

k-CONNECTED HYBRID RELAY NODE PLACEMENT IN WIRELESS SENSOR NETWORK FOR RESTORING CONNECTIVITY

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Abstract

Wireless Sensor Network (WSN) consists of a number of sensor nodes for monitoring the environment. Scenario like floods, volcanic eruptions, earthquakes, tsunamis, avalanches, hailstorms and blizzards causes the sensor nodes to be damaged. In such worst case scenario, the deployed nodes in the monitoring area may split up into several segments. As a result sensor nodes in the network cannot communicate with each other due to partitions. Our algorithm investigates a strategy for restoring such kind of damage through either placement of Relay Nodes (RN's) or repositioning the existing nodes in the network. Unlike traditional schemes like minimum spanning tree, our proposed approach generates a different topology called as spider web. In this approach, both stationary and mobile relay nodes are used. Thus we are making our topology as a hybrid one. Though the numbers of relay nodes are increased, the robust connectivity and the balanced traffic load can be ensured. The validation of the proposed approach has been simulated and verified by QualNet Developer 5.0.2.

Keywords:

Spider Web Topology, k-Connected Relay Nodes, Partitioning, Federation of Disjoint Networks

1. INTRODUCTION

Wireless Sensor Network (WSN) consists of a number of sensor nodes distributed over a physical environment to monitor the environmental conditions like temperature, sound, pressure, speed etc., and finally monitored data can be collected. Then it is organized in the server or source or main location where the data from different nodes can be stored for further purpose [1]. The sensors are battery powered and have limited energy, which is used to perform data acquisition and processing and to sustain the communication. Efficient use of energy is of fundamental importance in sensor networks and several techniques have been proposed in order to prolong the battery lifetime. Although current technologies used for wireless networks can be used for small area networks, it is hard to apply them to sensor networks directly. The placement of wireless sensor network in harsh surroundings lead the network into several physical damages. As a result, the network is divided into multiple disjoint networks. A traditional technology used to federate the disjoint networks is Minimum Spanning Tree (MST) [4], which is a better way to connect multiple disjoint networks. But still there is a problem called non-balanced traffic overload. If the relay node, sometimes called as extra node which helps to connect the remaining nodes fail, then the network again gets partitioned. Our algorithm helps to determine the minimum number of nodes and their positions to

connect other partitions. k-CHRNP (k-Connected Hybrid Relay Node Placement) algorithm is used not only to connect the segments and also it ensures the balanced traffic load and connectivity. Spider web based relay node placement problem is used to federate the various partitions of the network segments. The proposed approach is mainly used to improve connectivity, robustness of network and balanced traffic load. Existing method fail to deal with balanced traffic load. MST (Minimum Spanning Tree) is a traditional and simple way to federate the network segment. But problem here is bottleneck behavior of gateway node. The relay node which connects two or more segments is called as gateway node. Connectivity is another major issue in the existing approach. The k-connectivity is achieved in order to improve the robustness against relay node failure as well as balanced traffic load. We are not considering the number of relay node, since our proposed approach dealing with balanced load. Section 2 involves the related work about the federation of partition of network segments. Section 3 highlights the detailed architecture of k-CHRNP algorithm. Section 4 highlights the implementation of k-CHRNP algorithm. Section 5 describes the simulation results of the k-CHRNP algorithm. Section 6 concludes the paper.

2. RELATED WORKS

The network topology defines different arrangement/placement of computer components/nodes in order to make efficient network. In dense network, topology of nodes are constructed to avoid overlapping, unnecessary dissipation of power and sensing hole. In [2] to avoid the sense hole, relay nodes are placed which has four states namely listen, sleep, active and relay state. Any node from the network is considered as sink or centre node. The farthest node from centre node is made active and a virtual line is formed between them. Then virtual line is constructed between centre and marked node. Two or more nodes can be preferred by horizontal and vertical of the virtual line. The active node is selected by sending advertisement message to its neighbour. When the active node receives advertisement messages more than three times, then the active node became a relay node. When the residual energy of the node is less than threshold value then the node became sleep state. This process is continued until entire network is covered. The advantage of this work is that the number of relay nodes can be reduced, thus the network lifetime is improved and residual energy is considered for data transmission. The drawback of the method is, if the leaf active node failed, then the relay nodes are activated unnecessarily. Many Papers

[5][6][8][10] investigates strategy for recovering from such damage through the placement of relay nodes (RNs). To find the minimum number of nodes, which connects the entire segments convex hull algorithm is used. The polygon is constructed from the convex hull points. The centre of mass (CoM) is calculated to place the relay nodes (RN's). The advantage of the work is that cut-vertex problem can be eliminated in the 1-C spider web (1-Connected) approach. A reliable, strong network topology can be constructed again. The drawback is numbers of relay nodes are increased, that leads to increase cost.

The harsh environments, such as forest fires and flood leads the WSN into several segments. In order to activate the network again, network needs to federate the segments. Optimized two-phase Relay Placement (ORP) approach has two phases [6]. The first phase is used to setup a connected network backbone using the minimum number of relays, called First Phase Relay Nodes (FPRNs) on a grid model. The second phase is to find a set of relatively small number of candidate positions. Connectivity has been improved even the probability of node/link failure, number of deployment and number of disjoint sectors are increased. The advantage of ORP is that the connectivity can be achieved by federating the segments. The drawback of ORP is optimized relay count is not considered. The cost of the relay node is high compared to sensing nodes. In some of the applications such as battle field monitoring and forest fire monitoring, multiple networks need to be in collaborative manner. So that the network can perform the decision about the environment and it's behaviour. This federation problem is used when the number of available Mobile Data Collectors (MDC) is less than that of the number of RN's required, where the number of segments are more than RN's required [7]. The advantage is that, when the relay node resource is very low compared to available segments, then this approach is used. Inhospitable environment like forest fire, tsunami etc., causes multiple node failures in the wireless sensor network. As a result the whole network gets divided into multiple disjoint networks. To resume the remaining operation the disjoint network segments need to be interconnected with each other. For this, the contemporary algorithm called, MiMSI (Mix of Mobile and Stationary nodes for interconnecting a set of terminals) [8] groups the terminals into clusters by connecting gateway nodes. The data collectors called mobile nodes tour in-between the clusters to carry the data. The advantage is, both MDC and Relay nodes are used to achieve good connectivity. Thus the number of relay nodes are optimized in order to reduce the cost. Drawbacks of this paper are MDC consumes more battery energy when compared to relay nodes. Unnecessary tour of MDC may occur, if there is no data to send. Contemporary solution to restore the network is achieved by placing relay nodes (RN'n) and MDC. MDC's are able to move within the network and it can transfer the data to one segment to another segment. As a result the network can be partitioned into several segments. The relay nodes are placed in order to establish the connectivity between network segments using MDC. This approach had been done by finding Connected Dominant Set (CDS) of the segment. In [10] the work has two phases; one is used to find out the CDS and non-CDS of the nodes in the segments. Another phase

involves finding the Non-CDS in the segments which are then moved to the location where the bridge nodes to be placed to restore the connectivity again. SMT (Steiner Minimum Spanning Tree) are constructed after finding the CDS to for the topology. Connected Inter-Segment Topology (CIST) is used to find the location of relay bridging nodes. Then a non-CDS node from the segment has been moved to the relay position. The strength of the work is it reduces the set of locations for the existing mobile nodes in the network to the locations of relay nodes that would ensure connectivity with the least count. A greedy based heuristic approach is followed to move the nodes in the partitions whose absence would not violate the inter-partition connectivity. The drawback is the node replacement consumes more energy. Cut-vertex may cause the network into segments again. In [9] a set of M segments are connected with other by using k MDMs (Mobile Data Mules). A viable approach for establishing connectivity among these network segments is by employing MDC. To solve the federation problem when the number of available RNs is less than the required count for establishing a stable inter-segment topology and even fewer than $(M - 1)$ MDCs can be employed [9]. It forms an efficient network topology so that the overall data delivery delay in the federated network is reduced. The main objective is to minimize the average and maximum delay between any two segments. The algorithm is divided into two phases. The first phase implements an algorithm for grouping segments into clusters so that the touring distance of the MDCs is minimized. In the second phase the clusters are further optimized so that the travel overhead is balanced over all MDCs. The idea is to relocate the rendezvous points of the MDCs in order to equalize the tours. The advantages are when the number of available RNs is less than the required count for establishing a stable inter-segment topology and even fewer than $(M - 1)$ MDCs can be employed. The relay node count can be considered. The intermittent link can be formed from MDC tour. Touring and data transmissions of MDC consume more energy compared to stable relay node connectivity is the weakness of the work.

3. PROPOSED SYSTEM

The Ad Hoc On-Demand Distance Vector (AODV) [11] routing protocol provides quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network. Route Requests (RREQs), Route Replies (RREPs) and Route Errors (RERRs) are the message types defined by AODV. Our proposed approach uses AODV to implement the k-CHRNP algorithm. Fig.1 shows the complete architecture of the proposed system k-CHRNP.

k-CHRNP approach allows handling the federation problem through either placement of relay nodes (RN's) or repositioning the existing node in the network for establishing the connectivity again. The relay nodes are placed at the perimeter of the line of the segments connected with CoM (Centre of Mass). For each segment one stationary relay nodes are placed on the line connecting CoM. Thus the stationary nodes form the ring

topology around the CoM. Then the mobile data collectors are placed in order to connect the segments in the network. To find the representative node from each segment convex hull algorithm is used.

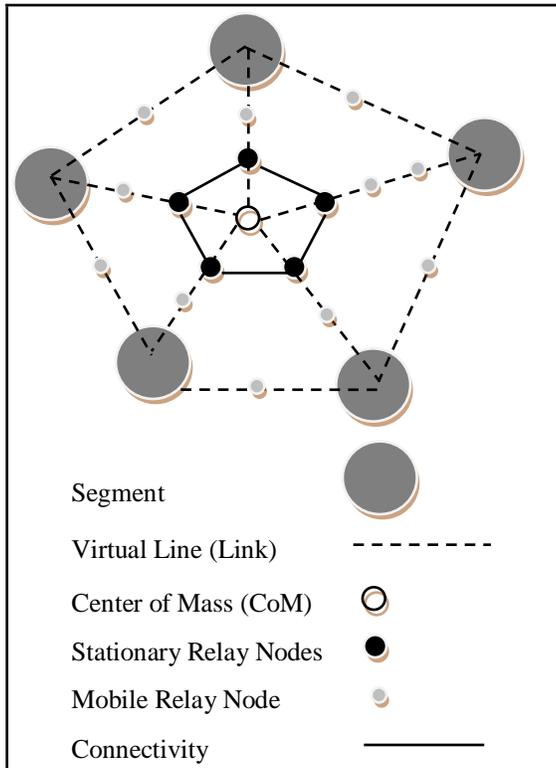


Fig.1. Proposed Architecture (k-connected topology)

After finding the convex hull node, virtual line is drawn from each segment. Thus the ring topology is created around the center of mass. Here every node k-connected, so the traffic load can be distributed normally and it ensures the robust, since we are using our approach in the defense kind of applications. So we are not considering the number of relay nodes. Segments are considered as clusters.

4. IMPLEMENTATION

In order to implement our k-CHRNP: K-Connected Hybrid Relay Node Placement in Wireless Sensor Network, we used QualNet 5.0.2 [2] simulator. k-CHRNP uses 3 phases. They are finding partitions, forming ring topology and mobile relay node placement. The k-CHRNP is responsible for finding the position where the relay nodes have to be placed and Energy Election Algorithm (EEA) is responsible for node selection.

4.1 FINDING PARTITIONS

Finding disjoint partitions is the initial task to federate disjoint network segments. It has been done by using convex hull algorithm. After finding the convex hull points, cluster head is selected. Relay nodes are chosen as a cluster head or node with

high energy can be elected as cluster head. The convex points are calculated by finding the orientation of the triplet points. The triplet (p, q, r) has three points with x, y, z as its coordinates. For the triplet (p, q, r) , the orientation is calculated as follows,

```
//To check the 3 points are right turn
int orientation (Point p, Point q, Point r)
{
    double val = (q.y - p.y) * (r.x - q.x) - (q.x - p.x) * (r.y - q.y);
    if (val == 0) return 0;
    return (val > 0)? 1: 2;
}

//iterations for finding orientation
int p = 1, q;
do
{
    q = (p+1) % n;
    for (int i = 0; i < n; i++)
        if (orientation (points[p], points[i], points[q]) == 2)
            q = i;
    next [p] = q;
    p = q;
} while (p != 1);
```

Fig.2. Convex Hull Algorithm

Initially the triplet point p is assigned as topmost left node l of the network. So the right turn will be selected to find the convex hull points. For every iteration, the p, q, r can be changed to some other points on the terrain. If the Orientation returns the value 0, then the triplet (p, q, r) points are collinear. If it returns 1, then the triplet (p, q, r) is clockwise otherwise counter clockwise (right turn). The points in the triplet (p, q, r) should be counter clockwise in convex points set. The Fig.2 shows the calculation of orientation as well as iteration. For each point q, p and r can be updated to do the further iteration. Thus every combination of triplet (p, q, r) can be checked against the right turn in order to find the convex hull points.

4.2 FORMING RING TOPOLOGY

Based on the distance between Center of Mass (CoM) and partitions, the ring topology is formed with radius r . Here r is the radio range of the sensor node. Thus the static topology can be formed.

4.3 MOBILE RELAY NODE PLACEMENT

Based on the value r , the mobile relay node position is determined and mobile relay nodes move with constant speed. A new mobility model called Chainsaw mobility has been implemented in the QualNet Network Simulator [3], in order to move the node towards to the segment. Rather than deploying new relay nodes the existing nodes can be used mostly. The number of nodes in the intersegments n is used as relay nodes. The number of required relay nodes are equal to the number of nodes in the intersegment. The energy election algorithm is used in order to identify the nodes with higher energy. Based on

threshold energy value E , the node can be elected then the node with highest energy can be moved to the longer distance. Similarly node with shortest energy can be moved to the shorter distance. If the distance between two segments is less than $2r$ then the node can be act as gateway node. Otherwise chainsaw mobility model is used to act the node as data collectors.

4.3.1 Chainsaw Mobility Model:

In order to make the segments to communicate which are present in the network, relay nodes/nodes work on the basis of Chainsaw Mobility model. In this model the node find its current position and destination position from the convex hull points. Then the node will move from current position to destination position and vice versa until the simulation completed. The Fig.3 shows the configuration of Chainsaw Mobility in QualNet 5.0.2.

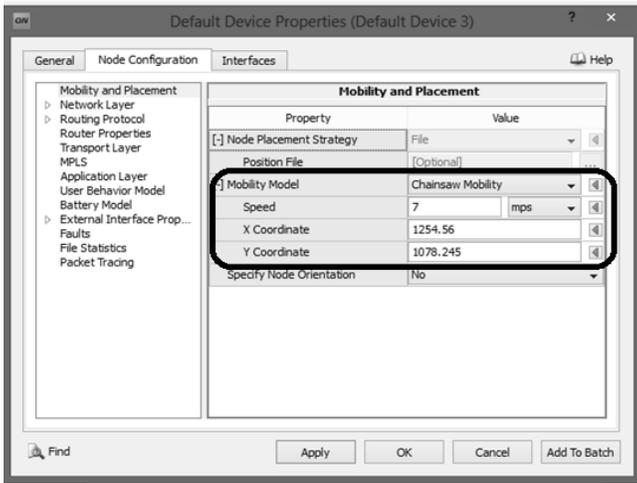


Fig.3. Chainsaw Mobility Model

The Fig.3 shows that, the user can define their own speed, x-coordinate and y-coordinate. Here chainsaw mobility is added to node 3. The x-coordinate and y-coordinate shows the destination position of the node. The current position of the node can be stored for further motion. Unlike the Random waypoint mobility model [12], we can configure the node to a particular position with particular speed.

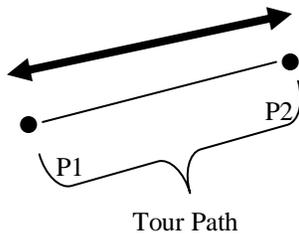


Fig.4. Chainsaw Mobility Tour Path

The Fig.4 shows working of chainsaw mobility model where $P1$ and $P2$ are the tour point where the mobile nodes can be moved towards each other. If the distance between $P1$ and $P2$ is $2r$ then the relay node will act as a gateway node. Otherwise mobility can be assigned to resume the remaining operation of the

network. The points $P1$ and $P2$ can be determined by phase 1 of k-CHRN algorithm.

5. SIMULATION RESULTS

We analysed the performance of k-CHRN algorithm in terms of Packet Delivery Ratio (PDR), Average End-to-End Delay and Throughput. The QualNet Network Simulator is used in order to measure the performance of the proposed algorithm. The following table shows the simulation parameter. Here cluster head is assigned based on the energy level in each segment.

Table.1. Simulation Parameters

Terrain	1500*1500 m ²
No of common nodes	20,30,40
Simulation time	110s
Items to Send	100
Item Size	72
Routing protocol	AODV (Convex Hull)
Physical layer	802.15.4 Radio
MAC	802.15.4
Application Layer Traffic	CBR
Start Time	5s
Speed	7 Mbps
Mobility Model	Chainsaw
Number of CBR	3

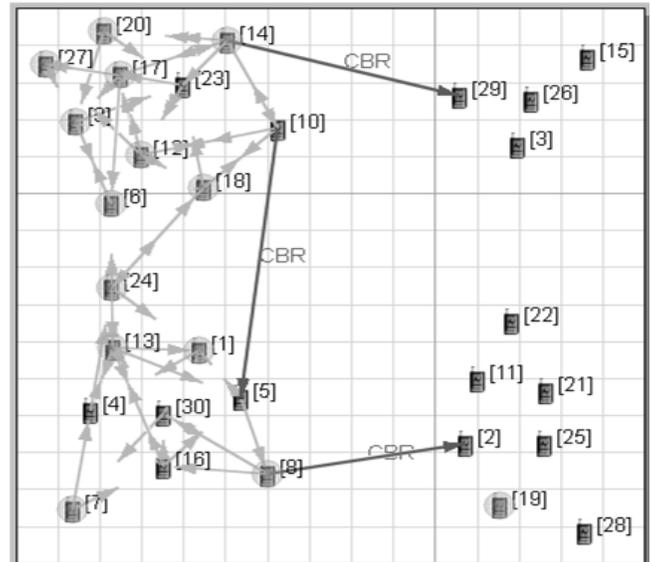


Fig.5. Segments in the Network

OTE Initiated at 38

Convex Hull Points are...
 (293, 104)
 (134,146)
 (1362, 1367)
 (208, 1439)
 (70, 1349)
 (1355, 86)

Area of the Convex Hull Terrain is -81229.50 m².
Center of the Convex Polygon is (570.33, 748.50)

Segment [0]: dist[CoM, (293, 104)] = 259.74
Segment [1]: dist[CoM, (134, 146)] = 178.57
Segment [2]: dist[CoM, (1362, 1367)] = 178.24
Segment [3]: dist[CoM, (208, 1439)] = 1243.83

Fig.6. Convex Hull and COM

The Fig.5 and Fig.6 shows the Segments of the Network and the Convex Hull Points which is used to find out the segments in the network.

5.1 PACKET DELIVERY RATIO (PDR)

The Number of received data packets divided by the number of generating data packets is called as a Packet Delivery Ratio (PDR). The PDR value can be calculated by using following Eq.(1).

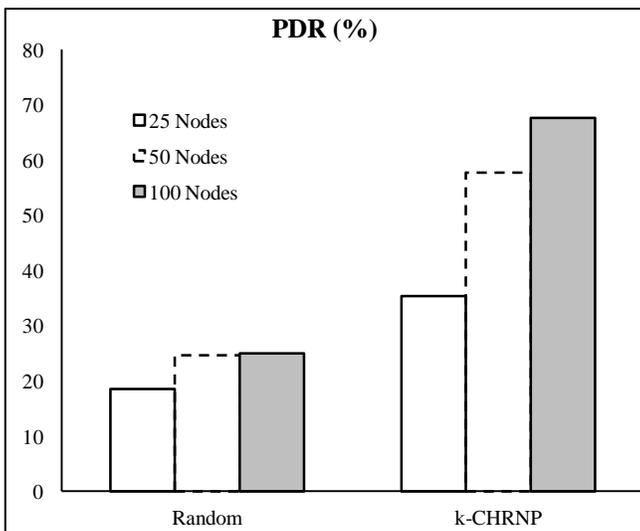


Fig.7. PDR

$$PDR = (Total\ Packets\ Sent / Total\ Packets\ Received) * 100.(1)$$

The PDR Value of k-CHRNP is increased, when the numbers of nodes are increased. k-CHRNP is approximately two times greater than the Random Deployment. Thus the data delivery ratio is higher than the random deployed network.

5.2 AVERAGE END TO END DELAY(SECONDS)

Average end to end delay is referred as the ratio between time taken for a packet to transmit from the source of time taken for a packet to transmit from the destination over the network.

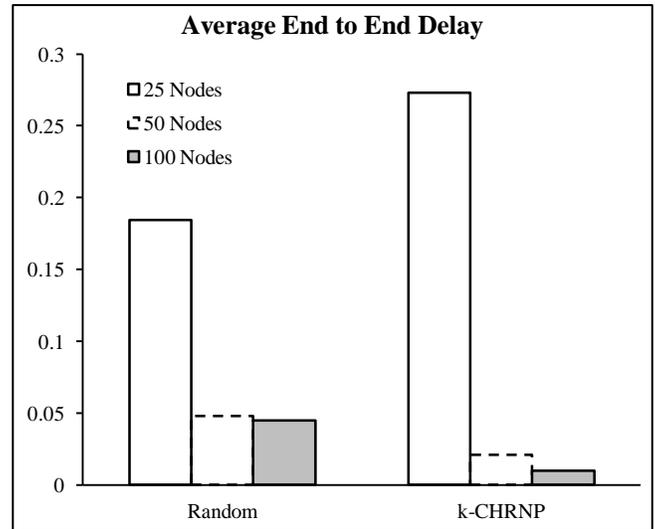


Fig.8. Average End to End Delay (seconds)

From Fig.8, the spider web based k-CHRNP algorithm takes some delay to transfer the data packets. Since the cluster heads are used for data transmission between nodes. Thus the network takes minimum traffic balance.

5.3 THROUGHPUT (BITS/SEC)

Throughput is defined as the rate of the message delivered successfully over the established communication channel. The server and client throughput value can be compared and percentage can be calculated as follows. The unit of throughput can be measured as (bits/Sec).

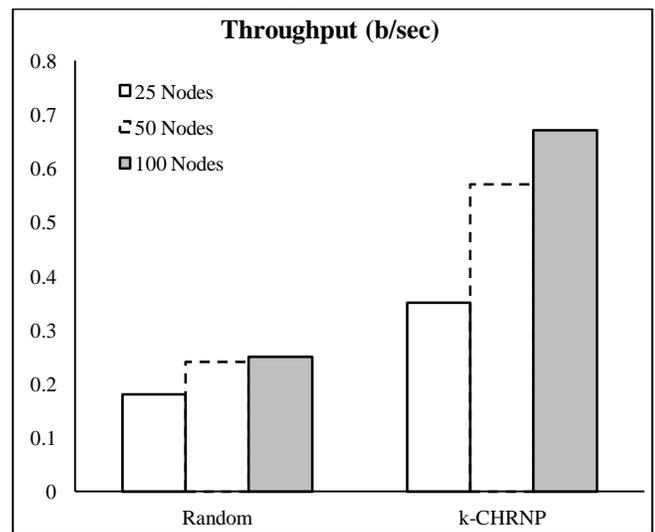


Fig.9. Throughput

The Fig.9 shows the throughput of Spider is better performance than the Random deployed Sensor node placement.

6. CONCLUSION AND FUTURE WORK

We enhanced the AODV protocol by adding convex algorithm in its function. The simulation takes a set of input coordinate location of deployed nodes and it generates set of output coordinate location of deployed nodes, in order to find the representative node of the cluster. Then the representative nodes from each segment are connected with other segments through the relay nodes. K-CHRNP achieved better performance in terms of PDR and Throughput. The future work involves adding a new layer in between transport and network layer to perform the topology control and topology maintenance. We planned to evaluate the protocol with other QoS metrics like control message overhead and energy consumption.

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