Research Article

Optimization of Energy Consumption in WSN Based on PSO

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Abstract: In this research, we are proposing new protocols for energy used in wireless networks. We are optimizing energy usage based on Improved Particle Swarm Optimization (PSO) integrated with conventional Ad-hoc On Demand Distance Vector (AODV) used to generate the minimum amount of cluster heads (CHs) and the objective work involves two main components. First, the total energy used between the cluster head and the nodes; second the total energy used to collect data at the cluster head level as well as to transfer the information to the base station. Thus, in order to achieve energy efficient cooperative transmission, we are providing a new approach and applying to transmit the data to the suitable next node of the cluster far from the head of the previous cluster in the clustered head sensor network.

Keywords*:* Wireless Network, Cluster Head, Base Station, Particle Swarm Optimization, Energy Consumption

1. Introduction

The Wireless Sensor Network (WSN) is a collection of interconnected sensor nodes that access the information from nodes through the multi-hop and self-organized network. Sensing, capturing and processing of data is the function of the network nodes. Such abilities depend on the energy usage of network nodes which needs to be increased to meet WSN applications. The network source cluster head node needs to communicate with the multiple destinations cluster head nodes simultaneously. All the nodes in network sense data, collects the data and then process before sending packets to the base station(BS).

The major challenge in wireless sensor networks is to limit the use of energy over wired media. While receiving and transmitting information from other nodes in the wireless sensor network, the sensor nodes use energy to perform their function. The batteries in each node work independently. In high-risk areas, the wireless sensor network is usually stationary and located where it is almost impossible to recharge or replace the battery. The performance of this network depends entirely on the life of the network and the size of its scope. It is important to use energy awareness algorithms in the design of strong sensor networks. The entire lifespan of a network depends on the power source of sensor nodes. This problem is creating many questions in the life of nodes and in the use of energy, making it the subject of much research debate. A cluster-based approach has been developed to conserve energy in sensor nodes in which only certain nodes are allowed to interact with the BS to save energy. One of the solution that can greatly reduce energy consumption is to choose the right cluster head technique. Clustering increases the scalability of wireless sensor networks. Therefore clustering reduces direct dependence on sensor nodes and base stations of multiple traffic loads, as well as makes local decisions for the transmission of information.

The goal of this paper is to achieve high energy efficiency in wireless sensor networks and to compare it with the traditional AODV routing techniques and to make proper use of AODV-particle swarm optimization algorithms.

2. Related Work

With numerous research initiatives, energy consumption in the wireless sensor network has been achieved in various ways, including data aggregation[1], circular sector[2], multi-hop hierarchical routing protocol (EMHR)[3], energy-efficient stationary and mobile routing (EERSM)[4], to optimize the energy usage and to find the short wsn routes. Cognitive radio sensor networks (CRSN) is based on randomly accessing the channel available in wsn to reduce the energy consumption for sensing the channel [5]. Yiming Shenet et al. [6] observed that reducing the distance of communication minimizes the energy based on the AGEAR and AGEAHAR routing techniques. In this scheme, they adjusted the power according to communication distance between the nodes. The virtual infrastructure solution used multi-hop clustering as a backbone at one stage. Clusters are created around the sensor area and the head of the cluster is selected. The main objective is to reduce the number of clusters and the number of cluster heads that limit network size. The actual position of the sink node is familiar to the nearby cluster head and the rest of the cluster is being exchanged. [7].

Cross-layer based techniques have been developed for energy consumption and have been implemented in positive protocols for sensitive pathways [8]. This reduces the total listening time of each node in the network and reduces the distance between the nodes in the network.

Neeraj b. Nakeet. et al. [9] proposed a energy consumption scheme based on grid organized system. The cell header is the primary component of the network [18] and is responsible for routing. Sure, an optimal path is established and each node in the network interacts with the base station.

The clustering strategy is used in the dynamic multi-hop routing scheme [10] to reduce the node's residual energy consumption. CH enhances the communication range which detects the high residual energy of the nearest cluster and transmits the data to the base station once the data has accumulated in the cluster[11].

3. Proposed Methodology

3.1 Particle Swarm Optimization

PSO [12] is a totally population based method. As human being is used to share their ideas and experiences, in the similar manner, birds have some techniques to share their experiences. They usually talk to each other and share the information about food, their inhabitants and some other information. So, the same behavior is analyzed for some applications.

The idea deals with the group of random variables, and all those variables are defined in some predefined patterns, and the behavior of those particles is not known e.g. flock of birds. Swarm of birds continuously moves in some direction and form a pattern. Some values are estimated for them, and then some analysis is performed accordingly. PSO works on the group of particles and not on single particle.

3.2 PSO Process

This process is initialized based on the population to select the random solution or particles. Each solution is allocated a random speed and location in the d^{th} dimension of the search space. The purpose of the PSO is to find the particle location that best evaluates the fitness function. As group of particles is working for optimization, all the pbest values are combined to give a global solution. All the pbest values are compared and the one particle which is having much closer results, much optimized result, will be assigned as a global best particle "gbest". In first two cases (gbest & pbest) the search space is assigned to all the particles and all have moved in that search space. It has been found that PSO gets optimized results as good as other methods, therefore, applied successfully in many research and application areas from last several years. In our research, we have used parameters with slight variations and they work well.

3.3 Proposed Model

3.3.1 Network Model

- Total nodes in network are placed randomly in the Network area. A homogeneous network is considered which means initial energy of nodes is same.
- BS is located at the centre network area and is not power constraint.
- Sensor nodes are stationary after random deployment. The BS location is also fixed.
- Sensor nodes are energy constrained and battery replacement or recharging is not possible after deployment.
- Clustering hierarchy is considered for the sensor nodes. Sensor nodes send the data to the CH and after aggregation the data is transferred to the sink.

3.3.2 Selection of CH Node

Particle Swarm Optimization concept comes from the group of birds searching food without conflict with each other and reduces the time and efforts for food searching. PSO is inspired by random search methods of evolutionary algorithm. Each particle continuously updates two "best" possible values called as pbest and gbest. A particle P_i has a position and a velocity in the d^{th} dimension of the search space[14]. The same dimension of all the particles is considered for the proposed work. The notation for representing the i^{th}particle $P_i$of the population is as follows:

$$P = \left[P_{1,} P_2, P_3 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . P_D\right] \qquad (1)$$

Each particle location is calculated based on fitness value which is judged by each iteration. Each particle can continuously updates the speed and location of particle $V_{id}$and $X_{id}$are as follows:

$$V_{new\_i} = w \times V_i + c_1 \times r_1 \times \left(X_{p_{besti}} - X_{id}\right) + c_2 \times r_2 \times (X_{g_{best}} - X_i) \qquad (2)$$

$$X_{new.d} = X_{old.d} + V_{new.d} \qquad (3)$$

Initial position and velocity of the particle is randomly selected and then updated according to the given equations.

Where, w = Initial Weight

$c_1$and c_2= Accelerating Factors

$r_1$and r_2= Distributed random no's with range 0 to 1

The inertia weight balances the global and local exploration and exploitation [13]. The value of inertia w is ranging between 0.4 to 0.9 in each iteration. An appropriate selection of inertial weight reduces the number of iterations to find the best possible solution. The inertia weight can be defined using equation (4) to avoid the particles being trapped in local optima.

$$W = w_{initial} - (Max.Iteration - Current\ Iteration)/\ Total\ number\ of\ Iteration \qquad (4)$$

Now, with the new updated position, we evaluate the fitness function of the particle and update pbest as well as g_{best}. Then, we compare particle fitness with thep_{best}. Compare fitness best particle fitness with the g_{best}. If current value is better than p_{best}, then set p_{best}as equal to the current value otherwise update current value. The process of updating continues till we reach to an acceptable solution.

In this research, it has been assumed that network nodes are placed randomly in the network area. If the node is in the communication range then the network sensor node is used as the cluster head. Each node in the network transmits the aggregated data to the cluster head, redundant data can be discarded and the useful data can be passed to the next cluster head or the base station. All the communication is assumed to happen on a wireless link [19]-[20]. In our research work, PSO technique is implemented for the generation of minimum number of cluster heads.

3.3.3 Objective Function

In wireless sensor networks, cluster head selection is completely dependent on how fitness function is designed. The proposed fitness function is designed in such a way that the energy consumption of the cluster head is minimum. The proposed fitness function consists of two parts; In first part, the total energy used between cluster head and the nodes; and in the second part the total energy used for data assembling at cluster head level and the data transmission to the base station [16][17]. Equations (5) to (9) are used to evaluate the total energy consumption between nodes and CH.

$$(x + a)^n = \sum_{\mathrm{k=1}\ \forall\ \mathrm{nk}}^{\mathrm{k}} \sum_{\mathrm{k} \in \mathrm{ck}}^{\mathrm{k}} \left\{\frac{\mathrm{Ekj - f}\ (K_j,C_k)}{\mathrm{Emax - Emin}}\right\} \mathrm{x\ kj\ where\ j} = 1,2,3 \qquad (5)$$

$\mathrm{F}(K_j,C_k) = s^2 (K_j,C_k)$ if $s\ (K_j,C_k) \le d_0$

$S^4(K_j,C_k)$ if s (K_j,C_k) > d_0 (6)

$s(K_j,C_k) = \min(K_j,C_k)$, k=1,2,3 (7)

WhereEK_j denotes the energy of j^{th}node of k^{th}cluster.

$F(K_j,C_k)$ is the function used to compute the energy consumption between sensor nodes and CHs.
E_{max} andE_{min}denotes maximum and minimum energy decay in WSN.
$C_k$represents the k^{th}cluster.

S is the function which computes the minimum distance of j^{th}node of k^{th}cluster, the value of K_j=1 if it is a j^{th}node of k^{th}cluster otherwise 0, d_0 denotes the threshold distance.
Evaluate the total energy consumption between cluster head to base station from equation (8) and (9).

$$E_2(j) = \sum_{k=1}^{k}\left\{\frac{Eck-g(Ck,BS)}{Emax-Emin}\right\} x\ C_k \quad (8)$$

$$G(C_k,BS) = d^2(C_k,BS) if\ d(C_k,BS) \le d_0$$

$$d^4(C_k,BS) if\ d(C_k,BS) > d_0 \quad (9)$$

$G(C_k,BS)$ is a function used to compute the total energy usage at the cluster head (CH) and the base station (BS). C_k represents the k^{th}cluster.
The total energy consumption (fitness function) to transfer the M bit data from the sensor network nodes to the base station-

$$F(j) = E1(j) + \mu\, E2(j) \quad (10)$$

Where, E1 is the total energy usage between the network nodes and CH. E2 is the total energy usage between CH and BS. M computes the distance between CH and BS. It is a controlling parameter; higher value of μ signifies that CH is closer to BS.

3.3.4 Energy Model

In this work, an efficient and effective radio and energy dissipation channel is taken for experiment which is described in [15]. It is necessary to consider the free space and the fading channel for effective energy dissipation model. The consumption of the energy for M bits transmission of distance d is computed using equation (11).

$$E_{TX}(M,D) = M.E_{elect} + M.\in_{fs}.d^2 \quad if\ d \le d_0$$

$$M.E_{elect} + M.\in_{mp}.d^4 \quad if\ d > d_0 \quad (11)$$

Where, E_{elect}denotes residual energy, $\in_{fs}$and $\in_{mp}$denotes energy consumption of free space and multipath fading channels respectively and d denotes the distance between sensor nodes and CH.

$d_0$is the threshold distance between the transmitter and the receiver that can be measured using

$$d_0 = \sqrt{\frac{\in_{fs}}{\in_{mp}}}$$

The radio dissipation of receiving M bits data can be measured using

$$E_{R,X} = M.E_{elect}$$

3.3.5 Algorithm

1. Place the nodes $N = (N_1, N_2, N_3 \ldots\ldots N_n)$ w, c1, c2,iteration, iteration_max parameters.
2. Initialize the particles$P_i, j, k, 1 \leq i \leq NP, 1 \leq j \leq D = m$
No. of CHs

3. Using Equation (10), analyse each particle's fitness function and find the individual optimal state of the particle, set it to p_{besti}.
4. Evaluate g_{best} location of particles based on equations.

Gbest= [$Pbest_k$| Fitness ($Pbest_k$)] = min (Fitness ($Pbest_i$),i,1≤i≤NP)

5. Update the speed and location of each particle using equation (5) and (6) and calculate fitness of each particle.
6. $If\ Fitness(p_i) < Fitness(Pbest) than\ Pbest = p_i$
7. $If\ Fitness(p_i) < Fitness(Gbest) than\ Gbest = p_i$
8. Repeat the steps 3-7 until iteration >iteration_max.

4. **Results & Discussion**

In the proposed work, various sensor nodes are placed in the simulated network area of 100 * 100 meter size. This section describes the results of the proposed AODV-PSO algorithm. The proposed technique is verified using the total number of packets sent to the base station for performance analysis. The table 1 shows the parameter setting of the proposed AODV-PSO algorithm. For simulation, sensor nodes are implemented in NS2 software. No. of live nodes and dead nodes are used as network life time parameters.

Table 1. Parameters Setting

Description	Parameters	Values
Network Size	Network Area	1000m x 1000m
Total No. of nodes in field	No. of nodes	100
Initial energy of nodes (Joules)	E_0	0.5 J
Transmission Energy (Nano joules/bit)	E_{TX}	50 nJ/bit
Reception Energy (Nano joules/bit)	E_{RX}	50 nJ/bit
Radio amplifier energy-free space (joules)	E_{fs}	10pJ/bit
Inertial Weight	W_{init}	0.4
Data Aggregation Energy (Nano joules/bit)	E_{DA}	5 nJ/bit/Message
Radio amplifier energy-multipath (joules)	E_{mp}	0.00013pJ/bit
Message Size	Message Size	512 byte
Reference Probability for CH	P_0	0.1
Number of iterations	Maximum	5

	No. of Iteration	
Acceleration factor	$c_1 = c_2$	2
Velocity of Particle	V_{max}	0.4

Table 2. Network life cycle with reference to dead entries using AODV and AODV-PSO

Algorithm	**Total Simulation Time (Seconds)**		
	First Node Died	**Half of Node Died**	**Last Node Died**
AODV	561	645	746
AODV-PSO	590	690	816

Table 2 shows that in normal AODV, first node die at 561 seconds while AODV-PSO shows that first node die at 590 seconds, in normal AODV, half nodes in the network die at 645 seconds while AODV-PSO shows that half nodes die at 690 second and in normal AODV all nodes die at 746 seconds while AODV-PSO shows that all nodes die at 816 seconds. From this data, it can be concluded that the life of the network is extended using AODV-PSO algorithm compared with normal AODV algorithm.

Table 3. Number of live nodes at 600 seconds, 700 seconds and 800 seconds

Algorithm	**Total Simulation Time (Seconds)**		
	No. of Live node at 600 seconds	**No. of Live node at 700 seconds**	**No. of Live node at 800 seconds**
AODV	64	43	0
AODV-PSO	78	57	10

Table 4. Number of dead nodes at 600 seconds, 700 seconds and 800 seconds

Algorithm	**Total Simulation Time (Seconds)**		
	No. of Dead node at 600 seconds	**No. of Dead node at 700 seconds**	**No. of Dead node at 800 seconds**
AODV	36	57	100
AODV-PSO	22	43	90

Table 3 and Table 4 shows that how many nodes are live and dead after simulation time of 600 seconds, 700 seconds and 800 seconds. From both tables it could be concluded that AODV-PSO survived 10 nodes after 800 seconds of simulation time when compared with normal AODV where all nodes are dead within 800 seconds. Both the data are represented in Fig.1 and Fig. 2.

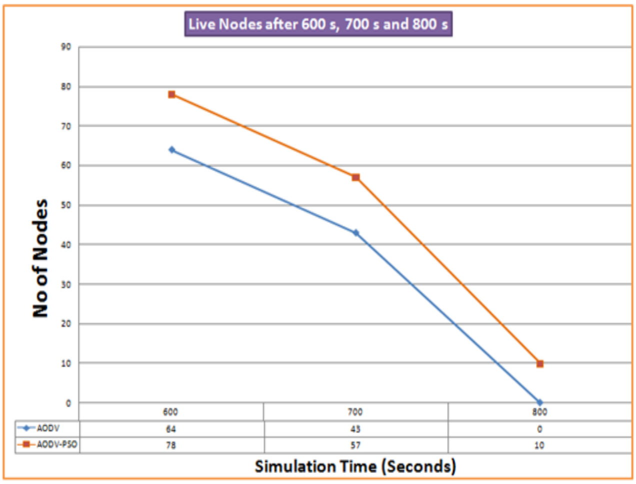

Fig. 1 Comparative Analysis of live nodes

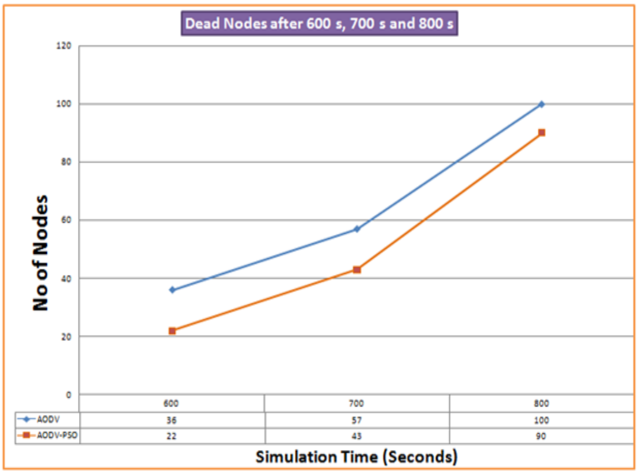

Fig. 2 Summary of Dead Nodes

Table 5. Packets sent to the BS

Simulation time	**Number of Packets Sent**	
	AODV	AODV-PSO
200 seconds	5000	7000
400 seconds	11000	13500
600 seconds	13000	17600
800 seconds	13000	18600
1000 seconds	13000	20000
Total	**55000**	**76700**

Table 5 shows the statistics of packets sent from CH to the base station in 200, 400, 600, 800 and 1000 rounds using AODV and AODV-PSO algorithms. It is found that the number of packets sent by AODV algorithm is 55000 and 76700 packets are sent by AODV-PSO protocol. Total amount of packets transferred after integration of the AODV-PSO appears to be gradually increasing. Fig. 3 shows a comparative analysis of the total amount of packets transferred to the base station using AODV and AODV-PSO. It is observed that AODV protocol has been effectively improved.

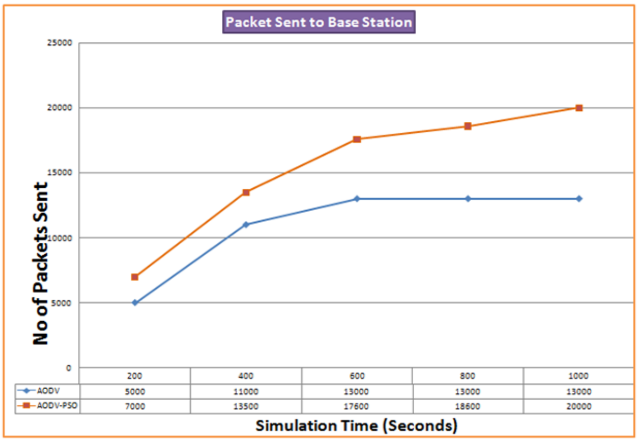

Fig. 3 Comparative Analysis of total packet transferred to BS

Table 6. Packets sent to Cluster Head

Number of Seconds	Number of Packets Sent	
	AODV	AODV-PSO
200	48000	56000
400	10500	12250
600	11000	13000
800	11000	13000
1000	11000	13000
Total Packets	**91500**	**107250**

Table 6. shows the statistical analysis of the total amount of packets transferred from the network node to CH using AODV and AODV-PSO after 200, 400, 600, 800 and 1000 rounds. It is observed that the number of packets sent through AODV algorithm is 91500 and through AODV-PSO protocol is 107250 packets. It is seen that there is gradual increase in the packets sent parameter after integration of AODV-PSO algorithm. Fig. 4 shows the comparison of packets sent to CHs for AODV and AODV-PSO protocols for each round and it indicates that the performance of the AODV protocols is effectively improved.

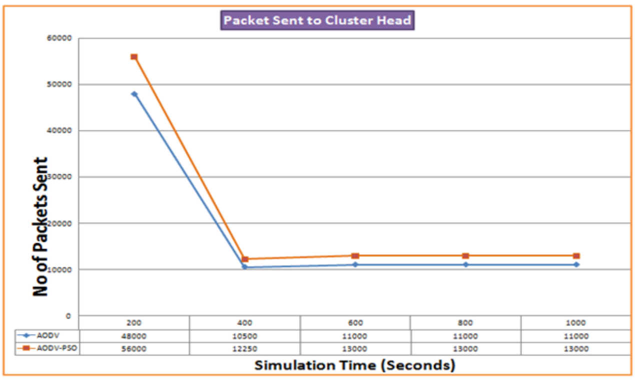

Figure 4. Comparison of Packets sent to Cluster Heads

It has been found that the total power consumption of a network node using AODV-PSO is less than that of AODV and the life of the network is extended. The total amount of packets transferred to BS and CH is also gradually increasing which also confirms the effect of the proposed CH selection algorithm.

5. Conclusion

In hierarchical clustered network, the sensor nodes send information to the CHs, which aggregates the information. Then, the aggregated information is transferred to the base station (BS). Many goals are aimed while clustering the nodes like energy efficiency, fault-tolerance, topology control etc. The PSO algorithm is used for efficient clustering. It is observed that the PSO algorithm increases the lifetime of WSN by reducing the power consumption. The conventional PSO algorithm is used with slight modification in inertial weight. The behavior of the PSO algorithm is analyzed when one or more affecting parameters are differed. The experimental results revealed that AODV-PSO algorithm provides more robust, efficient and effective results as compared to AODV in presence of hard faulty sensor nodes with respect to the network lifetime and the data packets sent as parameters. It is observed that there is an increase in the packet sent rate (Node to BS and Node to CH) by the integration of PSO with traditional AODV. The inclusion of PSO algorithm in AODV has improved the efficiency of AODV algorithm.

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