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Advancements in Energy Efficiency and Quality of Service Routing For Internet of Things Using Bio-Inspired Algorithms and Machine Learning Algorithms: A Literature Review

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ABSTRACT

The Internet of Things (IoT) landscape necessitates effective energy management and reliable quality of service (QoS) routing to meet the evolving demands of connected devices and applications. This literature review explores recent developments in energy efficiency and QoS routing for IoT systems, with a focus on bio-inspired algorithms. The review examines the significance of energy efficiency and QoS routing in IoT deployments, evaluates existing techniques and algorithms, discusses the application of bio-inspired algorithms as well as machine learning algorithms in addressing energy efficiency and QoS routing challenges, presents case studies showcasing the efficacy of bio-inspired approaches and outlines future research directions and challenges. By providing a comprehensive overview, this review aims to inform researchers and practitioners about cutting-edge solutions for enhancing energy efficiency and QoS in IoT networks.

KEYWORDS: Internet of Things (IoT), energy efficiency, quality of service (QoS), routing, bio-inspired algorithms and machine learning algorithms.

1. INTRODUCTION

The Internet of Things (IoT) refers to a network of interconnected devices, objects, or "things" that can communicate and exchange data with each other over the internet or other communication networks. These devices are typically embedded with sensors, actuators, and other technologies that enable them to collect, transmit, and receive data, as well as perform specific actions or tasks based on that data [1]. The concept of IoT revolves around the idea of connecting physical objects to the internet or to each other, enabling them to share information and collaborate autonomously. This interconnected network of devices extends beyond traditional computing devices such as computers and smartphones to include everyday objects and environments such as household appliances, vehicles, wearable devices, industrial machinery, infrastructure systems, and more. At its core, IoT aims to enhance efficiency, convenience, and productivity by enabling seamless communication and interaction between devices and systems [2]. By collecting and analyzing data from various sources, IoT systems can provide valuable insights, automate processes, optimize operations, and improve decision-making in a wide range of domains and applications.

Key components of IoT systems include [3]:

• Devices and Sensors: These are the physical objects or "things" equipped with sensors, actuators, and processing capabilities to collect data from the surrounding environment.

• Connectivity: IoT devices rely on various communication technologies such as Wi-Fi, Bluetooth, Zigbee, cellular networks, and LPWAN (Low-Power Wide-Area Network) to connect to the internet or to each other.

• Data Processing and Analytics: Data collected by IoT devices is processed, analyzed, and interpreted to extract meaningful insights and actionable information. This may involve edge computing, cloud computing, or a combination of both.

• Applications and Services: IoT applications and services leverage the data and insights generated by IoT devices to deliver specific functionalities, automate tasks, and enable new experiences for users.

• Security and Privacy: Given the sensitive nature of the data collected by IoT devices, security and privacy are paramount. IoT systems must implement robust security measures to protect against cyber threats and unauthorized access to data.

Overall, IoT represents a transformative paradigm shift in how we interact with and leverage technology, enabling a more connected, intelligent, and responsive world. It has the potential to revolutionize industries, improve quality of life, and drive innovation across various sectors, from healthcare and transportation to agriculture and manufacturing.

1.1. Challenges Faced in Achieving Energy Efficiency and QoS in IoT Networks

Achieving energy efficiency and quality of service (QoS) in IoT (Internet of Things) networks presents several challenges that need to be addressed to ensure optimal performance and functionality. Some of the key challenges include [4] [5]:

• Limited Resources: Many IoT devices operate with constrained resources such as processing power, memory, and energy. Optimizing energy efficiency while maintaining QoS becomes challenging due to these resource limitations. Balancing energy consumption with the computational and communication requirements of IoT applications is essential but challenging.

• Heterogeneity of Devices and Technologies: IoT networks often consist of diverse devices with varying capabilities, communication protocols, and energy profiles. Integrating heterogeneous devices into a cohesive network while ensuring energy efficiency and QoS across all devices can be complex. Compatibility issues, interoperability challenges, and disparate energy optimization techniques must be addressed to achieve seamless integration and operation.

• Dynamic and Unpredictable Environments: IoT deployments operate in dynamic and unpredictable environments where network conditions, device mobility, and user behavior can change rapidly. Adapting to these fluctuations while maintaining energy efficiency and QoS poses a significant challenge. Dynamic resource allocation, adaptive routing protocols, and real-time monitoring and optimization mechanisms are needed to address these challenges effectively.

• Security and Privacy Concerns: Energy-efficient IoT devices may prioritize performance over security, potentially exposing vulnerabilities that could compromise data privacy and integrity. Implementing robust security measures without sacrificing energy efficiency is a delicate balance. Secure communication protocols, encryption techniques, access control mechanisms, and secure firmware updates are essential to mitigate security risks while maintaining energy efficiency and QoS.

• QoS Requirements of Applications: IoT applications have diverse QoS requirements based on factors such as latency, reliability, throughput, and scalability. Meeting these requirements while optimizing energy consumption can be challenging, especially in resource-constrained environments. Tailoring

QoS-aware routing protocols, traffic management strategies, and data aggregation techniques to specific application needs is crucial but requires careful consideration and optimization.

• Scalability and Network Management: As IoT networks scale to accommodate thousands or even millions of devices, managing energy consumption and ensuring QoS becomes increasingly complex. Scalable network management solutions, efficient resource allocation algorithms, and distributed energy optimization strategies are needed to support large-scale IoT deployments while maintaining performance and reliability.

Addressing these challenges requires a holistic approach that integrates energy-efficient design principles, QoS-aware routing protocols, adaptive resource management strategies, and robust security measures. Collaboration between researchers, industry stakeholders, and policymakers is essential to develop innovative solutions and best practices for achieving energy efficiency and QoS in IoT networks.

2. LITERATURE REVIEW

Mohamed Essaid et al., (2016) [6] propose a novel selection approach for IoT service composition, focusing on user satisfaction through QoS optimization and energy efficiency. Their method, named EQSA (Energy-Centered and QoS-Aware Services Selection Algorithm), employs a lexicographic optimization strategy and QoS constraints relaxation to preselect services meeting desired QoS levels. Subsequently, to minimize energy consumption while maintaining user satisfaction, the most suitable services from the preselected pool are chosen using a relative dominance concept based on Pareto principles. This evaluation considers each service's energy profile, QoS attributes, and user preferences. The algorithm's performance is evaluated through various simulation scenarios, demonstrating its effectiveness in selection time, energy efficiency, composition lifetime, and optimality compared to algorithms addressing QoS and energy consumption separately. Initially, a lexicographic optimization method is utilized to preselect services based on QoS attributes, followed by comparison using the relative dominance concept to determine the best service. Looking ahead, the research suggests extending the EQSA algorithm to handle dynamic service re-selection by predicting changes in QoS and energy parameters, considering various composition operators in a given plan. The drawback of the EQSA algorithm is the need for further exploration in handling dynamic service re-selection, especially in predicting changes in QoS and energy parameters, which may pose challenges in real-time adaptation.

Srinidhi et al.,(2019) [7] introduce the Hybrid Energy Efficient and QoS Aware (HEEQA) algorithm, a fusion of Quantum Particle Swarm Optimization (QPSO) and enhanced Non-Dominated Sorting Genetic Algorithm (NGSA), aimed at achieving energy balance across devices. Additionally, the algorithm optimizes MAC layer parameters to further reduce device energy consumption. IoT device QoS attainment poses a significant challenge, necessitating energy balancing for prolonged device lifespan. HEEQA, proposed in this research, represents an energy-efficient QoS-aware model by amalgamating NSGA and QPSO to identify nodes with high residual energy for efficient cluster communication. Simulation results demonstrate several key findings are Cooperative node utilization enhances cluster head efficiency, optimizing QoS, and overall performance, particularly in long communication modes. MAC layer parameter tuning reduces energy consumption for each node within the IoT network. The proposed method outperforms QPSO across various metrics including residual energy maximization, end-to-end delay, delivery ratio, transmission overhead, network lifetime maximization, and throughput. However, its performance may diminish when nodes exhibit varying mobility speeds. Drawback of the HEEQA algorithm is its susceptibility to performance degradation in scenarios with nodes exhibiting varying mobility speeds, potentially impacting overall network efficiency and QoS optimization.

Shankar Dattatray Chavan et al.,(2019) [8] propose a novel routing algorithm for Wireless Sensor Networks (WSNs) utilizing a clustering-based approach and Bio-inspired Energy-Efficient Clustering Protocol (Bee-Cup). This method leverages clustering, a widely employed technique for reducing energy consumption and enhancing performance. Their innovation, IBeeCup, extends the BeeCup protocol by incorporating a shortest path-finding mechanism. Location information is determined via Received Signal Strength Indication (RSSI), exploiting biologically inspired computation to enhance network performance. The results of the improved Bioinspired Energy-Efficient Clustering Protocol demonstrate promising outcomes across various parameters. Average Energy Consumption is reduced by 29% compared to BeeCup, attributed to the optimization of route selection, lower RSSI values, and minimized distances. IBeeCup exhibits a 36% increase in Time until First Node Dies compared to BeeCup, consequently prolonging network lifetime by selecting optimal Cluster Heads (CHs) and achieving balanced energy consumption. Furthermore, IBeeCup enhances Cluster Head Residual Energy by 37% on average, facilitating dynamic cluster adjustments and improving network performance. Control overhead is also reduced by 27% compared to BeeCup, leading to increased network efficiency through optimal path selection and well-addressed node and cluster head management, leveraging a location-based approach. Drawback of the IBeeCup routing algorithm proposed is its reliance on Received Signal Strength Indication (RSSI) for location determination, which may suffer from inaccuracies or inconsistencies in real-world deployment scenarios, potentially affecting routing efficiency and network performance.

Parvinder Singh et al.,(2019) [9] have proposed a hybrid technique aimed at enhancing energy efficiency and network longevity while preserving service quality integrity. They developed a fitness function encompassing parameters such as cluster node count, cluster head tenure, neighboring node count, residual node energy, average network energy, and distance between cluster head nodes and the base station. This fitness function significantly influences the cluster head selection process when integrated with the probability threshold function. Their redesigned TDMA protocol ensures uniform packet traversal by nodes across different clusters in each round. A mathematical radio energy model is employed to justify transmission and reception energy consumption based on a fixed packet size (x bits) at a transmission rate (r bits/s). The proposed method maintains stability in selecting the optimal cluster head value for each round, outperforming LEACH and other previous homogeneous protocols. Comparison with previous heterogeneous protocols like DEEC, EDDEEC, and ATEER reveals the superiority of the proposed protocol in terms of network lifetime, energy efficiency, delay, and network throughput. Experimental results indicate that the presented scheme surpasses EDDEEC, DEEC, and ATEER by 63%, 26%, and 10%, respectively, in terms of network lifetime and throughput. Consequently, the proposed work demonstrates suitability for real-time wireless sensor network deployment. Drawback of the hybrid technique is the complexity introduced by the fitness function and probability threshold integration, which may increase computational overhead and system complexity, potentially impacting scalability and real-time performance in large-scale deployments.

Inam Ullah Khan et al.,(2020) [10] proposed routing protocol, named eAntHocNet, leverages the principles of ant colony optimization (ACO) to navigate flying ad hoc networks (FANETs). By harnessing the collective behavior of ants, eAntHocNet efficiently discovers optimal paths within the network. The protocol encompasses the generation of initial feasible solutions, optional daemon actions, and the pheromone update process. Evaluation of the eAntHocNet routing protocol involves various metrics such as packet drop rate, network throughput, packet received ratio, average end-to-end delay, and work done (bits per joule).eAntHocNet capitalizes on the ACO algorithm, drawing inspiration from nature to optimize pathfinding. Through the use of pheromone trails and heuristics, ants are guided toward optimal routes within the network. Simulation results demonstrate the superiority of the eAntHocNet routing protocol over alternatives like AntHocNet, DSR, MDART, and TORA across multiple performance metrics. This enhancement contributes to heightened overall performance and efficiency within FANETs.While the research does not identify specific drawbacks of the eAntHocNet routing protocol, it's essential to acknowledge that its performance may be subject to variations based on network topology, mobility models, and other influencing factors. Drawback of the eAntHocNet routing protocol is its susceptibility to performance fluctuations due to changes in network topology, mobility patterns, and environmental conditions, which may impact its effectiveness and reliability in real-world FANET deployments.

Jing Xiao et al., (2021) [11] introduce the Clone Adaptive Whale Optimization Algorithm (CAWOA) tailored to mitigate routing energy consumption in

QoS-constrained Industrial Wireless Sensor Networks (IWSNs). They propose a novel clone operator alongside a discrete binary-based routing coding approach, facilitating robust support for optimal routing strategies. Moreover, they devise a comprehensive routing model for IWSNs considering bandwidth, delay, delay jitter, and packet loss rate constraints. Through extensive simulations, CAWOA is benchmarked against heuristic-based routing algorithms including Whale Optimization Algorithm (WOA), Simulated Annealing (SA), Particle Swarm Optimization (PSO), and Genetic Algorithm (GA). The primary aim is to curtail routing energy expenditure in IWSNs under QoS constraints, thus prompting the development of CAWOA. This algorithm stands out for its incorporation of adaptive technology and cloning operations. It effectively optimizes IWSN routing methods, resulting in reduced network energy consumption. Furthermore, a novel routing model accommodating QoS constraints is crafted, encompassing factors such as bandwidth, delay, delay jitter, and packet loss rate, which influence sensor routing energy utilization. Comparative analyses with GA, WOA, PSO, and SA demonstrate CAWOA's superior performance in optimizing IWSN routing energy consumption while meeting QoS criteria. Simulation outcomes highlight CAWOA's advantages in terms of energy efficiency, convergence speed, and optimization prowess. Particularly noteworthy is its scalability, making it well-suited for large-scale IWSNs. As sensor node count increases, CAWOA's efficacy in minimizing energy consumption becomes increasingly evident, affirming its efficacy in enhancing IWSN routing efficiency. Drawback of the Clone Adaptive Whale Optimization Algorithm (CAWOA) is the lack of analysis regarding its performance under dynamic network conditions, which may affect its adaptability and effectiveness in real-world scenarios with changing network environments and requirements.

Eyassu Dilla Diratie et al.,(2021) [12] introduce an energy-aware and Quality of Service (QoS) routing algorithm tailored for wireless mesh-connected visual sensor nodes within a hybrid Internet of Things (IoT) network. This algorithm facilitates the routing of video streams with ensured bandwidth and limited delay, operating under the assumption that end-to-end packet transmission delay correlates with the number of hops in a path. The primary objective is to minimize the number of active visual sensor nodes in the network while meeting bandwidth and delay constraints. To address this, the problem is formulated as an Integer Linear Program (ILP), where a branch-and-bound algorithm is employed to determine the minimum number of visual sensor nodes required, considering bandwidth and delay constraints. The proposed approach is evaluated through simulations and compared against existing methods from the literature, including an aggregation algorithm and a shortest path algorithm. Results demonstrate a clear tradeoff between energy conservation and QoS. The proposed approach achieves notable energy savings while upholding QoS standards in terms of bandwidth and delay. Notably, it permits the shutdown of as many visual sensor nodes as possible to reduce overall network energy consumption, thereby minimizing wireless interference among nodes. While the study focuses on mesh-connected visual sensor nodes with a single gateway, it suggests potential extensions to consider varying numbers of gateways to assess different performance metrics. Additionally, there is potential for further exploration to develop heuristic solutions suitable for networks with a large number of nodes. A drawback of the energy-aware and QoS routing algorithm is the limited exploration of its scalability and adaptability to networks with a large number of nodes, which may affect its effectiveness and efficiency in larger-scale deployments.

Celestine Iwendi et al., (2021) [13] proposed a novel approach utilizing a hybrid meta-heuristic algorithm, specifically the integration of Whale Optimization Algorithm (WOA) with Simulated Annealing (SA), to optimize energy consumption by selecting the most suitable Cluster Head (CH) in IoT networks. Various performance metrics including the number of alive nodes, load, temperature, residual energy, and cost function are employed to identify the optimal CH within IoT network clusters. The efficacy of the proposed method is compared against several state-of-the-art optimization algorithms such as Artificial Bee Colony (ABC), Genetic Algorithm (GA), and Adaptive Gravitational Search Algorithm (AGSA), demonstrating its superior performance. In this work, the Xively IoT platform is utilized to simulate the IoT network, running for 2000 iterations. The proposed approach is evaluated based on metrics including load, residual energy, number of alive nodes, cost function, and temperature. Experimental results confirm the superiority of the proposed hybrid algorithm over existing methods. Future endeavors may involve further optimization of energy utilization by considering additional performance metrics such as delay, node density, and link lifetime for CH selection. Additionally, scalability testing in real-time applications with a large number of sensors could enhance the applicability of the proposed approach. Furthermore, the energy consumption of the entire IoT network is assessed in this study, laying groundwork for comprehensive energy management strategies. A potential drawback of the proposed hybrid meta-heuristic algorithm is the limited exploration of its performance under real-time conditions with a large number of sensors, which may affect its scalability and applicability in practical IoT network deployments.

Diya Thomas et al., (2021) [14] have presented an extensive taxonomy of energy management schemes tailored for Wireless Sensor Networks (WSNs), focusing particularly on Quality of Service (QoS) aware node scheduling and elaborating on their advantages and drawbacks. Node scheduling leverages redundancy to identify and activate multiple schedules of sensor nodes, offering a cost-effective approach to energy conservation. The authors categorize and access node scheduling schemes based on their effectiveness in meeting crucial QoS requirements such as coverage, connectivity, fault tolerance, and security, while also discussing their strengths and limitations. It is posited that any node scheduling scheme meeting these requirements possesses the potential to significantly prolong network lifespan and thus support a diverse array of applications. The research review concludes by spotlighting key issues and challenges within node scheduling schemes, aiming to stimulate future research in this domain. Drawback of the extensive taxonomy is the lack of empirical validation or experimentation to assess the practical effectiveness of the discussed energy management schemes, which may limit the applicability and generalizability of the findings in real-world Wireless Sensor Network (WSN) deployments.

Lavanya et al. (2021) [15] introduce a novel energy-efficient and optimal Quality of Service (QoS) aware multi-path routing protocol, denoted as EHO-ETQRP, for Wireless Sensor Networks (WSNs) in IoT (Internet of Things) applications. This protocol is based on the Elephant Herding Optimization (EHO) algorithm and trust mechanisms. The objective function of this work prioritizes QoS parameters, particularly trust and energy considerations. EHO-ETQRP identifies optimal routing paths by assessing costs related to node congestion and lifetimes, ensuring efficient data transmission. The protocol undergoes evaluation to assess its suitability, yielding satisfactory results and proposing a novel optimal path selection protocol for IoT-based WSNs. In IoT applications, energy-efficient and QoS-aware multicast routing is crucial. EHO optimization facilitates optimal route selection for multicast routing, considering trust, energy, and QoS factors to establish effective communication routes. Secure communication is enhanced through the selection of secure nodes based on energy and trust updates. Simulation experiments conducted with 50 and 100 nodes using NS2 simulator under various conditions demonstrate superior performance of the proposed method compared to existing strategies. Evaluation parameters such as throughput, energy consumption, and delay indicate enhanced network performance with the proposed routing protocol, leading to increased delivery ratio, energy efficiency, and network lifetime. Drawback of the EHO-ETQRP routing protocol is the limited evaluation under diverse and dynamic network conditions, which may not fully capture the protocol's performance variability and robustness in real-world Wireless Sensor Network (WSN) deployments.

Idir Aoudia et al., (2021) [16] introduce an innovative adaptive QoS-Aware Service Composition Approach (P-MPGA) for Fog-IoT healthcare settings, leveraging a multi-population genetic algorithm. In order to enrich the Cloud-IoT architecture, they propose a comprehensive Fog-IoT 5-layered architecture. Additionally, they develop a QoS-Aware Multi-Population Genetic Algorithm (P-MPGA), taking into account 12 key QoS dimensions: Availability (A), Cost (C), Documentation (D), Location (L), Memory Resources (M), Precision (P), Reliability (R), Response time (Rt), Reputation (Rp), Security (S), Service Classification (Sc), Success rate (Sr), and Throughput (T). Their P-MPGA algorithm incorporates a sophisticated selection method for choosing the most appropriate service and includes a monitoring system to adaptively manage changes in the IoT environment. Experimental findings demonstrate the efficacy of P-MPGA, showcasing notable improvements in execution time, average fitness values, and the ratio of execution time to the best fitness value, even with an expanded population size. P-MPGA excels in rapidly achieving composite services that meet users' QoS requirements, rendering it well-suited for large-scale IoT environments. Drawback of the P-MPGA approach is the complexity introduced by considering 12 key QoS dimensions, which may increase computational overhead and limit scalability, especially in large-scale Fog-IoT healthcare settings, potentially impacting real-time responsiveness and efficiency.

Ameer Alhasan et al.,(2021) [17] propose the EA-IoT trust model, which places emphasis on energy as a fundamental parameter in constructing and updating trust throughout the network's lifespan. This Quality of Service (QoS) approach to IoT applications introduces an energy-aware trust model comprising four parameters: communication trust, dependability trust, delay trust, and energy trust. These parameters are tailored for four distinct scenarios using the k-means clustering algorithm. Subsequently, the final trust score is calculated for each node, facilitating node classification based on trust level. The results demonstrate that the proposed model exhibits reduced communication overhead, resulting in lower energy consumption compared to recently proposed models. Furthermore, the required number of packets for trust update is significantly reduced. Comparative analysis with two recent models, Context-IoT and STD-IoT, reveals that the proposed approach decreases energy consumption by approximately 50% compared to Context-IoT and 43% compared to Security & Trusted Devices (STD-IoT). Drawback of the EA-IoT trust model is its reliance on the k-means clustering algorithm for parameter tailoring, which may introduce challenges in accurately defining clusters and may not fully capture the dynamic nature of trust relationships in complex IoT environments.

Rajiv Yadav et al.,(2022) [18] research discusses three primary categories of bio-inspired algorithms: evolutionary, swarm-based, and plant-based optimization. Within evolutionary techniques, Genetic Algorithm (GA) and Differential Evolution (DE) are highlighted. Swarm-based methods encompass Genetic Algorithm-Presearch Swarm Optimization (GA-PSO) and Presearch Swarm Optimization-Ant Colony Optimization (PSO-ACO). However, specific mention of plant-based optimization is absent in the provided content. Regarding research metrics, various deterministic and probabilistic approaches are implemented to enhance network longevity, energy efficiency, packet loss, overhead, and Quality of Service (QoS). The study references several bio-inspired algorithms, including GA, PSO, ACO, DE, GA-PSO, and PSO-ACO. Additionally, other algorithms such as Gravitational Search Algorithm (GSA), Bat Algorithm (BA), Charged System Search (CSS), and Cuckoo Search (CS) are mentioned. Although detailed information about all algorithms is not provided, the research briefly outlines their advantages. For instance, GSA offers an adjustable learning rate and yields consistent and precise results. BA facilitates a seamless transition from exploration to exploitation, allows parameter control, and employs echolocation and frequency fluctuation. CSS boasts simplicity in implementation and avoids entrapment in local minima, while CS ensures rapid convergence utilizing Levy flights for global searches. Furthermore, the research acknowledges some drawbacks of these algorithms. For instance, GSA is computationally intensive, and searching can be sluggish in recent iterations. BA encounters challenges with initial parameter values and fluctuating convergence rates. CSS experiences increased computational costs with higher charges. Drawback of the research is the absence of specific discussion on plant-based optimization algorithms despite being mentioned as a primary category, which may limit the comprehensiveness of the study's coverage on bio-inspired optimization techniques.

Ashit Kumar Dutta et al., (2022) [19] introduce the Ensemble of Metaheuristic Optimization based QoS-aware Clustering with Multihop Routing (EMOQoSCMR) Protocol for IoT-assisted Wireless Sensor Networks (WSN). The EMO-QoSCMR protocol is designed to optimize QoS parameters such as energy consumption, throughput, delay, and network lifetime. The protocol involves two main stages: clustering and routing. Initially, the EMO-QoSCMR protocol employs the Cross-Entropy Rain Optimization Algorithm-based Clustering (CEROAC) technique to select an optimal set of cluster heads (CHs) and form clusters. Additionally, the Oppositional Chaos Game Optimization-based Routing (OCGOR) technique is utilized to establish optimal routes in the IoT-assisted WSN. A fitness function is derived based on parameters associated with IoT nodes, including residual energy and distance to the sink node. The proposed EMOQoSCMR technique demonstrates enhanced Network Activation Nodes (NAN), achieving 64 nodes compared to lesser NAN values of 2, 10, 42, and 51 rounds for LEACH, PSO-ECHS, E-OEERP, and iCSHS methods, respectively. The performance of the protocol is evaluated in terms of energy efficiency and network lifetime, showcasing its effectiveness in optimizing these metrics. A potential drawback of the EMOQoSCMR protocol is the reliance on specific metaheuristic optimization techniques such as Cross-Entropy Rain Optimization Algorithm-based Clustering (CEROAC) and Oppositional Chaos Game Optimization-based Routing (OCGOR), which may limit its adaptability and scalability across different IoT environments and scenarios.

Marzieh Hamzei et al.,(2023) [20] introduce a multi-objective fuzzy-based hybrid algorithm for IoT service composition. This algorithm combines Ant Colony Optimization (ACO) and Artificial Bee Colony (ABC) algorithms to determine an optimal path meeting specific Quality-of-Service (QoS) requirements within a directed acyclic graph. The proposed approach integrates fuzzy logic to manage uncertainty and imprecise information inherent in service composition tasks. Emphasizing QoS parameters such as availability, reliability, cost, and energy consumption, the research evaluates the algorithm's performance against these metrics and compares it with other optimization methods like FSCA-EQ, PSO, and GA. The multi-objective fuzzy-based hybrid algorithm exhibits several advantages over alternative optimization techniques, particularly in the realm of service composition. It adeptly handles uncertainty and imprecision, concurrently addressing multiple QoS parameters. Additionally, the algorithm demonstrates scalability and efficiency in managing extensive IoT device and service networks. However, potential challenges are identified, including difficulties in accurately distributing importance factors, adaptation to dynamic changes within cloud environments, and the necessity for meticulous tuning and experimentation with fitness functions and parameter values. Furthermore, the algorithm's scalability lacks explicit discussion, and practical considerations regarding its implementation in real-world IoT systems remain unexplored. A potential drawback of the multi-objective fuzzy-based hybrid algorithm is the complexity associated with accurately distributing importance factors and adapting to dynamic changes within cloud environments, which may require meticulous tuning and experimentation with fitness functions and parameter values, potentially hindering its practical implementation in real-world IoT systems.

Rashmi Prava Das et al.,(2023) [21] concentrate on reducing power consumption in IoT sensors to enhance network longevity. Their approach involves selecting the optimal IoT cluster header (CH) to maximize energy efficiency. Employing particle swarm optimization (PSO) combined with artificial neural networks (ANNs), the method identifies the most suitable CH within an IoT network cluster based on factors such as active nodes, load, residual energy, and a cost function. Comparative analysis with artificial bee colony, genetic, and adaptive gravitational search algorithms reveals the superiority of the hybrid solution over traditional methods. Despite the considerable promise of IoT across various applications, numerous challenges must be addressed to ensure its robustness. Issues related to data access, hardware compatibility, and power consumption optimization pose significant hurdles. This investigation specifically focuses on addressing the challenge of energy optimization. To tackle this, a hybrid metaheuristic algorithm, PSO-NN, is employed to optimize sensor power consumption within an IoT-based Wireless Sensor Network (WSN). Various performance parameters including cost function, residual energy, active nodes, temperature, and load are employed to identify the optimal CH for IoT network operation. The proposed method is then compared with existing approaches, with experimental results demonstrating its superiority. Future iterations of this approach may consider additional performance parameters such as link lifetime, node density, and latency to further refine CH selection. Furthermore, scalability testing in real-time applications, such as those involving diverse sensors, would be instrumental in assessing the effectiveness of the proposed method. The drawback of the PSO-NN hybrid solution is the necessity for addressing challenges related to data access, hardware compatibility, and power consumption optimization in real-world IoT sensor deployments, which may require further refinement and validation in diverse operational scenarios.

Abdullah et al.,(2023) [22] introduce an energy-conscious data management technique termed DMM (Energy-Aware Data Management Method). Within this approach, a selected group of IoT nodes is tasked with distributed data storage to optimize network longevity. Moreover, to extend battery lifespan, nodes not engaged in data transmission or storage are designated as idle or powered off. The network's data is categorized into urgent and normal data sets, each associated with differing access latency requirements. Thus, maximum latency thresholds are established for both urgent and normal data, ensuring that the combined maximum latency does not surpass the average latency for data access from these thresholds. The authors demonstrate that the proposed approach (1) effectively maintains data access latency below predefined thresholds and (2) exhibits superior network longevity compared to an offline centralized heuristic algorithm. Future research directions may include exploring the maximum network lifespan in both producer-to-proxy and proxy-to-consumer directions. Additionally, leveraging machine learning and deep learning mechanisms holds promise for further enhancing network lifetime and addressing related issues. Drawback of the EDMM technique is the potential complexity and overhead associated with managing the dynamic states of IoT nodes, especially concerning the decision-making process for transitioning nodes between active, idle, and powered-off states, which may introduce additional computational and communication overhead.

Nithyanandh et al., (2023) [23] introduce the EAP-IFBA protocol (Energy Aware Bio-Inspired Improvised Firefly Bio-Inspired Algorithm-Based Protocol), designed for adaptive sleep scheduling and secured data transmission in IoT networks. EAP-IFBA aims to enhance sensor node energy, ensure reliable and secure data transmission, and adapt to dynamic topology changes. The protocol employs dynamic key generation with ECM (Elliptic Curve Method) to address security concerns and prevent data loss during real-time data capture and delivery. Abnormal network patterns and topology changes, including those caused by attacks, are identified by ERNN (Enhanced Recurrent Neural Network), while data recovery errors are assessed using Mean Square Error Data Recovery (MSEDR). To optimize data transmission, EAP-IFBA utilizes Q-Learning Technique (QLT) action sets to establish finite transmission paths, minimizing data loss and maximizing sensor node energy. The protocol's performance is evaluated in a custom Testbed with physical IoT devices, measuring various metrics such as network lifespan, active nodes, and energy consumption. Results indicate that EAP-IFBA effectively combats network attacks, conserves energy, and enhances data security. Simulation in OMNETC++ software compares EAP-IFBA with baseline protocols, showing an 8% reduction in energy consumption and a 98% increase in network lifespan. Despite its promising outcomes, EAP-IFBA has limitations regarding sensor node placement, particularly in uneven terrains, which may lead to delays in data sensing. Additionally, its effectiveness is restricted in homogeneous environments. Future enhancements could focus on adapting the protocol for complex IoT systems, large-scale WSNs, and improving resilience against various attacks. Drawback of the EAP-IFBA protocol is its limitation in sensor node placement, especially in uneven terrains, which might result in delays in data sensing and could affect the overall efficiency of the protocol, particularly in challenging environmental conditions.

Shuling Yin et al., (2023) [24] introduce a novel QoS-aware resource allocation method for IoT systems termed ACO-TS, which utilizes a hybrid approach integrating Ant Colony Optimization (ACO) and Tabu Search (TS) algorithms. This method effectively manages resources, minimizes energy consumption, reduces communication delays, and enhances overall system performance. ACO-TS efficiently allocates limited resources in IoT systems while adhering to the QoS requirements of individual devices. The integration of ACO and TS techniques demonstrates the effectiveness and efficiency of the approach in optimizing resource allocation decisions. The ACO algorithm harnesses the behavior of ant colonies to explore the solution space, while the TS technique intensifies the search process to overcome local optima. Through the synergistic combination of these two techniques, a balance between exploration and exploitation is achieved, leading to improved convergence speed and solution quality. Experimental evaluations conducted in realistic IoT scenarios validate the effectiveness of the ACO-TS approach. Compared to existing resource allocation methods, ACO-TS achieve significant improvements in reducing energy consumption, maximizing network capacity, and satisfying QoS requirements. Drawback of the ACO-TS method could be its computational complexity due to the integration of both Ant Colony Optimization (ACO) and Tabu Search (TS) algorithms, which might require considerable computational resources, especially for large-scale IoT systems, impacting its scalability and real-time applicability.

Wenkai Lv et al.,(2023) [25] proposed a novel computation offloading strategy tailored for GEO/LEO hybrid satellite networks. Their approach focuses on minimizing overall energy consumption while ensuring the quality of service (QoS) for multiple missions. Initially, they creatively tackle the on-board partial computation offloading issue, typically a mixed-integer nonlinear programming (MINLP) problem, by transforming it into a more manageable minimum cost maximum flow (MCMF) problem. Subsequently, they introduce the successive shortest path-based computation offloading (SSPCO) method, which efficiently determines the offloading decisions within polynomial time. To assess the efficacy and performance of SSPCO, the team conducts a series of numerical experiments and contrasts SSPCO against alternative offloading techniques. The results of these experiments highlight SSPCO's superiority across various metrics, including total energy consumption, QoS adherence, and algorithmic execution time, outperforming the reference methods. A potential drawback of the SSPCO method may be its applicability to real-world scenarios, as its effectiveness might depend on the assumptions made in the mathematical modeling and the specific characteristics of the satellite network, which may not always accurately represent complex operational environments.

Xiao Liu et al., (2024) [26] propose a novel approach to tackle the challenge of Quality of Service (QoS)-aware service discovery in IoT environments. Leveraging whale optimization and genetic algorithms, their method aims to optimize decision-making processes in selecting IoT services. Given IoT's potential to enhance everyday activities with intelligent, efficient communication and processes, effective service discovery becomes paramount in this dynamic landscape. The utilization of bio-inspired optimization techniques in their approach facilitates more efficient service discovery compared to conventional methods. The dynamic nature of IoT necessitates a responsive sensor network infrastructure capable of adapting to emerging technologies. Within this context, the problem of service discovery and selection is framed as an NP-hard problem. The paper introduces a novel service discovery and selection technique that harnesses whale optimization and genetic algorithms to address this challenge. This approach offers a robust solution to the NP-hard problem of optimal service discovery, thereby reducing time and cost implications for cloud providers striving to meet QoS requirements. Simulation results validate the effectiveness of their algorithm, demonstrating superior performance compared to existing baseline approaches. Specifically, their method minimizes data access time, optimizes energy usage, and enhances cost-effectiveness. This research significantly advances the field by providing an advanced, efficient, and scalable solution to the challenges of dynamic service discovery in IoT environments. It lays the groundwork for future developments aimed at enhancing QoS-aware service discovery techniques, ultimately contributing to the evolution of responsive and adaptive IoT infrastructures. While acknowledging the notable advantages of the proposed method, it's important to recognize potential limitations, as the algorithm's performance may be influenced by specific network configurations and environmental factors. Drawback of the proposed approach is its sensitivity to network configurations and environmental factors, which could affect the algorithm's performance in real-world IoT deployments.

Dogra AK et al., (2022) [27] conducted a thorough review of utilizing Internet of Things (IoT) technology in transportation, coupled with the application of Machine Learning (ML) techniques. The researcher delineated several methodologies employed by different researchers utilizing diverse ML algorithms. These contributions have significantly advanced the concept of smart transportation by harnessing data collected from IoT devices and applying ML algorithms. The collective efforts of various authors have notably augmented the intelligence of transportation systems, addressing challenges stemming from escalating traffic volumes. Despite considerable progress, there remains ample opportunity for expanding ML applications within transportation, particularly in optimizing traffic management at intersections and enhancing parking solutions. Furthermore, leveraging appropriate ML techniques could prove instrumental in managing burgeoning vehicular populations within urban areas. The study also highlighted the utilization of select features for identifying congestion, detecting road anomalies, and developing accident prevention models. While substantial strides have been taken in integrating IoT and ML algorithms within transportation, future endeavors could explore additional features to bolster predictive modeling capabilities. The amalgamation of diverse IoT devices and ML algorithms holds promise for devising innovative solutions to address the challenges precipitated by the exponential growth in transportation data. Researchers are encouraged to pursue novel strategies to counteract the societal challenges arising from the disproportionate rise in vehicular traffic compared to population growth rates. Drawback of the reviewed literature is the limited exploration of ML applications in optimizing traffic management at intersections and enhancing parking solutions, suggesting a need for further research in these areas to fully exploit the potential of IoT technology in transportation.

Rajesh Kumar et al., (2021) [28] introduced an innovative energy-efficient routing strategy termed Energy-Efficient Routing using Fuzzy Neural Network (ERFN), aimed at minimizing energy consumption while equitably distributing energy among sensors to prolong Wireless Sensor Network (WSN) lifespan. The algorithm integrates fuzzy logic and neural network principles to intelligently select cluster heads (CH) that effectively manage sensor energy consumption. Through the development of fuzzy rules, sets, and membership functions, decisions regarding next-hop selection are made based on factors such as total residual energy, link quality, and progress towards the sink. ERFN demonstrates superior efficiency compared to existing algorithms, evidenced by metrics such as the number of active nodes, percentage of dead nodes, average energy decay, and standard deviation of residual energy. Specifically, an Adaptive Neuro-Fuzzy Inference System is utilized to merge routing-centric metrics including residual energy, forward progress, and sensor degree, facilitating the selection of the next hop for packet forwarding. The neuro-fuzzy routing algorithm efficiently routes packets from the source sensor to the sink, with simulations conducted using MATLAB's fuzzy logic simulator tool, Neuro-Fuzzy Designer. Results indicate ERFN's superiority over EeBGR and eBPR in terms of network lifetime, energy consumption, and standard deviation of residual energy. Future research directions include exploring alternative machine learning algorithms for diverse applications such as E-mobility route planning and information dissemination in traffic environments. Additionally, the incorporation of energy-saving techniques like duty cycling in sensor-oriented wireless communication environments is proposed for further enhancement. Drawback of the ERFN algorithm is the reliance on simulations conducted using MATLAB's fuzzy logic simulator tool, Neuro-Fuzzy Designer, which may not fully capture the complexities and real-world dynamics of Wireless Sensor Network (WSN) environments, suggesting the need for validation through physical deployments or more advanced simulation techniques.

Qianao Ding et al. (2021) [29] provide a comprehensive overview of routing algorithms in Wireless Sensor Networks (WSNs), discussing traditional and Machine Learning (ML) approaches to green routing algorithm design. They propose a mathematical hypothesis model for an ML-based routing algorithm to extend WSN lifespan. The study reviews various routing algorithm principles and characteristics, along with techniques to enhance their performance. Challenges of implementing ML for routing algorithms in WSNs are identified, suggesting future research directions. Key considerations include the deployment of ML algorithms in WSNs with limited computational power and energy, advocating for distributed cooperative learning methods. Additionally, the study proposes utilizing transfer learning to leverage varying computational capabilities among nodes, particularly emphasizing the role of sink nodes in distributed model training. Addressing Quality of Service (QoS)-aware routing presents a significant challenge, prompting exploration of hybrid ML techniques in WSNs. Drawback of the proposed ML-based routing algorithm is the challenge of implementing machine learning in

Wireless Sensor Networks (WSNs) with limited computational power and energy, which may hinder the feasibility and scalability of the approach in practical deployments.

Yuvaraj Natarajan et al. (2022) [30] devised a Machine Learning-assisted cross-layer routing system for a reconfigurable Cognitive Radio Internet of Things (CR-IoT) application. The system utilizes a distributed controller to sense the environment and generate reports for optimal decision-making regarding cluster member selection, cluster head selection, and routing path selection in CR-IoTs. This approach ensures efficient data transmission by considering the characteristics of CR-IoTs. ML assistance enhances selection through cluster reconfiguration, threshold adjustment, and network-based CR-IoT reconfiguration. Benefits include enhanced network utilization, heterogeneity management, and energy efficiency. The cross-layer mechanism facilitates periodic reconfiguration during routing, optimizing network stability and resource utilization. Additionally, the study extends to address channel imperfections in cooperative CR-IoTs and considers the possibility of incorporating cloud storage for routing operation updates. Overall, the system offers an upgradable cross-layer routing protocol to enhance routing efficiency and data transmission optimization in reconfigurable networks, demonstrating scalability and robustness in trials. Drawback could be the complexity and computational overhead associated with the distributed controller and machine learning algorithms, which may introduce latency and overhead in real-time decision-making processes, particularly in resource-constrained CR-IoT environments.

Srinivasa Babu Kasturi et al. (2022) [31] introduced a novel cluster-based routing technique to enhance IoT-based sensor network routing efficiency. Utilizing neuro-fuzzy rules, the algorithm achieves precise clustering for cluster-based routing, improving overall network performance. Energy modeling via a trust & energy manager optimizes packet routing to minimize energy consumption, integrating machine learning algorithms into the clustering process. A convolutional neural network with fuzzy rules is employed for load balancing, significantly extending the network's lifetime. The routing decision-making process considers factors such as CH degrees, CH leftover power, distances between CHs, sink nodes, and sensor nodes, crucial for optimizing energy consumption and network lifespan. Results indicate that the proposed protocol surpasses LEACH, FLCFP, & SCCH in network lifetime, attributed to the integration of a learned neuro-fuzzy system and cluster-based routing. The drawback could be the potential increase in computational complexity and overhead associated with integrating machine learning algorithms like neuro-fuzzy systems and convolutional neural networks, which may require additional processing power and memory resources, impacting the scalability of the protocol, especially in resource-constrained IoT environments.

Padmalaya Nayak et al., (2021) [32] emphasize energy conservation as crucial in Wireless Sensor Networks (WSNs), given the reliance of sensor nodes on battery power for IoT applications. Efficient communication protocols are needed to address WSN challenges and ensure prolonged network operation. While traditional technologies address many issues, they may lack accurate mathematical models for predicting system behavior. This researcher explores machine learning techniques applied to WSNs, focusing on routing problems to provide researchers with a comprehensive understanding. Drawback could be the increased complexity and resource requirements associated with integrating machine learning techniques into WSNs, which may pose challenges in terms of deployment and scalability, particularly in resource-constrained environments.

Naveed Islam et al., (2021) [33] introduce a secure and sustainable prediction framework for Multimedia Internet of Things (MIoT) data transmission using machine learning. The framework focuses on intelligent system behavior while ensuring information protection. It utilizes regression analysis at network edges for real-time multimedia routing, achieving precise delivery to media servers. Additionally, an efficient asymmetric process ensures secure data transmission between IoT devices, edges, and data servers. Experimentation using the OMNET++ network simulator demonstrates significant improvements, including a 71% reduction in energy consumption, 30.5% increase in throughput, 22% decrease in latency, 34.5% increase in bandwidth, 38.5% reduction in packet overheads, 12.5% decrease in computation time, and 35% decrease in packet drop ratio compared to existing schemes. The framework leverages intelligent edge nodes for routing using machine learning regression analysis and mutual authentication of IoT devices before media transmission. It employs a knapsack cryptosystem for asymmetric data encryption and decryption, enhancing security. While the proposed framework decreases computing load and identifies poor links using machine learning, future research aims to explore communication between mobile media devices and improve performance in fully distributed systems using network coding-based analysis. Additionally, incorporating software-defined networking to systematize the IoT environment and reduce communication costs is a focus for future work. Drawback could be the computational overhead associated with implementing machine learning-based regression analysis at network edges, which may increase complexity and resource utilization, especially in resource-constrained IoT environments.

3. CONCLUSION

In conclusion, the Internet of Things (IoT) holds immense promise for transforming the way we interact with technology and the world around us. Throughout this literature review, we have explored the importance of energy efficiency and quality of service (QoS) routing in IoT networks. In this review revealed the challenges as well as difficulties are clearly associated with various previously exiting methods belongs to Bio-inspired techniques and also machine learning approaches. Due to this reason, Energy efficiency is play crucial role for prolonging battery life, reducing operating costs, promoting environmental sustainability, enhancing reliability and enabling scalability in IoT deployments. By optimizing energy consumption, organizations can maximize the benefits of IoT technology while minimizing its environmental and financial impact. Similarly, QoS routing also plays a critical role in ensuring reliable and timely data transmission in IoT networks, particularly for mission-critical applications. Addressing challenges such as limited resources, heterogeneous devices, dynamic environments, security concerns and scalability is essential for achieving energy efficiency and QoS in IoT networks. Moving forward, it is imperative to develop innovative solutions and best practices for overcoming these challenges and optimizing energy efficiency and QoS in IoT deployments. Through innovative approaches such as machine learning-assisted routing, regression analysis for multimedia routing and asymmetric data transmission protocols, researchers strive to optimize network performance while addressing security concerns. These efforts result in significant improvements in energy consumption, throughput, latency, bandwidth, packet overheads, computation time and packet drop ratio, as demonstrated through extensive experimentation.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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