IMPROVING NETWORK LIFETIME OF WIRELESS SENSOR NETWORK USING BIO INSPIRED TOPOLOGY OPTIMIZATION

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Abstract: Wireless sensor networks (WSN) have numerous nodes which are running on small batteries. Small world networks provide a better option to reduce the connectivity among the nodes in terms of hop count. Therefore, in large scale sensor networks, the small world networks can play an important role in saving the energy of the network. This paper considers port-WSN scenario in which the sensors are scattered over a coal terminal. The paper proposes to optimize the topology of the network using ant colony approach. The performance of the network was analyzed based on average path length, energy consumption and throughput of the network. These parameters have shown improved when compared to existing topology optimization scheme for these networks.

Keywords: Small world network, wireless sensor network, energy efficiency, throughput

I. INTRODUCTION

Wireless sensor networks (WSNs) are usually made up of hundreds even thousands of distributed sensor nodes organized in ad hoc paradigm to monitor environments. Since they can be easily deployed and self-organized, WSNs can cover a wide range of applications domains [1, 2]. Since in WSNs high-degree nodes are always required to relay most of data flow to the base station, the energy of these nodes would be depleted rapidly so that normal operation of the entire network is threatened. The failure of sensor nodes would split originally connected network topology, would reduce the coverage of the network, and might even lead to a global network paralysis [3]. Thus, improving the network energy balance and energy consumption efficiency is the major challenge before establishing a highly efficient and reliable scale-free WSNs topology. As a transitive network type between random network and regular network, small-world network was proposed in 1998 by Watts and Strogatz [4]. Although most of nodes in small-world network are not directly connected, the vast majority of nodes can be connected to each other only via a few hops. It means that the small-world network exhibits a small average shortest path length along with a big clustering coefficient. As far as WSNs are concerned, lowering relay hops from sensor nodes to the base station is the basic idea to improve the network performance in terms of lifetime, overhead, and delivery delay. Thus, it is reasonable to expect that constructing WSNs topology with small-world effect is a feasible method to reduce the network energy consumption and improve the network connectivity.

This paper presents recent studies on small world networks in Section II. The ant colony based topology optimization technique for the small world networks has been presented in Section III. Results and conclusion have been presented in the last 2 sections of this paper.

II. LITERATURE REVIEW

This paper [5] built an optimized WSN topology based on small-world network according to the characteristics of the port monitoring and the particularity of network environment. The model increased a small amount of super nodes and balanced node energy. It could prolong the overall life of WSN and improve network survivability by decreasing the communication radius of the average node and increasing the network node clustering coefficient. Finally, the proposed topology optimization in the intelligent port was valid through the simulation analysis.

This paper [6] proposes a novel transformation which changes the topology of the DL architecture such that it reaches an optimal cross-layer connectivity. This transformation leverages the important observation that for a set level of accuracy, convergence is fastest when network topology reaches the boundary of a Small-World Network. The authors evaluate the networks on various DL model architectures and image classification datasets, namely, CIFAR10, CIFAR100, and ILSVRC (ImageNet). The experiments demonstrate an average of ~2.1x improvement in convergence speed to the desired accuracy.

This paper [7] scales distance labeling on small-world networks by proposing a Parallel Shortest-distance Labeling (PSL) scheme and further reducing the index size by exploiting graph and label properties. PSL insight fully converts the PLL’s node-order dependency to a shortest-distance dependence, which leads to a propagation-based parallel labeling in D rounds where D denotes the diameter of the graph. Extensive experimental results verify the efficiency on billion-scale graphs and near-linear speed up in a multi-core environment.

This paper [8] studies the efficiency issue on computing the exact eccentricity-distribution of a small-world network. The authors propose an efficient approach for exact eccentricity computation. The approach is based on a plethora of insights on the bottleneck of the existing algorithms - one-node eccentricity computation and the upper/lower bounds update. Extensive experiments demonstrate that the approach outperforms the state-of-the-art up to three orders of magnitude on real large small-world networks.

The authors in [9] introduced a parallel VLSI architecture featuring a random connection in Small World Network. The lower blocks are used for computation and the upper block is used for connection between every lower block. Both the upper block and lower blocks are randomly rewired using small world connection to get the shortest paths between all node pairs. In general, a link fault might negatively affect network dependability such as the no. of faulty network components, and also negatively affect network scalability such as the segmentation of the entire system, and the no. of faulty network segments. They concluded that small world connection helps to prevent the tendency to have faults.

The authors in [10] design and realize a greedy model with small world properties (GMSW) for heterogeneous sensor network of IoT. In GMSW, two greedy criteria are presented firstly, which are used to distinguish importance of different network nodes. The endpoints of these shortcuts are super sensor nodes with more powerful hardware. Simulation results show that GMSW can quickly present and maintain small word characteristics in the case of adding a few of shortcuts. Besides, it has good performance of network latency no matter suffering a random or specific failure.

This paper [11] proposes a deterministic network growth model based on the motif of rectangle. Because the clustering coefficient of network is zero, the authors construct small world network model through adding two non-intersect edges in the diagonal of rectangle. Combined with the characteristic of growth in real network, this paper proposes the generating algorithms of small world. Then they analyze the main topological properties, such as the degree and the degree distribution, average path length and clustering coefficient. The results show that our network has the characteristic of low average path length, high clustering and exponential degree distribution.

III. PROPOSED METHODOLOGY

As per the existing scheme, the network topology will be designed in coal terminal. 500 nodes randomly will be arranged in yard in small-world network theory using MATLAB. The architecture has been shown in figure 3.1.

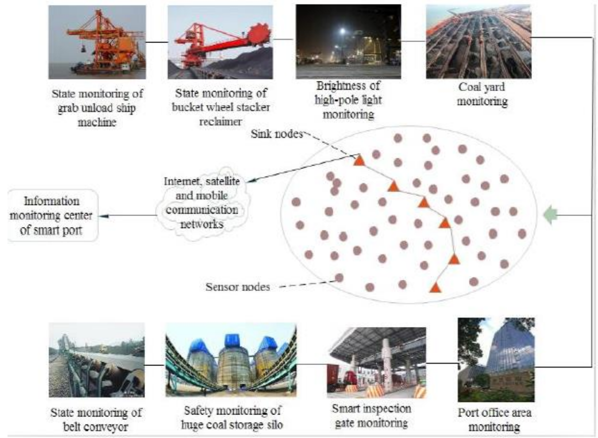

Figure 3.1: Port WSN Architecture [5]

The deployment of the nodes will be as follows:

6 super nodes are to be established with an equally 60 degrees on a circle, which will be circles centered in the port and carried in 125m radius. Port area will be equally divided into six parts. Every part could be seen as a cluster. Super nodes will be linked with 3 ordinary/root nodes (the farthest, the middle, the nearest) as first node of cluster, which will form the first topology structure and would have been extended the second topology structure. The radius of super nodes will be set at 300m. The number of root nodes linked with super nodes will be 3, and the number of best near super nodes K are to be set to 4.

In order to reduce transmit power, child nodes are linked by 30m in the existing scheme. Once the root nodes and child nodes are connected with each other, the unconnected nodes will not be connected to the root nodes randomly. Once the super nodes are connected with the three root nodes, every unconnected node will be linked to the root node based on their pheromone value.

Every node will find their pheromone levels with the root nodes. The nodes will join the root node for which the pheromone is maximum.

Thus, the resultant path will be the one having the optimized shortest distance which will help to reduce the energy consumption of the nodes.

IV. RESULTS

The small work network means any network that has every node connected to every another node within six hop count distance. This network greatly reduces the energy consumption as compared to normal wireless sensor networks where the hop count normally is more when the network size is also more. The small work network's topology was optimized using ant colony optimization and the proposed as well as existing topology optimization technique was implemented in MATLAB.

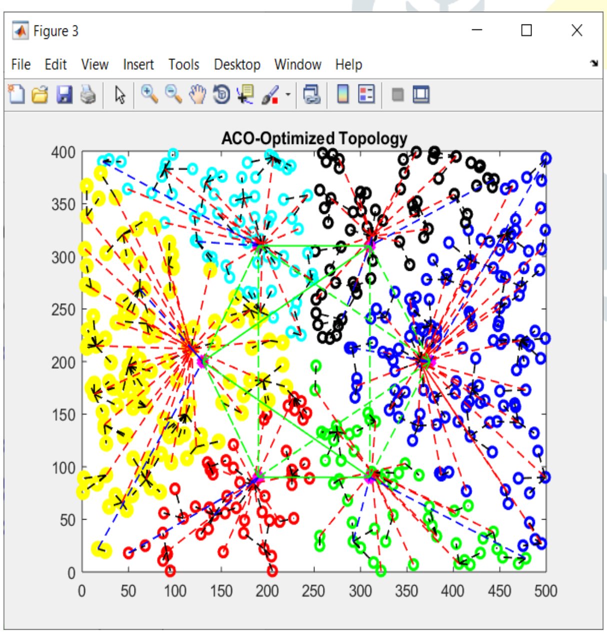

Figure 4.1: Optimized topology using ACO

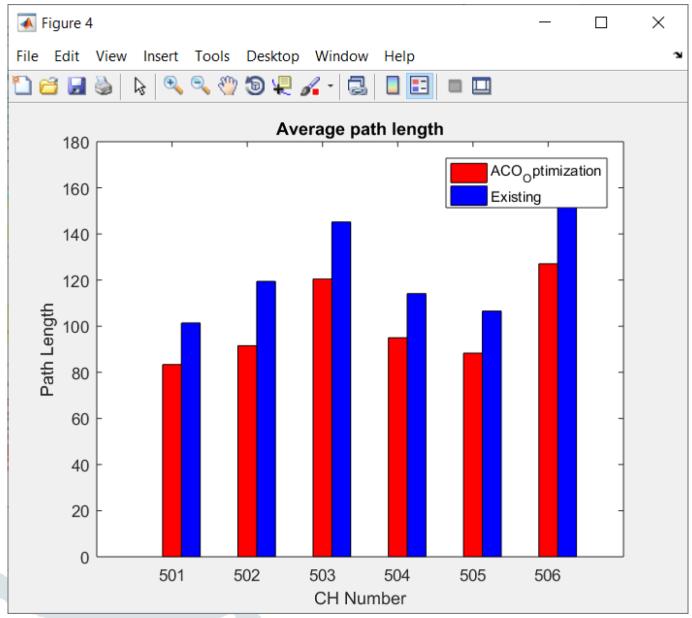

Figure 4.2: Path Length Comparison

This graphs shows the comparison of the path length for each super node in the network. The value of path length of the entire sector when optimized using ACO was found to be less as compared to the existing scheme.

Sector head	Existing path Length	ACO path length
501	101.41 m	83.35 m
502	119.44 m	91.54 m
503	145.17 m	120.46 m
504	114.107 m	94.97 m
505	106.55 m	88.31 m
506	162.92 m	127.06 m

Table 4.1: Average path length comparison

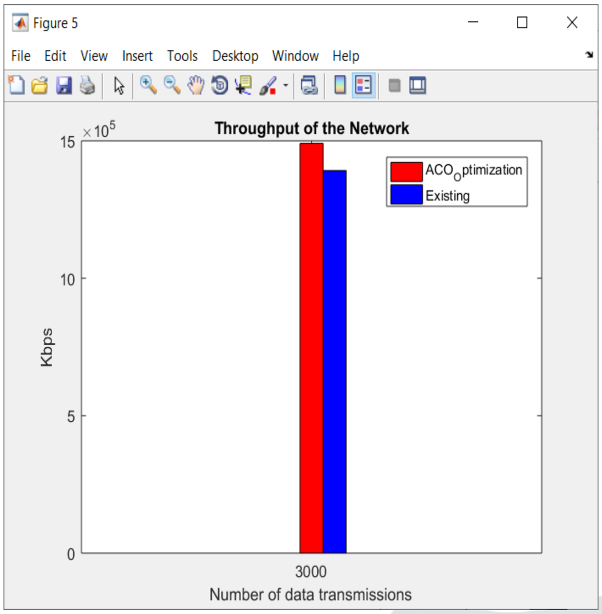

Figure 4.3: Throughput Comparison

The above graph shows the comparison of throughput achieved by both the schemes. The network was run for 3000 data transmissions which means that the nodes send data to the super nodes via root nodes 3000 times. The value of throughput achieved was 1491 Kbps using ACO and 1392 Kbps using the existing scheme.

Existing Scheme	ACO scheme
1392 Kbps	1491 Kbps

Table 4.2: Throughput Comparison

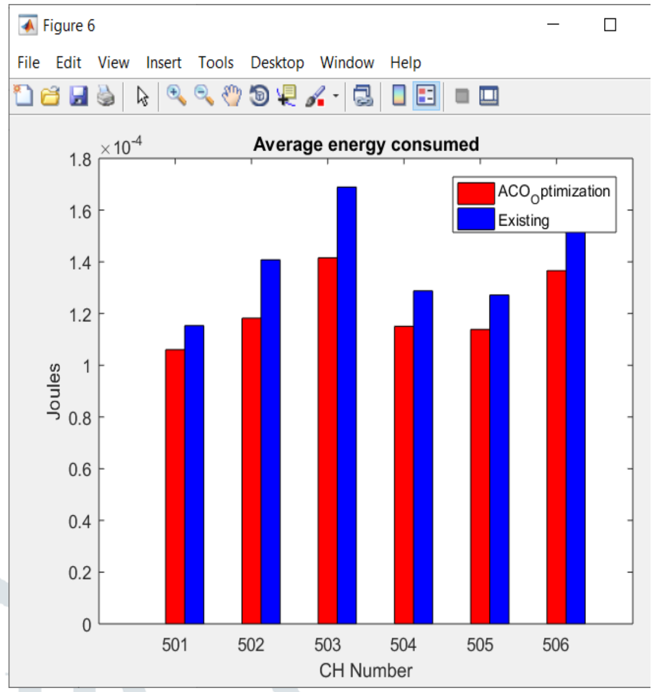

Figure 4.4: Energy consumed Comparison

The above graph shows the comparison of energy consumed in the network by both the schemes. The network was run for 3000 data transmissions which means that the nodes send data to the super nodes via root nodes 3000 times. The value of energy consumed was less for the proposed scheme as compared to the existing scheme which indicates better network performance.

Sector head	Existing Energy Consumed	ACO Energy Consumed
501	0.1153 Joules	0.1060 Joules
502	0.1408 Joules	0.1182 Joules
503	0.1689 Joules	0.1415 Joules
504	0.1288 Joules	0.1150 Joules
505	0.1272 Joules	0.1138 Joules
506	0.1666 Joules	0.1366 Joules

Table 4.3: Energy Consumed Comparison

V. CONCLUSION

This study was concerned with optimizing the topology for small world networks in which Port WSN scenario has been considered. The connections among the nodes are optimized uses ACO in the proposed scheme. The performance of the network was measured using average path length, throughput and energy consumption in the network. The ant colony optimization considers the pheromone levels between the nodes, consequently the node joins the head for which the pheromone level is maximum or the distance is minimum. The difference in the optimized path length was found to be approx. 20 to 40 meters less for the proposed scheme. When the data is sent over the shorter paths, the energy consumed is also less. This increases the network lifetime which furthermore means more nodes remain alive in the network thereby increasing throughput of the network as well. Therefore, we can conclude that the use of ant colony optimization increases the network performance by optimizing the topology in a better way.

The small world network can be redesigned for other applications such as airport monitoring or military applications as well. In such different applications the proposed technique can be used to optimize the topology.

References

1. W.-F. Li and X.-W. Fu, “Survey on invulnerability of wireless sensor networks,” Jisuanji Xuebao/Chinese Journal of Computers, vol. 38, no. 3, pp. 625–647, 2015.
2. G. Fortino, A. Guerrieri, G. M. P. O'Hare, and A. Ruzzelli, “A flexible building management framework based on wireless sensor and actuator networks,” Journal of Network and Computer Applications, vol. 35, no. 6, pp. 1934–1952, 2012.
3. A. Nazi, M. Raj, M. Di Francesco, P. Ghosh, and S. K. Das, “Deployment of robust wireless sensor networks using gene regulatory networks: An isomorphism-based approach,” Pervasive and Mobile Computing, vol. 13, pp. 246–257, 2014.
4. D. J. Watts and S. H. Strogatz, “Collective dynamics of “small-world” networks,” Nature, vol. 393, no. 6684, pp. 440–442, 1998
5. Puping Kong, Guihua Fang, Chaochao He, Zhiping Liu, “Topology Optimization of Port Wireless Sensor Network Based on Small-World Network”, International Conference on Circuits, System and Simulation, IEEE, August 2017.
6. Mojan Javaheripi, Bita Darvish Rouhani, Farinaz Koushanfar, “SWNet: Small-World Neural Networks and Rapid Convergence”, arXiv:1904.04862v1, April 2019.
7. Miao Qiao, Lu Qin, Ying Zhang, Lijun Chang, Xuemin Lin, “Scaling Distance Labeling on Small-World Networks”, SIGMOD '19, Proceedings of the 2019 International Conference on Management of Data, Pages 1060-1077.
8. Wentao Li, Miao Qiao, Lu Qin, Ying Zhang, Lijun Chang, Xuemin Lin, “Exacting Eccentricity for Small-World Networks”,

2018 IEEE 34th International Conference on Data Engineering (ICDE).

9. Hideki Mori, “Fault Tolerance of Small World Network Architecture”, 2018 Sixth International Symposium on Computing and Networking Workshops (CANDARW).
10. Diansong Luo, Tie Qiu, Nakema Deonauth, Aoyang Zhao, “A small world model for improving robustness of heterogeneous networks”, 2015 IEEE Global Conference on Signal and Information Processing (GlobalSIP).
11. Shen Anwei, Guo Jilian, Wang Zhuojian, “A novel deterministic small-world network created by rectangle iterations”, 2016 IEEE Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC).