Comparative Study of Optimized Wireless Sensor Network Routing Protocols

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ABSTRACT

Nowadays, Wireless sensor network applications are very important in most industrial fields. Most strategies are used to save energy of WSNs to prolong their life time. This problem attracted attention of many researches and many methods were proposed to optimize the energy consumption of WSNs. This paper presents a comparative study between two metaheuristics algorithms are used to optimize this problem. One of them is the improved harmony search algorithm, and the other is the particle swarm optimization algorithm. Showing the strategies which are used to build its routing protocol and overviews on optimization algorithm which depend on build its solutions. Energy model used to calculate fitness of each solution. Improved algorithms are used in routing to solve the proposed problem. And propose termination criteria, simulation and results for each algorithm. At last this of them preferred to implement.

Keywords

Wireless Sensor Network, Routing Protocols, meta-heuristic, Harmony Search, particle swarm

1. INTRODUCTION

In the last period, due to widely use of wireless sensor networks in different applications as military surveillance[1], environment monitoring[2], infrastructure protection[3] etc. WSN is considered as one of the most important technologies receiving tremendous attention from both academia and industry all over the world. Wireless sensor nodes are positioned by localization algorithm with GPS system[4]. WSN can be used in small scaled applications which is composed of some hundreds of nodes which is called SWSN or large scaled applications which may be composed of some hundreds of SWSN[5]. Sensor nodes are powered by batteries so the life time of each node is limited. The process of regeneration of power for nodes is an impossible process in large scale application. At the same time, energy saving in nodes is very important to ensure service continuity[5],[6]. Energy is consumed in sending data from source nodes to sink nodes. Data must consume small amount of energy and preferred to occur in small time. Many researches discussed this problem with different methods. One of the methods for saving energy is duty cycle secluding. Duty cycle can be classified into sleep secluding and route selection[7]. The operation of the node to sleep or wake up is called sleep secluding. Sleep secluding is designed for multi-hop WSN there is a great achievement of saving energy[7]. In sleep secluding the node can wake up and prepare a packet and send it at any time but only receive at the period of wake up only. Sleep secluding can be synchronous or asynchronous [8]. Synchronous sleep secluding neighbor nodes aggregated for sleeping pattern (if neighbor nodes wanted to change their active/sleep states, the states are changed concurrently)[8]. So the design of routing protocols for this type is very simple.

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But in asynchronous sleep secluding, each node determines its active/sleep state independently. So the nodes are different in phase of secluding. Route selection has two main tasks. One of them is the collection of the routing information and the other is the forward path decision. Routing information can be classified into global routing information and local routing information. Global routing information includes network topology used in routing; nodes sleep secluding and end-toend distance from a sensor node to a sink node. This global information can be obtained from control message from sink node. But local information includes one or two neighbor distance and one or two neighbor sleeping secluding [9], [10]. Meta heuristic algorithms are used also to find solutions for saving energy for WSN as harmony search algorithm [11], ant colony algorithm [12] and piratical swarm algorithm [13]. Meta heuristic is used when a path of solution is not required but the final solution only is important. Meta heuristic algorithms are used to send data from source to destination with small energy consumption.

Related works

M. Hasnat, M. Akbar, Z. Iqbal, Z. Khan, U. Qasim, and N. Javaid presented a B-DEEC protocol (Distributed energy efficient clustering protocol) for WSNs. It depends on a meta-heuristic algorithm called artificial bee colony (ABC). This protocol operation increases the life time of WSNs and increase its reliability. ABC algorithm derives its operation from honey bees in the way of foraging. It optimizes the next node selection so it decreases energy consumption of sending data and increases the life time of WSNs[14].

C. Sivakumar, and P. L. Parthiban presented IACO algorithm (improved ant colony algorithm). It uses fractional Brownian motions to improve the search way to improve the exploration capability. It maintains a good balance between exploitation and exploration abilities and improves energy efficiency of WSNs by selecting the optimal next node for sending data from source to destination[12].

D. Lobiyal, C. Katti, and A. Giri presented VANET (vehicular ad-hoc network) routing performance problem. Because of the large combinations of the values of parameters used in it, it is difficult to find optimal combinations. Algorithms depending on particle swarm have been proposed to find optimal combination of VANET[15].

2. NETWORK MODEL FOR APPLYING EACH ALGORITHM

2.1 Improved harmony search algorithm

Comparing a sink node that has DC power supply, big transmission power, strong computing power and big storage capacity with source nodes that have battery power supply, limited transmission power, limited computing power and limited storage capacity to give sink node ability to execute routing algorithm. Each node has a unique ID. All nodes have the ability of computing its remaining power and communicating with each other by CSMA-CA protocol[4]. At the beginning of initiation of network the routing protocols steps are as follow

Step1: Sink node broadcasts a packet containing a number of hops initialized to zero to sensor nodes, when sensor nodes in the communicating range of sink node receive this packet, a minimum number of hops to sink node has been registered and neglect packet containing higher number. Then it sets number of hops plus one to the packet and sends it to its neighbor's nodes. By this way each node has the minimum number of hops to the sink node.

Step2: Each node sets a packet containing its residual energy, number of hops to the sink node and IDs of its neighbor nodes then sends it to the sink node by single hop.

Step3: Sink node executes the routing algorithm and find best path from each node and send packet containing best forward path for each node in single hop.

Step4: When a source node senses a new data it set it in a packet and adds its residual energy to this packet and sends it to next node in forward path that is registered in its memory.

Step5: When a next node receives a packet it adds its residual energy, removes nodes that have been visited from the forward path, sends it to the next hop node and continues with this step until the packet reaches the sink node.

Step6: When a sink node receives a packet it processes the sent data and sends it to the specialists, executes the routing algorithm, calculates the new best forward paths for the nodes in the forward path and sends them to nodes in single hops.

2.2 Particle swarm optimization algorithm

A wireless sensor network is divided into two sections one of them is sensor nodes and the other is gateway nodes. Sensor nodes are used to sense useful data and send it to one of the gateway nodes. A sensor node could communicate with any gateway node but a gateway node must be in communicating range of a sensor node. Gateway nodes communicate with each other to reach sensed data by sensor node to specialist. Sensor nodes communicate with gateway node with TDMA[4], gateway nodes communicating with specialist by CSMA/CA[4]. There is more than one gateway node in the communicating range of sensor node but each sensor node can deal with one of them. Sensor nodes collect local sensed data and divided the data into rounds each node send its round to corresponding gateway node. Gateway node aggregates the local data and neglects the random of it then sends it to a specialist.

Step1: the beginning each node from sensor nodes and gateway nodes has a unique ID each node broad cast it's ID using CSMA/CA protocol.

Step2: The gateway node collects IDs from the sensor node and the other gateway nodes in communicating range of it and sends them to the base station.

Step3: The base station executes the routing algorithm and clustering algorithm. The execution of routing algorithm is first, and then information from it is used in clustering.

Step4: Each gateway node is informed by the next hop to the base station and each source node is informed by the gateway that will deal with it.

3. NETWORK MODEL FOR APPLYING EACH

3.1 Improved harmony search algorithm

Power consumption in WSN is estimated and the length of path are considered to describe the objective function[16]. Simple radio model of the circuit of transmitting or receiving dissipates $E_elec=50$ nj/bit for one bit and transmitted amplifier $E_amp=0.1$ nj/(bit/m^2) for one bit in one meter, to transmit k bits message in d meters power consumption of sending (1) and receiving (2) are

$$E_{TX}$$
 (k, d) = $E_{elec} * k + E_{amp} * k * d^2$ (1)

$$E_{RX} = E_{elec} * k \quad (2)$$

So the power dissipated for path $X=\{s,x1,x2,...,d\}$ containing L nodes, energy consumption for transmitting a kbits message along this path (3) is

$$\mathbf{E}(\mathbf{x}) = \mathbf{E}_{\mathbf{T}\mathbf{X}} + \mathbf{E}_{\mathbf{R}\mathbf{X}}$$

$$= 2 * E_{elec} * (d-1) * k + E_{amp} * k * \sum_{i=1}^{L-1} d_{i,i+1}^2$$
 (3)

An objective function is selected to balance the energy consumption in the network and restrict the length of path (4) as possible[17]

$$\mathbf{f}(\mathbf{x}) = \frac{\mathbf{E}(\mathbf{x}) \ast \mathbf{l}}{\mathbf{E}_{\min} \ast \mathbf{E}_{avg}} \tag{4}$$

Where the minimum residual energy of the node is E_{min} and E_{avg} is the average residual energy of all nodes in the path.

3.2 Improved harmony search algorithm

If the distance between transmitter and receiver is less than a threshold value d0, the free space (f_s) model is used, otherwise the multipath model (m_p) is used[18].

Energy required transmitting l bits message over distance d is as follows

$$E_{T}(l,d) = \begin{cases} lE_{elec} + l\epsilon_{fs} d^{2} & \text{ for } d < d_{0} \\ lE_{elec} + l\epsilon_{mp} d^{4} & \text{ for } d > d_{0} \end{cases}$$

Where E_{elec} is the energy required for electric circuit, ε_{fs} energy required for amplifier in free space and ε_{mp} energy required for amplifier in multiple path.

Energy required for receiving data l-bit message at any node

$$E_R(i) = lE_{elec}$$

Digital coding, modulation, filtering and spreading of the signal effect on E_{elec} and the distance between transmitter and receiver effect on ϵ_{mp} and ϵ_{fs} .

Objective function is to maximize the life time of the WSN, PSO achieve this propose by maximize life Time of channel and minimize the Average distance between sensor nodes and their corresponding gateway.

 $E_{cluster}$ (g_i) = n_i × E_R + n_i × E_{DA} × E_T(g_i, nexthop(g_i))

Where E_{DA} is the aggregation energy consumption, g_i is the gateway and n_i is the number of sensor nodes.

$$\begin{split} E_{forward} & (g_i) = N_{IN}(g_i) \times E_R + N_{IN}(g_i) \\ & \times E_T(g_i, nexthop(g_i)) \\ E_{Gateway} & (g_i) = E_{forward} & (g_i) + E_{cluster} & (g_i) \end{split}$$

$$l(i) = \left| \frac{E_{Residual} (g_i)}{E_{Gateway} (g_i)} \right|$$

Where l(i) is the life Time of WSN.

Fitness α l

As maximize the life time of average distance the maximum fitness is obtained. To minimize the average distance:

AvegDist =
$$\frac{1}{N} \sum_{i=1}^{N} \text{dist}(s_i, CH_i)$$

Fitness $\alpha \frac{1}{\text{AvegDist}}$

4. PROPOSED ALGORITHMS

4.1 Improved harmony search algorithm The harmony Search algorithm steps to achieve optimization

of wireless sensor network of sending data from sensor node to sink node as shown in Fig 3.

4.2 Particle swarm optimization algorithm

The Particle swarm algorithm steps to achieve optimization of wireless sensor network of sending data from sensor node to sink node as shown in Fig 4.

5. SIMULATION AND RESULTS5.1 Improved harmony search algorithm

These results were developed by C++ programming language on a PC with 2.3 GHZ, Intel core I7, 7610 QM processor and 8 GH ram to analyze the energy of sensor node and life time.

Metrics used to measure the performance of algorithm are:-

Average residual energy, the standard deviation of residual energy related to the average energy of all nodes and the standard deviation of residual energy level of all node respectively.

The minimum residual energy and the network life time denoted by the residual energy of the node with lowest residual energy among all nodes and the number of rounds that the network have sustained until any node runs out of energy.

The energy level of all nodes is set to 10 J, and all nodes send packets to sink node periodically. Simulation parameters are as following:-

Parameter	Value
Packet size	4098 bits
Communication radius	150 m
HMS	5

HMCR in IHSBEER	$HMCR_{min} = 0.2$
	$, HMCR_{max} = 0.9$
HMCR in HSBEER	HMCR=0.7 , PAR=0.02
Evolution items	500
α,β	$\alpha=1,\beta=5$
ρ	0.0
Initial pheromone	1.0
-	

Simulation and results were obtained in two scenarios. First of them the energy is set to 10J for all nodes and each sensor node sends periodically packets to a sink node as Fig 1. The other scenarios three energy levels were used: 10J, 20J and 30J. These levels are uniformly distributed over the nodes. And each sensor node periodically sends packets to the sink node as Fig 2.

5.2 Particle swarm optimization algorithm

This simulation and results were performed with MATLAB R2012b and C-Programming Language. Simulation parameters are for the network as follows[18]:-

Value
500×500
200-700
60-90
10Ј
2J
200
50 nJ/m
10 pJ/bit/m2
0.0013 pJ/bit/m4
87 m
5 nJ/bit
4000 bits
200 bits
150 m

Table 2. Simulation parameters



Fig 1: Result of Scenario # 1 at 10J Energy level for each node



Fig 2: Result of Scenario # 2 at 10 or 20 or 30 Energy level for each node



Fig 4: particle swarm optimization algorithm

PSO parameters for algorithm are as follows[19]:

Parameter	Value
N _p	60
C ₁	1.4962
C ₂	1.4962
W	0.7968
V _{Max}	0.5
V _{Min}	-0.5

Table 3. Simulation parameters

Simulation considers two different scenarios and the results of the proposed algorithm are compared with other algorithms as GA[20],GLBCA[21] and LDC[22]. The first one considers the base station to be positioned in aside of region with 60 nodes as in fig 5 and with 90 nodes as Fig 6 and the second consider base station to be at the center of the region with 60 nodes as in fig 7 and with 90 nodes as Fig 8.:

6. TERMINATION CRITERIA6.1 Harmony search optimization algorithm

It uses tradition way to measure the life time of the network. At start the algorithm set for each node determine energy then send number of packets from each node then calculate the residual energy which each node have. Then determine the life time of the network the network. If the residual energy of nodes is maximum, the longer life time of the network. If the residual energy of nodes is minimum, the shorter life time of the network.

6.2 Particle swarm optimization algorithm

Life time of the network can be defined by more than way[13]. The first way is the life time of the network until the first node die on the network. The second method is the life time of the network until the last node die (i.e. all nodes are died). The third method is until percent of nodes die (i.e. some of nodes are die)[13]. Some other consider the life Time of the network until the entire region are covered[23]. This algorithm considers the life time of the network until the first gateway node is died.

7. CONCLUSION AND FUTURE WORK

Results proved that particle swarm optimization algorithm is better than the harmony search algorithm. Number of nodes in swarm optimization algorithm particle network implementation is more than the harmony search algorithm network implementation. And the life time of network of particle swarm optimization is longer than the life time of the network of harmony search algorithm. In the future, Simulate other optimization algorithms such as sine- cosine algorithm and Ant colony algorithm in NS2 and compare results with these results. Implement these algorithms in real wireless sensor networks to see the effect of improving these algorithms.



Fig 5: Scenario #1 for 60 Gateways

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Fig 8: Scenario #2 for 90 Gateways

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