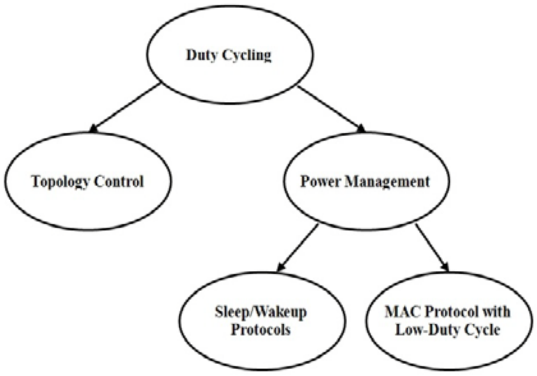


***Figure 2**: Duty Cycle*

Yamuna *et al*., [13] developed model for a Multi Hop Optical Position Based Opportunistic Routing [MOOR] to reduce the energy consumption on multiple hop network. MOOR chooses the shortest between source and destination. The MOOR chooses next node from the forwarding table which poses set of neighbor node of the source node based on distance from itself and the target node. MOOR protocol reduces the end-to-end delay between source and destination pairs.

Manjula *et al*., [13] developed an multi hop route discovering using opportunistic routing for WSN [EESOR] to reduce the size of forwarder list. EESOR uses the path followed by acknowledgment packet in a opportunistic way and applies the sorting technique over the forwarder list. EESOR maximizes end-to-end delay and not considered the link error problem.

Mandar *et al*., [14] proved Connectivity Based Energy Efficient Opportunistic Routing Protocol (CBEEOR) to preserve the connection between the nodes in Mobile Wireless Sensor Network (MWSN). CBEEOR is adaptable to node mobility and topology changes. CBEEOR used algebraic connectivity to create prioritized forwarder list for selecting the relay node for data forwarding. A back-off time mechanism is also used to seek co-operation of neighborhood nodes for forwarding the packets in case node in the path is dead.

Amrutkar et al., [15] developed central and distributed algorithm called Energy Efficient Local Opportunistic Routing (ELOR) protocol. ELOR can be implemented for large scale network with needing global information for energy based routing. But ELOR fails to use the hearing cost of every node. Mayank et al., [16] developed a Middle Position Dynamic Energy Opportunistic Routing (MDOR) to address the near node problem towards sink node. The nodes nearer to destination consumes higher energy than the nodes away from the destination. MDOR helps in reducing the transmission energy consumption and increases the network lifetime. Unnecessary transmission of hello packets can reduced for the further increase in lifetime of the network.

III. BACKGROUND

Industrial applications such as factory automation, process control, quality control or smart energy can greatly benefit from or even impose the use of wireless/mobile communication capabilities. Requirement of continuous monitoring and controlling of everything tend to ubiquitous with the distributed and embedded system in their physical environment.

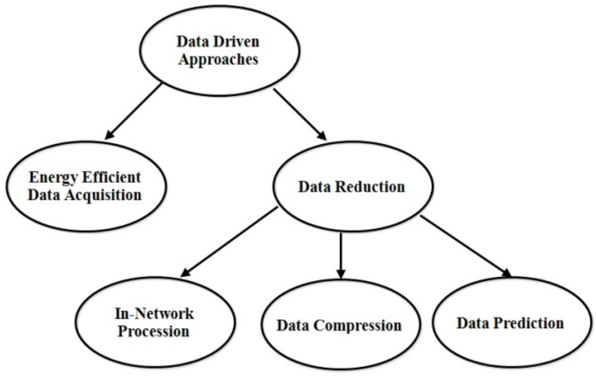


***Figure 3**: Data Driven Approaches*

A. *Opportunistic Routing*

In a large scale WSN with many battery-powered sensor nodes deployed in a wide area, data is usually delivered by multi-hop along a route from the source node to destination node. Therefore energy efficiency and communication delay are two fundamental metrics in evaluating the sensor network communication protocols. Multi-hop routing algorithms of wireless networks resemble the wired networks.

In this approach, the best route based on the link quality is first chosen from the source to the destination. The unicast-based approach does not take the advantage of broadcast nature of wireless communication and results in high routing cost and energy consumption. As wireless links are inherently lossy, transmission failures or retransmissions are pervasive, resulting in significant energy wastage and communication quality degradation. Recently, opportunistic routing has emerged as a novel routing scheme that can effectively improve the capacity of multi-hop wireless networks by taking advantage of broadcast nature of wireless communication.

In contrast to traditional unicast routing where the next-hop forwarder is designated before the data transmission, wherein opportunistic routing defers the decision of forwarder only after the data transmission. Such deferred decision gives a higher opportunities for packet to make progress towards the destination. For an example by traveling through long lossier communication links that the traditional unicast routing avoids such path and reduces the opportunities.

Furthermore, opportunistic routing is more robust for node and link failures. However, the existing opportunistic routing schemes, which are designed for wireless workstations. Instead of providing backup routes, opportunistic routing dynamically chooses the next hop for each and every packet. Since the transmission conditions are highly time-varying, a node may estimate the link quality and the best next hop just before the transmission.

Recent study shows that traditional routing faces difficulties in coping with unreliable and unpredictable wireless medium. Motivated by these observations, researchers developed opportunistic routing protocols for wireless mesh networks. Opportunistic routing exploits the broadcast nature of the wireless medium and does not commit to a particular route before the data transmission. Instead, the sender broadcasts its data; among the nodes, the one closest to the destination is selected to forward the data. In this way, opportunistic routing effectively combines multiple weak links into a strong link and takes advantage of broadcast transmissions. Duty Cycle, Data Driven and Mobility Based energy saving approaches are explained below.

B. Taxonomy of Approaches to Energy Saving in WSN

Duty Cycling: Duty cycling as given in Figure. 2 can be achieved through two different and complementary approaches. From one side it is possible to exploit node redundancy, which is typical in sensor networks, and adaptively select only a minimum subset of nodes to remain active for maintaining connectivity. Nodes that are not currently needed for ensuring connectivity goes to sleep mode and this helps in saving energy.

Data Driven Approaches: Data-driven approaches as given in Figure. 3 can be divided according to the problem. Specifically, data-reduction scheme addresses the case of unneeded samples, while energy-efficient data acquisition schemes are mainly aimed at reducing the energy spent by the sensing subsystem. However, some of them can reduce the energy spent for communication as well. In this case, it is worth discussing here one more classification level related to data-reduction schemes, as shown in Figure. 4. All these techniques are aiming at reducing the amount of data to be delivered to the sink node.

Mobility Based Schemes: Mobility helps in reorganizing the networks by removing voids and increases the lifetime of networks. In the case of static sink, nodes closer to the sink forwards the higher number of packets and thus it tends to premature the energy depletion. Wherein, mobile sink it periodically goes to all regions and collect the data and uniform energy is consumed and thus energy consumption at particular nodes are reduced and avoids void problem in the network.

Many approaches proposed in the literature about sensor networks with Mobile Sinks (MS) rely on an Opportunistic Routing formulation which is exploited in order to optimize energy, network lifetime and so on. For example, a model consisting of a MS which can moves to a limited number of locations (sink sites) to visit a given sensor and communicate with it (sensors are supposed to be arranged in a square grid within the sensing area). During visits, the sinkstays at the node location for a period of time. Nodes not in the coverage area of the sink can send messages along multi-hop paths ending at the MS through shortest path routing.

C. Existing Protocols

Extensible Opportunistic Routing (ExOR [17]), allows any node to overhear the transmission and participates in forwarding the packet. The routing path is selected based on the link quality. However, new design paradigm introduces several challenges. One among that challenge is the multiple nodes may hear packets and unnecessarily forwards the same packet.

During the source to destination transmission, Assistant Opportunistic Routing protocol (AsOR) [18] protocol forwards the data stream through a sequence of nodes, which are classified as three different node sets, namely, the frame node, the assistant node and the unselected node, each predetermined route can be divided into several disjoint segments and this uses a very complex mathematical model. The mutual interference between disjoint segments were not considered, which reduces the network throughput.

Opportunistic Routing with Asynchronous Sleep (ORAS) [19] node makes a sender rendezvous with asynchronous sleeping neighbors to ensure the packet received by a potential forwarder. The spatial and temporal diversity of data is exploited to do data transmission. The congestion back off timer of X-MAC caused by waiting for the medium and thus consumes higher energy.

Opportunistic Real Time Routing (ORTR) [20], guarantees delivery of data under time constraints with energy efficiency. In order to satisfy time requirements, an area where real-time data must be delivered is defined with effective transmission power and a relay node. The Assignment of Back off Exponent to choose the best forwarder causes the overhead to the network.

Simple Opportunistic Adaptive Routing protocol (SOAR) [21], effectively supports multiple simultaneous flow of data. It adapts data rate control to determine an appropriate sending rate according to the current network conditions. Timer-based forwarding node selection is need to applied before the data transmission.

IV. SYSTEM AND MATHEMATICAL MODEL

A. Network Model

Consider a wireless sensor network and assume that all wireless nodes have distinctive identities, as $i \in (1,n)$. Communication graph $G=(V,E)$ represents the model of wireless network denoted by a set of vertex '*V*' and '*E*' as a directed link . Each directed link (u,v) has a weight, denoted by w(u,v), which is the minimum transmission power required by node u to send a packet to node *v* successfully. Each link (*u*,*v*) has an error probability, denoted by *e*(*u*,*v*) which is the probability that a transmission over link (*u*,*v*) is not successful.

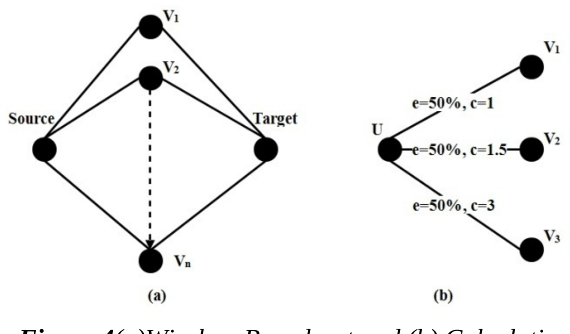


Figure 4*(a)Wireless Broadcast and (b) Calculating the Expected Cost*

The focus of opportunistic routing is as follows: We let $TC_u[Fwd]$ denote the expected cost needed by the node u using opportunistic routing strategy to send a packet to the target node when the forwarder list chosen by *u* is Fwd. For simplicity, we use TC_u to denote the expected cost of node u.

Initially, the expected cost of the target node is set to be 0 and the costs of all other nodes are set to be ∞. Using the similar mechanism of distance vector routing, the calculations of the expect cost for each node will be carried out periodically and every node updates the expected cost and forwarder list periodically. Two methods are used to compute the expected cost and choose the forwarder list. For each wireless node in Adjustable Power Model, the transmission power of each node is fixed and in case of Non-Adjustable Power Model, the transmission power of each node is adjustable.

B. Problem Definition

Wireless Sensor Network is assumed to be a graph $G = (V,E)$, where V = sensor nodes and E=connectivity between sensor nodes. The objectives of the proposed Energy Conservative Opportunistic Routing Protocol (ECOR) is,

- to maximize the energy conservation
- to maximize lifetime of the network
- to increase throughput of the network

C. Mathematical Model

To calculate the Total Communication Cost [TC^c_u] at the node u; we assuming a network with $N = u_1,u_2, ...,u_n$ nodes, and forwarder list [Fwd]with total forwarding cost i.e, [TC^f_i] from node i to its neighboring nodes u_i-1.

To generate the forwarder list, consider a set of sensor nodes as S_i, where S_i denotes list of sensor nodes arranged in ascending order of forwarder cost required to transmit data from S_i to a static target.

To calculate the expected cost at ńode u' from the forwarder list as Fwd^+ in increasing order of expected cost i.e $Fwd^+ = v_1,v_2, ...,v_{|Fwd(u)|}$ where $i<j$, where $TC_{vi} \leq TC_{vj}$.

Step 1: Hearing Cost Calculation

Consider $P_e$as error probability occurred while packet is not received by the receiver node from the source node u.

$$P_e=\prod_{i=1}^{Fwd+} e_{(\mathrm{uvi})} \qquad (1)$$

Next assume P_s as probability of success that a packet sent by node u is received byat least one node in forwarder list Fwd^+, then

$$P_s= 1-P_e \qquad (2)$$

To find hearing cost $TC^h_u(Fwd^+)$ of a node to send a packet to at least one nodein the forwarder list $Fwd+$ is calculated as given below.

$$TC^h_u(Fwd^+) = \qquad (3)$$

Where w is residual energy at the node u and P_s is the correct probability of packet been received by at least one node from the source node u.

Step 2:Forwarding Cost Calculation

Through an optimistic view let us infer that at least one node in the forwarder list received the packet successfully. The expected cost could be slightly lower than the actual cost when multiple nodes from forwarder list could forward the data packet.

Consider $TC^f_u(Fwd^+)$ denote the expected total cost of node u to forward the packet to the target node and to calculate $TC^f_u(Fwd^+)$.We consider prioritized forwarder list $Fwd^+ = v_1,v_2, . . . ,v_{|Fwd+|}$. The probability that node v_1 forwarding a packet is $1–e(u_1,v_1)$ and expected cost at v_1 is TC_{v1}.

Similarly the node v_2 shall forward the packet with probability as $e(u_1,v_1),1-e(u_1,v_1)$ and expected cost TC_{v2}. Basically, node v_2 forwards the packet if it receives any packets and similarly node v_j, (where $0<j<i$) has not received any packets, in such case the total expected cost at node v_i is TC_{uj} is as given below

$$\emptyset= (1-e_{uv1})TC_{v1} +\Sigma_{i=2}^{|Fwd+|}(\pi_{j=1}^{i=1} e_{(\mathrm{uvi})}. (1- e_{(\mathrm{uvi})}). TC_{\mathrm{vi}}) \qquad (4)$$

The total expected cost to forward a packet from any node to the target node S using the constant value obtained by$\emptyset$ isgiven by:

$$TC^f_u(Fwd+) =\emptyset/Pr \qquad (5)$$

The communication cost for obtaining agreement among nodes in effect to the total forwarding cost. Consider the total communication cost as $TC_u(Fwd+)$ from all nodes in the forwarder list in order to reach an agreement on which node will finally transmit the packet using relay nodes. Therefore:

$$TC_u(Fwd+) = TC^f_u(Fwd+)+TC^c_u(Fwd+)+TC^h_u(Fwd+) \quad (6)$$

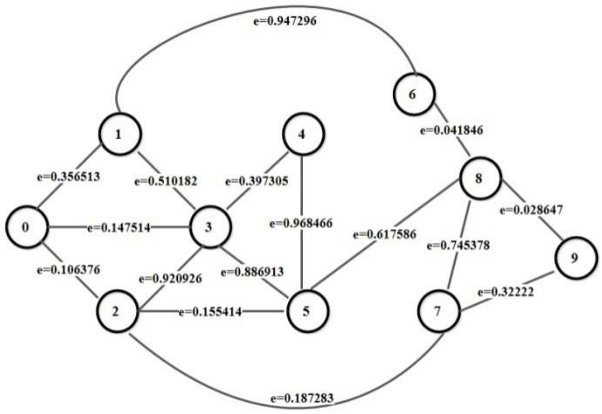


Figure 5.*Example Network Set Up*

Table 1.*Notations*

Notation	Meaning
N	Number of Node
U	Source Node
V	Neighbor of Source Node
Fwd	Unsorted Forwarding List
Fwd+	Sorted Forwarding List
P_e	Error Probability
P_s	Correct Probability
TC^h_u	Hearing Cost of Node u
TC^f_u	Forwarding Cost of Node u
TC^c_u	Communication Cost of Node u
TC_u	Total Communication Cost of Node u
$\emptyset$	Total Forwarding Expected Cost of Node v
ω	Residual Energy of Node u

Equation.6 denotes the total communication cost of node u is the combination of expected cost for sender to successfully transmit a packet to at least one receiver, expected cost that there is one node in the forwarder list and communication cost to reach an agreement on choosing the actual relay node from the forwarder list.

Example for ECOR is shown below. Figure.5 shows all possible routes from a source node to a destination node. Consider 10 sensor nodes, where source node is 0 and destination node is 8, there are total 10 routes available from source to destination. Considering 0 as source node and 9 as destination node there are total8 routes available from source node to destination. Forwarding cost is calculated considering error probability of the link total forwarding cost is calculated for all possible routes from source to destination. The route which is having the least cost is used to forward the packet as shown in Figure.6. Another example with source as node 0 to destination node as 9 is shown in Figure .7.

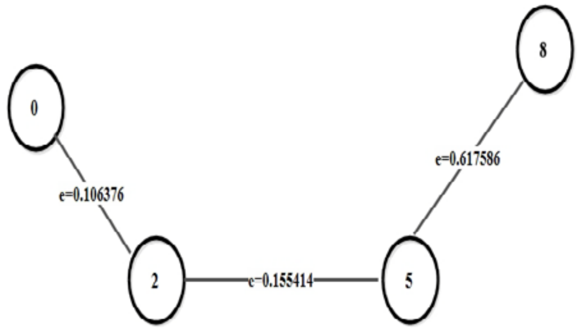


Figure 6.Minimum cost spanning tree for (0,8)

Table 2.*Error Probability Table for node 0 to node 8*

Possible Routes	**Total Fwd Cost (J)**
(0- >1)(1−>3)(3−>4)(4->5)(5−>8)	0.78
(0->1)(1−>3)(3−>5)(5−>8)	1.49
(0->1)(1−>6)(6−>8)	2.14
(0->2)(2−>3)(3−>4)(4−>5)(5−>8)	4.97
(0->2)(2−>3)(3−>5)(5−>8)	2.51
(0->2)(2−>5)(5−>8)	0.49
(0->2)(2−>5)(5−>7)(7−>8)	0.88
(0->2)(2−>7)(7−>8)	0.62
(0->3)(3−>4)(4−>5)(5−>8)	3.71
(0->3)(3−>5)(5−>8)	1.25

V. ENERGY CONSERVATIVE OPPURTUNISTIC ROUTING [ECOR]

Once the sensor nodes are deployed on the sensing region, each sensor node calculates their distance to every other node in the network. After distances are calculated, every node checks for the amount of energy required for communication i.e., $TC^c_u[Fwd+]$ using the residual energy of the node. Later the link error probability between node pair (u,v_i) is calculated. Then by assuming a target node as S, node u determines the total hearing cost, $TC^h_u[Fwd+]$, required to transmit packet for at least one node vi.e. N can hear node u. After assuming that one node v_i has heard the source node u, the node u makes attempt to create a sorted forwarder list of v_i and calculates the expected cost, $TC^f_u[Fwd+]$ to transmit the packet to target S. Finally the ECOR algorithm is given in the table 7, is executed to calculate the total communication cost, $TC_u[Fwd+]$, per packet transmission from source u to destination S.

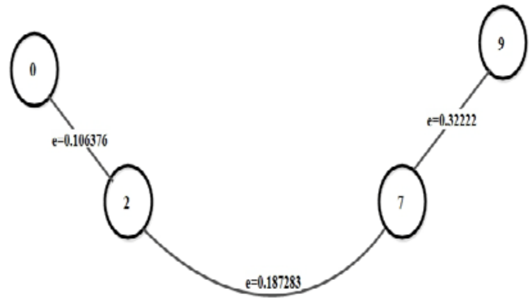


Figure 7.Minimum cost spanning tree for (0,9)

Table 3.*Error Probability Table for node 0 to node 9*

Possible Routes	**Total Fwd Cost (J)**
(0->1)(1−>3)(3−>4)(4−>5)(5−>8)(8−>9)	4.05
(0->1)(1−>3)(3−>5)(5−>8)(8−>9)	1.60
(0->2)(2−>3)(3−>4)(4−>5)(5−>8)(8−>9)	5.07
(0->2)(2−>3)(3−>5)(5−>8)(8−>9)	2.61
(0->2)(2−>5)(5−>8)(8−>9)	0.59
(0->3)(3−>4)(4−>5)(5−>8)(8−>9)	3.81
(0->3)(3−>5)(5−>8)(8−>9)	1.35
(0->2)(2−>7)(7−>9)	0.38

Table. 4 explains the algorithm of distance computation between node pairs of all nodes in the graph. Similarly table 5 explains the algorithm to computer the total hearing cost (THC) of the network. The total forwarding cost is calculated and explained in table 6. Finally table 7 explains ECOR algorithm.

Table 4. *Algorithm to Compute Distance between Two Nodes*

Algorithm:To Compute Distance $dist(u_i, v_i)$
Begin
Initialize u to be source node andv_i to be neighboring nodes for u,
i.eN-u neighboring nodes are there for u in the network
for i = 1toN
$dist(u_i, v_i)^2 = (u_{xi} - v_{xi})^2 + (u_{yi} - v_{yi})^2$
end for
end

A. *Simulation and Result Analysis*

In this section we are analyzing the performance of energy based opportunistic routing[ECOR] with simulation parameters shown in table.8 under NS2 simulator. Initially 50 nodes are randomly deployed with 50J of energy each. Subsequently the number of nodes is increased to 500 nodes for the purpose of analysis. It is observed that each node consumed0.003J at the time of ideal state, and 0.38J and 0.36Jof residual energy at the time of transmission and reception respectively. A source node can transmit 200 packets of 1000 bytes to the destination as given in table.8.Behaviorof the wireless sensor network using ECOR is studied for following parameters like energy consumption, end-to-end, error probability and transmission cost.

Table 5. *Algorithm to Compute Total Hearing Cost (THC)*

Algorithm: Computation of Total Hearing Cost (TC^h_u (Fwd+))
Begin
//check the initial energy of the node to transmit a packet
Initialize err = 1; // common error probability
Initialize P_r = 0.0; //correct probability
Initialize P_e = 0.0; // error probability
while 'w' be the current residual energy of node *u*
E_{th} be threshold energy every node $u_i$of N
if u(w) < E_{th} is true
node is dead
else
Calculate P_r
endif
for i = 1toN
if(Fwd(u_i , v_i)&&u_i! = v_i)
P_e= err * errTable(u_i , v_i)
P_r = 1-P_e
TC^f_u(Fwd+) =ϕ/Pr
elseif
terminate the link
endif
endFor
End

Table 6.*Algorithm to Compute Total Forwarding Cost (TFC)*

Algorithm: To calculate forwarder list and Total Forwarding Cost
Input weighted connected graph G = (N,E)
Output unsorted forward table (Fwd)
Begin
Assume N be set of node in graph G,
Let $C_{i\,j}$ is set to infinity if no link exist between i^{th} and j^{th} node.
C_{uvi}be non-negative cost associated with edge between node u
and v_i where, u, v_i∈ N.
Now u ∈ N is source node that is executing the algorithm to
check minimum cost for all other node of N.
Consider M as set if incorporated nodes M = v_i
for i=1 to N
for each node in N-u
TC^{vi}_u =TC^c_u/1−P_e
endfor
endfor
while N !=M
for i=1 to N
M = M * v_i * C_{uvi} is the minimum cost of all v_i&**N∈(N −M)**
TC^f_u= min (TC_u,TC_{vi}+TC_{uvi})
endfor
End

Table 7.*Algorithm for ECOR*

Algorithm: ECORu,N(u),TC_u,Fwd+
Initial Crange =100m //communicate range ofsingle node u ∈ N
E_{tx}//transmission energy
E_{init} = 10J//Initial energy
E_{TH}//threshold energy
N=100 // number of nodes
Input unsorted Fwd table
Output Total communication cost TC_u& sorted forwarder ListFwd+
Step 1 set TCu = ∞ ;
Fwd(u) = v1, v2, . . . , v|Fwd|
Step 2 sort the neighboring node Fwd+(u) based on its expected cost in increasing order.
Step 3 for i=1 to Fwd+(U)
if (TCu>TCvi) **then**
SetFwd+ = Fwd v*i*
TC_u = TC^h_u (Fwd+)+TC^f_u(Fwd+)+TC_u(Fwd+)
/ /from equation (6)
endif
endfor
End

Figure.8, Depicts the graph between energy consumption and number of sensor nodes deployed for EXOR (Extensible Opportunistic Routing)and ECOR (Energy Conservation in Opportunistic Routing) respectively. It shows that proposed algorithm consumes lower energy than the existing algorithm and also observed that energy consumption increases with the total number of nodes.

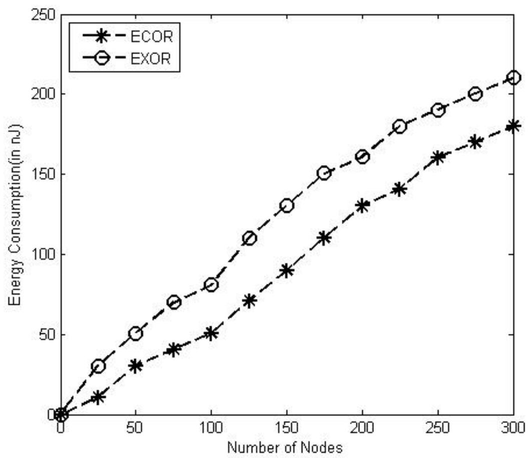


Figure 8.No. of nodes vs Energy Consumption

Table 8.*Simulation Parameters*

Parameter Types	Parameter Values
Simulation Area	100mX100m
Initial Energy	50J
Number of Nodes	500
Sleep Time	0.003J
Transmission Energy	0.38J
Reception Energy	0.36J
Packet size	1000
Ideal energy	0.003J
No. of packets/node	200

Figure.9 shows that the graph between end to end delay and total number of sensor nodes in the network. End to End delay is reduced in the proposed algorithm than the existing EXOR, since it selects the node from the forwards list and avoids multiple transmissions for the same data.

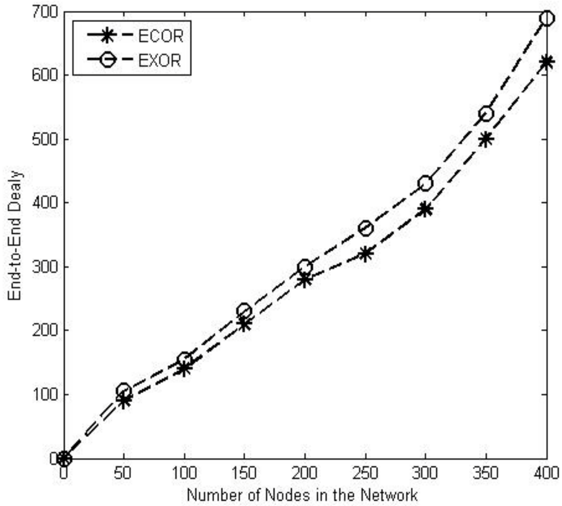


Figure 9.No. of nodes vs End-to-End

Figure 10 shows the graph between total number of packets versus error probability. Error probability is reduced as the number of nodes increased in the simulation. Since the distance between the nodes are reduced and nodes are selected from the forwarder list reduces the fault rate or error probability in the proposed algorithm.

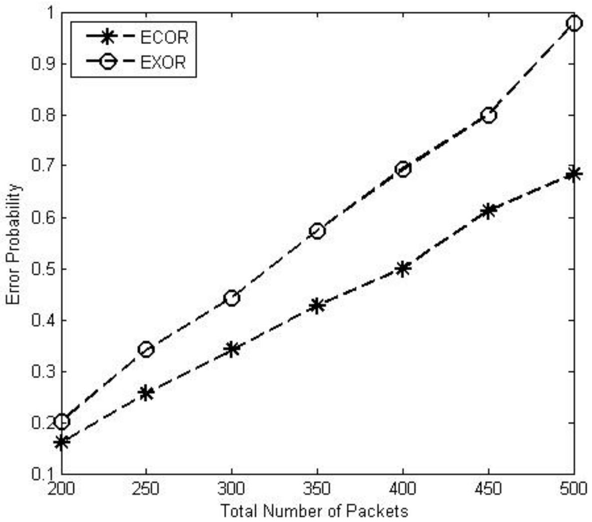


Figure 10.Total No. of Packets vs Error Probability

Figure 11 presents the graph between transmission cost and total number of node. Total transmission cost is reduced for the proposed algorithm ECOR (Energy Conservation in Opportunistic Routing) by considering nodes in the forwarder list. Nodes with least energy is selected as the next forwarder node and thus overall communication cost is reduced from source to destination.

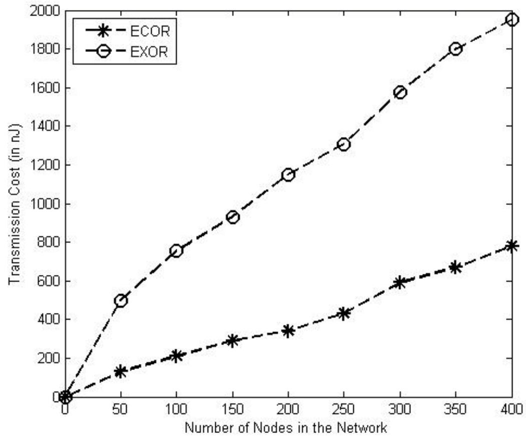


Figure 11. *Total No. of Nodes vs Transmission Cost*

VI. CONCLUSION

Efficient and reliable routing algorithms are essential requirements in Wireless Sensor Networks. Every sensor is usually restricted in their energy level, processing power and sensing capability. It is required to make use of the available energy efficiently. Since energy is a scarcer source for a sensor node, there is a need for energy optimization.

An Opportunistic Routing algorithm for sensor network, ECOR is implemented and proved to be a promising approach with mobile sink in Wireless Sensor Network. ECOR is an integrated routing protocol for multi hop wireless network in which the best of multiple receivers forward each packet. ECOR takes the advantage of broadcast nature of wireless communication which would otherwise have been neglected by traditional routing protocols. In ECOR, the nodes that receive each packet must agree on their identities and should choose one forwarder. Finally, ECOR chooses the forwarder with the lowest cost to reach the ultimate destination by saving energy. The algorithm is the most advantageous if it is used in a scenario with frequent intermittent connectivity as it consumes less energy for routing.

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