Fuzzy Logic Based Clustering With Firefly Optimized Routing Protocol For Qos Aware Wireless Sensor Networks

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Abstract: Nowdays, Wireless sensor networks (WSN) becomes familiar due to its applicability in diverse areas of gathering and processing data from the physical environment. At the same time, the advanced applications and new multimedia sensors have raised the demand for highly sufficient management of their quality of service (QoS). The constraints and requirements for theQoS management entirely based on the application perspective. In this view, this paper presents a QoS aware cluster based routing (QoS-CR) technique for WSN. The proposed QoS-CR involves three main processes, namely clustering, routing and maintenance. At the earlier stage, fuzzy logic based clustering (FBC) technique gets executed to organize the nodes into clusters and selects cluster heads (CHs) effectively. Then, a firefly with a levy (FF-L) algorithm is employed for identifying the optimal paths between two CHs or CHs to BS. Finally, the maintenance process is invoked to balance the load and energy consumption throughout the network evenly. A detailed simulation analysis takes place to ensure the performance of the QoS-CR model, and the results are validated interms of several measures under a distinct number of nodes and simulation rounds. The outcome of the extensive simulation verified the superior characteristics of the proposed model over the compared methods.

Keywords: Clustering, Routing, QoS, WSN, Firefly algorithm, Fuzzy logic

1. Introduction

Wireless Sensor Network (WSN) still being an active research area due to its applications in various fields like military surveillance, environmental monitoring, home automation, smart buildings, healthcare, industrial control, etc. [1]. The applications of WSN in diverse fields become practical owing to the versatile characteristics of sensor nodes. WSN comprises of a massive number of autonomous nodes undergo arbitrary deployment in the target area. It is commonly used for data gathering or target tracking applications where human involvement is complicated. Since the sensor nodes are smaller in size and are connected in a wireless medium, it is limited by energy, bandwidth, memory and processing capabilities. Practically, sensor nodes are deployed with limited power supply interms of inherent battery; it should sustain for a longer period based on the application at a stretch without any intervention. For example, a WSN is deployed by a team of engineers on a small island ten miles off the coast of Maine to explore the nesting behavior of petrels. Now, the biologists can monitor the petrels from their labs; browse information from sensors connected by the satellite. The entire operation is planned upto nine months and the sensor nodes should be active only with its inbuilt battery. It is not possible to renew or change the sensor nodes in a harsh environment and the nodes should exploit the available energy efficiently to extend its lifetime. In WSN, energy is spent on three operations such as sensing, processing and data transmission. Some studies indicated that the maximum quantity of energy is depleted for data communication and the energy spent on sensing and processing is highly negligible.

Unfortunately, routing has been considered as a major problem in WSNs. Conventional routing protocols could not be used directly by sensors due to the presence of battery-dependent sensors and requires delicate routing protocols with suitable communication principle [2]. As WSNs is constrained of structure-less ad hoc topology, identifying a new path as well as forwarding data to BS becomes a tedious process. For instance, stable and delay sensitive fields such as patient observation, fire prediction, gas leakage observance, homeland security and many other aspects, the sensed data must be transferred in a limited delay and an optimal information exchange ismainly required. The above mentioned process could be activated in WSN by applying QoS and minimum power consumption that has to be taken into account for diverse layers of a protocol stack. The basic architecture of WSN is shown in Fig. 1.

The main aim of WSN is to decrease the sensor overhead by offering maximum liability to BS and project a delicate clustering along with routing protocols by assuming multi-constrained QoS parameters. In WSN, the sensor nodes closer to BS often transfer massive data and finally, the node gets expired because of complete energy exhaustion. Consequently, network connectivity has been broken and BS could not be able to obtain desired data. To achieve energy efficiency and reduce the amount of energy consumption, the clustering technique is assumed to be one of the effective models which preserve the sensor's energy. To develop this module, the network undergoes partition of several groups, named Clustering is an energy efficient technique that aims to diminish the energy utilization and stretches the lifetime of WSN. Network lifetime can be termed as the active lifetime of a network after node deployment or it can be defined as the total period between deployment and network failure. The basic idea behind clustering is the process of grouping nearby nodes to clusters and a cluster head (CH) is chosen from the nodes whereas rest of the nodes are considered as cluster members (CMs). The CM simply senses the attributes and forwards the sensed data to CHs. The CHs are responsible for the following duties: receiving data from its cluster members, performing data aggregation, relaying aggregated data to BS and forwarding data from the lower level CHs. Clustering offers some benefits like energy efficiency, low bandwidth requirement, less overhead, high stability, less delay and uniform load distribution. Therefore, an appropriate election of CHs is considered to be a vital process in preserving energy and improving the lifespan of WSN. Also, CH selection is assumed to be an optimizing issue which belongs to NP-hard.

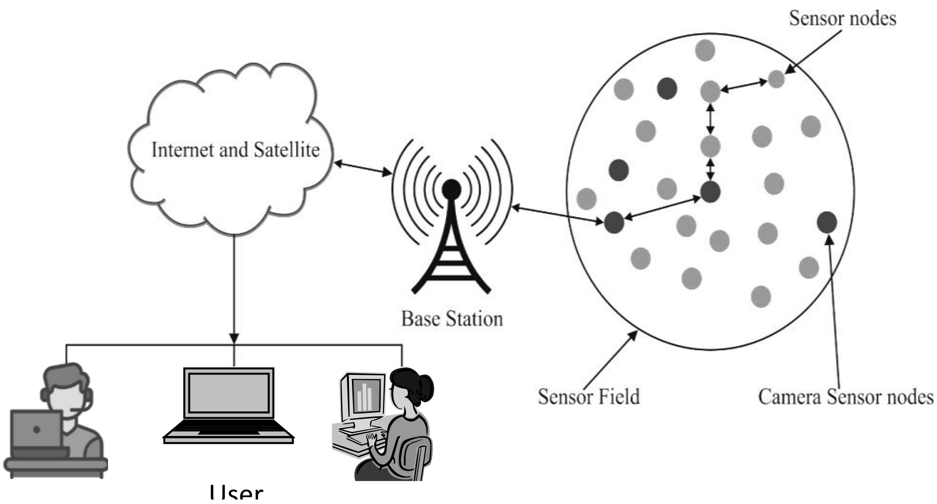


Fig.1. Architecture of WSN

Moreover, the routing protocol is volatile to successive path interruptions, which occurs due to the node failure. There are few routing protocols which identifies routing path; but somehow, it fails at the time of data transmission resulting to minimal reliability. In order to resolve this problem, an effective model with improved multipath routing protocol (MRP) is required [19]. This protocol enables many paths among source and BS. When any one path gets failed, then data could be passed by another path. This function leads to increase throughput with reduced delay in the network [20-22]. In addition, it applies multipath routing to obtain stable transmission of data that minimizes the network overhead for route discovery and enhances throughput of the system. To develop a best communication path from BS and sensors, route discovery process gets executedwhich decides the next hop node from sensors on the basis of topological structure and QoS parametric values of adjacent nodes [23-25].

This paper presents a QoS aware cluster based routing (QoS-CR) technique for wireless sensor network. The proposed QoS-CR makes use of fuzzy logic based clustering (FBC) technique for cluster construction. Besides, it makes use of a firefly with levy (FF-L) algorithm for the identification of optimal paths from source to destination. Finally, the maintenance process is invoked for evenly balancing the load and energy consumption evenly throughout the network. A detailed simulation analysis takes place to ensure the performance of the QoS-CR model and the results are validated interms of several measures under varying number of nodes and simulation rounds.

The organization of the study is provided as follows. Few recent works are surveyed in Section 2. The system model is given in Section 3. The presented QoS-CR technique is clearly elaborated in Section 4 and then validated in Section 5. At last, section 6 draws the conclusion of the study.

2. Literature survey

In this section, recent works developed for clustering and routing process in WSN has been reviewed. In [3], the QoS factors existed in WSN clustering protocols has been analyzed. A novel protocol has been proposed for image-based domain as well as to estimate the fitness function (FF)based on endtoend (ETE) delay, and the significant QoS attributes. Researchers in [4] presented an effective WSN clustering protocol which tends to enhance QoSattributes like maximum delay and throughput under a fixedBS. Subsequently, alternate protocols applied an ad hoc cluster-relied structure which is suitable for network topology changes [5]. Such types of clusters are deployed on the basis of QoS metrics like bandwidth, and delay offering ETEQoS for every data stream. In recent times, [6] proposed a QoS-aware clustering routing protocol for Actuator Networks. It offersQoS by means of delay; however, it has been specifically applied for non-identical features and cannot be used for WSNs in a straightforward manner.

Later, [7] proposed an extended LEACH method that adopts CH selection process. It applies QoS metrics namely, throughput and packet delivery ratio (PDR)to measure the performance of a protocol in contrast to actual LEACH model. But, the main goal of LEACH technique is to minimize the power application and enhance the network lifespan, and not to increase specified QoS factors. Similarly, in [8], researchers established a multi-processing LEACH variant protocol, which helps to minimize energy utilization, expands network lifetime, extends throughput of a network and so on. Therefore, such types of methods consume only QoS parameters to estimate the working process of deployed model.

In [9], it considers the merits of node power heterogeneity in WSN by the development of Energy Efficient Heterogonous Clustered (EEHC) protocol in case of tri-level network. It selects CH on the basis of remaining energy present in sensors with the help of possible threshold function. Since it is comprised with heterogeneous mechanism, EEHC is more effective when compared with LEACH by means of enhanced network lifetime. Likewise, [10] deployed an energy concept as well as traffic and energy-aware routing (TEAR) to clarify a stabilized interval, when considering sensor nodes with random energy levels as well as discrepancies in traffic generation value to overcome the shortcomings present in this module.

Also, [11] presented CH restricted energy efficient protocol (CREEP), Automata-based multilevel heterogeneous routing (LA-MHR), as well as Efficient and dynamic clustering scheme (EDCS) for heterogeneous clustering network. Here, CREEP aims in decreasing the count of CH for a single iteration in order to enhance the network lifetime under the application of 2-level heterogeneity. Then, LA-MHR presents multi-level heterogeneous node model on the basis of automated learning. While the performance of LA-MHR is carried out, an S-model based learning technique has been applied for CH selection and cognitive radio spectrum is helpful to select CHs by a BS. Eventually, it estimates the network lifetime and robustness, while considering the problem of energy hole. Besides, EDCS invents an energy detecting model to save node's power and extend the lifetime of a network. But, realistic network status are said to be mobile and tedious, and as a result, it is not a simple to estimate the network lifetime.

Afterwards, [12] designed a Clustering-tree topology control based on the energy forecast (CTEF) to overcome the issues like network overhead and energy consumption under various circumstances like link reliability, PDR, and so on. As an inclusion, traditional CH election process and cluster evolution adopts core hypothesis as well as log normal distribution strategy to predict the exact mean power of network by estimating the variations among original and standard remaining power. Followed by, [13] seriously examined the features of QoS-relied routing protocols in WSNs. Also, [14] proposes a geographic position-based QoS protocol that is termed as SPEED. This SPEED protocol tends to introduce an adjacent table method. These neighboring tables set the adjacent position as well as delay of single-hop neighbors for each node. Thus, the business among best delay delivery and load balancing has taken into account to precede the process.

In [15], a multi-objective as well as multi-constraint optimizing routing technique has been deployed. The data overhead, link superiority, remaining energy metrics and many other aspects were assumed as performance measures to determine the quality of a routing protocol. This model ensures a rapid data delivery as well as connection reliability. Then, [16] presented a difficult realistic protocol named as Self-stabilizing Hop-constrained Energy efficient (SHE). This method performs when a cluster-developing process gets completed, and the data packets from CHs to BS undergo routing by various paths. Additionally, Aging Tag (AT) is a technique applied to obtain QoS requirements.

Subsequently, [17] developed an energy-aware QoS routing protocol (EQRP) clustering mechanism. In this protocol, the network is altered with the application of bird mating optimization (BMO) and based on highly stable infrastructure. The projected routing protocol is capable of improving throughput, network stability, and decreased additional data retransmissions, increase PDR, minimize ETE delay and so forth for WSNs. Also, [18] modeled a bi-hop neighborhood data-based routing protocol. The energy balancing as well as 2-hop velocity a model has have been combined as single concept. As a result, its adaptability is ensured by using QoS metrics in real-time applications, respectively.

3. System model

3.1. Network model

A WSN is labelled in the form of undirected weighted graph$G(V,E,W)$, where$V=\{v_1,v_2,\dots v_n\}$, is a definite set of vertices which denotes the sensor nodes, $E=\{(v_1,v_2),\dots(v_{n-1},v_n)\}$, represents the limited collection of edges that shows the bi-directional wireless links whereas W implies the weight set of each link. Here, it is considered that the sensor nodes static and has an exclusive ID. All CHs consist of equal communication range $r$as well as corresponding CMs are arbitrarily shared inside a region ofπr^2. Every sensor node determines its own remaining energy and power deficiency that modifies on the basis of sensor position. Hence, radius measure of BS is $2r$ and higher transmission region is defined as $2\pi r^2$.

3.2. Metric Definitions

The presented protocol concentrates on 2 major QoS parameters in sensor network model as energy consumption and delay to create a novel clustering method along with multipath routing procedure across wider network (Deepa et al., 2016). Every sensoris capable of storing the connectivity function among the respective and adjacent nodes by means of energy(E_{link}), delay(D_{link}), distance to BS and hop count. Here, path-based parameters are referred as (E_{path}) and(D_{path}). In multipath routing, to explore overall ETE guarantee for every paththat has been portioned as ETE energy consumption (E_{e2e}) as well as ETE delay(D_{e2e}).

3.2.1. Energy metric

In WSNs, optimization of energy is a major technique. Energy concepts were employed in physical and MAC layer of WSN according to power depleting approach that is directly proportional to transmission distance. Additionally, 2 channel propagation methods are applied as free space (d^2 power loss) for data transmission under the employment of single-hop communication whereas multipath fading (d^4 power loss) channel is applied for multi-hop communication. Therefore, power utilization while sending n bits of data packet by distance d is measured as

$$E_T(\mathrm{n},\mathrm{d})=\begin{cases} nE_{elec}+\mathrm{n}\varepsilon_{\mathrm{fs}}\mathrm{d}^2, & \mathrm{d}<\mathrm{d}_0 \\ nE_{elec}+\mathrm{n}\varepsilon_{\mathrm{mp}}\mathrm{d}^4, & \mathrm{d}\geq\mathrm{d}_0 \end{cases} \quad (1)$$

where the amplifier energy, ε_{fs} and ε_{mp} is based on communication distance, E_{elec} implies the digital power exist in transceiver, d represents distance from source and target whereas threshold d_0 is assumed to be crossover distance

$$d_0 = \sqrt{\frac{\varepsilon_{\mathrm{fs}}}{\varepsilon_{\mathrm{mp}}}} \quad (2)$$

The power application to receive n bits of data can be estimated as,

$$E_R(n)=nE_{elec} \quad (3)$$

Therefore, energy level of transmitting and deriving n bits of data from a link is presented as,

$$E_{link}=E_T(\mathrm{n},\mathrm{d})+E_R(n) \quad (4)$$

The residual energy of a node is indicated in the form of,

$$E_{current}=E_{current}-E_T(\mathrm{n},\mathrm{d})-E_R(n) \quad (5)$$

The energy utilization of a path is measured by the sum of power applied at every link towards the path of data transmission from source to BS which is evaluated by,

$$E_{path_i}=\sum_{j=1}^{hop_i}E_{link_j} \quad (6)$$

For transmitting n bits of data packet, energy application of a path E_{path} should be minimum when compared with essential lower energy E_{req}. Hence, energy objective function f_E helps to reduce the overall power utilization on a path and is determined by,

$$f_E = \min\{E_{path}\} \quad (7)$$

From multipath routing, the overall ETE power consumption E_{e2e} of every applied path has been provided by,

$$E_{e2e} = \sum_{i=1}^{np} E_{path_i} \quad (8)$$

3.2.2. Delay metric

In WSNs, many of the application areas belongs to delay sensitive module, thus delay is a major requirement in QoS parameter to address data transmission to BS with minimum delay. It is defined as time expired while sending data packet from source to BS. The delay from 2 sensors are presented as D_{link_j} that is provided by,

$$D_{link_j} = d_{trans} + d_{propa} + d_{proces} + d_{queue} \quad (9)$$

where transmission delay d_{trans} determines the duration from when first bit leaving the source and final bit arriving to BS,

$$d_{trans} = \frac{nbits}{bbits/sec} \quad (10)$$

Propagation delay d_{propa} calculates the essential time period for a bit to move from source to BS,

$$d_{propa} = \frac{dmeters}{smeters/sec} \quad (11)$$

Computation time is the time used to decide upcoming hop sensor to forward data packet. Queuing time is referred as the latency time acquired by all middle sensors to capture data packet in prior to compute the received data. The delay of a path D_{link_j} is measured as the delay incurred at every middle sensor which is computed as given in the following

$$D_{path_i} = \sum_{j=1}^{hop_i} D_{link_j} \quad (12)$$

Thus, the delay objective function, f_D ensures that the path latency on desired single path is lower, so that$D_{path} \leq D_{req}$, where D_{req} denotes a domain-specific threshold measure that mimics the essential single path delay to transmit data. In case of multipath routing, total ETE delay D_{e2e} is estimated according to count of paths applied that is presented as given as follows:

$$D_{e2e} = \sum_{i=1}^{np} D_{path_i} \quad (13)$$

4.Proposed QoS aware CBR (QoSCR) technique

4.1. Overall process

The overall working principle of QoS-CR model is depicted clearly in Fig. 2. As shown in figure, the proposed model operates on three main stages. Once the nodes are deployed and initialized, the FBCprocess gets executed to organize the nodes into clusters and performs CH selection. Then, FF-L algorithm is employed to discover the optimal paths between sources to destination. Finally, maintenance phase is invoked to steadiness the load and energy consumption evenly throughout the network.

4.2. Fuzzy based clustering (FBC) technique

The entire process of FBC technique is depicted in Algorithm 1. When the nodes are placed in the sensing region, BS advertises a beacon signal to overall system. Each node receives a beacon signal and estimate the corresponding distance to BS on the basis of received signal strength indicator (RSSI). Later, nodes transmit a handshaking message in a limited communication range to collect data regarding its own neighbouring nodes. The handshaking message involves node ID, qualified link, residual energy as well as distance to BS. For example, if an adjacent node j obtains a handshaking message from node i, it saves the obtained information and response to the corresponding node i. Then, node$i$would increments its node degree by 1 and estimates the distance to node j under the application of node$j$'s distance to sink and records the details of node$j$. Likewise, node$i$ receives data from each nearby node, and then node degree and distance to neighboring nodes are measured. By applying this strategy, all nodes collect data regarding its adjacent nodes and expand corresponding details. Then, the clustering process would be initialized.

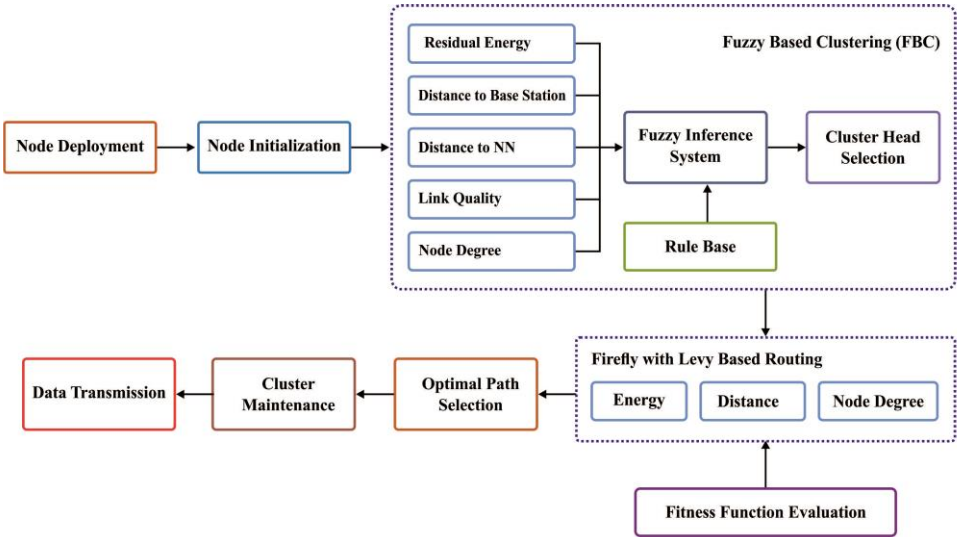


Fig. 2. Overall working principle of QoS-CR model

Fuzzification of input variable

Some of the input metrics of FBC are residual energy (RE), distance to BS (DBS), distance to its neighbor (DNN), node degree (ND) and link quality (LQ). First, actual inputs have been provided to fuzzy logic (FL) system and match them with applicable linguistic variables. Fig. 3 offers the linguistic parameter of input as well as output attributes.

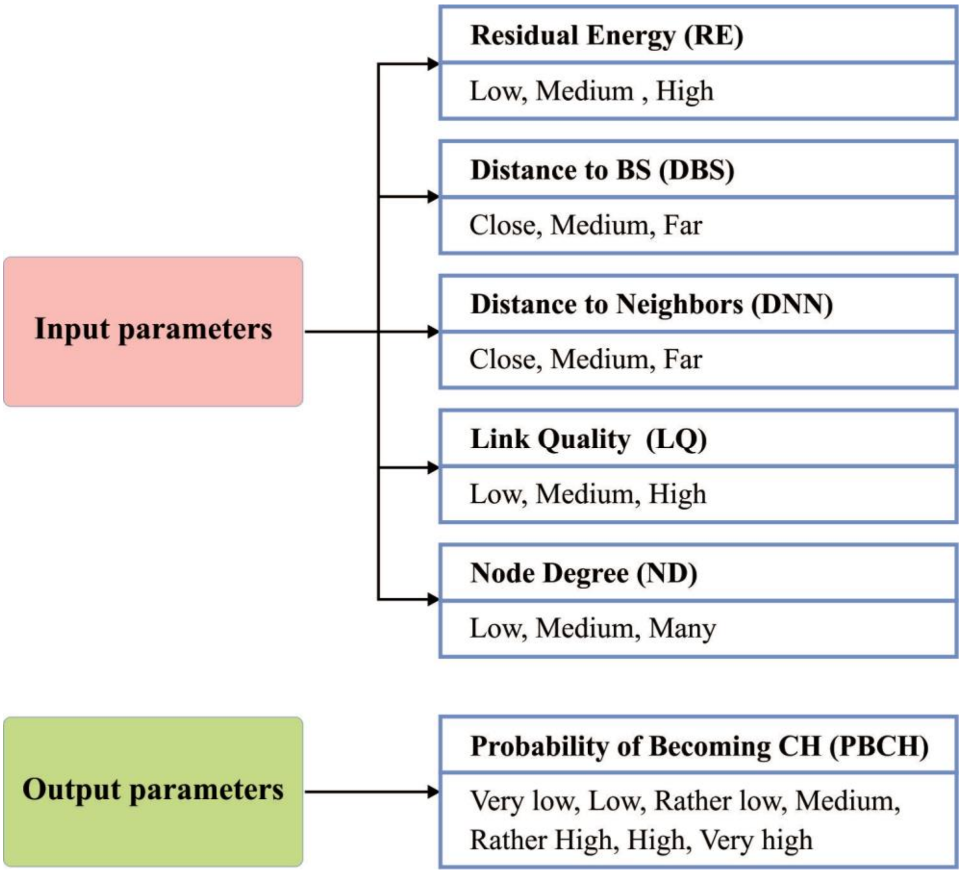


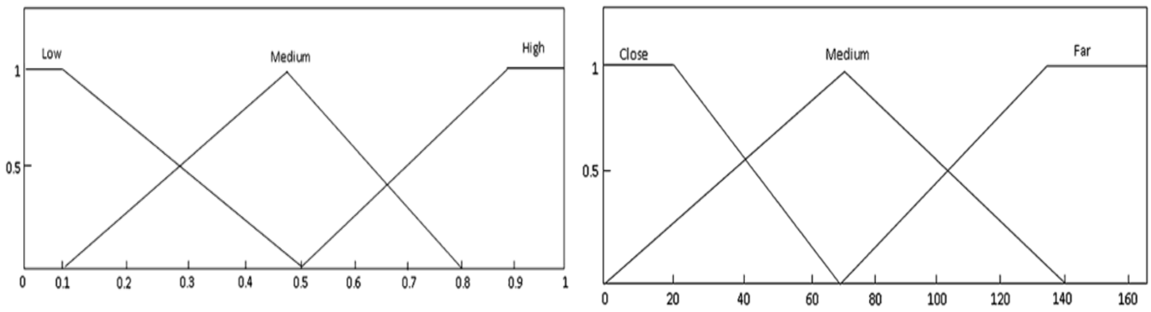
Fig. 3. Parameters and their possible values

Membership Functions (MF)

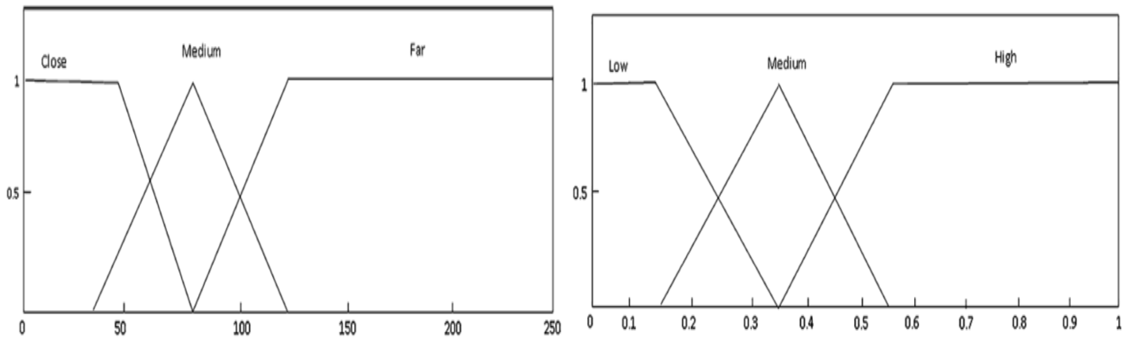
Here, the MF of input and output variables is shown in Figs.4(a)-(f). A trapezoidal MF has been applied for boundary variables while triangular MF can be employed for intermediate features. Both triangular as well as trapezoidal MFs are presented in Eqs. (14) and (15).

$$\mu_{P1}(u) = \begin{cases} 0 & u \leq \alpha 1 \\ \dfrac{u-\alpha 1}{\beta 1-\alpha 1} & \alpha 1 \leq u \leq \beta 1 \\ \dfrac{\gamma 1-u}{\gamma 1-\beta 1} & \beta 1 \leq u \leq \gamma 1 \\ 0 & \gamma 1 \leq u \end{cases} \tag{14}$$

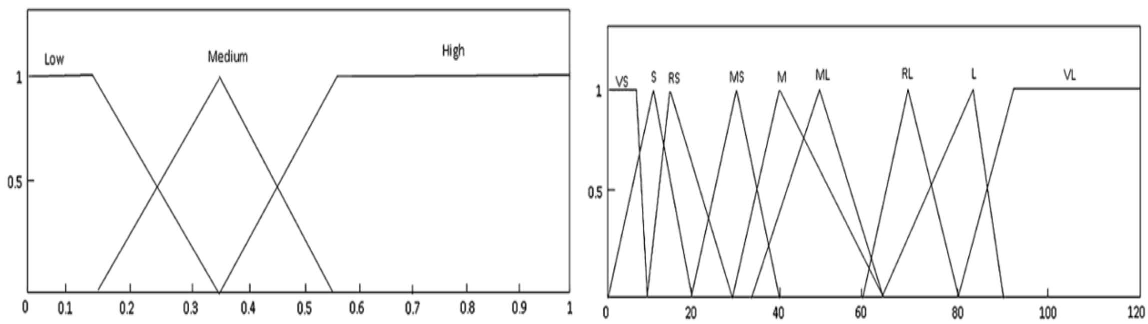
$$\mu_{P1}(u) = \begin{cases} 0 & u \leq \alpha 1 \\ \dfrac{u-\alpha 2}{\beta 2-\alpha 2} & \alpha 2 \leq u \leq \beta 2 \\ 1 & \beta 2 \leq u \leq \gamma 2 \\ \dfrac{\delta 2-u}{\delta 2-\gamma 2} & \gamma 2 \leq u \leq \delta 2 \\ 0 & \delta 2 \leq u \end{cases} \tag{15}$$



(a) RE (b) DBS



(c) DNN (d) ND



(e) LR (f) PBCH

Fig. 4. MF (a) RE, (b) DBS, (c) DNN, (d) ND, (e) LR, (f) PBCH

Table 1 Fuzzy rule base table

Rules	Input variable					Output variable
	Residual Energy	Node Degree	Distance to BS	Distance to its Neighbors	Link Quality	Probability of Becoming CH
1	Low	Few	Far	Far	Low	Low
2	Low	Few	Far	Far	Low	Very low
3	Low	Few	Far	Far	Low	Very low
20	Low	Few	Near	Near	Low	Low
28	Low	Medium	Far	Far	Low	Rather low
57	Low	Many	Far	Far	Low	Low
61	Low	Many	Far	Far	Low	Rather low
63	Low	Many	Far	Far	Low	Very low
82	Middle	Few	Far	Far	Middle	Medium
109	Middle	Medium	Far	Far	Middle	Rather high
127	Middle	Medium	Near	Near	Middle	Rather low
136	Middle	Many	Far	Far	Middle	Rather high
190	High	Medium	Far	Far	High	High
217	High	Medium	Far	Far	High	Very high
218	High	Many	Far	Far	High	Rather high
219	High	Many	Far	Far	High	Medium
223	High	Medium	Far	Far	High	Rather high
224	High	Many	Far	Far	High	Medium
225	High	Many	Far	Far	High	Rather low
226	High	Medium	Medium	Medium	High	Very high
227	High	Many	Medium	Medium	High	High
228	High	Many	Medium	Medium	High	Rather high
232	High	Medium	Medium	Medium	High	Medium
233	High	Many	Medium	Medium	High	Medium
234	High	Many	Medium	Medium	High	Medium
238	High	Medium	Near	Near	High	High
239	High	Many	Near	Near	High	Rather high
240	High	Many	Near	Near	High	Medium
241	High	Medium	Near	Near	High	Rather high
242	High	Many	Near	Near	High	Medium
243	High	Many	Near	Near	high	Medium

Fuzzy decision blocks/ Rule base

The rule base table is composed with the count of input and output attributes with respect to linguistic parameters. These variables are associated with the application of a group of if *then*-rules. Such rules are determined through inference engine. The fuzzy rule base table is provided in Table 1. For example, a piece of *if-then* condition is projected in Eq. (16). If 5 inputs are $P_1^i AND P_2^i AND\ \ P_3^i AND\ P_4^i\ AND\ P_5^i$ give, then simulation outcome would be Q_1^i and Q_2^i.

$$Rule(i) IF u_1 is P_1^i AND u_2 is P_2^i AND u_3 is P_3^i \qquad (16)$$

$$AND u_4 is P_4^i AND u_5 is P_5^i THEN v_1 is Q_1^i\ AND v_2 is Q_2^i$$

where 'i' is i^{th} rule from rule base table, $P_1, P_2, \ldots, P_5$ are fuzzy set of $u_1, u_2, \ldots, u_5$. As five input variables were applied, the total value of rules might be 243. The resultant value has been created by easy as well as efficient Mamdami inference system.

Defuzzification

Centroid of Area (COA) model has been employed for defuzzification task which is implied in Eq. (17). The main aim of this module is to convert fuzzified output parameters to accurate value by representing a chance of becoming a CH and to select the cluster size.

$$COA = \frac{\int \mu_P(u).udu}{\int \mu_P(u).du} \quad (17)$$

After the computation of PBCH, every singly node forwards CH_C_MSG to alternate nodes within the communication range. This message contains node ID and measure of PBCH. Any node with maximum probability has been selected as CH and forwards CH_W to the adjacent nodes. A node may receive many CH_W from neighboring nodes. At this point, it transmits CH_J message and combine with closer CH.

Algorithm 1: FBC Algorithm

```
n= Node count
i = a sensor node
i.State = provisional CH
it= indicator of current node
for k=1:N
            • k.RE     = RE
            • k.ND    = ND
            • k.DBS  = DBS
            • k.DNN  = DNN
            •k.LQ      = LQ
            • PBCH = calculateFuzzy(k.RE, k.ND, k.DBS, k.DNN, k. LQ)
end
for k=1:n
    Transmit CH_C to every r adjacent node
    x=directory of every CH_C from adjacent node
   if (it. PBCH > PBCH (x))
            broadcast CH_W
            it.State= Final CH
  else
            transmit CM_JOIN to closest CH
  end
end
FCH=listing CH
FCM=listing CMs
if count (FCH)i<  Sizei
             FCH sends CM_A
else
             FCH sends CM_A
 end
for w= 1:size(FCM)
   if
WhenCM_A receives
   Join CH which has CH_W
w.State=Member Node
   else
   Announces itself as CH
w.state=Final CH
```

```
  end
end
```

Upon receiving CH_J message, the nearby CH assures the recent cluster size in prior to accept novel members. Since the overall number of current cluster members are not more than estimated cluster size, it agrees a fresh cluster member by sending CM_A message, else, it would forward CH_R message.

If a gets a CM_R message, it again transmits a CM_J message to consecutive CH by leaving the currently removed CH and this strategy is repeated till it integrates with novel CH. In few scenarios, if nodes do not combine with other CH which is present within the coverage region 'R', it assigns itself as CH. Consequently, each node comes under the cluster, where there is no presence of isolated nodes in WSN. In order to eliminate primary death of CHs, CHs rotation task is carried out. If RE of CH attains a threshold value, CH rotation occurs in the basis of PBCH. As a result, it removes the premature death of CH and result in an improved network lifespan. These processes will be clearly explained in maintenance stage.

4.3. FF-L based Routing technique

FF algorithm is assumed to be a novel approach to optimize the associated problems. It mainly depends upon the FF flashes and brightness. The patterns generated by FF flashes are exclusive which is based on specific species. There are 2 major functions involved in FF algorithm, namely attracting matting partners and preys. Initially, the attracting matting phase contributes a female to response to a male by different procedure with similar species. Hence, light expended by FFs are inversely proportional to distance which refers that distance from 2 FFs gets improved that results in decreased light intensity. Here, FF technique is mainly applied to resolve the routing issue exist in WSN. The processes involved in the routing process are provided in Algorithm II.

In FF module, a capable solution is presented by a FF as well as count of fireflies with respect to number of solution(N_t). All FFs $F_i, \forall_i 1 \leq i \leq N_f$ consist of a position $X_{i,d,} \forall_d 1 \leq d \leq$ D. The proportion of all FFs can be denoted as D. To enhance the solution, minimum luminous FF moves in the direction of most illuminated FF as demonstrated in Eq. (18). Similar process is followed periodically till an acquired result is obtained.

$$x_i = x_i + \beta_o e^{-yr_{i,j}^2}(x_j - x_i) + a\left(rand - \frac{1}{2}\right) \quad (18)$$

Where $\alpha \in (0,1)$ and β are considered to be randomized variables, *rand* is a random value, x_i implies the location of i^{th} firefly and x_j signifies the place of jth FF.

The FF make use of a search space efficiently as it is performs in every dimension of search space. The parameters in the solution are subjected to modify with respect to efficiency. But, at the time of exploration, FF technique applies an arbitrary initialization that tends to reduce the alteration from recently exploited process. If exploration has minimum value than exploitation, then this model gets trapped into local optima.

Reporting the shortcomings mentioned above, a FF-Levy model is presented in this work to find the provided search space with the help of effective arithmetic distribution function. Thus, Levy Distribution is defined as a mathematical method applied to initialize immediate drift. It is also considered as a random walk which helps to improve the length of searching task along with immediate deterioration. This model could be defined as follows.

$$Levy(\beta) \sim t^{-1-\beta}, 0 < \beta < 2 \quad (23)$$

where t is a arbitrary parameter with limited interval [0, 1], and β denotes the reliability index. Some of the numerical techniques like Gaussian as well as Cauchy distributions are assumed to be more important while β is assigned with 2 and 1 correspondingly. At the time of implementing Levy Distribution in a search space, mathematical approach is refined in the form of

$$Levy\ (\beta) = \frac{u \times \emptyset}{|v|^{\frac{1}{\beta}}} \quad (24)$$

where$u$ and v implies normal distribution measures, β represents levy exponent and $\emptyset$ is signified as

$$\emptyset = \left[\frac{\Gamma(1+\beta) \times \sin\left(\frac{\pi\beta}{2}\right)}{\Gamma\left(\frac{(1+\beta)}{2}\right) \times \beta \times 2^{\left(\frac{\beta-1}{2}\right)}}\right]^{\frac{1}{\beta}} \quad (25)$$

where βvalue could be assigned with 1.5, u and v are considered to be a random measure along with a mean of 0 and standard deviation (SD) of 1 acquired from normal distribution. In FF-L technique, once the processing variables are computed, there is an enhancement for all individuals and an arbitrary individual might be originated in the following

$$X_i = \begin{cases} X_{lb} + \alpha \times Levy(\beta) \times (X_j - X_k) & if r_l() < r_2() \\ X_{ub} - \alpha \times Levy(\beta) \times (X_j - X_k) & otherwise \end{cases} \quad (26)$$

where $r()$ is a random variable, X_j, X_k are named as 2 arbitrary individuals.

The main objective of FF-L is to explore new route from CH to sink. To identify a novel path, FF-L technique applied as crisp FF that is comprised with RE, DBS as well as ND.

Initialization phase

In this mechanism, every FF denotes an applicable solution to the given problem. In case of routing, all FFs indicate data forwarding route from CH to BS. The importance of every FF is same as overall CH present in the system, and an additional location has been included for BS. The quality of FF is similar to $m+1$, where m implies the count of CH exist in network and 1 for BS.

Let, $F_i = \left(F_{i,l}(t), F_{i,2}(t) \ldots F_{i,m+1}(t)\right)$ be i^{th} FF, and all locations $F_{i,d}, \forall_i 1 \leq i \leq \mathrm{m}+1, \forall_d 1 \leq d \leq \mathrm{m}+1$, denotes next-hop to forward data to sink.

Derivation of FF

This system mainly focuses on selecting optimized route from every CH to BS. In order to attain this function, FF has been used by different sub objectives like RE, Euclidean distance and ND.

RE of subsequent hop: In case of packet delivery, next hop performs reception of data and assembles them to forward to BS. Hence, Maximum residual power next-hop is preferred mostly. Thus, the initial sub objective with respect to RE$f1$ is improved as

$$f1 = \sum_{i=1}^{m} E_{CHi} \tag{19}$$

Euclidean Distance: It is defined as the distance among CH to subsequent hop and from corresponding BS. When it has lower distance, then it consumes minimum power. The second aim is to decrease the distance from CHsto BS. This results in maximized network lifetime. Thus, second sub objective corresponding to distance is $f2$ increased as

$$f2 = \frac{1}{\sum_{i=1}^{m} \mathrm{dis}(\mathrm{CH_i}, \mathrm{NH}) + \mathrm{dis}(\mathrm{NH}, \mathrm{BS})} \tag{20}$$

ND: It refers the count of CH member that contains next-hop. When next-hop is composed of reduced CH members, it consumes only minimum energy while obtaining data from its own members and stay alive for prolonged time. However, next-hop with less node degree is selected often. As, third sub objective is by means of node degree is $f3$ expanded as

$$f3 = \frac{1}{\Sigma_{i=1}^{m} \mathrm{I}_i} \tag{21}$$

Afterwards, weighted sum model has been employed to every sub objectives and transformed as individual objective as illustrated in Eq. (22). Where α_1, α_2 and $\alpha_3$are assumed to weights declared for all sub objectives, and $\alpha_i \varepsilon (0,1)$ as well as $\alpha_1 + \alpha_2 + \alpha_3 = 1$.

$$Fitness = \alpha_1(f1) + \alpha_2(f2) + \alpha_3(f3) \tag{22}$$

Algorithm II: FF-L based Routing

Steps to find out near optimal route [h]
Initialization of FFs $F_i, \forall_i 1 \le i \le N_f$
Determine Intensity of every FF
while$i = N_f$
        $\mathrm{I_i} = \mathrm{Fitess}(\mathrm{F_i})$
end
$\mathrm{T}! = Max.rounds$ do
Movement of FFs with respect to intensity
while $i! = N_f$
while $j! = N_f$
if$(I_j > \mathrm{I_i})$then
for $k \leftarrow 1$ to m
        Movement of FF $I_{i,k}$ to $I_{j,k}$
        Determine new solution and updates intensity
end for
end
end
end
Sort the existing FFs and determine the optimal one
Determine Next-Hop$(CH_i), \forall_i 1 \le i \le \mathrm{m} + 1$, (i.e., route$\zeta$) by max (fitness (F_i)).

Distance and Movement

For all rounds, less illuminated FF moves toward a maximum brightened FF whereas the location of all FFs are known in advance with the help of Eq. (18). In mathematical estimation, when a novel extended location might not satisfy the range such that, either it may be negative or more than$m+1$. At this point, location might be interchanged by arbitrary value produced among 1 and$m+1$. Thus, every above mentioned computation is followed regularly till maximum iteration value is attained.

4.4. Maintenance process

Maintenance process is assumed to be a more significant process to manage the overhead of clusters. After certain rounds of operation, clusters present nearby BS are burdened with massive inter-cluster traffic and exhaust the energy in a rapid manner. Thus, a cluster maintenance process is required for equal load distribution and improves network lifespan. In this presented technique, maintenance phase is operated on 2 stages: CH rotation from cluster and crosslevel communication.

Initially, CH rotation is carried out while remaining energy of CH falls below threshold value of 15%. Alternatively, if residual energy is more than threshold value, novel CH would be selected according to the chance of becoming CH. In order to obtain equal load distribution and make every CHs to acquire minimum energy, cross-level data transmission has been employed. While 15% of nodes are facilitated as CHs in a cluster, then BS should be known that lower number of nodes cannot be assigned as CH. Then, BS forwards a message to upcoming CHs to send data in straightforward manner as depicted in Fig. 5. This procedure is repeated for consecutive level CHs which are placed distant from BS. It leads in uniform power depletion as well as improve the lifespan of network respectively.

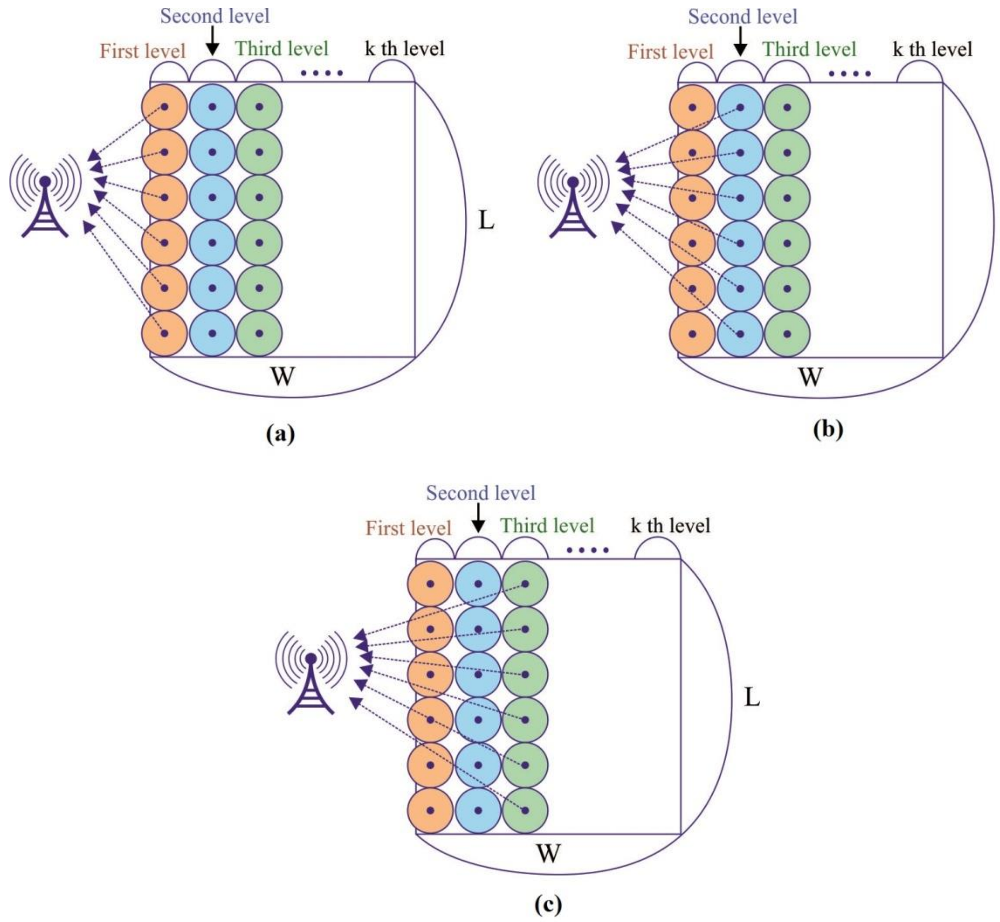


Fig. 5. Cluster maintenance

5. Performance Validation

5.1. Simulation setup

In this section, the performance of the QoS-CR model has been validated under several aspects. The proposed model is simulated using NS2.35 simulation. Networks of 50-250 nodes are deployed arbitrarily in a sensing region. The parameters involved in the simulation are provided in Table 2.

Table 2 Parameter Settings

Parameter	**Value**
Target region	300*200m^2
Data rate	250kbps
Max. node count	250
R	40m
Simulation period	500s
E_{elec}	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4
Packet size	4000 bits

5.2. Network lifetime analysis

The lifetime of a WSN is solely based on the number of alive nodes and their connectivity between them. Fig. 6 shows the network lifetime analysis of the QoS-CR model under varying number of sensor nodes. From the figure, it is evident that the EE-LEACH model attains minimum lifetime over all the compared methods. Next to that, slightly higher network lifetime is achieved by EPSO-CEO model. At the same time, the OQoS-CMRP model has offered even higher network lifetime over the compared methods, but not higher than the proposed QoS-CR model. The QoS-CR model achieves maximum network lifetime under varying number of nodes. For instance, under the existence of 50nodes, the QoS-CR model stays upto 2.4x10^{4}s whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models reaches upto a minimum network lifetime of 2x10^{4}s, 2.1x10^{4}s and 2.31x10^{4}s respectively. Similarly, under the presence of 250 nodes, the QoS-CR model achieves a maximum network lifetime of 1.86x10^{4}s whereas the sensor nodes in EE-LEACH, EPSO-CEO and OQoS-CMRP models ended to a minimum lifetime of 1.26x10^{4}s, 15.x10^{4}s and 1.8x10^{4}s respectively. These values ensured that the QoS-CR model incurs maximum network lifetime over the compared methods.

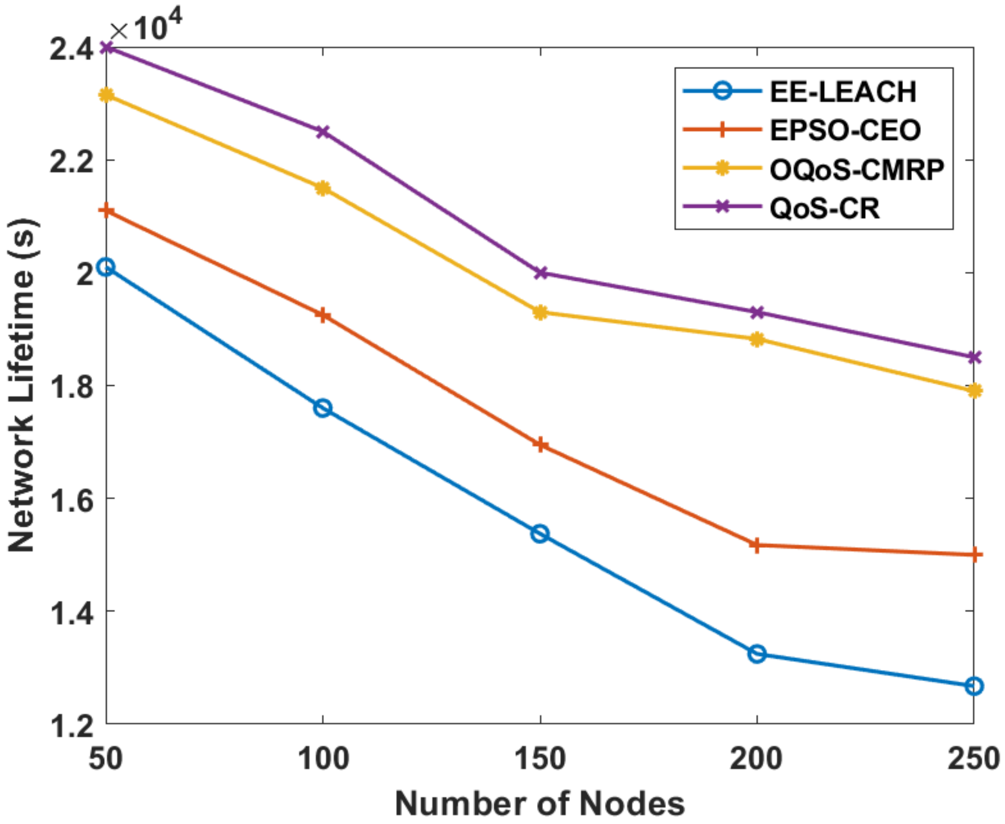


Fig. 6. Network lifetime analysis of QoS-CR model

5.2. Total energy consumption (TEC) analysis

The TEC of sensor nodes includes the energy spent for sensing, processing and transmission. The TEC of a cluster based routing protocol should be low to signify maximum energy efficiency. Fig. 7shows the TEC analysis of the QoS-CR model with the existing methods under diverse node count. The figure clearly portrayed that the EE-LEACH algorithm consumes maximum amount of energy over the compared methods. Along with that, the EPSO-CEO model requires slightly lesser amount of energy than EE-LEACH, but not than OQoS-CMRP and QoS-CR models. At the same time, it is exhibited that OQoS-CMRP model has tried to achieve minimum TEC under diverse node count. However, the proposed QoS-CR model has attained minimal TEC over the compared methods under varying node count. For instance, under the existence of 50 nodes, it is apparent that the QoS-CR model needs least TEC of 3J whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models requires higher TEC of 7.1J, 6.3J and 3.5J respectively. Likewise, in the presence of 250 nodes, it is apparent that the QoS-CR model needs least TEC of 10.7J whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models requires higher TEC of 17.1J, 16.3J and 11.5J respectively. These values clearly pointed out the QoS-CR consumes only a minimum amount of energy for all operations takes place in the network.

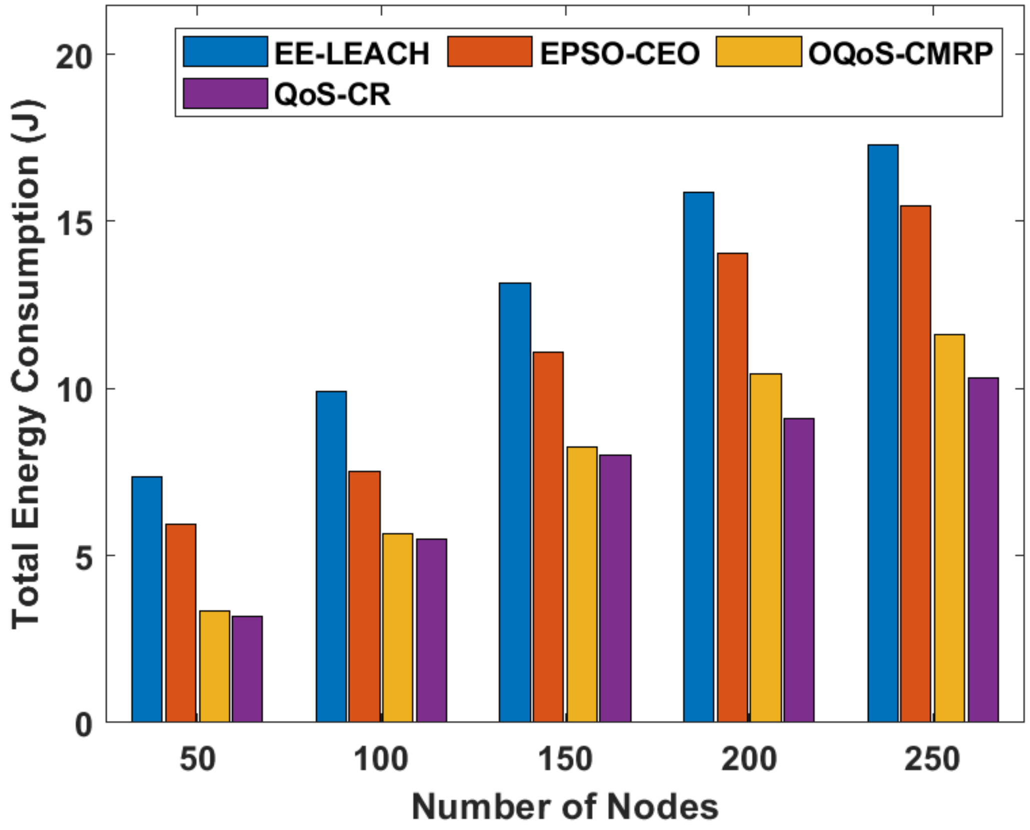


Fig. 7. TEC analysis of QoS-CR model

5.3. Throughput analysis

It can be represented as the total number of packets reached at the destination over a time period. Fig. 8 shows the results analysis of QoS-MR with over models interms of throughput. The maximum value of throughput implies effective routing performance. The figure clearly stated that EPSO-CEO model obtains lowest throughput compared to existing methods. The EE-LEACH offers slightly higher throughput over the EPSO-CEO model. In the same way, the OQoS-CMRP model has provides considerably higher throughput over the compared methods, but not superior to QoS-CR model. The QoS-CR model provides maximum throughput under varying number of nodes. For instance, in the presence of of 50nodes, the QoS-CR model achieves a maximum throughput of 52kbps whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models reaches upto a minimum throughput of 41kbps, 37kbps and 47kbps respectively. Similarly, under the presence of 250 nodes, the QoS-CR model achieves a maximum throughput of 64.5kbps whereas the sensor nodes in EE-LEACH, EPSO-CEO and OQoS-CMRP models leads to a minimum throughput of 55kbps, 52kbps and 63kbps, respectively. These values ensured that the QoS-CR model has provided maximum throughput over the compared methods.

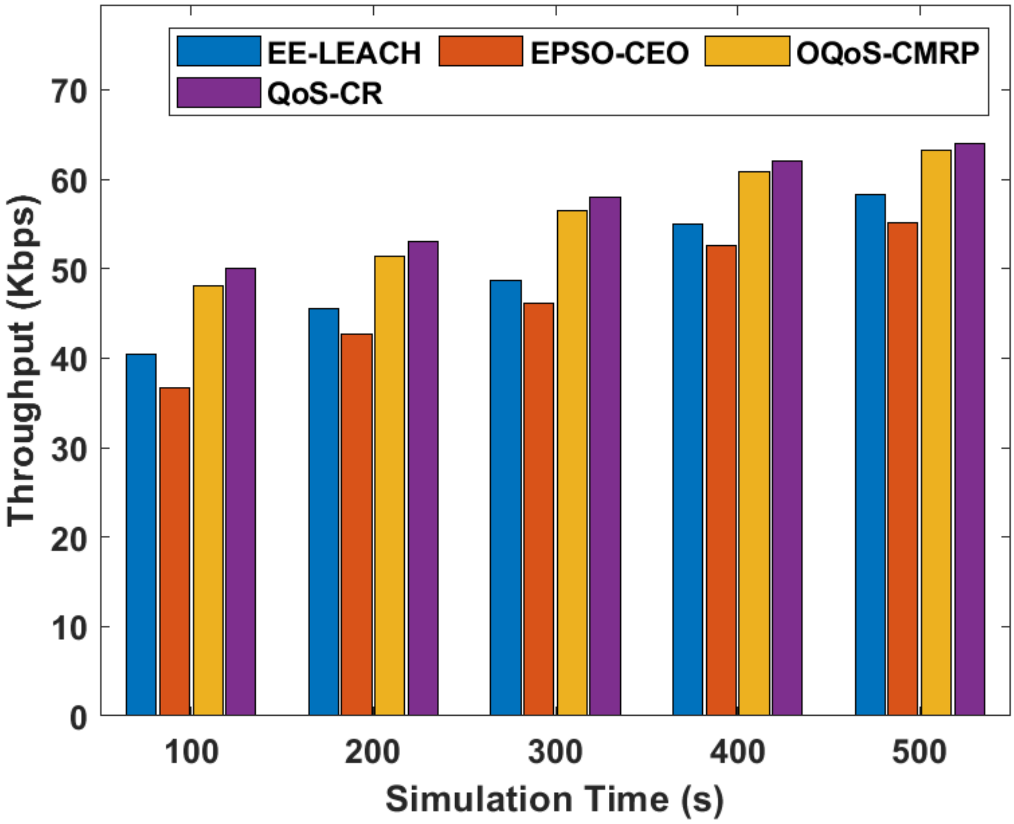


Fig. 8. Throughput analysis of QoS-CR model

5.4. Normalized Overhead analysis

It can be represented as the total number of control packets normalized by the total number of received data packets. Fig. 9 shows the outcome of the normalized overhead under the presence of diverse nodes. It is believed that an increase in number of nodes leads to an increase in overhead. The figure also confirmed that the overhead gets increased with an increase in number of nodes. It is shown that the EE-LEACH and EPSO-CEO models has incurred maximum overhead over all the existing methods. Simultaneously, the OQoS-CMRP faces slightly lower overhead compared to earlier models. However, the proposed QoS-CR model has achieved least overhead under all the cases.

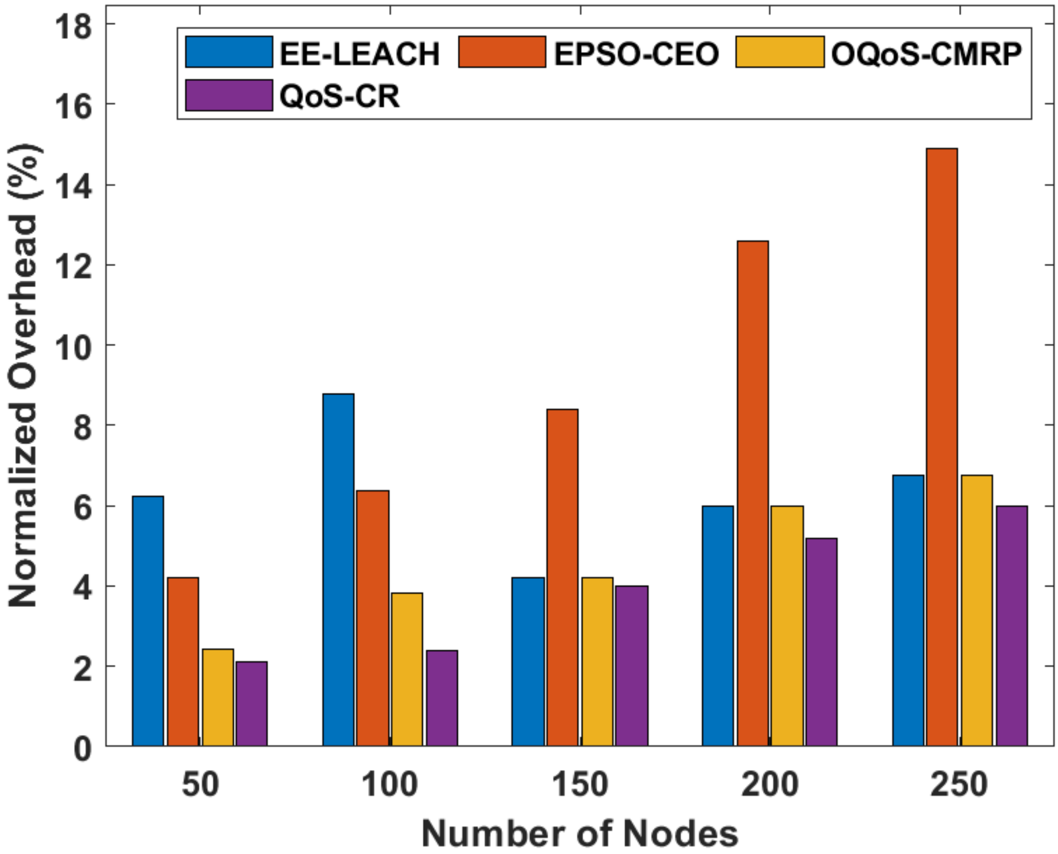


Fig. 9. Normalized overhead analysis of QoS-CR model

For instance, in case of 50 nodes, it is apparent that the QoS-CR model attains minimal overhead of 2% whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models has maximum overhead of 6.5%, 4% and 3.5% respectively. Equally, in case of a maximum of 250 nodes, it is obvious that the QoS-CR model obtains a minimum overhead of 5.9% whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models require maximum overhead of 6.5%, 15.2% and 6.5% respectively. These values evidently pointed out the QoS-CR does not incur maximum overhead like the existing methods.

5.5. Average Delay analysis

ETE delay represents the total amount of time taken by a packet to be communication in a network from transmitting node to destination. It includes different kinds of delay namely communication delay, queuing delay, processing delay, etc. It is used to represent the robust characteristic of the routing technique. Fig. 10 shows the ETE analysis of diverse models under varying simulation time.

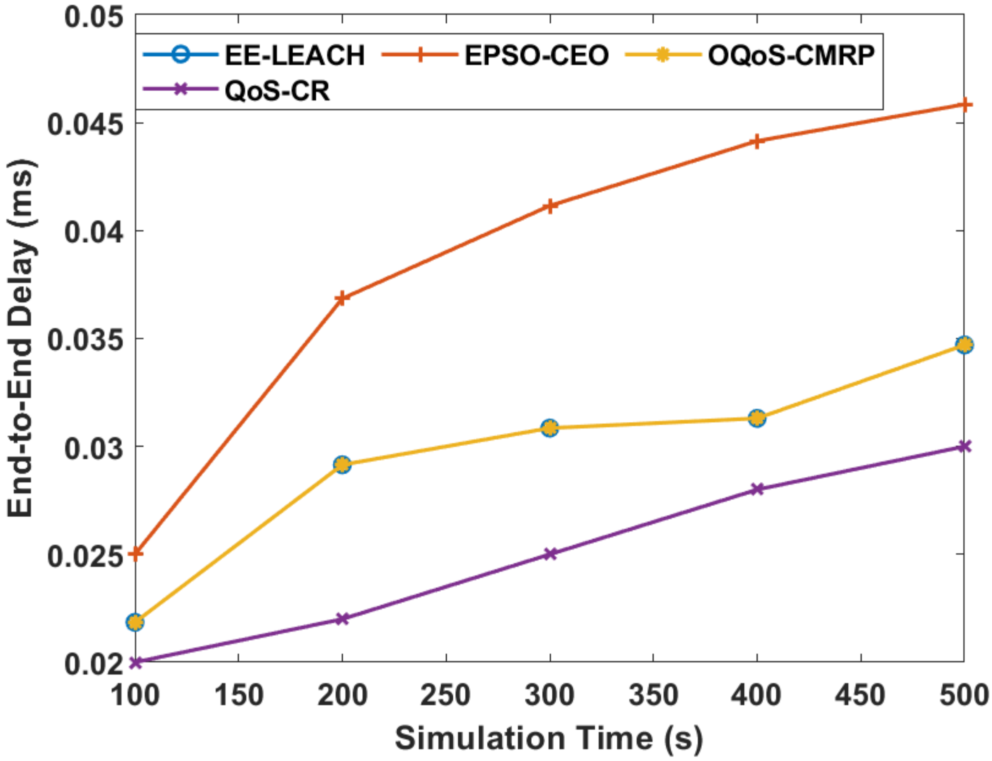


Fig.10.ETE delay analysis of QoS-CR model

The figure evidently depicts that the proposed QoS-CR model requires minimum ETE delay over the compared methods. It is also interesting that the EE-LEACH and OQoS-CMRP models have incurred moderate and identical ETE delay whereas a maximum ETE delay is obtained by EPSO-CEO model. For instance, under the simulation time of 100s, it is apparent that the QoS-CR model attains minimal ETE delay of 0.02s whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models has maximum ETE delay of 0.022s, 0.022s and 0.025s respectively.Equally, in case of a maximum of 500 nodes, it is obvious that the QoS-CR model obtains a minimum ETE delay of 0.03s whereas the EE-LEACH, EPSO-CEO and OQoS-CMRP models requires maximum overhead of 0.035s, 0.035s and 0.046s respectively. These values evidently pointed out the QoS-CR model do not incur maximum ETE delay similar to the existing methods. By looking into the above mentioned figures and results analysis, it is apparent that the QoS-CR model satisfies the QoS requirement of energy efficiency and delay. It is also evident that the QoS-CR model is effective over the compared methods under several aspects such as TEC, ETE delay, overhead, throughput and especially network lifetime. Therefore, it can be employed as an effective cluster based routing protocol to achieve QoS in real time WSN.

6. Conclusion

This paper has presented as effective QoS aware cluster based routing protocol, named as QoS-CR to construct optimum paths to transmit data under the QoS constrained scenario. The proposed model operates on three main stages. Once the nodes are deployed and initialized, the FBCprocess gets executed to organize the nodes into clusters and performs CH selection. Then, FF-L algorithm is employed to discover the optimal paths between sources to destination. Finally, the maintenance phase is invoked to steadiness the load and energy consumption evenly throughout the network.The proposed model is simulated using NS2.35 simulation. Networks of 50-250 nodes are deployed arbitrarily in a sensing region.The performance of the QoS-CR model has been validated under varying node count and simulation time. The comprehensive experimental validation pointed out that the QoS-CR model has attained maximum network lifetime and throughput with minimal TEC, ETE delay and overhead. The detailed empirical analysis ensured the superior performance of the QoS-CR model under all the applied scenarios. In future, the performance of the proposed model can be enhanced by the use of fault tolerant routing, meta-heuristic and cryptographic techniques.

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