Neighbor Assisted Connectivity Recovery Protocol: An Efficient Deployment Approach for Improved Connectivity in Star Topology Wireless Sensor Networks

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Abstract - *The internet has grown and changed ever since the first connections were made in 1969. The problem of routing assignments has been one of the most intensively studied areas in the fields of data networks since then. Network routing essentially consists of two entities the Routing Protocol and the Routing Algorithm. The routing protocol provides each node in a network, a consistent view of the topology and the routing algorithm provides the intelligence to compute paths between nodes. The focus of this thesis is on Routing Algorithm. Neighbor Assisted Connectivity Recovery Protocol (NACRP),a new protocol to automatically restore connectivity in a star topology wireless sensor network (STP-WSN) when obstructions clutter the communication link between sensors and the AP. The contribution of our work is twofold: i) we detail NACRP that, to the best of our knowledge, provides a clean slate solution to the problem of connectivity and ii) we investigate connectivity and the trade-offs that arise from the adoption of the NACRP in the STP-WSN, relying on stochastic geometry and in particular on Poisson Point Processes (PPPs).*

Key Words: NACRP: Neighbor Assisted Connectivity Recovery Protocol, WSN: Wireless Sensor Network, STP-WSN: Star Topology Wireless Sensor Network, AP: Access Point, PPP: Poisson Point Processes

1.INTRODUCTION

Computer networks have been growing at an enormous rate ever since the concept was first proposed, for example, networks were first designed with two different purposes which later on merged to form the internet. The military network (MILNET) was designed to keep military communications working under a war. The American University Networks (National Science Foundation Network, NSFNET / Advanced Research Projects Agency Network, ARPANET) were designed to make the exchange of research results easier.

The basic function of a data network is very simple: delivering data from one network node to another. Data networks can be viewed as huge graph with routers as vertices and transmission lines as edges. On such a huge graph the data packets must find their way from the source to the destination. Routing can be described as the process of creating a logical connection between nodes in a network so that packets sent by a node can reach their destination [1].

The challenge in developing network routing algorithms is in dealing with the scale and distribution of the physical network. As wide area networks have nodes on the order of tens of thousands, routing algorithms must be scalable. Moreover, routing algorithms must be able to calculate paths in a distributed manner due to the global and distributive nature of physical networks. Also, routing algorithms need to cope with events such as node and link failures and recalculate paths whenever such events occur. Finally, routing algorithms need to calculate paths to allow nodes to achieve high network performance. [2]

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The IEEE 802.15.4k standard defines PHY and MAC layers specifications to support Low Energy Critical Infrastructure Monitoring (LECIM) networks. The standard supports simultaneous operation of at least 8 co-located orthogonal networks, with a transfer rate up to 40 Kbits/s, minimum 1000 endpoints per AP and reliable operations in dramatically changing environments. Channel time is organized in super frames, with each divided in several sub-beacon intervals (BIs) plus an optional inactive period delimited by the transmission of beacon frames transmitted by the AP.[3]

They proposed the asymptotic critical transmission radius for k-connectivity in a wireless adhoc network whose nodes are uniformly and independently distributed in a unit-area square provided a precise asymptotic distribution of the critical transmission radius for k-connectivity. The critical neighbour number for k-connectivity is the smallest integer such that if every node sets its transmission radius equal to the distance between itself and its nearest neighbour, the induced (symmetric) topology is k-connected [4]. Applying the critical transmission radius for k-connectivity, we can obtain an asymptotic almost sure upper bound on the critical neighbour's number for k-connectivity.

3. PROPOSED SYSTEM

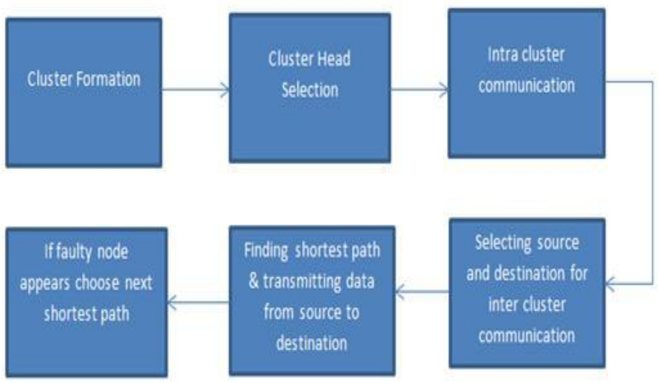

Fig 3.1: Block Diagram of the Project

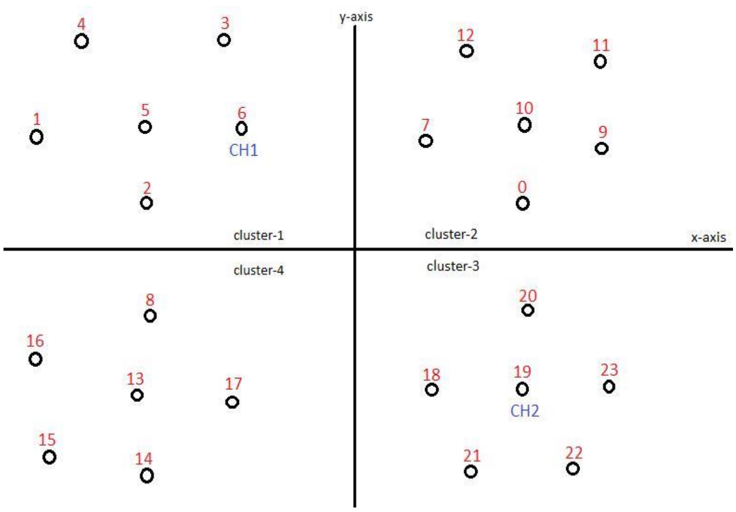

Fig 3.2: Network Structure

Wireless sensor network refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. Wireless sensor networks measure environmental conditions like temperature, sound, pollution levels, humidity, wind, and so on.

These are similar to wireless ad hoc networks in the sense that they rely on wireless connectivity and spontaneous formation of networks so that sensor data can be transported wirelessly. Wireless sensor networks are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to main locations. The more modern networks are bi-directional, also enabling control of sensor activity.

There are four clusters in fig 3.2. Clustering is done based on quadrant system. The total number of nodes which are in network are divided in x and y axis. The nodes which comes under first quadrant is known as cluster-1, the nodes which comes under second quadrant are known as cluster-2, the nodes which comes under third quadrant is known as cluster-3 and the nodes which comes under fourth quadrant is known as cluster-4. Each cluster will be having cluster head. The function of cluster head is aggregation of data from all cluster members and if any problem occurs with cluster members then they send message to cluster head and cluster head will send message to base station

4. CLUSTER FORMATION IN WIRELESS SENSOR NETWORKS

4.1 Quadrant System Cluster Formation

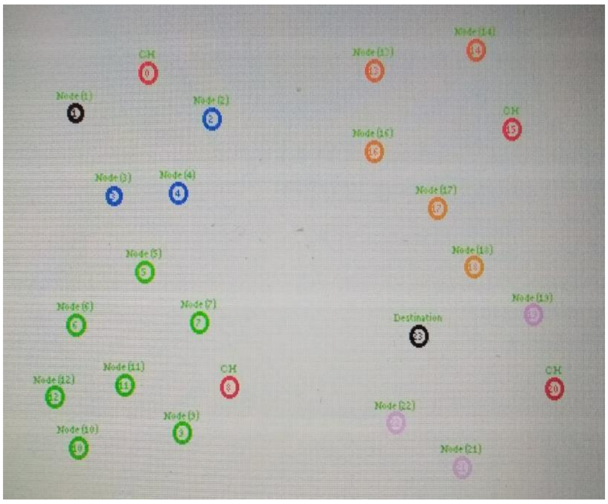

Fig 4.1: Cluster Formation

Fig 4.1 shows cluster formation in wireless sensor networks. In wireless sensor network all the nodes are divided in groups as shown in above figure. The nodes which belong to first quadrant are considered as cluster-1, the nodes which belong to second quadrant are considered as cluster-2 and the nodes which belong to third and fourth quadrant are considered as cluster-3 and cluster-4 respectively.

In some cases the nodes may located exactly between two clusters, as shown in above figure node-5 and node-18 are located exactly between two clusters then calculate the distance of that particular node to cluster heads of both clusters, then compare both the distances. Finally the node is belongs to less distance cluster head.

5. AN EFFICIENT APPROACH TO THE SELECTION OF CLUSTER HEAD FOR WIRELESS SENSOR NETWORKS

Cluster Head (CH) selection is the process to select a node within the cluster as a leader node. Wireless Sensor Network (WSN) is composed of nodes with non-renewable energy resource, elongating the network lifetime is the main concern. To support scalability, nodes are often grouped into disjoint clusters. Each cluster would have a leader, often referred as cluster head (CH). A cluster head is responsible for assigning the general nodes to route the sensed data to the target nodes. The power consumption of a CH is higher than non-CH nodes. Therefore, the CH selection will affect

the lifetime of a WSN [5]. By using following procedure cluster heads are selected:

1) Initialization

N = Total number of nodes

E = Current energy of a particular node

2) Calculate average energy of sensor nodes

$E_{avg} = \sum_{i=0}^{n-1} E_i$

3) Determine the nodes that are eligible for being cluster head

for I → 0 to N-1

begin

all nodes[i]= true;

if $(E_i < E_{avg})$

C[i] = false;

// not eligible for being cluster head

else

C[i] = true;

// eligible for being cluster head

end if

end

6. INTRA CLUSTER COMMUNICATION

The communication among one cluster members; usually the communication is from members to their head through single-hop or multi-hops. As shown in fig 3.2 Intra cluster communication occurs in cluster-1, means all the member nodes i,e node-1, node-2, node3, node-4, node-5 send message to cluster head i,e to node-6.

7. INTER CLUSTER COMMUNICATION

The transmission of cluster data outside it by its head is known as inter cluster communication. This transmission may be through single-hop to the base station or through multi-hops among clusters' heads towards the base station. As shown in fig 3.2 Inter cluster communication takes place between cluster-1 and cluster-3. Here, node-6 is source and node-19 is destination. Packets are sent through source node to destination node via shortest path i,e N6-N7-N10-N0-N20-N19.

8. PROCEDURE TO FIND THE SHORTEST PATH

8.1 Euclidean Distance [6]

The Euclidean distance is the ordinary straight line distance between two nodes in Euclidean space. According to the Euclidean distance formula, the distance (d) between two nodes in the space with coordinates (x1,y1) and (x2,y2) is given by

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

The distance between two nodes in three dimensions with Coordinates (x_1, y_1, z_1) and (x_2, y_2, z_2) is given by $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$

9. FAULT NODE RECOVERY

If there is a fault in the shortest path then routing algorithm provides another path to send all the packets. For example As shown in fig if fault is there in the node-20 then node-20 moves out from the cluster then link breaks then the packets will not be sent through this path because when control signal sent from source to destination through this path ,the acknowledgement will not be sent by the destination node. This indicates that there is a link failure in this path; therefore it takes another path to send the packets.

10. RESULTS

We have obtained simulation results in NS2 software for three cases i) when there is no fault in the communication link ii) when there is a fault in the communication link iii) when fault is avoided in the communication link. Simulation parameters are as following

Simulation parameters:

Number of nodes= 24
Packet size= 1540 bits
Antenna type= Omni directional
Routing protocol= NACRP
Simulation end time= 50ms
Maximum packet in ifq= 50

CASE1) When there is no fault in the communication link

Table1: When there is no fault in the communication link

A	B	C	D	E	F	G	H	I	J	K
1	Simulation Time	Sent	Received	Loss	PDR	Throughput	Delay	Jitter	Packet Size	Simulation End Time
2	10	0	0	0	0	0	0.325	0.0235	1540	10
3	20	0	0	0	0	0	0.285	0.0215	1540	20
4	30	0	0	0	0	0	0.295	0.0225	1540	30
5	40	20	20	0	100	770	0.299	0.0235	1540	40
6	50	109	101	8	92.66055	3110.8	0.285	0.0275	1540	50
7	Total	129	121	8	96.33027	1940.4				

Simulation time 50ms is divided into 0-10ms, 10-20ms, 20-30ms, 30-40ms, 40-50ms time slots. In column-c the sent packets in each time slot is calculated. In column-D the received packets in each time slot is calculated. In column-E the loss packets each time slot is calculated. During 0-30ms there is no packets are sent from the source therefore destination node will not be receiving any packets. During 30-40ms 20 packets are sent by the source and all 20 packets are received by the destination node. Therefore there is no loss in packets. In 40-50ms 109 packets are sent by the source and 101 packets are received by the destination. Therefore 8 packets are lost. The parameters used to compare all the three cases are packet delivery ratio, throughput, end to end delay and jitter

CASE2) When there is a fault in the communication link

Table2: When there is a fault in the communication link

A	B	C	D	E	F	G	H	I	J	K
1	Simulation Time	Sent	Received	Loss	PDR	Throughput	Delay	Jitter	Packet Size	Simulation End Time
2	10	0	0	0	0	0	0	0	1540	10
3	20	0	0	0	0	0	0	0	1540	20
4	30	0	0	0	0	0	0	0	1540	30
5	40	0	0	0	0	0	0	0	1540	40
6	50	0	0	0	0	0	0	0	1540	50
7	Total	0	0	0	0	0				

Simulation time 50ms is divided into 0-10ms, 10-20ms, 20-30ms, 30-40ms, 40-50ms time slots. In column-c the sent packets in each time slot is calculated. In column-D the received packets in each time slot is calculated. In column-E the loss packets each time slot is calculated. The control signal is sent to destination node by the source node, when there is a fault in the communication link acknowledgement from destination node will not be sent to source node. Therefore no packets are sent to destination and no packets are received by the destination node. Therefore all parameters like PDR, Throughput, Delay and jitter are zero.

CASE3) When fault is avoided in thecommunication link

Table 3: When fault is avoided in the communication link

A	B	C	D	E	F	G	H	I	J	K
1	Simulation Time	Sent	Received	Loss	PDR	Throughput	Delay	Jitter	Packet Size	Simulation End Time
2	10	0	0	0	0	0	0.335	0.0225	1540	10
3	20	0	0	0	0	0	0.315	0.021	1540	20
4	30	0	0	0	0	0	0.305	0.0225	1540	30
5	40	24	22	2	91.66667	847	0.305	0.0235	1540	40
6	50	105	97	8	92.38095	2987.6	0.298	0.0265	1540	50
7	Total	129	119	10	92.02381	1917.3				

Simulation time 50ms is divided into 0-10ms, 10-20ms, 20-30ms, 30-40ms and 40-50ms time slots. In column-c the sent packets in each time slot is calculated. In column-D the received packets in each time slot is calculated. In column-E the loss packets each time slot is calculated. During 0-30ms there is no packets are sent from the source therefore destination node will not be receiving any packets. During 30-40ms 24 packets are sent by the source and all 22 packets are received by the destination node. Therefore there is 2 packets are lost. In 40-50ms 105 packets are sent by the source and 97 packets are received by the destination. Therefore 8 packets are lost. The parameters used to compare all the three cases are packet delivery ratio, throughput, end to end delay and jitter.

10.1 PACKET DELIVERY RATIO

Table 4: Packet Delivery Ratio in all three cases

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0	0	0
20	0	0	0
30	0	0	0
40	100	0	92
50	93	0	92

The packet delivery ratio of all the three cases in each time slots is mentioned in table 4. The total simulation time 50ms is divided into time slots like, 0-10ms, 10-20ms, 20-30ms, 30-40ms and 40-50ms. When there is no fault in the communication link the packet delivery ratio is 96.5. When there is a fault in the communication link the packet delivery ratio is 0. When fault is avoided in the communication link the packet delivery ratio is 92. As shown in fig 10.1 when fault is avoided in the communication link, we have achieved 95.33% of packet delivery ratio.

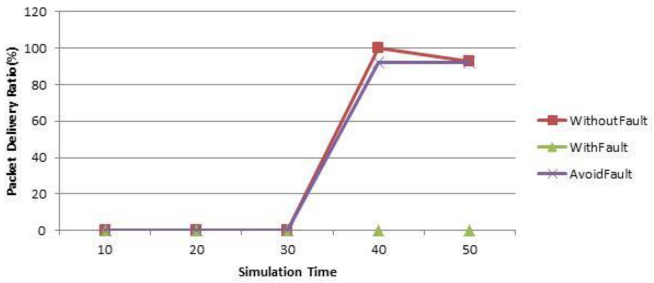

Fig 10.1: Packet Delivery Ratio Vs. Simulation Time

10.2 THROUGHPUT

Table 5: Throughput in all three cases

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0	0	0
20	0	0	0
30	0	0	0
40	770	0	847
50	3110.8	0	2987.6

The throughput of all the three cases in each time slots is mentioned in table5. The total simulation time 50ms is divided into time slots like, 0-10ms, 10-20ms, 20-30ms, 30-40ms and 40-50ms. When there is no fault in the communication link the throughput is 1940.4. When there is a fault in the communication link the throughput is 0. When fault is avoided in the communication link the throughput is 1917.3. As shown in fig 10.2 when fault is avoided in the communication link, we have achieved 98.80% of throughput.

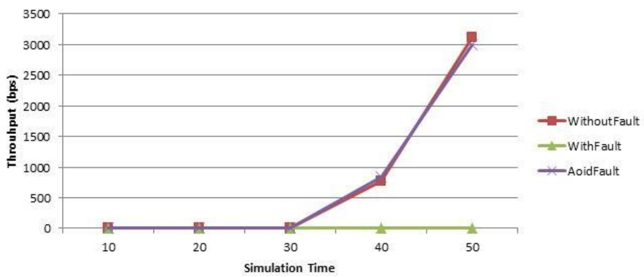

Fig 10.2: Throughput vs. Simulation Time

10.3 END TO END DELAY

Table 6: End to End Delay in all three cases

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0.325	0	0.335
20	0.285	0	0.315
30	0.295	0	0.305
40	0.299	0	0.305
50	0.285	0	0.298

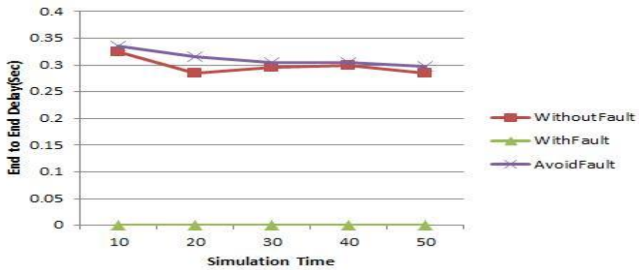

Fig 10.3: End to End Delay Vs. Simulation Time

10.4 JITTER

Table 7: Jitter in all three cases

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0.0235	0	0.0225
20	0.0215	0	0.021
30	0.0225	0	0.0225
40	0.0235	0	0.0235
50	0.0275	0	0.0265

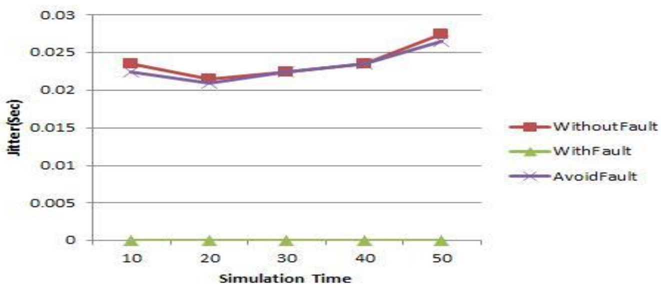

Fig 10.4: Jitter Vs. Simulation time

10.5 SENT PACKETS

Table 8: Sent Packets in all three cases.

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0	0	0
20	0	0	0
30	0	0	0
40	20	0	24
50	109	0	105

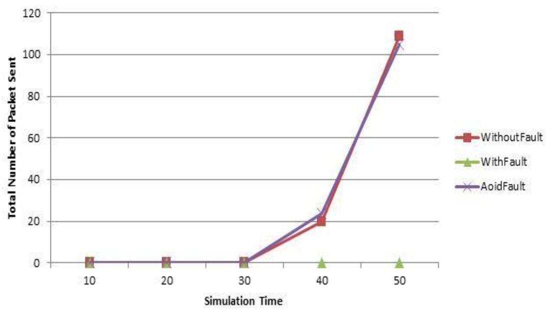

Fig 10.5: Total number of packets sent Vs. Simulation time

10.6 RECEIVED PACKETS

Table 9: Received Packets in all three cases

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0	0	0
20	0	0	0
30	0	0	0
40	20	0	22
50	101	0	97

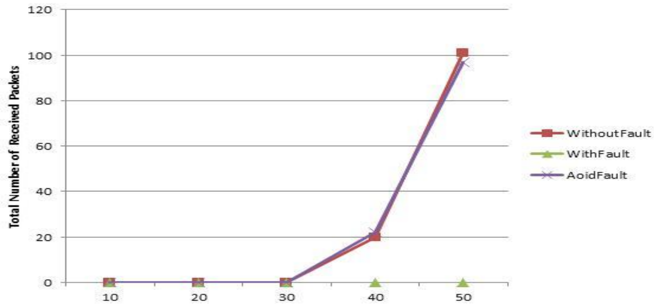

Fig 10.6: Total number of received packets Vs. Simulation time

10.7 LOSS PACKETS

Table 10: Loss Packets in all three cases

Simulation Time	Without Fault	With Fault	Avoid Fault
10	0	0	0
20	0	0	0
30	0	0	0
40	0	0	2
50	8	0	8

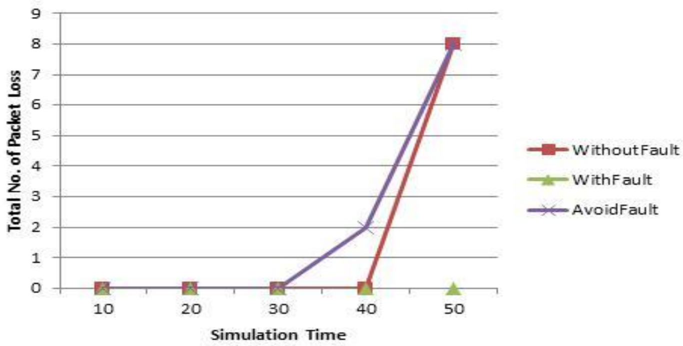

Fig10.7: Total number of loss packets Vs. Simulation time

CONCLUSION

In this paper how intra and inter communication takes place in wireless sensor network is shown using NS2 software. Clusters are formed using "Quadrant based cluster formation" algorithm. Cluster heads within the clusters are selected using "an efficient approach to the selection of cluster head for wireless sensor networks" algorithm. In Wireless Sensor Networks, distance between two nodes is calculated using Euclidean distance formula. Fault node is detected and provided other nearest neighbor path to transmit packets from source node to destination node.

In this method the packet delivery ratio, Throughput, end to end delay and jitter is calculated for the cases;

i) When there is no fault in the communication link ii) When there is a fault in the communication link iii) When fault is avoided in the communication link.

When fault is avoided in the communication link then we have achieved 95.33% of packet delivery ratio and 98.80% of throughput. End to End Delay is increased by 4.43%. Jitter is decreased by 2.1%.

Routing algorithm need to cope with events such as node and link failures and recalculate paths whenever such events occur. Finally, routing algorithms need to calculate paths to allow nodes to achieve high network performance.

FUTURE WORK

In future work, it must be concentrated on fully distributed clustering and try to simulate some other parameters for performance comparison.

Future work includes system scaling studies and parameter analysis. More tests can be done on larger test beds with different number of nodes and it can be extended to existing network models.

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