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ADAPTIVE ALGORITHMS FORM THE BASIS FOR IMPLEMENTING MULTIPATH ROUTING IN INTERNET OF THINGS (IOT) NETWORKS

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The emergence of the Internet of Things (IoT) has captured the interest of many researchers due to its ability to facilitate collaboration among objects, providing users with services and data. This paper presents the development of a multipath routing technique tailored for IoT networks.

The optimization method, named Adaptive-SFG, is formulated by incorporating adaptive principles into the SFG technique. A novel fitness function has been devised, considering various factor such as delay, energy consumption and connection longevity. This fitness function serves as the basis for the Adaptive-SFG approach to select the optimal multipath routing.

Keywords: IoT, Multipath Routing, Route Maintenance

1. INTRODUCTION

The rapid evolution of the internet has spurred the creation of numerous applications across diverse domains. The Internet of Things (IoT) represents the next frontier in global networking, facilitating connectivity for a multitude of objects to the internet, thereby unlocking new avenues for innovation. Wireless devices seamlessly interact with conventional networks and other devices, offering a plethora of solutions. [9].

The majority of IoT applications have focused on analyzing individual events, leading to the generation of vast volumes of data. Sensors serve as the primary mechanism for extracting this substantial data. The extensive deployment of wireless networks in IoT applications has introduced several security challenges concerning data transmission and communication. [12]. Minimizing power consumption and latency is vital for ensuring efficient communication within IoT networks. The characteristics of Small World networks suggest that incorporating network shortcuts can decrease the number of hops required for data transmission. To conserve energy and reduce overall latency, low-power devices can transmit data by taking advantage of these network features, thereby traversing fewer hops. Hence, the development of IoT routing strategies that govern Small World properties is imperative. [10] By redirecting traffic to underutilized networks, multipath routing mitigates congestion and optimizes network utilization, thereby improving load balancing compared to existing routing methods [13]. Congested links result in reduced performance and increased routing variability. Employing diverse path routing can yield more consistent and smooth data transmission, especially in such scenarios. [14].

Multipath routing algorithms distributed traffic across available pathways, subsequently analyzed in flow control. This routing approach influences outcome efficiency in various ways. Despite the utilization of numerous flow-control methods for routing, the effectiveness of the system is influenced by the selection of path sets [15]. The routing technique comprises two components: braided and disjoint multipath routing. In disjoint multipath routing [16], unlike other forms where paths are not disconnected, there exists no correlation between routes . n [19], a strategy leveraging multipath routing is devised to address optimization challenges. Specifically, when employed in energy-focused scenarios, the method targets to ensure network robustness and longevity. Furthermore, [20] introduces a method aimed at evaluating path reliability to facilitate load balancing, accounting for potential disruptions caused by wireless interferences that may hinder communication provision.

In [18], a technique is formulated to ascertain multiple routes, aiming to strike a balance between network resilience and durability. However, a drawback of this approach lies in its reliance on linear models for battery assessment.

The objective of the research is to deploy multi-path data transfer using Adaptive SFG, a newly developed optimization technique. Among the factors considered in route creation, the fitness function plays a significant role.

Transmitting data from the source to the base station involves establishing efficient routes through the suggested Adaptive SFG method. Route maintenance is conducted to ensure uninterrupted routing and prevent link failures.

The primary contributions of the paper are twofold:

1) Introducing a novel routing technique, Adaptive SFG, this integrates the adaptive concept into SFG for multipath data transmission in IoT networks.

2) Developing a fitness function that identifies energy-efficient paths for multipath data transmission, thereby enhancing overall network performance.

2] LITERATURE SURVEY

The eight traditional multipath routing algorithms possess both strengths and weaknesses. Min Chen et al. [1] introduced the MPSS technique, leveraging sink nodes and B-spline trajectories with inter-path distance to optimize multiple route pathways. Utilizing hop distance in this strategy reduces cumulative error and ensures adherence to Quality of Service (QoS) requirements. Moreover, MPMS was adapted to achieve significant energy conservation while meeting QoS demands, albeit at the expense of increased network downtime, potentially affecting network performance adversely. In another approach, Waheb A. Jabbar et al. [2] developed a hybrid MEQSA-OLSRv2 method for creating multipath routing within the network.

This approach employed node ranking utilizing diverse metrics. To streamline the complexity associated with diverse node limitations, various factors are consolidated based on Quality of Service (QoS) and energy considerations. The MPR set was adjusted to prioritize energy selection. Fadi Al-Turjman et al. [3] introduced the agile data delivery paradigm, which was applied in smart city applications for transmitting multimedia data. Through the utilization of active topologies, an optimal routing method was devised to facilitate resource allocation..

While the technology offered pathways for data packets to optimize resource utilization within Quality of Service (QoS) constraints, it fell short in addressing challenges related to large-scale navigation.

Amol V. Dhumane and Rajesh S. Prasad [4] proposed a method for identifying the optimal cluster head node. They introduced the (FGSA) to determine the ideal cluster head, considering various factors within its fitness evaluation.

Jaiswal, K. and Anand, V. [6], devised efficient routing protocols aimed at enhancing network performance and service quality. They introduced an energy-efficient IoT routing algorithm designed to identify the optimal path for initiating transmission. This method considered three key features to determine the most suitable route, resulting in enhanced scalability compared to prior protocols.

The nodes monitor packet transmission across paths, facilitating the detection of issues such as packet loss and latency. Through consideration of the bridge node, multipath routing enhances connectivity via inter-path communication.

The subsequent phase involved establishing multipath, a mechanism developed to optimize transmission efficiency. In order to provide the most effective transmission routes, the method considers various factors.

2.2. CHALLENGES

- Industries and organizations consistently prioritize security in IoT sensor networks. These measures aim to safeguard users' data from potential breaches or losses. However, in the event of a crisis, complex communication network issues may emerge, potentially leading to multimodal communication scenarios [5].

- Designing an original and efficient communication protocol for the IoT may present various challenges, such as limited resources and the unreliability of low-power wireless networks [6].
- Multiple routing strategies have been developed to facilitate multipath routing in the (IoT). However, the network architecture employed for delivering IoT services might not allocate sufficient resources to support multipath implementation. Consequently, these limitations may lead to degraded performance.

3. IoT Network Model

The (IoT) comprises a diverse range of items, including smart gadgets interconnected to exchange data collected across a network. These IoT smart devices serve as virtual resources, enabling data exchange through analysis and communication capabilities.

For efficient data transmission, IoT nodes are linked to the network via a gateway node, emphasizing the pivotal role of data transmission in driving the development of an efficient trust-based routing system for IoT networks. Each IoT node is tasked with evaluating link lifetime, energy levels, and trustworthiness.

Figure 1 illustrates the IoT paradigm, where nodes are interconnected to form a communication network.

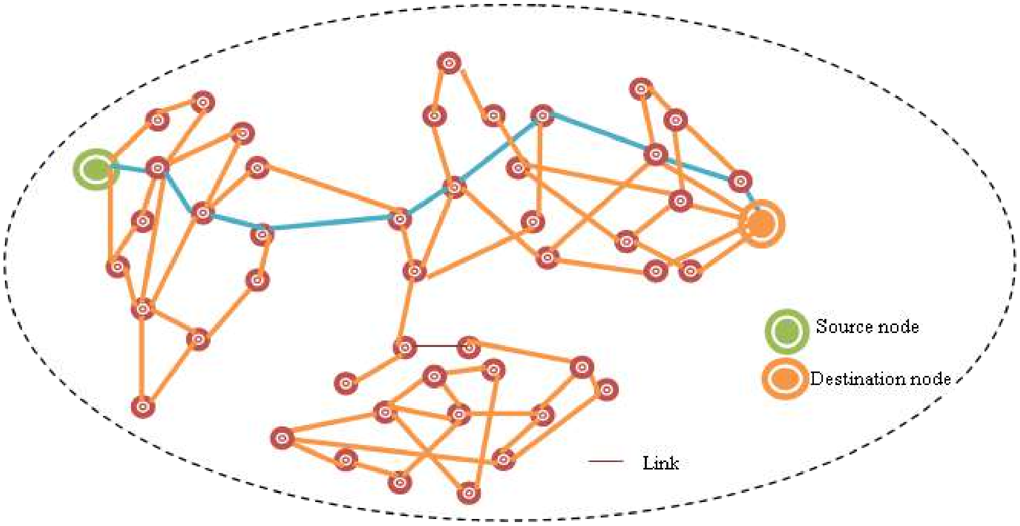


Figure 1. Multipath routing for route maintenance

3.1 Energy Model in IoT

Numerous distributed sensors within the IoT are battery-powered, implying that as the number of operations increases, energy consumption may raise, potentially shortening the network's lifespan. With the presence of radio electronics and amplification equipment in the transmitter, energy dissipation occurs according to set rules during system transmission. Consequently, the energy model for the IoT network is as follows:

$$E_x(m) = Ey(m) + Ez(m,n)$$

E_x (m)-Transmitted Energy, Ez-Consumed Energy

m-Data bits, n-Communication distance

$$E_x(m) = \begin{cases} x \times E_y + x \times E_j \times d^2; \; if \;\; d \le d_0 \\ x \times E_y + x \times E_k \times d^4; \; if \;\; d > d_0 \end{cases}$$

E_k-Consumed Energy in Multipath fading model

E_j-Consumed Energy in free space model

$$d_0 = \sqrt{\frac{E_j}{E_k}}$$

Sensor nodes' energy consumption to receive data points is stated as,

$$E_{tr}(x) = x \times E_y$$

Where, total energy calculated

$$E = E_x + E_{tr} \tag{1}$$

3.2. Link Lifetime model

Failures in routing within IoT networks may stem from broken network links. To alleviate the repercussions of such connection failures, the routing protocol evaluates the lifespan of network links, considering factors such as speed, direction, and coordination of the nodes.

Lifetime model evaluated with’ $L = \dfrac{-(rs + yz) + \sqrt{(r^2 + z^2)q^2 - (rz - ys)^2}}{(r^2 + z^2)}$

(2)

$$r = G_{d1} \cos\theta_{d1} - G_{d2} \cos\theta_{d2}$$

$$s = J_{d1} - J_{d2}$$

$$y = G_{d1} \sin\theta_{d1} - G_{d2} \sin\theta_{d2}$$

$$z = K_{d1} - K_{d2}$$

3.3. Trust model

In the suggested model to provide trust-based data transfer, the trust model provides privacy. To determine a group of trusted nodes, the trust factor of each IoT network is calculated. The trust is stated based on four parameters and is customized to find trusted nodes. The following factors consider for model forwarding rate, indirect trust, recent trust, and direct trust.

$$TM = \frac{1}{4}\sum_{j=1}^{B} TD + TI + TR + RF \tag{3}$$

4. Proposed Adaptive based multipath routing

Therefore, if provided, the best or next paths can make the routing process simpler. As a result, multipath data transmission is modified to use several pathways for data transfer from the source to the destination node for utilizing best pathways while taking into account suggested Adaptive algorithm to carry out multipath transmission. The fitness is a recently developed measure that combines various goals.

4. Solution Encoding

Hence, incorporating the best or alternate paths can streamline the routing process. Consequently, multipath data transmission is adapted to utilize multiple pathways for transferring data from the source to the destination node, optimizing the use of the most favorable pathways while implementing the suggested Adaptive algorithm for multipath transmission. The fitness metric is a newly devised measure that integrates various objectives

Considering the proposed Adaptive algorithm, let y represent the optimal path utilized for data transfer, as depicted in Figure 2. Consequently, the dimension of the solution vector is determined. $\left[1\times y\right]$

p_1	p_2	....	P_x

Figure 2. Encoding for optimal path

4.1 **Fitness Function**

Fitness is assessed using a series of solutions with parameters to find the best solution. The suggested Adaptive algorithm's to determined fitness by.

$$Fitness = \sum_{n=1}^{j} (L_{n,p} + E_{n,p} + T_{n,p} + (1 - V_{n,p})) \tag{3}$$

The fitness is calculated with considering four parameter wih n^{th} nodes in p^{th} path.

L=Network lifetime,E-Total Energy,T-Trust value,V-Delay

4.2 Adaptive Algorithm

The proposed Adaptive-Algorithm enhances the effectiveness of initiating multipath routing by amalgamating the strengths of Sunflower-based techniques and adaptive concepts. Leveraging the self-adaptive approach provides the flexibility to alternate between multiple operators, ensuring both robustness and efficiency, thus offering several advantages. Moreover, this approach, besides being more straightforward, demonstrates proficiency in handling significant nonlinearity, navigating through multiple local optima, addressing interdependence, and managing unevenness. Moreover, it paves the way for enhancing the robustness and efficiency of the optimization algorithm. The method aids in handling optimization challenges with diverse constraints without the need for additional parameters. Essentially, the self-adaptive approach enables parameter settings to adapt autonomously based on learning experiences, eliminating the necessity for prior specification of control parameters and the learning process.

Step 1. Initialization

Initialization is the first step, where the number of wolves and other settings are set. The population of as a whole is calculated as,

$$Y = \{Y_1, Y_2, \ldots, Y_\ell, \ldots, Y_\rho\} \tag{4}$$

ℓ Represents total number of population. Y_ρ Indicates ρ^{th} value.

Step 2. Fitness function Calculation

Fitnesss value calculated from equation(3)

Step 3. Update position equation

$$\vec{W}(v+1)=\frac{\vec{W}_1+\vec{W}_2+\vec{W}_3}{3} \qquad (5)$$

$\vec{W}_1+\vec{W}_2+\vec{W}_3$ Represents position vector

The most recent version is created by adding $\vec{W}_4$

$$\vec{W}(w+1)=\frac{\vec{W}_1+\vec{W}_2+\vec{W}_3+\vec{W}_4}{4} \qquad (6)$$

Using the SFO technique, the updated position is given as

$$\vec{W}_4=W_\mu+x_\mu\times y_\mu \qquad (7)$$

$$x_\mu=U\times Q_\mu(\| W_\mu+W_{\mu-1}\|)\times\| W_\mu+W_{\mu-1}\| \qquad (8)$$

Q(.) Show that the chance of pollination is constant and stays u constant

$$y_\mu=\frac{W^*-W_\mu}{\| W^*-W_\mu\|} \qquad (9)$$

Each position stated as,

$$\vec{W}_1=\vec{W}_\alpha-G_1(\vec{N}_\alpha) \qquad (10)$$

$$\vec{W}_2=\vec{W}_\beta-G_2(\vec{N}_\beta) \qquad (11)$$

$$\vec{W}_3=\vec{W}_\gamma-G_3(\vec{N}_\gamma) \qquad (12)$$

$\vec{W}_\alpha$-First Search agent, $\vec{W}_\beta$-Second search agent, $\vec{W}_\gamma$-Third search agent

U represents coefficient vector,

$$U=2\vec{r}\vec{s}_1-r \qquad (13)$$

Here ‘r’ is a random number that, after a specified number of rounds, decreases linearly with values from 2 to 0.

$\vec{r}$ is made self-adaptive and its components decrease linearly from 2 to 0, as shown by the following expression:

$$r=r_u\sigma^{-i/j} \qquad (14)$$

r_u-Maximum value, i-current iteration, j- admissible maximal iteration.

Step 4: finding fitness:

The optimal approach is to identify the most effective pathways for transmitting data packets to the target nodes. Equation (3), from which the fitness is derived, forms the basis for constructing the fitness function. Maximizing this fitness is essential for selecting the best solution.

Step 5: End Process:

The optimization process concludes upon satisfying the stopping criterion, signaling its completion. Optimal solutions are iteratively obtained until the maximum number of iterations is reached.

5. Results and Discussion

In this section, simulations are conducted on IoT networks comprising 50 and 100 nodes to demonstrate the effectiveness of the proposed technique compared to conventional methods. The analysis involves varying the number of rounds to assess performance.

5.1 Experimental setup

The suggested technique is implemented using between 50 and 100 nodes in MATLAB.

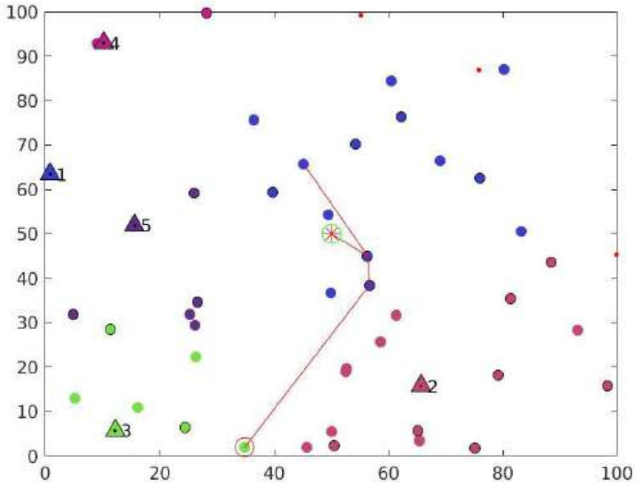


Figure 3. Adaptive algorithm simulation results with 50 nodes

The standard nodes are depicted by green, red, and blue circles. Data transmission entails selecting a specific path, denoted by a red line. Utilizing the suggested Adaptive algorithm method, the optimal path for data transmission between source and destination nodes is determined. Consequently, the IoT network achieves secure communication.

5.2 Performance measures

The metrics employed to analyze approaches include delay, which refers to the total time taken for data transmission regardless of any interference. The formula for delay is represented as

$$De = \frac{R_a}{S}$$

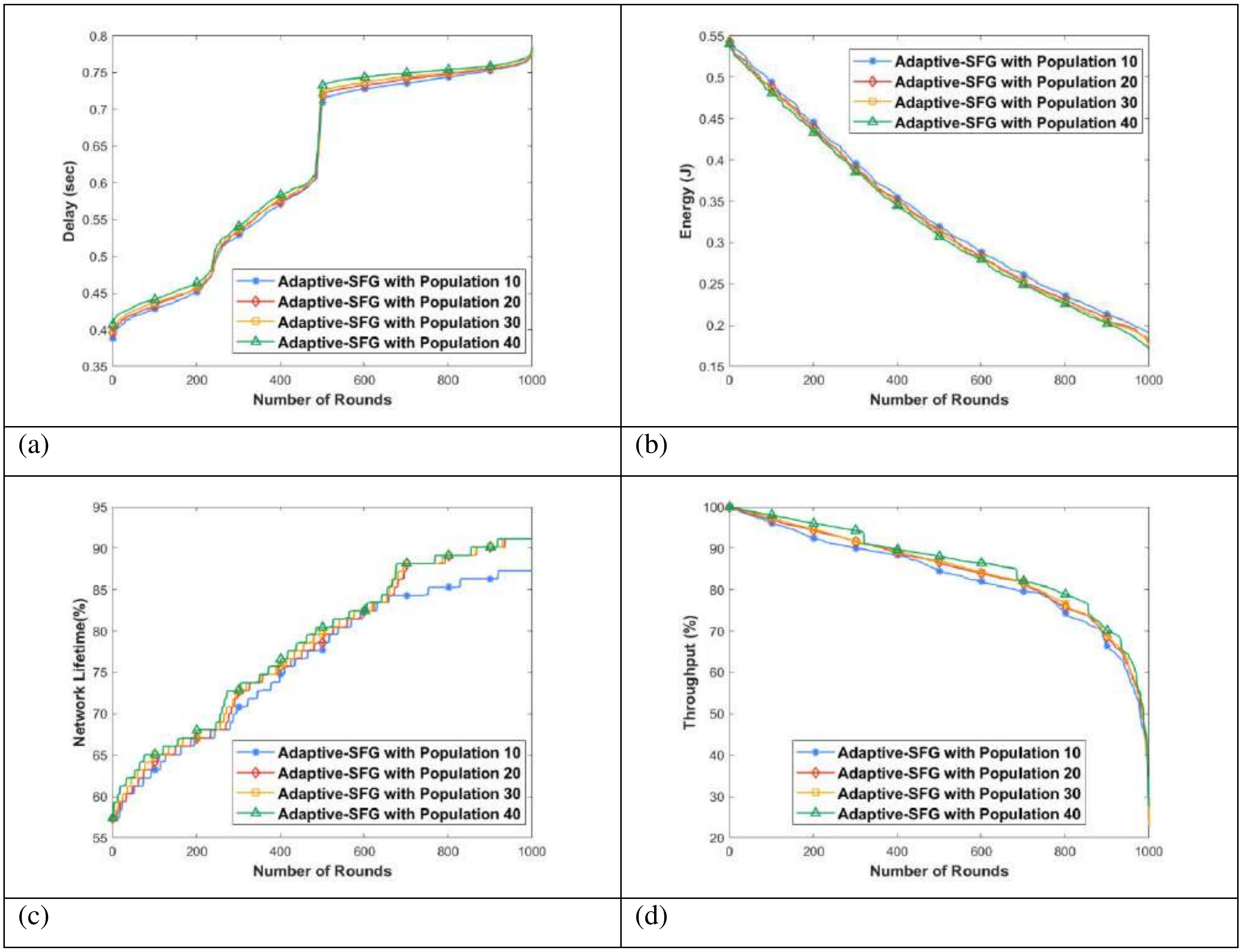
Ra-Represents Number of bits, S-Transmission rate

5.3. Performance analysis

The performance evaluation involves adjusting parameters and analyzing the outcomes using the suggested Adaptive Algorithm. The impact is assessed by varying the number of rounds from 1 to 1000. The SFG is customized to showcase the effectiveness of the proposed method. Furthermore, the analysis is carried out using 50 nodes.

5.4 Analysis based on 50 nodes:

The analysis illustrates the variation in performance as the population size ranges from 10 to 40, focusing on the evaluation of the suggested Adaptive algorithm with 50 nodes. Figure 4 depicts the examination of the suggested Adaptive algorithm based on parameters



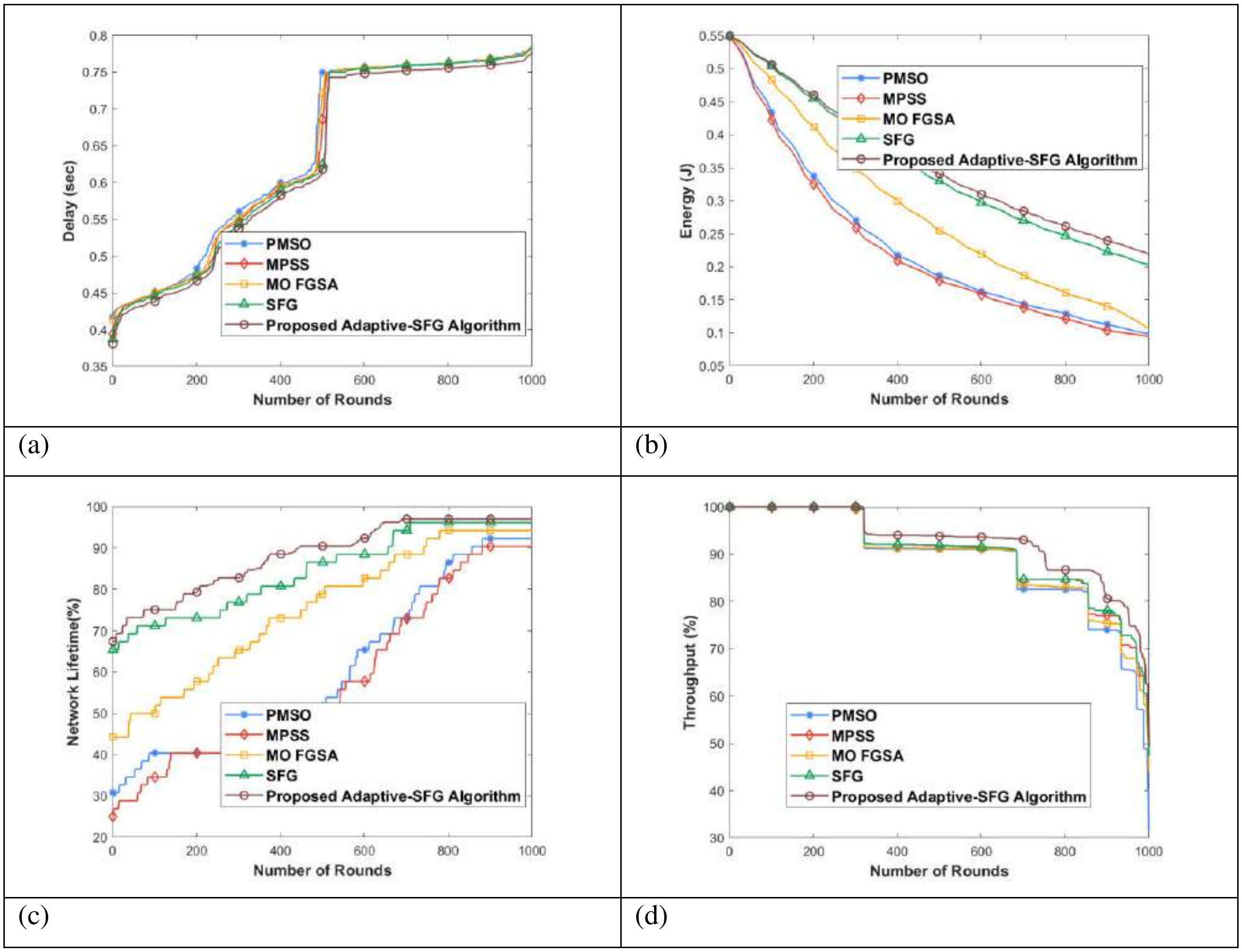
(a) (b)

(c) (d)

Figure 4. Proposed Adaptive algorithm with 50 nodes.

5.5 Comparative analysis

The suggested Adaptive technology is evaluated against traditional techniques across multiple factors. Various rounds of analysis are conducted using 50 nodes to compare their performance. with PMSO, MPSS, MOFGSA, SFG.



(a) (b)

(c) (d)

Figure 5. Comparative analysis using 50 nodes.

The suggested Adaptive algorithm are among the techniques that have been modified for analysis.

Nodes	Metrics	PMSO	MPSS	MOFGSA	SFG	Proposed Adaptive
Using 50 nodes	Delay (sec)	0.789	0.785	0.786	0.785	**0.778**
	Energy (J)	0.099	0.095	0.106	0.203	**0.218**
	Network lifetime (%)	92.308	90.385	94.231	96.154	**97.000**
	Throughput (%)	31.818	47.368	44.186	47.368	**49.368**

Table-1 Comparative Analysis

6 .CONCLUSION

The proposed Adaptive algorithms have been subject to modifications for analysis. By integrating the Adaptive concept into SFO, multipath transmission is achieved. The fitness evaluation encompasses various variables. The suggested Adaptive algorithm is employed to determine the path with the highest energy, minimum delay, and maximum lifetime. Finally, route maintenance is conducted to ensure uninterrupted routing and prevent link failures. In the future, multipath routing is expected to consider a blend of advanced optimization algorithms.

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