OPTIMIZATION OF SPEED PROTOCOL USING GENETIC ALGORITHM IN WIRELESS SENSOR NETWORK

Gaganpreet Kaur
PG Scholar
GZS PTU Campus
Bathinda, Punjab, India

Abhilasha
Department Head
GZS PTU Campus
Bathinda, Punjab, India

Abstract— A Wireless Sensor Network (WSN) consists of a large number of distributed autonomous devices called sensor nodes (SNs). Sensor nodes monitors physical or environmental conditions like temperature, sound, vibration, pressure at different locations. Different wireless sensor network applications, like battlefield surveillance, health monitoring, disaster management and earthquake response systems, are developed to cope up with fast changing events in the real world. Each underlying communication infrastructure is required to meet real-time constraints and Quality-of-Service (QoS) requirements. Spatiotemporal communication protocol, called SPEED, is a real-time QoS protocol. SPEED supports spatiotemporal communication service by ensuring a desired delivery speed across the sensor network, and making end-to-end delay proportional to the distance between the source and destination. Limited power resources pose a great challenge in meeting QoS real-time routing. The purpose of the research carried is optimize SPEED protocol routing using Genetic Algorithm (GA).The whole simulation is taken place in the MATLAB environment.

Keywords— Wireless Sensor Network (WSN), Quality-of-Service (QoS), SPEED, Optimization, Genetic Algorithm (GA).

INTRODUCTION

Wireless Sensor Networks (WSNs) consists of a large number of portable tiny sensor nodes, randomly dispersed in a sensing field. Sensor nodes (SNs) sense, process and transmit the physical and environmental conditions data like temperature, pressure, sound to other sensor nodes and to sink node. Small size, lower cost and multifunctional sensor nodes have imposed very considerable resource constraints in WSN. Different constraints on resources are bandwidth, memory, buffer size, transmission capacity and energy/power consumption of the sensor nodes. The sensor networks can be, used in a vast variety of fields like military environment, disaster management, habitat monitoring, medical and health care etc. [7]. Power constraints, limited hardware, decreased reliability, and a typically higher density and number of failure nodes are few of the problems that have to be considered while developing the protocols for use in sensor networks [7]. Routing of data packets is a challenging face in WSN. In WSN routing protocols are categorized as network structured and protocol operation based protocols. Network structure is further divided into three different classes" viz. flat routing, hierarchical routing, and location-based routing protocols. Protocol operation based routing protocols are divided into negotiation based, query based, quality-of-service (QoS) based, and multi-path based routing protocols. Various WSN applications like disaster management and fire detection require real-time QoS response for effective and accurate results of the system. A lot of research studies are being done on Quality-of-Service (QoS) routing protocols to enhance their efficiency. Limited resource constrains like limited power energy, limited communication capability, limited processing and storage capacity make it difficult to design a WSN meeting QoS real-time routing. Many designed QoS routing protocols are SAR (Sequential Assignment Routing) [5], SPEED (Stateless Protocol for End-to-End Delay) [2], MMSPEED (Multipath Multi SPEED) [3], QEMPAR [6], REAR (Reliable Energy Aware Routing) [12], MBRR (Majority Based Re-Routing) [11], TBRR (Tree Based Reliable Routing) [13] etc. The protocol discussed in this paper is SPEED. SPEED is a real-time QoS routing protocol, but some deficiencies like node failure or congestion leads to dropping of the data packets decreasing the performance and quality of the system. To achieve a better quality of WSN SPEED in fusion with optimization algorithm Genetic algorithm (GA) is designed in this paper.

Remaining paper is organized as Section II will contain the related work or literature survey, Section III will contain the Basic concept of proposed work, Section IV will contain proposed work, and Section V will contain results and simulation, and finally Section VII will contain the conclusion part.

RELATED WORK

The rising interest in real-time QoS based routing in WSNs has received a considerable attention from the research community. Many QoS based routing protocols have been survey in [10]. This section gives a brief discussion about work related to proposed method.

Akyiddiz, et al. surveyed on sensor networks [1]. Sensor networks come into existence by the union of micro-electro-mechanical system technology, digital electronics and wireless communications. They cover a wide range of new and exciting application areas for remote sensing. Different factors like fault tolerance, cost, scalability, topology change, hardware, environment and power consumption introduces constraints on the design of sensor network.

Sohrabi, et al. proposed first QoS routing protocol Sequential Assignment Routing (SAR) [5]. The objective of this algorithm is to make a WSN energy-efficient and fault tolerant. SAR a multipath routing protocol makes its routing decision based on different factors viz. energy resources, QoS on each path, data packet's precedence level. SAR suffers from a drawback of overhead involved in maintaining the routing path tables and QoS metrics at all sensor nodes.

He, et al. proposed real-time QoS routing protocol SPEED [2]. Spatiotemporal communication protocol SPEED is a stateless, localized routing protocol with minimum control overhead. This protocol maintains end-to-end soft real time communication by assuring desired delivery speed of routing data packets across the network. In SPEED routing of packets is done through a novel combination of non-deterministic geographic forwarding and feedback control loop.

Felemban, et al. designed another QoS protocol called Multi-path and Multi-Speed Routing protocol (MMSPEED) [3]. MMSPEED overcomes one of the deficiencies of SPEED protocol by providing many delivery speeds for different data packets. This protocol supports two quality of service domains namely, timeliness and reliability. Timeliness is provided by multiple delivery speeds and reliability is achieved by using probabilistic multipath forwarding scheme. Various other developed QoS routing protocols are REAR, QEMPAR, and MBRR etc [7].

Kumbharana, et al. compared different optimization algorithms viz. Ant Colony Optimization (ACO), Genetic Algorithm (GA), Simulated Annealing (SA) for solving Travelling Salesman Problem (TSP) [8]. Travelling Salesman Problem is an example of classical optimization problem, which is difficult to be solved by using conventional mathematical approach. ACO, GA and SA are used to solve TSP. GA performs better than both ACO and SA, if number of cities are increased in TSP.

BASIC CONCEPTS

A. SPEED Protocol

SPEED supports soft real-time communication service by maintaining the required delivery speed across the network so that the end-to-end delay is minimized. Each node keeps information only about its immediate neighbors and utilizes geographic location information to make localized routing decisions. The protocol is called "stateless," as it does not use routing tables for storing routing paths of the data packets. Different components viz. an API, a neighbor beacon exchange scheme, a delay estimation scheme, the Stateless Non-deterministic Geographic Forwarding algorithm (SNGF), a Neighborhood Feedback Loop (NFL), Backpressure Rerouting, and last mile processing are used in packet forwarding [2]. Stateless Non-Deterministic Geographic Forwarding (SNGF) routing module selects the next hop neighbor. It works in coordination with 4 other modules namely backpressure rerouting, beacon exchange, neighborhood feedback loop (NFL), delay estimation, at the network layer to maintain the desired delivery speed across the sensor networks. The neighbor beacon exchange component finds the geographic location of the neighbor nodes by sending beacons across the network in timely manner. The geographic location of the neighbors is stored in the neighbor table. The delay estimation component calculates the delay in each node, which helps the SNGF to select the node meeting speed requirements and also helps to determine the occurrence of congestion. If a node meeting required delivery speed requirement can't be found, the relay ratio of the node is calculated. The relay ratio is calculated by the Neighborhood Feedback Loop (NFL) component. The Relay Ratio tells whether the packet should be dropped or relayed in a network. If the relay ratio is less than a number between 0 and 1, which is randomly generated, the packet is dropped. The backpressure rerouting component is activated if congestion or voids exist. This component sends packet back to source node so that rerouting of packets can be done to new routes.

The limitation of SPEED protocol is that it does not consider any packet differentiation mechanism. It gives the same preference to both real time and non-real time data packets [4]. It is not scalable, as it maintains a single desired speed for each packet and if the parameter is changed then protocol performance degrades. Energy metric and reliability is also not mentioned in this protocol.

B. Genetic Algorithm

Genetic algorithm (GA) also called global heuristic algorithm is an example of Evolutionary Algorithm (EA). Evolutionary algorithms (EAs) are random search methods that imitate the metaphor of natural biological evolution and the social behaviour of species [9].Genetic Algorithm is motivated by Charles Darwin's principle of "survival of the fittest" in selecting the fittest solution from the existing ones. In GAs, a random population of chromosomes is created to test against the fitness using suitable fitness function. An objective or fitness function is related with each chromosome that refers the degree of goodness of the chromosome. Based on the principle of survival of the fittest, fittest chromosomes are selected to undergo the process of producing offspring chromosomes. Biologically inspired operators viz. crossover and mutation are used on these chromosomes to produce offspring. The process of selection, crossover and mutation is continued for a large number of generations till a termination condition or a best-fit solution is obtained.

PROPOSED WORK

In this section, a novel optimized SPEED routing protocol using Genetic Algorithm (GA), named SPEED-GA is presented. The SPEED-GA extends the Spatiotemporal real-time communication SPEED routing protocol [2] by fusion with GA.

In WSN, sensor nodes may be failed or be congested due to deficient rechargeable power resources, physical damage or increase in the traffic. SPEED is a real –time QoS routing protocol which needs to deliver a data packet to the destination within a certain time period, if the packet cannot be reached within the time period, the packet is dropped back decreasing the performance of speed protocol. Node failure or congestion leads to, large amounts of dropping of the data packets, which may lead to devastating consequences. To address these issues, this research paper proposes a new optimized SPEED protocol in case of packet dropping by using GA.

A. Methodology

Firstly, the wireless sensor network (WSN) is deployed with a finite number of sensor nodes, randomly in a fixed sensor area. The source and destination nodes are selected randomly for data transmission path establishment. For the path establishment, nodes under the radio coverage area of source are found. Forwarding Candidates Sensor nodes are chosen from the coverage-set area and Euclidean distance is calculated between source and destination. If the distance is less than the defined radio range, the destination lies in the coverage area of sensor node and the packet is transferred directly to the destination. If distance is greater than the radio range, Stateless Non-Deterministic Geographic Forwarding (SNGF) routing algorithm is used for transmission of data packets. If dropping of data packets occur Genetic Algorithm is initialized with hundred initial population sizes.

Parameters like node speed, average speed, mutation function and crossover intermediate function are configured. Fitness function is called and each node is tested against the fitness function to check its goodness. The procedure continues until the fitness criterion is not meet and destination is not found.

B. Flow-chart

Figure1. Shows the different steps of methodology in form of the flow chart of the proposed methodology that is SPEED- GA.

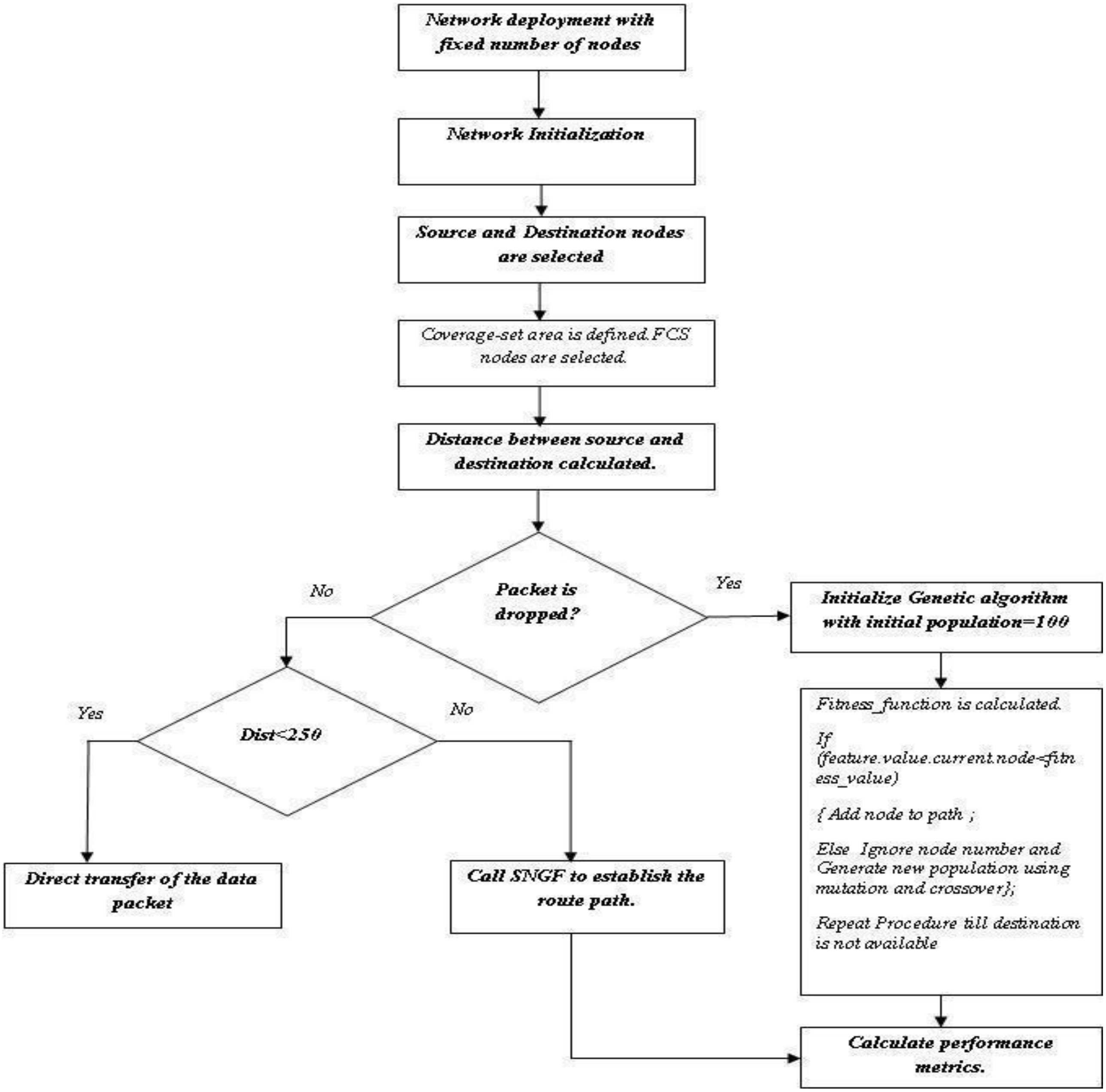

Figure1. Flow-chart of proposed work

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SIMULATION AND RESULTS

In this section, proposed work algorithm that is SPEED-GA is compared with SPEED routing protocol. Both SPEED and SPEED-GA is simulated on Matrix Laboratory (MATLAB) software for performance comparison. MATLAB is a high performance programming platform that integrates computation, visualization and programming environment [15]. Different QoS metrics like throughput, bit error rate (BER), packet delivery ratio and average end-to-end delay are used in this paper to evaluate the performance of both simulated approaches. Simulation setup is constructed by keeping the network area fixed of 1000*1000 m^2 and varying the number of deployed nodes in the network from 100 to 200 nodes. The result of different simulation rounds for the performance metric is calculated and these results are used to compute the average result per round for different metric. Then average result per round for the metric is plotted on the graph with respect to the varying number of nodes deployed in the sensor network. Simulation environment are shown in Table I. Nodes are deployed in a random fashion in the network area. Source and destination nodes are also selected randomly. Genetic algorithm is initialized with an initial population of size 100. Parameters configured in GA are mutation with mutation uniform function of 0.03 and crossover with crossover intermediate function of 0.8.

TABLE I
SIMULATION PARAMETERS

Parameters	Value
Routing Protocol	SPEED, SPEED-GA
Network Size	1000 m * 1000 m
Number of Nodes	100, 150, 200
Node Distribution	Random and Uniform
Data Packet Size	512 bytes
Radio Range	250 m

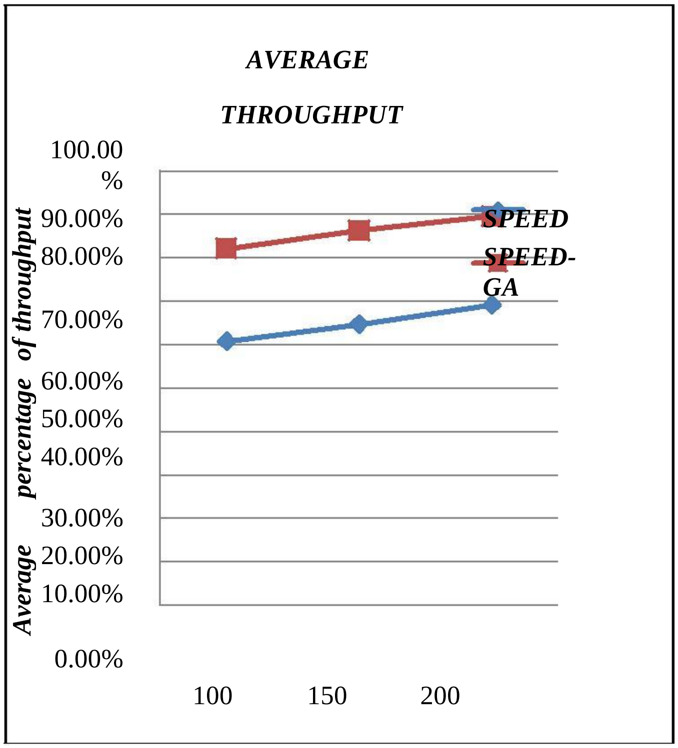
The simulation results of SPEED and SPEED GA are discussed below.

A. Throughput

Throughput is a QoS metric to determine the performance of a routing protocol. It is defined as number of data packets successfully transferred from source to destination in a given time period. Figure2 shows the plot of throughput for both SPEED and SPEED-GA. In this paper throughput is calculated in percentage form. From the figure2, it is concluded that proposed algorithm SPEED-GA has more throughput than SPEED routing protocol. The figure also tells that the throughput of the network increases with the increase in the number of nodes of the network. The increase in throughput is because of the availability of more nodes in the routing process of the network which decreases the chances of packet dropping.

B. Bit Error Rate (BER)

The bit error rate (BER) is defined as the percentage of bits having errors in relation to the total number of bits successfully delivered in a transmission [14]. The BER is a warning of how frequently a data packet has to be rerouted because of an error. Figure 3 show that SPEED protocol has a higher percentage of BER as compared to SPEED-GA. Figure tells that BER decreases with increasing number of nodes. More the number of deployed sensor nodes in the network, more will be the successful transmission decreasing the BER of the network.



Nunber of sensor nodes Figure 2.Snapshot for comparison of throughput plot when nodes vary.

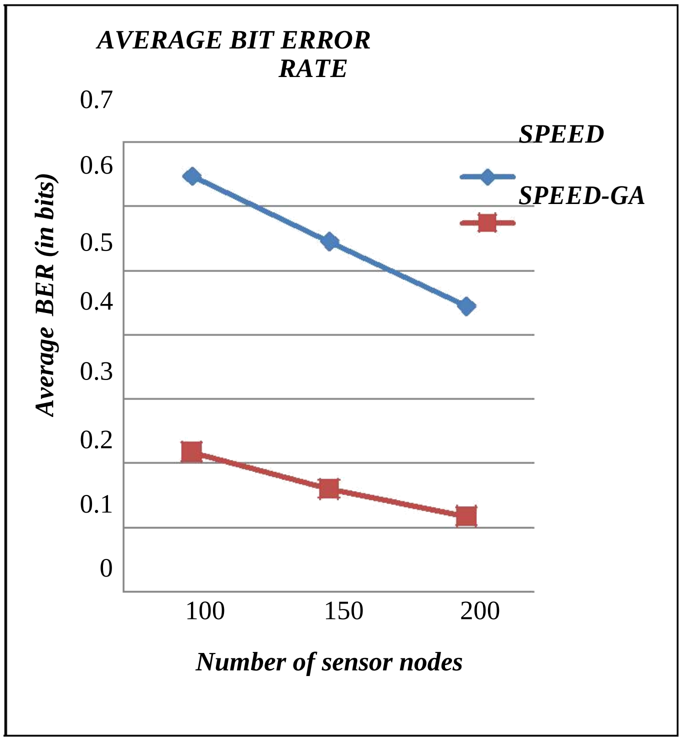


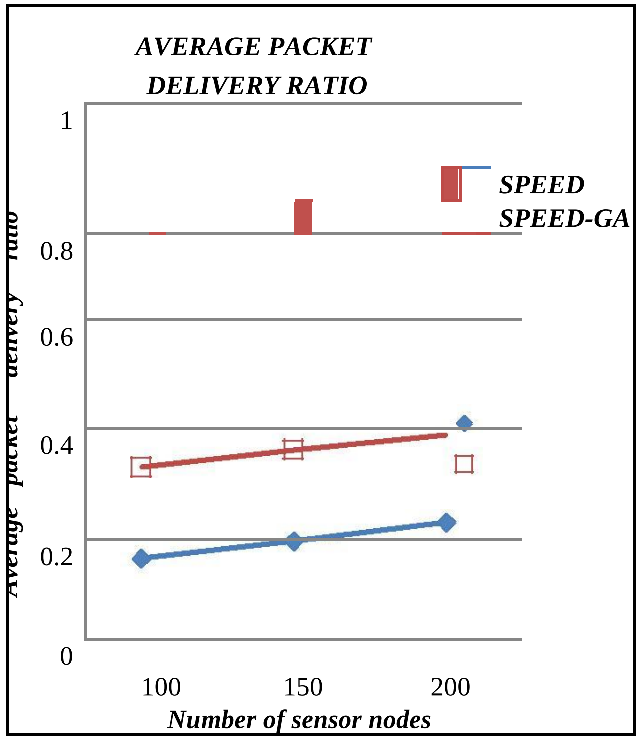
Figure3 Snapshot for comparison of BER plot when nodes vary.

C. Packet Delivery Ratio

Packet delivery ratio is an example of a QoS metric used to evaluate the performance of both SPEED and SPEED-GA routing algorithms. It is defined as the ratio of total number of packets successfully received by the destination node to the total number of packets send by the source node. As shown in Figure 4. SPEED-GA routing algorithm has more successful transmission or packet delivery ratio as compared to SPEED routing algorithm. The figure also tells that the packet delivery ratio increases with increase in number of nodes. More the number of nodes more will be the number of successful packet transmissions, therefore more will be the packet transmissions. More the packet delivery ratio more will be the performance of the network. Thus performance of network increases with increase in number of nodes.

D. Average End-to-End Delay

Average End-to-End delay is defined as the average time taken by a data packet to be successfully transmitted from the source node to the destination node. The delay caused by route finding process and the row in data packet communication is also added in it. Lesser the end-to-end value more is the performance of the protocol. Figure5 shows that SPEED has greater value of end-to-end delay in



comparison to the SPEED-GA. The delay in the network will decrease with increasing number of nodes because more the throughput lesser will be the delay of the network.

Figure4 Snapshot for comparison of packet delivery ratio plot when number of nodes varies

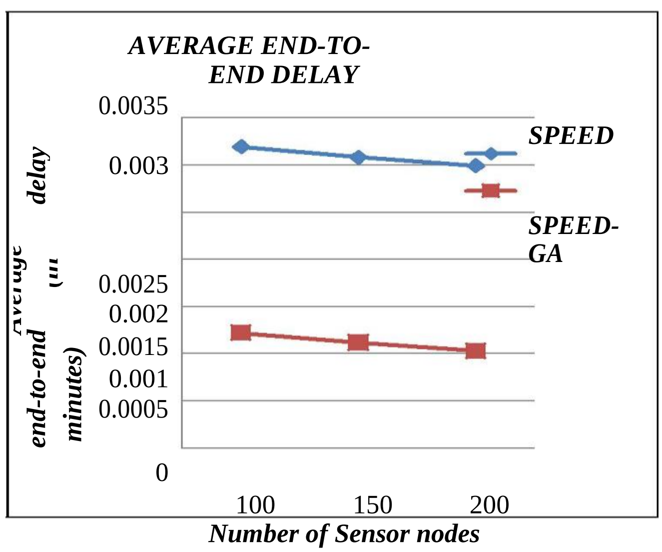


Figure5 Snapshot for comparison of end-to-end delay plot when number of nodes varies

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CONCLUSION

In this paper, a genetic algorithm based SPEED-GA which is a real-time QoS routing algorithm has been presented for WSN. If a node failure, network congestion or packet dropping occurs, the transmission scheme will call genetic algorithm, which can reduce the end-to-end delay and deliver the data packet within the real-time QoS constraints. Through simulation results, the performance of the SPEED routing algorithm and SPEED-GA routing algorithm is evaluated. Simulation results illustrate that the performance of SPEED-GA outperforms the SPEED routing algorithm by increasing the throughput, packet delivery ratio and decreasing the bit error rate and end-to-end delay.

FUTURE SCOPE

For the future work of the carried research, the performance of network using optimized routing algorithm SPEED-GA could be compared with the performance of network using other routing algorithms like MMSPEED, QEMPAR, MCBR, MCMP etc. Another optimization algorithm like Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), neural network back propagation, and Simulated Annealing (SA) can also be used for extending the SPEED routing algorithm proces

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