PERFORMANCE ANALYSIS OF ENERGY EFFICIENT ALGORITHMS IN WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless sensor network (WSN) is a collection of spatially distributed and devoted sensor nodes which are used to observe and record the conditions of the physical environment. Sensor nodes areconsisting of battery, transmitter, and memory and so on. It supports to gather the information from the various locations continuously. One of the major issues in WSN is energy consumption because the replacement of battery is not applicable in the environment. It may cause the nodes dead and lost the data as earlier.To overcome these issuesvarious algorithms had been used to enhance the energy efficiency. For the betterment of the future reference herewith few algorithms are analyzed and verified which are mainly used to increasing the energy. TL-LEACH, PDORP, QABC, REACH-IN are the papers which are compared and substantiated with the simulation result analysis. Ultimately, this paper reveals the best energy efficient algorithms.

Keywords*:Cluster Head, Energy Efficiency, PDR, SN, WSN*

I. Introduction

For past few years WSN has become a vast approach used in the area of research. Sensor nodes are used to collect the information from the physical environment such as humidity, pressure, heat, light etc. Information is transmitted from sensor node to controller for further processing. WSN consist of hundreds to thousands of tiny sensor nodes equipped with sensing, data processing, and communication units to perform distributed sensing tasks. In general, since sensor nodes are powered by limited energy source, energy conservation is commonly considered the most key challenge in order to guarantee the connectivity of the network and extend the lifetime of the sensor nodes, especially when the deployment field is inaccessible and battery cannot be replaced. It is also recognized that usually communication task consumes the most energy during the network operation. Many routing protocols have been proposed to obtain energy-efficient communication for the WSNs [1]-[2]. The architecture diagram of hierarchical wireless sensor network is displayed in Fig1, and Fig2 shows the structure of clustered wireless sensor network.

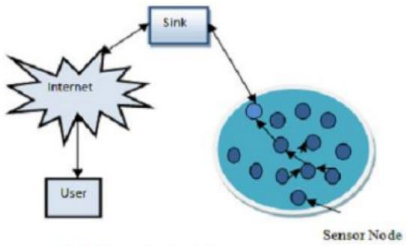


Fig1. Hierarchical wireless sensor network

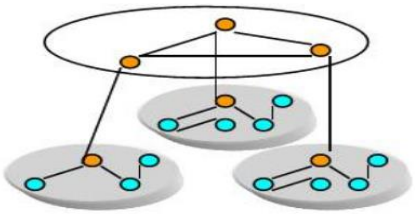


Fig 2. Structure of clustered wireless sensor network

Hierarchical and Cluster based protocols are best to increase the energy consumption with help of some nodes called Cluster Head (CH). It supports to gather the information from member node (MN) and transmit it to Base station (BS). Group of node formed the cluster; each cluster had CH to aggregate the data and preserve the energy in the cluster. Sometimes clustering techniques also reduce the energy, for that moving nodes (sink) are introduced to receive the information from the cluster head and transmit the information to BS instead of direct communication between the CH to BS. Various algorithms are introduced to increase the energy to the sensor node such as LEACH, SEECH, HEED, and PEGASIS so on. To understand the behaviour of the network and analysing the performance of these types of algorithmssome of the techniques are used, which are analytical method, computer simulation and physical experimentation.

In analytical method, mathematical representations and approximations are done to study the system and routing algorithms are verified before actual implementation. The analytical method is cost effective but may lead to inaccurate results because designing algorithms considering all practical limitations is difficult. Computer simulation is another cost effective method to analyse the network performance by simulating network scenario for the required application. It offers more flexibility by controlling the design of simulated network scenario. Debugging the simulation code is easy. Sometimes insufficient data, factors selected may not be enough to study the exact behaviour of the network. Though cost involved for physical experimentation is high, it is the optimum method for analysing the performance of the network as it gives reliable results. Hence before actual WSN deployments, test WSN is established and common performance metrics like packet delivery ratio, throughput similar to [3], [4] has been used to characterize the network behaviour.

In this paper we discuss about the performance analysis of energy efficient algorithm in WSN by simulation. The remaining section of this paper structured as follows: Section II listed the related algorithms supports for energy efficiency, Section III show the performance analysis, Section IV describes the experimental analysis, Section V defines the conclusion and Section VI contains the papers which supported for this analysis.

II. Energy Efficient Algorithms

In WSN inbuilt batteries are used to make the sensor nodes alive. Battery replacement is also not possible in the location where the nodes deployed. During the transmission the node lost its energy quickly, if the node lost its energy completely then the active node dead. Rechargeable and Battery deployment is not possible in network. To make the network active and efficient to gather the information then efficiency and consumption of energy of is more important for all sensor nodes in the network.In the recent years, all the research works are done for the Energy conservation, because it is the major issue in WSN. To increase the lifetime of sensor node and makes the node activelonger, various algorithms are used. The energy efficient algorithms such as TL-LEACH, QABC, REAC-IN, and PDORP are analyzed with same parameters.

1. TL-LEACH (Three Layered – low-energy adaptive clustering hierarchy)

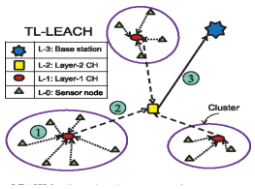
Low energy Adaptive Clustering Hierarchy (LEACH) protocol is used to enhance the lifetime of the nodes in WSN. It contains two types of phase like setup phase and steady phase. Setup phase supposed to elect the cluster head dynamically. Steady phase is used to organize the transmission from each cluster head. LEACH contains two phases and it reestablishes the cluster depends upon the round duration. It helps to monitor only homogeneous environment. Each sensor node will generate a random number between 0 and 1 and it is less than a threshold T (n) value. During cluster head selection Threshold value is set to zero. It will help to avoid the cluster head election again using the equation (1)

$$\mathrm{Pi(t)} = \begin{cases} \frac{k}{N-k+\left(r \bmod \frac{N}{k}\right)} : c_i(t) = 1 \\ 0 \qquad\quad : c_i(t) = 0 \end{cases} \tag{1}$$

where$Ci(t)$ is the indicator function determining whether or not node i has been a CH within the most recent (r mod Nk) rounds ($Ci(t)$ = 0 means node i has been a CH). Thus, only nodes that have not already been CHs recently (i.e. (t) = 1) may become CHs at round r +1.

LEACH protocol extends into TL-LEACH [5].In Fig3. TL-LEACH architecture is shown to demonstrate the structure of the protocol. Using this protocol it minimizes the energy consumption and increases the lifetime. In setup phase, CH election is same as LEACH. CH in the network cannot communicate or transmit the information to the Base station. TL-LEACH, the selection of CHs is a bottom-up approach. The layer-1 CHs are selected from the layer-0 sensor nodes, and then the layer-2 CHs are selected from the layer-1 CHs. Even though this approach is fully distributed, however, some results of previous work show that partially or semi-distributed control would lead to better performance [6].

Fig 3.TL-LEACH



1.2. QABC (Quantum Artificial Bee Colony)

Ant Colony Optimization algorithm is a is a probabilistic method which helps to solve computational to finding good paths through graphs. Bees algorithm is one type of approach, it is more analogous to the foraging pattern of the honey bee. This method is known as swarm intelligence. This QABC is an extended version of ABC to improve the efficiency through optimization technique. It integrated the

quantum computation and ABC algorithm. It supports to improve the network efficiency and reliability. In QABC four phases are used which are Initialization phase, clustering phase, stabilizing phase and renewal phase. ThisInitialization phase supposed to inform to the neighbour node about the CH selection via broadcast. If the neighbouring node received the signal then automatically location and residual energy will be calculated by the sink node. Clustering phase helps to choose the cluster head is elected by the residual energy of the node depends upon certain conditions in the algorithm. After the election process completed it moves to Stabilizing phase, this assist to transfer the data from node to CH. Renewal phase is used to update the node information like distance and residual energy of each node. It helps to increase the energy efficiency.

In general, the energy consumption balance analysis will be expressed by the variance of all the node loads. Mathematical formula is expressed (2)

$$\varphi = \frac{\sum_{i=1}^{n}(E_i - \bar{E})^2}{n} \tag{2}$$

whereEi is the energy consumption of the sensor node, E is the average of the network load, and n is the number of nodes of WSNs. The bigger the load variance φ value of the node, the worse the load balance of the load, and if the smaller the φ value, the better the network energy balance [7].Load balancing analysis factor is also helps to increase the energy efficiency in WSN. It aims to increase the performance analysis to improve the network throughput, data processing capacity, network efficiency and increase the network lifetime (3). Mathematical formula is expressed as

$$L_{LBF} = \frac{n_c}{\sum_{i=1}^{n_c}(x_i - u)^2} \tag{3}$$

where n_c is the number of nodes in the sensor network, x_i is the number of i^{th}nodes in the cluster head, and u is the average node number of all the head nodes of the cluster.[8] QABC satisfies the unbalanced load in the WSN clustering, it adapt to the network topology, evaluate the balanced distribution of network node and guarantee that every round can select the cluster head with the proper ratio, reduces the node energy consumption and prolongs the network lifetime.

1.3 REAC-IN (RegionalEnergyAwareClusteringwithIsolated Nodes)

This algorithm is used to elect the CHs based on threshold involving the residual energy of each sensor node and it distributes the CHs evenly. REAC-IN entails adapting the rotating epoch of each node to its energy and indicates the problem of node isolation. Isolated nodes link with the sink by overriding an excess amount of energy. Moreover, the regional average energy and the distance between sensors and the sink are used to determine whether the isolated node sent its data to a CH node in the previous round or to the sink.

This protocol indicates a different p based on the residual energy and the regional average energy of all sensors in each cluster to prolong the lifetime of network. Let $E_{c,i(}r-1)$ be the regional average energy of node n_i in its

cluster c at the round r−1, n_c is the number of nodes in the cluster, and $E_i(r)$ is the residual energy of the node n_i.[9] The regional average energy $E_{c,i}(r-1)$ is defined as(4)

$$\overline{E_{c,i}}(r-1) = \frac{\sum_{i=1}^{n_c} E_i(r)}{n_c} \quad (4)$$

During the Data Transmission, if CH selection process is completed the elected node broadcast a join-request message to the other nodes in the network. It allows grouping the nearest node in the network through the message. If anyone of the node in the network does not receive the messages from anywhere then the node considered as isolated node. First Order Radio Model(FORM)[10] is the power consumption model allows to data transmission between the transmitter and the receiver. The REAC-IN protocol presented improves the cluster head selection process and solves the problem of node isolation.

1.4PDORP (PEGASIS-DSR Optimized Routing Protocol)

Power-Efficient GAthering in Sensor Information Systems is allows to receive and transform the data to nearest neighbour and pass the information to the BS. It distributes the energy load among the entire sensor node in the network. BS can compute the link and broadcast the message to all the nodes.Using Greedy algorithm constructed the chain and transmits the message through the nearest neighbour, if the node dies, then the chain is reconstructed in the same manner to bypass the dead node.

Dynamic Source Routing (DSR) is used for routing packets. It transmits the data through the packets from source to destination. If the destination host is not found then this mechanism will helps to find the route. Route Request (RREQ) and Route Reply(RREP)is helps to identify the route easily.

PDORP algorithm proposes the hybrid optimization based on PEGASIS-DSR routing protocol which utilizes the features of both proactive and reactive routing model. The method can be applied for the design of several types of sensor networks that require reliability, energy efficiency, scalability, prolonged network lifetime, and low end to end transmission delay without requiring location information. This protocol allows transmitting the data from source to destination node, it calculate the distance from the neighbour node. If the distance between the node is less than or equal to the threshold distance the transmission direction will be allotted. It accepts the minimum distance neighbor node should be in the direction of reaching node.The simulation results of our proposed protocol show reduction in end to end transmission delay and bit error rate without compromising with energy efficiency. In PDORP, both the proactive routing and reactive routing methodology have been used in order to obtain fast and non-damaged path along with lower transmission delay. The performance of PDORP has been evaluated by comparing with existing available methods viz.

III. Performance Analysis

In this section it helps to analyzes and compare the algorithms with various parameter types. It helps to identify the performance of the algorithms which are used here for experimental analysis. It supports to use the algorithms efficiently in the WSN research works. In Table1 it shows the types and the flexibility of the algorithms which supports to increase the energy efficiency, Packet delivery

ratio, Delay and so on. Performance analysis is evaluated by the same parameters and analyzes the result with simulation result done in ns2. In this analysis we differentiate the algorithms and its advantages. Some specialization types and its ratings are classified and mentioned below:

Table 1

Algorithm	Improved TL-LEACH	Improved QABC	REAC-IN	PDORP
Classification	Cluster Based	Cluster Based	Cluster Based	Path selection
Base Station	Fixed	Fixed	Fixed	Fixed
Route Selection	Adaptive	Reactive	Reactive	Hybrid
CH Selection	Yes	Yes	Yes	No
Scalability	Very Good	Low	Good	High
Energy Efficiency	High	High	Moderate	Very High
Latency	Low	High	High	Very High
PacketDelivery Ratio	Very Low	High	Low	Very High
Life Time	High	High	Moderate	Very High
Complexity	Low	Very High	Moderate	High

IV. Experimental Analysis

This experimental analysis is analyzed in network simulator (NS2) with equal number of parameters. In Table 2 it represents the simulation parameter setting. Main purpose of this section is used to find in which way the algorithms supports to increase the energy to the node.Each and every algorithm is supposed to increasing lifetime, efficiency, throughput and packet delivery ratio. Four different algorithms are compared which are improved TL-LEACH[11], improved QABC[12], REAC-IN[13], and PDORP[14]. Simulation results have shown that the best algorithm for energy efficiency and energy consumption.

The set of parameters are used in this experimental analysis is defined in the Table 2, deployment of nodes are randomly placed into the location. It is a sample network scenario from the point of network connectivity used to analyze the performance analysis, if the network size is increased then automatically the parameters also changed depends upon the size of the network. Parameter selection is highly important for analysing the algorithms.

Table 2: Simulation Parameter Settings

Width of the Network	1070m
Height of the Network	1070m
No.of Nodes	25 to 100
BS Location(x,y)	330,432
Initial Energy	100J

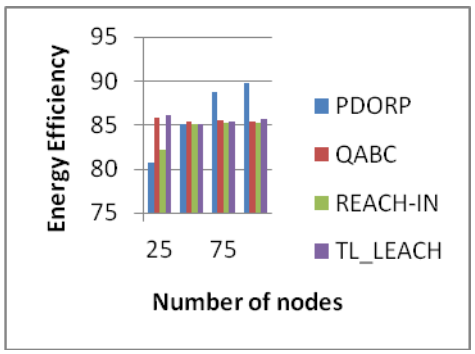
Energy consumption for sleeping	0J
Network Coverage	$\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
Simulation Time	40ms
Data packet Size	500 bytes
Bandwidth	1Mbps

4.1. Energy Efficiency in WSN

In Wireless sensor network energy efficiency is the major need to make network active. WSN are used in various applications like weather forecast, underwater, traffic monitoring, Forest and so on. Rechargeable and replaceable of battery is not possible in all the location. Initially each sensor node has equal energy level. For this experiment analysis the initial energy level is 100J for each node. It helps to transmit the message, gather the message and receive the message from other sensor node. At the time of each process the sensor node lost its energy from its initial energy. If the node lost its energy fully then automatically it can't able to do the process further.

During this experimental simulation, it calculates the residual energy of each node after the node completes its work. Depends upon the residual energy level of each node energy efficiency is identified. As per the analysis Fig. 4 Shows the comparison of energy efficiency of various algorithms which supports to increase the energy efficiency. If the number of nodes increased result may vary from the previous. Result analyzed by the network size. By this experiment the TL-LEACH shows the best result for energy efficiency while using less number of nodes in the network. QABC supports to increase the energy efficiency constantly while increasing the number of nodes. REAC-In gradually increases the efficiency of the network by little variations depends upon the size of the network. If the node count is increased then PDORP supports to gather more energy to extend the lifetime of the network than others. Experimental data value is shown in Table3.

Fig 4 Comparison of Energy Efficiency



No.Of. Nodes	PDORP	QABC	REAC-IN	TL_LEACH
25	80.6341	85.8627	82.1663	86.0779
50	85.073	85.3523	85.014	85.084
75	88.6875	85.4848	85.1848	85.4116
100	89.79	85.3753	85.2625	85.7143

4.2 Energy Consumption in WSN

Many researchers try to increase the network lifetime by energy consumption. It is evaluated by the low power consumption of each node to complete its work. After the time of transmission the energy level is calculated by how the algorithms consume energy for a particular process. If the process is done quickly then it may take less energy otherwise it will use more energy to do the process. It helps to increase the energy efficiency.In Fig 5. The graph displays the energy consumption of each node. The total energy consumption is also an important indicator to evaluate the network lifetime, network performance and reliability in wireless sensor network. The simulation result identifies the less energy consumed algorithm which helps to increase the energy efficiency in the WSN. TL-LEACH consumes less power than the others because TL-LEACH classified into layers. The layer-1 CHs are selected from the layer-0 sensor nodes, and then the layer-2 CHs are selected from the layer-1 CHs. TL-LEACH, QABC, REAC-IN shows the constant performance.TL-LEACH consumes less energy, if the network size is small. PDORP consumes more energy than others because it uses the path selection method and find out the trust worthy node to pass the message quickly. It supports for large network. Experimental data value is shown in Table4.

Fig: 5 Comparison of Energy Consumption using various numbers of nodes

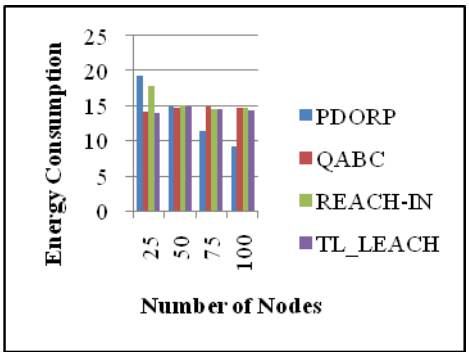


Table 4: Comparison values for Consumption

No.of. Nodes	PDORP	QABC	REAC-IN	TL_LEACH
25	19.3659	14.1373	17.8337	13.9221
50	14.92	14.6477	14.9852	14.916
75	11.3125	14.8152	14.5154	14.5884
100	9.20705	14.6247	14.7375	14.2857

4.3 Packet Delivery Ratio

PDR helps to evaluate the network energy level after successfully transmit the node from one to another. If the node not receives the packets correctly then it will send the message or it will wait for a long to receive the message. At that time the node lost its energy and network congestion is occurring. Packet delivery ratio also helps to increase the energy efficiency. As per experimental analysis Fig.6 shows the comparison results of the algorithms.In PDR analysis all the algorithms has the best performance, Because TL-LEACH has three layer approach it pass the information from one layer to another layer, if the message is not received by CH properly then automatically network congestion occurs in the WSN.If the network size is increased then QABC has the best result for PDR. It uses the

four different phases to connect the group to transmit the message.Experimental data value is shown in Table5.

Fig: 6 Comparison of Packet Delivery Ratio using various numbers of nodes

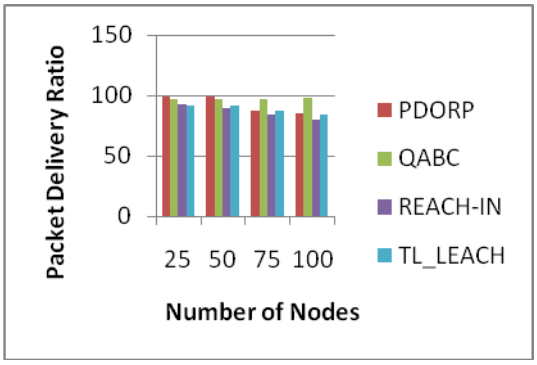


Table 5: Comparison values for PDR

No.of. Nodes	PDORP	QABC	REAC-IN	TL_LEACH
25	98.7686	96.6649	92.6649	91.0755
50	98.4639	96.8599	88.9328	91.1076
75	87.203	97.053	83.7543	87.6412
100	85.3807	97.7541	79.7541	83.6412

4.4. Delay time of Packet transmission

Delay depends on the sum of the times spent at each relay. Time taken to sending messages from one node to another is reduced then automatically PDR is increased and it helps to elongate the network lifetime. Messages are not delivered properly means it makes the hole between the network. Sometimes it takes lot of energy to waiting for message. This parameter also helps to increase the energy in the entire sensor node. Fig 7. Shows the comparison of delay time with same parameters and it supports to identify the algorithm which reduces the delay time to transmit the messages. Delay time duration is calculated by difference between the time of node sending and receiving the message from sensor node to CH and it calculate the transferring time between the CH to Base station. QABC helps to reduce the delay time between the transmissions, if the network size is less. During the number of nodes increased the experimental analysis shows PDORP has the less delay time than the other algorithms. This algorithm selects the path to transfer the information and verify the trust worthy node and accept the acknowledgment from the node it pass the information to the node. It can easily avoid the delay. Experimental data value is shown in Table 6.

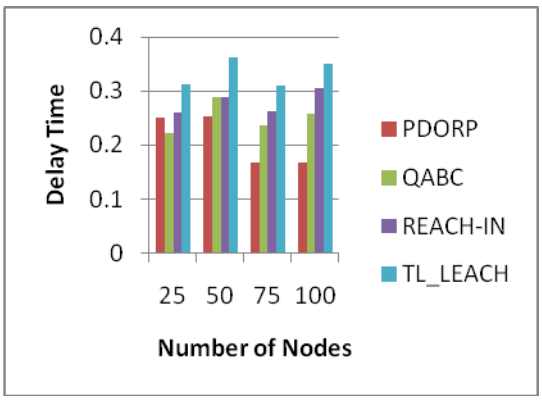


Fig: 7 Comparison of Delay Time using variousnumbers of nodes

Table 6: Comparison values for Delay

No.of. Nodes	PDORP	QABC	REACH-IN	TL_LEACH
25	0.2511	0.2215	0.2611	0.3131
50	0.2523	0.2877	0.2894	0.3624
75	0.1687	0.2378	0.2616	0.3111
100	0.1686	0.2591	0.3044	0.3508

V. Conclusion

The main objective of this work is to find out the specialization of the algorithms which extends the lifetime. This paper analyse the performance evaluation of various recent algorithms like TL-LEACH, QABC, REACH-IN, PDORP. Same numbers of parameters are used to analyse the experimental result. The paper analyzed with (i) Energy Efficiency, (ii) Energy consumption, (iii) Packet Delivery Ratio, and (iv)Delay. It has been observed that the algorithms have different methodology to increase the lifetime of the nodes. While compare energy efficiency of the nodes in the network TL-LEACH performs wellfor less number of nodes in the network it has the layered approach, so it passes the information quickly and it consumes less energy to transmit messages. While compared cluster based algorithm like TL-LEACH, QABC, REAC-IN algorithms,QABC performs well for large network to increase the energy efficiency. PDORP is not a cluster based approach; it supports path selection procedure to communicate with the other nodes easily. It passes the information with trust worthy node and helps to increase the energy efficiency for large network. Finally each and every algorithm compared in this experiment supports to increase the lifetime of the network. Every algorithm has the individual specialization to improve the energy by different ways. This work helps to identify the algorithms and its methodologies to prolong the network lifetime.

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