IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

NQF – IPSO – A node quality factor based CH selection & Improved PSO for efficient relay selection

S Anuradha

Research Scholar,ECE

JNTUHCEH ,Hyderabad,

India

Dr . D.Sreenivasa rao

Professor ,

ECE JNTUH Hyderabad

India

Abstract

The sensor node lifetime plays a key role in a wireless sensor network and it relies on the battery life. After deploying the batteries in an unattended or remote area, their replacement is very difficult. To overcome this issue, a lot of research had performed, but they are suffering from one or other way. Energy efficiency is improved by clustering technique. The efficient and stable CH selection is an important task in clustered network. The CHs failure can collapse the entire data aggregation of the network. Energy efficient relay selection for data aggregation plays an important role in controlling energy consumption during data aggregation. There are a plenty of energy efficient routing protocols exists in this cause. But most of them considers node residual energy as the primary parameter for relay selection and failed to consider other prominent parameters for relay selection which can affect the sensor node lifetime. To address the CH failure issue and to select the stable CHs, in this paper we introduce Node Quality factor algorithm to estimate and rank the nodes based on their selection quality. This method considers the channel quality of the relay-destination link, distance between the nodes and the residual energy as selection parameters. An improved Particle Swarm Optimization Algorithm is introduced for selecting the energy efficient relay nodes. The improved Particle Swarm Optimization Algorithm takes into account node residual energy, node distance to CH, average energy, node degree, and ECR for calculating the fitness function. The simulation results proves that the proposed NQA-IPSO method outperforms the previously proposed energy efficient techniques in network lifetime, data delivery rate, and energy consumption.

Keywords: WSN, Clustering, PSO, Data aggregation, Relay selection, NQA-IPSO.

I. Introduction

A wide range of small and lower energy sensor nodes contain in WSNs and they are distributed randomly or manually in a target region or area. The communication component, sensing unit, data aggregation unit, and an energy unit contain in the sensor node. To process within a target region or area, Global Positioning System (GPS) may include for every sensor node [1]. WSNs are having numerous applications in variety fields, such as environmental monitoring, healthcare, disaster warning systems, safety systems, including intruder detection, surveillance, defence reconnaissance, etc. For data collection from the environment and establish the inferences about the monitored objects, the sensor networks have been used. Because of bandwidth and power constraints, the limited capabilities of communication characterize the sensor nodes. However, WSNs have a challenging task as the minimization of network energy consumption [2].

Sensor nodes in the cluster-based WSNs categorize into various groups known as clusters [3], each of which includes a cluster head (CH). From nearby sensor nodes, the data is collected by CHs and it forwards to the BS directly through the other CHs. By comparing with other sensor nodes, more workload involves in CHs in the cluster-based WSNs [4]. In WSNs, high energy-level devices have deployed as CHs by assessing various researches. The below figure shows the data transmission process of clustered WSNs.

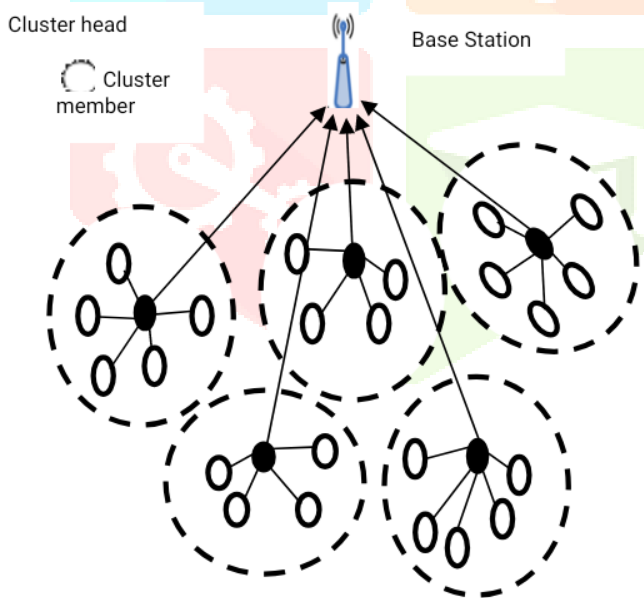

Fig 1: clustered WSN

In addition to the handling of data, CHs require to do other work is that collecting data from sensor nodes within the respective cluster in a clustered WSNs [5]. In the respective cluster, data fusion is used by CHs for detecting the unwanted and duplicate data that is sent by sensor nodes. The battery power is used to operate these CHs. It's required to improve an algorithm for reducing power consumption and improving the network lifetime [6]. Usually, sensor nodes of a network operate with lower powered batteries and a better way is needed for using its battery power efficiently. Based on the devices availability and network structure, the data may send by CHs to another CH or to BS directly. The more CH power improves the capability of data processing. The dependent devices of a network may get effect when any CH is failed owing to the lack of energy. For sending data, this intermediate node is used by the nodes and need to searching for other alternative nodes if a failure of intermediate node is occurred. More load is caused on newly detected alternative nodes. An efficient relay selection between sensor nodes is used to overcome this problem [7].

From each cluster, data is transmitted to their respective cluster head nodes in the routing algorithm of clustering WSNs. The cluster head can act as both a backbone router and an aggregator. It consumes higher energy comparative to the other remaining nodes in a cluster due to the sending of data to the CH node through the multiple or single hops. An imbalance of network energy is resulted due to the undesirable amount of energy conservation. When data route to a non-optimal path, energy consumption will increase. To address all these issues, in this paper we introduce Node Quality factor (NQF) algorithm to estimate and rank the nodes based on their selection quality. This method considers the channel quality of the relay-destination link and the residual energy as selection parameters. An improved Particle Swarm Optimization (IPSO) Algorithm is introduced for selecting the energy efficient relay nodes. The improved Particle Swarm Optimization Algorithm takes into account node residual energy, node distance to CH, average energy, node degree, and ECR for estimation of fitness.

Our contributions

- A node quality factor calculating algorithm is introduced to select the CHs to address the CH failure issue. This method considers the channel quality of the relay-destination link, distance between the nodes and the residual energy as the selection parameters.

- The IPSO is used for selecting the relays in the WSN due to its high stability and less computational complexity. In this study, IPSO node residual energy, node distance to CH, node degree, average energy and energy consumption rate (ECR) for fitness calculation.
- The network lifetime is increased because of the energy efficient CH selection and optimal relay selection for data transmission.
- In addition, more number of data packets are transmitted with less energy consumption while transmitting the data packets.

II. Literature survey

Samaleswari Pr. Nayak et al., (2017) [8] considers a proposed sink mobility assisted algorithm for decreasing the total number of hop counts to the destination and minimizing power consumption of battery. A stable and better accuracy cluster is provided by the proposed algorithm than the existing models like EEZECR and EASR. Because of the effective movement of sink, routing path length has reduced that ensures faster data gathering.

A.Muthu Krishnan and P. Ganesh kumar et al., (2015) [9] has proposed data gathering technique using clustering architecture and TDMA for achieving energy-efficiency. The proposed algorithm evaluation is performed based on network lifetime, number of received data packets, and residual energy. It achieves prolonged network lifetime and minimized power consumption than the existing methods.

Jin Wang et al., (2017) [10] proposes an energy-efficient cluster-based dynamic routes adjustment approach for mobile sinks in WSNs. Based on the selection of optimal routes, the network lifetime prolongs by alleviating the hot-spot issue. The sensor network lifetime improves by using the proposed approach.

Muralitharan Krishnan et al., (2018) [11] proposes an efficient path selection algorithm for mobile sink using ACO. Due to the dynamic cluster head selection in each round, the cluster head selection algorithm implements based on the load-balancing technique. The overall sensor network lifetime enhances based on ACO routing with mobile sink that ensures maximum operability.

Kambiz Koosheshi and Saeed Ebadi et al., (2018) [12] has proposed an unequal clustering technique based on fuzzy logic to reduce the distance among sensor nodes with respect to the movement towards sink. The energy hole issue eliminates by reducing the cluster size and choosing the optimal route. The optimized energy consumption of 19% is achieved by the proposed method for WSNs.

III. Proposed system

Preliminaries

Network model

- The sensor nodes are in heterogeneous nature in WSNs in terms of processing power and initial energy.
- Based on the Euclidean distance formula, the distance is estimated between sensors.
- In the sensing area, the random deployment of sensor nodes and the sensors' position is constant after deployment.
- The mobile sinks are moving in GRID mobility pattern in the network.

Energy model

The energy model is used to evaluate the consumption of energy for data reception and transmission and radio signals have utilized for communication between nodes in WSNs. In energy model, two different channels are included such as multi-path fading channel and free space channel. If the distance (d) is lower between sender and receiver compared to the threshold d_0, free space channel is utilized. If not, the multi-path fading channel uses. The required energy for sending an l-bit message over d is shown in below equation 1:

$$E_T\,(l,d) = \{l * E_{elec} + l * \epsilon_{fs} * d^2,\ \ d \le d_0\ l * E_{elec} + l * \epsilon_{mp} * d^4,\ \ d \ge d_0$$

Eq (1)

Where, $\in_{mp}$ refers to the required energy based on multi-path channel, $\in_{fs}$ refers to the required energy by the free space, Eelec indicates the required energy for electronic circuit, and d_0 is a threshold. For receiving l-bit of data, the required energy is given as equation 2:

$$E_R(l) = l * E_{elec} \quad \text{Eq (2)}$$

An electronic circuit (Eelec) consumes the energy using various factors such as modulation, filtering, digital coding, and signal spreading, etc. In multi-path $(\in_{mp} * d^4)$ or free space $(\in_{fs} * d^2)$, the amplifier energy consumption is relied on the bit error rate and distance between sender and receiver.

Proposed method

Two algorithms include in the proposed technique such as one algorithm is used for CH selection, and other algorithm is for routing over the network. For optimal sensors selection as CH, a node quality factor based algorithm uses and the optimal route between CH and sensor nodes is selected using an enhanced particle swarm optimization algorithm. Based on the generated path from IPSO, the collected data transmit to CH by sensor nodes.

Clustering and CH selection

Let's consider a network with N nodes, which are randomly distributed across the area S. The cluster radius has satisfied the coverage requirement by the cluster radius when network partitioned into k clusters as shows in equation 3:

$$r = \sqrt{\frac{\alpha S}{k\pi}} \quad \text{Eq (3)}$$

Where, α ≥ 1 is set as a constant for meeting the coverage requirement. Based on the minimum required coverage requirement, the nodes are clustered using unequal clustering method. Below equation represents the distance amongst each of sensor nodes to each of the cluster centres based on Euclidean distance shows in equation 4:

$$Dist_n = \sqrt[2]{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad \text{Eq (4)}$$

Where, x and y represent the nodes 'n' of coordinates on the search field.

CH selection using NQF algorithm

The calculation of node quality factor is considered while processing the CH election in the CH selection phase. In the proposed protocol, a node's rank decides based on three different parameters such as channel quality, distance between nodes, and node's residual energy. The energy consumption is effected by the distance among nodes and CH. The node importance is reflected by these factors and it deserved to elect as one of the CHs by serving as large number of nodes in a network.

NQF algorithm

Based on NQF or node quality factor algorithm, the CH election is processed. Each node is assigned with a rank by estimating the selection parameters. The proposed NQF algorithm takes into account residual energy for each node, channel quality, and distance between nodes for efficient CH selection and it represents in equation 5.

$$NQF_n = E_{res}(n) * \alpha * \Sigma_0^j \frac{\frac{1}{d_{ij}}}{\Sigma \quad CQ_{ntoNH_n}} + (1 - \alpha)$$

Eq (5)

Here, E_{res} denotes the residual energy of node n, d is the distance between the nodes, CQ is the channel quality and NH_n denotes the neighbour hops of node n and ◻ is the weighting coefficient between 0 to 1.

The selection parameters are explained follows:

Residual energy

The most essential resource of WSN is considered as the energy. Higher energy is consumed by the cluster heads than the cluster members while aggregating, processing, and routing of data. The below expression as equation 6 is used for estimating the residual energy.

$$E_{res} = E_{init} - E_{consumed} \quad \text{Eq (6)}$$

Where, E_{init} & $E_{consumed}$ are the initial energy & consumed energy of the sensor nodes respectively.

Channel quality

Typically, the time-variant and random nature of fading channel is involved in WSNs. The re-transmission of packets will occur after receiving the packets by the receiver. Additional energy consumption of sensor node is required for re-transmission. For controlling the re-transmission, the channel quality should be considered to achieve desired energy efficiency. The below equation 7 is used for computing the channel quality:

$$CQ_n = \frac{RT_n - RT_{min}}{RT_{max} - RT_{min}} \quad \text{Eq (7)}$$

Where, RTn indicates the total re-transmission number between the node and the neighbours, RTmin and RTmax are the minimum and maximum number of re-transmission from the neighbor nodes respectively.

The NQF calculation is repeated for every node in the cluster and the node which achieves the high quality factor value will be selected as CH for that particular cluster.

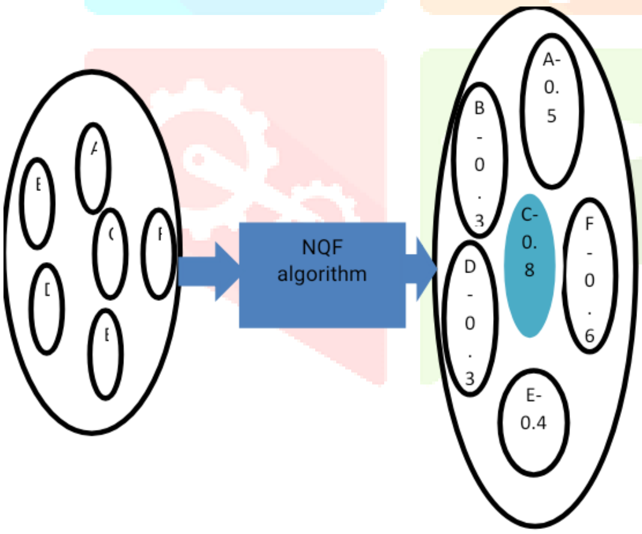

Fig 2: calculating Node quality factor

In the above example, node A, B, C, D, E & f forms a cluster. During CH selection phase, the NQF algorithm calculates the weight of all the nodes in the clusters using NQF equation. IN the above example, node C has more QF than the remaining nodes in the cluster. Which means, the node C has more residual energy, easily accessible to the remaining nodes due to the less distance and better channel quality. Based on CSMA MAC protocol, the node members informed by the node C through the small advertisement message. The acknowledgement message will reply by the remaining node and it informs the CH to be a CH member.

For managing the data transmission and save power consumption, a TDMA schedule allocates by CH based on the active or sleep status. In steady-state phase, data transmission occurs in regard to the time slot that allocates for each member node. The nodes' power will turn off by all workless nodes except CH and sensed data waits from the member nodes. The data aggregation performs by CH and transmits to MS after data delivery from nodes.

Efficient relay selection using IPSO

Particle swarm optimization

The social behaviour of fish schooling or bird flocking inspires to develop the Particle Swarm Optimization, which is a population based stochastic optimization method. A swarm of S potential solutions contain in the basic PSO and it refers to the particles that flying over a dimensional-D problem space to search for the global optimum position to generate the best value of fitness for an objective function.

A position Xid is assigned by each particle i and a velocity Vid (i=1,2,…S), where = 1, 2…D. The global best gbesti and the personal best position pbesti are tracking by each particle.

The original PSO algorithm is shown below:

For each particle do

    Initialize particle

End for

While target fitness or maximum epoch is not attained do

For each particle do

    Calculate fitness

    If current fitness value better than $(pbest)$ then

    $Pbest - current\ fitness$

End for

Set $gbest$ to the best one among all $pbest$

For each particle do

Update velocity

Update position

End for

End while

The position and velocity of the particles are updated as follows:

$$V_{id}(t+1) = w * V_{id}(t) + L_1 * R_1 * \left(pbest_i(t) - X_{id}(t)\right) + L_2 * R_2 * \left(Gbest_i(t) - X_{id}(t)\right)$$

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1)$$

Where, w refers to the weight factor controlling the particle velocity, L1 and L2 are the learning factors, and r1 and r2 are random variable between [0, 1].

Relay selection using IPSO

In the relay selection phase, the best relay nodes are discovered using the fitness function of the PSO algorithm. The Improved PSO algorithm takes into account node residual energy, node distance to CH, node degree, average energy and energy consumption rate (ECR) for fitness calculation and selects the best relay nodes between sensor nodes and the CH for data transmission. The sensor nodes are initialized as particles $P_i = P_{i,1}, P_{i,2}, P_{i,3}, \ldots . P_{i,d}$. The $Pbest, Gbest$ values are calculated for each particle and the node with high fitness value will be selected as the relay node.

Modified fitness function

For selecting the optimal relay nodes from sensor nodes' group of a network, the fitness function of IPSO is utilized. To calculate the fitness function, the PSO algorithm is considered ECR, average energy, node distance to CH, node energy, and node degree. The fitness functions demonstrate as follows:

- Node residual energy: It is considered as one of the most essential factors while choosing the node. Due to the network is heterogeneous, the node that has maximum energy is chosen as relay node. The below equation 8 is used to define the residual energy, which is the ratio of residual energy and the total energy.

$$f1 = RE = \frac{1}{\sum_{i=1}^{n} \frac{E_R}{E_T}} \quad \text{Eq (8)}$$

Where, E_T refers to the total energy, E_R indicates the node energy.

Average node energy: As the network deploys with the heterogeneous nodes, the node's average energy is considered. For selection, the nodes with higher initial energy are preferred. By comparing with the advanced nodes, it's prefer to use advanced nodes than the normal nodes due to the sustainability of super nodes for longer duration. It represents as follows in equation 9:

$$f2 = AE = \frac{1}{N}\sum_{i=1}^{N} E_R \quad \text{Eq (9)}$$

Where, N indicates the total number of nodes, and ER refers to the node energy.

- Node distance to CH: In communication, the distance factor decides the energy consumption of a node. If the distance is low between CH and node, the lower energy is consumed. This parameter is considered for routing strategies that allows minimizing the average distance between CH and sensor nodes and it shows in equation 10.

$$f3 = D_{n2CH} = \sum_{i=1}^{N} \left(\frac{D_{(N-CH)}}{D_{AVG\,(N-CH)}}\right) \quad \text{Eq (10)}$$

Where, $D_{AVG(N\text{-}CH)}$ indicates the average distance between CH and node, and $D_{(N\text{-}CH)}$ refers to the Euclidean distance of node from CH.

- Node degree: A dominant entity is the intra cluster communication if the network area is large. If number of neighbouring nodes are independent to the node, it chooses as a relay node that locates far away from other nodes. The number of neighbouring nodes is considered to restrict such selection as shows in equation 11.

$$f4 = ND = \frac{D_{ij}}{NUM_c} \quad \text{Eq (11)}$$

Where, NUM_C indicates the cluster's total number of member nodes, and Dij indicates the distance between nodes i and j.

- Average energy consumption ratio: It is a major parameter that takes a decision of a node's energy consumption rate. It is the significant concern for a node selection. It refers to the difference between node's initial energy and remaining energy after first round. The node's energy in the previous round is the initial energy as the number of rounds are processing. AEC evaluates and compares with its threshold average value. The node becomes eligible when the threshold average value is higher than the computed value. Otherwise, it doesn't eligible for that round. The below equation 12 is represents as ACE.

$$f5 = ACE = \frac{(E_P - E_C)}{E_P} \quad \text{Eq (12)}$$

E_p & E_C are node energy in previous round and current round.

The combination of various fitness parameters is the fitness function of a network that represents as follows in equation 13:

$$F = \frac{1}{\varphi 1f1 + \varphi 2f2 + \varphi 3f3 + \varphi 4f4 + \varphi 5f5} \quad \text{Eq (13)}$$

Where, $\sum_{i=1}^{5} \varphi_i = 1, \varphi_i \in (0,1)$

Based on the selection of relay nodes using fitness evaluation, the data sends to the CH by each non-CH node via relay nodes after initiating the data communication. The information summarized by each CH node after all packets collected from associated nodes and the data delivered to the Mobile sink whenever it visits.

Algorithm

f1 = residual energy; f2 =average node energy; f3 =distance to ch; f4 = node degree; f5= average energy consumption ratio

##

For all the nodes

Divide the network as 'n' clusters

For each cluster 'n'

Calculating NQF value

Estimate $node\ energy_n$

Estimate $channel\ state_n$

Calculate NQF_n

If $NQF_n > NQF_{n+1}$

$CH \rightarrow n$

End for

Relay selection

For each cluster 'k'

Initialize particles p_i

For i= 1 to $sizeof(k)$

Compute fitness value of p_i

$pbest \rightarrow fitness(p_i)$

If $pbest_i > gbest$

$gbest \rightarrow pbest_i$

End if

End for

End for

End

IV. Result and discussion

The proposed method performance compares with other existing techniques like MOCH-EPSOR[14], ECADA[13], and EN-LEACH[15] for different sensor nodes. By using NS-2 simulator, the simulation tests were performed using parameters as mentioned in Table 1.

Table 1 Network details

Parameter	Value
Network area	1000x1000
Number of nodes	100 to 500
Initial energy	80j to 100j
Packet size	1024
MS mobility pattern	GRID

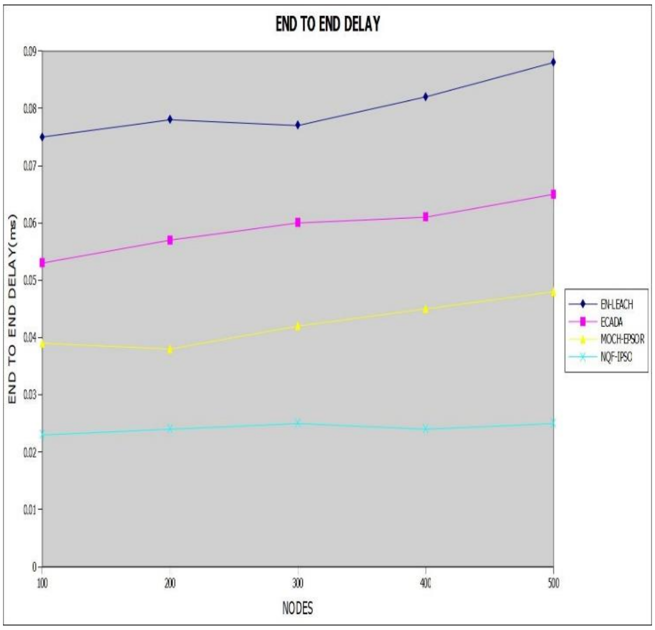

Fig 3: End to end delay

Fig. 3 shows above simulation results demonstrates the evaluation of end to end delay time of the proposed NQF-IPSO method. The relay selection scheme is improved using the modified fitness function in the proposed relay selection scheme. It ensures only quality nodes are selected as relay. It helps to minimize the end to end delay in the network.

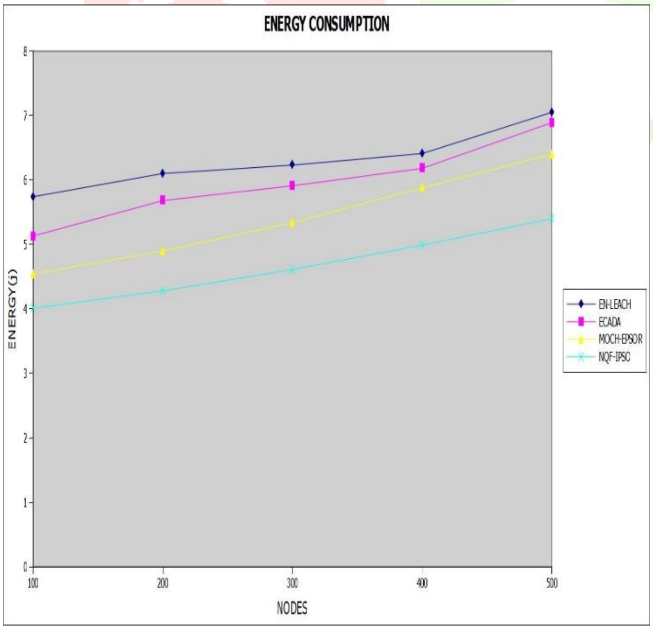

Fig 4: Energy consumption

Fig. 4 displays the energy consumption results for all network activities. Initially all the sensor nodes are equipped with considerable amount of energy. The energy is depleted during network activity. In the proposed method, the efficient selection of CH nodes and relay nodes helped to contain the unwanted energy consumption in great manner. The simulation results mentioned in the above table proves that the proposed method saved considerable amount of energy than the previous methods.

.

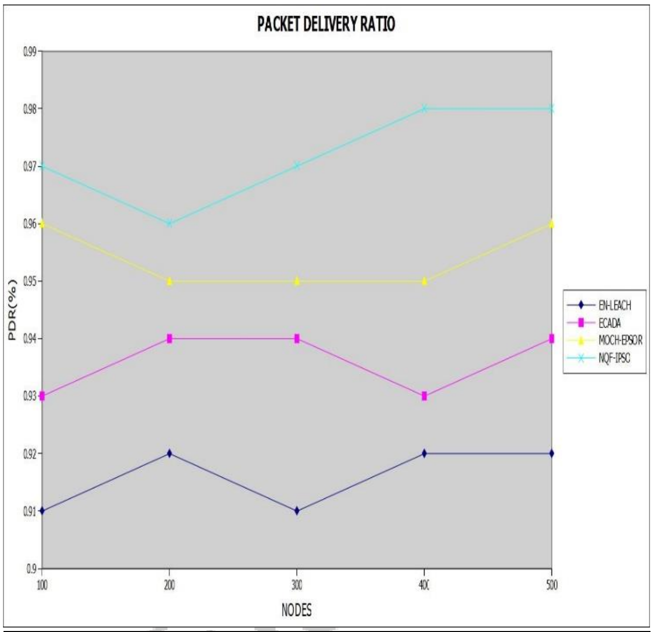

Fig 5: Packet delivery ratio

Fig 5 indicates the outputs of packet delivery ratio for proposed method. The packet delivery ratio refers to the ratio of packets delivered successfully to the intended destination. PDR defines the quality of the network for data transmission. The selection of stable CHs and the efficient data aggregation at the CHs through efficient relay nodes selected by the pso helped to deliver the packetssuccessfully.

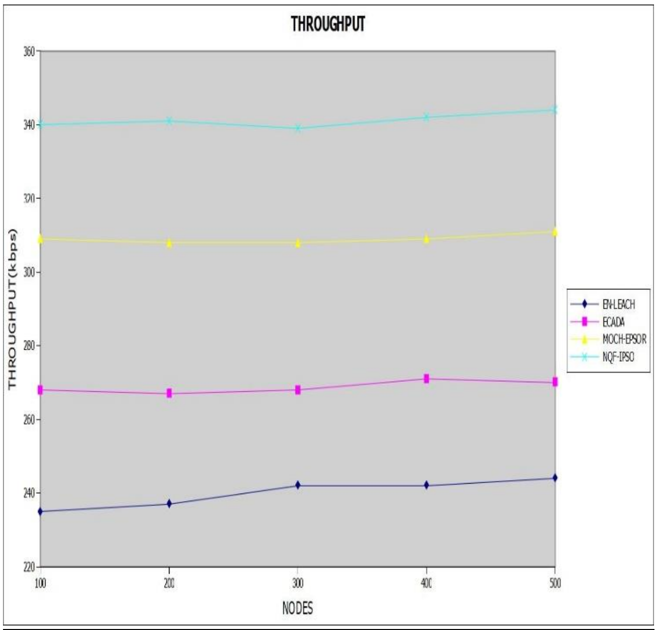

Fig 6: Throughput

Fig 6 demonstrates the results of throughput. Throughput is nothing but amount of data that can be transmitted between the sensor nodes. High throughput ensures the high amount of data delivery. The proposed method exhibited better Throughput compared to the other referred methods.

Conclusion

A wireless sensor network includes the challenging tasks as the relay node selection and optimal CH selection. For choosing optimal CHs with minimum overhead, an integration of improved PSO relay node selection scheme and NQF based CH selection was exploited to reduce power consumption and enhance network lifetime. This method considers the channel quality of the relay-destination link, residual energy, and distance among nodes as CH selection parameters. An improved Particle Swarm Optimization Algorithm is introduced for selecting the energy efficient relay nodes. The improved Particle Swarm Optimization Algorithm takes into account node residual energy, node distance to CH, ECR, average energy, and node degree for fitness calculation. The simulation results proves that the proposed NQF – IPSO method outperforms the previously proposed energy-efficient methods for the considered network performance parameters.

References:

[1] Khalaf, O.I. and Sabbar, B.M., 2019. An overview on wireless sensor networks and finding optimal location of nodes. *Periodicals of Engineering and Natural Sciences (PEN)*, *7*(3), pp.1096-1101.

[2] Al Aghbari, Z., Khedr, A.M., Osamy, W., Arif, I. and Agrawal, D.P., 2019. Routing in wireless sensor networks using optimization techniques: A survey. *Wireless Personal Communications*, pp.1-28.

[3] Akhtar, M.N., Ali, A., Ali, Z., Hashmi, M.A. and Atif, M., 2018. Cluster based Routing Protocols for Wireless Sensor Networks: An Overview. *INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS*, *9*(12), pp.389-396.

[4] Neamatollahi, P., Abrishami, S., Naghibzadeh, M., Moghaddam, M.H.Y. and Younis, O., 2017. Hierarchical clustering-task scheduling policy in cluster-based wireless sensor networks. *IEEE Transactions on Industrial Informatics*, *14*(5), pp.1876-1886.

[5] Wang, J., Gu, X., Liu, W., Sangaiah, A.K. and Kim, H.J., 2019. An empower hamilton loop based data collection algorithm with mobile agent for WSNs. *Human-centric Computing and Information Sciences*, *9*(1), pp.1-14.

[6] Osamy, W. and Khedr, A.M., 2018. An algorithm for enhancing coverage and network lifetime in cluster-based Wireless Sensor Networks. *International Journal of Communication Networks and Information Security*, *10*(1), pp.1-9.

[7] Su, Y., Lu, X., Zhao, Y., Huang, L. and Du, X., 2019. Cooperative communications with relay selection based on deep reinforcement learning in wireless sensor networks. *IEEE Sensors Journal*, *19*(20), pp.9561-9569.

[8] Nayak, S.P., Rai, S.C. and Pradhan, S., 2017. A multi-clustering approach to achieve energy efficiency using mobile sink in WSN. In *Computational Intelligence in Data Mining* (pp. 793-801). Springer, Singapore.

[9] Krishnan, A.M. and Kumar, P.G., 2016. An effective clustering approach with data aggregation using multiple mobile sinks for heterogeneous WSN. *Wireless Personal Communications*, *90*(2), pp.423-434.

[10] Wang, J., Cao, J., Ji, S. and Park, J.H., 2017. Energy-efficient cluster-based dynamic routes

adjustment approach for wireless sensor networks with mobile sinks. *The Journal of Supercomputing*, *73*(7), pp.3277-3290.

[11] Krishnan, M., Yun, S. and Jung, Y.M., 2019. Dynamic clustering approach with ACO-based mobile sink for data collection in WSNs. *Wireless Networks*, *25*(8), pp.4859-4871.

[12] Koosheshi, K. and Ebadi, S., 2019. Optimization energy consumption with multiple mobile sinks using fuzzy logic in wireless sensor networks. *Wireless Networks*, *25*(3), pp.1215-1234.

[13]. Krishnan, A.M. and Kumar, P.G., 2016. An effective clustering approach with data aggregation using multiple mobile sinks for heterogeneous WSN. *Wireless Personal Communications*, *90*(2), pp.423-434.

[14]. S anuradha,Dr.D sreenivasa rao,2021," A multi-objective CH selection and Enhanced Particle Swarm Optimization for relay selection with Mobile sinks"JETIR,volume 8,issue7

[15]. Salem, A.O.A. and Shudifat, N., 2019. Enhanced LEACH protocol for increasing a lifetime of WSNs. *Personal and Ubiquitous Computing*, *23*(5), pp.901-907.