A Tree Based Energy Efficient Routing Protocol using Particle Swarm Optimization

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Abstract. **Wireless sensor network (WSN) is a group of spatially distributed autonomous sensors for monitoring and recording physical or environment conditions, such as temperature, pressure, humidity, speed, intensity etc.WSN consists of different types of sensors that are equipped with wireless interfaces through which they can communicate with one another with in the network. Routing is the transmission of packets from a source to a destination address. Routing protocol specifies the communication between the routers and transformation of information between them. Routing algorithms determine the specific choice of route which is to be used for communication. A routing protocol shares this information first among immediate neighbors, and then throughout the network. This way, routers gain knowledge of the topology of the network. The routing process usually directs forwarding on the basis of routing-tables which maintain a record of the routes to various network destinations. In this paper, we proposed a new routing protocol named Optimal Tree Based Routing Protocol (OTBRP). We have considered the parameters like First node dead (FND), Half node dead (HND) and Last node dead (LND) and these are selected as key parameters for the measurement of network lifetime. The comparison is made between the GSTEB, PEGASIS and proposed protocol OTBRP. There is a gain of approx. 200% and 150% in stability period against PEGASIS and GSTEB respectively. Similarly instability period reduces to approx. 50% and 60% against PEGASIS and GSTEB.**

Keywords: **Tree branching, GSTEB, OTBRP, Network lifetime, Residual energy, WSNs.**

I. INTRODUCTION

A WSN contains geographical scattered self-governing sensor nodes cooperatively monitor environmental conditions and different physical quantities such as humidity, pressure, temperature etc. These nodes may be hundreds and thousands in number combined with a gateway and routers to create a typical WSN system. These nodes actually meant for processing, data gathering and aggregation capability along with the communication with other nodes. Each node has its own processing capability that can include one or more microcontrollers which is having system on chip capability, CPUs or DSP chips, and also makes use of external memory known as flash memory. These nodes are having a RF transceiver, batteries and solar cells as a power source, and hold numerous actuators as these nodes. The various sensor nodes communicate wirelessly and infrequently as these are self-governing after being arranged in an improvised manner [1,2]. The main limitation of WSNs is limited power supply and irreplaceable batteries. Moreover, in many applications it is almost impossible to replace batteries so energy consumption is foremost needed in these networks [3-5].

II. BACKGROUND AND MOTIVATION

WSNs are absolutely distinct from the wireless networks by virtue of prominently application explicit nature of WSNs and various constraints. Thereupon, different research challenge [49] are posed by WSN. The models for signal strength dropped over a distance are well developed in wireless communication. In WSN the radio communication is of short range and low power when it is compared with the other wireless communication network. In WSN, the system performance features or characteristics vary considerably even though it follows the same principle for communication which is used in wireless communication network. There are few constraints in WSN like power, cost, size and their tradeoffs. Many issues have been identified and investigated by taking into account that WSN is quite different field from the wireless communication network [6].

Hierarchical-based routing protocols are used in the applications where their high energy-efficiency, data aggregation and good expandability are needed the most [7]. These protocols work on the basic idea to select some nodes in charge routing in particular regions [8-9]. The selected nodes possess greater responsibility as compared to other nodes of the network which leads to the incompletely equal relationship between sensor nodes and only the selected nodes will communicate and monitors the channel [10].

In the tree based approach [11-12], at level 0 root node is placed which is the main node that does data transmission directly to BS after aggregating data. At level 1, parent node of each leaf node is placed, all the leaf nodes gathers data and send it to their respective parent nodes. At level 2, leaf nodes are placed, which are having zero to N number of nodes depends upon the scenario. At level 3, child nodes are placed. Firstly these child nodes gather data which is further send to their leaf node. In the recent past the routing was emphasized with clustering but nowadays tree based routing is having inherent property of efficient routing by using different tree branching techniques. Tree based protocols are simple. A tree-based routing protocol establishes and maintains a shared routing tree to deliver data from a source to receivers of group. Tree based protocols gives the high data forwarding efficiency and low robustness [13]. Tree-based Efficient Protocol for Sensor Information (TREEPSI) is proposed in that a root node is selected before data transmission [14]. In paper [15], General Self-organizing Tree Branching Energy Balancing Protocol (GSTEB) is introduced; its aim is to achieve a longer network lifetime for different applications in WSN environment.

III. OTBRP ROUTING PROTOCOL

In this work a new protocol named an optimal tree based routing protocol (OTBRP) for WSN is proposed. This is a tree based protocol in which the BS itself acts as root node. This protocol is an enhancement of general self-organizing tree branching energy balancing protocol (GSTEB) in which the parent node is selected using Particle Swarm Optimization (PSO) on the basis of energy of nodes, distance between parent node and child nodes and distance between parent node and root node.

1.1 Communication Model

The radio model used in OTBRP is shown in Fig 1. Both the multi-path fading (d^4 power loss) and the free space (d^2 power loss) are used depending upon the distance between the transmitter and receiver. If the distance between transmitter and receiver is more than the threshold then multi-path (*mp*) model is used and if the distance is less than the threshold then free space (*fs*) model is used.

Thus if a node transmits k number of bits, the energy used in the transmission will be:

$$E_{TX}(k,d) = E_{elec}.k + E_{amp}(k.d) \quad (1)$$

Where, E_{elec} is energy consumed in electronic circuit to transmit or receive the signal.

If $d < do$, then

$$E_{TX}(k,d) = k.E_{elec} + k.\varepsilon_{fs}.d^2 \quad (2)$$

And if $d > do$, then

$$E_{TX}(k,d) = k.E_{elec} + k.\varepsilon_{amp}.d^4 \quad (3)$$

Here, threshold

$$do = (\varepsilon_{fs}/\varepsilon_{amp})^{1/2} \quad (4)$$

Where, ε_{fs} is the energy consumed by the amplifier to transmit at a longer distance and ε_{amp} is the energy consumed by the amplifier to transmit at a longer distance.

To receive k number of bits, the radio spends energy

$$E_{TX}(k,d) = E_{elec}.k \quad (5)$$

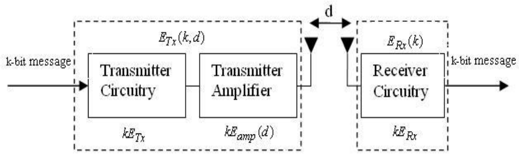


Fig. 1 Energy dissipation radio model

1.2 Proposed Fitness Function

Let's assume network consists of N sensor nodes which is divided into K number of branches, the number of candidate parent node (PN) is denoted by M it generally greater than K, there can be C_M^K ways of clustering.

Fitness function is defined as:

$$f = \alpha f_1 + \beta f_2 + \gamma f_3 \quad (8)$$

Here $\alpha, \beta, \gamma \in [0,1]$, $\alpha + \beta + \gamma = 1$

In the fitness function, f_1 is the reciprocal of the total sum of the energy of the present round PN and total initial sum of energy of all the sensor nodes in the network, f_2 is the maximum of the Euclidean distance average how much distance is found from every cluster sensor nodes to this PN, f_3 is the distance ratio of the average distance from the PN to the BS and the Euclidean distance from the BS to the centre of the network.

$$f_1(p_j) = \frac{\sum_{i=1}^{N} E(nj)}{\sum_{i=1}^{N} E(PNP_{j,k})} \quad (9)$$

$$f_2(p_j) = \max_{\forall k = 1,2,3 \dots N} \frac{\sum_{\forall ni \in Cpj,k}^{N} d(ni,\ PNP_{j,k})}{|BP_{j,k}|} \quad (10)$$

$$f_3(p_j) = \frac{\sum_{i=1}^{N} d(BS,PNP_{j.k})}{K * d(BS,NC)} \quad (11)$$

1.3 OTBRP Protocol Phases and Operation

OTBRP is a tree based routing protocol. The main aim of OTBRP is to attain a longer network lifetime for various applications. In each round, BS assigns itself as root node and broadcasts its ID and coordinates to all the sensor nodes. The operation of OTBRP is divided into four phases.

Initial Phase: In initial phase, the network parameters are initialized. BS broadcasts a packet to all the sensor nodes to inform them of beginning time, timeslot length and the *N* number of nodes.

Tree Constructing Phase: In the tree constructing phase, sensor nodes are selected as parent nodes with some predefined parameters termed as fitness function (described in section 3.2) using BPSO. It starts with the initial population in the binary form on the basis of probability of nodes to become parent nodes. The number of parent nodes varies in each round.

Data Transmitting Phase: Every node selects its parent by considering energy as well as distance optimal values. There may be many leaf nodes sharing one parent node in the same time slot. If all the leaf nodes try to send the data to the parent node at the same time, the data messages may interfere and cause routing overhead and thus decrease throughput. By applying Code Division Multiple Access (CDMA) or Frequency Division Multiple Access (FDMA), these access techniques are efficiently meant to avoid collisions.

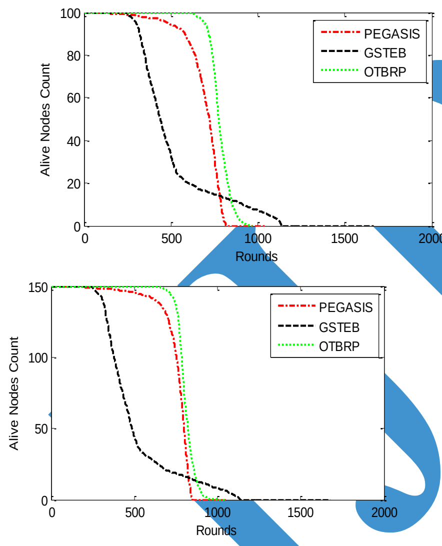
Information Exchange Phase: In the initial phase, BS can collect the energy and coordinate information of all the sensor nodes. For each round, BS builds the routing tree and network schedule by using coordinates and energy information. The BS exchange information by sending DATA-PKT to sensor nodes and in return receives CTRL-PKT from them.

IV. SIMULATION RESULTS

The performance of OTBRP protocol is explored in terms of network lifetime and stability period (the time internal or the rounds before the first node dead) against the GSTEB and PEGASIS protocols. The performance evaluation of OTBRP is done on 10 different WSN networks as shown in Figure 2. To make a fair comparison between the protocols characteristics of the network are used for the proposed protocol are made identical and are described in the table below:

Table 1 Network parameters used in MATLAB simulation for OTBRP

Parameter	Setup 1	Setup 2
Number of nodes, N	100	150
Network size	$100m \times 100m$	
Location of BS	(50, 175)	
Initial energy of normal node, E_0	$0.25J$	
Number of CH nodes, K	5% of nodes	
Radio electronics energy, $E_{Tx} = E_{Rx}$	$50\ nJ/bit$	
Energy for data-aggregation, E_{DA}	$5\ nJ/bit$	
Radio amplifier energy, ε_{friss_amp}	$100\ pJ/bit/m^2$	
Radio amplifier energy, $\varepsilon_{two\_ray\_amp}$	$0.0013\ pJ/bit/m^4$	



(a)

(b)

Fig 2 Number of alive nodes per round using OTBRP for (a) Setup 1, (b) Setup 2

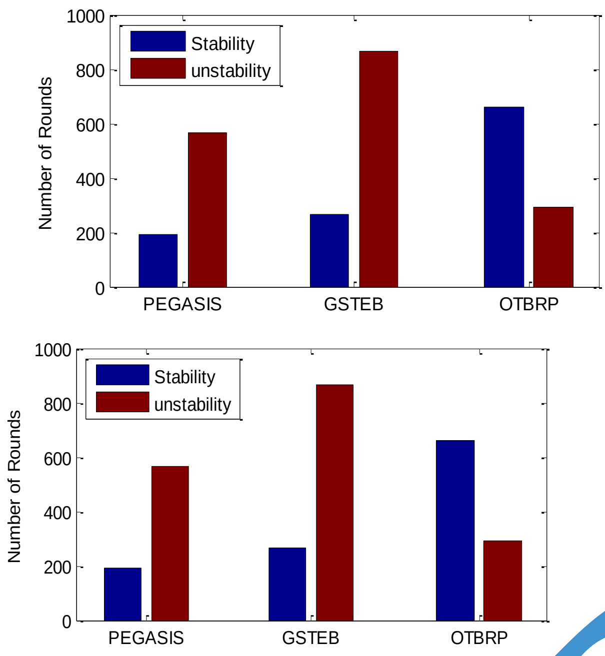
From the figures 2 and 3 and from tables 2 and 3 we conclude that the OTBRP performs better than the PEGASIS and GSTEB till the 90% nodes dead for setup 1 and setup 2 respectively. These tables show the average network lifetime in terms of rounds it takes until FND, HND and LND and it is done for the 10 WSN networks.

Table 2 Comparison of network lifetime of protocols together with stability and instability periods (Setup 1)

Protocol	**FND**	**HND**	**LND**	**Stability Period**	**Instability Period**
PEGASIS	215.2	718.2	804.3	215.2	589.1
GSTEB	**277**	436.1	**1131.1**	277	854.1
OTBRP	**641.9**	**771.9**	931	**641`.9**	**289.1**

Table 3 Comparison of network lifetime of protocols together with stability and instability periods (Setup 2)

Protocol	**FND**	**HND**	**LND**	**Stability Period**	**Instability Period**
PEGASIS	192.7	700.8	758	192.7	565.3
GSTEB	265.8	428.2	**1133.7**	265.8	867.9
OTBRP	**661.8**	**799**	953	**661.8**	**291.2**



(a)

(b)

Fig 3 Performance Results for OTBRP for (a) Setup 1, (b) Setup 2

V. CONCLUSION & FUTURE WORK

In WSNs, the major design issues in the research of routing protocols are energy consumption and network lifetime. In tree based routing protocols, parent node selection is an NP-hard problem. Therefore, nature inspired optimization algorithms may be applied to tackle parent node selection in WSN. In this work, we have proposed OTBRP. In OTBRP, parent nodes are selected using BPSO on the basis of residual energy of nodes, distance between parent node and root node and the distance between parent node and child node. Simulation results show that the application of BPSO optimization technique in the GSTEB improves the energy efficiency and prolongs the stability period of the network. Future work can be done to decrease the routing overhead and transmission delay. Though load balancing is not a major problem in OTBRP but still one can work on it.

VI. REFERENCES

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