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Original Article

CSPBOT - boQIEKC: QoS Enhanced Integration of Energy-Aware Clustering with Routing Protocol for WSN

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Abstract - *Nowadays, demanding ideals in Wireless Sensor Network (WSN) research are prolonging the network lifetime and lessening the energy consumption. However, the WSN with dynamic topology communication among Sensor Nodes (SNs) is liable to various attacks. SNs with low power may create some issues between security and energy consumption. In this proposed methodology, a protected energy-efficient routing approach, namely the Combinable Stochastic Patterned Bat Optimization Technique based on Quantized Indexive Energy Knowledgeable Clustering (CSPBOT -boQIEKC), is introduced. It performs SN clustering, shortest path identification, and path maintenance. Clustering and CH election are done by the Quantized Schutz Indexive Linde Buzo Gray (QSILBG) Algorithm. Meanwhile, the Cluster Head (CH) election is done by considering distance, residual energy of the SNs, and delay. Shortest path identification is performed by Combinable Stochastic Patterned Prevosti's Bat Optimization (CSP2BO) Technique. Furthermore, the fitness of the bat is estimated based on the distance, energy, trust and link stability among SNs. In addition, the fault tolerance approach is utilized to ensure that the WSN continuously works regularly, even in the state of CH failure. The Stochastic Universal Sampling Selection (SUSS) procedure is activated to elect the best shortest path for data transmission. Finally, path maintenance is accomplished for alternative paths when link failure happens among SNs of the network. The performance of the proposed methodology is estimated on residual energy, energy consumption, packet delivery ratio, network lifetime and throughput. The proposed CSPBOT-boQIEKC technique provides an 18% improvement in energy consumption, 6% improvement in PDR, and 26% improvement in throughput than existing Taylor C-SSA, QEBSR and IoNM-BSOLyD approaches.*

Keywords - *Energy efficiency, Clustering, Routing, Cluster Head, Fault tolerance.*

1. Introduction

The WSN plays a major role in the Internet of Things (IoT). It holds multiple SNs, which are linked through wireless channels [1]. These channels can provide a digital interface for sensing different environmental constraints. Two major challenges faced by the WSN are low network lifetime and transmission delay during data transmission [2]. The incorporation of WSN is more critical in some specific applications like ecosystem monitoring, military and disaster management, and information routing [3]. Moreover, energy efficiency also plays a vital role in the operation of WSNs. Therefore, clustering in WSN is mainly focused on the energy-efficient approaches in WSN [4]. Clustering is one of the most fundamental objectives for routing in WSN to enhance the network lifetime and improve energy consumption [5]. Moreover, congestion occurs when the sensed data is directly transmitted to the sink node. It automatically consumes a huge amount of energy from SNs, which leads to a decrease in network lifetime [6]. Therefore, clustering is one of the best techniqssues to preserve the energy of SNs in WSN. Here, the cluster-based routing is done by separating the SNs into multiple clusters. CHs are elected for each cluster in the network based on some predefined parameters [7]. Different stages of cluster-based routing are clustering, electing CH, packet transmission, data aggregation and so on [8]. These stages eminently need energy conservation.

This cluster-based routing effectively enhances the network lifetime and deduce the energy consumption of SNs in the network [9]. Therefore, in this kind of routing, the inter-cluster and intra-cluster communications may act in a multi-hop format. To save energy and avoid wasting time communicating with the adjacent node, which is far away, the SNs only make communication with the adjacent node [10]. For this purpose, researchers initially developed a LEACH protocol. By following this protocol, multiple techniques are developed to consume the energy level of the SNs in the network.

One of the main key anxieties in WSN is secure data communication. When the communication channel between the SNs is open, the network has a high chance of being susceptible to multiple attacks [11]. Moreover, the central communication is more complex in dynamic topology structure. Also, in the wireless network, the communication network is exposed to physical, link and network layer attacks. The attacks may be in the form of congestion, forgery, and collision than the wired networks.

Therefore, security and privacy are major factors in WSN because it is used in different jobs like military and sensing jobs in deceptive situations. This leads to the enhancement of various encryption-based standards for data and image security purposes. Furthermore, the security implementation in WSN automatically reduces the energy. Therefore, there should be a trade-off between security implementation and battery usage.

An efficient routing technique must be introduced to balance complexity and energy usage. If the energy usage of the SNs in the network is reduced, then automatically the network lifetime is prolonged. Generally, the routing is done between the sender and the receiver to provide secure data transmission. For this purpose, multiple routers are used. Among these routers, the optimal path for data transmission is predicted which is illustrated in Figure 1.

In Figure 1, the sender sends a message to the receiver. In the meanwhile, the routers are used for data transmission purposes. Multiple routers are involved in this process. However, some of the routers which are closest to the receiver with the shortest path are determined.

By following that path, the data is securely transmitted between the sender and the receiver. Still, the management of energy remains a problem. So, the main motive of this proposed methodology is to reduce energy consumption. It is done by integrating cluster formation and CH election to provide secure routing within the network. By following this factor, it effectively achieves the trade-off between the implementation of security and energy consumption. To attain the actuality mentioned above, a Combinable Stochastic Patterned Bat Optimization Technique based on Quantized Indexive Energy Knowledgeable Clustering (CSPBOT - boQIEKC) is proposed. Initially, clustering and CH election are done by the Schutz Indexive Linde Buzo Gray Algorithm used for clustering.

Meantime, CH selection is carried out by considering the distance, residual energy of the SNs, and delay. After that, an efficient and secure routing process is performed. Here, the shortest path is identified by combinable stochastic patterned prevosti’s bat optimization technique. Pursuing this, path maintenance is carried out by observing the malicious nodes with the help of using the fitness value. The proposed research is organized as Section I, which contains an introduction to our proposed methodology. A survey of some related works is summarized in Section II. Section III explains efficient-aware secured cluster-based routing in WSN. Section IV offers the performance analysis along with some comparative results. At last, Section V holds a conclusion with future scope.

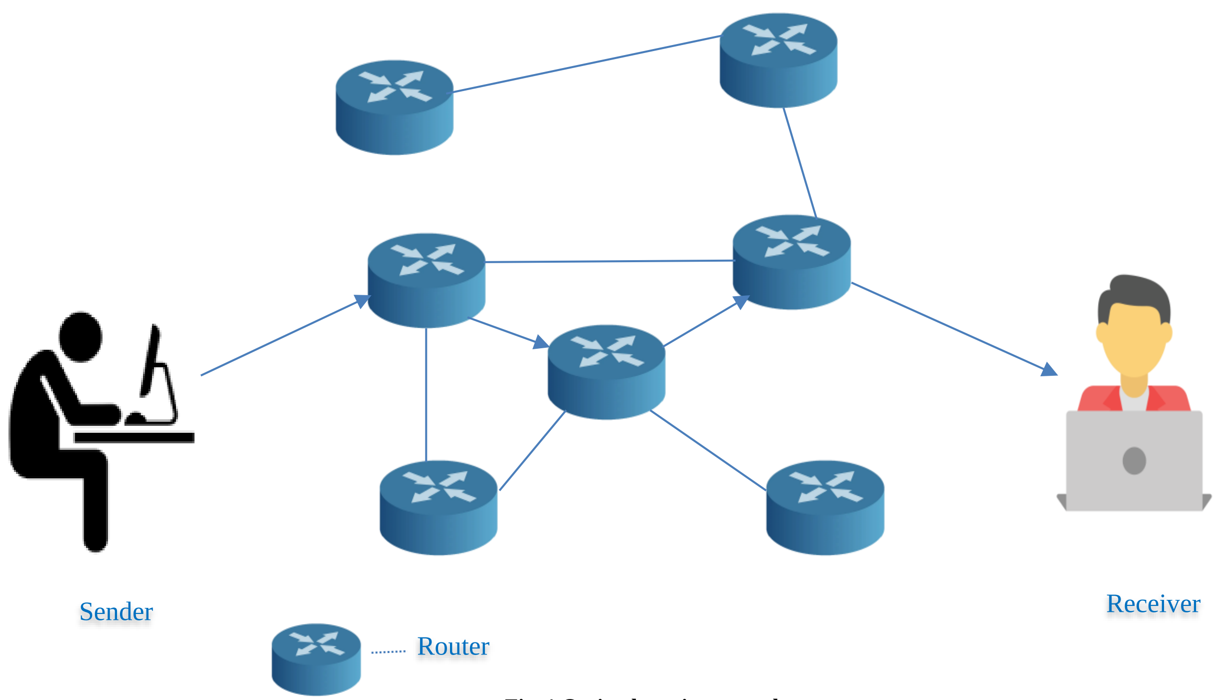

Fig. 1 Optimal routing procedure

2. Overview of Existing Research Works

Some of the existing approaches proposed for energy-aware secure cluster-based routing in WSN within the period of 2020 – 2023 are briefly discussed in this section.

2.1. Overview of Existing Articles

In 2020, Shin and Lee [12] presented a swarm intelligence-centric routing algorithm. The main motive of this approach is to influence the merits of the ACO algorithm. It effectively addresses the issues in the AODV technique. This kind of approach provides an optimal solution to more complex issues in the network and enhances the network performance. In 2020, Chen et al. [13] reviewed a DL on computational resource-limited platforms. The reviewer summarizes the traditional applications of resource-limited DL. It clearly states that this approach is more needed energy of prevalent computing. In addition, it explores the reasons for the high computational overhead of DL. It is done by considering some basic concepts like capacity. In 2020, Zhang et al. [14] proposed a seamless clustering multi-hop routing protocol based on an enhanced ABC technique. The movement oif sink node generates a huge amount of energy for positioning the sink node. To overcome this issue, the routing table is generated by using the ABC algorithm. Here, a novel CH election technique is used in which the SN uses the mean energy value of the adjacent node and the remaining energy of its own.

It is used to estimate the claimed CH time. In 2019, Arora et al. [15] introduced a tree-based energy balance approach for WSN. It is mainly used to provide an efficient route at the time of intra-cluster communication. Three different phases of this approach are cluster generation, multi-path formation, and data transmission.

However, in 2020, the same team, Arora et al. [16], introduced a multiple pheromone ACO approach. It enables the sensing nodes to transmit sensed information to the Base Station (BS). This transmission is done in an optimal path with energy consumption to prolong the network lifetime. Because above mentioned routing system has a low convergence rate, the next hop election is limited. In 2020, Kiran et al. [17] presented a network lifetime enhancement using fuzzy clustering and routing for WSN. Clustering is done by considering some different descriptors, such as remaining energy and distance. For routing, possible paths are elected from that least hop will be elected as a path for data communication.

In 2020, Akshay et al. [18] adopted a fuzzy logic-based clustering of homogeneous WSNs for mobile sinks. To enhance the network lifetime, this technique uses the average energy concept based on the probability and mean threshold for suitable CHs election. It effectively resolves the limitation of LEACH. In 2020, to solve the energy depletion issue, Indu and Karan [19] proposed an energy-balanced integrated atom swarm and electromagnetic force optimization technique.

Clustering is obtained based on some specific constraints such as node degree, intra and inter cluster distance and remaining energy of the SNs in the network. Atom search optimization is done to elect suitable CH among SNs. Moreover, routing is performed by using electromagnetic force optimization for data transmission.

In 2020, Cai et al. [20] presented a unified heuristic bat algorithm to minimize the selection in CHs. By using this algorithm, the election of CH can change to both global and search. In 2020, Mohamad et al. [21] initiated swarm intelligence-based energy efficient clustering with routing for sustainable WSNs. At first, an enhanced PSO algorithm is used for the CH election, and it organizes the clusters. To select the optimal path, the GWO technique is used for routing. In 2021, Maheshwari et al. [22] reviewed that the BOA is employed to elect optimal CH from the SNs group.

The CH is elected based on the residual energy of SNs, distance to the adjacent nodes, node degree, and node centrality. ACO approach is used to identify the optimal path based on the distance, remaining energy, and node degree. In 2022, Senthil et al. [23] proposed an optimized orphan LEACH for clustering to minimize energy usage and enhance the network lifetime. This approach covers a complete network with the least number of orphan nodes with high connectivity rates. In 2022, Wang et al. [24] designed an energy efficient cluster-based routing using FA and ACO algorithms. Here, optimal CH is elected by using a self-organizing map neural network. The basic concept of the decision domain is induced with FA to form accurate clusters. Routing is performed by using the ACO algorithm by considering angle, energy, and node energy. In 2023, Suresh et al. [25] introduced a cluster-based routing using the F2SO algorithm.

Originally, the honey badger algorithm is used for the CH election. Routing between the BS and the CH is done by using the F2SO algorithm. In addition, cluster maintenance is done to eliminate the failure nodes in the cluster. It effectively eliminates the fault SNs and builds an efficient path between the source node and the BS. In 2022, Kavita and Anand [26] presented a fault tolerance cluster-based routing in WSN. Here, FA is used for clustering and GWO selects the better path between the CH and BS to minimize the energy usage and prolong the network lifetime.

In 2023, Ishita and Mathumathy [27] designed a clustering-based routing scheme using stochastic modelling. It uses a k-medoid approach for clustering and a stochastic model for CH election. To conserve the energy of the network, the slot scheduling scheme is incorporated with this designed approach. In 2023, Nithin et al. sproposed a 3-tier prolonged energy-efficient clustering hierarchy protocol for heterogeneous WSN. Here, the CH is elected by using threshold based enhanced LEACH. In addition, the cluster formation is done with the help of the modified FCM technique. In 2022, Vinitha et al. [28] proposed a Taylor-based hybrid optimization algorithm for multi-hop routing.

It provides better security and energy-efficient multi-hop routing. In this approach, the LEACH protocol is used for data transmission and the Taylor-based Cat Salp Swarm Algorithm (Taylor C-SSA) is used for optimal hop selection. In 2021, Rathee et al. [29] designed an ACO-based QoS aware Energy Balancing Secure Routing (QEBSR) algorithm for WSN.

It effectively estimates the end-to-end transmission delay, and the node's trust factor for routing is done. Finally, in 2023, our existing work IoNM-BSOLyd approach is proposed for clustering to provide better energy optimization based on cluster-based routing.

In this approach, CH is elected by considering some major factors such as energy, distance to neighbour node and BS, and network load. Here, routing is done by using the WWO-HCg approach.

Moreover, the QoS aspects of this work are estimated in the form of network delay, energy consumption, packet delivery ratio, network lifetime and residual energy. Table 1 holds the main abbreviations used in this section. Based on the approaches mentioned above, some limitations of the existing techniques are stated in the upcoming subsection.

Table 1. Main abbreviation

Abbreviation	Description
ACO	Ant Colony Optimization
AODV	Adhoc On-demand Distance Vector
DL	Deep Learning
ABC	Artificial Bee Colony
BS	Base Station
LEACH	Low Energy Adaptive Clustering Hierarchy
PSO	Particle Swarm Optimization
BOA	Butterfly Optimization Algorithm
FA	Firefly Algorithm
F2SO	Fuzzy Firebug Swarm Optimization
FCM	Fuzzy C-Means
WWO	Water Wave Optimization
QoS	Quality of Service

2.2. Limitations

Various protocols are designed for clustering-based routing schemes. There are several limitations to the existing approaches. When security is accurately implemented, the energy becomes the challenging one. Based on the techniques mentioned above, some of the research gaps are discussed as follows,

- The researchers have not attained the expected time for data packet delivery. Hence, time delay is maximized. Delay-aware routing, SN authentication, and throughput are not achieved properly.
- The researchers have not utilized the energy harvesting mechanism to improve the WSN process. Metaheuristic technique with less complexity was not enhanced for route identification purposes.
- Some of the researchers did not achieve node authenticity, energy-efficient secure data transmission and the attack within layered construction.
- In some techniques, the researchers fail to consider the common parameter and the security is done by CH, which does not worry about the remaining SNs in the network.

In order to overcome the drawbacks mentioned above in existing techniques, this proposed methodology mainly focuses on the implementation of upcoming contributions:

- To provide efficient data communication, the SNs which use remaining energy in a better way are chosen as CH. In addition, it also considers the distance and delay for the CH election.
- To choose a better optimal route for data transmission, the distance, energy, trust, and link stability are considered into account.
- To provide secure data transmission, a stochastic universal sampling procedure is applied to the optimization technique. The velocity updates are used to find the global best solution for secure transmission.
- If the optimal path for routing is elected for data transmission, then the packet delivery ratio is enhanced as well as it minimizes the packet drop.
- At last, route maintenance is done to enhance the data transmission and deduce the delay by finding an alternate route at the time link failure occurs between SNs in the network.
- Simulation is carried out to evaluate the performance of this proposed CSPBOT -boQIEKC approach and compare it with some existing techniques.

The basic architecture of this proposed methodology is illustrated in Figure 2. It clearly illustrates the overall workflow of this proposed methodology which is briefly discussed in the upcoming section.

3. System Model

In this section, a Combinable Stochastic Patterned Bat Optimization Technique based on Quantized Indexive Energy Knowledgeable Clustering (CSPBOT-boQIEKC) is proposed to provide a protected energy-efficient routing approach.This proposed methodology is the integration of two different approaches, such as the Quantized Schutz indexive Linde Buzo Gray (QSILBG) algorithm for clustering and CH election and Combinable Stochastic Patterned Prevosti's Bat Optimization (CSP2BO) technique for shortest path detection and path maintenance. By following this method, the SNs in the network are clustered. Moreover, the shortest path is determined, so that the scheme consumes less amount of energy.

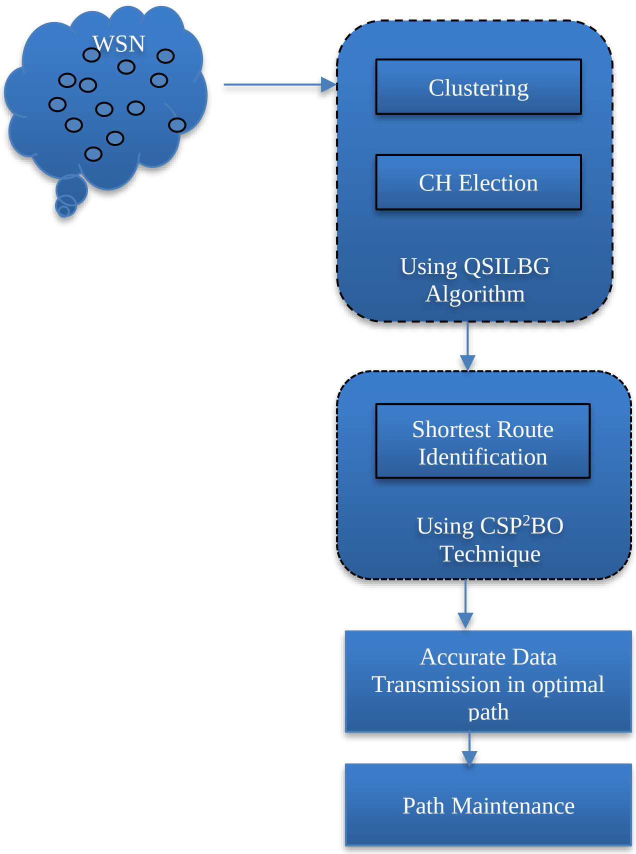

Fig. 2 Basic architecture of proposed CSPBOT -boQIEKC approach

3.1 Network and Energy Model

This proposed CSPBOT -boQIEKC approach utilizes the direct graph for protected data transmission, where the direct graph is represented in a mathematical format. It is used to determine the relationship between two different variables. This direct graph is illustrated in Figure 3. From this graph, the Undirected Graph (UG) is determined as follows,

$$UG = (SN_k, L) \tag{1}$$

Here, SNk denotes the k-number of SNs, where k varies from 1 to n in r x r square region, and L denotes the link between two SNs in the network. In Figure 3, five SNs and seven links are shown in a directed graph. Each SN in the network gathers information in the form of data packets ($dpt_a = dpt_1, dpt_2, ...dpt_n$).

After that, the SNs are segregated into multiple clusters ($Ct_1, Ct_2, ...Ct_n$). We must know some basic functions of each SN in WSN, such as distance, trust, energy, and link stability between SNs to provide secure data transmission. The initial energy of the SN in the network is estimated as follows,

$$Egya = P_r \, x \, T_e \tag{2}$$

where Pr and Te denote the power and time, respectively. After the completion of a single process of SN_s, the energy sustained in the SN is considered as remaining energy (Egy_{Rsl}), which is evaluated as follows,

$$Egy_{Rsl} = Egy_{Ini} - Egy_{Cons} \tag{3}$$

It clearly states that the remaining energy is the difference between the initial energy (Egy_{Ini}) and energy consumed during the process (Egy_{Cons}).

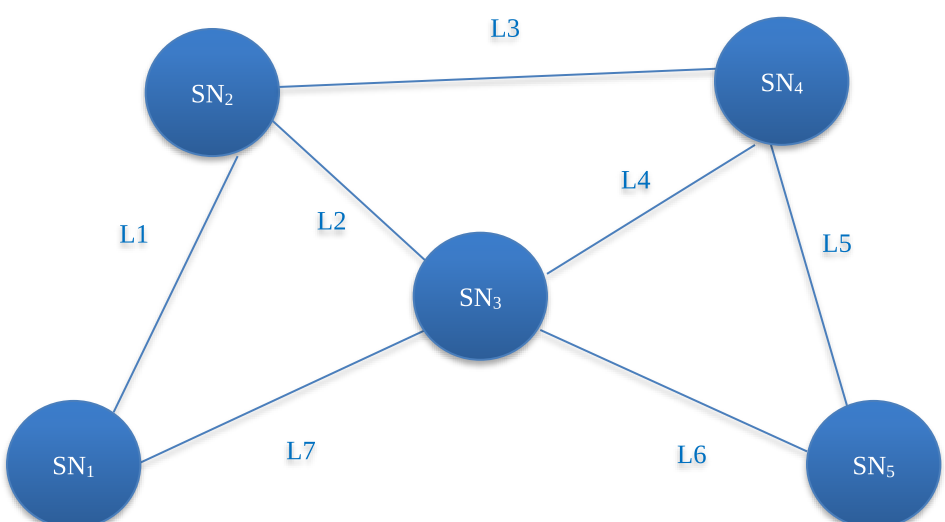

Fig. 3 Directed graph

3.2. Proposed Methodology

Three phases of this proposed CSPBOT-boQIEKC scheme for providing energy-efficient secure communication are clustering, shortest path identification, and route maintenance.

1. QSILBG algorithm for cluster formation and CH (C_{hd}) election.
2. CSP^{2}BO Technique for shortest path identification ($R_{optimal}$) to provide secure data transmission.
3. If any path fails during data transmission, an alternate route is identified by utilizing the route maintenance technique.

These three phases are clearly discussed in the below section.

3.2.1. QSILBG Algorithm

The first phase of this proposed CSPBOT-boQIEKC approach is the implementation of the QSILBG algorithm for cluster formation and CH election. This algorithm is used to cluster the SNs in the network for prolonging the network lifetime. The clustering is done based on the distance and energy of the SN_s.

It is one kind of vector quantization algorithm which operates based on the cluster and the large set of SN_s which have the same number of SN_s nearest to them. This finding is done by the Schutz index which effectively determines the sameness between the energy level and centric of clusters. The complete workflow of this QSILBG algorithm is illustrated in Figure 4.

Originally, the SN_s in the network were separated based on energy and distance. Initially, all the SN_s have the same amount of energy during SN deployment. Then, the nodes use some amount of energy for detecting, processing, and communication purposes.

Therefore, there is some degradation in the energy level of SN_s. After completion of this task, the remaining energy level of the SN_s is evaluated. Once the evaluation is completed, the distance between the SN_s in the network and distance measurements are carried out to determine the nearest node. So, the nodes with equal energy levels and closest nodes are grouped into one cluster. Next, n- number of clusters (Clr_1, Clr_2….Clr_n) and centric of clusters (G_1, G_2…..,G_n) are originated. The remaining energy of SNs and the centric of clusters are evaluated by using the Schutz index and it is given in Equation 4.

$$\alpha_{sic} = 0.5\ X\ \left[\frac{\sum_a \sum_b |Egy_{resl}(SN_a) - G_b|}{\sum_a Egy_{resl}(SN_a)}\right] \quad (4)$$

where α_{sic} denotes the coefficient of the Schutz index, $Egy_{resl}(SN_a)$ indicates the remaining energy of SN_s, and G_a is cluster-centric. The output of this estimation is within the range from 0 to 1. If the value of α_{SIC} is 1, then the node has high similarity or else low similarity. The cluster formation is done depending on the energy level of clusters, which is compared with centric by using this similarity index.

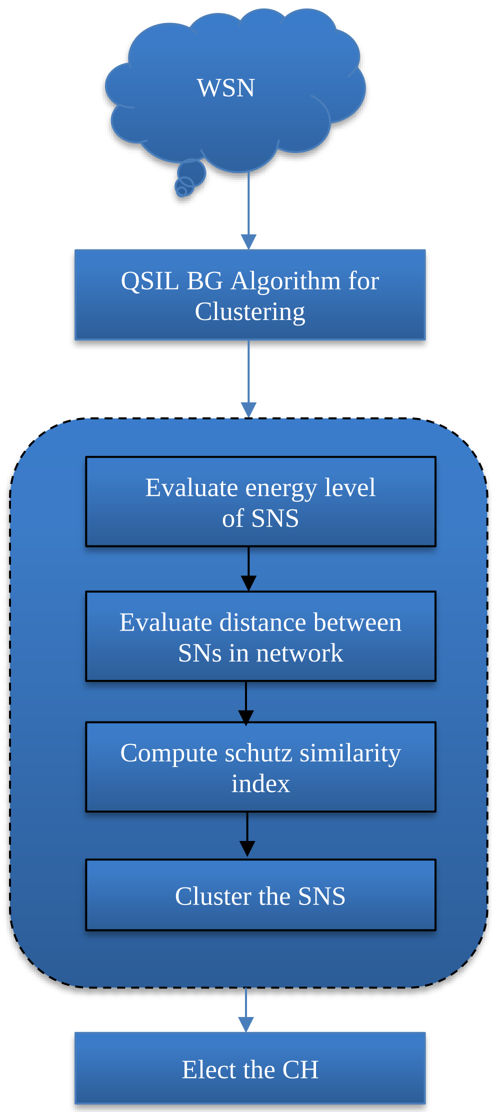

Fig. 4 Workflow of QSILBG algorithm

Once the energy level estimation of SN_s is completed based on the similarity index, then automatically, we focus on the distance between the SN_s to know the closest node with the same residual energy. The distance between the SN_s is determined based on the SN speed and time, which is evaluated as follows,

$$\text{Distance} = \text{Speed} * \text{time}. \quad (5)$$

After the distance and residual energy of the SN_s in the network are completed, the nodes with the same residual energy and the nearest nodes are hammered in different clusters. Next, in this proposed methodology, the CH is elected based on SN_s with high residual energy and security constraints to provide effective data transmission with low delay. For that elected node, the security constraints are evaluated.

In the security mode, the CH is elected by considering the security demand (St_{dd}) and security rank (St_{rk}). If the node satisfies the constraint $St_{dd} \leq St_{rk}$, then it can be authorized to be a CH. Five different security levels are very low, low, medium, high and very high. If the SN in the cluster satisfies these constraints, then that particular node is chosen as CH. Above mentioned procedure is clearly stated in Pseudocode 1.

Pseudocode 1: QSILBG Algorithm
Input: Sensor Nodes (SN_k), k ε 1 to n
Output: Multiple Clusters
Start
***Step1**: for each SN_k*
***Step 2**: Estimate remaining energy $Egy_{resl}(SN_a)$*
***Step 3**: Originate n number of clusters (Clr_1, Clr_2, ….Clr_n)*
***Step 4**: for each cluster (Clr_n)*
***Step 5**: Centric initialization (G_1, G_2…..,G_n)*
***Step 6**: End for*
***Step 7**: for each cluster centric G_n*
***Step 8**: Estimate residual energy of SNs $Egy_{resl}(SN_a)$*
***Step 9**: Calculate similarity α_{SIC}*
***Step 10**: Calculate distance between SNs*
***Step 11**: if (α_{SIC} =1) and distance closest to SN then*
***Step 12**: Group SNs in specified cluster*
***Step 13**: end if*
***Step 14**: end for*
***Step 15**: end for*
***Step 16**: Get cluster result*
***Step 17**: for each cluster Clr_n*
***Step 18**: Elect CH*
***Step 19**: end for*
***Step 20**: end for*
End

In this stage, the cluster formation and cluster head election are effectively done by using the QSILBG algorithm. Here, the fault tolerance method is used to ensure that the network works continuously, even in the situation of CH failure. Next, the routing using CSP^2BO Technique is done to provide secure data transmission.

3.2.2. CSP^2BO Technique for Data Transmission

The second phase of this proposed CSPBOT-boQIEKC approach is the implementation of the CSP2BO technique algorithm for secure-path data transmission. In general, WSN does not have any static infrastructure and utilizes a broadcast transmitting channel for communication purposes. Due to this reason, WSNs have less protection, so it is highly vulnerable to attacks.

Therefore, the hackers have a high chance of sending malicious packets or taking over the SNs in the network. To overcome this issue, security plays a vital role. These scenarios are widely used in military applications, so we need to give more attention to providing high security during data transmission. Two common security issues are SN authentication and secrecy assurance.

In this proposed methodology, the CSP2BO technique is introduced for SN authentication. It is performed based on demand and investigation of security. This is the swarm intelligence-based technique which provides better solutions in multi-dimensional search space. Here, the bat is considered a search agent.

It effectively initiates its food search in its current position and velocity. Moreover, its search ends in the location of prey, where the prey is the better location for bats. Here, the function performed by the bat is like the CH, and the prey is similar to the various objective functions. Each bat that searches for and locates its prey is considered as a best shortest path for data transmission. This shortest path routing is performed by using a bat optimization algorithm. However, it has a high convergence rate; hence, the enhancement of this optimization algorithm is required.

Therefore, this proposed methodology originates the population of CH (i.e. bat) (C_{Hd1}, C_{Hd2}, C_{Hd3},…, C_{hdk}), which is stimulated around the search space of the bat. It is incorporated with the starting position and velocity followed by fitness value. This measure is evaluated based on some objective functions such as distance, energy, trust, and link stability of the SNs. Let us assume that the two-dimensional space, distance between two SNs is evaluated by Prevosti's Distance (PV_{Dis}) equation. It is used to find the nearest node for shortest path discovery, which is estimated by using the following equation,

$$PV_{Dis} = \frac{1}{k}\sum_{a=1}^{n}\sum_{b=1}^{m}|SN_a - SN_b| \quad (6)$$

where PV_{Dis} represents the distance between SN_a and SN_b. The trust value is also estimated as follows,

$$Trst = \left[\frac{Fwd(dpt_{b\to n})}{Trans(dpt_{a\to b})}\right] \quad (7)$$

Node trust (Trst) is estimated based on the forwarded dpt from b to n and transferred dpt from a to b. The evaluated trust value lies between 0 and 1. At last, the link stability is used to identify the stable link between the SNs in the network. By identifying this stability, the proposed approach provides better stability and reduces the packet drop ratio during data transmission. The stability of the link between node a and b at time (tm) is calculated as follows,

$$LkCy_{a\to b}(tm) = \left[\frac{T_r(SN)}{Dis}\right] \quad (8)$$

where $LkCy_{a\to b}$ denotes the link connectivity between SN a and SN b. T_r (SN) is the transmission range of SN, and *Dis* represents the distance between node *a* and node *b*. Here, T_r (SN) > *Dis*. If $LkCy_{a\to b}$ is greater than the threshold value, then the nodes *a* and *b* are linked, and this type of value is considered a positive report. By using these objective functions, the fitness value is measured.

$\Delta_{ftf} = arg\ min\ (Dis)\ \&\&\ arg\ max\ (Egy_{Rsl}, Trst)\ \&\&\ LkCy_{a \to b}(tm) > Thd$ (

Δftf denotes the fitness function, *arg min* and *max* indicate the argument of the minimum and maximum function, and *Thd* is a threshold value. In this stage, the SUSS procedure is used to elect the best individuals based on this fitness function. This election is done based on the probability calculation, which is stated below,

$$Pbty = \frac{\delta F_a}{\sum_{b=1}^{n} \delta F_b} \quad (9)$$

Probability (Pbty) is calculated based on the average fitness of ath individual to bth individual. In addition, the second and third-best individuals are elected as follows,

$$SN_a(Scd) = Pbty \text{ x } [1 - Pbty] \quad (10)$$

$$SN_a(Thrd) = Pbty \text{ x } [1 - Pbty]2 \quad (11)$$

Likewise, all the best solutions are elected, and others are removed to find the best global solution. This solution is identified by updating the current position and velocity based on the fitness function.

$$\alpha_a\ (tm+1) = \alpha_a\ (tm) + \beta_a\ (tm+1) \quad (12)$$

$$\beta_a\ (tm+1) = \beta_a\ (tm) + \Delta_{ftfglobal} \quad (13)$$

Where $\alpha_a\ (tm+1)$ and $\alpha_a\ (tm)$ denote the updated and current position of the bat, respectively. $\beta_a\ (tm+1)$ and $\beta_a\ (tm)$ indicate the updated and current position of velocity. Moreover, $\Delta_{ftfglobal}$ is the best global solution. This global best solution is elected as optimal. The global best path is identified between the source and BS based on the updated bat position to provide energy-efficient secure data transmission.

The flowchart illustrates the CSP2BO Technique for finding the best path for routing. It effectively enhances the security during information delivery in WSN which is shown in Figure 5. To discover the optimal route path for secure data transmission, initially, the source node sends the data packets to the nearby CH. This CH finds another optimal CH to establish the path.

By continuing this procedure, the route is established. Likewise, the optimal path for data transmission is predicted. Finally, if any link between the SNs is broken, the alternate adjacent nodes are identified for improving data security and reducing the delay. In the end, route maintenance is carried out for this proposed CSPBOT-boQIEKC approach for finding the optimal path when the link failure happens among SNs in the network. While distributing the data packets, we can provide protected link maintenance by performing route maintenance to improve data security and reduce the delay.

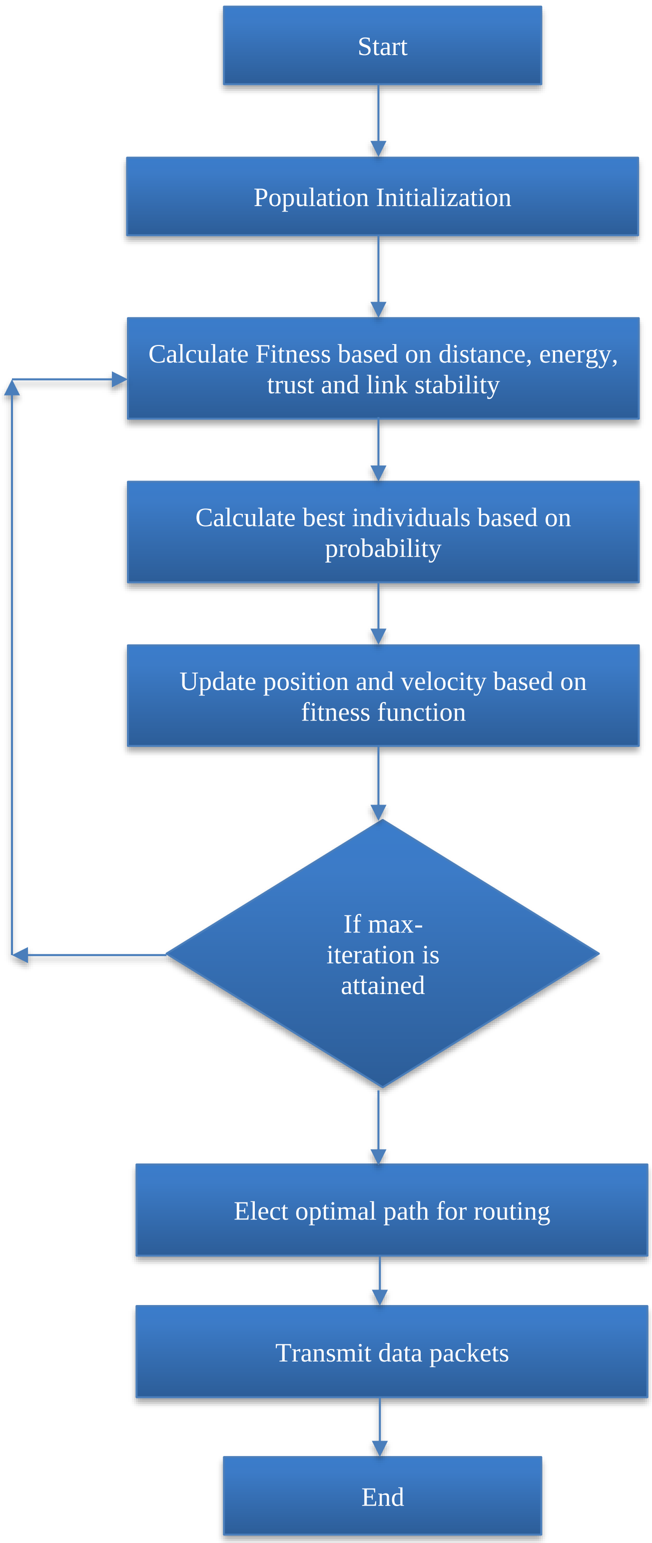

Fig. 5 Flow chart of CSP^{2}BO technique

4. Simulation Results and Discussion

The simulation is performed by using the NS2.34 simulator. Some of the simulation parameters considered for this proposed methodology is tabulated in Table 2.

Table 2. Simulation parameter

Parameter	Value
Simulator	NS2.34
Sensor nodes	100, 200, 300, 400, 500
Network region	1000 m x 1000 m
Simulation time	350s
Mobility	Random way
Routing scheme	DSR
Speed of SN	0-20m/s
Data packets	Starting from 100 upto 1000
Starting energy of each SN	0.5J
Data packet size	257-515 bytes
Number of runs	10

The simulation of this proposed CSPBOT-boQIEKC approach is compared with some existing techniques. The performance of this proposed technique is evaluated in terms of energy consumption, packet delivery ratio, pack drop rate, throughput, and end-to-end delay. Initially, the SN in the network holds the energy level for sensing. Therefore, the energy level is reduced slightly at the time of data processing. It is named as residual energy or remaining energy, which is estimated as follows,

$$\text{Res Engy} = SN_{Stg\text{-}Egy} - SN_{Utild\text{-}Egy} \quad (14)$$

The value of residual energy (*Res Engy*) is the difference between the starting energy ($SN_{Stg\text{-}Egy}$) of the SN and the utilized energy ($SN_{Utild\text{-}Egy}$) of the SN. A comparison of the residual energy of SNs is tabulated in Table 3. The graphical representation of the simulation result of residual energy is illustrated in Figure 6.

Table 3. Comparison of residual energy

No. of SNs	Residual Energy (%)			
	Taylor C-SSA	QEBSR	IoNM-BSOLyD	Proposed CSPBOT-boQIEKC
100	82	85	96	97
200	85	87	98	98.2
300	86	88	98	98.5
400	87.4	88.6	99.1	99.4
500	89.1	90	99.3	99.7

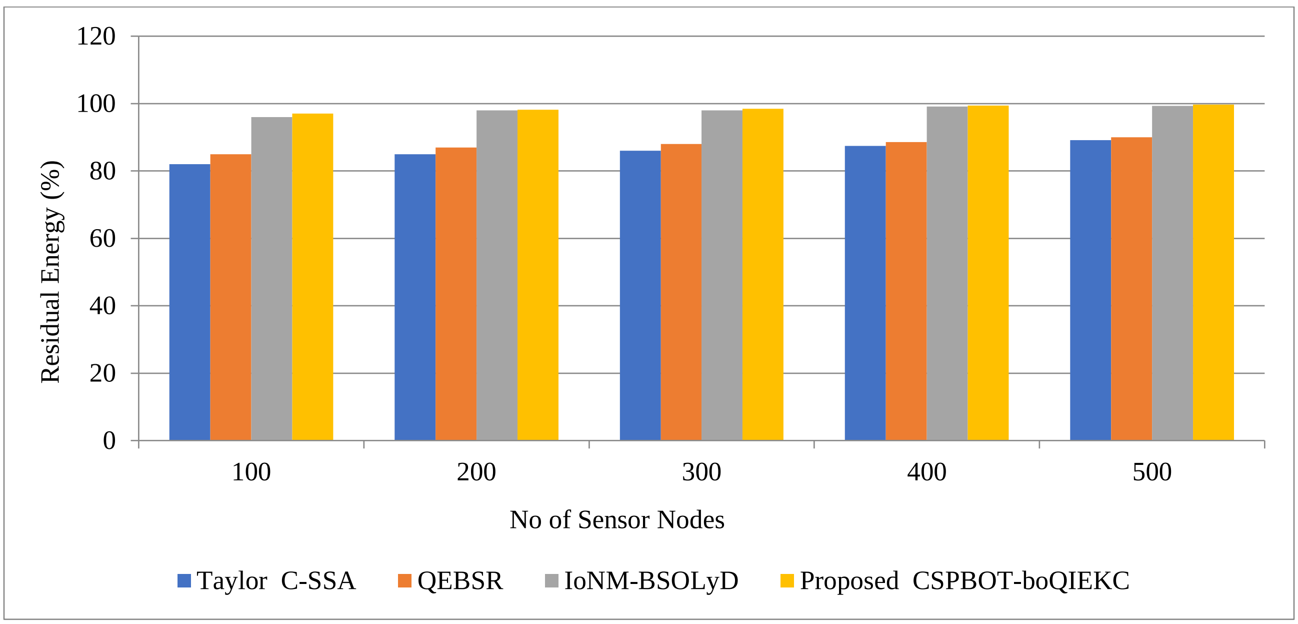

Fig. 6 Comparative analysis of residual energy

The overall workflow of the proposed CSPBOT-boQIEKC scheme is briefly explained in Section III, which provides better performance results than the existing approaches. Therefore, the energy consumption of this proposed CSPBOT-boQIEKC scheme is reduced when compared to the existing Taylor C-SSA approach [28], QEBSR approach [29] and IoNM-BSOLyD technique. In general, energy consumption is the amount of energy consumed by the SNs in the network for sensing, which is estimated as follows,

$$Egy_{Conspn} = k \times Egy_{Conspn}(SN) \quad (15)$$

Where Egy_{Conspn} denotes the energy consumption and $Egy_{Conspn}(SN)$ indicates the amount of energy consumed by SN.

Comparative analysis of both energy consumption and network lifetime is tabulated in Tables 4 and 5, respectively.

Table 4. Comparison of energy consumption

No. of SNs	Energy Consumption (J)			
	Taylor C-SSA	QEBSR	IoNM-BSOLyD	Proposed CSPBOT-boQIEKC
100	3	2.8	2.4	2.1
200	5.3	5.1	4.8	4.1
300	10.4	9.2	8.5	8.2
400	13.1	12.3	11.2	10.5
500	14.6	14.1	13	11.8

Table 5. Comparison of network lifetime

No of SNs	Network Lifetime			
	Taylor C-SSA	QEBSR	IoNM-BSOLyD	Proposed CSPBOT-boQIEKC
100	1425	1580	1650	1725
200	1550	1620	1700	1800
300	1625	1700	1750	1875
400	1700	1750	1800	1925
500	1785	1800	1850	1910

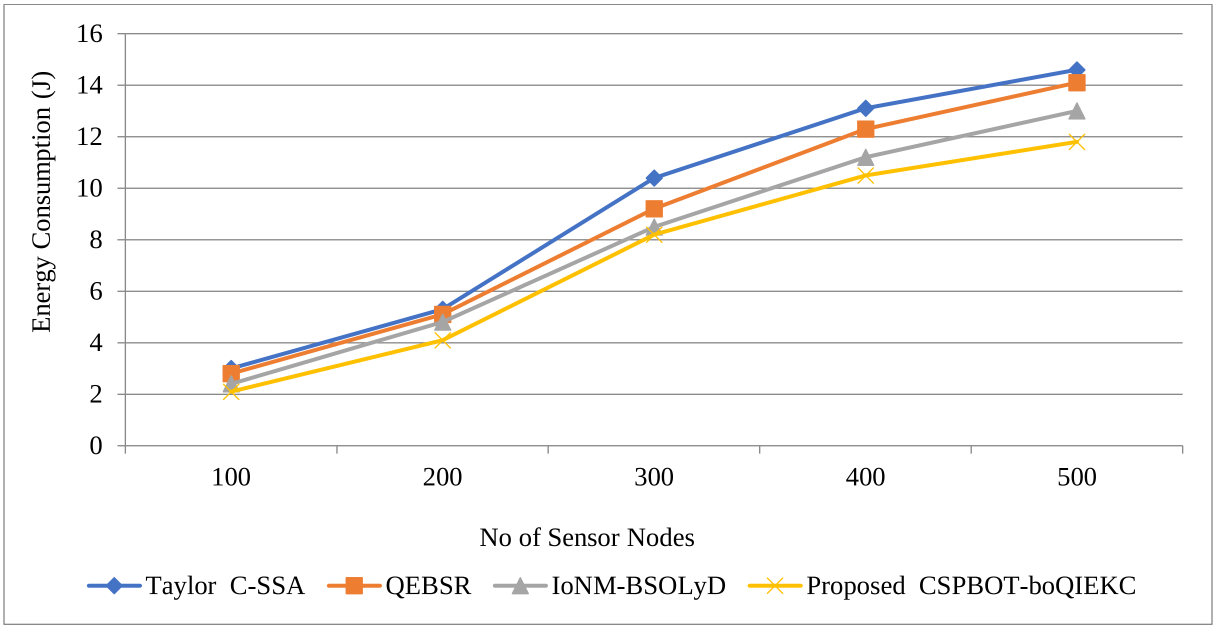

Fig. 7 Comparative analysis of energy consumption

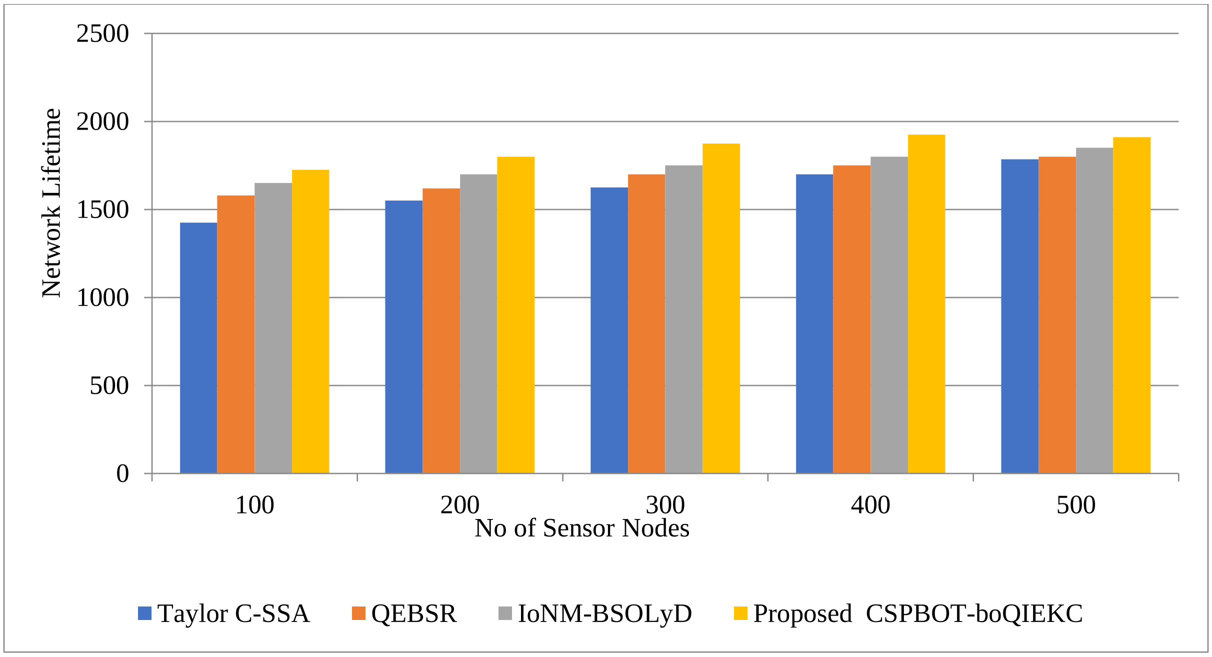

Fig. 8 Comparative analysis of network lifetime

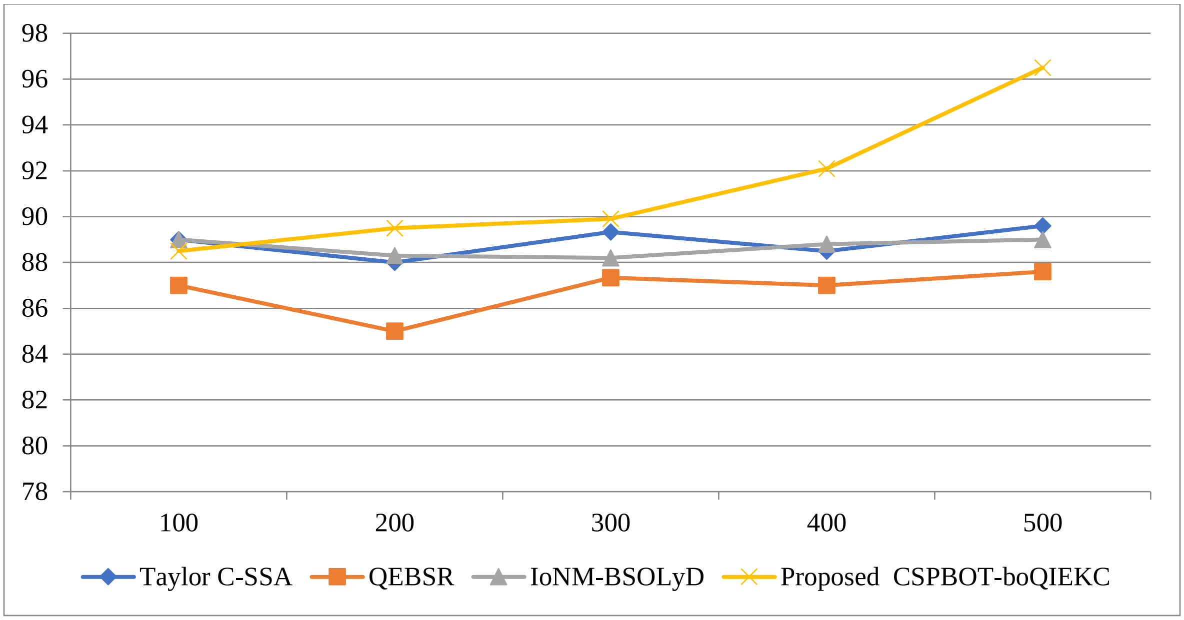

Fig. 9 Comparative analysis of packet delivery ratio

Table 6. Comparison of PDR

No. of dpt	PDR			
	Taylor C-SSA	**QEBSR**	**IoNM-BSOLyD**	**Proposed CSPBOT-boQIEKC**
100	89	87	89	88.5
200	88	85	88.3	89.5
300	89.33	87.33	88.2	89.9
400	88.5	87	88.8	92.1
500	89.6	87.6	89	96.5

Moreover, it is a graphical representation of energy consumption and network lifetime in Figures 7 and 8, respectively. The energy consumption of this proposed methodology is compared with existing Taylor C-SSA, QEBSR and IoNM-BSOLyD approaches. Here, the energy consumption of the proposed CSPBOT-boQIEKC scheme is reduced to 9%, 18% and 24% when compared to above mentioned existing approaches. If the consumption of energy of SNs in the network is reduced, then automatically the network lifetime is enhanced, because both are inversely proportional to each other. Approximately the network lifetime of the SN has been prolonged by 15%. This energy conservation is a major aspect of WSN, as the battery level will sustain longer so there is no need to alter the battery often.

Figure 9 illustrates the performance analysis of the proposed CSPBOT-boQIEKC technique and existing Taylor C-SSA approach [28], QEBSR approach [29] and IoNM-BSOLyD technique in terms of Packet Delivery Ratio (PDR).

It is defined that the number of data packets received at BS from the total number of data packets transmitted from the source node which is estimated as follows,

$$PDR = \frac{dpt_{received}}{dpt_{sent}} X\ 100 \tag{16}$$

where dptreceived denotes the received data packet to the BS and dptsent indicates the transmitted data packet from the source node. The comparative analysis of this PDR is tabulated in Table 6. This proposed methodology attains a higher packet delivery ratio than the existing one so that it achieves high security. The network performance is estimated based on the number of packets delivered at the sink node. So, the network needs to perform high when the value of PDR is high. By using the proposed optimization technique, the data transmission is more secure and it is free from attackers within the network.The performance result shows that the PDR of the proposed CSPBOT-boQIEKC technique is improved by 3%, 6% and 8% compared with existing [28, 29] techniques, respectively. As a result of successful data transmission, the throughput is evaluated. It is considered successful based on the data transmission. In addition, this transmission is attained with high PDR. This throughput is estimated as follows,

$$Thg_{put} = \left[\frac{delivered\ dpt(bits)}{tm(seconds)}\right] \tag{17}$$

The performance in terms of throughput is analyzed between the proposed and existing methodology. Overall, the throughput of this proposed methodology is improved by 26% than the existing one. This is attained when the SNs with the closest distance and high energy level are involved in the data packet transmission to enhance the data delivery/unit time. At last, if any link failure has occurred, the proposed CSPBOT-boQIEKC technique carried out the path maintenance procedure to elect an alternate shortest path for data transmission. It effectively reduces the delay in data achievement on the destination side.

5. Conclusion

The Energy efficiency and security are the major challenges in distributed WSNs. To attain this, cluster formation, CH election, optimal path discovery and path maintenance are designed by the CSPBOT-boQIEKC technique. Initially, clustering and CH election are done by the Quantized Schutz Indexive Linde Buzo Gray (QSILBG) Algorithm. Here, the Cluster Head (CH) from SNs is elected by considering distance, SNs with high residual energy and security constraints to provide effective data transmission with low delay. In this stage, the fault tolerance method is used to ensure that the network continuously works even in the situation of CH failure. After that, shortest path identification is performed by Combinable Stochastic Patterned Prevosti's Bat Optimization (CSP2BO) technique. Furthermore, the fitness of the bat is estimated based on the distance, energy, trust and link stability among SNs. The Stochastic Universal Sampling Selection (SUSS) procedure is activated to elect the best shortest path for data transmission. Finally, path maintenance is accomplished to determine the alternative path while link failure happens among SNs in WSN. The performance of this proposed methodology is evaluated based on some metrics such as residual energy, energy consumption, packet delivery ratio, network lifetime and throughput. The proposed CSPBOT-boQIEKC technique provides 18% enhancement in energy consumption, 6% enhancement in PDR, and 26% enhancement in throughput than the existing Taylor C-SSA approach [28], QEBSR approach [29] and IoNM-BSOLyD technique approaches. If the energy consumption of SN during the process is enhanced, then the network lifetime is also prolonged. In future, we will implement the cryptographic algorithm during data transmission to provide well-secured data which is free from various attacks.

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