Energy-efficient Expected Transmission Count protocol for WSN

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Abstract

The applications of wireless sensor networks comprise a wide variety of scenarios. In most of them, the network is composed of a significant number of nodes deployed in an extensive area in which not all nodes are directly connected. Then, the data exchange is supported by multihop communications. Routing protocols are in charge of discovering and maintaining the routes in the network. However, the appropriateness of a particular routing protocol mainly depends on the capabilities of the nodes and on the application requirements. This paper proposes an Energy-efficient expected transmission count protocol in WSNs, and a Route Optimization Technique (ROT) using expected transmission metric count in clustered WSNs among obstacles. ROT forms an energy-efficient path between the CHs and other members in clusters and CHs to the sink

Keywords: WSN, Cluster, ROT, ETX

1 Introduction

Wireless sensor network (WSN) consists of several tiny and low-power sensors which use radio frequencies to perform distributed sensing tasks. WSNs find their applications in many areas that include plant monitoring, battlefield surveillance, fire detection, and leakage of toxic chemicals, radiations, and gas detection [1]–[5]. In such WSNs, a large number of sensors are deployed in a field of interest (FoI) in stochastic manner. In stochastic deployment, sensors are usually dropped randomly in large numbers to guarantee reliability [1], [4], [6], [7].

Due to limited capacity of wireless communication media and lossy wireless links, it is extremely important to carefully select the route that can maximize the end-to-end throughput, especially in multi-hop wireless networks. a fundamental problem with existing wireless routing protocols is that minimizing the overall number (or time) of transmissions to deliver a single packet from a source node to a destination node does not necessarily maximize the end-to-end throughput. So we are going to propose a new routing protocol to increase high throughput in multi-hop wireless networks, to achieve high end-to-end throughput considering inter flow spatial reusability.

Minimising the energy consumed while ensuring the connectivity of a network is an important issue to be addressed in WSNs because the batteries powering the sensors may not be accessible for recharging often. Cluster-based routing in WSNs has been investigated by researchers to achieve the network scalability and management, which maximizes the lifetime of the network by using local collaboration among sensors [2]–[5], [8]–[10]. In a clustered WSN, every cluster has a cluster head (CH). CHs periodically collect, aggregate, and forward data to the sink.

We propose an Energy-efficient expected transmission count technique in WSNs, that selects the CHs to create a backbone to the network. EEETX is a distributed technique, where sensors are communicated to the CH in a distributed manner. We design Route Optimization Technique (ROT) using expected transmission metric count in clustered WSNs among obstacles. ROT forms an energy-efficient path between the CHs and other members in clusters and CHs to the sink, based on this process which it increases increase high throughput in multi-hop wireless networks, to achieve high end-to-end throughput considering inter flow spatial reusability.

2 ETX

The expected transmission count metric (ETX), which finds high-throughput paths on multi-hop wireless networks. ETX [11] minimizes the expected total number of packet transmissions (including retransmissions) required to successfully deliver a packet to the ultimate destination. The ETX metric incorporates the effects of link loss ratios, asymmetry in the loss ratios between the two directions of each link, and interference among the successive links of a path. In contrast, the minimum hop-count metric chooses arbitrarily among the different paths of the same minimum length, regardless of the often large differences in throughput among those paths, and ignoring the possibility that a longer path might offer higher throughput.

We can calculate ETX by using the following equation

$$\mathbf{ETX} = \frac{1}{P_f \times P_r}$$

Where

P_f : Probability of a successful forward packet delivery ratio

P_r : Probability of a successful reverse acknowledgement delivery ratio

3 Energy-efficient Expected Transmission Count Protocol

In this paper, we design an Energy-efficient expected transmission count protocol (EEETX) for WSNs. This Protocol is the combination of three different schemes; one is for cluster formation in the entire network, cluster head selection, optimal multi-hop route selection, In the protocol, the entire network is divided into different circles, and clusters are formed within each circle. The cluster formation procedure presents the clustering process which is discussed in section 3.1, once the network was clustered, the cluster head selection process procedure was shown in 3.2, optimal route discovery process for data distribution was presented in 3.3.

3.1 Cluster Formation

A cluster is formed with fixed radius by choosing (either arbitrarily or with highest cooperating neighbor density within range of 2 hop distance) a node as center and randomly small distance as radius. Center of the new cluster is calculated as mean of the points within the zone whereas the radius is increased by the distance of two successive centers. The nodes then reply back and in this way clusters are formed which is shown in Fig (2).

It consist of the following parameters:

- Set of nodes $N_i = \{n_1, n_2, \ldots, n_{i-1}\}\{\}$
- A matrix of node (n_i and n_j)
- Random length r

Algorithm -1 Cluster formation

1) *First select a node n_i which is 2 hop distance apart from other participating node with a random length r_1.*
2) *Perform the cluster formation technique*

Do

$B=b_i$, $r=r_1$;

Draw a circle with b_i as center and r as radius

Compute new radius $r_1 = r + |b_i - b_j|$

While $b_i \neq b_j$

Cluster-1 is formed with all cooperating nodes lying within the circles.

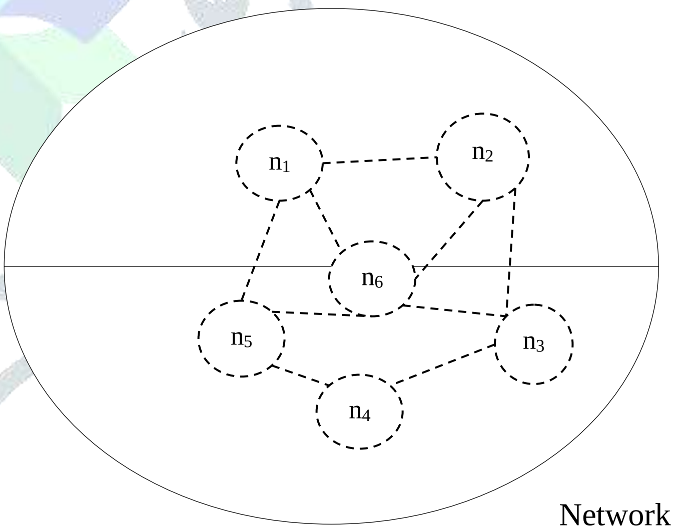


Fig 1: Cluster Formatic

3.2 Cluster Head Selection

A cluster head selection process computed all the nodes characteristics such as energy threshold, node degree (Number of neighbour nodes), node position, distance to the sink node, to elect a suitable cluster head. To know each node characteristics, here we maintain node characteristics table, this table represents each node characteristics. Table-1 represents node characterstic table. The node energy status is measure as follows

Let consider each node status such as sensing, receiving, transmitting and idle status as $S = \{S_0, S_1, S_2, \dots, S_n\}$

The state of node keeps changing during the process of data transmission or reception at time t_1. In time duration t_n, the probability that the node changes its state is denoted using Equation (1) [9]

$$P_{xy}^{n} = P\{S_n = y \mid S_0 = x\} \quad (1)$$

Where x and y represents two different stats

The node state probability P_{xy}^{n} is computed using the following equations:

$$P_{xy}^{n} = \sum_{z=0}^{n} P_{xz}^{(i)} P_{zy}^{(n-i)} \quad (2)$$

The probability of each node state in a same status is derives with the time duration T u using the equation (3)

$$TS = \sum_{t=1}^{T} P_{xy}^{n} \quad (3)$$

The energy dissipated in the subsequent time duration TS is estimated using Eq (4), which consider the four different node stats as sensing, transmission, receiving and idle.

$$E_d = \sum_{y=1}^{4} \left(\sum_{t=1}^{T} P_{xy}^{n} * E_y \right) \quad (4)$$

The remaining energy (RE_i) of each node (N_i) in the susbsequent time duration is measure as

$$REi = Eini - (Etx + Erx) \quad (5)$$

Where E_i = Initial energy of the node

E_{tx} & E_{rx} = energy utilized at the time of transmission and reception of data.

3.2.1 Node Degree

Each node have defined communication range, some of the nodes are placed at different positions, while choosing suitable cluster head its essential to consider number of neighbour nodes surrounded to the node. To determine node velocity, first we estimate the distance by using Euclidian distance function, this function contains distance across set of nodes in a cluster, in equation (6) we derive the each node distance, afterwards , the node degree threshold presents the threshold rate value to extract a neighbour nodes. The flowing equation (6) derives the node degree of each node.

$$D_{N_i} = \sum_{i=1}^{n-1} \sqrt{(X_i - X_{i-1})^2 + (Y_i - Y_{i-1})^2} \quad (6)$$

D_{N_i} represent distance of each node, X,Y represent each node coordinates. Based on the node distance from node to the sink node we determine the group of neighbour nodes

$$\begin{gathered} for\ i: 1\ to\ n \\ if\ (D_{N_i} \leq CR) \\ Add\ node\ i\ to\ neighbor\ set\ \{S_i\} \\ end\ if \\ end\ for \end{gathered}$$

Where CR is communication range, S_i is neighbour set

Nodes	Energy Threshold	Neighbor nodes/ node Degree	Distance to Sink	Node position
A	RE_A	B,C,D,E,F / 5	D_A	(A_x, A_y)
B	RE_B	C,D,E,F,G / 5	D_B	(B_x, B_y)
C,	RE_C	E,F,G / 3	D_C	(C_x, C_y)
D	RE_D	E,G / 2	D_D	(D_x, D_y)
E	RE_E	B,C, / 2	D_E	(E_x, E_y)
F	RE_F	C,D,A /3	D_F	(F_x, F_y)
G	RE_G	E,F,C,D /4	D_G	(G_x, G_y)

Table 1: Node characteristics table

The CH selection derived based on the table-1 data, the following technique derives the CH selection process

Step 1: First, Initialize the parameters to 0 or null.

$CH_{cur} \leftarrow 0$

$CH_{prev} \leftarrow 0$

$Time_{prev} \leftarrow 0$

$Curr\ () \leftarrow 0$

Step 2: Calculate the Average Node character data based on the equations (5) (6)

$$CH_{i,j} = \sum_{i=1}^{n-1} P_E(i,j) + P_{Dist}(i, Sink) + P_{ND}(i)$$

P_E is energy probability, P_{Dist} distance probability, P_{ND} node degree proabability

Metric	A	B	C	D	E	F
ETX	*4.17*	*2.50*	*1.25*	*0*	*2*	*3.33*
EATX	*3.24*	*1.82*	*1.25*	*0*	*2*	*3.33*

Step 3: Compare the given condition to select CH

While ($Time_{prev}$_Curr () ≤ 1=true) do

CH_{prev} remains as Cluster Head

End while

Step 4: Compare Average node character data of previous and current Cluster Head

If Avg(CH_{prev})=Avg(CH_{cur}) and Cost(CH_{prev})=Cost(CH_{cur})

then

both CH_{prev} and CH_{cur} remains as cluster heads

Else

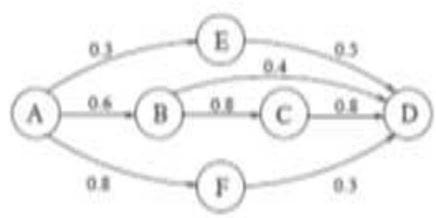
select new Cluster Head

Select new cluster head(s)

end if

3.3 Expected any-path transmissions metric (EATX)

The expected any-path transmissions metric EATX [12] for opportunistic any-path forwarding captures the expected number of transmissions between them under opportunistic forwarding and selection. Prioritization method based on EATX. Opportunistic routing that exploit the broadcast nature of wireless transmissions for selecting the best next-hop at that instant among a set of candidates are being actively explored.



EATX metric was defined to reflect overall transmissions in any-path forwarding.

Figure 2: EATX estimation process

$$EATX = \frac{1+\sum_i EATX\left(A_i^{S,R},R\right)p_i\prod_{j=1}^{i-1}(1-p_i)}{1-\prod_i(1-pi)}$$

Where

S : Sender

R : Receiver

A_i : Adjacent set of links

P_i : Probability of link failure

j : is the set of links to be consider from the current Sender

3.3.1 Expected Transmission Count(ETX)

The goal of the metric is to choose a high-throughput path between a source and a destination. Our metric assigns weights to individual links based on the Expected Transmission Count (ETX) of a packet over the link. The ETX is a function of the loss rate and the bandwidth of the link. The individual link weights are combined into a path metric called Weighted Cumulative ETX (WCETX) that explicitly accounts for the interference among links that use the same channel. The WCETT metric is incorporated into a routing protocol that we call Multi-Radio Link-Quality Source Routing. The expected transmission time is a function of the loss rate and the bandwidth of the link.

ETX = ETX x [Packet size / Bandwidth]

Algorithm 2 :ETX Algorithm

INPUT : Paths (p'), cost of each link(ci).

OUTPUT : Path cost (C) and path P.

Step 1: Identify the set of path {pi'} from source to destination.

Step 2: Find the cost for the path(Ci').

Step 3: Find the set of non-interfering links (nil) in that path (p)

if nil = NULL

then path of the cost is C=min(Ci').

Step 4: From the set of non-interfering links find the maximum cost.

nil(c') = max{nil}

nil(c) =∑{nili}- nil(c')

then path cost is C=Ci'- nil(c).

Step 5: Compare the cost of all paths with the new cost C.

Step 6: The minimum cost C and path P.

4 Simulation Results

This section presents the performance evolution of energy efficient expected transmission count protocol for HWSN to determine the efficiency for various network scenarios and various energy rates, we configure multiple network models to achieve energy efficiency in Heterogenous WSN by configuring different energy rates to nodes, we measure the proposed model efficiency by considering various data rates. This section presents the comparative results between EEETX and a dynamic multipath routing algorithm (IDDR) [13]

4.1 Simulation Model and Parameters

We use Network Simulator Version-2 (NS2) to simulate our proposed protocol. In our simulation, the channel capacity of sensor nodes is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage.

In our simulation, sensor nodes are deployed within the area of 1000 meter x 1000 meter region for 20 seconds simulation time. All nodes have the same communication range of 250 meters. Our simulation settings and parameters are summarized in table 2

No. of Nodes	50,100,150 and 200.
Area Size	1000 X 1000
Mac	802.11
Radio Range	250m
Simulation Time	20 sec
Traffic Source	CBR
Packet Size	512
Receiving Power	0.395
Sending power	0.660
Idle Power	0.035
Initial Energy	10.3 J
Rate	50,100,150,200 and 250Kb

Table 2: Simulation Settings

4.2 Performance Metrics

We evaluate mainly the performance according to the following metrics.

Average Packet Delivery Ratio: It is the ratio of the number .of packets received successfully and the total number of packets transmitted.

Average Throughput: It is the average number of packets reached at sink node at time instance

End-to-End Delay: It is the time taken by the packets to reach the receiver.

Energy Consumption: It is the amount of energy consumed by the nodes for the data transmission.

A. Based on Nodes

In our first experiment we vary the number of nodes as 50,100,150 and 200.

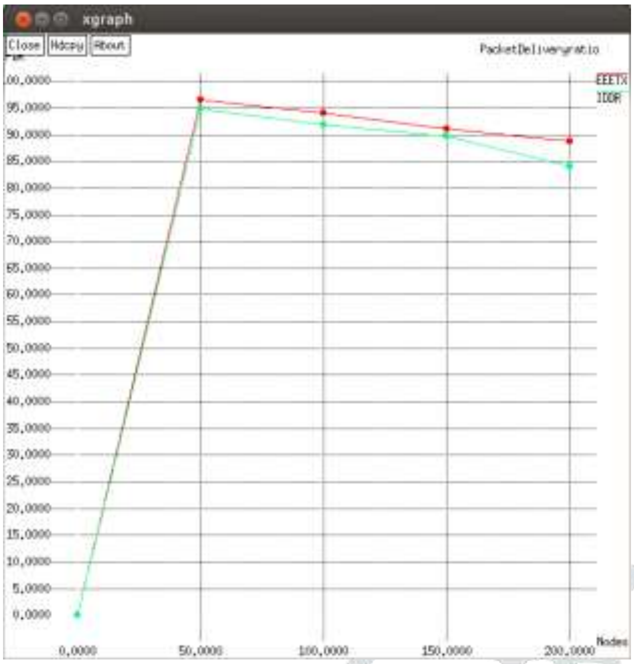


Fig 3: PDR : EEETX vs IDDR

Fig 5: End-to-End Delay : EEETX vs IDDR

Fig 4: Energy Consumption : EEETX vs IDDR

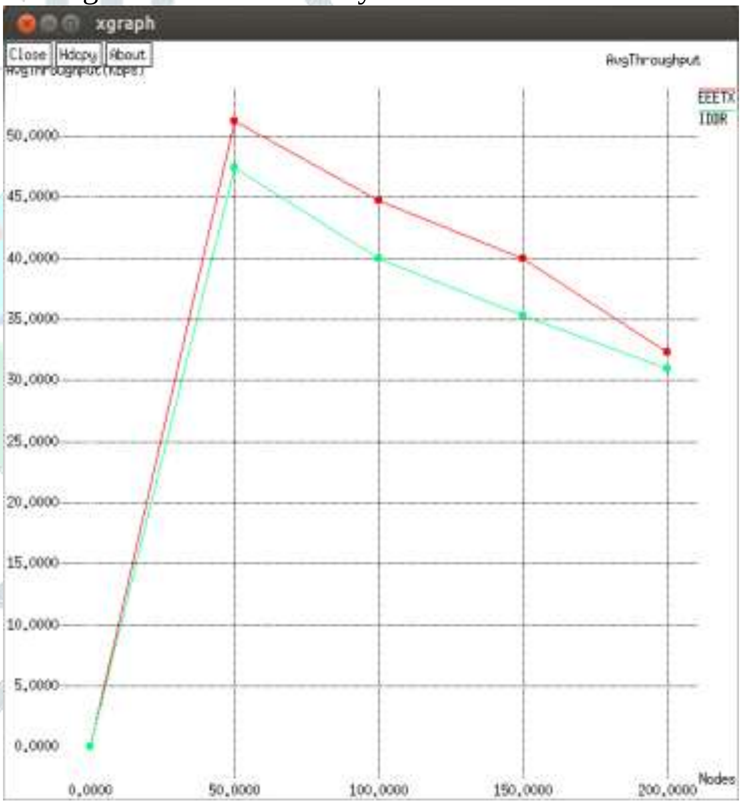


Fig 6 : Avg Throughput: EEETX vs IDDR

From figure 3, we can see that the delivery ratio of our proposed EEETX is higher than the existing IDDR technique.

From figure 4, we can see that the energy consumption of our proposed EEETX is less than the existing IDDR technique.

From figure 5, we can see that the delay of our proposed EEETX is less than the existing IDDR technique.

From figure 6, we can see that the throughput ratio of our proposed EEETX is higher than the existing IDDR technique.

Conclusion

In this paper, we proposed an Energy-efficient expected transmission count protocol for WSN to meet the desired connectivity requirements. We mainly focused on energy-efficient for WSNs to prolong the lifetime of WSNs. We also proposed a technique to optimize the routing path among obstacles in clustered WSNs by designing Expected Transmission Count path mechanism. We simulated the performance of the proposed EEETX for different network scenarios and demonstrated that the energy consumption and average hop count in WSNs are reduced due to the clustering of sensors and optimization of routing path, hence the lifetime of WSNs is increased. The results demonstrated that the geometry and location of the obstacles should be considered to compute an optimized routing path

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