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Multi-Objective Optimization in WSN: Opportunities and Challenges

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Abstract

Wireless sensor networks (WSNs) plays a significant role in the field of surveillance, monitoring the real time applications. Regardless its strong ability to handle such tasks, it is difficult to maintain a trade-off between the conflicting goals of network lifetime, transmission delay, high coverage and packet loss. Various solutions have been proposed by the researchers to address these issues comprising the solution in real-time network scenarios. This paper delivers a brief analysis of the solutions addressing recent research problems in WSN comprising conflicting goals, i.e. multi-objective optimization (MOO) technique. Firstly, an illustration of key optimization objective in WSNs is given which constitutes existing issues such as power control, rate control ant routing. Then, an elaboration of various objective functions used in MOO with its merits and demerits is also provided. Later, existing approaches for improving optimizing metric, applications performance of existing approaches and proposed architecture have been discussed.

Keywords WSN · Routing · Optimization techniques · Problems in optimization and objective functions

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1 Introduction

WSNs have extensive applications in various scenarios associated with emergency response, environmental tracking, earthquake and flood detection, security mission and much more. WSNs consist of large number of sensors with low power and high sink power which is accountable for establishing paths within conventions of convinced transmission. WSNs are preferred due to its hassle-free installation and timely coordination with other sensors in dynamic networks. However, sensor nodes have limited capacity, energy, sensing range and computational power [2]. Practically sensors are heterogeneous in nature with their functionalities and adjoining sensors sense environmental data within synchronized fashion. An isolated sensor node is limited to collect information with respect to their domain applications, therefore large number of sensors are required to form WSN.

In WSN, Quality of Service (QoS) [3] plays an important role that satisfies end-to-end user requirements. WSN focuses to enhance and evaluation of robustness and security. Routing demands optimum route from source station to destination satisfying QoS requirements in terms of delay, jitter, throughput, and bandwidth for end users with different real time applications [2]. Figure 1 represents association between infrastructure based network and WSN. Sink node gathers uplink information from sensors through single hop or multi-hop communication, then sink node transfers the collected information to the user via gateway using internet or other communication channel.

In today’s scenarios, integration of WSN with IoT is also an emerging technology. Numerous applications like transportation, education, agriculture and healthcare utilize it for sensing, computing and communication. Objects communicate with each other via different protocols and interfaces i.e. TCP/IP and IEEE 802.x standards. Rapid growth of devices will result in an enormous necessity of data storage and optimal routing techniques conserving more energy which require other issues to be taken care of scalability, lifetime maximization, security and much more [4].

Focusing on one optimization parameter while considering others is one of the major shortcomings of the conventional methods. Therefore, to handle such situations, MOO techniques have been adapted where multiple objectives of the WSN are treated

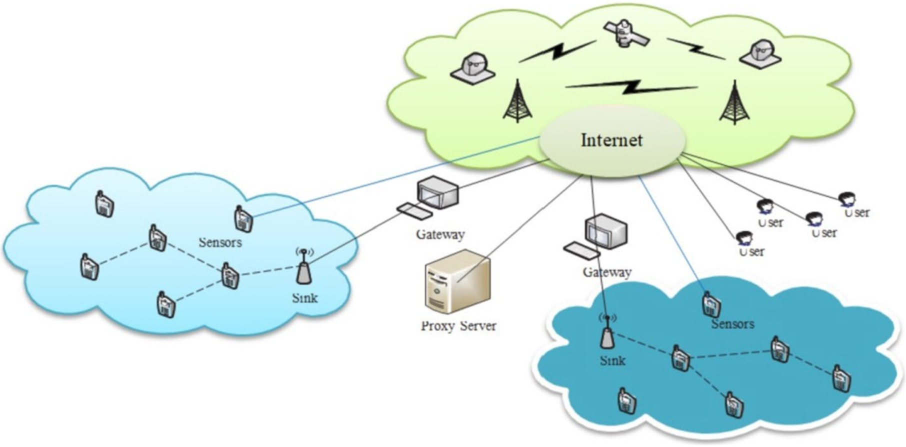


Fig. 1 Wireless senor network example with infrastructure based networks

accordingly with various other constraints [5]. Furthermore, to generate a set of multiple non-dominate solutions to such problems, Pareto-Front (PF) is utilized. Numerous optimal PF based solutions based on classical, nature inspired and meta-heuristics based solutions have been proposed to handle MOPs. Earlier, MOEA [6] was used for efficient power and rate control and then MOGA proved its better convergence properties for routing problems in WSNs. Variant of MOGA such as NSGA-II has proved its effectiveness for both problems in [6].

1.1 Motivation

Sensor nodes have limited battery life, therefore it is required to reduce energy consumption which will enhance network lifetime and coverage lifetime. For energy utilization reduction some overlapping sensor nodes should be turned off with the help of optimizing protocol in coverage area. Optimization using coverage protocols are of two types distributed and clustering protocols. These protocols include sensing model, mechanism used, node location and node's neighboring information [4].

Locate sensor in forest environment is also a complexity, question arises here how to deploy and monitor sensor in forest area, because main reason is its energy consumption so that it could work long time and coverage could be enhanced. PSO was used in that area and gives better outcomes [5].

Prolonging network lifetime is basic need of sensor network, for that CH is elected based on remaining energy of each node and transmits the packets to the sink node. Markov scheduling [6] also used for election of efficient and optimum CH. Proposed scheduling algorithm enhances network lifetime and reduces energy consumption. Various coding techniques for network to tackle the issue of energy consumption have been proposed in multi-hop wireless sensor network [7].

Wireless Multimedia Sensor Networks (WMSN) uses in much application, which improves utilization of channel rate, reduces E2E delay, balances network load. In all crucial application multipath routing is an auspicious solution. Multipath routing helps for data transmitting and reduces delay, congestion [8].

Sensor nodes communicate through diverse routing strategy, PEGASIS [9] is extended chain base protocol which prolongs network lifetime, where each node communicates with neighbor's node, make chain of nodes and elect leader from chain that collects environmental data and transfer to sink node.

WSN is highly densely distributed network having small size and low energy nodes. Packet scheduling is an important concern based on priority of information and reduces E2E. DMP prevents deadlock situation occurrence in network which works on threshold value and data rate priority [10].

TDMA [11] technique reduces the energy consumption in network and prolongs network lifetime. It balances energy consumption throughout the network and minimizing energy utilizing during packet transmitting. TDMA technique enhances network lifetime, reduces energy consumption, optimizes CHs selection and enhances packet transfer rate to base station with minimum delay and low energy.

Major transmission factor is hop device selection which can be adopted by various techniques, but these techniques are not alone sufficient in prolonging the network lifetime and minimizing energy. MAC [12, 13] uses optimized technique to select hop device. MAC [14] also controls time point transmission using time slot scheduling.

Deploy and forget solution in wireless sensor network provides efficient and rapid development of WSN and assist to user's onsite, reducing deployment complexity and protocol stack for long lasting procedures. Technology involved in evolution of WSN problems were identified in [15].

WSN plays important role in optics, environments, physics, biometry and gas, every application associated with WSN requires QoS requirements for satisfying users with optimizing resources. A QoS requirement varies according to application specifications and maintains QoS trust and reliability [16].

WSN accommodate fluctuations in topology, specific task, node density and mobility. Zigbee [17] incorporates in node's mobility and optimizes QoS. Specific model using Zigbee has been designed including parameters transmission range, back-off numbers and components and impact of node's mobility. Zigbee best performs on various parameters such as E2E delay, SNR, node density and node's mobility.

Security is again crucial issue in WSN, for that a cellular model has been proposed [18] which provides many fluctuations in terms of node density, sink node placement, influence factor of neighbor and probability of each cell. Proposed model handles many security issues in today's scenarios applications.

For secured data transmission data aggregation technique is needed which performs between every route while transmitting the data. Lifetime of sensors decreases due to insufficient data aggregation techniques and energy. Therefore, data aggregation should be done in an energy optimized manner. When sensors are deployed in various locations then many security attacks may arise, for that TESDA [19] algorithm much used in data aggregation process to avoid attacks.

Data collection using mobile sinks consumes much battery power while transcieving. Sink mobility depends upon the applications required by the user. Difficult situation may arise due to the lack of availability of sink nodes when data is about to deliver to sink node and loss the data. ECS algorithm handles this issue effectively and avoids from data loss [20, 21].

1.2 Contribution and Roadmap of the Article

In this context, by considering the contributions of MOO in WSNs, this paper focuses on the following aspects:

- Discussion on various routing optimization challenges including scalability, energy consumption, connectivity, node deployment, security and coverage.
- Distribution of different parameters including routing, power, rate, scheduling, QoS provisioning, security and mobility over recent years has been revealed.
- Detailed description of Network layer architecture optimization for different applications.
- Comparison of optimization routing protocols with objective functions, along with their merits and demerits.
- Techniques for improving optimizing metrics and applications performances of existing approaches.
- Optimization techniques and problems in optimization have been identified and proper solution given in this paper.
- Multi-Optimization Algorithm (M-OA) to solve problems in optimization has been proposed.

This article is organized as follows: Sect. 2 discuss the research gaps in different QoS metrics of WSN. Section 3 presents an overview of the problems handled via different optimization techniques along with a detailed description of the work handling multi-objective optimization problems. In Sect. 4, mathematical analysis of the key research papers is given. Then, Sect. 5 discusses the proposed architecture and Sect. 6 concludes the article.

2 QoS: Research Gap

Routing is an essential factor in WSN that should be done optimally. Routing is used for communicating among the sensors and sending data from sensors to base station. Routing issues tend to degrade the performance of complete network, decreasing network lifetime. Diverse routing protocols have been industrialized for prolonging network lifetime by reducing energy consumption [22]. WSNs have various routing challenges [23] which are yet to be solved in many applications including scalability, energy consumption, connectivity, node deployment, security and coverage. Research gaps in routing in WSN are discussed as follows [24, 25].

2.1 Multi-objective Routing

Developed routing algorithms or protocols should meet precise necessities such as coverage, throughput, end-to-end delay, capacity, collision and real-time delay. Therefore, there is the requirement of the development of routing protocol that meets specific optimization requirements [26].

2.2 QoS Constraints

QoS necessities in terms of jitter, probability, bandwidth ingesting, delay, end-to-end delay and outage probability should be taken in consideration of flexible routing algorithm or protocol. Outage probability is a specific QoS obligation for routing algorithm [27].

2.3 Secure Routing

Existing routing algorithms have been developed to enhance network coverage and performance of network, but avoid security factor that is essential in WSN while collection aggregate data at a central location. Therefore, it is needed to design secure routing algorithm without degrading the coverage and network performance [28].

2.4 Energy Requirement

Most of the sensors work on inbuilt battery with limited capacity, but energy can be achieved by solar, vibration and extra corporeal standards. Sensors engross conservational energy to maintain operative communication. From the survey it was found that very few energy winning nodes are being used in today’s applications, consequently these types of sensors should be taken in consideration for prolonging network lifetime [29]. Sensors deployed in hostile areas are required work longer without recharging as it is difficult to charge them frequently. Prolonging network lifetime is a foremost factor in WSN, which should be considered in today’s scenarios.

2.5 Large Source and Destination Set

Lot of algorithms or protocols work on single source and destination except few. Multiple source and destination demand in real-life applications leads to the problem of packet collision. Hence, avoiding this difficulty in WSN is a big research challenge. Further, with multiple sinks, there is lot of chances for information flooding, which wastes energy and it should be reduced [25].

2.6 Network Applications

Lot of protocols work on WSN’s applications, but few focus on applications such as limited bandwidth and delay sensitive applications. Therefore demanding probable applications to collaborate in routing include cellular network, LTE network, wireless LAN and intellectual radio network [30].

2.7 Enlargement Platforms

After survey, it is found that mostly routing algorithms or protocols work upon hypothetical investigation, whereas only few algorithms consider aspects based on practical routing implementation in real-time applications [31].

2.8 Strategy and Applications

WSN is being used in different areas includes monitoring biological system, fire detection, monitoring, tissue implanted and air fallen sensors. In some applications sensors have a precise position and some don’t have. Therefore, it is essential to design and locate sensor in future work [33].

2.9 Sensor Localization

Localization of sensors provides the cognizance of position organized at an exact point. Accurate statistics can be attained through Geometric aware routing. Localization techniques that exploit implication of coming signals from base station [35].

2.9.1 QoS Aware Routing

QoS is considered to satisfy end-to-end user/applications requirements. QoS is most important factor in real time applications of WSNs. QoS parameters comprise of fairness, packet loss, delay, jitter, accessible of bandwidth. It is important prolonging network lifetime with satisfying QoS parameters as per necessities of WSN applications. QoS affecting factors in WSN have been shown in Fig. 2, which replicates solicitation necessities of WSNs. It shows network concert can be enumerated in terms of network lifetime, energy consumption and QoS metrics for specific applications [37].

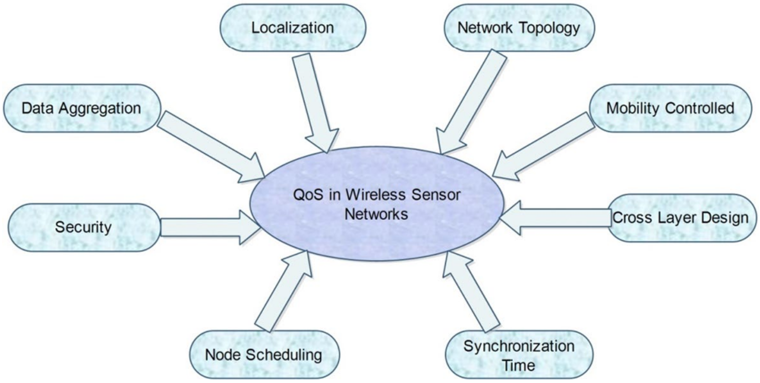


Fig. 2 QoS affecting factors in WSNs

3 Multi-objective Optimization

Multi-objective optimization approach presents WSN in adaptive manner, energy managing, self-organizing, application-oriented, energy preservation and communication restraints. The problems and techniques in optimization have been identified in this survey as follows [39]. An illustration of optimization problems and their corresponding techniques is shown in Fig. 3.

3.1 Optimization Issues

Different optimization issues exist in WSN:

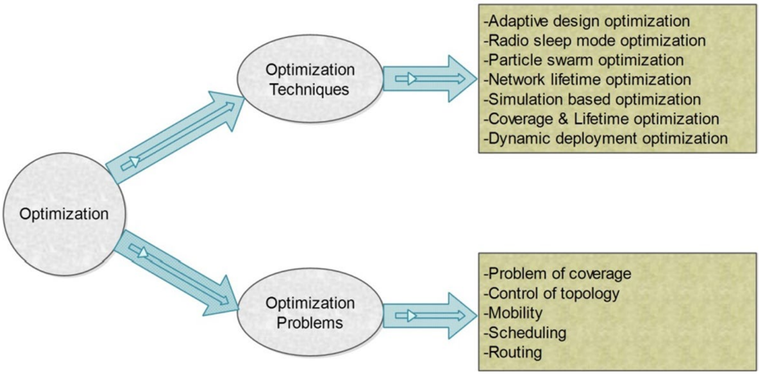


Fig. 3 Optimization techniques and problems in WSNs

3.1.1 Problem of Coverage

Coverage is considered as a QoS parameter in optimization of WSNs. Target area can be observed well through coverage of sensor nodes. In case of moving objects coverage problem becomes more challenging [55].

3.1.2 Control of Topology

Topology control problem provides the network connectivity and therefore minimizing energy consumption for continous information transmission to base station with low cost path satisfying QoS parameters is a big challenge of optimization in WSNs [56].

3.1.3 Mobility

Mobile sinks familiarized for data gathering gives the solution of coverage connectivity for prolonging network lifetime in WSNs. Travelling Salesman Problem (TSP) provides to discover shortest path which reduces the cost of data gathering sink travel. In densely deployed sensor network, sensors are organized into clusters then solve TSP through clusters [57].

3.1.4 Scheduling

Scheduling is existing problem in WSN optimization such as collisions, management of channel orientation, prolonging network lifetime and QoS attentiveness. This is challenging issue for researchers to improve scheduling strategy [58].

3.1.5 Routing

Data transmission in WSN through effective path is called routing problem, that can be expressed in graph flow based on classical approaches [59]. These problems are categorized as low cost flow, multi-commodity flow, minimum spanning tree and shortest path problem. Lot of work has been done based on flow problems for wired network, but challenges seem in wireless network especially in WSN. In the problem of network flow, link capability is a robust restraint that is relieved constraint of energy node in WSN [60].

3.2 Optimization Techniques

Different optimization techniques can be used in WSN:

3.2.1 Adaptive Design Optimization

Genetic algorithms (GAs) much used in optimization for developing the system with suitable fitness functions for many facets of network performance. Main characteristics of GA is to know sensor node's status (active mode or inactive mode). Strategy of finest sensor node fabricated by GA for satisfying explicit necessities of applications, energy preservation features and connectivity extant. Energy management tends to prolonging network lifetime without degrading the performance of network. In optimization problem solving GAs is used. GA replicates and allocates fitness value to each candidate elucidation for regular advancement [41].

3.2.2 Radio Sleep Mode Optimization

Energy proficiency is major issue in sensor network and radio acts as a provider to energy node feasting. MAC protocols works on stable squat power mode to laid radio to sleep. This power mode inherent tradeoff, deep sleep modes provide high energy cost and low current enticement for transferring radios to active mode. This method suggests adaptive sleep mode based on low power in the network of contemporary traffic circumstances. It presents all-inclusive energy model, transmission, listening, radio transferring energy mechanisms, reception and sleeping [43].

3.2.3 Particle Swarm Optimization

Particle Swarm Optimization (PSO) is an unpretentious, effectual and operative computationally algorithm for optimization. It is used to tackle issues in WSN includes localization of nodes, data aggregation, ideal deployment and clustering. PSO also used for technique of multidimensional optimization. PSO gives better outcomes in terms of speed of convergence, high quality solution and effectiveness of computational [45].

3.2.4 Network Lifetime Optimization

Network lifetime plays an important role in WSN for designing energy constrained applications. A design of joint optimal is used with MAC, routing layer and physical layer prolonging network lifetime of multi-source and single sink with energy constrained. Problem of prolonging network lifetime can be articulated as an assorted integer convex problem in optimization with TDMA technique. For taking real values integer restraints are relaxed and problem can be transformed into a convex problem for achieving upper bounds solution. An analytical framework is used for relaxed problem of prolonging network lifetime [47].

3.2.5 Simulation Based Optimization

Intention of consistent, fault tolerant and dynamic in WSN are major challenges which are yet to solve in WSN applications. For these issues optimization technique is introduced for providing optimal performance and middleware services. It based on simulation which handles noisy fault outward. This optimizing algorithm is demonstrated by formation of spanning tree which can be operated even asymmetrical links between nodes. In future large scale of WSN used in space and aviation is a key challenge for researchers such as safety control and monitoring system, smart dust, smart surface and intelligent space. These types of sensors habitually used as middleware services [49].

3.2.6 Coverage and Lifetime Optimization

WSN maintains required sensing coverage and transmit sensed information periodically to the central location. Information transmitting period may range from week to months.

Prolonging network lifetime and coverage are two issues in WSN due limited battery power in sensor nodes. Most of the analysis focus on lifetime and coverage focuses on specific scenario, distribution of sensors in random and uniformly. In this optimization Gaussian distribution is used for better performance of coverage and prolonging network lifetime [51].

3.2.7 Dynamic Deployment Optimization

Deployment of sensors is a key challenging issue in WSN. Self-technique is used for enhancing coverage in WSN consisting fixed and mobile nodes. Mobile nodes relocated itself according to situation and cover large area. Mobile nodes' new location can be resolute using parallel PSO and suitable to solve function of multidimensional in continuous space [53].

4 Detailed Analysis of the Literature

In this section, a detailed analysis of the literature in the domain of optimization in WSN is provided.

Yogarajan et al. [61] proposed a clustering algorithm based on Ant Lion optimization which enhances performance of network. Another distinct Ant Lion optimization to search optimum path and data gathering for mobile sink node with minimum length of data gathering. Distinct Ant Lion optimization mainframes for ideal directive of mobile sink for selecting cluster head and collect essential information. A simulation result of proposed algorithm shows that cluster scheme performs better in terms of prolonging network lifetime and throughput which minimizes discrete nodes. Also, Ant Lion optimization produces ideal tour for mobile sink node to collect data from CH. ALO algorithm works on random movement ants used with random walk phenomena can be calculated as follows.

$$A_i^t = \frac{(A_i^t - a_i).(d_i - C_i^t)}{(d_i^t - a_i)} + c_i \tag{1}$$

Specific symbols used in Eq. (1) are described in paper [49].

Particle swarm optimization (PSO) and Ant colony optimizations (ACO) has been proposed and evaluated by Kaur et al. [62], which improves data aggregation in inter cluster. Proposed algorithm prolongs network lifetime than other algorithm. ACOPSO is used to find shortest path between existing CHs and sink node. This technique provides optimal path taking into consideration energy efficient so that network lifetime could be enhanced. When ants move from CH_i *to* CH_j where i ≠ j then simple ant is calculated

$$P_{i,j} = \frac{(\tau_{i,j})^\alpha + (\eta_{i,j})^\beta}{\sum (\tau_{i,j})^\alpha (\eta_{i,j})^\beta} \tag{2}$$

where $\tau_{i,j}$ is deposit amount of pheromone from CH_i *to* CH_j and $\eta_{i,j}$ represents visibility function of trail which is correspondent to distance of energy from CH_i *to* CH_j. α and β are parameters of pheromone and heuristic visibility function respectively.

Yang et al. [63] proposed a protocol based on trust disseminated model called Energy Optimized Secure Routing (EOSR). It is designed for path length with residual energy, trust level of sensor node and strategy for multi factor. EOSR transmits data through trusted nodes and balances energy utilization throughout trusted nodes. EOSR gives better performance in terms of throughput, delivery rate and average power utilization. EOSR includes route construction, evaluation and maintenance; trust evaluation value is calculated based on node's communication behavior Beta distribution is used to evaluate trust node's value. Trust node's value DT_{ij} can be obtained as:

$$DT_{ij} = E(Beta(\alpha_{ij}, \beta_{ij})) = \frac{\alpha_{ij} + 1}{\alpha_{ij} + \beta_{ij} + 2} \tag{3}$$

where α_{ij} and β_{ij} represents cooperation and non-cooperation interaction between node i and j.

Power Energy Gathering in Sensor Information System (PEGASIS) protocol has been developed by Natasha et al. [64] which uses optimization of ant colony to attain finest chain. PEGASIS redundant data with optimization based on ant colony, transmission delay nodes distance concomitant with elongated links and CHs selection by appropriate method. CHs works on inter cluster communication and high level cluster heads transmits data to base station. Cluster head is selected on remaining energy and trade off, this selection is executed is as follows:

$$fitness = (w_1 \times E_{residual}(CH)) + \frac{w_2}{d_{dest}} \tag{4}$$

where w_1 and w_2 are weighted parameters whose sum = 1, $R_{esidual}$ represents remaining power of CH and d_{dest} is distance from destination.

Xu et al. [65] proposed two algorithms namely, hybrid MOEA/D-I and MOEA/D-II which cover problem of optimization in WSN and balances network lifetime and network coverage. These algorithms bets fit on enhancing energy utilization steadiness, exploit coverage rate and reducing energy consumption. Differential evolutionary and Genetic algorithm effectively optimize sub-problems of WSN based on multi-objective optimization. Therefore MOEA/D-I and MOEA/D-II algorithms have been developed for optimization. Energy consumption, coverage rate and energy equilibrium can be calculated from Eqs. (5)–(7) respectively.

$$E(I) = \left(\sum_{i=1}^{num} \sum_{S \varepsilon C_i} E_{S,CH_i} + E_{RX} + E_{DA} \right) + \sum_{i=1}^{num} E_{CH_{i,\mathrm{Sink}}} + E_{total} \tag{5}$$

$$N(I) = \sum_{i=1}^{M} U(S_t) \tag{6}$$

$$EQ_k = \frac{\sum_{i=1}^{n_k} E_{k_i}}{n_k} \tag{7}$$

Specific symbols used in Eqs. (5)–(7) have been described in paper [65].

A DV-maxhop globalization scheme has been developed and evaluated by Shahzad et al. [66]. DV-maxhop gives efficiency and noble accuracy. A multi-objective optimization function has been used for reducing localization errors and transmissions number throughout localization phase. DV-maxhop has been evaluated on extensive simulation using different topologies. Convergence time reduction is obtained by reducing network overhead. Reduction of number of transmissions tends to reduce energy consumption. Two objectives functions have been used in DV-maxhop as follows:

$$f1(p) = \frac{1}{N_r} \sum_{i\varepsilon N_r} \sqrt{(\hat{x}_i - x_i)^2 + (\hat{y}_i - y_i)^2} \tag{8}$$

$$f2(p) = \frac{1}{N} \sum_{i\varepsilon N} N_{T_{X_i}} \tag{9}$$

where $(\hat{x}_i, \hat{y}_i)$ and (x_i, y_i) are positions of estimated and actual node i and $N_{T_{X_i}}$ represents packets transmitted by node i.

Dimitriois et al. [67] has been proposed an algorithm called Evolutionary Quantum Pareto Optimization (EQPO) which identifies optimal routes. EQPO has been improved by implementing back tracing algorithm. Therefore improved algorithm proposed known BTA-EQPO which reduces complexity overhead and improves performance metrices. Further SO-BTP and MO-BTP framework developed based on dynamic programming of multi-objective for obtaining experiential accuracy. SO-BTP provides all possible optimal Pareto solutions and MO-BTP detects Pareto optimal routes. The route can be expressed as follows:

$$f(x) = [P_e(x), L(x), D(x)] \tag{10}$$

Symbols used in Eq. (10) can be elaborated by author in paper [67].

Optimized QoS Multipath Routing (OQoS-MRP) has been developed by Onthachi et al. [68] which estimates finest multipath from sink node to diverse sensor nodes considering QoS parameters. Best case path is selected for data transmitting to sink node. Performance of proposed routing protocol OQoS-MRP has been compared with existing routing protocols EE-LEACH and MRBCH. OQoS-MRP balnces the energy consumption reduces overhead and delay of entire network. Link cost function used in OQoS-MRP with route, energy and delay can be calculated as follows:

$$\mathrm{Cos}t_{vw} = \frac{R_{req}}{R_{vw}} + \frac{E_{vw}}{E_{\min}} + \frac{D_{vw}}{D_{req}} \tag{11}$$

Zhang et al. [69] developed an algorithm called multi-objective optimization for WSN (AWN-MO) based on image separation. AWN-MO works with variance of maximum inter class and SNR. Accuracy of SNR on image synthesis accuracy also deliberated. Threshold value in AWN-MO is considered in post processing for additional value. Performance of AWN- MO with existing algorithms is better in terms of convergence exactness and robustness.

A multi-objective QoS routing (MQoSR) has been proposed by Alwan et al. [70] for various QoS applications. QoS routing problems are considered as link and path based metrics. The link based metrics includes sink distance, delay, reliability and energy. On the other hand path based metrics includes lifetime of network, end-to-end delay and data transmission reliability. MQoSR achieves optimum path, delay necessities and data delivery ratio. Consumption of energy for data transmission from any node to sink node on path p with hop count can be calculated as:

$$E_{path_p} = \sum_{i=1}^{hop_p} E_{con_i} \tag{12}$$

Arya et al. [71] introduced system for optimization in WSN which is applied and optimized between two nodes and signal strength from source to sink node. ACO method is analyzed with gradient based protocol, direct diffusion, rumor, energy aware routing and network layer routing protocol. Residual energy of nodes in WSN has been computed using assorted parameters. ACO performs better in terms of node's residual energy and bandwidth reduction than existing routing protocols. if E_{p_remain} and E_{q_remain} be the energy of current p and next hop q node then ACO transfer regulation can be calculated as:

$$\eta_{pq}(t) = \frac{E_{p\_remain} + E_{q\_remain} - E_{pq\_consume}}{\sigma(p, q)} \tag{13}$$

3D coverage uncertain model has been developed by Cao et al. [72] which uses improved 3D sensing model and fusion operator for uncertainty. The problem of positioning is enhanced into multi-objective optimization which includes key features: reliability, lifetime and coverage. The main goal of proposed model is prolonging network lifetime, coverage large area and extraordinary reliability. DPCCMOLSEA has been also proposed for nautical applications. The effectiveness of this algorithm is measured has been verified with algorithm of state of the art. Both the proposed methods effectively perform in performance of optimization and reducing computation time. 3D sensing model is given as follows:

$$P^S(s, t) = P^S_{LOS}(s, t) \times P^S_D(s, t) \times P^S_P(s, t) \tag{14}$$

Specific notations and symbols given in Eq. (14) have been elaborated in paper [72].

Armando et al. [73] implemented two algorithms namely, Storn/Price's multiobjective and Differential Evolution (DE) which enhances network coverage area and reducing energy utilization. Random M parameter also used as a protracted demonstration. Proposed algorithms optimize distribution of nodes randomly in diverse shapes, maintaining the connectivity throughout the network using Prim's algorithm. Hungarian algorithm also implemented to calculate minimum distance between first and last node's position. DE provides certain optimal accuracy solution. If *S(x,y)* be number of times covered coordinates *(x,y)* by node then nodes are represented in network area as:

$$S(x, y) = \sum_{i=1}^{Z} P_{\mathrm{cov}}(x, y, N_i) \tag{15}$$

Advanced Threshold Sensitive Energy Efficient (A-TEEN) has been proposed and evaluated by Ge et al. [74]. A-TEEN optimizes election of CH technique than TEEN. A-TEEN performs better than TEEN on the parameters of energy efficiency and prolonging network lifetime. A-TEEN measures electromagnetic environment noise and set the bandwidth according to application necessity. It uses empty channels calculating by weighted probability of every node to be CH. The probability can be calculated as:

$$P_i(t) = \min(k\alpha \frac{C_i}{m}, 1) \tag{16}$$

where k represents probable number of CHs, α is a static parameter, C_i denotes availability of channels.

Hajizadeh et al. [75] proposed Controlled Deployment Algorithm (CDA) based on multi-objective Bee swarn optimization yaking consideration of honey bee behavior. Coverage and network connectivity are two important factors of proposed algorithm. Control deployment is similar to NP-complete problem. Since deploying sensors consider one objective, hence multi-objective technique is more considerable. Swan astuteness has produced novel ways to resolve optimization problems called optimization algorithm based on swarm. These algorithms are implemented and motivated ordinary comportment of penetrating nourishment in community instinctive.

A concurrent transmission model has been introduced by Han et al. [76] which deals with mutual interference constraints and resource link competition in transmissions. Spectrum allocation plan has been formulated based on this model called Chromosome in Genetic Algorithm for resolving spectrum allocation of multi-objective. Proposed model addresses problem in spectrum allocation with respect throughput of network and utilization of spectrum in radio based internet of things. In one hand enhances end-to-end throughput by improving the performance of assigned spectrum channel of each link path. On the other hand same spectrum channel link is shared for concurrent transmission for enhancing spectrum utilization. If T_{ij} be opportunities of transmission on link *(i,j)* then link transmit data rate on m channel spectrum can be calculated as:

$$R^f_{ij}(m) = T_{ij} \times C_{ij}(m) \tag{17}$$

Kang et al. [77] proposed Mobile Data Collectors (MDCs) strategy for reestablishing connectivity of multi-objective optimization. MDCs balances delay with respect to data collection. Problem of data acquisition and network connectivity are converted into an improved multi-travelling salesman problem (IMTSP). An improved multi-objective genetic algorithm has been imposed for resolving collector position of optimal collected data. It provides hierarchical structure of virtual segments, custom coding and decoding and improved diversity.

An energy aware clustering based routing (EACBR) protocol has been proposed by Khabiri et al. [78] which provides clustering in network and selects optimal CHs. EACBR selects the clusters based on residual energy nodes, targeted cuckoo algorithm, distance from BS and distances within clusters. EACBR balances the energy utilization, packet delivery ratio and prolonging network lifetime.

Carlos et al. [79] developed Strength Pareto Evolutionary Algorithm (SPEA) which provides finest efficient routes, balances energy utilization, reduces bandwidth utilization and minimizes end-to-end delay. EACBR is used in multicast or unicast transmission schemes without any constraints in centralized environments. EACBR solve mathematical model o of multi-objective optimization, it works as a dispersed manner because every node estimates routes to other nodes. If S_i and F_j be the strength and fitness value of each node i to node j can be calculated as:

$$S_i = \frac{n_i}{N+1} \tag{18}$$

$$F_j = 1 + \sum_{i \varepsilon P_t \wedge i} S_i \tag{19}$$

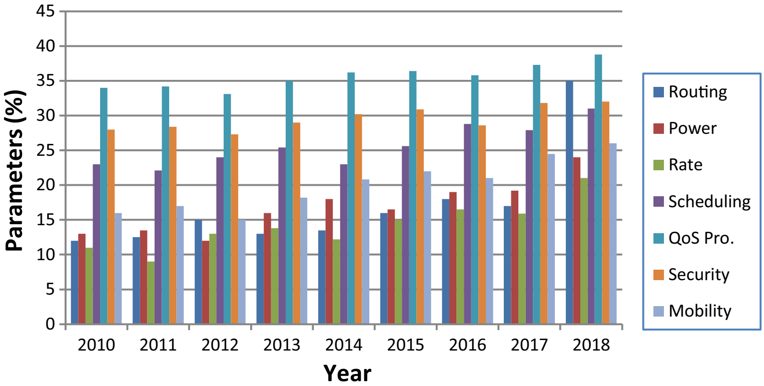


Fig. 4 Parameters distribution over recent years

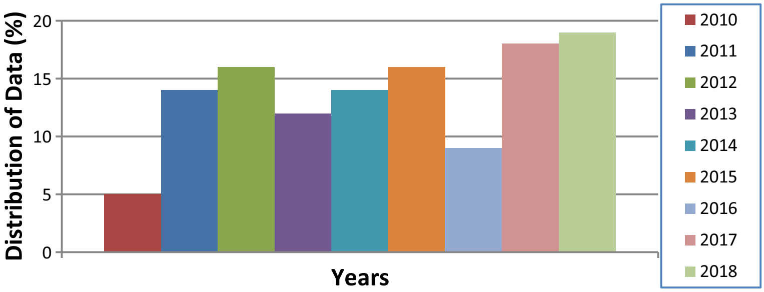


Fig. 5 Literature distribution over recent years

A novel cluster based valid lifetime maximization protocol (CVLMP) has been proposed by Xiaoping et al. [80] which prolongs network lifetime. CHs are nominated and swapped based on probability information of energy, then clusters are appointed around CHs according to model designed based on multi-objective optimization, which balances and minimizes energy utilization among all CHs. CVLMP prolongs valid network lifetime and enhances packet delivery to sink node. Total energy consumption can be calculated as follows:

$$E_{total} = \sum_{i=1}^{k} (E_{CH}^{i}) + \sum_{j=1}^{n-1} E_{non-CH}^{ji} \tag{20}$$

where E_{CH}^{i} and E_{non-CH}^{ji} represents consumption of energy by ith and jth CHs, and n is the number of sensors divided into k clusters.

Distribution of different parameters focused for the research over recent years has been shown in Fig. 4 from 2010- 2018. Few challenging parameters including routing, power, rate, scheduling, QoS provisioning, security and mobility have been considered and shown variation over the years 2010–2018. QoS provisioning improved much better over these years in optimization, security and scheduling also touches better performance.

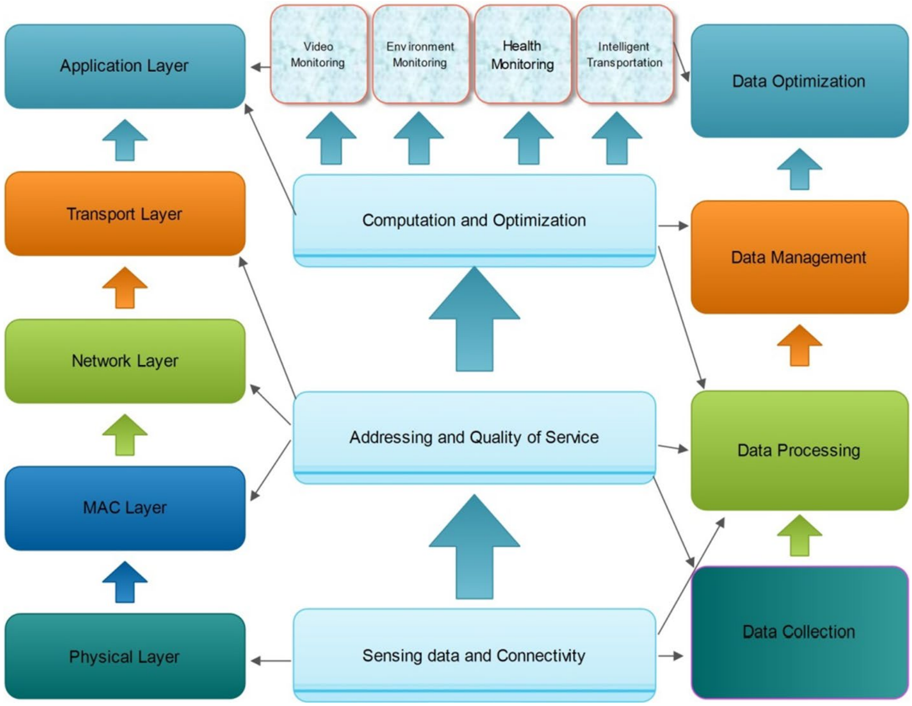


Fig. 6 Network layer architecture of optimization

Whereas, Fig. 5 shows literature distribution over recent years from 2010 to 2018. Data distribution from 2017 to onwards was better than previous years. In the year 2013—2016 literature data goes to down fall then improves in rest years.

Network layer architecture for optimization has been shown in Fig. 6. In this architecture, sensing service nodes joins the network and provides the data using storage and software tools. A computation and optimization expert uses data mining techniques and converts information in a specific knowledge base system. Computation integrates all specific applications on scalable storage using optimization techniques.

The comparison of optimization routing protocols with objective functions, merits and demerits have been shown in Table 1. Approaches for improving optimizing metrics and applications performances of existing approaches have been shown in Tables 2 and 3.

5 Proposed Architecture

Multi-Optimization Algorithm (M-OA) to solve problems in optimization has been proposed as shown in Fig. 7. M-OA can be best fit over programming based on mathematical in terms of handling multifarious complications and expedient enactment. M-OA can be used for different kinds of objective functions, be it continuous or discontinuous, linear or non-linear and stationary or non-stationary which depends upon processes of initializing, assessment, assortment, crossover, transformation and replacement. The function value and derivatives with respect to optimized parameters take appropriate direction towards

Table 1 Optimization based comparison of different routing protocols

Proposed approach	Objective function	Merits	Demerits
ALO algorithm [31, 32]	$A_i^t = \frac{(A_i^t - a_i).(d_i - C_i^t)}{(d_i^t - a_i)} + c_i$	Prolongs network lifetime, enhances throughput	Restricted for homogeneous environment
ACOPSO [33, 34]	$P_{i,j} = \frac{(\tau_{i,j})^\alpha + (\eta_{i,j})^\beta}{\sum (\tau_{i,j})^\alpha (\eta_{i,j})^\beta}$	Enhances network lifetime, balances energy consumption, extending throughput	It works limited size of networks
EOSR [35, 36]	$DT_{ij} = E(Beta(\alpha_{ij}, \beta_{ij})) = \frac{\alpha_{ij} + 1}{\alpha_{ij} + \beta_{ij} + 2}$	Enhances packet delivery ratio and network throughput, reduces energy consumption	High bandwidth required for packet transmitting
PEGASIS [37, 38]	$fitness = (w_1 \times E_{residual}(CH)) + \frac{w_2}{d_{dest}}$	Extending network lifetime, minimizes delay, increases throughput	Lack of fault tolerance and robustness, increases packet loss during packet transmitting
MOEA/D-I MOEA/D-II [39, 40]	$E(I) = (\sum_{i=1}^{num} \sum_{S\varepsilon C_i} E_{S,CH_i} + E_{RX} + E_{DA}) + \sum_{i=1}^{num} E_{CH_{i,\mathrm{Sink}}} + E_{total}$ $N(I) = \sum_{i=1}^{M} U(S_t)$ $EQ_k = \frac{\sum_{i=1}^{n_k} E_{k_i}}{n_k}$	Minimizes energy utilization, balances energy consumption, enhances network coverage	Lack of learning strategy in proposed algorithm, coverage in limited applications
DV-maxhop [41, 42]	$f1(p) = \frac{1}{N_r} \sum_{i\varepsilon N_r} \sqrt{(x_i^\wedge - x_i)^2 + (y_i^\wedge - y_i)^2}$ $f2(p) = \frac{1}{N} \sum_{i\varepsilon N} N_{T_{X_i}}$	Improves energy cost, minimizes localization errors, effective energy cost	Lack of analysis with network algorithm such as data gathering, clustering, routing and optimization
EQPO [43, 44]	$f(x) = [P_e(x), L(x), D(x)]$	Provides route optimization, low error detection, reliable	Algorithm is not scalable
OQoS-MRP [45, 46]	$\mathrm{Cost}_{vw} = \frac{R_{req}}{R_{vw}} + \frac{E_{vw}}{E_{\min}} + \frac{D_{vw}}{D_{req}}$	Reduces energy consumption, transmission delay and overhead	Required high link cost and bandwidth
AWN-MO [47, 48]	-	Gives convergence accuracy, provides robustness of network	Algorithm is not completely stable and realistic

Table 1 (continued)

Proposed approach	Objective function	Merits	Demerits
MQoSR [49, 50]	$E_{path_p} = \sum_{i=1}^{hop_p} E_{con_i}$	Enhances network lifetime, data transmission, data delivery, reduces overhead	Protocol is suitable only for static WSN, lack of optimum praobability
ACO Technique [51, 52]	$\eta_{pq}(t) = \frac{E_{p\_remain}+E_{q\_remain}-E_{pq\_consume}}{\sigma(p,q)}$	Optimized link bandwidth, balances energy consumption	Works on limited QoS parameters, not support sacalability
DPCCMOLSEA [53, 54]	$P^S(s,t) = P^S_{LOS}(s,t) \times P^S_D(s,t) \times P^S_P(s,t)$	Enhances network lifetime, improves network coverage and reliability	Unable to implement GPUs and MICs
DE [55]	$S(x,y) = \sum_{i=1}^{Z} P_{\mathrm{cov}}(x,y,N_i)$	Reduces energy utilization, prolongs network lifetime, enhances network coverage area	High overload on routing tables, problem in link failure
A-TEEN [56]	$P_i(t) = \min(k\alpha \frac{C_i}{m}, 1)$	Reduces data transmission unnecessary, routing links are stable and reliable	More energy consumption and low network lifetime
CDA [57]	–	Extends network coverage, balances energy consumption	High link cost, more delay
CT Model [58]	$R^f_{ij}(m) = T_{ij} \times C_{ij}(m)$	Extending throughput, minimizes end-to-end delay	Lack of QoS parameters fairness
MDCs [59]	–	Improves delay, link failure and provides reliability for network	Required high bandwidth for data transmitting
EACBR [60]	–	Reduces energy utilization, enhances network lifetime, balances network load	Limited coverage, chances of link failure
SPEA [61]	$S_i = \frac{n_i}{N+1}$ $F_j = 1 + \sum_{i \varepsilon P_t \wedge i} S_i$	Find shortest path, reduces end-to-end delay and bandwidth consumption	Algorithm work for limited size of network
CVLMP [62]	$E_{total} = \sum_{i=1}^{k} (E^i_{CH}) + \sum_{j=1}^{n-1} E^{ji}_{non-CH}$	Minimizes energy consumption, prolongs network lifetime and balances energy consumption throughout the network	High probability of link failure, high bandwidth required for data transferring

Table 2 Existing approaches for improving optimizing metric

References	Parameters	Design protocol	Mathematical implementation	Hybrid analysis	Theo-retical analysis	Simulation
[22, 33]	Network lifetime	✓	✓			✓
[1, 12, 33]	Detection accuracy	✓	✓			✓
[11, 35]	Fault tolerance	✓	✓	✓		✓
[23, 37]	Fair distribution	✓	✓			✓
[10, 39]	Network coverage	✓	✓		✓	✓
[9, 24, 41]	Robustness	✓	✓		✓	✓
[25, 43]	Error detection	✓	✓		✓	✓
[8, 45]	Network overhead	✓	✓			✓
[6, 26, 47]	Network security	✓			✓	✓
[27, 49]	Network reliability	✓			✓	✓
[5, 28, 51]	Link bandwidth	✓	✓	✓		✓
[13, 53]	Coverage area	✓			✓	✓
[29, 55]	Network latency	✓	✓	✓		✓
[5, 14, 56]	Route maintenance	✓	✓		✓	✓
[30, 57]	Network connectivity	✓			✓	✓
[15, 58]	Network services	✓	✓		✓	✓
[59]	Fair rate distribution	✓			✓	✓
[4, 16, 60]	Energy distribution	✓			✓	✓
[3, 61]	Shortest path	✓	✓	✓		✓
[17, 19, 62]	Energy Efficiency	✓	✓		✓	✓

maximum or minimum. The intension in proposed architecture is to maximize a function with M-OA which is needed to evaluate fitness individually and will be used to bias better genes in next generation. In M-OA we must come up with single metric and will be used for comparing two possible solutions for better performance. For an airfoil, drag and lift function can be used.

$$Fitness = W_1 Lift(P) - W_2 Drag(P) \tag{21}$$

It depends upon simulation sets such as speed, different angles of attack and much more.

$$fitness = \sum_{i}^{simulations} W_i Lift(P) - \sum_{i}^{simulations} W_i Drag(P) \tag{22}$$

The fitness for empirical density functional may be weighted deviation from experimental values.

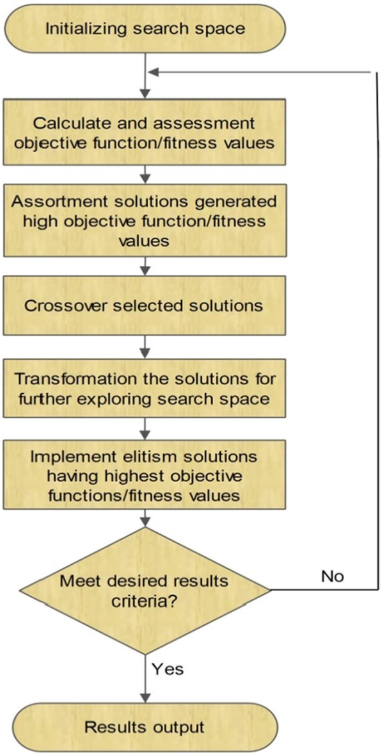
$$fitness = -\sum_{i}^{dataset} \left(E_i^{calc}(P) - E_i^{Exp}\right)^2 \tag{23}$$

M-GA simplifies the problem and finds regions in the parameter space of interest. In future, efforts will be made to utilize the proposed solution for implementation in different network domains such as WSN, VANET and SDN.

Table 3 Application performance of existing approaches

Proposed approach	Routing	Types of sensors	Scope of application	Topology	Evaluation methodology
ALO algorithm [31, 32]	Routing	Homogeneous and static	General purpose	Flat	Simulation
ACOPSO [33, 34]	Routing	Homogeneous and static	Large scale WSN	Hierarchical	Simulation
EOSR [35, 36]	Data aggregation	Homogeneous and static	General purpose	Hierarchical	Simulation
PEGASIS [37, 38]	Routing	Heterogeneous and static	Information services	Flat and clustering	Simulation
MOEA/D-I MOEA/D-II [39, 40]	Optimal flow control	Homogeneous and static	General purpose	Flat	Simulation
DV-maxhop [41, 42]	Routing	Homogeneous and static	Online query application	Hierarchical	Simulation
EQPO [43, 44]	Deployment	Heterogeneous and static	General purpose	Hierarchical	Simulation
OQoS-MRP [45, 46]	Routing	Homogeneous and static	General purpose	Flat	Simulation
AWN-MO [47, 48]	Scheduling and routing	Homogeneous and static	Large scale WSN	Flat	Simulation
MQoSR [49, 50]	Routing	Homogeneous and static	Self-regulating WSN	Flat	Simulation
ACO Technique [51, 52]	Routing and MAC	Homogeneous and static	General purpose	Hierarchical	Simulation
DPCCMOLSEA [53, 54]	Routing	Heterogeneous and static	General purpose	Hierarchical	Simulation
DE [55]	Routing	Homogeneous and static	Event detection	Flat	Simulation
A-TEEN [56]	Deployment	Homogeneous and static	Deployed environment	Flat	Simulation
CDA [57]	Coverage control	Homogeneous and static	General purpose	Hierarchical	Simulation
CT Model [58]	Data aggregation	Homogeneous and static	Large scale WSN	Flat	Simulation
MDCs [59]	Deployment	Heterogeneous and static	Densely deployed	Hierarchical	Simulation
EACBR [60]	Deployment	Homogeneous and static	General purpose	Flat	Simulation
SPEA [61]	Deployment	Homogeneous and static	General purpose	Flat	Simulation
CVLMP [62]	Spectrum sensing	Homogeneous and static	General purpose	Hierarchical	Simulation

Fig. 7 Flow-chart of M-OA



6 Conclusion

In this paper, a brief analysis for applicability of diverse multi-objective optimization techniques in existing wireless sensor network area has been explored and discussed with an appropriate study of research gap in routing issues. A brief analysis of objective functions in multi-objective optimization with its merits and demerits, existing approaches for improving optimizing metric, application performance of existing approaches and proposed architecture will be helpful for researchers and acquire more vision into ways of optimization enactment. After rigorous examination and analysis of various papers an effective algorithm based on multi-objective optimization technique can be developed satisfying various QoS parameters in energy efficient manner for real time and dynamic network for real time applications.

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Declaration

Conflict of interest The authors of this paper declare that there is no conflict of interest.

References

1. Deepa, O., & Suguna, J. (2017). An optimized QoS-based clustering with multipath routing protocol for wireless sensor networks. *JKSU-Computer and Information Sciences, 13*, 1–12.
2. Zhou, Z., Xu, J., Zhang, Z., Lei, F., & Fang, W. (2017). Energy-efficient optimization for concurrent compositions of WSN services. *IEEE Acess, 17*, 1–15.
3. Na, W., & Tianhua, W. (2016). A trusted QoS routing model for wireless sensor networks. In *ICCSE* (pp. 627–630).
4. More, A., & Raisinghani, V. (2017). A survey on energy efficient coverage protocols in wireless sensor networks. *Journal of King Saud University – Computer and Information Sciences, 29*, 428–448.
5. Li, H., & Lin, Z. (2017). Study on location of wireless sensor network node in forest environment. *ICICT, 107*, 697–704.
6. Arasu, K., & Ganesan, R. (2018). Effective implementation of energy aware routing for wireless sensor network. *PMME, 5*, 1186–1193.
7. Migabo, M., Djouani, K., Olwal, T. O., & Kurien, A. M. (2017). A survey on energy efficient network coding for multi-hop routing in wireless sensor networks. *FNC, 94*, 288–294.
8. Ansane, A. A., & Satao, R. A. (2017). A survey on various multipath routing protocols in wireless sensor networks. *CCV, 79*, 610–615.
9. Patnai, S. (2016). Energy management in wireless sensor network using PEGASIS. *ICCC, 92*, 207–212.
10. Mahidhar, R., & Raut, A. (2017). A survey on scheduling schemes with security in wireless sensor networks. *ICISP, 78*, 756–762.
11. Elshrkawey, M., Elsherif, S. M., & Wahed, M. E. (2018). An enhancement approach for reducing the energy consumption in wireless sensor networks. *Journal of King Saud University Computer and Information Sciences, 30*, 259–267.
12. H. Sandor, P. haller and Z Gal, “Performance Analysis of Wireless Sensor Networks”, *INTER-ENG*, vol. 19, pp. 842–849, 2016.
13. Kakhandki, A. L., Hublikar, S., & Kumar, P. (2018). Energy efficient selective hop selection optimization to maximize lifetime of wireless sensor network. *Alexandria Engineering Journal, 57*, 711–718.
14. Lu, Y., Zhang, T., He, E., & Comşa, I. S. (2018). Self-learning-based data aggregation scheduling policy in wireless sensor networks. *Journal of Sensors, 18*, 1–12.
15. Ferrandis, T. D., Blanes, J. S., Climent, S. S., Sempere-Paya, V., & Vera-Pérez, J. (2018). Deploy&Forget wireless sensor networks for itinerant applications. *Computer Standards & Interfaces, 56*, 27–40.
16. Tawalbeh, L. A., Hashish, S., & Tawalbeh, H. (2017). Quality of service requirements and challenges in generic WSN infrastructures. *SCE, 109*, 1116–1121.
17. Arora, V. K., Sharma, V., & Sachdeva, M. (2018). On QoS evaluation for ZigBee incorporated wireless sensor network (IEEE 802.15.4) using mobile sensor nodes. *Journal of King Saud University Computer and Information Sciences, 13*, 1–9.
18. Ahlwat, P., & Dave, M. (2018). An attack model based highly secure key management scheme for wireless sensor networks. *ICSCC, 125*, 201–207.
19. Padmaja, P., & Marutheswar, G. V. (2018). Energy efficient data aggregation in wireless sensor networks. *PMME, 5*, 388–396.
20. Snigth, I., & Gosain, D. (2016). Energy analysis for trajectory based sink mobility in WSN. *IMCIP, 54*, 118–126.
21. Achour, A., Deru, L., & Deprez, J. C. (2018). Mobility management for wireless sensor networks a state-of-the-art. *IUPT, 52*, 1101–1107.
22. Manikandan, S., & Chinadurai, M. (2021). Effective energy adaptive and consumption in wireless sensor network using distributed source coding and sampling techniques. *Wireless Personal Communications, 118*, 1393–1404.
23. Fei, Z., Li, B., Yang, S., Xing, C., Chen, H., & Hanzo, L. (2016). A survey of multi-objective optimization in wireless sensor networks: Metrics, algorithms and open problems. *IEEE Communications Surveys & Tutorials, 111*, 1–38.
24. Ebhota, V. C., & Srivasatva, V. M. (2021). Performance analysis of learning rate parameter on prediction of signal power loss for network optimization and better generalization. *Wireless Personal Communications, 118*, 1111–1128.
25. Li, H., & Lin, Z. (2018). Study on location of wireless sensor networks in P.Padmaja and G.V.Marutheswar. *PMME, 5*, 388–396.

26. Maheshawri, M., & Karthika, R. A. (2021). A novel QoS based secure unequal clustering protocol with intrusion detection system in wireless sensor networks. *Wireless Personal Communications, 118*, 1535–1557.
27. Jiang, A., & Zheng, L. (2018). An effective hybrid routing algorithm in WSN: Ant colony optimization in combination with hop count minimization. *MDPI, 28*, 1–17.
28. Kumar, R., & Venkatesh, I. (2018). SDN-based QOS-aware multipath routing mechanism using openstac. *International Journal of Pure and Applied Mathematics, 118*(20), 357–364.
29. Sendra, S., Parra, L., Lloret, J., & Khan, S. (2017). Systems and algorithms for wireless sensor networks based on animal and natural behavior. *International Journal of Distributed Sensor Networks, 112*, 1–19.
30. Umamaheshwari, S. (2021). Hybrid optimization model for energy efficient cloud assisted wireless sensor network. *Wireless Personal Communications, 118*, 873–885.
31. Lavangya, N., & Shankar, T. (2017). Energy optimization in wireless sensor network using NSGA-II. *ARPN, 12*(23), 6698–6702.
32. Maheshwari, P., Sharma, A. K., & Verma, K. (2021). Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization. *Ad Hoc Networks, 110*, 1–52.
33. Hammoudeh, M., & Newmanb, R. (2016). Adaptive routing in wireless sensor networks: QoS optimisation for enhanced application performance. *Information Fusion, 113*, 1–14.
34. Reddy, D. L., Puttamadappa, C., & Suresh, H. N. (2021). Merged glowworm swarm with ant colony optimization for energy efficient clustering and routing in wireless sensor network. *Pervasive and Mobile Computing, 71*, 13–38.
35. Yahiaoui, S., Omar, M., Bouabdallah, A., Natalizio, E., & Challal, Y. (2018). An energy efficient and QoS aware routing protocol for wireless sensor and actuator networks. *International Journal of Electronics and Communications, 83*, 193–203.
36. Hao, X., Yao, N., Wang, L., & Wang, J. (2020). Joint resource allocation algorithm based on multi-objective optimization for wireless sensor networks. *Applied Soft Computing, 94*, 1064–1070.
37. Magaiaa, N., Hortab, N., Nevesb, R., Pereira, P. R., & Correia, M. (2016). A multi-objective routing algorithm for wireless multimedia sensor networks. *Applied Soft Computing, 145*, 1–27.
38. Ghosal, A., Halder, S., & Das, S. K. (2020). Distributed on-demand clustering algorithm for lifetime optimization in wireless sensor networks. *Journal of Parallel and Distributed Computing, 141*, 129–142.
39. Iqbal, M., Naeem, M., Anpalagan, A., Qadri, N. N., & Imran, M. (2016). Multi-objective optimization in sensor networks: Optimization classification, applications. *Computer Networks, 2016*, 1–30.
40. Phoemphon, S., So-In, C., & Leelathakul, N. (2021). Improved distance estimation with node selection localization and particle swarm optimization for obstacle-aware wireless sensor networks. *Expert Systems with Applications, 175*, 47–73.
41. Jha, S. K., & Eyong, E. M. (2017). An energy optimization in wireless sensor networks by using genetic algorithm. *Telecommunications Systems, 66*, 31–39.
42. Zhang, X., Lu, X., & Zhang, X. (2020). Mobile wireless sensor network lifetime maximization by using evolutionary computing methods. *Ad Hoc Networks, 101*, 94–102.
43. Li, X., Liu, A., Xie, M., Xiong, N. N., Zeng, Z., & Cai, Z. (2018). Adaptive aggregation routing to reduce delay for multi-layer wireless sensor networks. *MDPI, 18*, 1–28.
44. Younus, M. U., Khan, M. K., Anjum, M. R., Afridi, S., Arain, Z. A., & Jamali, A. A. (2021). Optimizing the lifetime of software defined wireless sensor network via reinforcement learning. *IEEE Access, 9*, 259–272.
45. Zaki, M., Al, H., & Gunay, M. (2017). Lifetime maximization by partitioning approach in wireless sensor networks. *Journal on Wireless Communications and Networking, 15*, 1–29.
46. Tsoumanis, G., Oikonomou, K., Aissa, S., & Stavrakakis, I. (2021). Energy and distance optimization in rechargeable wireless sensor networks. *Green Communications and Networking, 5*, 378–391.
47. Mehari, M. T., De Poorter, E., Couckuyt, I., Deschrijver, D., Vermeeren, G., Plets, D., Joseph, W., Martens, L., Dhaene, T., & Moerman, I. (2016). Efficient identification of a multi-objective pareto front on a wireless experimentation facility. *IEEE Transactions on Wireless Communications, 2016*, 1–13.
48. Kaur, T., & Kumar, D. (2021). MACO-QCR: Multi-objective ACO-based QoS-aware cross-layer routing protocols in WSN. *IEEE Sensors Journal, 21*, 6775–6783.
49. Prasad, D. R., Naganjaneyulu, P. V., & Prasad, K. S. (2016). Energy efficient clustering in multi-hop wireless sensor networks using differential evolutionary MOPSO. *IJETT, 59*, 1–15.

50. Luo, C., Satpute, M. N., Li, D., Wang, Y., Chen, W., & Wu, W. (2021). Fine-grained trajectory optimization of multiple UAVs for efficient data gathering from WSNs. *IEEE/ACM Transactions on Networking, 29*, 162–175.
51. Prusty, A. R., Sethib, S., & Nayakc, A. K. (2017). Multi-objective optimality in energy efficient routing for heterogeneous wireless ad hoc sensor network with clustering. *IJIDT, 11*, 61–70.
52. Zhu, Y., Gong, S., Chi, K., Li, Y., & Fang, Y. (2021). Optimizing superframe and data buffer to achieve maximum throughput for 802.15.4-based energy harvesting wireless sensor networks. *IEEE Internet of Things Journal, 8*, 3689–3704.
53. Sarkar, A., & Murugan, T. S. (2016). Routing protocols for wireless sensor networks: What the literature says? *Alexandria Engineering Journal, 55*, 3173–3183.
54. Rathee, M., Kumar, S., Gandomi, A. H., Dilip, K., Balusamy, B., & Patan, R. (2021). Ant colony optimization based quality of service aware energy balancing secure routing algorithm for wireless sensor networks. *IEEE Transactions on Engineering Management, 68*, 170–182.
55. Iqbal, M., Naeem, M., Anpalagan, A., Ahmed, A., & Azam, M. (2016). Wireless sensor network optimization: Multi-objective paradigm. *MDPI, 16*, 17573–17609.
56. Srinivasan, R., & Kannan, E. (2018). Energy harvesting based efficient routing scheme for wireless sensor network. *Wireless Personal Communications, 101*, 1457–1468.
57. Tan, J., Liu, A., Zhao, M., Shen, H., & Ma, M. (2018). Cross-layer design for reducing delay and maximizing lifetime in industrial wireless sensor networks. *Journal on Wireless Communications and Networking, 2018*, 1–26.
58. Yang, Q., & Yoo, S. (2018). Optimal UAV path planning: Sensing data acquisition over IoT sensor networks using multi-objective bio-inspired algorithms. *IJDCN, 118*, 1–4.
59. Xua, Y., Dinga, O., & Qub, R. (2018). Hybrid multi-objective evolutionary algorithms based on decomposition for wireless sensor network coverage optimization. *Applied Soft Computing, 68*, 268–282.
60. Chun Li, S., Wang, P., & Lu, M. (2016). Jointly optimized QoS-aware virtualization and routing in software defined networks. *Computer Networks, 96*, 69–78.
61. Yogarajan, G., & Revathi, T. (2017). Improved cluster based data gathering using ant lion optimization in wireless sensor networks. *Wireless Personal Communications, 2017*, 1–21.
62. Kaur, S., & Mahajan, R. (2018). Hybrid meta-heuristic optimization based energy efficient protocol for wireless sensor networks. *Egyptian Informatics Journal, 66*, 1–6.
63. Yang, T., Xiangyang, X., Peng, L., Tonghui, L., & Leina, P. (2018). A secure routing of wireless sensor networks based on trust evaluation model. *ICICT, 131*, 1156–1163.
64. Ramluckun, N., & Bassoo, V. (2018). Energy-efficient chain-cluster based intelligent routing technique for wireless sensor networks. *Applied Computing and Informatics, 66*, 1–12.
65. Xu, Y., Ding, O., Qu, R., & Li, K. (2018). Hybrid multi-objective evolutionary algorithms based on decomposition for wireless sensor network coverage optimization. *Applied Soft Computing, 66*, 1–30.
66. Shahzad, F., Sheltami, T. R., & Shakshuki, E. M. (2016). Multi-objective optimization for a reliable localization scheme in wireless sensor networks. *Journal Communications and Networks, 18*(5), 796–805.
67. Alanis, D., Botsinis, P., Babar, Z., Nguyen, H. V., Chandra, D., Ng, S. X., Hanzo, L. (2018). Quantum-aided multi-objective routing optimization using back-tracing-aided dynamic programming. *IEEE Transactions on Vehicular Technology, 2018*, 1–5.
68. Onthachi, D., & Jayabal, S. (2017). An optimized QoS-based multipath routing protocol for wireless sensor networks. *IJIES, 11*(2), 49–56.
69. Zhang, J., & Zhang, X. (2018). "A prototype", adaptive wireless network multiobjective optimization algorithm based on image synthesis. *AIES, 225*, 1–23.
70. Alwan, H., & Agarwal, A. (2017). MQoSR: A multiobjective QoS routing protocol for wireless sensor networks. *ISRN Sensor Networks, 13*, 1–3.
71. Arya, R., & Sharma, S. C. (2016). Optimization approach for energy minimization and bandwidth estimation of WSN for data centric protocols. *International Journal of System Assurance Engineering and Management, 17*, 1–15.
72. Cao, B., Zhao, J., Yang, P., Lv, Z., Liu, X., & Min, G. (2018). 3D multi-objective deployment of an industrial wireless sensor network for maritime applications utilizing a distributed parallel algorithm. *Transactions on Industrial Informatics, 66*, 1–10.
73. Céspedes-Mota, A., Castañón, G., Martínez-Herrera, A. F., & Cárdenas-Barrón, L. E. (2018). Multiobjective optimization for a wireless ad hoc sensor distribution on shaped-bounded areas. *Mathematical Problems in Engineering, 2018*, 1–23.
74. Ge, Y., Wang, S., & Ma, J. (2018). Optimization on TEEN routing protocol in cognitive wireless sensor network. *Journal on Wireless Communications and Networking, 2018*, 1–9.

75. Hajizadeh, N., Jahanbazi, P., & Javidan, R. (2018). Controlled deployment in wireless sensor networks based on a novel multi objective bee swarm optimization algorithm. *CSIE, 66*(1–7), 2018.
76. Han, R., Gao, Y., & Wu, C. (2018). An effective multi-objective optimization algorithm for spectrum allocations in the cognitive-radio-based internet of things. *Geneal of Latex Class File, 66*, 1–10.
77. Kang, Z., Zeng, H., & Hu, H. (2017). Multi-objective optimized connectivity restoring of disjoint segments using mobile data collectors in wireless sensor network. *EURASIP, 117*, 1–22.
78. Khabiri, M., & Ghaffari, A. (2017). Energy-aware clustering-based routing in wireless sensor networks using cuckoo optimization algorithm. *Wireless Personal Communications, 217*, 1–23.
79. Lozano-Garzona, C., Camelob, M., Vilab, P., & Donoso, Y. (2016). A multi-objective routing algorithm for wireless mesh network in a smart cities environment. *Journal of Networks, 430*, 60–69.
80. Ma, X., Dong, H., Liu, X., Jia, L., Xie, G., & Bian, Z. (2018). An optimal communications protocol for maximizing lifetime of railway infrastructure wireless monitoring network. *IEEE Transactions on Industrial Informatics, 66*, 1–11.

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