A GENERIC ALGORITHM TO IMPROVE THE PERFORMANCE OF WIRELESS SENSOR NETWORK PROTOCOL

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ABSTRACT:-A multi-hop wireless network is composed of large number of nodes and consecutive links between them so that when a packet is transmitted from one node to another it goes through several paths. Wireless sensor network normally consists of a large number of distributed nodes that organize them into a multi-hop wireless network. In wireless sensor network one of the main problems is related to energy issue because every node is operated by battery. To have large network life time all nodes need to minimize their energy consumption. Node is composed of small battery so that the energy associated with this node is very less. So replacing and refilling of battery is not possible which is very costly. Hence some techniques are applied through which the energy associated with each node can be conserved. Energy conservation can be done by controlling the transmission power of each node. In this thesis we have tried to implement a protocol in the literature and the performance of the protocol in sensor network.

Keywords: Multi-hop Wireless network; Adhoc Sensor network; Topology control

1.1 Introduction

The term "wireless" has become a generic and all-encompassing word used to describe communications in which electromagnetic waves to carry a signal over part or the entire communication path. Wireless technology can able to reach virtually every location on the surface of the earth. Due to tremendous success of wireless voice and messaging services, it is hardly surprising that wireless communication is beginning to be applied to the domain of personal and business computing. [1]. Ad-hoc and Sensor Networks are one of the parts of the wireless communication.

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In ad-hoc network each and every node is allow to communicate with each other without any fixed infrastructure. This is actually one of the features that differentiate between ad-hoc and other wireless technology like cellular networks and wireless LAN which actually required infrastructure based communication like through some base station. [2].

Wireless sensor network are one of the category belongs to ad-hoc networks. Sensor network are also composed of nodes. Here actually the node has a specific name that is “Sensor” because these nodes are equipped with smart sensors [2]. A sensor node is a device that converts a sensed characteristic like temperature, vibrations, pressure into a form recognize by the users. Wireless sensor networks nodes are less mobile than ad- hoc networks. So mobility in case of ad-hoc is more. In wireless sensor network data are requested depending upon certain physical quantity. So wireless sensor network is data centric. A sensor consists of a transducer, an embedded processor, small memory unit and a wireless transceiver and all these devices run on the power supplied by an attached battery [1].

2.1 Topology controls for proposed Algorithm

**Topology:**
The topology of a multi-hop wireless network is a collection links by which various nodes in the network communicate with each other. It is just like a structure of a network. This topology is used by various mechanisms to select path in a network to send traffic so that the transmission of data from source to destination can be done efficiently. Topology affected by various factors like transmit power, antenna direction that can be controlled by proper implementation but there some factor like mobility, noise can’t be controlled [4].

\[ D(u, v) = ((x_1-x_2)^2 + (y_1-y_2)^2)^{1/2} \]

**2.2 Topology Control:**
Topology control is the mechanism by which nodes are arrange in such a way based upon their transmission range to increase network capacity and reduce node energy consumption [2]. The main goal of Topology control are

- Maximize network capacity
- Minimize Energy consumption

**2.3 Classification:**
Classification based on critical transmission range it broadly divided into two categories [2]:

- Homogeneous critical transmission range
- Heterogeneous critical transmission range

**Homogeneous critical transmission range:**
- Every node in the sensor network uses the same transmitting range.

**Heterogeneous critical transmission range:**
- Every node in the sensor network uses different transmitting range.

**Topology control** can be classified according to the critical transmitting range [2]:

- Homogeneous
- Non Homogeneous

Depending upon type of data available during computation of topology Non homogeneous topology control classified as:

a. **Location based Topology control**
   i. Range assignment and variant
   ii. Energy efficient communication

b. **Direction based Topology control**

c. **Location free Topology control**

**a. Location based topology control:**
Location based approach can be applied when the node location are known to compute the corresponding topology. This topology control scheme can be applied to both centralized and distributed network. In case of centralized schemes the information about node location is used by centralized authority to calculate set of transmitting range. And in case of distributed network information is transformed between various nodes to find out the optimal transmission range. In sensor network the
nodes are equipped with low power GPS receiver to find out the appropriate position. As it is a new hardware attached to node it increases the cost factor which is a disadvantage in this scheme. By this way the cost factor increases [2].

Let u and v are two nodes having coordinates (x1, y1) and (x2, y2) & D be the Euclidian distance between two nodes u and v. Transmission power \( P_{uv} \) can be calculated as:

\[
P_{uv} = (D(u, v))^{\frac{\beta}{c}}
\]

Where \( \beta = \text{Distance power gradient} \);
\( c = \text{path loss component} \)

For free propagation model value of \( \beta = 2 \).

Free propagation model [2]:

In this model the path between the sender and the receiver is clear and unobstructed. The value of received power can be expressed by the following formula:

\[
Pr(d) = \frac{P_t^2}{(\frac{\lambda}{d^2})*C}
\]

Where \( \lambda = \text{Wavelength in meters} \);
\( L = \text{System loss factor} \).
\( P_t = \text{power of the radio signal received by the node located at distance d from the transmitter} \).
\( G_t = \text{Transmitter antenna gain} \).
\( G_r = \text{Receiver antenna gain} \).

In this above parameter \( \lambda, L, G_t, G_r \) are all constants and the above formula can be replaced by

\[
Pr(d) = \frac{P_t}{(\frac{\lambda}{d^2})^2*C}
\]

Where \( C = \text{Constants depends upon the Characteristic of transceiver} \). There are two schemes those are used this location based topology control:

**Range assignment schemes:**

Range assignment schemes is one of the location based topology control schemes that is used to decide the power level assignments that generate a connected communication graph and also minimize the energy consumption.

**RA problem** [2]:

Let \( N \) be a set of nodes in the \( n \)-dimensional space, with \( n = 1, 2, 3 \). The range assignment function \( R \) for which corresponding communication network is strongly connected and Cost associated with this \( R \) can be expressed as:

\[
\text{Cost}(R) = \sum_{u \in N} (R(u))^{\beta}
\]

Cost is minimum over all connecting range assignment function, where \( \beta \) is the distance power gradient.

**Energy – efficient communication Scheme** [2]:

Energy – efficient scheme based on either the end to end communication scheme between various node or it depends upon communication to all node simultaneously. The first scheme known as unicast schemes and the later one is known as broadcast schemes.

**Energy – Efficient unicast:**

When the entire node transmits at maximum power a communication graph is created known as maxpower graph denoted by \( G(N, E) \). The power cost between any two nodes is defined as the sum of the power cost of the single edges.

\[
\text{PCost}(P_{uv}) = \sum (D(u, v))^{\beta}
\]

Where \( \beta = \text{Distance power gradient} \);
\( D(u, v) = \text{Euclidian distance between two nodes u and v} \).

The minimum-power path between nodes can be found out by above formulation and if the minimum-power path is not unique then we can take any path as the minimum power path.

**Energy – Efficient Broadcast:**

Here the main goal is to find the sparser graph of the broadcast graph broadcasting is more energy efficient. The main cause of using sparser graph to solve the problem that occurs when many nodes in a neighbourhood try to relay the broadcast
message at the same time, resulting in serious redundancy, collision and bandwidth contention

b. Direction based topology control:
This topology control schemes depend upon the ability of node to find the relative direction of their neighbours. It is actually less accurate information than location. If the direction is given then we can find out the location. IEEE antenna and propagation community proposed various mechanisms for estimation of direction in which the node transmit. This problem is known as Angle - of- arrival problem. This can be solved by equipping nodes with one directional antenna. Advantage of using Angle-of-arrival technique rather than location based techniques is that it can be using in case of indoors application [2].

c. Location free topology control:
Location or direction information nothing is given, here the node should explore knowledge about their neighbour by some message passing schemes. So that each and every node should know some minimal amount of information about their neighbour it. The information may be node id, location and order them according to certain criteria. Every node requires some minimum amount of information to build network topology it may be number of node or node id. If the node not able to find out information about the neighbour it is very difficult to built topology [2].

2.3 Layer concepts:
a. Routing Layer:
When one node sends some message to another node then the route discovery and maintenance part is done by the routing layer. This work is done by the routing protocol present in routing layer. Firstly the routing protocol checks whether the route is already known or not. If not then it starts the routes discovery phase. This layer is responsible for sending packets from sender to destination through intermediates node. When no routes found the communication is delayed [2].

b. Topology control Layer:
Topology control layer presents in between the routing layer and MAC layer. The main work of topology control protocol to create and maintain the list of immediate neighbour node. When some node fails or some modification is done to the list then this protocol trigger a route update phase .This modification is mainly done by many leave and join operation of node in the neighbour list. To minimize delay without waiting for routing layer the topology control layer triggered route update phases that the response time became faster leading to reduce packet loss rate [2].

c. MAC layer:
This layer is responsible for regulating access to shared channel, wireless. The main issue associated with this layer is to reduce the conflicts. This layer is also responsible for maintaining the network capacity to reasonable level. Collision detection, avoidance is done at this layer. So that no conflict occurs in communication between various node of network [2].

3.1 Related Work
We discussed briefly about the basics and classification of Topology control in Wireless sensor network. Among that we realized that power consumption of a node is the most important factor to be noticed. So we have made a detailed literature review about the different Topology control protocol in order to minimize energy consumption that already exists.

As we discussed earlier that the topology control mechanism are applied to increase the network capacity and decrease the energy consumption. There are three scheme are there to control the topology

a. Location based Topology control
i. Range assignment and variant
ii. Energy efficient communication
b. Direction based topology control
c. Location free topology control

3.2 Location based Topology control:
- LMST protocol (Local minimum spanning tree):
LMST protocol [2] is one of the protocols based on the location based topology control approach. In this protocol symmetric wireless medium is consider. The node have same maximum transmit power. LMST protocol first involves Information Exchange in which each node makes a data structure it may be a table that composed of both Node id and location transmit this beacon message to all neighbours at maximum transmit power. Then it constructs topology by creating local minimum spanning tree for each node. Which can be done when the beacon message is received by the neighbours within the corresponding range each node try to construct its local minimum spanning tree by the help of prims algorithm. The link weight is same as the Euclidian distance between two nodes. From this distance the power can be calculated by using the following
formula:
\[ P_{uv} = (D(u,v))^{\beta} \cdot C \]
Where
\[ C = \text{path loss component} \]
\[ \beta = \text{Distance power gradient and } \beta \geq 1 \]

After the formation minimum spanning tree then define the set of neighbours in the final topology depending upon the distance that is at one-hop distance from source. Then it determine the transmit power of each node by comparing the received energy of the beacon message and the maximum transmit power of node that is received the message. Every node can estimate minimum power level needed to reach the destination node by comparing with the maximum transmit power with the receiving power of beacon message.

Broadcast power is also compute by nodes, this power required to reach to the farthest node in the network. The topology produced by the LMST protocol can be preserves in worst case.

3.3 Direction based topology control:
- **CBTC protocol (Cone-based topology control):**
  In cone-based topology control [2] the transmit power of every node is set to some minimum power. Power is function of width \( \omega \) so that when this minimum power is given to the respective node let say \( u \) and minimum power given to the node \( u \) be \( P_u, \omega \) such that node \( u \) can reach at least one node in every cone of width \( \omega \) centred at the respective node. A node must retain connection to at least one neighbour in every direction where determine \( \omega \) direction. In this protocol each node determines the minimum power required to reach the neighbour in every direction then identified the energy inefficient edge and remove it from final topology.

  Every node can communicate with other node within its range by transmitting beacon message to these node which contain the node Id and power used to send the message and the receiving node also send acknowledgement message in response to beacon message. The ack message contains the Id of sender, receiver and power used to transmit the message.

3.4 Location Free Topology control:
- **XTC protocol (extreme topology control):**
  In XTC protocol [2] every node in the network maintains an order relation with its neighbour set. The ordering relation can be explaining in terms of strength of received signal or by packet delivery ratio. Here the link quality is measured in terms of received signal strength. Neighbour order can be found out by sending a beacon message at maximum power. Then the receiver node measures the received signal strength and order accordingly. This process repeated for some time to find out the proper order then form neighbour list. Then broadcast the neighbour list with maximum power. Then network topology is constructed at each node locally. The XTC protocol computes the topology for bidirectional links. It also preserves connectivity at worse case.

4.1 Algorithm:
The work is an implementation of a proposed protocol present in paper” Topology control of Multi-Hop wireless Networks using transmit power adjustment” by Ramanathan and Regina Rosales-Hain [4].

**Algorithm CONNECTIONCHECK**

**INPUT:**
N=number of Nodes in a wireless sensor network G be the MAXPOWER graph. L (Xx, Yx) =Location of each node x in the WSN G.
Pmin= minimum power required to communicate through a distance d; it is a function of distance.
C=number of possible nodes pairs NC=number of cluster
R=sorted pair list

**OUTPUT:** Transmit power level of each node P to form a connected topology

```plaintext
Begin
  1. Initialization:
     1.1 d(x,y)=0
     1.2 Pmin=a*d(x,y)  // 0≤a<1
     1.3 N=0
     1.4 Create Cluster per node depending upon N
     1.5 C=0
     1.6 NC=0
```
2. Enter the Number of Nodes N
3. Calculate the Euclidian distance $d(x, y)$.
4. Arrange the $(x, y)$ on the basis of $d(x,y)$ in ascending order and store in R and return $C$
5. $NC=N$
6. For $i=1$ to $C$
7. Select node pair(C)
8. If cluster of both node pair are different then
9. Assign $P(x)$ and $P(y)$ to the $d(x,y)$
10. Merge Both node pair cluster to form new cluster
11. $NC=NC-1$
12. If $NC$ is equal to 1 then stop
13. Minimum_power($G,pmin,P,k,R$)

End

Procedure minimum_power ($G, pmin, P, k, R$) {
1. For $i=N$ to 1
2. Select(node)
3. Create a set S of node pairs in which the selected node is the source or destination node.
4. Arrange the set S in descending order of $d(x,y)$
5. Calculate $p_{min}$ for each node and compare with the power level of each node
6. If $p_{min}(d)>P(u)$ then Remove that node pair from T
7. Search node pairs in T and check if $P(u)=p_{min}(d)$ then the graph is not K-connected stop
8. Else assign $P(u)$ to $p_{min}(d)$
}

We have reproduced here the proposed protocol for the sake of completeness. The detailed protocol found in a paper [Topology Control of multi-hop wireless networks using transmit power adjustment by Ram Ramanathan and Regina Rosales-Hain][4].

4.2 Parameter description:
1. $G$ represents the multi-hop-wireless network. This is represented as $G (N, L)$.
2. $N$=number of nodes
3. $L$=location of each node
4. $P$ is the transmit power associated with each node.
5. $p_{min}$ is least power function is the minimum power needed for transmission between nodes.
6. $K$ is the connectivity parameter e.g. $k=1$ for one-connectivity [4].

4.3 Algorithm analysis:
I have implemented a polynomial time algorithm CONNECTIONCHECK [4] for a connected STATIC network. I referring this algorithm from paper proposed by Ram Ramanathan, Regina Rosales-Hain CONNECT [4]. The multi-hop wireless network contain several nodes. A packet must be successfully sent to destination through several nodes. The communications possible if there is a link exist between source nodes to destination whether direct or indirect through several intermediate nodes. Here actually the multi-hop wireless network is represented as a graph. Ever vertices are represented as nodes and communication links as edges. So the two nodes are communicated as if there exist an edge between corresponding vertices.

Multi-hop wireless network is represented as $G= (N, L)$ [4] where $N$ represents the number of nodes and $L$ represent their location with respect to the node. This algorithm is a simple greedy based algorithm. The greedy method suggests that one can devise an algorithm that works in stages, considering one input at one time. At each stage, a decision is made regarding whether the solution is an optimal solution or not. Every greedy approach has some constraint function and objective function. Any subsets that satisfy the constraint are called feasible solution. We have to find the feasible solution that maximizes or minimizes the objective function. Here this algorithm is a minimization problem. Here the main objective of the algorithm is to minimize the maximum transmit power of each node rather than the overall nodes. Here the constraint are simply the network connectivity between node and the transmission power of nodes must be less that the maximum possible transmit power.

While The CONNECTIONCHECK [4] algorithm can found out the transmit power of each and every node but it may not be per-node minimal due presence of some side-effect edges and this node may have some negative effect on the transmit power of every node. It may involve lowering of power level or elimination some edges. So another procedure that is applied to have per
node minimum transmit power that is minimum power [4]. It uses the presence of side effect edges and found out the per node minimal power. This procedure simply decrease the transmit power of node to a certain level so that the induced graph can’t be disconnected.

4.4 Implementation:

I have implemented the above algorithm using C#.Net programming language. First I create each node that is present in the (nodes) file and specify the attribute of each node that is the node location in term of x-coordinate and y-coordinate, Node id, power associated with each node, receiver sensitivity and the Euclidian distance from node considered to the all other node. Each and every node has some region of communication that is known as node boundary, we here assign node boundary to each and every node. Location of each and every node are randomly assigned and the node location are checked with the boundary condition whether the node present inside the boundary or not. If it is present inside the boundary then considered otherwise discarded. Another node attribute is the node id of the destination node to which the current node can communicate. We first made cluster for each and every node by specifying the node boundary. In which the node can able to communicate. The cluster can be created by the help of generic collection class present in the System. Collections. Generic name space.

Syntax:
1. List<node> li=new List<node>()
2. For n is greater than 0
3. li.Add(new node())

Here List is a collection which can contain object of type node. All the node property including the node id, power, boundary condition etc is encapsulate in the respective list object. List object are nothing but nodes. And every List object can be access by the help of indexer e.g. li[i] where i represent node no.

After that from each location the Euclidian distance can be found out. And from this distance we can found out the power associated with each node by applying the following formula:

\[ P_{uv} = (D(u, v))^2 \]

Where

- \( C = \) path loss component
- \( \beta = \) Distance power gradient

Here we consider the free space propagation model so for this model the value of \( \beta \) be 2 and \( c = 1 \)

So the generalized formula is:

\[ P_{uv} = (D(u, v))^2 \]

Initially all the calculated power assign to each node and all nodes transmit with this maximum power. Then by applying the above algorithm we can calculate the per node minimal transmit power. Here I take \( k = 1 \) that is for one – connectivity only. Here one thing I took \( p_{min} \) as constant multiple of x let say a and the value of \( 0 \leq a < 1.0 \).

With \( p_{min} \) we check the connectivity issue in the minimum power procedure. Here I write the program for 20 nodes. Then the average transmits power of the entire node for a particular number of nodes calculated. And a graph is plotted between the density and the average transmits power of node.

4.5 Simulation result:
4.6 Result analysis:

Here we plot a graph between density and average energy of node in a wireless sensor network. From this result we found that with increase in density the average power decreases because suppose a area of radii 2 contain two nodes then the Euclidian distance between node are larger as comparison to ten nodes in the same area because their mutual distance decreases. As the power is calculated directly from distance and with increase in distance the power increases and vice-versa. Here the density plotted on x-axis and average power on y-axis.

Conclusion:

We proposed a basic topology, efficiently used in Wireless Sensor Network for our proposed algorithm suitable for wireless sensor network and simulated the proposed and verified the results.

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