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Divergent Multipath Routing in Cognitive Wireless Sensor Networks

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Abstract—*Energy is one of the important factors that must be considered in designing Wireless Sensor Networks (WSN). Multipath routing is an efficient solution for energy efficiency in WSNs. In this article we propose a Genetic Algorithm based energy efficient divergent multipath routing algorithm, which increases network life time. We derive a fitness function for divergent multipaths from various parameters. The algorithm is tested with NS2 simulator and evaluated with different performance metrics*

Keywords—*Wireless Sensor Networks, Genetic Algorithm, Energy efficiency, Divergent Multipath Routing.*

I. INTRODUCTION

This work aims at building a new multipath routing protocol for Cognitive Wireless Sensor Networks (CWSN) to ensure the maximization of the lifetime of a network. In past few years, the domain of Wireless Sensor Networks (WSNs) has been investigated thoroughly because of its varied applicability in real life, like military surveillances, habitat analysis, health care and so on [1], [2].

Energy is one of the major constraints in CWSN because of its small batteries. The sensor nodes are deployed randomly in the surveillance area, which is not human approachable and hence it is difficult to replace their batteries. Also, the sensor nodes tend to fail because of the surroundings in which they work. This leads to work in the direction of energy efficient and fault tolerant sensor networks that maximizes network lifetime. Researchers have developed many solutions for the same [2].

Multipath routing is one of the impressive solutions for energy efficiency. In multipath routing, information in terms of packets are traversed over multiple paths in the network, and in turn minimizing packet loss at the recipient, usually called as base station (BS) [3]. Thus multipath routing has more fault tolerance than the single path routing [4]. Multipath routing also ensures the data security against malicious nodes that modify the packet while routing [5].

Most widely used idea for energy efficiency in WSN is achieved node clustering. In clustering, sensors are grouped to form the cluster. Each cluster has a cluster head (CH) which collects the data from its member nodes and forward to BS.CHs are from selected from the deployed sensor nodes having same energy, and hence has higher chance of dying early due to its extra efforts of aggregation and dissemination [6]. To overcome this issue every sensor node acted as a relay node or a gateway node in the network [7].These relay nodes takes over the job of CHs. Thus multipath routing in relay based WSNs is studied as a part of this work.

The rest of the research paper is organized as follows: Section II describes the literature related to the proposed algorithm. Section III details about System Analysis. System Design is discussed in Section IV. Implementation is discussed in section V. The experiments and results are presented in section VI and we conclude in section VII.

II. RELATED WORK

In [8] C. Intanagonwiwat et al. proposed multipath routing based on query called Direct Diffusion(DD).This routing in the network is initiated by flooding the interest packet. When any node in the network receives this packet, it creates gradients to the source node from which this packet was received and multiple paths are identified between every source and base station pair. With the detection of an event the node sensing it sends the data packet to the BS in all the paths. BS then decides the best path after receiving the packet from the source using latency as a metric.

D. Ganeshan et al. [9] discussed a novel multipath routing and they compare its performance with single path routing algorithm on network lifetime. Here in this algorithm minimum hop count is chosen as a parameter to choose the routing path. The idea behind that is minimum hop counts ensures lesser number of relay nodes and hence lesser energy consumption. However, the absolute distance between the nodes and the residual energies of the relaying nodes are not considered in this algorithm, which had the potential to make it more energy efficient.

Reliable and Energy-Aware Multipath Routing (REAR) is a protocol introduced in [10]. The aim of this algorithm is to make the network energy efficient. For every path between the source and BS there is a backup path maintained by the system to ensure reliability.BS initiates the route discovery process by flooding a request packet. With the reception of the request packet, a node transmits a reservation message to ensure the route between the source and the BS. This approach has limitation in finding an alternate route in case of a node failure.

Energy-Efficient and QoS-based Multipath Routing (EQSR) is described in [11] by J. Othman and B. Yahya.The proposed approach addresses the issue of reliability and latency in an application. They use lightweight XOR-based FEC [12], introducing data redundancy during data dissemination fulfilling the delay constraints. EQSR uses flooding for neighbour table generation and mayex aggerate the exact value of mutual interference in multiple paths.

In [13], Prasenjit Chanak and Indrajit Banerjee proposed a fault tolerant routing. It has two steps 1) recovery process and 2) fault identification. In this protocol shortest path is used by every node to transmit data to BS.In [14] a multipath routing protocol based on hop count is published. Initially BS floods the packet for network setup and every node based on the hop count with respect to BS identifies which ring it belongs to. The ring level of sink is 0. The sensor node belongs to a particular ring level will forward the packet only to the node having a ring level one lesser than itself.

E. Felemban et al. introduced Multipath Multispeed Protocol (MMSPEED) [15], that is based on cross layer design approach. It is the extension of SPEED protocol [16] with multiple speeds to guarantee packet delivery latency.

III. SYSTEM ANALYSIS

In [17], Suneet Kumar Gupta et al. propose Genetic Algorithm (GA) based energy efficient multipath routing algorithm for WSNs. We use this model for the simulation work.

In this research article, we propose a Divergent Multipath Routing in Cognitive Wireless Sensor Networks. We have considered genetic algorithm, which is proven to energy efficient. To make the algorithm efficient, the parameters distance between the nodes, hop count and distance between the node and the BS are considered and tuned.

Figure 1 gives the example of multipath routing. In this there are 9 forwarding nodes and a BS. For the node 1 there are 2 paths with the first one is 1 → 4 → 5 → BS and second is 1 → 2 → 6 → 9 → BS. Except for source and destination there are no other nodes that are common in these paths. So, we can say path1 and path2 are node disjoint in nature.

Figure 1 illustrates that the total of 9 nodes and 18 links in the network. Considering the links as bi-directional, we see that every node in graph has an approximately 4 neighbors. The total number of paths possible to cover all the nodes in the graph by shear brute force would have 9^4 combinations. This is huge search space to prune the best possible path of our choice. The idea of GA is to prune this space based on the fitness function of our choice. The cost metric that is used to maximize or minimize the fitness function uses the distance as a metric.

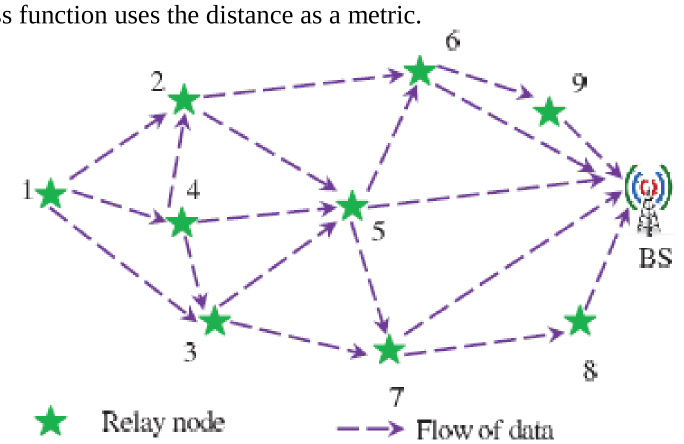

Fig. 1. WSN with 9 relay nodes and single base station.

Network lifetime is the parameter that is expected to be maximized and to do so we calculate the number of rounds of data transmission from every node to the BS without a node failure in between.

IV. SYSTEM DESIGN

The system developed has two stages of processing and involve understanding the networking concepts as well as genetic algorithm concepts. Both these areas are very advanced in their own way and we try to bring the benefits of both these areas into this work. The system is designed to be in two stages as explained below:

- Learning the graph from the deployed network: Learning the graph from the deployed network is essential to know the number of nodes and also the number of links that connect amongst these nodes in the network.

- Divergent Multipath identification using genetic algorithm: With the graph in hand, the next task is to identify the best path for routing in the network using genetic algorithm. The output of this module is to provide the best path through which each of the nodes can disseminate data to base station.

Both these stages are run separately, with stage 1 we identify the neighbors of each node in the network and then we prepare the chromosome consisting of next hop information from this neighbour table. The chromosome generated is then fed to the genetic algorithm for mutation and crossover functions to optimize the fitness function of choice in the second stage of the system.

The steps done in the first stage of the system are as follows:

- The first step in this module is to setup the network infrastructure by deciding the number of nodes and the node positions in the network. Along with this several other parameters are also set to establish the network connectivity in order. The communication range of the node and the type of the antenna are set in this step.

- The second step is to initiate a protocol to establish the neighbor table generation among the nodes in the network. The idea here is to initiate a broadcast packet from every node in the network with the TTL set to vale 1. This TTL value ensures that the packet is not transmitted beyond the first hop. The first hop nodes make an entry into their neighbor table the information from the packet source. Every node follow this procedure so that one hop neighbors of each of these nodes makes an entry into the neighbor table. Once this step is done all the nodes will have information about the nodes that they can communicate with in a single hop.

- The neighbor table information along with the node position is then consolidated as the output of the module 1 which is then fed into the genetic algorithm process.

The second module of the system is the genetic algorithm phase where the following steps are executed in order:

- Node positions and the neighbor table information are used in this step to create a chromosome for the network. An example chromosome is depicted in figure 2. The values for each gene in the chromosome are one of the neighbors of the node. The sample chromosome shown below is for the network graph shown in figure 1. Each chromosome consists of two possible paths concatenated with each other. This ensures the multipath routing.

- Second step in this module is the calculation of fitness of a chromosome. The fitness of a chromosome is defined as the strength of the chromosome for a given application. In general a fitness function is either a minimization or a maximization function depending on the cost metric of choice. The cost metric for our work is based on the distance between the nodes and the base station. There are two cost functions defined in our work.

  1. Cost between two non-BS nodes: If two nodes of consideration are non-base station nodes.
  2. Cost between a node and BS: In such case our cost function will have single component and it is the distance between the node and base station as shown below.

$$C_i n_i = \frac{1}{hop^{BS}(n_i) + 1} \qquad (1)$$

$$\boldsymbol{hop}^{BS}\ (i) = \boldsymbol{hop\_count}\ (i \rightarrow BS) \qquad (2)$$

For a particular path 'p'

$$C_i n_i^p = \frac{1}{hop_p^{BS}(n_i)+1} \qquad (3)$$

$$hop_p^{BS}(i) = hop\_count^p(i \rightarrow BS) \qquad (4)$$

The fitness function of the algorithm is then defined as below:

$$C_i n_i^{p1} = \frac{div(p_1^i, p_2^i)}{hop_{p1}^{BS}(n_i) + 1} \qquad (5)$$

$$div(p_1^i, p_2^i) = 1 - \frac{CIN(p_1^i, p_2^i)}{MIN(p_1^i, p_2^i)} \qquad (6)$$

The above equation indicates that the fitness function is the maximization function for every entry in the chromosome.The cost of every relay node to tits next hop of choice is added and the value is said to be the fitness value of that particular chromosome. When two chromosomes are compared for the better one, then the higher fitness valued chromosome is considered.

	1st path									2nd path								
Relay node no.	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Possible next hop	2	5	5	5	BS	BS	BS	BS	BS	3	6	7	2	7	9	BS	BS	BS

Fig. 2. Chromosome representation for subgraph

The crossover operation is the next step in this module. The crossover operation generates the next generation chromosomes from the initial population. The next generation chromosomes will then participate in the race to become a best fitted solution according to the fitness function. The child chromosome in turn the next generation chromosomes are generated by using The 2-point crossover operation. The 2-point crossover operation is demonstrated below in figure 3.

The figure 3 illustrates the crossover operation. As compared to classical genetic algorithm, this is special case crossover operation where the points of crossover are chosen with constraints. The constraints to choose the point of crossover is that the first point has to be in the first path (i.e., first half of the chromosome) and second point of crossover should be in the second path (i.e., second half of the chromosome). This ensures that the new generation does not have repeated path as the parent chromosome.

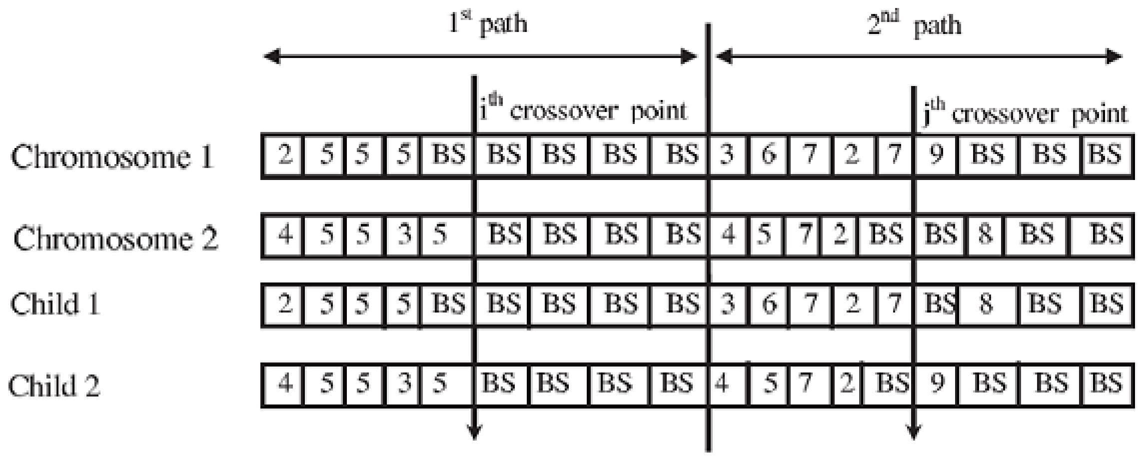

Fig 3: Crossover operation.

Next step in this module is the mutation process. The mutation process emphasis on pruning the population. All those chromosomes in the current population are pruned which do not have the ability to become a best solution going forward. Since our fitness function is a maximization function, we choose the minimum vale fitness chromosome for the mutation process.

We repeat the all these steps in module 2 until our fitness function does not change with iteration. This is to ensure the best possible paths for data transmission from relay nodes to base station.

The designed system is evaluated for the metric of network lifetime. The network lifetime is measured based on the number of rounds of data transmission from all the nodes in the network to the base station. The nodes in the network loose energy for transmission and reception. With every forward of data all the nodes in the path loose transmission and reception energy in one round. The number of rounds stops even if a single node in the path runs out of energy.

V. IMPLEMENTATION

The proposed algorithm has been implemented using the NS-2.35 simulator and java module which reads the input to create the initial population and then runs the genetic algorithm to give the best fitness function.

There are few implementation constraints that are followed in this work. Here is the list of all of them.

- The initial population is chosen based on the Roulette-Wheel method.
- Every node in the network is started with same amount of energy.
- All the nodes in the network are non-malicious and does not behave spuriously.
- The node 0 is the base station and all the other nodes in the network are relay nodes.

Representation of nodes and edges of a network in the form of a chromosome demands the notion of edges between the node (represented by the index number) to the node (represented as the chromosome value).

The number of edges in the network restricts the possible chromosomes to be considered for finding the "fit" chromosome of interest. In previous sections we have defined the representation of two path chromosome. We run over experiments to capture a chromosome that possess two divergent multipaths in a network.

We treat the problem as travelling salesman problem in order to define the operators of genetic algorithm. The contrary of a TSP is defined as follows:

- The destination in this case is always BS
- No node is revisited as the case with TSP
- The objective function is to reduce the path length of the traveler in TSP as is the case for our approach. However, having divergent paths in a chromosome expects minimum number of common nodes among paths.

- Mutation and crossover operations are constrained to have only possible paths defined by the network.

We run our experiments for multiple epochs to capture the lifetime of a network. As in the WSN literature, the lifetime of the network is defined by the number of rounds of successful data transmission. As shown in the results, our divergent multipath routing ensures better lifetime of the network as compared to the traditional multipath routing without considering the divergence.

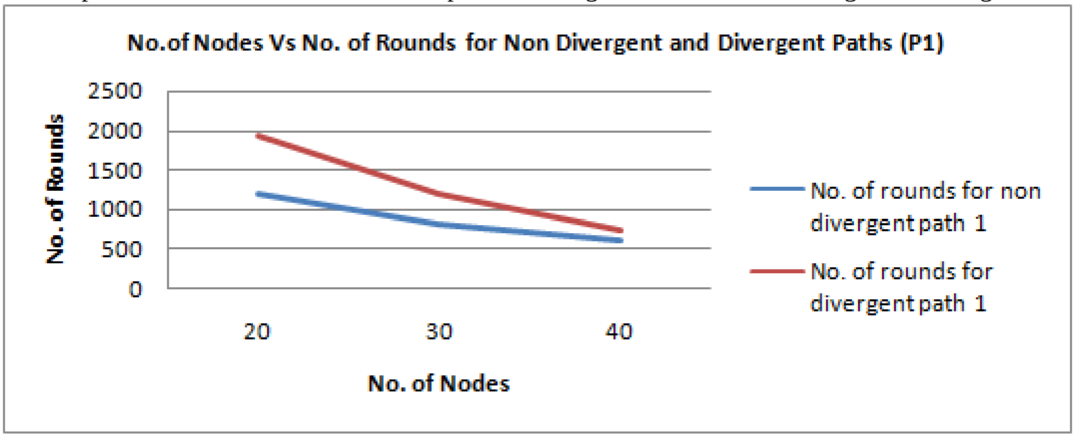

Fig 4: No. of rounds for path 1

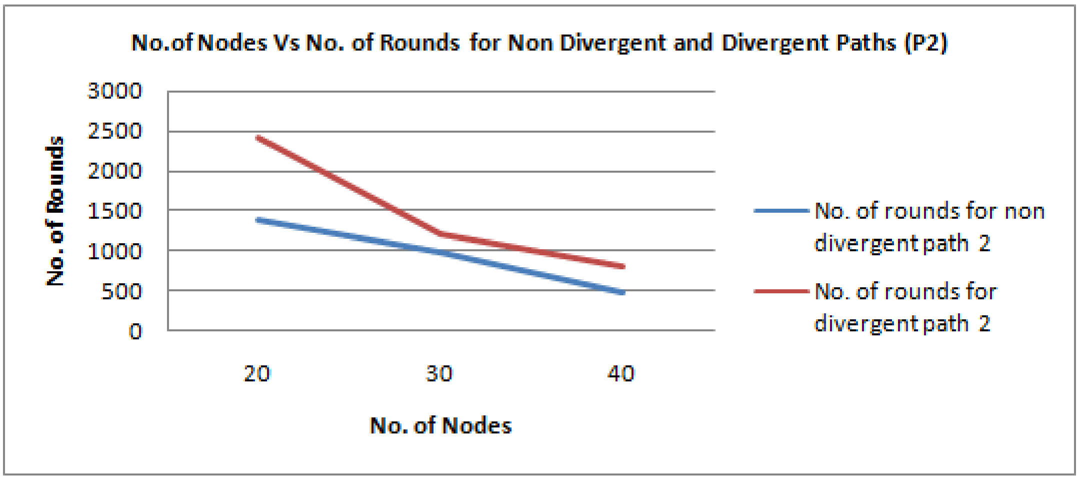

Fig 5: No. of rounds for path2

VI. CONCLUSIONS

To achieve energy efficiency in sensor network, multipath routing is the preferred method of choice. In this work, we introduced Divergent multipath routing using genetic algorithm for Cognitive wireless sensor networks. We elaborate all the basic steps of genetic algorithm and map our multipath problem into the travelling sales man problem.
In order to conduct experiments we made use of NS 2.35 and Java, we have executed the algorithm by varying the number of nodes in the network and pictorially represented results in terms of network lifetime. The number of rounds that data transmission could take place for multiple paths are evaluated and seem to be improved as compared to the initial population chosen.
The cost function considers only the distance metric and hence we would like to evaluate the system by changing the metric that considers residual energy as well along with the distance function.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wirelesssensor networks: a survey," *Computer networks*, vol. 38, no. 4, pp. 393–422, 2002.C.E. Perkins, P. Bhagwat, in ACM SIGCOMM computer communicationreview, vol. 24 (ACM, 1994), vol. 24, pp. 234–244.
[2] I. F. Akyildiz and M. C. Vuran, *Wireless sensor networks*. John Wiley& Sons, 2010, vol. 4.
[3] S. M. Zin, N. B. Anuar, M. L. M. Kiah, and I. Ahmedy, "Survey ofsecure multipath routing protocols for {WSNs}," *Journal of Networkand Computer Applications*, vol. 55, pp. 123 – 153, 2015.
[4] M. S. A. Nabil Ali Alrajeh and M. S. Elwahiby, "Secure ant-basedrouting protocol for wireless sensor network," *International Journal ofDistributed Sensor Networks*, vol. 2013, 2013.

[5] E. Kohno, T. Okazaki, M. Takeuchi, T. Ohta, Y. Kakuda, and M. Aida,“Improvement of assurance including security for wireless sensor networks using dispersed data transmission,” *Journal of Computer andSystem Sciences*, vol. 78, no. 6, pp. 1703 – 1715, 2012.

[6] K. Akkaya and M. Younis, “A survey on routing protocols for wirelesssensor networks,” *Ad hoc networks*, vol. 3, no. 3, pp. 325–349, 2005.

[7] M. Younis and K. Akkaya, “Strategies and techniques for node placement in wireless sensor networks: A survey,” *Ad Hoc Networks*, vol. 6,no. 4, pp. 621–655, 2008.

[8] C. Intanagonwiwat, R. Govindan, D. Estrin, J. Heidemann, and F. Silva,“Directed diffusion for wireless sensor networking,” *IEEE/ACMTransactions on Networking (ToN)*, vol. 11, no. 1, pp. 2–16, 2003.

[9] D. Ganesan, R. Govindan, S. Shenker, and D. Estrin, “Highly-resilient,energy-efficient multipath routing in wireless sensor networks,” *ACMSIGMOBILE Mobile Computing and Communications Review*, vol. 5,no. 4, pp. 11–25, 2001.

[10] H. Hassanein and J. Luo, “Reliable energy aware routing in wirelesssensor networks,” in *Dependability and Security in Sensor Networks and Systems, 2006. DSSNS 2006. Second IEEE Workshop on*. IEEE,2006, pp. 54–64.

[11] J. Ben-Othman and B. Yahya, “Energy efficient and qos based routingprotocol for wireless sensor networks,” *Journal of Parallel and Distributed Computing*, vol. 70, no. 8, pp. 849–857, 2010.

[12] L. Rizzo and L. Vicisano, “Rmdp: Anfec-based reliable multicastprotocol for wireless environments,” *SIGMOBILE Mob. Comput.Commun. Rev.*, vol. 2, no. 2, pp. 23–31, Apr. 1998. [Online]. Available:http://doi.acm.org/10.1145/584017.584020.

[13] P. Chanak and I. Banerjee, “Energy efficient fault-tolerant multipath routing scheme for wireless sensor networks,” *The Journal of China* Universities of Posts and Telecommunications, vol. 20, no. 6, pp. 42– 61, 2013.

[14] G. M. Huang, W. J. Tao, P. S. Liu, and S. Y. Liu, “Multipath ring routing in wireless sensor networks,” in *Instruments, Measurement, Electronics and Information Engineering*, ser. Applied Mechanics and Materials, vol. 347. Trans Tech Publications, 10 2013, pp. 701–705.

[15] E. Felemban, C.-G. Lee, and E. Ekici, “Mmspeed: multipath multi-speed protocol for qos guarantee of reliability and. timeliness in wireless sensor networks,” *IEEE Transactions on Mobile Computing*, vol. 5, no. 6, pp. 738–754, June 2006.

[16] T. He, J. A. Stankovic, C. Lu, and T. Abdelzaher, “Speed: a stateless protocol for real-time communication in sensor networks,” in *Distributed Computing Systems, 2003. Proceedings. 23rd International Conference on*, May 2003, pp. 46–55.

[17] Suneet Kumar Gupta, Pratyay Kuila and Prasanta K. Jana , “Energy efficient multipath routing for Wireless Sensor Networks: A Genetic Algorithm approach”, ICACCI, 2016.

