International Journal of Computer Applications (0975 - 8887)
Volume 65 - No. 21, March 2013

An Optimized Low Loss Energy-Aware Routing Protocol for Wireless Sensor Networks

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ABSTRACT

This paper examines the QoS of an energy efficient cluster based routing protocol called Low-Loss Energy Aware Routing Protocol (LLEAP) in terms of network lifetime and aims some modifications on this protocol to increase its performance. Biological inspired algorithm helps to enhance the performance parameters of LLEAP.

General Terms:

Optimization, Wireless Sensor Network (WSN)

Keywords:

Ant colony optimization (ACO), Routing Protocol, energy-efficient, network-lifetime

1. INTRODUCTION

Routing is a process of selecting paths in a Wireless Sensor Network. According to [1] the key challenges in WSNs are fault-tolerance, network lifetime, and communication management. The communication in WSN includes node to node communication. This communication includes optimal route selection, route maintenance etc. to compete with user expectations and better network performance. Thus there is a need for efficient routing protocols which should not only be suitable for the application demands but also assists network with respect to its limited resources and performs well even in adversities in terms of energy and traffic metrics. For identifying and selecting best routing protocol for an application, it is required to understand the demands of that application first and then to select the appropriate protocol to be implemented.
LEACH which is adaptive clustering protocol for distributing the energy load among the sensor nodes in the network. LEACH uses [5] randomized rotation of the cluster base stations or cluster-heads and the corresponding clusters and is able to distribute energy dissipation evenly throughout the sensors, doubling the lifetime. PEACH [14], a clustering protocol for maximizing the network lifetime of the wireless sensor networks. Clustering protocols enable sensor nodes to reduce data packets by data aggregation on WSN. In wireless sensor networks, a node can recognize the source and the destination of packets transmitted by hearing the neighboring nodes. [15] described HEED in which tentative cluster heads are randomly selected based on their residual energy. Therefore, HEED cannot guarantee optimal head selection in terms of energy, since it uses the secondary parameter to solve the problems. EEABR based on the Ant Colony Optimization heuristic [2]. Initially the forward ants are sent to no specific destination node, which means that sensor nodes must communicate with each other and the routing tables of each node must contain the identification of all the sensor nodes in the neighbourhood and the correspondent levels of pheromone trail. For large networks, this can be a problem since nodes would need to have big amounts of memory to save all the information about the neighboring nodes. BACCA [6] for radar sensors which consume a better balanced energy and increase the life cycle of the radar sensor network. The difference between wireless sensor network and radar sensor network is that there is one more step in radar sensor network, which is radar scanning process, so deduce radar sensor network radio model can be deduced from wireless sensor network radio model. In this algorithm when the new cluster head is chosen, both the residual energy and aggregation of radar nodes are considered.
ECRPW was proposed [12] to prolong the lifetime of the network, residual energy of the nodes is to be considered during the election process of cluster-head. The cluster-heads were distributed uniformly as they consider the distance that had been forced to optimize the cluster scheme. The constraint of distance is considered in formation of cluster to avoid extra energy consumption. The network lifetime of this protocol is longer than that of LEACH. The lifetime curve increases with node density. According to [9] energy efficient unequal clustering was introduced for large wireless networks which balance the power of node consumption and increase the network lifetime as long as possible. This protocol focuses on inter-cluster routing protocol. Fuzzy logic system is used to determine node's chance of becoming cluster-head and adaptive max-min ant colony optimization is used to construct inter-cluster routing between cluster heads and base station which further balances the energy consumption of cluster-heads. Base station broadcasts a beacon message to all the sensor nodes at fixed power. Each sensor node can compute the approximate distance to the base station based on the received signal strength. This proposed clustering scheme is divided into rounds and the main feature of this algorithm is the application of Fuzzy Logic called unequal clustering Fuzzy logic improved ACO algorithm (UCFIA). ACO is used to find the optimal path between cluster head and base station. UCFIA improves the network lifetime over LEACH and EEUC. Khalil et al. EAERP in which authors [7] reformulate the design of important feature of EA (Evolutionary Algorithms) so that the routing protocol provides more robust results as compared to the existing heuristics. The authors have presented a new evolutionary dynamic cluster formation in WSN. This protocol proves to be an important for deriving clustered routes with better trade-off between network stability and network lifetime with well-distributed energy consumption. Researchers in [8] changed the threshold function of the node so as to increase the network's lifetime and balance the energy consumption of nodes. The randomness of choosing head node, energy load imbalance in cluster-head nodes, energy utilization rate of head

nodes are the problems of classical LEACH protocol. The improvement of LEACH protocol includes optimum factor, modified threshold function, and method for normal nodes joining the head nodes which leads to the formation of a new protocol called NEWLEACH. This protocol introduces the optimal factor by considering the residual energy of the nodes, times of the nodes to be elected as a cluster head node, the distance between nodes and base station. This improvement fines the quality of wireless sensor networks. This mainly extends the lifetime of the network. The even distribution of dead nodes exhibits the balanced energy in the network. Thus NEWLEACH protocol has an advantage over classical LEACH routing protocol. A protocol based on Bayesian game was introduced [16] to avoid uneven energy consumption in wireless sensor networks. The authors used the theorems of game theory for routing analysis in wireless sensor networks. Network initialization, cluster-head election, data transmission are the three parts of this protocol. In network initialization, nodes receive initial information from a sink node, then all the nodes broadcasts the data packets to the neighboring nodes and the sink node. The packets include information like ID, residual energy etc. After this all the nodes form a routing table which consists of the information related to those nodes. The real time property of this protocol can be measured by average number of hops from source to sink. This protocol ensures the reliable communication under high real time requirements due to uniformly distribution of cluster-heads and the logical design of utility function.
EAP [10] includes the QoS of an energy efficient cluster based routing protocol in terms of lifetime, loss percentage, delay and throughput. EAP works like LEACH and each round consists of two important phases, set-up phase and data phase. The set-up phase is subdivided into two phases, cluster formation phase and cluster heads tree construction phase. The main disadvantage is that the protocol slightly degrades lifetime of the network.

2. PROBLEM FORMULATION

Today, most of the research is done to develop ultra-low powered WSN which is only possible only if the overall network lifetime increases and the network run with high stability and reliability. To achieve this, many algorithms have been implemented which take their concept from some biological processes. Therefore, they are called bio-inspired algorithms. These algorithms in their basic form have already been implemented on various network protocols including LEACH, AODV etc. However, these bio-inspired algorithms [4] (for e.g. ACO) need further research for getting higher level of optimization in terms of power management, Packet delivery ratio etc. As network observable behavior of bio-inspired processes need to be incorporated in existing algorithms like ACO. The mathematical formulation by which the weights and paths are calculated need improvisation as per the requirement of the routing protocol like LEACH, EAP, and LLEAP. Therefore there is an urgent need to enhance existing ACO especially for LLEAP protocol.

3. IMPLEMENTATION

This section attains the objectives:

(1) Develop a simulated environment of WSN having configurable parameters.

(2) Implement LLEAP routing protocol and measure performance parameters which include network Lifetime.

(3) Optimize LLEAP routing protocol using ACO.

(4) Develop a comparative performance evaluation.

3.1 Parameters of WSN for deploying a network

The parameters considered during simulation have their own significance for the better performance of the network. The Table 1 contributes the simulation parameters used.
The simulation is carried out using Custom Built Iterative Based Simulator in MATLAB 7.12.0.635 (R2011a) which simulates the sending, receiving, dropping and data forwarding etc. The wireless channel is used because the nodes deployed in the network are communicating wirelessly based on their distance, transmission range etc. Propagation model is used to calculate the received power. When a packet is received, the propagation model determines the attenuation between sender and receiver. This model also computes the received signal strength. The two ray ground propagation model is used. An Omni-directional antenna is used for carrying out transmissions in all the directions i.e. over 360 degree. Omni-directional WSN are designed such that a bi-directional link is established between the neighboring nodes if they are within the communication range.

3.2 Routing path optimization technique

The ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. Initially proposed by [3] in 1992 in his PhD thesis, the first algorithm was aiming to search for an optimal path in a graph, based on the behavior of ants seeking a path between their colony and a source of food as described in Fig. 1 .

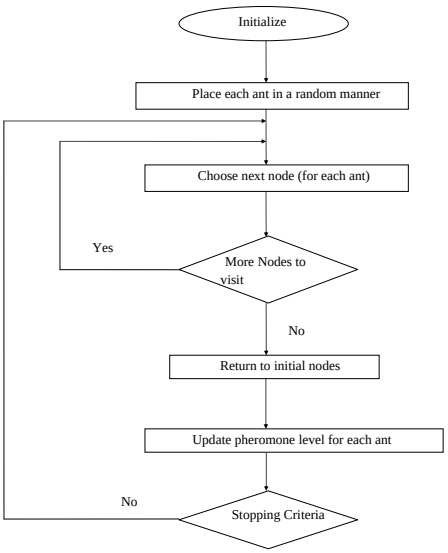

Fig. 1. Flow-chart of ACO.

3.3 LLEAP (Low-loss Energy Aware Routing Protocol)

According to [10] the phase of EAP operations are desribed which is similar to LLEAP as the cluster formation phase is same for the case of both EAP and LLEAP. To eliminate the EAP losses, recovery method is directly used from Cluster Head (CH) death or failure. This will deplete a lot of energy and reduce lifetime. Thus LLEAP, a new modified protocol consists of two techniques, the first is used to increase the network lifetime. The second technique is used to decrease the number of times of occurrence for common cause of loss in EAP to decrease the loss.

Table 1. Parameters for deploying a Wireless sensor network

Parameters	Values
Topology	Mesh
Number of nodes	500
Channel Type	Wireless Channel
Mobility Model	Two-Ray Ground Radio Propagation Model
Network Interface Type	Wireless Phy/IEEE 802.15.4
Antenna Model	Omni-Directional
Routing Protocol	LLEAP
Optimization Technique	ACO
Simulation Area	500*500
Simulator	Custom built Iterative based simulator

EAP uses the same weight for head selection and tree construction. For studying the weights the equation of head selection weight should satisfy that relation among its parameters: the less ratio of the average residual energy of node neighbors to its residual energy ($\frac{E_a}{E_{residual}}$) the greater the node weight, the greater the likelihood of that node become a CH (so that the selected CH will collect in its cluster the maximum number of small residual energy nodes decreasing the load on them and giving the other nodes which have relatively higher energy the chance to become CHs), this requires reversing the ratio $\frac{E_a}{E_{residual}}$ which used in the equation of head selection weight in EAP. The weight used in LLEAP for head selection uses the reversed ratio Eq. 1:

$$\text{LLEAP CH Selection Weight} = \frac{D(RSS_i) \times E_{residual}}{D(RSS_{max}) \times E_a} \quad (1)$$

In tree construction phase, E_a has no meaning and no effect, rather, it may have a negative impact on the selection of inappropriate CH as a root. E_a is the average residual energy of all the neighbors in the cluster range, $E_{residual}$ is the remaining energy left. RSS_i denotes node $i's$ received signal strength of the signal broadcasted by the base station. RSS_{max} is a constant which is determined by the location of the base station. D is a function used for estimating the distance between node i and the base station. So, the tree construction weight in LLEAP is mentioned in Eq. 2:

$$\text{LLEAP Tree construction weight} = \frac{D(RSS_i)}{D(RSS_{max})} \times E_{residual} \quad (2)$$

4. PSEUDO CODE OF PROPOSED ROUTING PROTOCOL

Pseudo code of the proposed algorithm is given for packet movement in a WSN towards sink with objective of achieving maximum network life time in which *Q* represents each event in the simulation. *R* is round in each simulation based on iteration *I*. Directed Acyclic Graph (DAG) [13]is formed by a collection of various vertices and directed edges, each edge connecting one vertex to another, such that there is no way to begin at some vertex and follow a sequence of edges that eventually loops back to vertex again. *RN* describes the selection of root node, *W* is the weight of nodes depicting the distance and residual energy of the node and d_0 is the threshold distance.

5. RESULTS

To assess the performance of the protocols, a set of simulation runs were carried out. The simulation runs were conducted using MATLAB [11]as the simulation platform to generate a network in 500*500 meter square area in which sensor nodes are distributed statically and uniformly. The sink node is located randomly and it is assumed that it has finite power and other resources. The results and analysis conclude that ACO implemented on LLEAP prolongs the lifetime of the network in Fig. 2

PSEUDOCODE OF THE PROPOSED ALGORITHM

for i = 1 to *Q*
  for j= *R*
    for k= *I*
      choose *RN*
  consider it as first edge
for each closed DAG
  choose CH, having highest *W*
else other
  child nodes
    calculate Inter-cluster Node Matrix
    calculate Distance Matrix
for each time slot *t*
  If Node is Alive
  If Inter-cluster distance between source and forwarding node is ≤ *3r*
  If the forwarding node is an established links
  If value of d_0 ratio is < *D*
  If the link is having selection of Cluster Head weight ≤ $\frac{D(RSS_i) \times E_{residual}}{D(RSS_{max}) \times E_a}$
    Cluster head is selected
      Construct tree construction weights = $\frac{D(RSS_i)}{D(RSS_{max})} \times E_{residual}$
  Find links having weights with highest residual energy and smallest distance
Until
  Sink edge is reached
  end
  end
end
end

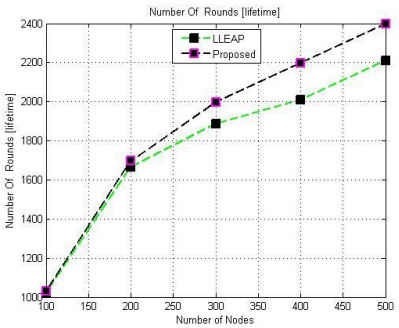

Fig. 2. Number of nodes Vs. Lifetime

6. CONCLUSIONS AND FUTURE SCOPE

Here the proposed algorithm used a single sink. For future directions, multi-sink scenario must be implemented to understand

network lifetime behavior. The concept of death of nodes in existing algorithms is used which makes it more aware about which node has some battery power left or not assuming that the data is going at constant bit rate (CBR). Therefore for future work, other traffic models like exponential can also be explored. Here, it is assumed that each round of simulation consists of at-least 5 communication rounds. Therefore, this type of simulation is iteration based. However for future work this simulation can also be implemented using another techniques or models.

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