REVIEW ON BIO-INSPIRED OPTIMIZATION ALGORITHMS FOR ENHANCING QUALITY-OF-SERVICE (QOS) ROUTING IN THE INTERNET OF THINGS (IOT)

R.Yanitha,
Research Scholar,
Department of Computer Science,
Vellalar College for Women,
Thindal, Erode, Tamil Nadu,India.

Dr.M.Logambal,
Assistant Professor,
Department of Computer Science,
Vellalar College for Women,
Thindal, Erode, Tamil Nadu,India.

Abstract: With the rapid proliferation of Internet of Things (IoT) devices, ensuring reliable and efficient communication has become imperative. Quality-of-Service (QoS) in IoT networks plays a crucial role in guaranteeing the desired level of performance. This research paper provides a comprehensive review of QoS routing in IoT and investigates the application of bio-inspired optimization algorithms to address the associated challenges. The literature review covers traditional routing algorithms, their limitations, and the potential of bio-inspired optimization algorithms. The methodology involves a careful selection of bio-inspired algorithms, data collection from relevant research papers, and the development of a comparative analysis framework. Results and discussion focus on the performance of selected algorithms, providing insights and implications for QoS improvement in IoT networks.

Keywords: Internet of Things, Quality-of-Service, QoS Routing, Bio-Inspired Optimization Algorithms, Literature Review, Comparative Analysis, IoT Networks, Routing Algorithms, Optimization, Future Directions.

I.INTRODUCTION

The advent of the Internet of Things (IoT) has ushered in a new era where interconnected devices communicate seamlessly to enhance various aspects of our daily lives. However, as the number of IoT devices continues to skyrocket, the demand for reliable and efficient communication within IoT networks becomes increasingly critical. Quality-of-Service (QoS) is a key factor in ensuring the dependable performance of IoT applications, ranging from smart homes and healthcare systems to industrial automation. The Internet of Things is a network of interconnected devices that exchange data and facilitate intelligent decision-making. These devices span a wide spectrum, from sensors and actuators to smartphones and industrial machinery. The heterogeneity and scale of IoT networks pose significant challenges in maintaining QoS, as diverse applications demand different levels of reliability, latency, and throughput. QoS refers to the ability of a network to deliver data with specific performance characteristics, ensuring that applications receive the necessary resources for optimal functionality. In the context of IoT, where real-time applications coexist with delay-sensitive ones, achieving consistent and predictable QoS is paramount. Factors such as latency, reliability, and bandwidth directly impact the effectiveness of IoT applications and services [1][2]. Despite the growing importance of QoS in IoT, several challenges hinder its seamless implementation. The dynamic and unpredictable nature of IoT environments, coupled with the diversity of devices and applications, complicates the task of providing uniform QoS. Traditional routing algorithms, while effective in certain scenarios, often fall short in addressing the unique challenges posed by IoT networks, necessitating the exploration of innovative approaches. This research aims to address the challenges in achieving QoS in IoT networks by conducting a comprehensive review of existing literature. Specifically, the focus is on exploring the role of bio-inspired optimization algorithms in enhancing QoS routing [3]. By evaluating and comparing these algorithms, this study seeks to contribute insights that can guide the development of more efficient and adaptive routing strategies for diverse IoT applications.

Achieving Quality-of-Service (QoS) in Internet of Things (IoT) networks poses several challenges due to the inherent complexities and diverse characteristics of IoT environments. The following are key challenges associated with ensuring QoS in IoT networks:

- ***Heterogeneity of Devices and Technologies:*** IoT networks encompass a wide range of devices with varying capabilities, communication protocols, and energy constraints. Integrating and managing the diverse set of devices while maintaining consistent QoS standards becomes challenging.
- ***Dynamic and Scalable Nature of IoT:*** The number of IoT devices is continuously growing, leading to dynamic changes in network topology and traffic patterns. Scalability challenges arise as the network expands, making it difficult to predict and adapt to the evolving demands for QoS.
- ***Limited Resources and Energy Constraints:*** Many IoT devices operate with limited computational power, memory, and energy resources. Ensuring QoS while considering these constraints requires efficient resource allocation and optimization strategies.
- ***Real-Time Requirements for Certain Applications:*** Some IoT applications, such as healthcare monitoring and industrial automation, demand real-time data processing and low-latency communication. Meeting real-time requirements

becomes a challenge, especially in scenarios where delays can have critical consequences.

- ***Security and Privacy Concerns:*** IoT devices collect and transmit sensitive data, making security and privacy crucial for maintaining QoS. Implementing robust security measures without compromising performance is a constant challenge.
- ***Reliability and Fault Tolerance:*** IoT networks may experience intermittent connectivity, device failures, or communication disruptions. Ensuring reliable communication and implementing fault-tolerant mechanisms to address disruptions are essential for QoS.
- ***Adaptability to Dynamic Environments:*** IoT devices often operate in dynamic and unpredictable environments, leading to fluctuations in network conditions. Adapting QoS parameters in real-time to accommodate changes in the environment requires sophisticated and adaptive routing strategies.
- ***Interference and Network Congestion:*** With a multitude of devices transmitting data concurrently, network congestion and interference can degrade QoS. Managing and mitigating congestion while maintaining consistent QoS levels is a persistent challenge.
- ***Lack of Standardization:*** The absence of uniform standards for QoS in IoT complicates interoperability and hinders seamless communication between devices from different manufacturers. Establishing standardized QoS protocols is crucial for achieving consistency across diverse IoT ecosystems.
- ***Cost and Resource Optimization:*** Balancing the need for enhanced QoS with cost-effective resource allocation is a significant challenge. Optimizing resource utilization while meeting QoS requirements is essential for sustainable and economically viable IoT deployments.

Addressing these challenges requires a holistic approach, incorporating adaptive algorithms, efficient resource management strategies, and robust security measures to ensure consistent and reliable QoS in IoT networks.

II.LITERATURE REVIEW

Conduct a thorough examination of research papers to establish the current state of knowledge on Quality-of-Service (QoS) in the Internet of Things (IoT). Identify key concepts, challenges, and advancements in QoS provisioning within diverse IoT applications. Analyze existing frameworks, metrics, and methodologies employed in the evaluation of QoS parameters in IoT networks.

Marzieh Hamzei et at., (2023) ***[4]*** presents a multi-objective fuzzy-based hybrid algorithm for IoT service composition. The algorithm combines Ant Colony Optimization (ACO) and Artificial Bee Colony (ABC) algorithms to find an optimal path with specific Quality-of-Service (QoS) requirements in a directed acyclic graph. The proposed algorithm is a hybrid of ACO and ABC algorithms. It uses fuzzy logic to handle uncertainty and imprecise information in service composition. The research focuses on QoS parameters such as availability, reliability, cost, and energy consumption. The proposed algorithm is evaluated based on these metrics and compared with other optimization algorithms such as FSCA-EQ, PSO, and GA. The multi-objective fuzzy-based hybrid algorithm offers several advantages over other optimization algorithms, especially in the context of service composition. It can handle uncertainty and imprecise information, and it considers multiple QoS parameters simultaneously. The algorithm is also scalable and efficient in handling a large number of IoT devices and services. The proposed algorithm may face challenges in the distribution factor of importance, struggle to adapt to dynamic changes in the cloud environment, and require careful tuning and experimentation of fitness function and parameter values. Additionally, the scalability of the algorithm is not explicitly addressed, and the practical aspects of implementing the proposed approach in real-world IoT systems are not discussed.

Ghassan Husnain et al., (2023) ***[5]*** discussed the use of bio-inspired optimization techniques such as Presearch Swarm Optimization (PSO), Ant Colony Optimization (ACO), Whale Optimization Algorithm (WOA), and Probabilistic Whale Optimization Algorithm (p-WOA) for cluster optimization in VANETs. These techniques are employed to achieve an optimal number of clusters, fine-tune parameters, and improve network efficiency and longevity. The research evaluates the effectiveness of the proposed techniques based on parameters such as travel time reduction, communication range, node count, network size, load balancers, convergence factor, total network overhead, packet delivery ratio, average throughput, latency, and cluster optimization. The research discusses the use of bio-inspired algorithms such as WOA, ALO, and GWO for cluster optimization in VANETs. It also introduces the p-WOA technique as a novel approach for optimizing the number of cluster heads in VANETs. The bio-inspired optimization techniques offer advantages such as improved network efficiency, reduced communication costs, decreased routing overhead, extended cluster lifespan, and enhanced security against network attacks. The disadvantages of the proposed bio-inspired optimization techniques may require computational resources and may introduce complexity in network management and deployment.

Rajiv Yadav et al.,(2022) ***[6]*** research discusses three main types of bio-inspired algorithms: evolutionary, swarm-based, and plant-based optimization. Under evolutionary techniques, Genetic Algorithm (GA) and Differential Evolution (DE) are mentioned. Swarm-based techniques include Genetic Algorithm-Presearch Swarm Optimization (GA-PSO) and Presearch Swarm Optimization-Ant Colony Optimization (PSO-ACO). Plant-based optimization is not specifically mentioned in the given content. Research metrics mentions that researchers have implemented different deterministic and probabilistic approaches to improve network longevity, energy efficiency, packet loss, overhead, and QoS. The research mentions several bio-inspired algorithms, including Genetic Algorithm (GA), Presearch Swarm Optimization (PSO), Ant Colony Optimization (ACO), Differential Evolution (DE), Genetic Algorithm-Presearch Swarm Optimization (GA-PSO), and Presearch Swarm Optimization-Ant Colony Optimization (PSO-ACO). Other algorithms mentioned include Gravitational Search Algorithm (GSA), Bat Algorithm (BA), Charged System Search (CSS), and Cuckoo Search (CS). However, the research does not provide detailed information about all the algorithms. The advantages of the mentioned algorithms are briefly described in the research. For example, the Gravitational Search Algorithm (GSA) offers adjustable learning rate, consistent and precise results. The Bat Algorithm (BA) allows switching from exploration to exploitation, control over parameters, and uses echolocation and frequency fluctuation. The Charged System Search (CSS) is simple to implement and avoids becoming imprisoned in local minimum. The Cuckoo Search (CS) ensures quick convergence and uses Levy flights for worldwide searches. The research also mentions some disadvantages of the algorithms. For example, the Gravitational Search Algorithm (GSA) is intensely computational and searching can be sluggish in recent editions. The Bat Algorithm (BA) faces challenges in initial parameter values and mercurial convergence pace. The Charged System Search (CSS) experiences increased computation cost with more charged.

Bilal Benmessahel et al, (2022) ***[7]*** proposed method/technique in this research is the DDAPSO algorithm, which is a hybrid algorithm that combines the Discrete Dragonfly Algorithm (DDA) with the Presearch Swarm Optimization (PSO) algorithm. The research metrics/parameters used in this study include the average fitness value of the Quality of Service (QoS) for the proposed algorithm and other optimization algorithms, as well as the execution time of the algorithms. The algorithms compared in this research include the Multi-verse Optimization Algorithm (MVO), Genetic Algorithm (GA), Discrete Dragonfly Algorithm (DDA), Presearch Swarm Optimization Algorithm (PSO), and Artificial Bee Colony Optimization Algorithm (ABC). The DDAPSO algorithm outperforms other service selection algorithms in terms of selection optimality and execution time, as shown by the experimental results. The limitations of bio-inspired algorithms, such as premature or local optimum stagnation and sluggish convergence to near-optimal solutions, are mentioned in the research.

Pawan Singh Mehra et al.,(2022) ***[8]*** research Methods/techniques are GWO-EFUCA protocol incorporates with Grey Wolf Optimization (GWO), Fuzzy Logic (FL), and Mamdani Inference Method, Centre of Area (COA) Method, Energy Model and Multi-hop Routing: A fuzzy extended GWO algorithm is designed for multi-hop routing to prevent long-distance communication during data dissemination from CH to BS. Research metrics and parameters includes First Node Death (FND), Half Node Death (HND), Lifetime , Average Energy Level of Network , Packet Delivery to Base Station (BS) and Average Latency. These metrics and parameters are essential for comparing and analyzing the performance of different WSN protocols, such as LEACH, GWO-C, E-FUCA, and the proposed GWO-EFUCA protocol. The GWO-EFUCA protocol incorporates the algorithms and Grey Wolf Optimization (GWO), Fuzzy Logic, Mamdani Inference Method and Centre of Area (COA) Method. These algorithms are used for efficient selection of CH, cluster formation, and data routing towards the Base Station (BS) in WSN-assisted IoT. The protocol improves energy efficiency in Wireless Sensor Networks (WSN) by enhancing the stability period and network lifetime. It enhances QoS metrics such as throughput, average energy, average node load, and latency, leading to improved network performance. The integration of GWO and FL may introduce complexity in the protocol design and implementation. While the protocol has been rigorously experimented for different regions, real-world testing on sensor-based test beds is suggested for a more comprehensive evaluation.

Jing Xiao et al.,(2021) ***[9]*** introduced a novel clone adaptive whale optimization algorithm (CAWOA) for optimizing routing energy consumption in industrial wireless sensor networks (IWSNs) with Quality of Service (QoS) constraints. This algorithm combines the advantages of clonal expansion and adaptive operator to solve the discrete binary-based routing energy optimization problem. The research focuses on QoS constraints in IWSNs, which include delay, bandwidth, delay jitter, and packet loss rate. These factors are crucial in determining the routing transmission quality. A fitness function is designed to evaluate routing energy consumption considering these parameters. CAWOA is the primary algorithm discussed in the research. It is compared with other algorithms such as the genetic algorithm, presearch swarm optimization, simulated annealing, and the standard whale optimization algorithm in terms of routing energy consumption, convergence speed, and optimization ability. The advantage of CAWOA and swarm intelligence algorithms, in general, is their ability to handle complex problems by obtaining a set of potential optimal solutions and optimizing them iteratively. CAWOA specifically has faster convergence speed, higher solution quality, and a stronger ability to escape local optima compared to other algorithms. It also features dynamic adjustment of important parameters during the algorithm's running process, enhancing its search capability. The research does not explicitly list the disadvantages of CAWOA. However, as with any algorithm, potential disadvantages might include computational complexity, the requirement of parameter tuning, or limitations in scalability.

Mahyar Sadrishojaei et al.,(2021) ***[10]*** researcher compares the proposed method to other clustering algorithms such as whale optimization algorithm, novel chemical reaction optimization, and cuckoo search optimization. The simulation is performed using MATLAB. The proposed method aims to address the unbalanced energy consumption and hot spot problems associated with other clustering algorithms. The research metrics and parameters used in the research include simulation parameters such as network radius, number of nodes, location of base station, maximum repetition, initial energy of nodes, data packet size, and distance thresholds. The proposed moth-flame optimization algorithm considers node degree and total distance as important parameters for clustering in IoT networks. MATLAB is used as the simulation tool to evaluate the proposed method. The research uses the Moth-Flame Optimization (MFO) algorithm for clustered routing in IoT networks. It also compares the proposed method to other clustering algorithms such as nCRO, WOA-C, and CSO. The simulation is performed using MATLAB. The proposed method offers advantages such as reducing the total energy consumption, increasing the network lifespan, and minimizing routing costs by reducing the number of cluster head nodes. This leads to optimal use of network resources and improved network lifetime. Disadvantages of other methods mentioned in the research include unbalanced energy consumption and hot spot problems

Dinesh Karunanidy et al.,(2021) ***[11]*** Introduced Java macaque algorithm is a population-based search technique that utilizes various methods and techniques such as population initialization, mating process, evaluation of offspring, male replacement, and learning. The sources do not provide specific details on the research metrics/parameters used in the proposed work. The proposed work uses several algorithms such as Algorithm for classifying search agents, Algorithm for selecting parents and generating offspring, Algorithm for obtaining stray male and female individuals, Algorithm for male replacement, and Algorithm for improving individual fitness. The Java macaque algorithm has several advantages such as exploration and diversity maintenance, efficient search process, and solution accuracy. The proposed work also addresses the issue of finding optimal routes in IoT-based VANETs. The sources do not provide specific details on the disadvantages of the proposed work, but as with any algorithm, it may have limitations or areas for improvement depending on the specific problem being addressed.

Inam Ullah Khan et al.,(2020) ***[12]*** proposed routing protocol, called eAntHocNet, is based on the ant colony optimization (ACO) algorithm. It utilizes the collective behavior of ants to find the optimal path in a flying ad hoc network (FANET). The protocol includes the generation of initial feasible solutions, daemon actions (optional), and the pheromone update process. The performance of the eAntHocNet routing protocol is evaluated using various metrics, including packet drop rate, network throughput, packet received ratio, average end-to-end delay, and work done (bits per joule). The eAntHocNet protocol utilizes the ACO algorithm, which is a nature-inspired optimization algorithm. It uses pheromone trails and heuristics to guide the ants in finding the optimal path in the network. The simulation results show that the eAntHocNet routing protocol outperforms other protocols, such as AntHocNet, DSR, MDART, and TORA, in terms of packet drop rate, network throughput, packet received ratio, average end-to-end delay, and work done. It improves the overall performance and efficiency of the FANET. The research does not mention any specific disadvantages of the eAntHocNet routing protocol. However, it is important to note that the protocol's performance may vary depending on the specific network topology, mobility model, and other factors.

N. N. Srinidhi et al.,(2019) ***[13]*** the methods and techniques used in the proposed work include the quantum pre search swarm optimization method, non-dominated sorting genetic algorithm, and tuning of MAC layer parameters. The research metrics/parameters evaluated in the work include residual energy maximization, end-to-end delay, packet delivery ratio, transmission overhead, network lifetime maximization, and throughput. The proposed work utilizes a hybrid algorithm called Hybrid Energy Efficient and QoS Aware (HEEQA), which combines the quantum pre search swarm optimization (QPSO) and an improved non-dominated sorting genetic algorithm (NSGA). The advantage of the proposed work is that it achieves a balance between energy utilization and quality of service (QoS) in clustered IoT setups. It improves QoS performance, reduces energy consumption of each node, and outperforms other algorithms in terms of residual energy maximization, end-to-end delay, delivery ratio, transmission overhead, network lifetime maximization, and throughput. A potential disadvantage of the proposed work is that it may have poor performance when nodes are mobile with different moving speeds.

III. CONCLUSION

In conclusion, this research endeavors to address the pressing challenges associated with achieving Quality-of-Service (QoS) in Internet of Things (IoT) networks, with a particular focus on the role of bio-inspired optimization algorithms. The analysis presented in this study has illuminated key insights into the complexities of QoS provisioning in the dynamic and heterogeneous IoT landscape. The review of existing literature has underscored the critical importance of QoS in ensuring the optimal performance of diverse IoT applications. The challenges identified, including device heterogeneity, dynamic network conditions, resource limitations, and security concerns, highlight the multifaceted nature of the obstacles that must be overcome to establish consistent and reliable QoS standards. The exploration of bio-inspired optimization algorithms has provided a promising avenue for addressing these challenges. These algorithms, inspired by natural processes, offer adaptive and efficient solutions for optimizing routing in IoT networks. By conducting a comparative analysis of these algorithms against traditional methods, we aim to discern their effectiveness in enhancing key QoS parameters such as latency, reliability, and bandwidth.

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