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Energy Efficient Routing In Wireless Sensor Network

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Abstract

Wireless sensor networks can provide a low cost solution to variety of real-world problems. Since sensor nodes are small and energy-constrained, they possess severely limited computational capabilities and memory resources, Energy efficiency is an essential aspect in the applications of WSN. Clustering is an effective topology control approach to improve energy efficiency. Data gathering also improve energy efficiency to prolong the network lifetime. A minimum connected dominating set (MCDS) can be used as a virtual backbone for efficient routing and broadcasting in WSN. Construction of the minimum connected dominating set is based on the construction of a maximal independent set (MIS). In this paper there is a framework of three phases, in first phase an algorithm is proposed for finding minimum connected dominating set using maximal independent set .In second phase we propose an algorithm for data gathering by Leader selection and in third phase we try to minimize the data transmission power consumption among the sensor nodes.

*Keywords:*Unit disk graph(UDG); Maximal independent set(MIS); Cluster, Leader; Cluster-head; WSN; Energy-efficient.

1. Introduction

Wireless sensor networks have emerged as an important new area in wireless technology. The wireless sensor networks consist of many inexpensive nodes, each having sensing capability with limited computational and communication power[1]. Every sensor has the same power and can be formulated as an unit disk graph[2]. An unit disk graph is a graph where there is an edge between two nodes if and only if their Euclidean distance is at most one[3]. In wireless sensor networks, there is no fixed or predefined infrastructure. Nodes communicate via a shared medium, through either a single-hop communication or multi-hop relays [4].Although there is no physical infrastructure, a virtual backbone can be formed by constructing a minimum connected dominating set (MCDS). A backbone in a wireless sensor network reduces the communication overhead, increases the bandwidth efficiency, decreases the overall energy consumption and thus increases network's operational life [5].In a graph G = (V,E), a dominating set is a subset S ⊆ V such that every node is either in S or has at least one neighbor in S.A connected dominating set is a subset S ⊆ V such that the sub-

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graph induced by S is connected and S forms a dominating set in G. The minimum connected dominating set problem asks for a dominating set S of minimum cardinality. Construction of the minimum connected dominating set is based on the construction of a maximal independent set. An independent set $S \subseteq V$ of G is a subset of nodes such that no two nodes $u, v \in S$ are neighbors in G. S is a maximal independent set (MIS) if any node not in S has a neighbor in S. Computing the minimum connected dominating set is NP-hard even in unit disk graphs. Therefore a popular idea is to first, construct a dominating set and then connect it by adding more vertices[6].As maximal independent set is a dominating set, in this paper we create a maximal independent set to construct a connected dominating set.

The clustering technique can also be used to perform data gathering. Cluster-heads will help to collect interested data within their own clusters. Data gathering can eliminate the data redundancy and reduce the communication load.

In this paper, we propose a framework called Energy efficient sensor network framework (EESNF) which consists of three interacting components that can be used to design energy efficient protocols which are adaptive to the environment.

2. Related Work

In the absence of any distance information of the nodes, a convenient way to solve the minimum dominating set problem is proposed by Gao et al.[7] in the One round MDS algorithm.

Algorithm : One-round MDS Algorithm
1: Each node v randomly selects an ID $\nu(v)$ from an interval $[1, \dots, n^2]$.
2: Nodes exchange $\nu(v)$ with all neighbors.
3: Each node v elects the node $w \in \nu(v)$ in its neighborhood with the largest $\nu(w)$.
4: All nodes that have been elected at least once become dominator.

The algorithm computes a correct dominating set in two communication rounds. If there is worst case node distributions, the selected dominating set is $O(\sqrt{n})$ times larger than the optimal solution in expectation. So, in the search of a better solution, we use MIS for creating a minimum dominating set in unit disk graph.

Luby[8] proposed a fast distributed MIS algorithm which provides an elegant and faster solution to the problem of computing a MIS. The fast distributed MIS algorithm operates in round of phases. At the beginning of each phase, each node informs it's neighbors about it's active or passive state. Similarly, the second and third step is implemented using a single round of communication. The algorithm produces a MIS because two neighboring nodes can never join the MIS. Also if a node does not have a neighboring node which has joined the MIS, it will eventually mark itself and consequently join the MIS.

Algorithm: Fast distributed MIS Algorithm

Code executed by node v, which is initially active.
while v is active do
1: v marks itself with probability $1/2d(v)$, where $d(v)$ is the current degree of v.
2: If no higher degree neighbor of v is also marked, v joins the MIS. If two neighbor have the same degree, ties are broken by identifier.
3: If there is a node $u \in N^{+}_{v}$ that has joined the MIS, become passive.
end while

The algorithm's expected running time is $O(\log n)$.

The knowledge of distance among the nodes significantly helps in reducing the time-complexity required for computing a MIS. The knowledge of distance is considered in our EDMISKD.
Data gathering can eliminate redundant data and reduce the communication load. Hierarchical clustering can be effective in network scalability and to reduce data latency. Low energy adaptive cluster hierarchy (LEACH) proposes a two-phase mechanism. Each node in a cluster sends the data to their corresponding cluster-head and the cluster-head transmits the aggregated data to the base station (BS).Power efficient gathering in sensor information systems (PEGASIS) prolongs the network lifetime greatly with a chain topology. A greedy algorithm is used to configure the network into chains. In each iteration, a randomly chosen leader node directs the aggregated data to the base station.

3. Proposed Algorithm

The energy efficient sensor network framework has been proposed which can achieve certain level of energy efficient routing in the wireless sensor networks.

3.1 Efficient distributed maximal independent set with known distances
The algorithm aims to create a minimum connected dominating set by creating a maximal independent set.

V	set of vertices
E	set of edges
E_{Ini}	initial energy of node
E_{Res}	residual energy of node
T_{Sur}	survival time of node
T_{Pst}	lifetime of a node
T^D_{Pst}	desired lifetime of a node
Span	number of uncovered nodes in neighbourhood
N	set of all nodes that are at most two hops away
Support	number of candidates that cover a node

Algorithm: Efficient distributed maximal independent set
1. Compute span d(v).
2. d'(v) = d(v) rounded up to next smallest power of 2.
3. v is candidate if $d'(v) \geq d'(w)$ for all $w \in N$ and $T^V_{pst} > T^D_{pst}$.
4. Compute cover C(v) ,$\|C(v)\| = d(v)$.
5. Compute support s(u),$s(u) = \|\{v \in V \mid u \in C(v)\}\|$
6. Join maximal independent set M with probability P(V)=1/(med(v))   med(v)=median support for all $u \in C(v)$

In the algorithm we find out T_{Pst} for all nodes. The average energy dissipation ratio of node i ($1 \leq i \leq n$) is

$$R^i_{Ec} = \frac{E\ Ini - E\ Res}{T\ Sur \times E\ Ini} \tag{1}$$

We use this dissipation ratio to find the time to live of the node.

$$T_{Pst} = \frac{E\ Res}{REc} \tag{2}$$

After we find out the T_{Pst} for all nodes, we find the desired time to live $T^D_{Pst.}$

$$T^D_{Pst} = \text{AVG } T_{Pst} \text{ of all nodes.} \tag{3}$$

The span d(v)of a node v be the number of uncovered nodes in v's neighborhood. The algorithm continuously add the node with the maximum span to the maximal independent set, until all nodes are covered. The algorithm selects nodes depending on their span and T_{Pst}. In each step, every node computes its span. A node v joins the set if it has the largest span in its 2-hop neighborhood and it's $T_{Pst}>T^{D}_{Pst}$ .It then broadcast a message to it's neighbor of it being covered. Here we consider nodes covered by an individual node, are also covered by other nodes. Let the number of candidates that cover a node u be its support s(u).The algorithm allocates each candidate a probability that is the reciprocal of the median support s(u) of all nodes it covers. The nodes forms a maximal independent set M with probability P(V).

3.2 Energy aware data routing technique

The algorithm is based on hierarchical structure where data is routed from sensor nodes to the sink through cluster-heads. After selecting the cluster-head each sensor sends it's data to the cluster-head.

E_{res}	remaining amount of energy of the node.
E_{ini}	the amount of initial energy.
CH	the cluster-head.
CH_{pnt}	proportion of the number of cluster heads to the number of nodes in the cluster.
P_r	remaining power of the signal at the receiving end.[$P_r = P_t \times (\lambda / 4\pi d)^2$]
P_t	transmission power of the sending node.
λ	wavelength of signal.
d	distance.
W_D	weight of the cluster-head.

Algorithm: Energy aware data routing technique

Initialization: for each node send E_{resi} to Sink.
Cluster-head selection
1. Select Four nodes with highest E_{resi} .A>B>C>D.
2. If in A, E>E'
3. A is Cluster-head.
4. else Step 1.
Leader selection
5. for each Select cluster-head with highest W_D . (C_1 , C_2 ,……….,C_n).
6. If in C_1, E>E'
7. C_1 is Leader.
8. else Step 5.
9. if in A, E<E' goto Step 1.
10. else Continue.
11. end

The sink broadcast message to all nodes in a cluster to select the cluster-head and in reply all nodes send their location and energy information to sink. The sink selects four nodes with the greatest remaining energy A,B,C,D. Where the energy status are A>B>C>D. Then A becomes the first provisional cluster-head and other nodes become the candidates. The base station then sends E' to A after calculating.

$$E = \frac{ERes}{EIni} \times CH_{Pnt} \quad (4)$$

$$E' = \frac{\sum ERes}{\sum EIni} \times CH_{Pnt} \quad (5)$$

Here CH_{pnt} has been used as a multiplying factor because, if the number of nodes in a cluster is high then more energy dissipation of the cluster head would occur during receiving of packets from the nodes.. If E of node A is greater than the E' of node A then A is chosen as the cluster-head. The cluster-head sends the data to another cluster-head and ultimately a cluster-head sends the fully aggregated date to the sink. Thus in this way a chain is formed the cluster-head which sends the data to the sink is called the Leader. Leader sends it's chain information to the sink and sink reply with the chain completion message. The leader is selected by

$$W_D=(P_t / P_r) ((\lambda / 4\pi))^2 \quad (6)$$

The weight of all cluster-heads are calculated and arranged in ascending order (C_1, C_2,……….,C_n).The highest weighted cluster-head C_1 becomes the leader followed by C_2 and so on. C_2 becomes leader only when E of cluster-head $C_2$is greater than the E' of cluster-head C_2 .After the leader is elected, members of each cluster send their data to the cluster-head. The cluster-heads then send their data to the leader, which sends the final gathered data to the sink. This process continues until E of node A is less than the E' of node A, then the cluster-head is switched to node B and a new leader is chosen based on the new highest weight. Cluster-head to cluster-head routing occurs in such a way that, after a Leader is chosen among the cluster-heads the cluster-heads sends their accumulated data directly to the Leader in a single hop communication. The probability of the leader being at the furthest point from the sink is very low , as during the selection of the leader in respect of highest weight we have considered the remaining power of the node along with the distance to sink.

3.3 Balanced shortest path tree for data gathering

This algorithm proposes a self-coding single-input coding strategy, to get a minimum-energy data gathering topology in the model of explicit communication by reducing cost function of a routing topology.

Algorithm: Balanced shortest path tree for data gathering
Input: Graph G = (V,E), sink node t $\in V$
Pre-processing: Compute SPT where if v within ρ then $v \in T$
1. for each non-tree node v_0 do
2. if $(u_0, v_0) = \min\{u\in L_T, v\in V/V_T\}\ w(v, u)+d_T(u, t)$
3. $v_0 \in T$
4. end

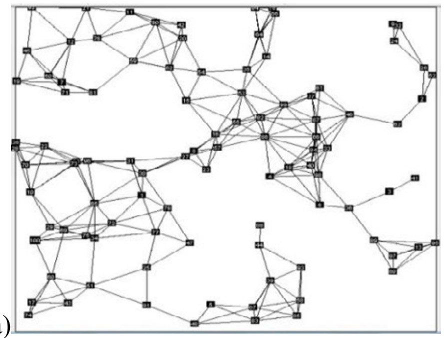
In the first step of the algorithm a shortest path tree T rooted at the sink node t is built on a graph induced by the sink node and the nodes within ρ distance from the sink, where ρ is the data correlation coefficient. Then the remaining nodes are attached incrementally in a following way. An edge between a non-tree node $v_0 \in V/V_T$ and a leaf node u_0 of the tree T is added to the tree if (u_0, v_0) is a pair with minimum energy cost. That means if $(u_0, v_0) = \min\{u\in L_T, v\in V/V_T\}\ w(v, u)+d_T(u, t)$, where L_T denote a set of leaf nodes of the tree T , w(v, u) is the weight of the edge (v, u) and $d_T(u, t)$ is the cost of a path in the tree T from the node u to the sink node t.

4. Performance Evaluation by Simulation

In this section, we present the results of simulating our algorithm. We have chosen Sinalgo[10]as a simulation framework for testing and validating network algorithms. Sinalgo focuses on the verification of network algorithms, and abstracts from the underlying layers: It offers a message passing view of the network, which captures well the view of actual network devices. Sinalgo was designed, but is not limited to simulate wireless networks. The goals of these simulations are to determine the cluster creation the time taken by the algorithm, the maximal independent set size and the energy consumption per bit. In fig1(a) we have shown the creation of a minimum connected dominating set of 100 nodes, in fig 1(b) a minimum dominating set is created with 500 nodes. In fig 2(a) we have compared the number of nodes of our minimum connected dominating set with that of one round MDS algorithm ,in fig 2(b) we shave shown the time taken by our Efficient distributed maximal independent set in creating a minimum connected dominating set with that of one round MDS algorithm. In fig 3(a) we have shown a chart of the amount of energy consumed to transfer 1 bit of data by Energy aware data routing technique and by multi-hop relay communication, in fig 3(b) we have shown the amount of energy consumed for transmitting every bit by Energy aware data routing technique and PEGASIS.

Simulation parameters	
Number Of Nodes	20-500
Distribution	Random
Connectivity	Unit disk graph
Mobility	Random Direction
Reliability	Reliable Delivery

5.Simulation Output

(a) 

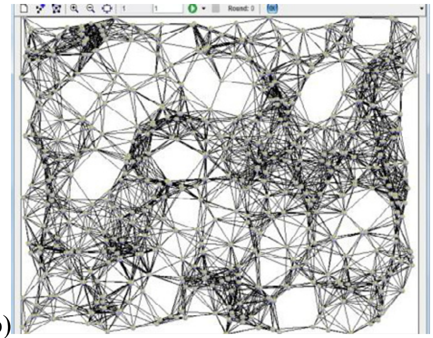
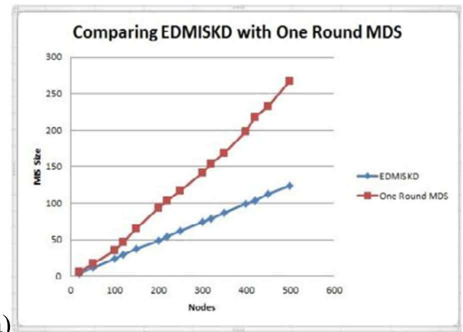
(b) 

Fig 1. (a) 100 node CDS by EDMISKD ; (b) 500 node CDS by EDMISKD

We have evaluated the performance of EDMISKD in respect to One round MDS algorithm.

(a) 

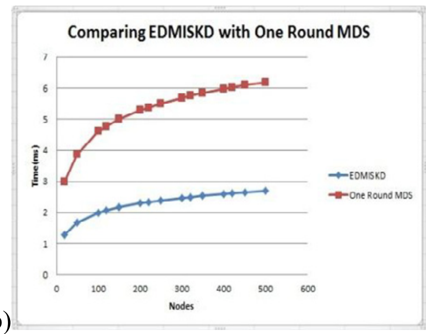
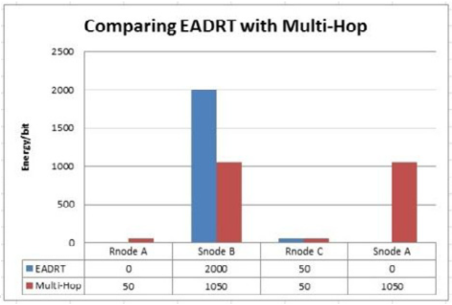
(b) 

Fig. 2.(a) CDS size of both algorithms;(b) Cluster creation time of two algorithms

(a) 

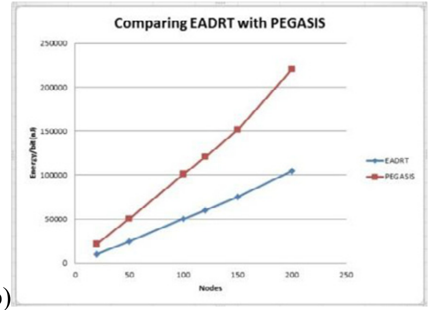
(b) 

Fig. 3.(a) 1bit transmission cost of EADRT and multi-hop relay; (b) Energy consumed/bit by EADRT and PEGASIS.

The node energy model of EADRT is shown here. We have evaluated the performance of EADRT in respect to PEGASIS.

6.Performance Analysis of EADRT

Radio dissipation at the sender and receiver is E_{ele} = 50 nJ/ bit. If distance is d, energy loss = d^2. Transmit amplifier at sender consumes $E_{amp} \times d^2$, E_{amp} = 100 pJ/bit/m^2. So, power for sender to send 1 bit at distance d $=E_{ele} + E_{amp} \times d^2$, whereas for receiver it is E_{ele}. For multi-hop communication, a sensor consumes E_{ele} = 50 nJ/ bit to run the transmitter or receiver circuitry and E_{amp} = 100 pJ/bit/m^2 for the transmitter amplifier and distance between two nodes is 10 meter[9]. Thus, the energy consumed by a sensor j in receiving a 1-bit data packet is given by.

$$E_R\ x,j = E_{ele} \times 1 \quad (7)$$

While the energy consumed in transmitting a data packet to sensor i is given by,

$$E_T\ x,j,1 = E_{ele} \times 1+ E_{amp} \times d_i\ ,\ i^2\times 1 \quad (8)$$

Suppose then j send packet to the cluster-head ,so again energy consumption by node j is given by,

$$E_T\ x,j,g = E_{ele} \times 1+ E_{amp} \times d_i\ ,\ g\times 1 \quad (9)$$

While the energy consumed in receiving a data packet from node j to cluster-head is given by,

$$E_R\ x,j,g = E_{ele} \times 1 \quad (10)$$

Suppose then cluster-head send packet to another the cluster-head c ,so again energy consumption by is given by,

$$E_T\ x,j,g,c = E_{ele} \times 1+ E_{amp} \times d_i\ ,\ g\times 1+ E_{ele} \times 1+ E_{amp} \times d_i\ ,\ c\times 1 \quad (11)$$

While the energy consumed in receiving a packet from cluster-head to c is given by,

$$E_R\ x,j,g,c = E_{ele} \times 1 \quad (12)$$

So, total energy consumption by equation 7,8,9,10,11 and 12 will be 50+1050+1050+50+1050+50=3300 pJ/bit/m^2.But in EADRT sensors directly send the packet to its cluster-head and the cluster-head to the leader. Energy consumption in transmitting a data packet from the sensor node i to cluster-head is given by,

$$E_T\ xi,g = E_{ele} \times 1 + E_{amp} \times d_i\ ,g \times 1 \quad (13)$$

While the energy consumed in receiving a data packet by the cluster-head is given by,

$$E_R\ x,g = E_{ele} \times 1 \quad (14)$$

Energy consumption in transmitting a data packet from the cluster-head to c is given by,

$$E_T\ x,j,g,c = E_{ele} \times 1+ E_{amp} \times d_i\ ,\ g\times 1+ E_{amp} \times d_i\ ,\ c\times 1 \quad (15)$$

While the energy consumed in receiving a packet from cluster-head to c is given by,

$$E_R\ x,j,g,c = E_{ele} \times 1 \quad (16)$$

So, total energy consumed in EADRT by equation 13,14,15 and 16 will be 2000+50+1000+50=3100 pJ/bit/m^2. Thus in our algorithm we can save 200 pJ/bit/m^2 energy by only sending the data to the cluster-head. More energy can be saved when we elect a leader and data from cluster heads is aggregated in the leader and send to the sink.

7. Conclusion

In this paper, we have proposed a framework, Energy Efficient Sensor Network Framework (EESNF) which consists of three interacting components that can be used to design energy efficient protocols which are adaptive to the environment: An energy-efficient clustering technique, Efficient distributed maximal independent set with known distances (EDMISKD),an Energy efficient way of data routing energy aware data routing technique (EADRT),a data gathering process in nodes of sensor network Balanced shortest path tree for data gathering (BSPTDG).Each of these algorithms can achieve certain level of energy efficient routing in the wireless sensor networks. EESNF takes into consideration the communication and computation limitations of sensor networks. While there is always a trade-off between energy consumption and performance, experimental results prove that the proposed framework can achieve energy efficient routing and high degree of performance.

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