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Generalized Iterative Scaling for Energy Efficient Based Multi-Hop Clustering in Wireless Sensor Network

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Abstract: Wireless Sensor Network (WSN) is spatially distributed independent network to sense the physical or environmental characteristics such as temperature, sound, pressure, energy with minimum number of sensor nodes. Most of the existing research works had concentrated on energy efficient routing, but the multi-hop clustering is a major issue in distributed wireless sensor network. In this study, a Generalized Iterative Scaling based Energy Effective Distributed Multi-hop Clustering (GISEDC) method is developed to improve the multi-hop clustering with minimal energy consumption. The Generalized Iterative Scaling is a log linear model to maximize the clustering efficiency and also reduce the energy consumption. Initially, the multi-hop clustering is performed on the distributed sensor nodes with multi-sink for energy savings in WSN. Accordingly, the cluster head is selected by using two factors in Generalized Iterative Scaling approach. The GISEDC method uses the principle of maximum entropy model to improve the clustering efficiency on the distributed sensor nodes and the principle of minimum entropy model to reduce the energy consumption. The formation of cluster head in Generalized Iterative Scaling consists of the grid includes cluster id, number of nodes grouped in that cluster and adjacent cluster information. GISEDC method uses the adjacent cluster information and identifies the node in more than one cluster called periphery node. The periphery node is used to improve the network performance with minimum delay time for a particular large scale sensor network environment. Finally, an energy effective distributed multi-hop clustering algorithm is applied to increase the network throughput with minimum energy consumption. Experimental analysis is performed using NS2 simulator to prove the effectiveness of the proposed GISEDC method in terms of clustering efficiency, energy consumption, delay time and throughput. The results demonstrate the advantage of the proposed model over state-of-art methods.

Key words: Wireless sensor network, generalized iterative scaling, minimum entropy model, maximum entropy model, India

INTRODUCTION

The most important task of Wireless Sensor Network (WSN) is the irregular monitoring of the environment, where the object sensed is then sent to the sink node for further processing. With the growing demand of the application, the design of sensor nodes should be performed in such a manner with minimum energy efficient routing. The objective of energy efficient multi-hop routing has become a significant issue.

Energy utilization plays an important role for wireless network transmission. As sensor nodes work on batteries, the maximum network usage is dependent on available energy in the sensor nodes. A Store Carry and Forward (SCF) mechanism was designed (Kdios *et al*., 2014) by applying mathematical formulation to identify shortest route to base station and determined the optimal routing to attain maximum energy savings. Available data rate set in SCF is not effective on routing with minimal energy consumption in WSN.

Clustering is the major issue for determining the network lifetime. Most of the well-known clustering methods in WSN were developed only to reduce overall energy consumption in the network and improves the network lifetime. Genetic Algorithm based Energy Efficient Clustering Hierarchy (GAECH) (Baranidharan and Santhi, 2015) was introduced to improve the stability and lifetime of the network. However, the multi hop clustering based energy savings remained unaddressed.

Energy conserved supervised scheme (Rajarajeswari *et al*., 2015) was designed to preserve the energy. The energy efficient scheme provides better performance by integrating efficient clustering and routing schemes. The cluster head is randomly selected

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and the nodes are chosen based on their location and Residual Energy (RE). However, it was failed to minimize the energy consumption at a required level. The multi-hop energy efficient clustering scheme was developed by Kumar *et al.* (2014) for improving the performance of multi-hop communications and clustering with minimum energy consumption but compromising transmission power.

Grid based clustering (Abdullah *et al.*, 2015) has established for high dynamic networks. The girds based approach used to implement on dense network and divides the network area into multiple grid cells with minimum energy. Then the cluster head will be selected based on highest energy. However, the delay was not considered. An energy efficient routing protocol (Mahapatra *et al.*, 2015) was designed for improving the network lifetime with minimum delay in WSN. However, it does not obtain more efficient and robust clustering approach to improve energy consumption and enhance network lifetime in small and large WSN.

Gao *et al.* (2015) a distributed clustering algorithm based on fuzzy weighted was introduced aiming at reducing the collision and improves energy efficiency for large scale WSN. It was generating a higher delay in the data transmission from a node to the sink node. However, the better cluster head distribution and network robustness remained unaddressed. A cross-layer optimization method was introduced by (Singhal *et al.*, 2014) for improving the Quality of user Experience (QoE) and energy efficiency of the heterogeneous network. Secure and Energy Aware Routing Protocol was designed (Gong *et al.*, 2015) for energy efficiency and security for WSN and it handles the several applications. However, the protocol has minimum transmission efficiency.

For efficient routing in WSN, cluster based routing was introduced by Thippeswamy *et al.* (2014) based on the energy density of cluster. The on- demand routing approach is used for balancing energy utilization from source to sink. However, the latency with respect to data transmission was not concentrated. Therefore, the challenge lies in energy efficient based multi-hop clustering overcoming limitations in existing works.

In this study, an efficient Generalized Iterative Scaling based Energy Effective Distributed Multi-hop Clustering (GISEDC) is introduced to increase the multi-hop clustering and reduce the energy consumption. By applying a Generalized Iterative Scaling on the distributed sensor nodes, clustering efficiency is improved. Then the minimum and maximum entropy factor is used. The GISEDC method uses the adjacent cluster information and identifies the periphery node which used to increase the network performance with minimum delay time. Finally, the energy effective Distributed Clustering algorithm achieves the higher throughput rate in WSN.

Related works: Wireless Sensor networks are equipped with various communications and measuring capacity and hence are appropriate to different operating circumstances. Hence energy efficient based clustering is the one of the most important to be performed in WSNs involving different environments.

An energy efficient algorithm was introduced by Anandan and Ram Kumar (2015) with review in WSNs. The Communication paths are chosen where the total energy consumed beside the path is reduced. Clusters generate hierarchical structure of WSNs that provides effective usage of restricted resources of sensor nodes and increases the network life time. Multi-parametric clustering provided an insight into channel availability and topology characteristics to aid in the coordination of sensor nodes during packet transmission. The sensor nodes are grouped together across several network parameters. However, the real world implementation and energy consumption is remained unaddressed.

Energy aware MTTP routing protocol was designed in WSN sensor node for capable of measuring the energy consumption. The MTTP routing also determines that the real-world performance of energy-aware protocols. Probability-based Prediction and Sleep Scheduling protocol (PPSS) (Jiang *et al.*, 2013) properly selects the nodes to reduce their active time and also increase the energy efficiency with limited tracking performance loss. However, it fails to have a best energy performance tradeoff for a particular network environment.

Reliable minimum energy and cost energy routing (Vazifehdan *et al.*, 2014) increases the energy-efficiency, reliability, and network lifetime. However, the traffic creating nodes consumes more energy. A token-based routing protocol was designed (Cerik and Zaim, 2013) with multitier cluster based approach. The token-based routing protocol considers the data aggregation, multi-hop data communication with minimum amount of energy savings for increasing the network lifetime. The Predictive Energy Consumption Efficiency (PECE) based clustering model (Zhang *et al.*, 2015) in WSN. An energy-saving clustering routing algorithm selects the cluster head with minimum cost of communications within the clusters. The design of PECE strategy uses bee colony optimization and it minimizes the energy consumption of entire network.

Reliable routing approach for in-network aggregation (Subhashini and Parani, 2014) in WSNs is used for reducing number of overlapping routes, high aggregation rate and efficient data transmission even in the nodes failure situation. However, the reliable routing approach does not reduce the network overhead. To reduce the network overhead, an Energy Efficient Cluster Based Scheduling Scheme was introduced by (Elangeswaran and Parasuraman, 2015) and it also balances the energy of sensor nodes for improving the network lifetime. The LEACH clustering algorithm (Grobler *et al*., 2014) was used in mobile WSNs for the objective of locating the optimal path connecting cluster heads and moves the sink in the network with minimum energy consumption.

Based on the above said methods, the generalized iterative scaling based energy effective distributed multi-hop clustering is designed in the forthcoming sections.

MATERIALS AND METHODS

GISEDC approach: In this study, Generalized Iterative Scaling Based Energy Effective Distributed Multi-Hop Clustering is described. The proposed GISEDC model consists of two parts. The Generalized Iterative Scaling is used to improve the clustering efficiency and energy effective Distributed Clustering algorithm is used to minimize the energy consumption. The block diagram of GISEDC model is shown in Fig. 1.

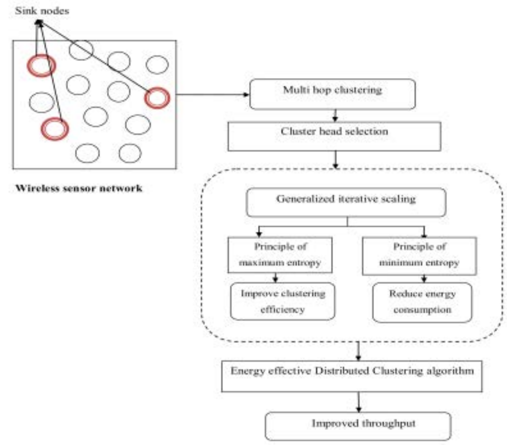

Fig. 1: Flow diagram of generalized iterative scaling based energy efficient multi-hop clustering

Figure 1 shows the generalized iterative scaling based energy efficient multi-hop clustering mode. The multi hop clustering is performed on the distributed sensor nodes with multiple sink nodes. Then, the cluster head is selected based on two factors in generalized scaling approach for improving the clustering efficiency and reducing the energy consumption. Based on the cluster head selection, the periphery node is identified to improve the network performance with minimum delay time for a particular large scale sensor network environment. Finally, the energy efficient distributed clustering algorithm is applied for increasing the network throughput. The generalized iterative scaling method is explained in the study.

Multi-hop clustering and cluster head selection: A multi-hop clustering is performed with multiple sink nodes for energy savings in WSN. In GISEDC model, the cluster head is selected based on two factors such as remaining energy and number of sensor nodes in WSN. Let us consider ‘n’ number of sensor nodes are spread over the network environment at a random manner. All the sensor nodes have unique ID. Initially, the sensor and sink nodes are located. In multi-hop, the sensor near to the sink has the higher density. The data distribution among sensor node and their cluster head is a single hop. Similarly, the data transmission between the cluster head and sink node is multi-hop. Before the multi-hop clustering process, the sink node transmits a start message to all sensor nodes for performing the clustering in WSN. The sensor nodes that are near to the sink receive this message at first then it calculates the threshold value (T) for them. The threshold value is calculated based on Residual energy (R_E) and other neighboring nodes (NN). The threshold values is selected as given below:

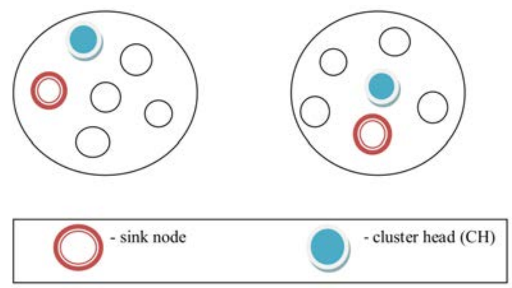

Fig. 2: Cluster head formation

$$\text{Threshold}(T) = R_E + NN \quad (1)$$

After measuring the threshold value, the sensor node sends the value of T to their neighboring nodes. The neighbor node receives the value and it compares with their threshold value. The sensor node that has the maximum threshold value and itself it selects as cluster head. The formation of cluster head in Generalized Iterative Scaling consists of the network includes cluster id, number of nodes grouped in that cluster and adjacent cluster information.

Figure 2 shows the cluster head formation with sink node. GISEDC method uses the neighbouring cluster information and identifies the node in more than one cluster called periphery node. This node increases the network performance and also minimizes the delay time for a particular large scale sensor network environment. Let us consider the periphery node (P) is calculated as follows:

$$P = \frac{\sum D}{n} \tag{2}$$

In Eq.2, the D is the distance between the nodes and ‘n’ is number of sensor nodes in network. After grouping the sensor node, the routing path is selected and the sensor nodes are ready for efficient data transmission. Upon successful identification of sensor nodes, the preference is given to adjacent node by each sensor node to select the path for packet transmission. The routing path is selected for efficient packet transmission with minimal energy in WSN. The entropy based model in generalized iterative scaling is described in following sections.

Entropy model used in generalized iterative Scaling: Generalized Iterative Scaling is a log linear method that determines the exponential family of a Maximum Entropy and minimum entropy clarification for improving the multi-hop clustering efficiency and energy consumption on the distributed sensor nodes in WSN.

Principle of maximum entropy model for clustering efficiency: Principle of maximum entropy is applied for multi hop clustering for handling the intrinsic data packet transmission between the determinations of the clusters and also it provides the flexibility to various distributed network. The entropy principle applied to an estimation of the node of a random variable. The random variables are represented as $u_1, u_2, u_3, ...u_n$ and the probability of random variable isp (u_i). From that, the information (I_n) is inversely proportional to the log likelihood function and the information is expressed as:

$$\begin{aligned} l_n &= \log\left(\frac{1}{p(u_i)}\right) \\ l_n &= -\log(p(u_i)) \end{aligned} \tag{3}$$

From Eq. 3 the information entropy theory can be written as:

$$H(U) = -\sum_{i=1}^{N} p(u_i)\log(p(u_i)) \tag{4}$$

In Eq. 4, H(U) obtains the higher value when p (u_i) = 1/n, where I = {1, 2... n}, due to the maximum entropy probability distribution is the uniform distribution. The maximum entropy model is given as:

$$\begin{aligned} p &= \max_{p \in P} H(v/u) \\ &= \sum_{u,v} p(u,v)\log\left(\frac{1}{p(v/u)}\right) \end{aligned} \tag{5}$$

where:

P = The probability distribution in

U and (u, v) = The context information. Based on the maximum entropy model, the GISEDC method achieves better clustering efficiency on the distributed sensor nodes.

Principle of minimum entropy model for energy consumption: The principle of minimum entropy model is used in GISEDC method, the total energy is minimized at equilibrium with respect to any unconstrained nodes for a wireless sensor network. This minimum energy entropy principle shows that at constant entropy the internal energy is reduced. The internal energy value is calculated as:

$$E(R) = \min_x (E(R, Y)) \tag{6}$$

In Eq. 6 where E and R are the internal energy value and the stable entropy at equilibrium. The variables have been changed by ‘y’ which stands for any internal unconstrained variables. By applying the principle of minimum energy entropy, the energy consumption is reduced in GISEDC method.

The energy effective distributed multi-hop Clustering algorithm is applied for increasing the successful data transmission between the source and destination node with minimum energy consumption. The algorithmic description is given below:

Algorithm 1; Energy effective distributed multi-hop clustering algorithm:

Input: sensor nodes $SN_i = SN_i, SN_i, ...SN_i$ and sink, ‘s’, minimum entropy, maximum entropy
Output: Energy efficient and multi hop clustering based transmission
Step 1: Begin
Step 2: For each sensor node and sink node
Step 3: Evaluates multihop clustering
Step 4: Cluster head is selected based on the threshold value for seleeting the route path using (1)
Step 5: Evaluates principle of maximum entropy mode to maximize the clustering efficiency using (5)
Step 6: Evaluates minimum energy entropy mode to reduce the energy consumption using (6)
Step 7: End for
Step 8: End

The above algorithmic step describes the Energy Effective Distributed Multi-hop Clustering algorithm. Initially, the multi-hop clustering is performed and selects the cluster head based on threshold value for the entire sensor node. This helps to select the optimal route path for efficient data transmission. Next, the maximum entropy model is evaluates multi-hop clustering for maximizing the clustering efficiency. Subsequently, the minimum entropy model is evaluated aiming at reducing the minimum energy. As a result, the successful multi hop data packet transmission (i.e., throughput) is obtained with minimum energy consumption.

RESULTS

Experimental evaluation: In this study, we evaluate the proposed GISEDC method and compare its performance to two other existing works namely Store Carry and Forward mechanism (SCF) and Genetic Algorithm based Energy Efficient Clustering Hierarchy (GAECH). Simulations were conducted in NS2 using 70 sensor nodes for various network scenarios randomly distributed in a square area of A^2 (1400 m) placed in a random manner in the WSN that generates traffic for every 25 m^{-1}.

The nodes are distributed in an area using Random Way point model for simulation, whereas the link layer provides the link between two nodes and the design of link is multi direction. The sink node collects the data packets of range 9-63 and forwards the data to the sink node with each data packet size differing from 100 512 KB. The simulation time varies is 1500 simulation seconds. The following metrics like clustering efficiency, energy consumption, delay, and throughput in WSN is measured. Table 1 shows the simulation parameter.

Clustering efficiency is defined as the ratio of number sensor nodes that correctly grouped to the total number of nodes in the network. It is measured in terms of percentage (%):

$$CE = \frac{\text{No.ofcorrectlygrouped}}{T_n} \quad (7)$$

From Eq. 7:

Table 1: Simulation parameters

Parameters	value
Network area	1400m*1400m
Number of sensor nodes	70
Number of data packetsi.e., size of data block	9,18, 27, 36, 45, 54, 63
Range of communication	30 m
Speed of node	0-25 ms
Simulation time	1500 s

CE = The clustering efficiency and

T_n = The total number of sensor nodes. Energy consumption using GISEDC method is the product of sensor nodes, power (in terms of watts) and time (in terms of seconds). The energy consumption is measured in terms of Joules (J). The mathematical formulation for energy consumption using GISEDC method is given as below:

$$EC = \text{No. of sensor nodes} \times \text{power} \times \text{Time} \quad (8)$$

In Eq. 8 'EC' is the energy consumption where the energy consumed by sensor nodes to reach sink node. The measurement of delay is defined as the difference between the actual time and observed time of data packet. It is mathematically formulated as given below:

$$D = \text{actual}_T - \text{observed}_T \quad (9)$$

where:

D = Represents delay

$Actual_T$ = The actual time and

$Observed_T$ = The observed time. Throughput (T) is the defined as the ratio between the numbers of data packets sent by source nodes to the sink to the number of packets successfully received by the corresponding destination nodes. It is measured in terms of percentage (%).

$$T = \frac{\text{Data packet}_R}{\text{No.of data packet sent}} \times 100 \quad (10)$$

From Eq. 10 the throughput 'T' is measured using data packets receives by the destination and number of data packet sent.

DISCUSSION

In this study, the result analysis of GISEDC method is performed and compared with two existing methods, A Store Carry and Forward mechanism (SCF) and Genetic Algorithm based Energy Efficient Clustering Hierarchy (GAECH). The simulation parameters such as classification efficiency, energy consumption, delay and throughput in WSN is measured.

Impact of clustering efficiency: The clustering efficiency of proposed GISEDC method is obtained using Eq. 8. The GISEDC method is compared with two existing works SCF and GAECH. Table 2 shows the experimental values

Table 2: Tabulation for clustering efficiency (%)

No. of sensor nodes	Clustering efficiency (%)		
	GISEDC	SCF	GAECH
10	84.25	77.35	79.28
20	85.67	78.21	82.25
30	88.68	79.74	84.36
40	90.24	80.25	85.27
50	92.24	82.58	86.35
60	93.58	84.61	87.38
70	95.14	85.67	88.24

Table 3: Tabulation for Energy consumption

No. of sensor nodes	Energy consumption (Joules)		
	GISEDC	SCF	GAECH
10	28.64	35.12	37.54
20	31.30	37.33	42.58
30	35.53	39.56	51.64
40	38.13	41.27	53.24
50	40.21	45.22	55.65
60	41.14	48.12	56.54
70	43.22	49.58	60.24

Table 4: Tabulation for delay time

No. of packet sent	Delay time (ms)		
	GISEDC	SCF	GAECH
9	5	6	7
18	8	10	14
27	11	15	17
36	13	16	18
45	17	20	22
54	19	24	27
63	22	26	29

of proposed GISEDC method and existing SCF and GAECH methods. The simulation results of three proposed methods are illustrates in Fig. 3.

Figure 3 shows the measurement of clustering efficiency with respect to number nodes used in WSN. For the experimental consideration, number nodes are varies from 10-70. From the figure it is clear that, our proposed GISEDC method performs relatively well than the existing approaches SCF and GAECH. With increasing the number of sensor nodes, the clustering efficiency also increased. But, comparatively method has higher clustering efficiency. In Table 1, for 10 sensor nodes, the clustering efficiency of 84.25% is achieved using GISEDC method, whereas the clustering efficiency of 77.35 and 79.28% is achieved using SCF and GAECH. This is because the multi-hop clustering is performed on the distributed sensor nodes with multi-sink aiming at increasing the clustering efficiency by 9.72 % compared to existing SCF. Moreover, the principle of maximum entropy model is applied to determine the data transmission between the clusters. This helps to maximize the cluster efficiency by 5.79% compared to GAECH (Baranidharan and Santhi, 2015).

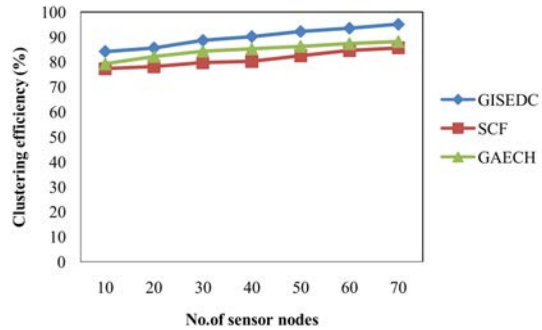

Fig.3: Measure of clustering efficiency

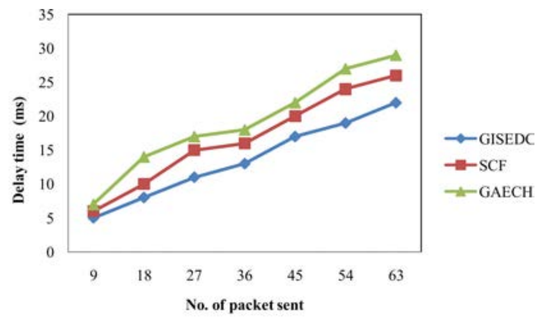

Fig. 4: Measure of energy consumption

Impact of energy consumption: The energy consumption of proposed GISEDC method and SCF and GAECH are measured using Eq. 8. Table 3 and Fig. 4 illustrate the performance result of energy consumption. The energy consumption resultant values of three methods GISEDC, SCF, GAECH are illustrated in Table 3. The proposed GISEDC method minimizes the energy consumption than the other state-of-art methods.

Figure 4 depicts the energy consumption based on different sensor nodes. Our proposed GISEDC method performs extensively well when compared to two other methods SCF and GAECH. As illustrated in the above figure, the energy consumption is minimized in all the three methods, but relatively it is reduced in GISEDC method. In GISEDC, the multi-hop clustering is performed on the sensor node, then the routing path is selected for efficient transmission with minimum energy consumption. In addition, by applying principle of minimum entropy model, the total energy is minimized at equilibrium with respect to any unconstrained nodes for a WSN. Therefore the energy consumption is reduced by 15% compared to SCF and 38.1% compared to GAECH, respectively.

Impact of delay time: The measurement of delay using proposed GISEDC method is calculated by the difference between the actual time and observed time of data packet using Eq. 9. It is measured using (ms). Lower the delay time, more efficient the method is said to be.

Table 4 and Fig. 5 illustrate the delay time measurement of proposed GISEDC method and existing

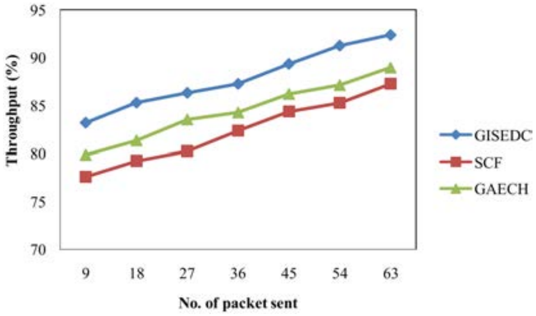

Fig. 5: Measure of delay time

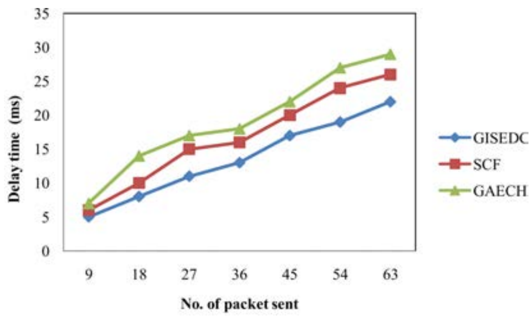

Fig. 6: Measure of throughput

SCF (Anandan and Kumar, 2014) and GAECH (Baranidharan and Santhi, 2015) methods. From the Table 4 values, it is clear that the proposed GISEDC method performs well with minimum delay.

Figure 5 depicts the measurement of delay based on the number of packet being sent. The GISEDC method is compared with existing SCF and GAECH. The proposed GISEDC method is comparatively minimize the delay time than the state-of-art methods. The multi hop clustering is performed and selects the cluster head for each cluster. GISEDC method uses the adjacent cluster information and identifies the node in more than one cluster which is called as periphery node and it helps to increase the network life time with minimum delay time. The GISEDC method reduces the delay time by 23.7% compared to existing SCF and 44.4% compared to GAECH, respectively.

Impact of throughput: Throughput is the average rate of successful packet transmission at the destination end. It is measured using 10. Higher the network throughput more efficient the method is said to be.

Table 5 describes the throughput measurement based on the number of packet sent. The packet varied from 9-63. While increasing the number of packet being sent, the throughput rate of three methods are improved. The resultant values are illustrated in Fig. 6.

Figure 6 shows the throughput rate of GISEDC method as compared to existing SCF

Table 5: Tabulation for throughput

No. of packet sent	Throughput (%)		
	GISEDC	SCF	GAECH
9	83.19	77.58	79.85
18	85.28	79.24	81.35
27	86.31	80.24	83.54
36	87.25	82.35	84.27
45	89.34	84.35	86.21
54	91.25	85.24	87.14
63	92.37	87.25	88.97

and GAECH. From Fig. 6, it is evident that the most significant improvements occur in the three methods and comparatively the throughput is higher in GISEDC method. For example, while considering the number of packet sent is 27, the throughput obtained is 86.31% in GISEDC method and 80.24,-83.54% using existing SCF and GAECH approaches. Due to this fact, the Energy Effective Distributed Multi-hop Clustering algorithm is applied to determine the energy efficient route path for successful data transmission. This helps to increase the network throughput rate by 6.31% compared to existing Store Carry and Forward mechanism (SCF) (Anandan and Kumar, 2014). In addition, the generalized iterative scaling approach uses maximum and minimum entropy for improving the clustering efficiency and minimizes the routing energy. This in turn increases the network throughput by 3.84% compared to GAECH (Baranidharan and Santhi, 2015).

CONCLUSION

In this Study, Generalized Iterative Scaling based Energy Effective Distributed Multi-hop Clustering (GISEDC) method is developed in wireless sensor network. At first, multi hop clustering is performed on a distributed sensor nodes to group the sensor node and selects the cluster head for each group. Based on, multipath routing is selected for efficient packet transmission. The generalized iterative scaling method uses the two entropy factor. The principle of maximum entropy model is applied in GISEDC method for improving the clustering efficiency. In addition, the minimum entropy model is used to minimize the energy consumption of routing. GISEDC method uses the adjacent cluster information and identifies the periphery node. This node reduces the delay time and increases the network performance. Finally, with the application of Energy Effective Distributed Multi-hop Clustering algorithm, the network throughput is increased with minimum energy consumption. Experiments were conducted and the performances were compared in terms of clustering efficiency, energy consumption, delay and throughput. The performance results shows that the proposed GISEDC method offers better performance with an improvement in clustering efficiency by 7.75% and energy consumption by 26.6% compared to state-of-art methods.

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