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
Energy Efficient AODV Routing in Wireless Sensor Network based on PSO

 S. Ravi Kumar and Dr.D. Sreenivasa Rao

Abstract

WSN is individual of the supreme important technologies that typically consist of a large amount of WSN through detecting, correspondences and calculation abilities. The continued activity of WSN is accomplished through the productive utilization of hub vitality. The existing literatures in routing find the destination with shortest path but with high energy consumption and decreased throughput. At this, we suggest an energy efficient routing in WSN based on PSO. The work is preceded by routing the packets from source node to destination by utilizing AODV routing protocol. The energy efficiency shortest path along with less energy consumption is selected by using PSO algorithm. The scheme is applied in the working platform of Network Simulator- Version 2 (NS2). The results are analyzed with the metrics such as throughput, delay, network life time, and delivery ratio and energy consumption. Results showed that the planned PSO algorithm outperforms the existing method with best energy efficiency rate.

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Energy efficient AODV routing in Wireless sensor network based on PSO

¹S. Ravi Kumar, ²Dr. D.Sreenivasa Rao,

¹*Research Scholars, Department of ECE, JNTUH.*

²*Professor, ECE Department, JNTUH.*

¹*Email: ravikumars789456@gmail.com*

Abstract

Wireless Sensor Network (WSN) is one of the most important technologies that typically consist of a large number of wireless sensor nodes with sensing, communications and computation capabilities. The sustained operation of WSN is achieved through the efficient consumption of node energy. The existing literatures in routing find the destination with shortest path but with high energy consumption and decreased throughput. In this paper, we propose an energy efficient routing in wireless sensor networks based on PSO. The work is preceded by routing the packets from source node to destination by using Ad hoc On demand Distance Vector (AODV) routing protocol. The energy efficient shortest path along with less energy consumption is selected by using Particle Swarm Optimization (PSO) algorithm. The system is implemented in the working platform of Network Simulator- Version 2 (NS2). The results are analyzed with the metrics such as throughput, delay, network life time, and delivery ratio and energy consumption. Results proved that the proposed PSO algorithm outperforms the existing method with best energy efficiency rate.

Keywords: Energy efficient, Ad hoc On demand Distance Vector (AODV), Particle Swarm Optimization (PSO), Energy consumption

1. Introduction

Wireless sensor networks (WSN) have been deployed in various applications to collect information from human body, battle fields, smart power grids, Interstate highways etc [1]. It has seen tremendous growth to support Quality of Service (QoS) and Quality of Expectation (QoE) requirements of diverse applications with increasing number of users [2]. The network composed of hundreds of sensor devices that communicate wirelessly with limited

energy consuming routing protocols [3]. Sensors are subjected by their physical limitations on hardware, storage space, computational power etc [1]. Routing in wireless network is different from other wireless networks due to sensor nodes which have constraints of energy, processing activities, transmitting collected data from multiple nodes to a single sink. A routing protocol specifies how routers communicate with each other, distributing information that enables them to select routes between any two nodes on a computer network. Routing algorithms determine the specific choice of route. Network life time can be increased by implementing routing protocols that consume less energy, choose path between sensor nodes and base stations [4]. Designing energy-efficient sensor networks is a key challenge in the intelligent use of battery energy. Recent studies are interested in the power control of transmitters, residual energy-based channel assignment, and combining network coding and CR.

Open research issues include the development of cross-layer approaches for MAC, routing or clustering protocols that take advantage of cognitive radio opportunities [5]. At the physical layer, a variety of modulation, synchronization, and antenna techniques have been designed for different network scenarios and applications. Whereas, at higher layers, efficient communication protocols have been developed to address various networking issues, for example medium access control, routing QoS, and network security [6]. The major source of energy consumption in the sensor nodes is their radio communication employed by their transmitter. Medium access control (MAC) protocols arbitrate sensor node's access to the channel [7]. Energy efficiency is considered to be a crucial issue due to the limited battery capacity of the sensor nodes. An effective mobile sink routing protocol should also avoid an extreme increase in the sensor data delivery latencies [8].

One of the inherent limitations of a wireless sensor node is its limited energy resources for use. Each WSN sensor node is battery operated, making battery recharging or replacements difficult or even impossible [9]. Utilizing the energy efficiently will extend the lifetime of WSN [10] [7]. The other major constraints of WSNs are the limited and generally irreplaceable power sources of the sensor nodes. However, reducing energy consumption of the sensor nodes is considered as the most critical for long run operation of WSNs. Energy efficient clustering and routing algorithms are the most two promising areas that have been studied extensively for WSNs [9]. The energy of a WSN can be saved by applying different techniques, such as duty-cycle scheduling, energy-efficient MAC (Medium Access Control), energy-efficient routing, node replacement, energy harvesting, energy replenishment and energy balance [11]. Some other challenges in WSN include high bandwidth demand, security, quality of service

(QoS) provisioning, data processing and compressing techniques and cross-layer design. Mobile nodes have the ability to sense, compute, and communicate like static nodes.

The contribution of the paper is organized as follows: section 2 illustrated the review about existing literatures in wireless routing. Section 3 depicts the problems found in existing literatures and the objectives of the proposed method. Section 4 and 5 details about proposed methodology and results obtained for the proposed method. Section 6 concludes the paper with future extension of the work.

2. Literature Review

Rajesh et. al [12] have proposed a new regional energy aware clustering method using isolated nodes for WSNs, called Regional Energy Aware Clustering with Isolated Nodes (REAC-IN). In REAC-IN, CHs were selected based on weight. Weight was determined according to the residual energy of each sensor and the regional average energy of all sensors in each cluster. Improperly designed distributed clustering algorithms can cause nodes to become isolated from CHs. Such isolated nodes communicate with the sink by consuming excess amount of energy. To prolong network lifetime, the regional average energy and the distance between sensors and the sink were used to determine whether the isolated node sends its data to a CH node in the previous round or to the sink.

Zhang et. al [13] have reviewed existing routing algorithms in the WSN and proposed a new method called Memetic Algorithm Based Hybrid Routing Protocol (MAHRP). The greater part of the consideration, nonetheless, has been given to the directing conventions since they may contrast depending upon the application and network structure. To build the life range of each mote, planning effective directing conventions was basic. Routing protocols in wireless sensor networks were being self-addressed to boost the usage of restricted network resources. Nature Inspired memetic algorithms were proved to be beneficial for solving many real world combinatorial problems.

Zaman et. al [14] have demonstrated an Energy- Efficient Heterogeneous Ring Clustering (E2HRC) routing protocol for wireless sensor networks was proposed and corresponding routing algorithms and maintenance methods are established to solve the energy balance problem in original RPL (IPv6 Routing Protocol for Low Power and Lossy Networks). A new clustering algorithm and event-driven cluster head rotation mechanism were also

proposed based on this topology. The clustering information announcement message and clustering acknowledgment message were designed according to RFC and original RPL message structure. Experimental results show that in comparison against the original RPL, the E2HRC routing protocol more effectively balances wireless sensor network energy consumption

Patel et. al [15] have demonstrated an energy efficient routing protocol, known as Position Responsive Routing Protocol (PRRP) to enhance energy efficiency of WSN. Position responsive routing protocol differs in several ways than other existing routing techniques. Position response routing protocol approach allows fair distribution of gateway or cluster head selection, maximum possible distance minimization among nodes and gateways or cluster heads to utilize less energy. Position responsive routing protocol shows significant improvement of 45% in energy efficiency of wireless sensor network life time as a whole by increasing battery life of individual nodes. Furthermore PRRP shows drastic increase for data throughput and provide better solution to routing energy hole due to it fair distributed approach of gateway selection

Zaman et. al [16] have proposed hierarchical routing protocols for minimizing energy consumption at the sensor nodes. One of the major design challenges in WSN is to minimize consumed energy at the sensor nodes. Hence, a number of routing schemes are designed that make efficient use of limited energy of the sensor nodes. Hierarchical routing protocols were best known in regard to energy efficiency. At first implemented routing strategies using Q-routing algorithms and compared them for the energy efficient aspects. Next, an energy efficient shortest path Q-routing algorithm using Reinforcement Learning property of ML techniques was developed and compared it with an existing energy aware Q-routing algorithm. They have applied those algorithms on different topologies like heterogeneous, homogeneous and introduced a novel hybrid topology by combining heterogeneous and homogeneous topologies

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of individual nodes. Furthermore PRRP shows drastic increases for data throughput and provide better solution to routing energy hole due to it fair distributed approach of gateway selection.

Azharuddin et. al [18] have demonstrated a cognitive neural network learning algorithm namely restricted Boltzmann machine (RBM), to detect the routing-based distributed denial of service attacks in dynamic source routing (DSR) protocol. RBM is a stochastic and unsupervised learning algorithm that self-learns the network conditions by using its reasoning capability and segregates malicious routes in the route cache using context-aware trust metrics such as reputation and energy consumption implemented in North Bound Application Programming Interface.

3. Problem definition

Wireless sensor nodes have the problem of high bandwidth demand, insecure transmission, high energy consumption, quality of service provisioning, data processing, compression and cross- layer design. Lot of researches exists till date does not consider the problem of energy efficiency. The conventional on-demand routing protocols does not consider the mobility of the mobile nodes in the routing path selection. They are almost based on shortest path and hence needs to find the alternative path or re- route constantly. This produces large broadcasting overhead with high power consumption and bandwidth wastage [18]. Energy efficiency becomes the most important issue to be considered while on designing the wireless sensor networks. Since sensor nodes are battery powered, they have limited energy capacity. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Major drawbacks found in conventional routing protocols are:

- More complex to configure and understand
- Does not support multiple paths for the same route
- Converges slowly, especially on large networks

Objectives

The major objectives found in this proposed methodology include:

- Requires less computation time
- Requires less bandwidth for routing updates
- Uses delay, bandwidth, reliability and load of the link. This helps in accurately selecting the proper routes.

4. Proposed Methodology

Wireless sensor networks are a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at the central location. Wireless sensor networks have the constraint of limited and generally irreplaceable power sources of the sensor nodes. Mobile Ad-Hoc Network is the infrastructure less network. MANET consists of randomly deployed nodes connected by various links. Important issues in MANET are link failure, power failure of node, limited bandwidth and limited transmission power. The energy efficient routing is the most important criteria for MANETs, since mobile nodes will be powered by batteries with limited capacity. Overall network lifetime is affected by reduced power failure of a mobile node and its ability to forward packets. In our paper, we propose Particle Swarm Optimization (PSO) based Ad- Hoc On demand Distance Vector (AODV) routing protocol have been designed to overcome the problem of energy efficiency in given figure 1.

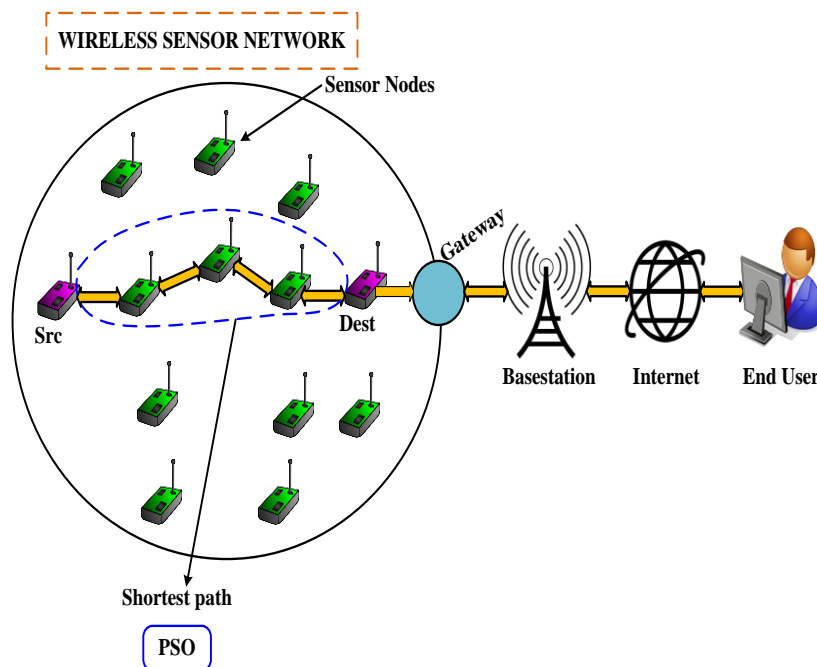


Figure 1: Block diagram of proposed methodology

4.1. Ad- hoc On demand Distance Vector (AODV) routing protocol

The routing of the packets from source to destination is deployed based on AODV protocol. The main objective of using AODV is Minimum energy (ME) routing that selects the route with least total energy consumption for packet transmission, and max–min routing that selects the route which bottleneck residual node energy is the maximum. AODV is a single path routing protocol and is divided into two parts:

- Detection of topology and construction of the initial population of solutions
- Routing management

Topology detection

Ad hoc on demand routing protocol in mobile ad hoc network provides unicast, multicast and broadcast operations. Ad hoc On demand Distance Vector (AODV) is a popular single path routing protocol. It creates route, when a node requests for packets. The packets are traversed through the network before it reaches the destination. Once the packet reaches destination, source node stops sending packets and timed out. Each node in the routing protocol has the routing table entry for the destination and have elements such as hop count, next hop and sequence number. Sequence number serves as the time stamp for determining the route of the node [19]. The node that transfers high sequence number is selected for routing with the destination because the node with higher sequence number will have more accurate route information. AODV consists of two modules: Route Discovery and Route Maintenance.

Route discovery

It utilizes RREQ (Route Request) and RREP (Route Reply) control packets. When a source node needs to transfer packets to the destination, it sends RREQ packets towards the nearby neighbors. If any node in between is found as the destination node, it responds back by RREP message to the source node. When the source node receives RREP, the route is established and the packets are transmitted along it. If there is no route to the requested destination, it can then rebroadcast RREQ to the nearby nodes.

Route maintenance

It utilizes RERR (Route Error) packet. All nodes monitor their own neighborhood. When the route is broken or be invalid, a Route Error message (RERR) is generated to notify the other nodes that use this route, that the route becomes invalid. This message is generated to avoid retransmitting by that route.

Advantage of using AODV protocol

- AODV has a capability of quickly adapting to dynamic link condition.
- Beside that, it is able to deal with a low processing, network utilization and also memory overhead.
- The main aim for the designing of AODV protocol is for reducing the overhead.
- Loop free, on demand
- AODV minimizes the number of broadcasts by creating routes on-demand

Route set up procedure:

- Source node broadcasts PREQ (Packet REQuest) message to discover a route to destination.
- This PREQ message propagates through the network and updates in the routing table.
- The valid destination route has a sequence number and that is stored in the RREQ and using the reverse pointer setup, it sends back to source by the intermediate nodes.
- The communication has been started when PREQ reaches to the destination.

Particle structure of routing protocol

AODV provides multiple routes for any source or destination pair and always selects route with shortest path. The shorter route with heavy load depletes energy and results in decreased lifetime and reduced throughput. So we develop a protocol that not only considers its shortest path but also includes high energy level (low energy consumption) [20]. This route is not necessarily the shortest one, since the shortest route may has a lower energy level. It is in fact one of the short routes that has a relatively high energy level. To find such a route with energy efficiency PSO algorithm is used.

4.2. Optimal path selection using Particle Swarm Optimization

Particle Swarm Optimization (PSO) developed by Kennedy and Eberhart, is a population-based algorithm motivated by regular life, similar to winged animal rushing, fish schooling and random search strategies for transformative calculation which uses a populace of people to iteratively look a multi-dimensional space for a worldwide least. The PSO algorithm contains a swarm of particles in which each particle indicates a potential solution. The particles fly through a multidimensional search space in which the position of each particle is adjusted according to its own experience and the experience of its neighbors. PSO system combines local search methods (through self experience) with global search methods (through neighboring experience), attempting to balance exploration and exploitation. As in evolutionary computation paradigms, the concept of fitness is employed and candidate solutions to the problem are termed particles, each of which adjusts its flying based on the flying experiences of both itself and its companion. PSO is an approach to problems whose solutions can be represented as a point in an n dimensional solution space. A number of particles are randomly set into motion through this space. In a gathering without impacting, it can be found from the nature that creatures, particularly winged animals, angles, and so forth dependably travel. This is on the grounds that every part takes after the gathering by adjusting its position and speed applying the gathering data. In this way it lessens person's exertion for looking of sustenance, shield and so on [21]. Basic structure of PSO algorithm is depicted in below figure 2.

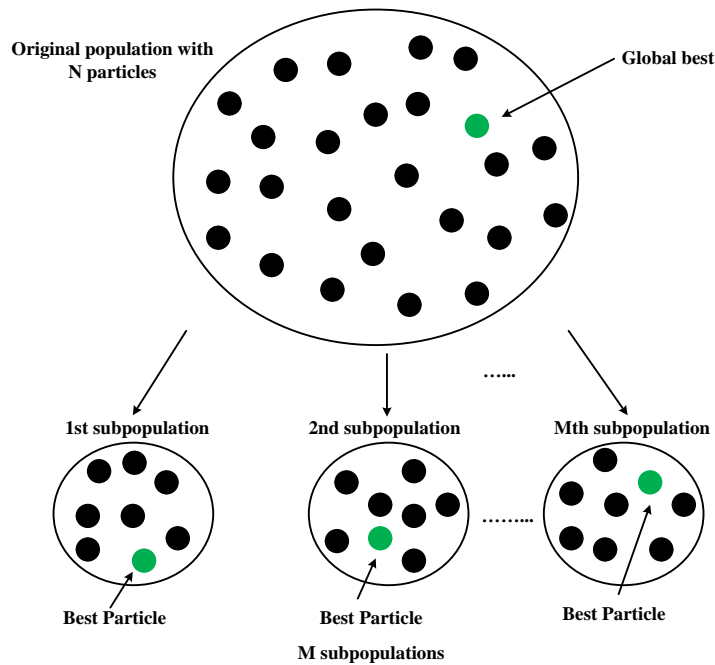


Figure 2: PSO general structure

PSO includes a swarm of a predefined estimate (say NP) of particles. Every molecule bears an entire answer for the multidimensional enhancement inconvenience. Every molecule monitors its directions in the issue space, which are joined with the best arrangement (wellness) it has achieved up until this point. This esteem is called 'pBest'. In the populace, another "best" esteem that is followed by the worldwide form of the molecule swarm improvement is the general best esteem and its area discovered so far by any molecule. This area is called as 'gBest'. The molecule swarm streamlining idea involves, at each progression, changing the speed (i.e. quickening) of every molecule toward its 'pBest' and 'gBest' areas (worldwide adaptation of PSO). Speeding up is weighted by an irregular term with partition arbitrary numbers being created for quickening toward 'pBest' and 'gBest' areas [22]. The diverse steps of a PSO calculation are delineated in the flowchart as exhibited underneath in below figure 3.

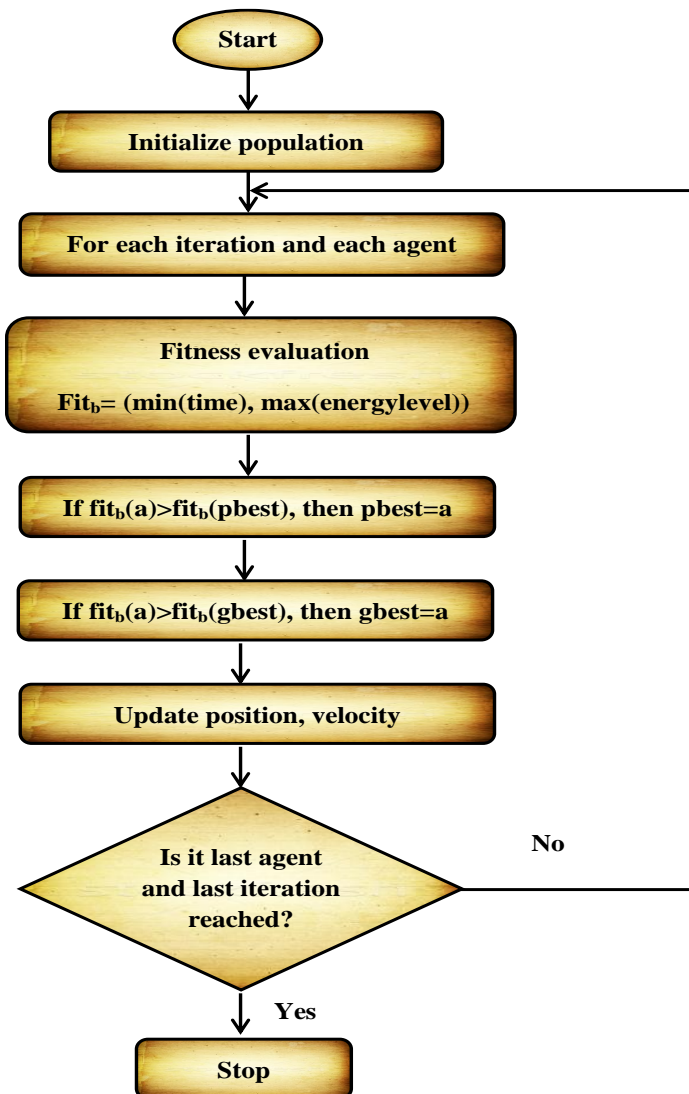


Figure 3: Flow chart of PSO

The process of optimal selection of parameters by PSO is depicted as follows [23],

- ❖ **Initialization:** In PSO, primarily the particles are randomly generated within the interval of $[n, m]$. The defined particles are composed of the parameter w_i , which is referred to as $p = \{w_0, w_1, \dots, w_i\}$; $i = 1, 2, \dots, N$.
- ❖ **Parameters used:** In PSO, learning parameters, inertia, weight the position, velocity and maximum numbers of iterations are defined for each particle.
- ❖ **Fitness Function:** In this work, energy and time consumption are used to evaluate the fitness of possible routes, by starting from any one of the neighbor nodes. The fitness value of node 'a' in case of choosing neighbor node 'b' as the next node of the route can be detailed in equation as follows:

$$Fitness_a(b) = [\min (time), \max(energy level)] \text{ from node 'a' to 'b'} \quad (1)$$

Every fitness value of each particle is computed using Equ. (1). The particle with maximum fitness is chosen as the best particle.

- ❖ **Update: Velocity and Position:** after the fitness calculation, solution is update using PSO. The particles velocity and positions are updated based on the pbest and gbest values by exploiting the Eqn. (2) and (3).

$$V_x^{(n+1)} = \omega V_x^n + C_1 \cdot r_1 \cdot (p_x - x_x^{(n)}) + C_2 \cdot r_2 \cdot (g_x - x_x^{(n)}) \quad (2)$$

$$X_x^{(n+1)} = X_x^{(n)} + \delta V_x^{(n+1)} \quad (3)$$

In Eqn. (2) C_1, C_2 are the learning factors, ω, δ refers the inertial weight and constraint factor, rand is positive random number among 0 and 1, $V_i^{(n)}$ is the velocity of i^{th} particle at iteration n, $X_i^{(n)}$ is the

current position of the particle i at iteration n , p_i is the position of the best fitness value of the particle at the current iteration and g_i is the position of the particle with the best fitness value in the swarm.

❖ **Stopping Criteria:** Repeat the process until maximum number of iterations are attained

5. Result and Discussion

This section discusses about the result and discussion about energy efficient AODV routing in wireless sensor network on PSO. There are many performance metrics available to do quantitative measures for the evaluation of protocol. For the simulation purpose four performance metrics were considered; Throughput, Delay, Delivery ratio, Network life Time (NLT) and Energy consumption. The execution of the proposed work is analyzed in the Network Simulation Tool- Version 2 (NS2).

5.1. Evaluation Metrics

The metrics used in the evaluation of proposed work is depicted in this section.

Throughput:- It is the successful delivery of messages or packets to the destination over a communication channel. It is expressed as in kilobits per second (Kbps) and is denoted as:

$$\text{Throughput} = \frac{\text{Number of bits reached the destination}}{1000} \quad (4)$$

Delay:- Delay is referred to as the time gap between source node sending a packet and receiver node received the same packet. While calculating delay, all possible delays such as propagation delay, transmission delay, processing delay, and queuing delay has been considered. It is denoted as

$$\text{Delay} = \sum_{n=1}^m (R_n - S_n) \quad (5)$$

Delivery ratio:The amount of information which was viably transferred to the end node related to the measure of information which was transferred by the transmitter.

Network life Time (NLT):-The amount of information which was viably transferred to the end node related to the measure of information which was transferred by the transmitter.

Energy consumption: - Energy utilization is very much characterized as the communication overhead of the nodes where a firm number of false information are infused into a network.

5.2. Performance Metrics

The performance of the energy efficient AODV routing in wireless sensor network based on PSO is shown by comparing it with the existing approach. Parameters like, throughput, delay, delivery ratio, NLT and energy consumption for varied number of nodes were analyzed.

Table 1: Throughput, delay, delivery ratio, NLT and energy consumption with varied number of nodes for proposed and existing algorithms

No. of nodes	Throughput		Delay		Delivery Ratio		NLT		Energy consumption	
	OC-KMS	DKM M	OC-KMS	DKM M	OC-KMS	DKMM	OC-KMS	DKM M	OC-KMS	DKM M
40	3339	2372	0.080	0.585	0.998	0.009996	50	23	89	139
80	3584	3098	0.05	0.590	0.999	0.009997	26	15	129	179
120	3797	3571	0.281	0.792	0.995	0.009997	18	11	169	219
160	4263	4052	0.562	3.632	0.991	0.009993	15	10	209	259
200	7583	5615	0.687	112.99	0.986	0.009777	22	11	247	297

Discussion

Table 1 shows the result analysis of, Throughput, delay, delivery ratio, NLT and energy consumption with varied number of nodes for proposed and existing algorithms. The values obtained from the implementation shows that as the throughput increases for each varied number of nodes when compared with the existing system. That is successful delivery of packets to the destination without any loss in packets is high for our proposed system. Similarly as much as delay decreases, the throughput will be high. The delay values in proposed work are reduced when compared with the existing method. The delivery ratio of packets is high. The lifetime of the network persists for a long time for each number of node variations in the existing system. Finally, the energy consumption of each node tremendously decreases for the proposed method which it is high for the existing system in below figure 4.

Finally the comparison plots obtained for all the evaluation metrics are depicted as follows:

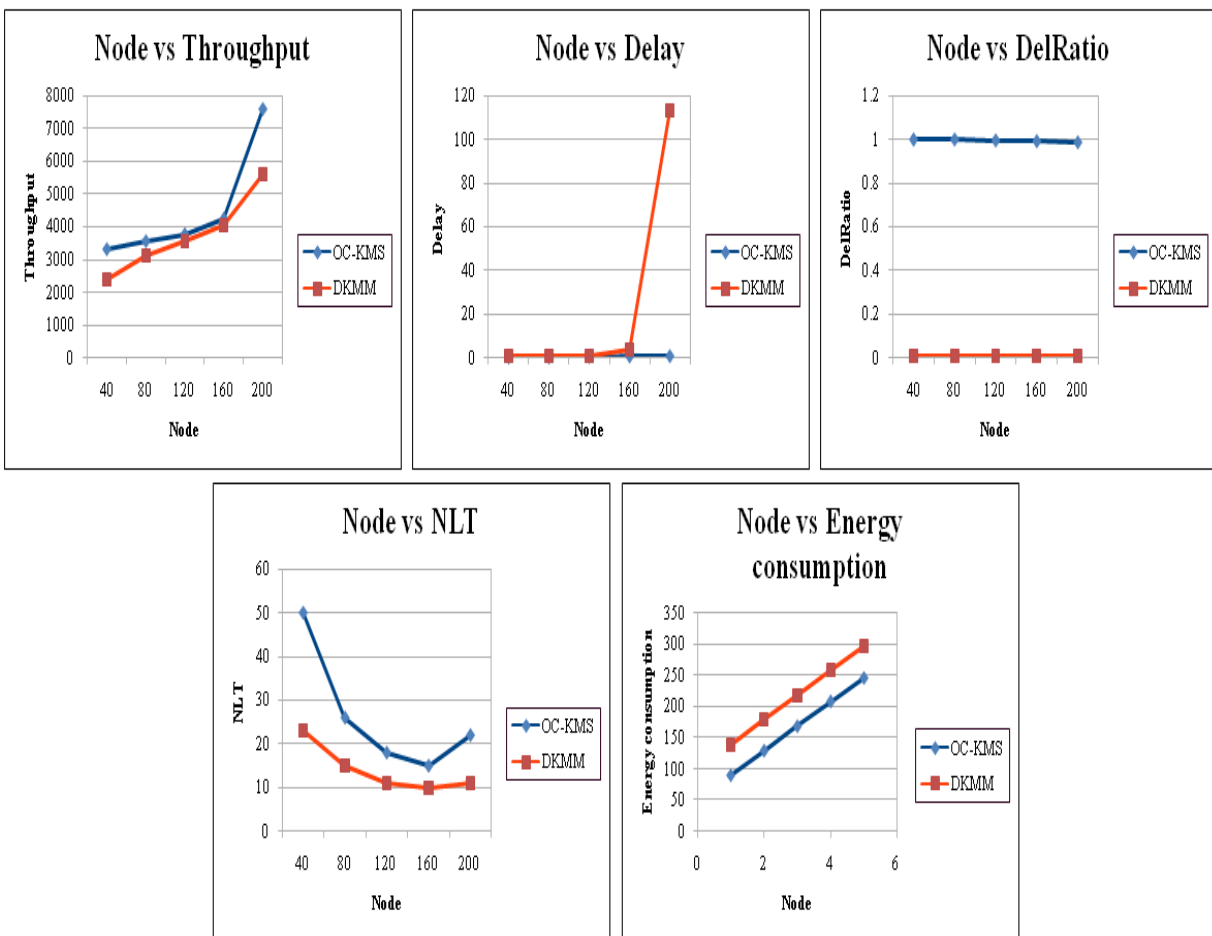


Figure 4: Comparison plot for the metrics such as, throughput, delay, delivery ratio, and network life time and energy consumption for proposed and existing system

6. Conclusion

This paper presents the energy efficient AODV routing in wireless sensor network based on PSO. The objective of efficient less energy consumption is attained using PSO algorithm. The work was proved to be efficient with less energy consumption and increased throughput on comparison with existing algorithm of routing. The routing was done with AODV protocol and the shortest path with efficient energy consumption is selected by PSO algorithm. The analyzed results prove to be more efficient in routing with less energy. This work can be extended in the future by improving the algorithms to increase the security and quality of service that provide better service in destination with decreased error rate and high confidentiality over the network.

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