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Network Lifetime and PDR Analysis of QoS Aware Routing Protocol for EH-WSN

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Abstract
Wireless Sensor Networks (WSNs) becomes more popular day by day which contains number of sensor nodes which monitors physical conditions of surrounding and transmit collected data to the Base Station or sink node for further process. Recently energy harvesting technology is integrated with WSN to power up sensor node due to limited capacity of primary battery of sensor node. In this paper we have proposed QoS aware routing protocol with solar energy harvesting technique. After simulation we analyzed the network lifetime and packet delivery ratio(PDR) of energy harvesting WSN by using proposed protocol with different number of nodes and compared results with existing LEACH protocol. We have used Network Simulator 3(NS-3) for simulation purpose. The simulation results shows that the proposed protocol has better performance in network lifetime and PDR as compared with existing protocol.
Key words: LEACH, network lifetime, PDR, solar energy harvesting, WSNs.
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I. Introduction

Wireless sensor network(WSN) is a network in which number of sensor nodes are deployed in monitoring area to sense physical conditions like temperature, noise, humidity, vibrations, pressure, pollution etc., to process the data and transmit data to the base station or sink node wirelessly. Sensor node is small embedded device which consist of sensing, processing, communication and power unit. Recently WSNs are used in most of the fields like medical surveillance, industrial, home automation, environmental monitoring, military monitoring, underwater etc. WSN are low powered and self organizing network which has flexible installation in environment for various applications. Though applications of WSN are in various fields, still there are some issues like synchronization, coverage, energy consumption, end to end communication delay, lifetime, security etc. [1]

As WSN are deployed mostly in remote area where human being cannot reach easily, in this situation after discharging of primary battery of sensor node replacement or recharging of battery is impossible. To overcome this issue the energy harvesting technique is best solution to recharge the sensor node battery. The energy harvesting nodes can harvest ambient energy from sources which are present in environment like wind, solar, mechanical, vibration, RF etc. and store the harvested energy in battery for current and future use. By using this technique sensor node uses harvested energy and network operates continuously, so EH-WSN has longer lifetime [2].

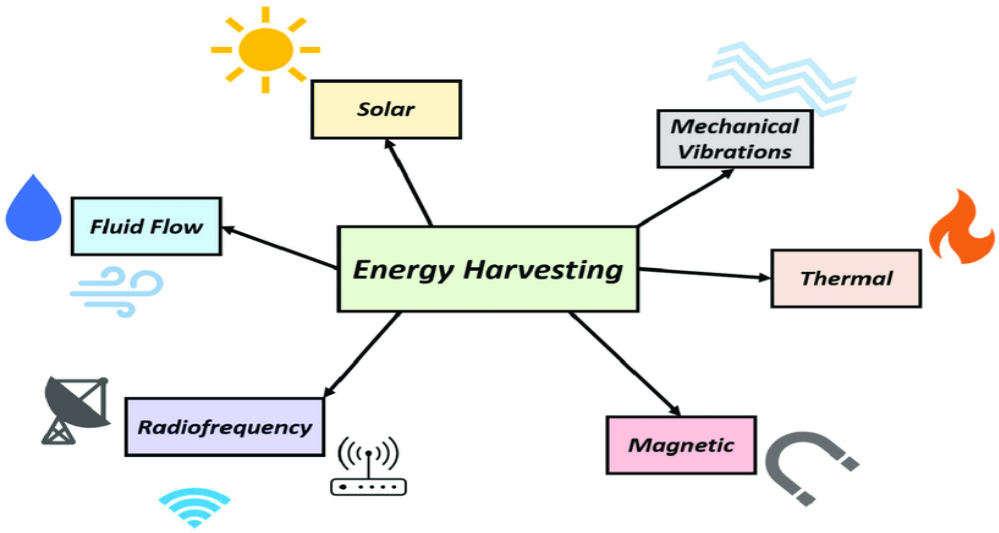

Fig.1 Energy harvesting sources [2]

In this paper solar energy harvesting technique with QoS aware routing protocol is discussed. Routing protocol is a process to select suitable path for transmitting data from source node to BS or sink node. In WSN Low Energy Adaptive Clustering Hierarchy (LEACH) is most popular routing protocol which is used to minimize power consumption [3]. We have proposed a modified LEACH protocol with solar energy harvesting to enhance the network life and packet delivery ratio. We analyzed network lifetime and PDR of QoS aware routing protocol with different number of nodes.

II. Related Work

Sivakumara et. al [4] used LEACH-GA to select an optimal cluster head based on optimal value of cluster head probability using Genetic Algorithm (GA). This proposed protocol is compared with LEACH AND LEACH-C protocol. The simulation and analysis results showed that by varying initial energy of network LEACH-GA has better network lifetime as compared with LEACH AND LEACH-C. Kamble et. al [5] has implemented Distributed Energy Efficient (DEEC) Protocol and Energy Aware Multi-hop Routing (EAMR) Protocol to enhance the performance of network by using LEACH protocol. They compared performance of implemented protocols with scheme has better lifetime as compared with LEACH and analysis is done on the basis of network lifetime, energy consumption, scalability, node death rate and stability of network, which gives better energy efficiency to enhance the network lifetime. Sharma et. al [6] have proposed Energy Harvesting, Traffic and Energy Aware Routing (EHTEAR) Scheme for the multi-heterogeneous and energy-harvesting WSN scenario. EHTEAR considered nodes' initial energy, residual energy, traffic requirements and energy-harvesting capabilities during cluster-head selection. The simulation results show this proposed existing algorithm like LEACH, DEEC and TEAR. Tang et. al [7] have studied the hierarchical routing protocol of utilizing the harvested energy efficiently for EH-WSN. They have analyzed The problem of maximizing the minimum energy conservation among the sensor node and proved its computational NP-hardness and also developed develop a polynomial time algorithm. The simulation showed that the proposed scheme has better performance improvements as compared with existing once. Bindaj et. al [8] have proposed an energy-aware clustering routing protocol for EH-WSNs. They have exploited a neural network based solar energy prediction model to improve the utilization efficiency of the harvested energy. CH selection is done on the basis of higher residual energy and stronger energy harvesting capabilities. They proved by using proposed protocol throughput, number of awake nodes and node energy of EH-WSN is improved. Priyanka et. al [9] have analyzed the effect of node placement in routing algorithm for energy homogeneous and heterogeneous WSN with and without using the harvesting energy. The simulation results showed that by using energy harvesting technique stability period of network is increased. By using proposed improved cluster head selection method energy

efficiency is enhanced in terms of improved stability period under different node placement scenario. Harish et. al [10] have studied robustness analysis and comparative analysis based on various network parameters and proposed Optimized and Energy Efficient Routing Scheme (OEERS) algorithm for WSN. The analysis result showed the robust network performance of the designed sensor network in the multi-level heterogeneous environment for various network parameters and comparative analysis has better performance of OEERS as compared to DL-LEACH scheme for all the corresponding network performance parameters. Rasyid et. al [11] have proposed Two Layer LEACH based on area Partition (TL-LEACH-P) routing algorithm to to decrease the energy consumption of network. The simulation is done with different numbers of clusters and they concluded that the TL-LEACH-P) routing algorithm has better improvement as compared to LEACH in terms of node remaining energy, network lifetime, first node die (FND), half node die (HND), and all node die (AND). Bhola et. al [12] have provided a new Distributed Energy Efficient Clustering Protocol with Enhanced Threshold (DEECET) to enhance the network lifetime as compared with previous probabilistic protocols. This protocol optimized the utilization of energy resources in WSN. Power consumption is mail benefit of this protocol. Son et. al [13] have proposed an energy-efficient cluster management using a mobile charger for Solar-Powered Wireless Sensor Networks (SP-WSN) for continuous operation of network. This is done to minimize the data loss due to blacked out nodes and also to ensure the maximum possible nodes. The proposed scheme is used to collect more data than the other schemes, and also achieved higher efficiency as the number of nodes increased. Komuraiah et. al [14] developed Numerous strategies and procedures to enhance efficiency and lifetime of WSN and also developed agenetic algorithm-based approach and clustered sensor node to improve scalability, robustness, and decreased network traffic. This proposed genetic algorithm optimizes the route to discover the quickest method to communicate the data. The simulation result showed that genetic algorithm based approach has better lifetime as compared with LEACH. Zareei et. al [15] have studied the effect of using adaptive transmission power control for energy harvesting sensors in both clustered and non-clustered networks. They have used a simple energy-based clustering, greedy routing, and relatively simple power control mechanism to prove the efficiency and proved that a basic power control can still improve the clustered network performance further and help the network to achieve better end-to-end performance. Haq et. al [16] proposed a new clustering protocol to achieve maximum stability period in order to enhance packets delivery rate at BS and a CH selection is based on a formulated parameters. After simulation results they concluded that there is improvement in overall residual energy in the network, stability and throughput of the network for the maximum time period. Yousif et. al [17] have proposed a novel energy-efficient routing protocol to make WSN more sustainable and optimize their operation in smart cities. The CH selection is on the basis of residual energy and distance from BS. The analysis of network lifetime and Node Death Ratio (NDR) is done by varying number nodes with 50, 100, 200 and 500. The simulation results proved that the performance of proposed protocol has better performance as compared with direct transmission and LEACH.

III. LEACH Protocol

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is TDMA based routing protocol which is proposed to balance the energy consumption among the nodes and to enhance the lifetime of network. In WSN LEACH is most popular hierarchical routing protocol for clustering. Each cluster has one cluster head node and others cluster members nodes, cluster member transmit their sensed data to the CH and CH aggregates the collected data and send to BS or sink node. The operation of LEACH protocol can be divided into number of rounds and each round consist of two phases i.e. set up phase and steady state phase [18].

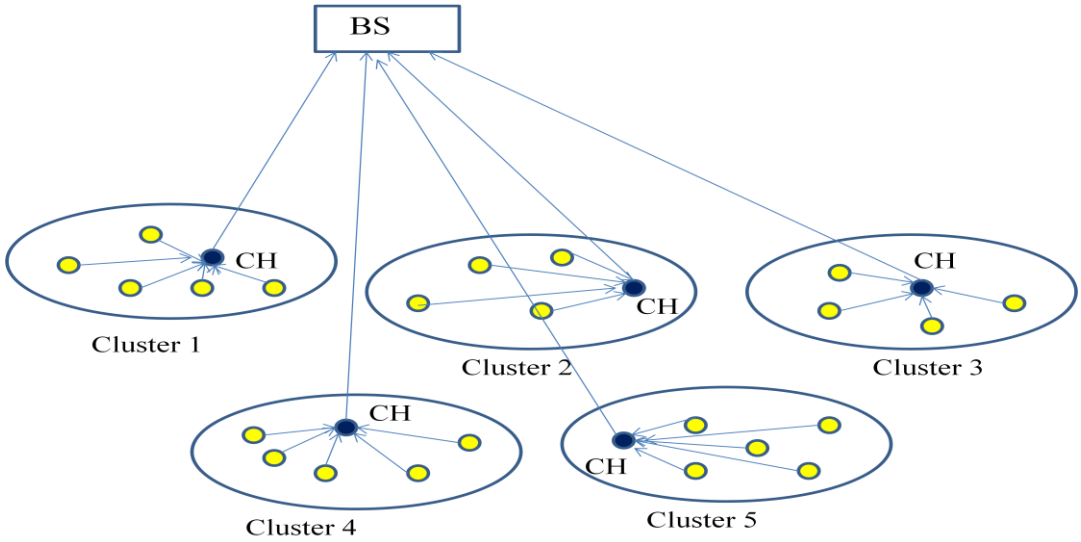

Fig.2 LEACH Protocol

3.1 Set up phase

In this phase cluster head selection, cluster formation and creation of transmission schedule is take place. Initially the sensor node which wants to be cluster head choose a random number (n) between 0 and 1 and if this number is less than threshold value calculated by eq. number (1), then the node is selected as a cluster head. After selection of CH, CHs send advertisement message to other node to inform that they become CHs. Depending on strong signal strength of advertisement message neighboring nodes send joint request message to corresponding CH and cluster is formed. After cluster formation CH creates TDMA based transmission schedule for respective cluster member to transmit their data only in particular timeslot.

$$T(n) = \begin{cases} \dfrac{P}{1 - p \times [r \bmod (1/p)]}, & \text{if } n \in G, \\ 0, & \text{elsewhere} \end{cases} \quad (1)$$

Where,
p = probability of cluster head selection = k/N (k-expected number of CH, N-total number of nodes), r = round value, n = sensor node, G = current round of nodes which has not become a cluster head in the 1/p round.

3.2 Steady state phase

In this phase data transmission by cluster member, data aggregation and transmission of data by CH to the BS takes place. Cluster members transmit their sensed data to the CH only in particular timeslot which is scheduled by respective CH. CH collects data from cluster members aggregates the data and transmit to the BS or sink node [19].

IV. Solar energy harvesting in WSN

As we know solar energy harvesting is most popular source of energy harvesting as it is easily available, reliable, convenient and renewable source of energy. Solar energy harvesting based on photovoltaic technology with highest power density about 15mW/cm^2. Light energy is converted into electrical energy by using solar panel which consists of number of solar cell. The harvested energy is used to recharge the battery of sensor node [20]. Fig.3 shows solar energy harvesting model which consist of solar panel to convert solar radiations into electrical energy, DC-DC converter to convert high DC voltage to low DC voltage as per requirement, charge controller Pulse Width Modulation (PWM) or Maximum Power Point Tracking (MPPT), rechargeable battery to store the harvested energy and finally the harvested energy is given to the sensor node.

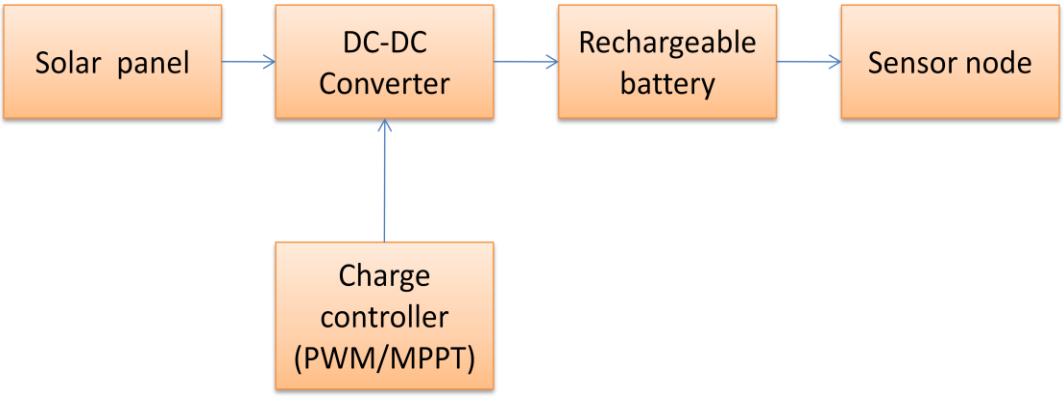

Fig.3 Solar energy harvesting in WSN

Solar panel is made up of number of solar cells which are connected in parallel and series to absorb the solar radiations and convert it into electrical energy. Solar cell is a semiconductor device. When solar energy is incident on solar cell or photovoltaic cell, electron hole pairs are generated and current flows through electronic device.

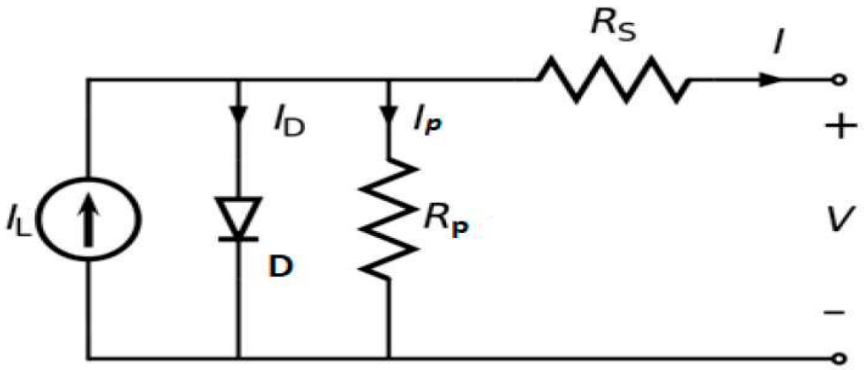

Fig.4 Equivalent circuit of Solar cell[21]

Fig. 4 shows equivalent circuit of solar cell and the IV equation of this circuit is given by:

Solar cell current:

$$(I) = I_L - I_0\left[\exp\left(\frac{q(V+IR_s)}{nkT}\right)\right] - \left(\frac{V+IR_s}{R_p}\right) (2)$$

Where, I= total output current of solar cell, I_L= current generated by solar cell, I_o= reverse saturation current, q= charge of electron ($1.6\times10^{-19}C$), V = open circuit current of solar cell, n = diode ideality factor, k = Boltzmann's constant $(1.38\times10^{-23}$ J/K, T= Temperature of solar cell, R_s=series resistance, R_p=parallel resistance.

V. Proposed Work

As we know the communication of LEACH protocol is take place in number of rounds and each round has set up phase and steady state phase.CH collects, aggregates and transmit data to the BS. In wireless scenario most of the energy is consumed during communication. In LEACH protocol only CH has directly communication with BS or sink node, due to this CH requires more energy than other nodes. So CH node dies earlier after serving as a cluster head, if CH dies then data collected by cluster member can't reach to the BS and networking gets disturbed. Considering this demerits we have proposed a new scheme for selection of CH on the basis of residual energy and distance from BS. Due to high residual energy CH work for long time and due to minimum distance from BS it requires less time for data transmission.

In LEACH protocol CH selection is done at every round but in proposed work CH selection is takes place only once on the basis of residual energy and distance from BS, due to this time required for selection of CH in every round is saved and delay will be decreased. As we know CH requires more energy than other nodes, we apply solar energy harvesting technique to recharge the battery of CH for continuous operation of network. In solar energy harvesting light energy (sunlight) is converted into electrical energy by using solar

panel with highest power density of around 15mW/cm^2. Solar panel is arrangement of multiple solar cells which are connected in parallel and series to absorb sunlight. Solar cell is semiconductor device which converts light energy into electrical energy. So by using solar energy harvesting technique with modified LEACH protocol network lifetime and packet delivery ratio of EH-WSN in enhanced as compared with existing LEACH. In this paper analysis of the Network lifetime and PDR is done with respect to different numbers of nodes in the network. Here we considered varying node density such as 50, 100, 300 and 500.

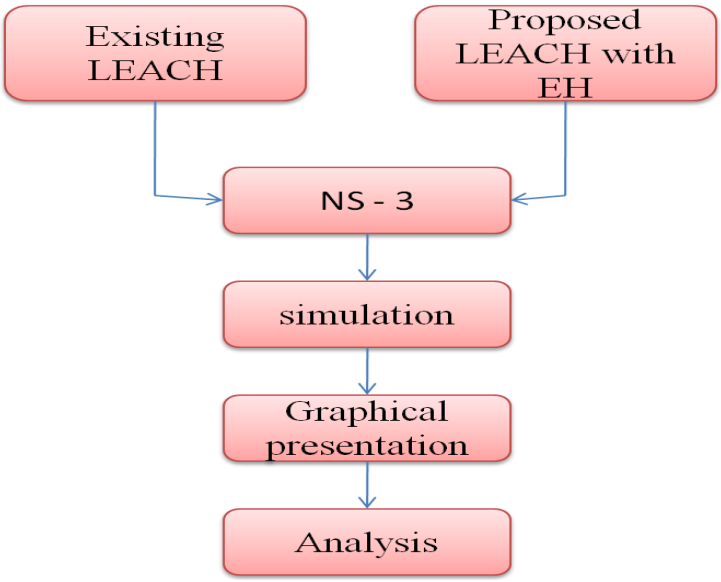

Fig.5 System design

VI. Results and analysis

The simulation of proposed QoS aware routing protocol is done with the help of Network Simulator-3 (NS-3) software. The analysis of network lifetime and PDR is takes place by varying number of nodes in the network. Result of both parameters is analyzed with 50, 100, 300 and 500 nodes by simulation. To design simulation model we have assumed some simulation parameters which is shown in Table 1.

Table 1 Simulation parameters

Sr.No.	Parameters	Values
1.	Network area	100m*100m
2.	Number of nodes	50,100, 300, 500
3.	Initial energy of sensor nodes	0.75J
4.	Base Station location	(100, 100)
5.	Data packet size	1600 bits
6.	Number of rounds	1500
7.	The cluster probability	0.3

6.1 Analysis of Network Lifetime:

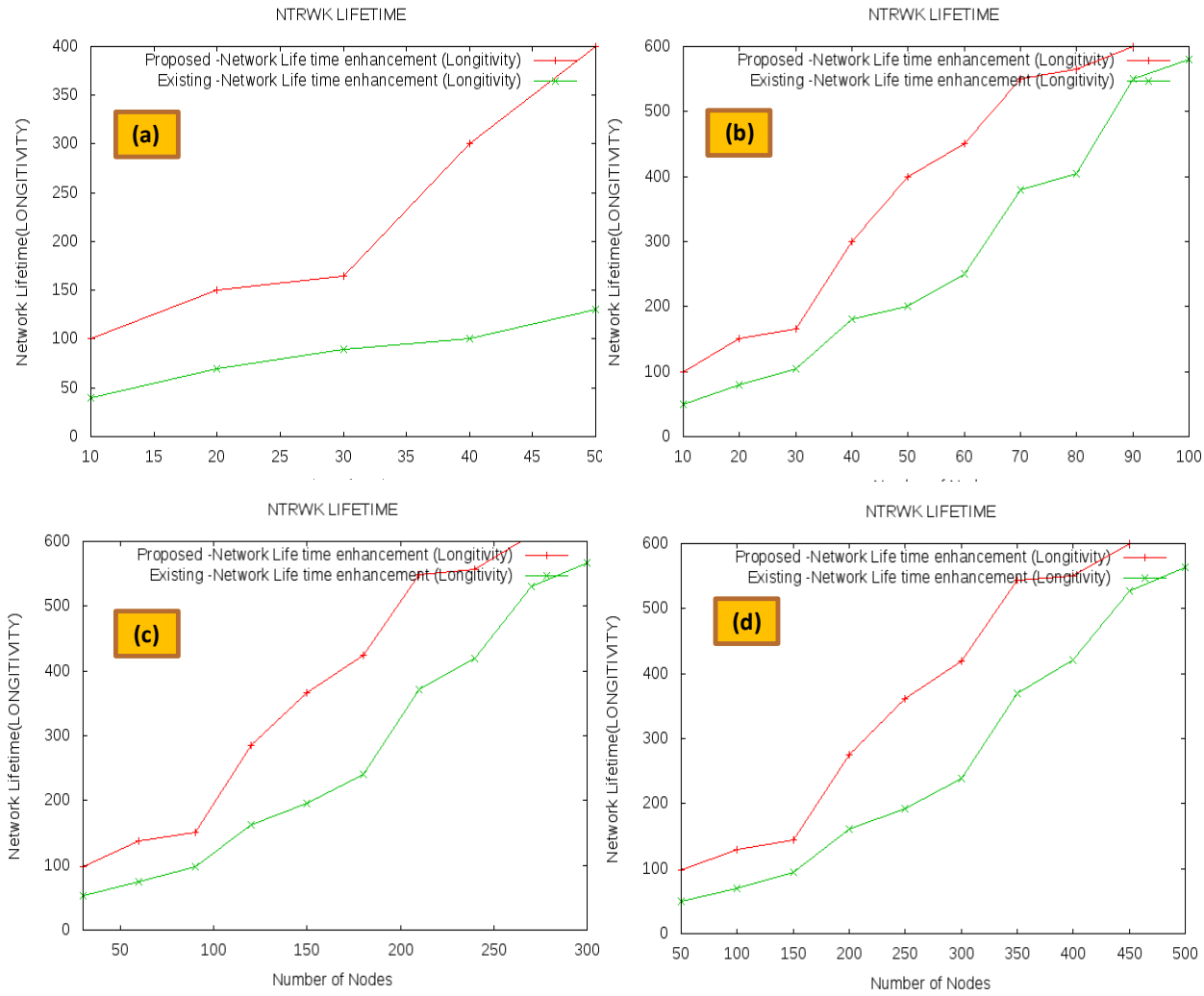

Fig.6 Analysis of Network Lifetime w.r.t. (a) 50 nodes (b) 100 nodes (c) 300 nodes and (d) 500 nodes

Network Lifetime is the time until which first sensor node run out of energy to send data packets. Network lifetime measures in terms of alive nodes presents in a network. Fig. 6 shows analysis of network lifetime with varying node density with size of 50, 100, 300 and 500. From figure we can see the existing LEACH protocol without using solar energy harvesting has minimum network lifetime because after discharging of primary battery of sensor node, node will be off and network collapse. But after applying solar energy harvesting technique with QoS aware routing protocol, sensor node battery has charged from harvesting energy so node survive for long time and network lifetime is enhanced as compared to LEACH. This is proved by using simulation method. Fig. 6 shows network lifetime vs number of node. The simulation result shows that by using solar energy harvesting technique with proposed LEACH protocol network lifetime is enhanced as compare with basic LEACH protocol.

6.2 Analysis of PDR:

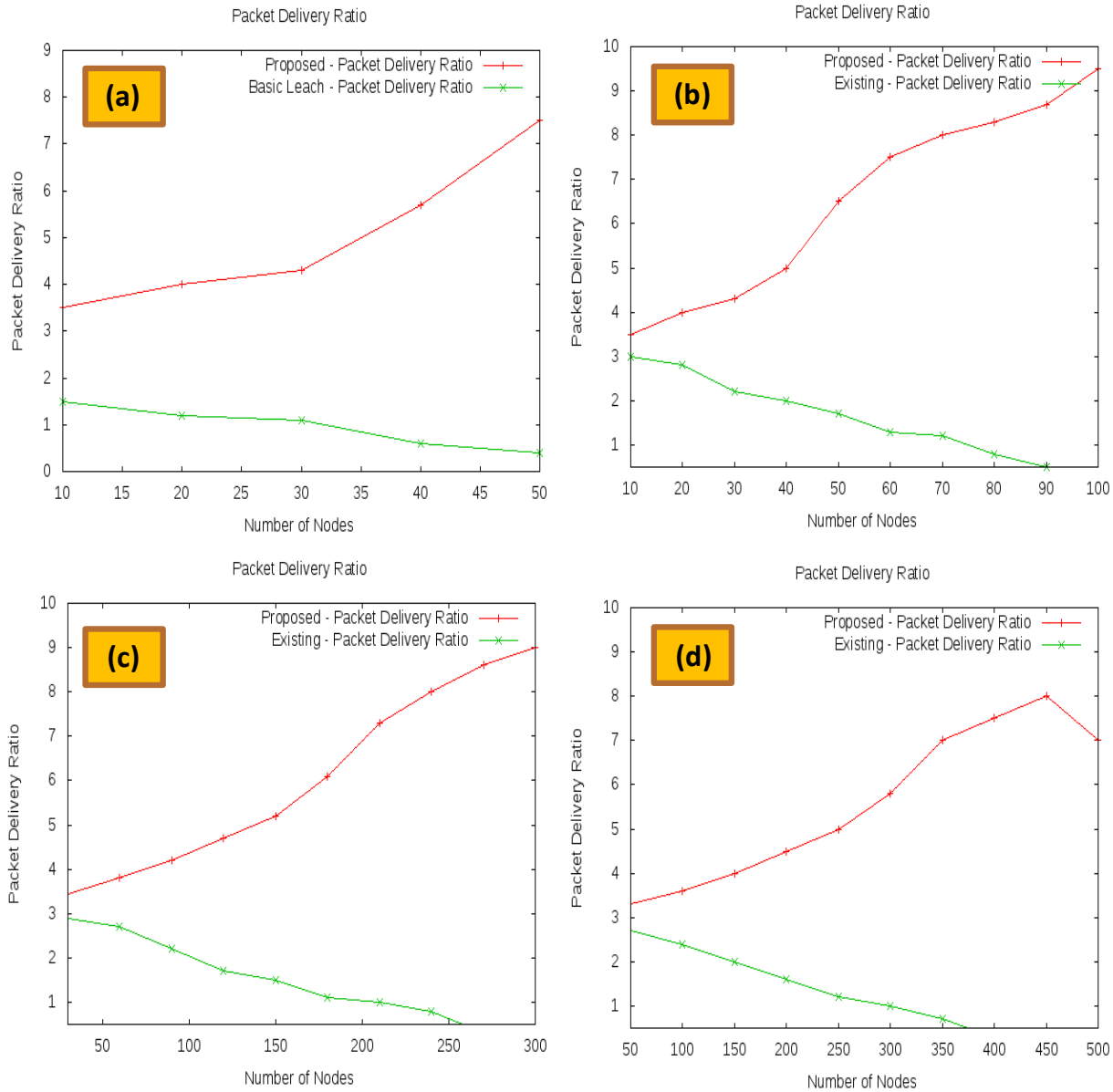

Fig.7 Analysis of PDR w.r.t. (a) 50 nodes (b) 100 nodes (c) 300 nodes and (d) 500 nodes

PDR is ratio of total number of data packets received at destination to the total data packets sent from sources. Fig. 7 shows analysis of packet delivery ratio with varying node density with size of 50, 100, 300 and 500 nodes. In existing LEACH protocol without applying solar energy harvesting technique packet delivery ration is less due to less network lifetime. But due to long operational period of sensor node, after discharging of battery, by using solar energy harvesting technique with QoS aware routing protocol node survive for more time and packet delivery ratio increases due to increased network lifetime. This is proved by simulation that packet delivery ratio of WSN by using solar energy harvesting technique with proposed LEACH protocol is enhanced as compare to basic LEACH protocol. From figure we can see up to 450 nodes PDR of network is increased with increased node density but after 450 nodes PDR of proposed protocol is slightly decreased with increased node density.

VII. Conclusion

In this paper the QoS aware routing protocol with solar energy harvesting technique for WSN to enhance the network lifetime and packet delivery ratio (PDR) is implemented. This protocol was designed to overcome limitation of existing

LEACH protocol by selecting CH on the basis of residual energy and distance from base station. We have analyzed the results of network lifetime and PDR with varying number of nodes density with size of 50, 100, 300 and 500 nodes. From simulation result we concluded that after applying solar energy harvesting technique with QoS aware routing protocol the network lifetime is enhanced as compared to existing LEACH. From analysis of PDR we have concluded that PDR with proposed protocol is increased with increased number of nodes but after 450 nodes PDR of network is slightly decreased. .

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