Coverage Hole Reduction in Wireless Sensor Networks using Swarm Technique

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Abstract: ***Proposed method tries to find holes by using information generated about network topology during route discovery and route maintenance. Each node in network maintains neighbour list, in which, name of each neighbour is stored along with status of respective neighbour. Individual nodes are responsible for maintaining status of neighbour. Each node also maintains routing table, in which routing information is stored along with pheromone value of each node. If for same destination, multiple entries are available in routing table of a node then the route with highest pheromone is selected. In this paper when a hole is detected in network path, to resolve this problem we have used three algorithms, first algorithm is routing protocol, second is hole detection algorithm and last one is to determine optimal hop count. The simulation results prove that the proposed swarm intelligence based technique remove excess burden on the network by routing algorithm used, when hole is detected in between path from source node to base station.***

Keyword: Wireless Sensor Networks (WSN), Swarm Intelligence, Source, Sink, Grid.

1. Introduction

A wireless sensor networks consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, enabling also to control the activity of the sensors. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer application, such as industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control [7]. The main characteristic of a WSN includes:

- Power consumption constrains for nodes using batteries or energy harvesting
- Ability to cope with node failures
- Mobility of nodes
- Dynamic network topology
- Communication failures
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions
- Easy to use

Wireless sensor networks represent a paradigm shift in wireless networks. They are being regarded as the enabling technologies for future surveillance-oriented application. A standard wireless sensor network consists of a large number of tiny sensor nodes. A sensor node basically consists of the following modules:

- The sensing module that collects information from the environment.
- The communication module that sustains wireless data communication between nodes.
- The processing module that processes the information provided by the sensor module or received from neighbour nodes.

2. Problem Formulation

A. Introduction

Holes in network decrease the efficiency of a network. Holes lead to uncovered regions in a sensor network, increased latency as more traffic will be sent via lesser route options which ultimately leads to early power exhaustion of the sensor nodes [1]. When data is to be transmitted and no route is available from Node A (White Colored Node) to Node B(Dark Gray Node) then route discovery is performed and when a route is established data transmission starts [11]. Fig.1 shows a sensor network deployed in a grid form and a source node i.e one of the sensor nodes want to report an event to the sink. As there is no route available therefore a route discovery is required.

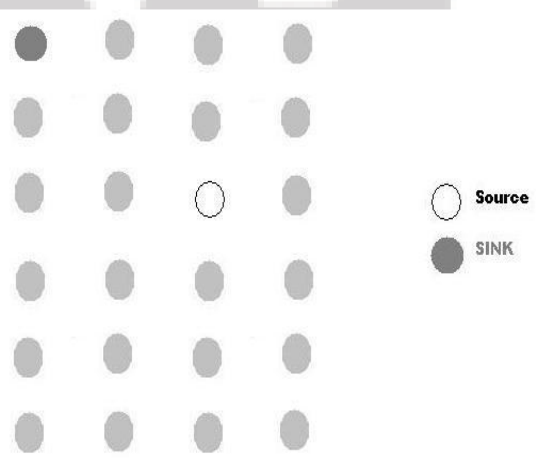

Figure 1: A grid network

Fig. 2 shows a path established between Source and Sink, which is obtained when route discovery is complete. But during transmission say one of the sensor nodes is damaged or its battery power drains then a new node is to be selected. This step is known as route maintenance. During data transmission, route maintenance is performed as soon as a link on an established route is broken. Different type of algorithm performs route maintenance in different way, but have same goal.

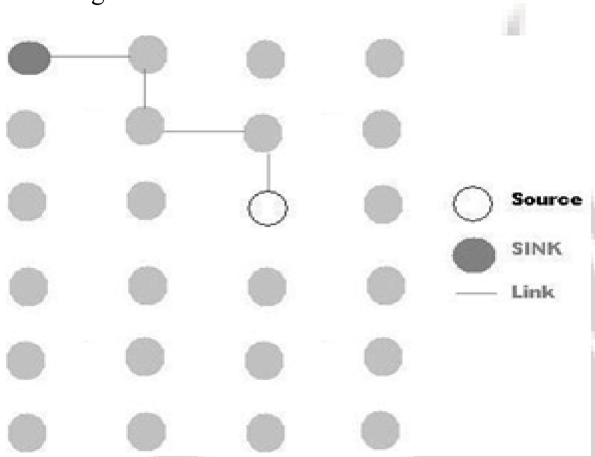

Figure 2: Route established between Source and Sink

In MANET, topology of a network keeps on changing as nodes can move from one location to another at any given time. Due to this dynamic topology when a link is broken it is best to choose any other available route as both source and destination node can change their location and even intermediate nodes may also posses dynamic properties. In a static wireless sensor network, nodes do not move and remain at same location at which they were deployed. Proposed protocol intends to use this basic property of a wireless sensor network. For a given static wireless sensor network, if route maintenance is required for any given transmission it means either any or some of the nodes have failed or any or some of the links amongst the nodes which were earlier available are no more available. So whenever such events occur, we propose hole detection algorithm should be performed.

B. Assumption for Proposed Protocol

In order to find the hole in network path, the following constraints have to be taken into consideration:

- Sensors in the network are placed to form a grid and coordinate of each node is known. Each node is static.
- Each node is at a distance of 1 Unit from its neighbours.
- Any given node can communicate with its neighbour located to top, bottom, right, left, top-left, top-right, bottom-left, bottom-right. Each node maintains neighbour table and routing table. Each entry in Neighbour table contains Neighbour name (NEIGH) and Neighbour state (NSTATE). NSTATE can have three values:

Table 1: Possible Neighbour State Values

Sr.	Value	Represents
A	1	Connected
B	0	Not Connected
C	-1	Dead

- Perform Swarm based route discovery are used to set Pheromone value of discovered path.
- Unique Sequence number is assigned to each new node over the path.
- Diagnostic the network when a non-responding node is found during route discovery or route maintenance.

C. Proposed Protocol

Proposed method finds the holes by using information generated about network topology during route discovery and route maintenance. Each node in network maintains neighbour list, in which, name of each neighbour is stored along with status of respective neighbour. Individual nodes are responsible for maintaining status of neighbour. Each node also maintains routing table, in which routing information is stored along with pheromone value of each node. If for same destination, multiple entries are available in routing table of a node then the route with highest pheromone is selected. Under this section we will discuss three proposed algorithms. First algorithm is routing protocol, second algorithm is a hole detection mechanism and last is a method to determine optimal hop count.

1) Algorithm-1

This is a routing algorithm that uses concept of swarm intelligence for discovering route from source to destination. This algorithm is also used to initiate another algorithm NODE-STATUS (NODE) which is our proposed hole detection algorithm and will determine if a node is dead or still alive, when communication link between two neighbours no longer exist. This algorithm may also be called when route maintenance is needed for any existing route [2].

SWARM_ROUTING (SOURCE S, SINK Si)

Step 1: S sends Status Information towards Si

Step 2: Next hop is chosen depending on routing table and neighbour table information
2.1: If NSTATE := 0 OR -1; Status Information is not sent to that NEIGH

2.2: If NSTATE := 1; STATUS INFORMATION can be sent to NEIGH

2.3: Route (if available) with highest pheromone value is chosen from routing table.

2.4: If no route is available STATUS INFORMATION will be broadcasted to neighbours after validating each neighbour with 2.1 and 2.2.

Step 3: If a NEIGH or selected Next HOP do not respond thenNPHER := 0;

NSTATE := 0;

and NODE-STATUS[NEIGH] will be initiated.

Current node will select an alternative route and send STATUS INFORMATION through that node.

Step 4: If no Next HOP is achievable from current node then previous node will beinformed to choose any alternative path.

Step5: If STATUS INFORMATION reaches destination it will be destroyed andSTATUS INFORMATION using route stack information will traverse back to source, incrementing pheromone level along the path.

Else Go To Step 2

2) Algorithm-2

This ensures that nodes impacted the sudden change in connectivity graph of network, be informed quickly. When a node dies all its neighbouring nodes will be impacted, so all these nodes must be informed so that in future communication they do not try to communicate with any damaged node. Using this algorithm, nodes in network will determine status of nodes and a perimeter will be set around damaged\dead nodes, on this perimeter will be around those nodes which are neighbour of dead\damaged nodes. So nodes can configure themselves for future communication and nodes along damage perimeter contain information about damaged nodes in the form of NSTATE in neighbour table. But sometimes it is needed that information of dead/damaged nodes be collected. For this we propose another algorithm, Algorithm 3, to determine optimal hop from source to destination. If there is a difference between optimal number of hops and actual hop count then a query can be sent on the same route to get details from neighbour list of nodes along the route.

NODE-STATUS (NODE N)

Step 1: S broadcast STATUS INFORMATION-STAT(N) to all NEIGH

Step 2: Nodes not having N in their neighbour table will destroy STATUS INFORMATION-STAT(N)packet.

Step 3: Node having N in their neighbour table will try to contact N

3.1: If N replies, NEIGH sends a STATUS INFORMATION-STAT(N,1) towards and NEIGH will

not pass STATUS INFORMATION-STAT to its neighbours. On receiving STATUS INFORMATION-STAT(N,1) all nodes in route to source including source will set NSTAT(N) := 0, signifying that N is still alive link between S and N no longer exist.

3.2: If N do not respond to NEIGH, NEIGH sets NSTAT(N) := -1 and send STATUS INFORMATION-STAT(N,-1) to the node from which it received STATUS INFORMATION STAT(N). NEIGH will also forward STATUS INFORMATION-STAT(N) to its neighbour. Go to Step 2.

3) Algorithm-3:

OPTIMAL-HOP(SOURCE X, DESTINATION Y)
X(X1,X2) gives coordinates of Source
Y(Y1,Y2) gives coordinates of Destination
Step 1: If Y1 = X1 //Scenario where nodes are on same axis
HOP: = |Y2 – X2|

Step 2: Else If Y2 = X2 //Scenario where nodes are on same axis
HOP: = |Y1 – X1|

Step 3: Else If (Y2 - X2) = (Y1–X1) //Scenario where nodes are on same axis
HOP := |Y2 – X2|

Step 4: Else
V_{inter} := min (|Y1 – X1| , |Y2 – X2|) //Obtain value to operate on S coordinates
If (Y1 > X1)

//S_{inter} gives value of intermediate coordinated to destination

Sinter := (X1 + Vinter , X2 + Vinter)

Else If (X1> Y1 & X2 < Y2)

Sinter := (X1 - Vinter , X2 + Vinter)

Else

Sinter := (X1 - Vinter , X2 - Vinter)

If (Y1 = $X1_{inter}$)

HOP := |X2 – $S2_{inter}$|+|$S2_{inter}$ – Y2|

Else If (Y2 = $X2_{inter}$)

HOP := |X2 – $S2_{inter}$|+|$S1_{inter}$ – Y1|

3. Results And Discussion

Simulation is done using the network simulator tool NS version 2.34. Comparison testing was conducted with other state-of-the-art routing algorithms such as DSDV and DSR. The aim of the experiment is to test and evaluate the performance of proposed protocol in comparison with DSDV and DSR under different network conditions. NS2 is an open-source event-driven simulator designed specifically for research in computer communication networks. Since its inception in 1989, NS2 has continuously gained tremendous interest from industry, academia, and government. Having been under constant investigation and enhancement for years, NS2 now contains modules for numerous network components such as routing, transport layer protocol, application, etc. To investigate network performance, researchers can simply use an easy-to-use scripting language to configure a network, and observe results generated by NS2. Undoubtedly, NS2 has become the most widely used open source network simulator, and one of the most widely used network simulators [3].

A. Evaluation Parameter

1) *Throughput*: Throughput of network is defined as total number of packets received at each destination node divided by total number of packets transmitted by each source node over the network.
2) *Loss-rate***:** Loss-rate of the network indicates number of packets dropped during transmission. It is calculated as total number of packets dropped per second in the network.
3) *Link delay*: It is the time taken by the link to transfer a packet from the source node to destination node.

B. Simulation Events

Under simulation Event, simulation parameters like number of nodes, network area, network type etc are defined which are crucial to a networks performance. We are going to discuss two events. In both events, coordinate location of each node is available. A sensor network composed of various nodes as shown in fig. 3 has been created using Tcl scripting. Green nodes represent active nodes in the network and yellow nodes represent those nodes that have lost connection with any of its neighbours. In fig. 4, node 6 is again turned to green signifying that node 6 is alive, but have lost connection with the node that initiated hole detection algorithm. In same figure node, 12 is colored red. Red nodes are used to signify dead nodes and possible region of hole.

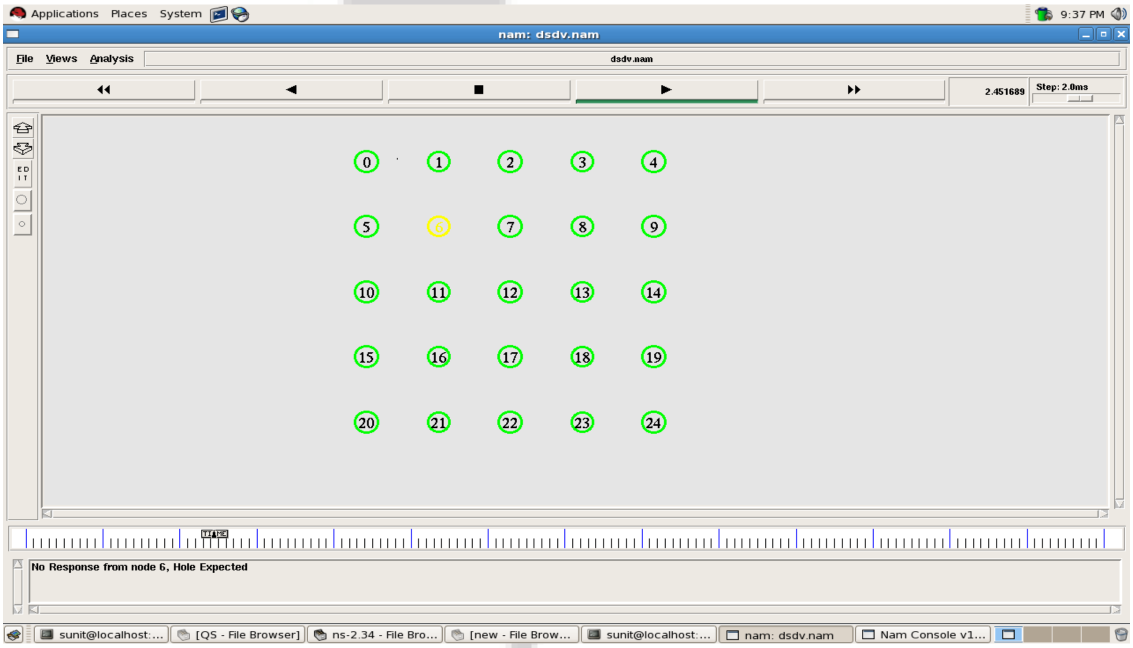

Figure 3: A sensor network depicting state of nodes in network

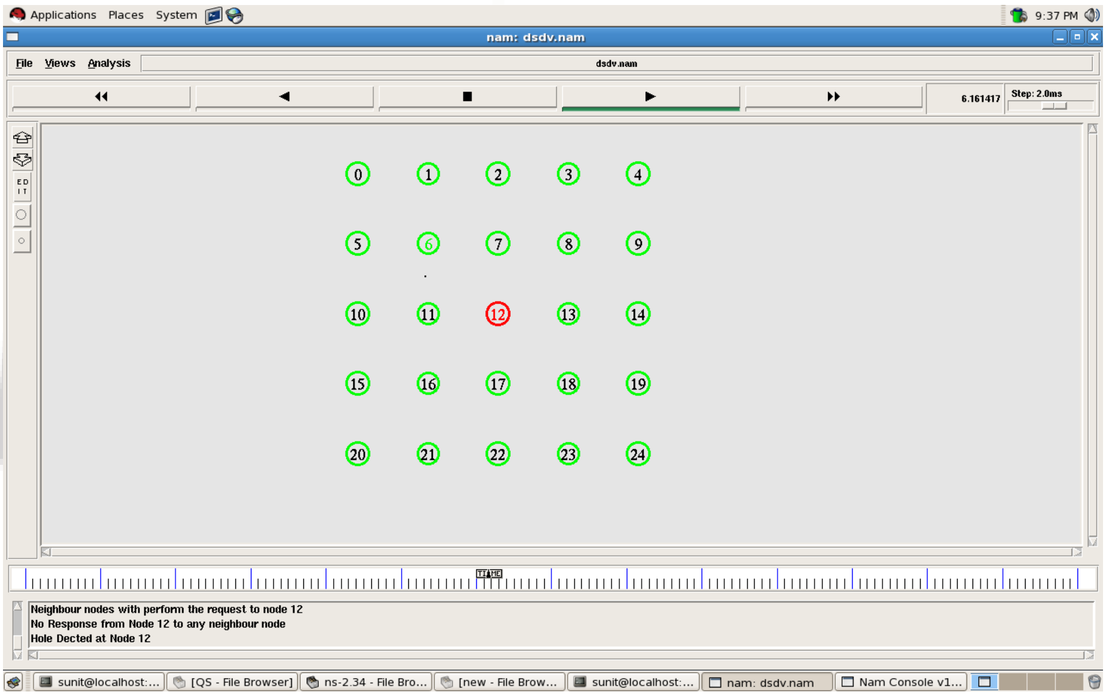

Figure 4: A sensor network depicting dead node in network

It simulates a wireless sensor network in NS-2.34. Different parameters of simulation event used by us for wireless sensor network are shown in the table number II.

Table 2: Simulation Parameter for Event 1

Parameter	*Value*
Number of Nodes	25
Topography Dimension	400 m x 400 m
Traffic Type	CBR
Radio Propagation Model	Two-Ray Ground Model
MAC Type	802.11.Mac Layer
Packet Size	512 bytes
Mobility Model	Random Way Point
Antenna Type	Omni directional
Network Topology	Grid

For Event 1, we compare our approach with DSDV protocol, which performs well where number of nodes in a network is small. In this event number of nodes is 25 and topological dimension is 400 sq. meter. Nodes are deployed in form of grid as shown in Fig.4 . Every given node is capable of communication with neighbours located at top, left, right, bottom, top-right, top-left, bottom-left, bottom-right. We assume that dead nodes, asymmetric links are emerging in network with time. Under Event I, nodes are failing at different location of network. At initial stage Node 0, is not receiving any response from Node 6, therefore it initiates hole detection procedure. But it turns out Node 6 is alive but it has lost connection with Node 0. Therefore, Node 0 sets NSTATE for Node 6, in its neighbour list as 0, which signifies direct connection not available. At later state in network, Node 11 do not receive response from Node 12 and hence Node 11 initiates hole detection procedure. With collaborative effort all neighbours of node 12 finds out that none of them is able to contact Node 12 and hence all neighbours mark Node 12 as dead and a perimeter is set all around dead node. The result discussed here are results obtained in form of graph by simulation using NS2 and mathematical computation.

1) End to End Delay: The end-to-end delay evaluates the efficiency of the routing methods. It is a critical parameter for network-layer routing performance. Routing algorithms that results in a high delay rate will experience greatly diminished throughput. Fig. 5 shows comparison of end to end delay for proposed protocol and simple wireless sensor network. Green line represents end to end delay for proposed protocol and red line represents end to end delay for simple wireless sensor network. For t=0 to t=30, delay of proposed protocol and simple wireless network is almost same. During this period proposed protocol encounters broken links and dead nodes, for which it initiates hole detection mechanism. Once this process is complete the delay for proposed protocol decreases as a result proposed protocol has low end to end delay as compared to simple wireless sensor network, so proposed protocol is more efficient than simple wireless sensor network.

2) Throughput: Throughput of network is defined as total number of packets received at each destination node divided by total number of packets transmitted by each source node over the network. Fig. 6 represents comparison of throughput for proposed protocol and simple wireless sensor network. Green curve represents proposed protocol and red curve simple wireless sensor network. In this graph, it can be observed that throughput of proposed protocol have more peaks then ridges as compared to throughput of simple wireless cluster sensor network, so proposed protocol is more efficient.

3) Packet Loss: High loss rate results in diminished data throughput and packet delivery ratio. Here, we measured packet loss by the number of dropped data packets at the source and intermediate nodes. Fig. 7 gives a comparison between proposed protocol and a simple wireless sensor network for packet loss during transmission. Green curve represents proposed protocol and red curve represents a simple wireless sensor network. It can be seen that red curve is having much higher peaks as compared to our proposed protocol. By using proposed protocol it has been determined which nodes are dead, therefore those nodes are not contacted in future, thus decreasing quantity of lost packets. So proposed protocol is more efficient.

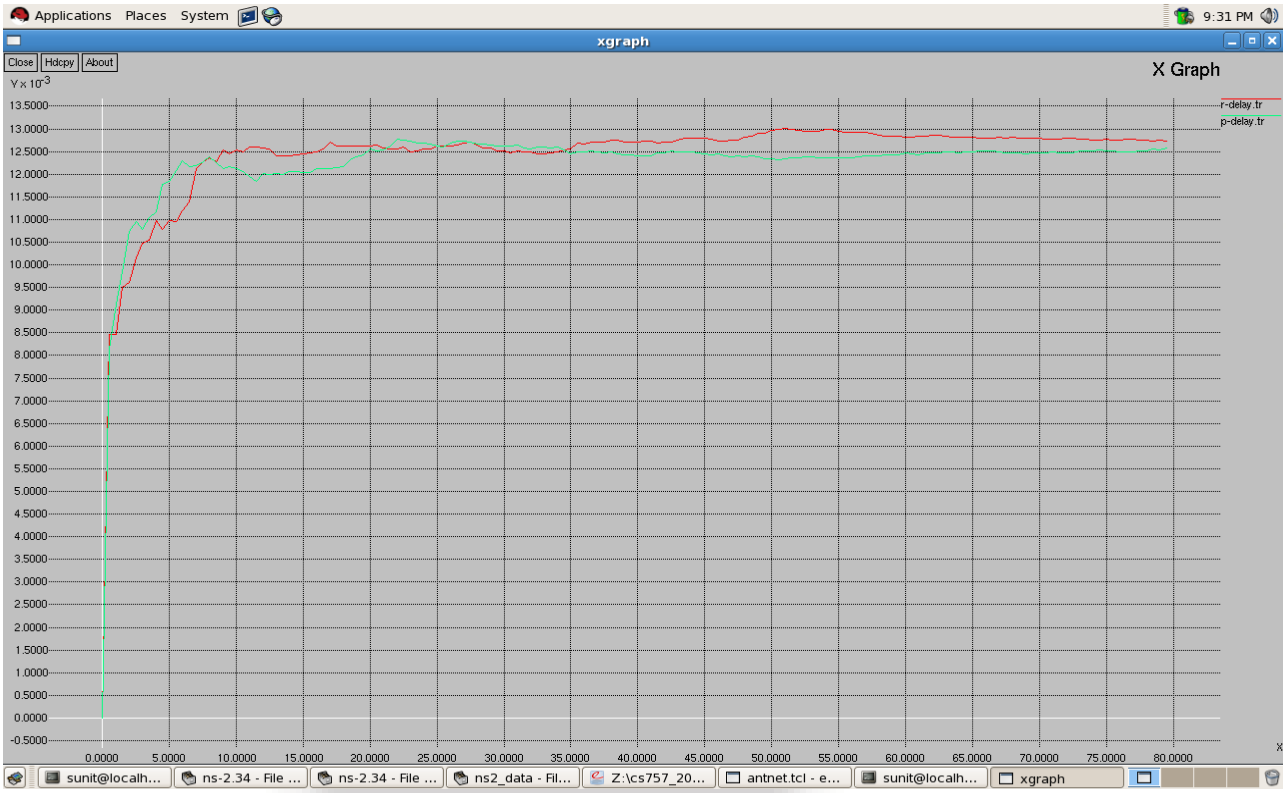

Figure 2: Comparison of Link Delay for Proposed Protocol with Simple WSN

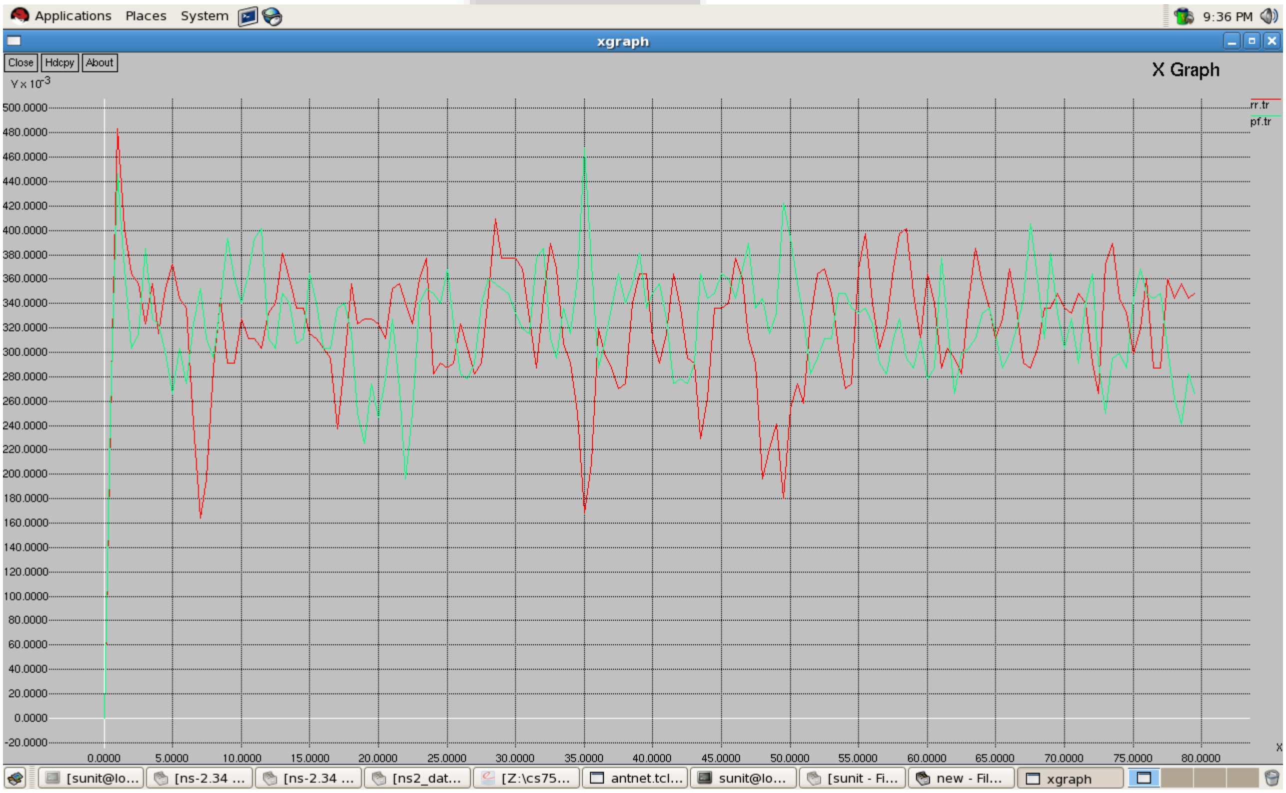

Figure 6: Comparison of Throughput for Proposed Protocol with Simple WSN

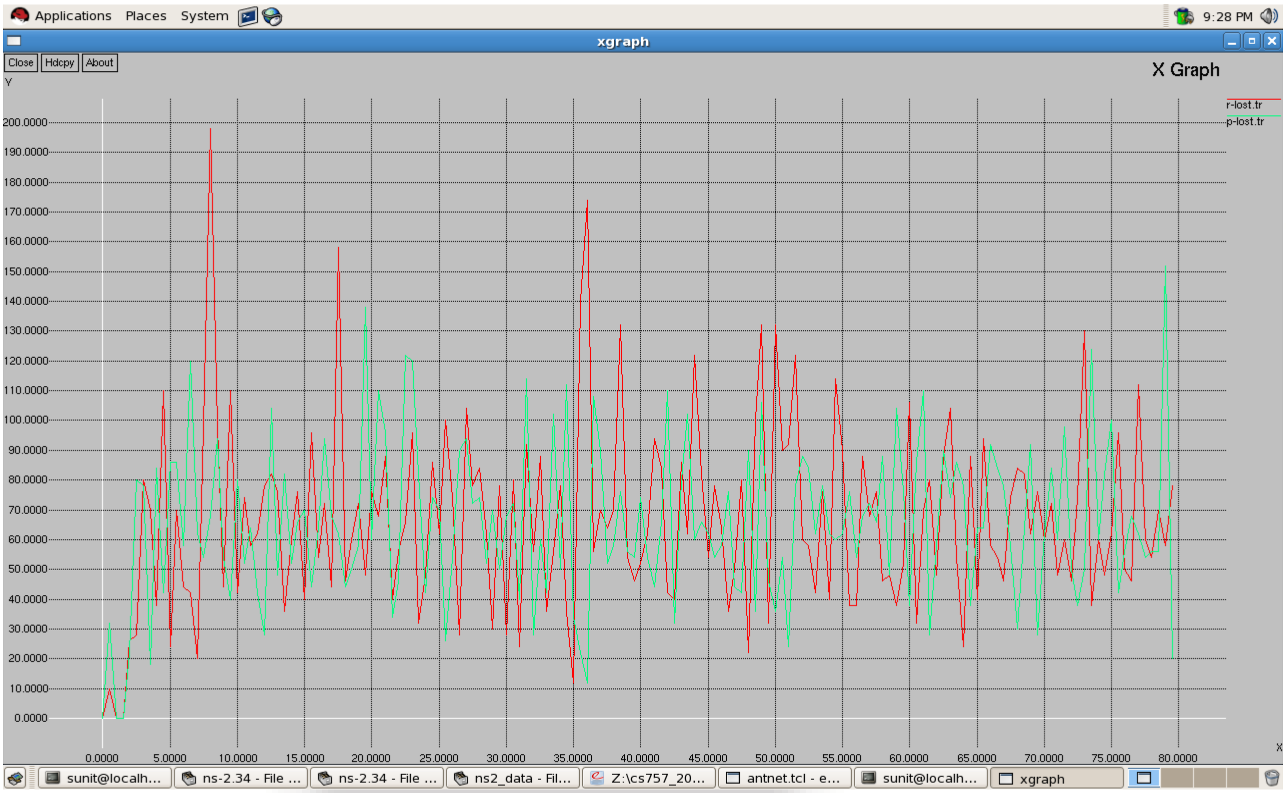

Figure 2: 7Comparison of Packet Loss for Proposed Protocol with Simple WSN

4. Conclusion and Future Scope

Every bit transmitted can provide lots of information about network. For example when sink receives data sent by some sensors node, by using route information sink node or control room can obtain lots of information. We tried to use one such concept to know if route followed is optimal or not. For this a novel procedure to determine optimal number of hops for a given node to sink was proposed. If sink node determine that route is not optimal it can send a query to nodes using same route through which data is coming to send name of neighbours which are dead. Advantage of this approach is that, it does not need route discovery as route is already available which is used by sensor node to send data. Thus very less resource of network used to get information about dead nodes. The proposed routing algorithm is similar to most swarm based algorithm, the only difference is how it handles when a neighbour do not respond to a route discovery request or when a existing route breaks. We proposed that whenever route maintenance is initiated or any neighbour do not respond NODE-STATUS or node diagnostic must be initiated. Advantage of this technique is that we are not adding any additional burden on network in the form of dedicated communication for hole detection, rather we are sensing node behaviour along route. Performance of this approach may be even better in sensor networks where sink node feed query into network at periodic event to obtain specific information. Limitation of our proposed mathematical computation is that it can be used only in a WSN where network is deployed in the form of grid and coordinates of each node are known. As we try to find optimal HOPCOUNT, coordinates of source and destination are important parameter in entire computation. So without coordinates our entire mathematical computation will collapse. Another limitation is the way hole detection initiated. We proposed that hole detection be initiated when route maintenance is initiated or a neighbour do not respond.

In this paper various concepts of WSN and different type of holes are discussed. Proposed system is for coverage holes in WSN mainly. There are several other type of holes like black hole, gray hole, jamming hole, routing hole etc. so work can be done in direction of detecting any or all of these holes. Moreover few evaluation parameters to compare performance of our proposed technique with other state of art routing protocols, so better experimental results can be obtained by considering more evaluation parameter.

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