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Intelligent Multipath Routing In Wireless Sensor Network Using Genetic Algorithm

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Abstract

Wireless Sensor Networks (WSN) is becoming an increasingly significant and a challenging research area. Improvements in WSN enable a wide range of environmental monitoring and object tracking applications. Furthermore multipath routing in WSN is affected by reduced network throughput and network performance and increased traffic load and delay in data delivery. Hence, optimized multipath routing mechanism is required to handle the problems occur very normally in WSNs. A novel approach called GA based Cost Based Multipath Routing (CBMR) is proposed. Path cost is plays a major role in finding route between the source and sink. CBMR with Genetic Algorithm has shown excellent results in discovering routes for WSN. In this paper, the Genetic Algorithm based Cost based multipath routing mechanism for WSN and its results are presented. Certain parameters like throughput, delay, energy and message overhead are considered to evaluate the performance of GA based CBMR.

Keywords: Path Cost, Genetic Algorithm, Multipath Routing,

Introduction

A Wireless Sensor Network (WSN) [1][2] is a huge set of sensor nodes with restricted power supply and controlled computational capability. WSN is a infrastructure less networks which serves an imperative task in monitoring. In WSN, there exist a restricted communication range between the sensor nodes and there will be a high volume of sensor nodes. Packet forwarding in WSN is usually performed through multi-hop data transmission. Therefore, routing in WSN has been considered an imperative field of research over the past decade. The main responsibility of the sensor nodes in each application is to sense the target area and transmit their collected information to the sink node for further operations. Resource limitations of the sensor node and unreliability of low-power wireless links, in combination with various performance demands of different applications impose many challenges in designing efficient routing protocols for WSN. Meanwhile, designing suitable routing protocols to fulfill different performance demands of various applications is considered as an important issue in WSN. The sensor nodes perform desired measurements, process the measured data and transmit it to a base station, commonly referred to as the sink node, over a wireless channel. The base stations collect data from all the nodes and analyze those data to draw conclusions about the activity. Sink which is a powerful data processor or access point for human interface can also act as gateway to other networks.

For multipath routing there are many parameters to be considered to find the best path. High throughput would be at a noticeable cost of increasing the average end-to-end delay and causes major degradation in the overall network performance. To meet its requirement evolutionary algorithms is used and find best path which will calculate fitness based on QOS parameters, so that our objective has been achieved. Evolutionary algorithms are typically used to provide good approximate solutions to problems that cannot be solved easily using other techniques To search all feasible paths in less time, many researchers have used the concept of Genetic Algorithm (GA), which is a computational strategy inspired by natural processes. Thus evolutionary algorithms like GA are used to optimize the objectives like maximizing the throughput and minimizing the delay. The genetic algorithm is a subset of evolutionary algorithms that model biological processes to optimized highly complex cost functions. It usually keep a set of points know as population. Genetic algorithm [3] maintains a pool of solutions which evolve in parallel over time. In each generation the genetic algorithm construct a new population using genetic operators such as selection, crossover and mutation. The various steps [4] of the genetic algorithm are

STEP 1: Fitness evaluation: After encoding the fitness of each member are calculated by putting the values in objective function.

STEP 2: Selection: After the fitness evaluation of the individuals the proper individuals are selected for the next generation.

STEP 3: Crossover: To exploit the potential of gene pool we use cross over operation to generate new chromosome. Crossover is the operator that gives Genetic Algorithm their strength; it allows different solutions to share information with each other. It operates over two chromosome list.

Example: 1 1 0 1 0 0 → string parent 1

0 1 1 1 0 1 → string parent 2

If we put the two point crossover over the above two strings then the resultant child strings will be as follows.

11 1 1 0 1 → string child1

0 1 0 1 0 0 → string child2

STEP 4: Mutation: Crossover exploits current gene potential but if it does not contain all the information then a mutation operator is used to generate new chromosomes. The most common way of implementing mutation is to flip a bit with a probability equal to a very low given mutation rate.

Example: 0 0 1 1 1 0

If we will put the mutation over the above chromosome then the last bit is converted to 1. So the resultant chromosome will be 0 0 1 1 1 1

The objective of the proposed system is to transmit data between source and sink efficiently in wireless medium with increased throughput, reduced delay, and minimum routing overhead and energy consumption. Multipath routing approach is used to implement the system with improved network performance through efficient utilization of available network resources.

Work presented here is organized as follows: Section 2 presents the related work with respect to multipath routing and Genetic based multipath routing. Section 3 presents a description of the proposed system. Section 4 discusses the implementation environment and the result analysis. Finally, the conclusions and the future work are provided on Section 5.

Related Works

The comparisons of multipath routing protocols were done in [5]. Ad hoc On Demand Multipath Distance Vector Routing [6] extends AODV [7] to provide the multipath. Here each Route Request and Route Reply defines an alternative path to the source or destination. Node-disjointness is achieved by suppressing duplicated Route Request at intermediate nodes. Routing entries contains the list of next hops in which the multiple paths are maintained. AOMDV introduces the maximum hop count value which is the advertised hop count. Since sensor nodes have limited energy capacity, the quality of some applications is influenced by the network lifetime and the energy consumption. The multipath routing protocol utilizes a multipath routing approach to provide energy-efficient communications through balancing of the network traffic over multiple paths. To this aim, the residual battery lives in the nodes are the most important metric considered in the route discovery phase. Nevertheless, as this protocol neglects the effects of wireless interference and assumes error-free links, it cannot achieve significant performance improvement in throughput and data delivery ratio.

An Interference Aware multipath routing protocol (IAMR) [8] to support high rate streaming in wireless sensor networks is proposed. This protocol constructs link-disjoint paths by assuming a specific network model and localization support. It is assumed that there are several gateway nodes connected directly to the command center using non-interfering and high capacity links.

The source node constructs three link-disjoint paths towards the three distinct gateway nodes. After that, the source node utilizes the primary and secondary paths for data transmission and preserves the third path for prompt packet recovery from path failures. Although IAMR shows higher performance compared to the standard

AOMDV. Moreover, to reduce the negative effects of intra path interference, IAMR constructs shortest paths towards the gateway nodes. Since the longest hops should be used to create the shortest paths, the time varying properties of wireless links highly affect the performance achieved by this protocol.

AOMDV-GA [9] procedure for route finding is similar with Ad-hoc On-Demand Multipath Distance Vector (AOMDV) except the intermediate node flooding a RREQ in inverse proportion to their residual energy capacity. If node has good residual energy, it is promoted to join the route and if not, it is avoided to join the route. The GA based multipath routing protocol, produces the time delay for RREQ flooded which proposed and selects multiple routes that have totally minimum time delay among candidate routes.

Proposed Model

Network Model and Assumption

The sensor network consists of N number of nodes deployed randomly over a finite, two-dimensional region. We assume that each node knows its position and also the position of its neighbors within its transmitting range R. These assumptions are satisfied if at least some nodes have access to a low energy GPS and all nodes exchange information about their positions at the network deployment stage. The proper transmission power level to reach each of the neighbors is also registered at the setting of the network to account for non-homogeneous transmission distance around the node. Additionally, we assume that each node knows the position of the sink node. This assumption is immediately satisfied in applications such as target tracking in which the unique sink node's position is known to every node in the network.

GA based Cost Based Multipath Routing

The flow of the system is represented in Fig 1. Initially the nodes are deployed randomly.The source and sink are identified when an event is being generated. The proposed approach includes two methods, first method is finding multiple paths between source and sink using Cost Based Multipath Routing (CBMR) approach and the second method is finding optimized path from the paths obtained from the CBMR approach using Genetic Algorithm. The process of CBMR has alienated into three different phases namely initialization phase, route discovery and establishment phase and route maintenance phase. The neighbourhood information is acquired by each node in the initialization phase. This information will be used in the route discovery and establishment phase to find the next best hop node towards the sink. The route discovery and establishment phase is triggered whenever an event is detected. The outcome of this phase is multiple-interference-minimized paths between the source and the sinks. Finally, the route maintenance phase handles path failures during data transmission. The load balancing algorithm is taken here by distributing the traffic over the multiple established paths. When a route is established the node starts transmitting data. The ETX is the Estimated Transmission cost of each node where that cost is used for the calculation of the path cost. Thus the ETX value is calculated, which gives the cost of the neighbour towards the sink [10]. This value indicates the required number of transmission for successful packet reception at the receiver.

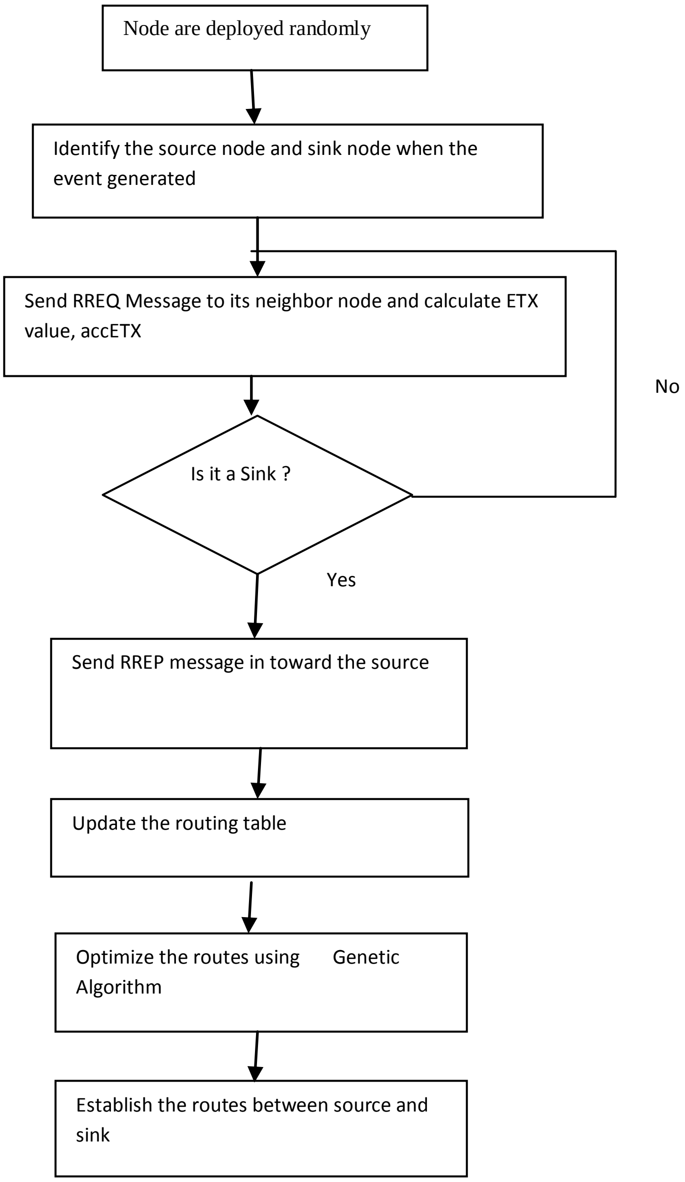

Figure 1: System Flow

The calculation of ETX and accETX is mentioned in [10].The second method is choosing the optimized multi path using Genetic Algorithm.

GA is a global optimization technique derived from the principle of nature selection and evolutionary computing techniques. A novel enhanced multipath routing protocol based on a light weight Genetic Algorithm has been proposed. GA survival of the fittest strategy in nature by preferentially selecting a fitter genetic pool so that future generation will have fitter population members.

Table 1: Path chosen by CBMR

S.No	Path	Nodes involved in a path
1	Path 1	1, 4, 11, 13
2	Path 2	14, 9, 19, 16
3	Path 3	22, 23, 12, 24, 15
4	Path 4	7, 18, 16, 25
5	Path 5	10, 20, 5, 21, 2

The Table 1 shows the number of path chosen by CBMR for 25 nodes. And this will be given to GA as input to optimize results of CBMR.

Depending on the choice of the objective function, the fitness function for that problem has been formulated. A fitness function is a particular type of objective function that is used to summaries, as a single figure of merit, how close a given design solution is to achieving the set aims. Our objective is to increase the performance of multipath routing. Performance includes decreasing the delay and increasing the throughput with low cost. So our fitness function includes delay, throughput of the path as a parameter in fitness function.

$$\text{Fitness(s)} = W1 \times \text{Delay} + W2 \times \text{Throughput} \quad (1)$$

The value of W1 and W2 are 0.5. The delay and the throughput are calculated based on the number of nodes and the energy of each node in path.

Table 2: Chromosomes

S.No	Chromosomes	Gene
1	Chromosomes 1	1, 4, 11, 13
2	Chromosomes 2	14, 9, 19, 16
3	Chromosomes 3	22, 23, 12, 24, 15
4	Chromosomes 4	7, 18, 16, 25
5	Chromosomes 5	10, 20, 5, 21, 2

Table 2 shows the chromosomes formed for this problem. Each path is considered as a chromosome and each node involved in a path is considered as gene. Fitness Function of each chromosome is calculated using equation 1. Genetic operations Selection, Cross over and mutation are applied on the chromosome. This will be iterated until the optimized result obtained.

Implementation Environment

In this section we describe the performance metrics, simulation environment and simulation results. We used MATLAB to implement and conduct a set of simulation experiments for our algorithms and did a comparative study with the EECA and normal CBMR protocol.

Our simulation environment consist of various set of nodes starting from 30 nodes to 250 nodes which are randomly deployed in a field of 1000mX1000m all nodes are identical with a transmission range 250m [11] [12]. Table 1 shows the simulation parameters.

Table 2: Simulation Parameters

Parameters	**Value**
Transmission range	250 m
Interference range	550 m
Simulation Time	>800s
Topology Size	1000m x 1000m
Number of Sensors	30 to 250
Number of sinks	1
Traffic type	Constant Bit Rate
Packet size	512 bytes
Bandwidth	2Mb/s
Initial energy in batteries	10 Joules
Energy Threshold	0.001mJ
Node distance	200

Result Analysis

In all graphs shown Fig 2, Fig 3, Fig 4, Fig 5, Fig 6 has x-axis as number of nodes and the y-axis varies according to its performance metrics. We evaluate the performance of CBMR-GA based on the following five performance metrics.

1. **Throughput:** Throughput is the average rate of successful message delivery over a network. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot. Here the throughput was measured as data packets per second.
2. **End to End delay**: End to end delay refers to the time taken for a packet to be transmitted across a network from source to sink. It is the sum of transmission delay, propagation delay and processing delay.
3. **Routing overhead:** Routing overhead refers to the time it takes to transmit data on a network. Each packet requires extra bytes of data that is stored in the packet header. Information will be combined during assembly and disassembly of packets which leads to reducing the overall transmission speed of the raw data.
4. **Energy:** Every time a node send or receive data the energy will be reduced.
5. **Number of paths:** It refers to the number of path has been selected through which the data will be sent to the sink.

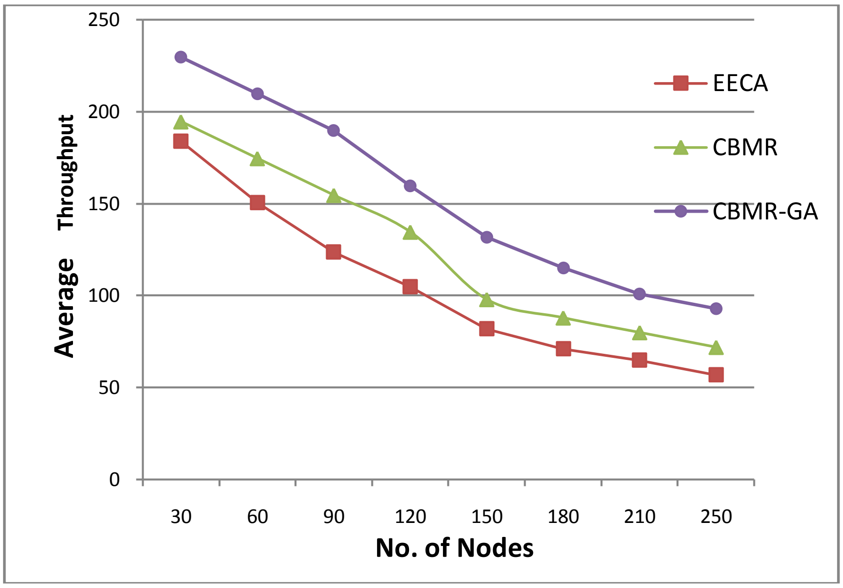

Figure 2: Average Throughput

The average throughput of CBMR-GA, CBMR and EECA has given in Fig 2. It shows that the performance of CBMR-GA is good than the other two approaches. Since only the optimized path is used for transferring data packets. The average delay of CBMR-GA, CBMR and EECA are given in Fig 3, here also, the CBMR-GA performs well compared with other two approaches. Fig 4 and Fig 5 shows analysis of message overhead and energy respectively.

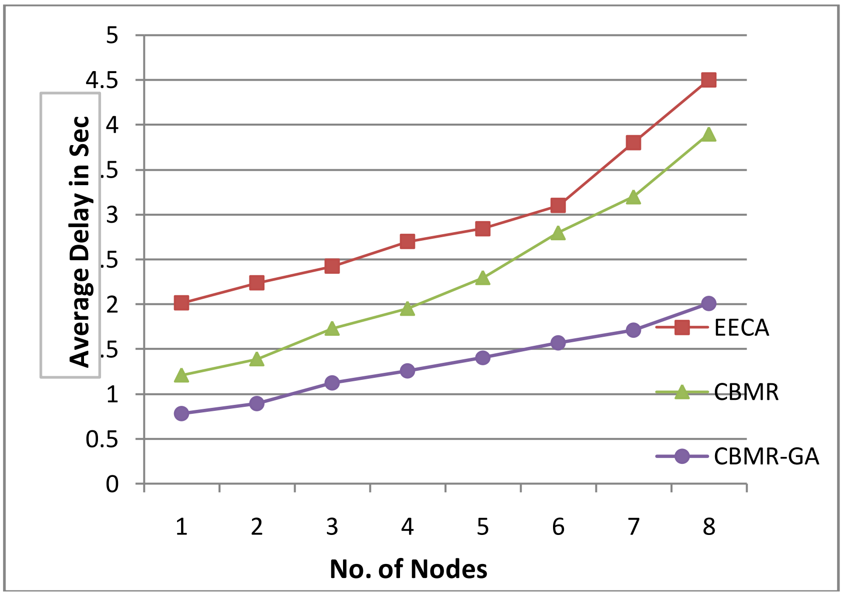

Figure 3: Average End to End Delay

Fig 6 shows the comparison of number of paths selected in CBMR and CBMR-GA. From the Fig 6, we infer that CBMR-GA produced the optimized path than CBMR. Number of path selected may vary depends upon the location of source node and sink node. Since we are using less number of path in CBMR-GA, we can avoid number of packets dropped and the life time of network will also increase.

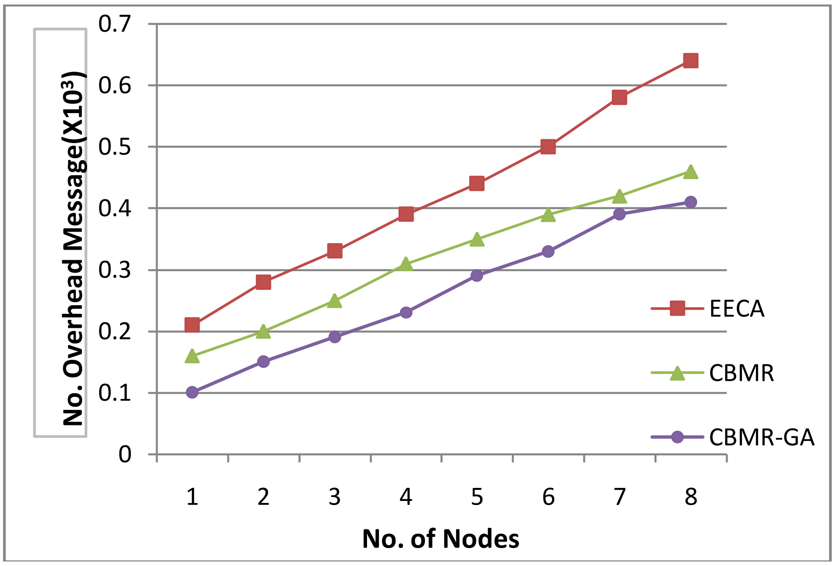

Figure 4: Average Number of overhead Message

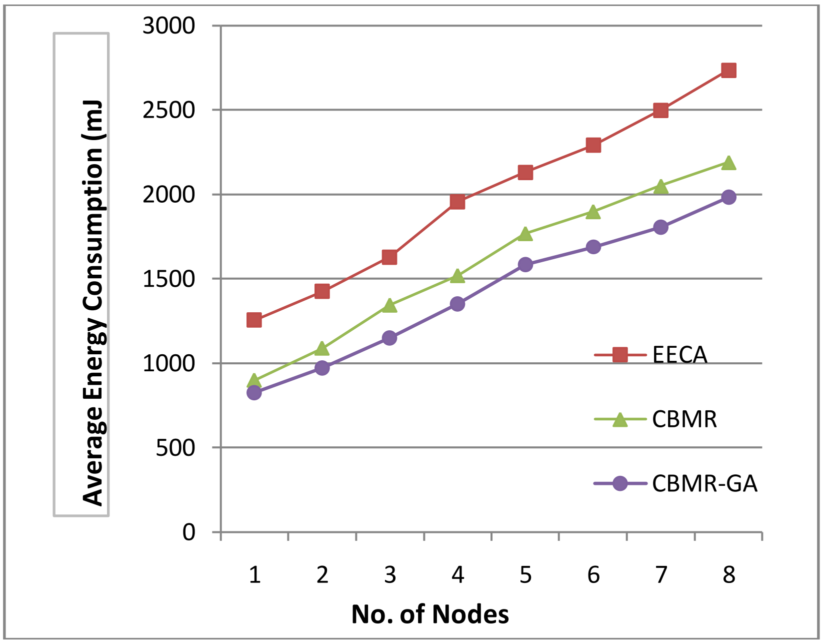

Figure 5: Average Energy Consumption

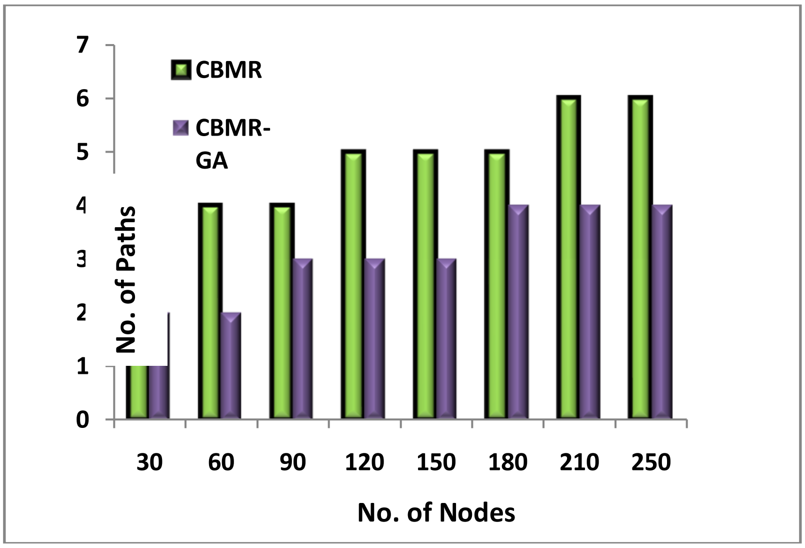

Figure 6: Number of paths selected

Conclusion

In this paper we have proposed a novel approach to enhance the performance of multi path routing in wireless sensor network. The proposed technique performs routing based on cost metrics and bio-inspired algorithm. Cost Based Multipath Routing (CBMR) protocol was implemented to improve QoS demand in Wireless Sensor Networks. The proposed system includes CBMR with evolutionary algorithm in order to optimize the results. Evolutionary algorithm like Genetic Algorithm was used to maximize the throughput and minimize the delay. By using Genetic Algorithms the average percentage of throughput is increased by 7 and delay is decreased by 14.5 than Cost Based Multipath Routing Protocol and EECA. In future, instead of sending normal text data a multimedia data could also be considered.

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