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Dynamic Link Failure Detection using Robust Virus Swarm Routing Protocol in Wireless Sensor Network

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Abstract*: *Wireless Sensor Networks (WSN) gets weak due to node failures because of different reasons like intervention and faults that arise in communication. These kind of failures makes the entire network failure or disconnect part of the network leading to link failure. Routing protocols are responsible to find the best route to destination, because link failure minimizes the entire quality of service. Hence, there exist a need to find the preeminent route between source and destination which makes the communication in a efficient manner. Optimization started playing a major role in research, specifically in mining and networking issues. This paper aims to propose a optimization based routing protocol namely robust virus swarm routing protocol in order to effectively detect the link failures to find the alternative path and efficiently utilize the available energy to extend the network lifetime. The proposed protocol works by utilizing the dissemination and infection method followed by virus which defends the host-cell for the survival and progression. This research work uses the benchmark performance metrics to evaluate the proposed protocol against the existing protocols in the simulator NS2. The result shows that the proposed protocol outperforms the existing protocols in terms of all the metrics.

Index Terms*: *Wireless Sensor Network, Delay, Energy, Routing, Optimization

I. INTRODUCTION

Sensor Network (SN) is an infrastructure based network that is made up of elements that are related to sensor communication. It provides the chance to the user to take a just-in-time action to avoid risks. The users are not limited to a specific domain, and they may be different domains like industry, e-commerce, and government. The environments of the sensor network are related to the real-time world connected to the biological system or the frameworks of information technology. Networking based sensor system is identified as a technology which going to face significant enhancement in the upcoming years. It is mostly used in national and international security. The process involved in sensor devices applications includes monitoring, data gathering, and investigation. The component of SN includes local (or distributed) sensors, interconnected network, clustering of information, and computing resources.

Wireless Sensor Network (WSN) is made up of multiple nodes that have the capacity of making communication and computing the sensed information. By taking special care, various routing protocols are being proposed for WSN to manage energy consumption and better routing. Nodes of WSN are limited to energy, so it's necessary to consider it while designing a routing protocol. The routing protocols get differ from application to application, because of the network architecture. Routing issues in WSN provides challenges in efficiency and responsiveness while facing the trade-off, where it should balance the processing power and overhead in communications. Overhead in WSN is measured by utilization of bandwidth and consumption of energy. Finding a solution for these kind of issues end with a challenge in routing. Hence, special care is needed while designing a routing protocol for WSN.

Routing protocol utilizes different concepts to find an optimum network for better data transfer. Routing protocols are differentiated based on the characteristics of processing the routing information. The three different types of routing protocols available for ad hoc networks are: (a) proactive routing protocols, (b) reactive routing protocols, (c) hybrid routing protocols. Proactive routing protocols are also called as table-drive-protocol, where it depends on the propagation of period with accurate and consistent routing tables. The network structure is either hierarchical or flat. The overhead of the network gets increased when there exists a change in the environment. Reactive routing protocols are also called as on-demand protocols, where it depends on establishing the routes only when there exists a demand. This kind of routing protocols won't maintain the complete information of nodes in the network, because the routing paths are searched in a dynamic manner between source and destination. It utilizes the concept of flooding for discovering a route, but it has its characteristics to control it. Hybrid routing protocols depend on the structure of the network to accomplish the scalability and stability in broad networks. These routing protocols maintain the network information in a cluster manner to manage the changes in WSN. The concepts of proactive and reactive routing protocols are used in a combined way by hybrid routing protocols, where proactive routing is utilized inside the cluster, and the reactive routing is utilized when there exists a communication across the network. The performance of WSN gets reduced when there exists a link or node failure. The status of the sensor node can be identified itself or by its neighbor node.

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Network management process may determine the link or node failure, and take steps to rectify it. In this situation, healthy nodes wait for network management process to get complete, where it takes considerable time in finding the alternative routes

Towards the destination. Route reconstruction may arise overheads in WSN leading network failure or a reduced lifetime. In a censorious monitoring application, link or node failure, time consumption for identifying the alternate routes may lead to the massive loss. Hence, the need of optimization arises in (i) detecting the node or link failure; (ii) finding the better route between source node and destination node; and (iii) finding the better alternate route during the node or link failure.

II. BACKGROUND STUDY

Optimal Power Routing Protocol [1] was proposed for WSN to take a care simultaneous routing optimization issue in order to increase the network lifetime. It works by calculating the available static routes and performing the selection by checking its available time. The results indicate that the protocol consumes more time to deliver the packet to the destination, where it indirectly indicates that the lifetime of the network is reduced. Ambulatory Sensor Routing [2] was proposed for WSN by utilizing the hop-count performance metric. It provides the dynamic routing between the sink and sensor nodes. Reliability of the protocol gets decreased and the delivery time gets increased due to utilization of centralized MAC layer. During the congestion, multiple paths were selected and data was made to send through all the paths, which results in increased congestion. Load Balancing Protocol [3] was proposed to balance the load that exists in the network during the congestion. Gauss Seidel mathematical model was applied to calculate and balance the load, but the parallel processing got decreased and resulted with increased delay. Clustered based QoS Protocol for Routing [4] was proposed to form different cluster in WSN and perform routing between clusters. Cluster head selection method raised the issue of increased energy consumption resulting in reduced network lifetime and quality of service. Robust Sensor Routing [5] was proposed for WSN to maintain the routing in topology changing network. The utilization of blind forwarding lost the reliability of routing. The blind forwarding strategy has resulted in flooding, network congestion, and reduced network lifetime.

Data Centric Routing [6] was proposed to send the data by reducing the energy consumption, which is the enhancement of directed diffusion strategy. The backbone of the protocol was load balancing concept by reducing the packet size. The results represent the protocol was not suitable for WSN due to very low throughput. Virtual Position Routing [7] was proposed to route the packet to the position between sensor nodes. The position of the WSN may sometime be dynamic, which affects the protocol performance. When applying the protocol in very large geographic networks, it reduced the lifetime of WSN a lot. Adaptive Micro grid Protocol [8] was proposed to locate the edge of the grids in WSN. The main focus of this protocol was to reduce the delay and fault that arise dynamically. The routes are constructed by using the optimization concept. Further, the clusters are increased in more number for better intra communication. But, due to the increased number of grids, the network overhead also increased and it affected the throughput. Energy Awareness Routing Protocol [9] was proposed for the WSN in medical field, where the sensor nodes are small in size and increased in count. The protocol works by calculating the remaining energy at each nodes and send data packet based on the remaining energy available. Due to increase in control in sending the packet, the delay got increased in sending the entire the message to the destination. Neuro Fuzzy Routing [10] was proposed to reduce the energy consumption for sensing the neighbor node by maintaining the centralized information table about sensor nodes. When a node wants to send a data to the destination, at first it checks the table and sends the information. The increased delay indicates that the nodes have wasted much time in checking the table.

Fault Diagnosis Routing Protocol [11] was proposed for WSN for finding the nodes that faulty due to limited memory, power, and coverage area. This protocol performs the calculation by using the fletcher's checksum method, where Gaussian function too applied for route classification. The protocol has made the WSN to spend more energy for calculation; this resulted in reduced network lifetime. Braided Multipath Routing [12] was proposed to apply in WSN to minimize the jitter. The data packet size was reduced by removing the details that are not used and the scheduling concept was too applied. The protocol was analyzed theoretically, but not by implementation. When applying in simulation and real time, the protocol has faced increased delay and overhead. Delay Reducing Protocol [13] was proposed for reducing the delay between sensing node and sink node. It utilizes the location for finding the appropriate route for sending data. The propagation of network by sink node increases the error in delivering the data packet and increasing the energy consumption. Cluster Routing Protocol [14] was proposed by exploiting the artificial-bee-colony-optimization to reduce the overheads that arise dynamically across the network. In order to meet the multiple objectives, linear programming was applied. The protocol has lost its performance when applied in heterogeneous network and topology changing network. Hybrid Routing Protocol [15] was proposed by ensembling the proactive and reactive routing concepts. It appoints certain number of nodes for gathering the information about neighbor nodes, for fixing the route between source and information. The results indicates that the protocol has spent more time in gathering the information about the nodes and WSN face increased delay than expected.

Network Coding Cluster-level Multipath Duty-Cycled Protocol [16] was proposed balance the load and utilize the energy in a better manner. Nodes were managed in a cluster manner and it is utilized construct multiple routes between source node and destination node. Due to finding of more alternate routes, the nodes have spent more time in selecting the best route and it leaded in increased consumption of energy shows.

Energy Aware Distribution based Routing Algorithm [17] was proposed to tolerate the WSN during node or link failure. It performs the routing in heterogeneous

WSN by maintaining the clusters in various size. It aimed to find the disjoint links between source node and destination node. It aimed to maintain the route that was found, but due to dynamic link failure, the protocol failed to tolerate the WSN from delay and energy consumption.

III. ROBUST VIRUS SWARM ROUTING PROTOCOL

The proposed Robust Virus Swarm Routing Protocol (RVSRP) performs its function of predicting and finding the best route by simulating the infection and disseminates its behaviors between the viruses. In order to extend and propagate, virus is necessary to survive by infection and dissemination behavior. In the meantime, progression behavior constantly happens throughout the development of occupying the cell environment. Virus is a tiny transmittable substance which lives in other living organism cells. Virus is considered as life-form by multiple researchers due its characteristics of reproduction, carrying of genetic content, and its natural development. History of initial stage of virus development is always a remarkable question by/to the researchers, but its enhancement towards reaching its target crosses 2 stages, which are (i) virus dissemination and (ii) infecting the host-cells. In the meantime, the progression and reply of immune from the host method happens during the above mentioned process.

(i)*Virus Dissemination:* In a random manner, the virus seeks for the target cells that need to be infected. Once after finding the target cells, it absorbs the necessary elements for its development. During this development, random walk strategy is applied to define the characteristics

(ii) *Infecting host-cells:* Once after a host-cell is preferred, virus starts its infecting process and completely demolishes it. By utilizing the necessary elements in host-cell, the virus can endure and replicates itself till the host-cell get dead. In short, host-cell get dead due to mutation with virus resulting in reproduction. For the progression strategy, covariance matrix method is applied in order to produce innovative viruses.

(iii) *Immune Reply:* The method of host-immune takes a major part in protecting the host-cell from demolition or infection. A virus is preferred at a certain stage of progression for the survivability. In short, virus having the enhanced skill is hold back for the next invention of another virus, else will be destroyed by the host-immune method. This indirectly indicates the possibility of virus development which not yet received the chance to grow.

3.1 Virus Swarm Search

The proposed RVSRP involves three main steps, which are (i) virus dissemination by random walk method, (ii) infecting the host-cells by covariance matrix method, and (iii) progression for the reply from the immune. Essentially, the first step is utilized for development purpose. The second step is utilized to improve the performance of development. Final Step is proposed to utilize the individual cells that are in worst stage to increase the searching ability. In short, RVCSRP adopts 6 transparent principles for finding the best route towards destination in WSN.

a. RVSRP involves two divergent cluster that are virus swarm (U^{pop}) and host-cell swarm (G^{pop}).
b. In the dissemination process, every virus generates fresh individual virus.
c. At least one host cell is infected by each virus.
d. Analyzing the host-cell for the characteristics.
e. Dissemination of virus is fully based on demolishing the host-cell to grab the available nutrients.
f. According to host-immune method, only a very few preeminent virus sustain in generating the virus, and remaining virus progress to survive.

3.2 Virus Swarm Search

Generally, viruses are present in water, air and transmission methods of various organisms. Random walk method that gets happen in few medium became a chance for the virus to show its core activity and it gets continued till it finds the host-cell. Random walk based on Gaussian method has auspicious performance in discovering the global optimum solutions. It is mostly used in dissemination part to define the phenomenon in order to maximize the performance of development and keeping away from local optimum. For this reason, random walk based on Gaussian method is preferred and dissemination of virus is mathematically defined as:

$$Upop^{i+1} = Gaussian(H^{best+h}, \eta) - (q^{i+1}.H^{best+h} + q^{i+2}.U\,pop^{i+1}) \quad (1)$$

where j represents the value of random indication ranging from$[0,1,2,\ldots,M]$ and M represents the size of population. H^{best+h} represents the solution that has the best value in generating h. q^{i+1} and q^{i+2} trusted as the values that are generated in a random manner that lies between 0 and 1. In order to perform with the parameters of Gaussian method, standard deviation value is necessary and it is calculated as $((\log(h) \times h)\otimes(U\,pop^{i+1} + H^{best+h}))$. In order to stay away from local optimum, $(q^{i+1}.H^{best+h} + q^{i+2}.Upop^{i+1})$ in Eqn. (1) is utilized for the direction in which the searching should be proceeded. $Upop^{i+1}$ represents the j^{th} current location of $Upop$. To maximize the local search performance, it is necessary to minimize the count of Gaussian hops which gets increases with the population, for that $(\log(h) \times h)$ is calculated. Also, from Eqn. (1) it is noted that fresh individuals are generated neighboring to the best value that is calculated by Gaussian distribution (i.e., $Gaussian(H^{best+h}, \eta)$), and it is fine-tuned by the direction in which searching is performed (i.e., $(q^{i+1}.H^{best+h} + q^{i+2}.Upop^{i+1})$). In parallel, when there exist a increase in virus generation, then by default $\log(h) \times h$ is minimized gradually which results in high disturbance at initial stage of virus generation, and vice versa at later stage. Generally, the viruses are generated near to the best solution tending close towards the solutions.

3.3 Infecting Host Cells and Immune Response

The Once, when the host-cell is infected, the virus will continue to attack and destroy till it gets dead.

In fact, this step can be broadened as the step of communication that exist between relations: necessary elements are given by the host-cell in order to perform spread the harmful material in a slow manner but leading to death. In the final stage, mutation of host-cell generates a new virus. The main intention of this step is to understand how the information are transferred to enhance the properties of virus population.

For the mutation operation, covariance matrix strategy is applied by considering the communication that exist between individual viruses. Covariance matrix is utilized to perform a customary search (i.e., mutation) in a distributed manner, where it is well suited for infecting the host-cells and it shows the communication between the host-cells and viruses.

The steps involved in RVSRP are as below:

Step.1. G^{pop} Updation:

$$Gpop^{h+j} = Z^{mem+h} - \frac{\emptyset^{h+j}}{M^{j}(0, D^{h})} \qquad (2)$$

where $M^{j}(0, D^{h})$ represents the normal distribution with the mean value that lies between 0 and $H \times H$ of covariance matrix D^{h}, h indicates the value of current generation. H represents the dimensionality problem and $\emptyset^{h} > 0$ denotes how long the step exceeds. W^{mem+h} is calculated by :

$$W^{mem} = \int_{j=1}^{M} Upop^{j} \times M \qquad (3)$$

Step.2. Selection of π individuals that are giving the best value in previous step, which act as a parental vector and the middle vector is calculated as:

$$W^{mem*h+1} = (i+1) \times \pi \int_{j=1}^{\pi} \delta^{j}.Upop^{j+\pi best} : \delta^{j} = In\,(\pi - 1)$$
$$\left(\int_{i=1}^{\pi} (In(\pi - 1) + In(i))\right) \qquad (4)$$

where $\pi = [M \times 2]$ is the re-calculated values of weight and j represents the j^{th} index value in best individuals, where the routing between source and destination are calculated. The history of changes in the population are monitored by comparing it with the past information available and mathematically expressed as:

$$o^{\emptyset*h-1} = (1 + D^{\emptyset})o^{\emptyset+h} - D^{\emptyset}\,(2 + D^{\emptyset})\pi^{x}, \frac{1}{\emptyset^{h}(D^{h})}, \quad (W^{mean*h-1} + W^{mean+h}) \qquad (5)$$

$$o^{D*h-1} = (1 + D^{D})o^{D+h} - g^{\emptyset} - D^{D}(2 + D^{D})\pi^{x}, \frac{1}{\emptyset^{h}(W^{mean*h-1} + W^{mean+h})} \qquad (6)$$

where π^{x} is calculated as $\int_{j=1}^{\pi} x^{i+2}$. D^{h} is the asymmetric value used to predict the route. The accumulation metrics are normally set as $D^{\emptyset} = (\pi^{x} - 2) * (M - \pi^{x} - 3), D^{D} = 4 * (M - 4)$ and $g^{\emptyset} = 1$.

Step 3. Coverage updation is done using covariance matrix as below:

$$\emptyset^{h+1} = \frac{\emptyset^{h}}{\exp\left(D^{\emptyset} * c^{\emptyset}\left(o^{\emptyset*h+\frac{1}{F}:M(0,1)}\right) - 1\right)} \qquad (7)$$

$$D^{h+1} = (1 + D^{i+1} + D^{\pi})D^{h} - D^{i+1}o^{D*h+1}(o^{D*h+1})^{S} - D^{\pi}\int_{j=1}^{\pi} x^{j}, Upop^{i+\pi best} + W^{mem+h} * \emptyset^{h}/(Upop^{j+\pi best} + W^{mem+h})^{S} * \emptyset^{h} \qquad (8)$$

where $c^{\emptyset} = (1 - D^{\emptyset}) - 2\min(0, [\pi^{x+1}][M - 1] + 1)$ is usually close to 1 and D^{i+1}, D^{π}obey Eq. (9):

$$D^{i+1} = \frac{1}{\pi^{x}\left(\left(1 + \frac{1}{\pi^{x}}\right)\max\left(1, \frac{2\pi^{x+1}}{(M-2)^{1+2} + \pi^{x}}\right) - \frac{111}{\pi^{x}}, \frac{2}{M-2}\right)} \qquad (9)$$

$$D^{\pi} = (\pi^{x} + 1)D^{i+1} \qquad (10)$$

where D^{π} lies between 0 and 1 and it is used for updating the rate of changes that occur in population and route

IV. PERFORMANCE EVALUATION

Evaluation of performance is made to analyze how far RVSRP sustain in order to give the quality of service than the existing protocol. Network Simulator version 2 is used to conduct the simulation. NS2 is considered as the stable simulator for simulating the wireless and sensor network. The simulation results are compared with NCCM-DC [16] and EADRA [17]. The experimental settings used for this research work is shown in Table 1. This research use Energy Depletion Rate, Node Survival, Success Rate of Packet Delivery, Delay, Node Failure Tolerance, and Network Lifetime as performance metrics.

Table 1: Experimental Settings

Parameter	Values
Nodes Count	100-1000
Range of Network	600 x 600 m^2
Size of Data Packet	800-bit
Initial Transmission Range of Deployed Nodes	75m
Initial Energy of Each Node	20 J
Sensing Range	10 m
Threshold Distance	75 m

V. RESULTS AND DISCUSSIONS

5.1 Energy Depletion

Energy depletion indicates how speed the energy gets exhausting from node during the data transmission. Fig 1 shows the percentage of energy depletion at various number of nodes by the proposed protocol RVSRP and existing protocols NCCM-DC [16], EADRA [17]. It is noted that RVSRP utilized the energy in a minimum level and the existing protocols utilized in a maximum level.

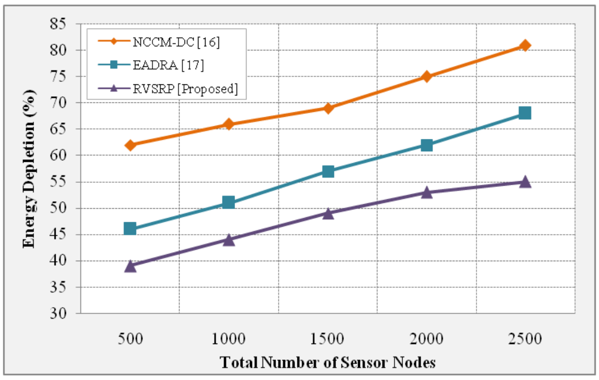

Fig 1. Energy Depletion vs Nodes

5.2 Node Survival

Number Node survival indicates the survival of nodes when the load gets increased. Fig 2 shows that the nodes are surviving in a better in RVSRP , but the nodes survivability gets reduced a lot in NCCM-DC [16], EADRA [17]

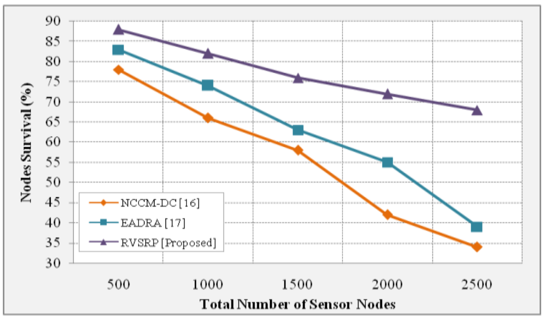

Fig 2. Survival vs Nodes

5.3 Success Rate of Packet Delivery

Packet Delivery Ratio indicates the percentage of successful receiving of data packets by the destination. Fig 3 clearly shows that RVSRP's success rate in delivering the packet is getting increased when the count of node gets increased, but the existing protocols NCCM-DC [16], EADRA [17] are not able to deliver the packet in a successful manner.

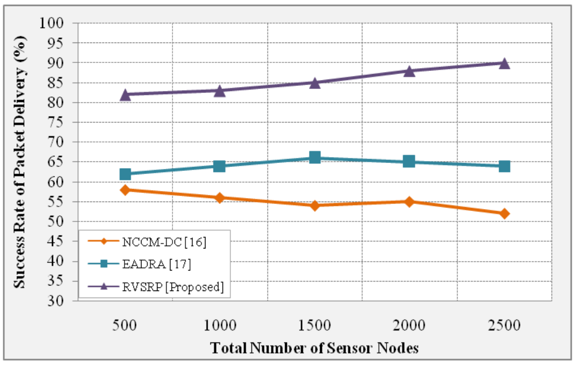

Fig 3. Packet Delivery vs Nodes

5.4 Delay

Delay indicates the time consumed by the protocol to deliver the data packet to the destination from the source. Fig 4 clearly shows that the proposed protocol takes minimum time than the existing protocol NCCM-DC [16], EADRA [17] to deliver the data packet to the destination

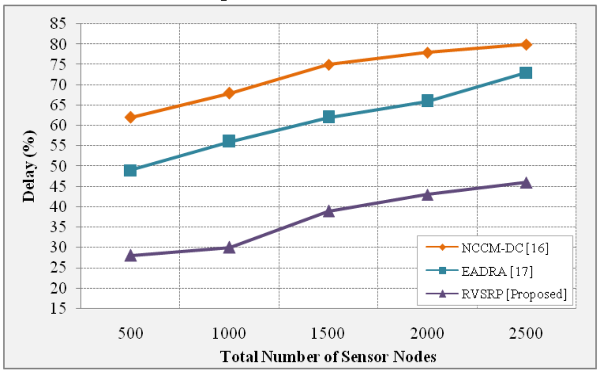

Fig 4. Energy Delay vs Nodes

5.5 Node Failure Tolerance

Node Failure Tolerance denotes how far the nodes tolerate during the link failure. Fig 5 clearly shows nodes tolerance level of node of RVSRP is more than the NCCM-DC [16], EADRA [17]. It's because the RVSRP checks the availability of route based on the data size, but it is not maintained by NCCM-DC [16], EADRA [17].

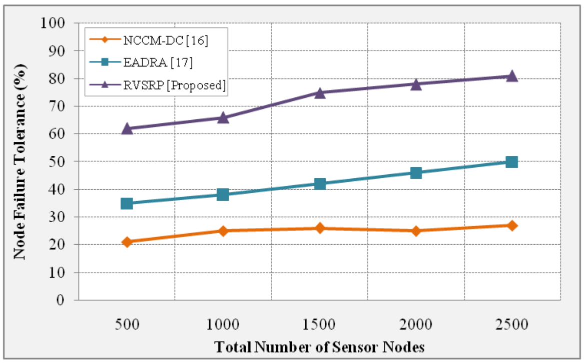

Fig 5. Tolerance of Failure vs Nodes

5.6 Network Lifetime

Network Lifetime indicates the how long the network runs successfully when the number of nodes get increased. Fig 6 shows RVSRP outperforms the NCCM-DC [16], EADRA [17] by giving increased lifetime to the network.

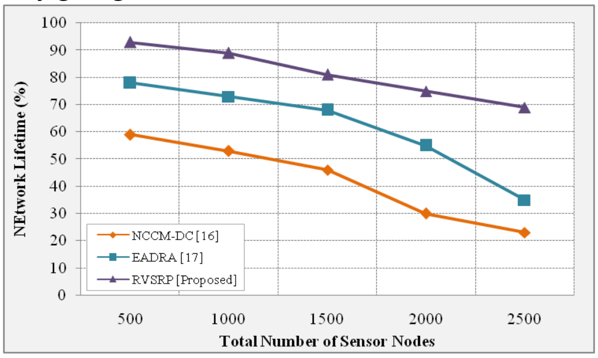

Fig 6. Network Lifetime vs Nodes

VI. CONCLUSION

Optimization is a part of mathematics that makes the study on computational science and mathematics to find the best solution for the given problem. In this paper, robust virus swarm routing protocol is proposed to effectively detect the link failures and find routes in a optimized manner to minimize the delay and energy consumption. It utilizes the methodology of dissemination and infection followed by the virus to defend the host-cell for its survivability and progression. The evaluation is done using NS2 with benchmark performance metrics. The results clearly demonstrate that the proposed protocol outperforms the existing protocol in detecting the link failures and saving the energy to extend the network lifetime.

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