

Improved and Comparative Study of Metaheuristics Techniques of Wireless Sensor Network

Sachin Kumar¹, Dr. Aleem Ali²

Research Scholar Department of computer science & Engineering¹

Associate Professor Department of Computer Science Engineering²

Glocal University Saharanpur

I. Introduction

Abstract- Wireless Sensor Networks (WSNs) and their pivotal role in modern technology. It is basically a wireless network in which sensor nodes are distributed in any environment condition, to collect the data or information such as temperature, pressure, wind, sea level etc [1]. and accordingly data or information will be passed to the main location. Reliable Trust and Reputation of a node stands for the measure of trust over a certain period which can be useful to evaluate the risk of attack from that node. We have combined all these parameters to risk of attack from a particular node. The dynamic nature of WSNs, comprising self-configured and autonomous Sensor Nodes (SNs) that collect specific event data[3]. It highlights the rapid advancements in wireless communication and the emergence of WSNs as a key player in collecting specific event data. WSNs are described as self-configured and autonomous networks of Sensor Nodes (SNs) that operate without fixed infrastructure, enabling dynamic networks and self-organization[4]. The versatility of WSNs in various applications such as habitat monitoring, surveillance, tracking, and smart farming. It underscores the challenges faced by WSNs, particularly in terms of energy-efficiency, node connectivity, localization, scalability, security, and overall network performance. The focus of the work presented the developing energy-efficient routing protocols for WSNs to enhance network longevity and performance.

Introduction WSNs are globally-distributed and customized systems to sense and collect atmospheric factors, then transmit this data back to a centralized position. Among other ones, such as heat, sound, particulate matter emissions like dust and smoke, humidity and weather may be detected by WSNs [9].

Keyword: WSN, SNs, Swarn Intelligent, Sensor Network

Historical development The field of network layer in Wireless Sensor Networks (WSNs) has been extensively researched, with numerous routing algorithms and protocols proposed over the past few years. The primary function of the network layer is to establish routes from Sensor Nodes (SNs) to the Base Station (BS) for transmitting data events. [6] There are two main data routing models commonly used in WSNs. single-hop and multi-hop. In the single-hop model, all SNs can communicate directly with the BS through a single hop.

This direct communication approach is straightforward, as data events travel through only one hop to reach the destination node. However, this model is only practical if all SNs are within direct communication range of the BS[7] otherwise, it is not feasible. On the other hand, in the multi-hop communication model, the network layer's primary objective is to determine a route[8].

The communication model from the sensor nodes to the base station via various intermediate sensor nodes acting as relay nodes poses challenges for WSNs [9]. These challenges stem from the need for protocols that do not overly burden resources, given the frequent and dynamic nature of WSN environments. As a result, routing schemes for WSNs must be adaptive and flexible, unlike traditional routing mechanisms. Specific attributes are required in protocols for WSNs to effectively address key issues[12].

In order to gain a better understanding of these key issues, the next section of this chapter delves into a routing metric[17]. Additionally, a thorough examination of existing routing protocols is provided, along with different routing mechanisms [21]. This review of the state of the art offers a comprehensive insight into the attributes, features, and limitations of some well-known existing routing protocols for WSNs [26].

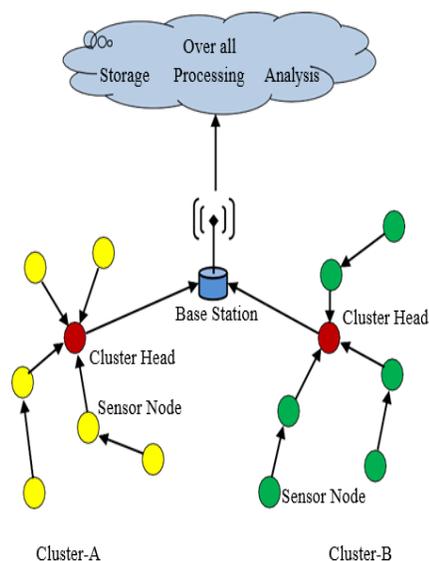


Fig. 1.1: A typical WSN Scenario

II. Applications

Wireless Sensor Networks (WSNs) have a broad range of applications in various industries due to their capability to gather, process, and transmit data from the surrounding environment. Some typical applications of WSNs include:

1. **Healthcare Management:** WSNs are utilized in healthcare applications to monitor patients with conditions like Parkinson's disease, epilepsy, and for patient rehabilitation. These networks can monitor vital signs such as heart rate, pulse rate, oxygen levels, and more, enabling remote health monitoring and timely intervention.
2. **Precision Agriculture:** WSNs play a vital role in precision agriculture by allowing farmers to monitor and manage their crops more efficiently. These networks provide real-time data on soil moisture levels, temperature, humidity, and other environmental factors, assisting farmers in optimizing resource usage and increasing crop yields.
3. **Environmental Monitoring:** WSNs are deployed in environmental monitoring applications to track changes in environmental conditions such as pollution levels, greenhouse gas emissions, and climate change. These networks aid in the early detection of environmental threats and facilitate better decision-making for environmental conservation [32].
4. **Structural Health Monitoring:** WSNs are used for monitoring the structural health of buildings, bridges, and other infrastructure [3]. By deploying sensors to detect structural changes, cracks, or

vibrations, these networks contribute to ensuring the safety and integrity of critical structures.

5. **Military Operations:** WSNs are employed in military applications for tasks such as intelligence gathering, surveillance, reconnaissance, and targeting. These networks provide real-time data on enemy movements, border security, and other crucial information, thereby enhancing military operations [1].
6. **Habitat Monitoring:** WSNs are employed in habitat monitoring to track and protect wildlife species. By monitoring habitats and tracking animal movements, these networks contribute to wildlife conservation efforts. Improved artificial bee colony metaheuristic

With its significant impact and remarkable achievements, Computational Intelligence (CI) based metaheuristic has emerged as a highly effective tool for addressing increasingly intricate real-world optimization problems. In the natural world, numerous species exhibit swarm behavior, which is also a defining characteristic of social insects such as bees, wasps, and ants. The communication patterns observed among individual insects within a social insect colony play a crucial role in the development of collective intelligence, giving rise to the concept of Swarm Intelligence (SI) as an integral branch of CI. SI focuses on studying the actions of individuals within decentralized systems, comprising physical or virtual elements that engage in communication, cooperation, collaboration, and information exchange to accomplish various tasks within their environment. Notable contributions of SI include Particle Swarm Optimization (PSO) (J. Kennedy, 1995), Ant Colony Optimization (ACO) (M. Dorigo, 1996), and more recently, Artificial Bee Colony (ABC) (D. Karaboga, 2005).

ABC procedure's schematic pseudo code:

- (i) Set up ABC and problem parameters
- (ii) Set up the Food Source Memory (FSM) & Iteration Deploy employee bees to the food sources.

III. Related Work

SNs are integral part of a WSN, which are responsible for sensing, processing, and transmission of data events. The quality, type, and frequency of the collected data are highly influenced by the physical characteristic of the sensor therefore, the designing of a SN is a critical step. Each SN consists of sensing, processing, transmitting, and power components as shown in Fig.1.2.

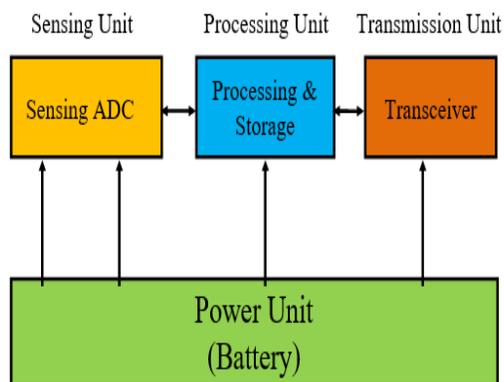


Fig. 1.2: Components of a sensor node

The processor component is the central element of the SN and the type of a processor determines the trade-off between energy consumption and performance. Some type of available processors types are micro-controllers, application-specific integrated circuits, digital signal processors and programmable gateways. The Analog-to-Digital Converter (ADC) converts continuous analog signal of a SN into a digital signal. The digitized and processed data is then transmitted to the BS through CHs, using multi-hop communication. With the above discussions, energy-efficiency has been seen as one the key issue in WSNs, which may influence the overall performance of the network, therefore, to design an energy-efficient routing protocol is a prime concern for WSNs. A robust energy-efficient routing protocol can prolong the network life by employing energy aware routing algorithms and appropriate energy saving techniques. Further, energy-efficient routing is a NP-hard optimization problem and nature inspired Computational Intelligence (CI) based metaheuristic need to be explored for effective solutions. Having characteristics like adaptation, high computational speed, versatility, self-learning and self-organization, CI based meta-heuristic are most sought and found suitable for dynamic WSNs. Nature inspired Swarm Intelligence (SI) is one branch of CI which is most explored and employed for number of multi-modal optimization problems in various domains. Many researchers has already presented SI based optimization solutions for localization, node deployment, data aggregation and even for energy-efficient routing in WSNs.

As every work need further improvement with better replacement, this motivates the idea to present an energy-efficient routing protocol based on nature inspired metaheuristic for WSNs. In general, through this work an attempt has been made to minimize the energy consumption of WSNs to improve the network lifetime by proposing an energy-efficient routing protocol based on nature inspired meta-heuristic.

IV. Objective

The objectives of the proposed work are as follows:

1. To review various existing routing mechanisms and classify existing routing protocols for WSNs.
2. To propose an energy-efficient routing protocol for WSNs based on nature inspired metaheuristic.
3. To implement the proposed routing protocol, LEACH, MRP, ERP and PSO for WSNs.
4. To compare and analyses the performance of proposed routing protocol with LEACH, MRP, ERP and PSO based on Energy consumption, Through-put, Average latency rate, Packet delivery ratio, Packet loss ratio, Energy- efficiency and Network lifetime.

V. OBJECTIVES AND PROPOSED METHODOLOGY

A comprehensive review of Classical as well as CI-based most prominent routing protocols are presented, moreover their strengths and weak-nesses are also evaluated for better insight. This critical review will be helpful in designing new and robust routing protocols of WSNs. As a whole, designing of energy-efficient as well as robust routing protocols for WSNs is an extremely challenging job for researchers. The domain of CI based metaheuristic offers better design principles, inspired by adaptive biological eco-systems, which can handle the constraints of WSNs in a better way.

iABC metaheuristic is presented which combine a refined initialization phase based on first of its kind Student's t distribution, a cPDF for better sampling with an improved solution search equation named ABC/rand-to-opt/1 for optimal search abilities. In the next chapter, an energy-efficient routing protocol is presented for WSNs by incorporating the capabilities of proposed nature inspired iABC metaheuristic.

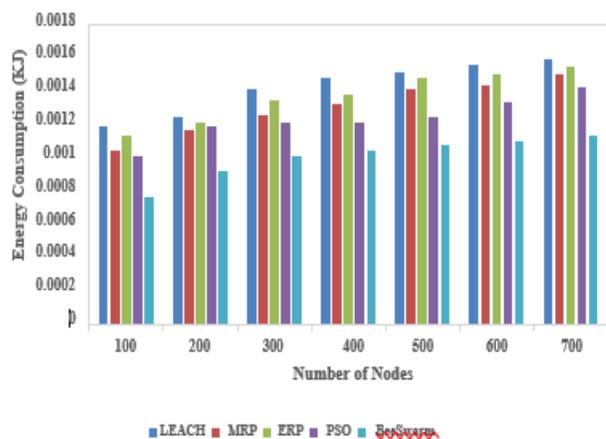


Fig. 1.3 Energy consumption- WSN

The performance of BeeSwarm is compared with existing LEACH, MRP, ERP and PSO protocols using NITSS, based on Energy consumption, Throughput, Average latency rate, Packet delivery ratio, Packet loss ratio, Energy- efficiency and Network lifetime as performance metric. The proposed protocol BeeSwarm outperforms its peers over these parameters and prove its robustness for dynamically distributed and scalable WSNs.

VI. CONCLUSION

Energy-efficient routing is ever challenging issue in constraint rich WSNs. Enormous efforts has been made time to time by researchers to present energy-aware solutions for efficient WSN enabled applications. While classical approaches of routing use traditional framework of designing, Computational Intelligence (CI) based techniques employ nature inspired metaheuristic to solve NP-hard optimization problems of energy-efficient routing for WSNs. In this research work, an energy-efficient routing protocol BeeSwarm is presented based on nature inspired improved Artificial Bee Colony (iABC) metaheuristic for WSNs. The key feature of BeeSwarm is utilization of available network resources efficiently keeping in view of the strict constraints of WSNs. It is found that empirical analysis of any routing protocol is not sufficient to judge its actual performance in real world scenarios thus, in future the proposed protocol would be tested on real test-bed of SNs. Further, the proposed work will be implemented for specific application domain like precision agriculture for better crop management with the goal of optimizing yield while preserving key resources. On the other hand, the properties of the proposed iABC metaheuristic need to be exploited further for various other optimization problems of WSNs like node localization, node scheduling, data aggregation or to improve Quality of Service (QoS) parameters.

References

1. Abro, J. M. S. (2012). Enhanced global-best artificial bee colony optimization algorithm. Sixth UKSim-AMSS European Symposium on Computer Modeling and Simulation, 95-100. Abbass, H. A. (2001). Mbo: Marriage in honey bees optimization a haplometrosis polygynous swarming approach. Proceedings of the Congress on Evolutionary Computation, 207- 214.
2. Akay, D. K. (2012). A modified artificial bee colony algorithm for real-parameter optimization. Inform. Science, 192 , 120-142. Chen, R. (1984). Location problem with cost being sum of power of euclidean distances. The Journal of computers and operational research, 11 (3), 285- 294.
3. Intanag on wiwat, D. E., R. Govindan. (2000). Directed diffusion: a scalable and robust communication paradigm for sensor networks. ACM Mobi- Com, 56-67.
4. Schurgers, M. S. (2001). Energy efficient routing in wireless sensor networks. Proceedings on Communications for Network-Centric Operations.
5. Braginsky, D. E. (2002). Rumor routing algorithm for sensor networks. Proceedings of the First Workshop on Sensor Networks and Applications.
6. Hoang, R. K. S. P., Parikshit Yadav. (2014). Real-time implementation of a harmony search algorithm-based clustering protocol for energy efficient wireless sensor networks. IEEE Transactions On Industrial Informatics.
7. Dilip Kumar, R. B. P., Trilok C Aseri. (2009). Ehc: Energy efficient heterogeneous clustered scheme for wireless sensor networks. Computer Communications, 32 (4), 662–667.
8. Mininno, D. N., F. Cupertino. (2008). Real-valued compact genetic algorithms for embedded microcontroller optimization. IEEE Trans. Evol. Computer , 12(2), 203-219.
9. Ferrante Neri, G. I. (2001). Compact optimization. Optimization Algorithm. Gaura, E. (2010). Wireless sensor networks: Deployments and design frameworks.
10. Springer G. Li, X. X., P. Niu. (2013). Development and investigation of efficient artificial bee colony algorithm for numerical function optimization. Appl. Soft Computing, 12 (1), 320-332.
11. H Drias, S. Y., S Sadeg. (2005). Cooperative bees swarm for solving the maximum weighted satisfiability problem. Computational Intelligence and Bioinspired Systems, 318-325.
12. He, T. (2003). Speed: a stateless protocol for real-time communication in sensor networks. International Conference on Distributed Computing Systems.
13. H F Wedde, Y. Z., M Farooq. (2004). Beehive: An efficient fault-tolerant routing algorithm inspired by honey bee behavior. Ant Colony Optimization and Swarm Intelligence, 83-94.
14. Jennifer Yick, D. G., Biswanath Mukherjee. (2008). Wireless sensor network survey. Computer networks, 52 (12), 2292–2330.
15. Jing Yang, W. Z. B. X., Mai Xu. (2009). A multipath routing protocol based on clustering and ant colony optimization for wireless sensor networks. Sensors, 10 (5), 4521–4540.
16. J. Kennedy, R. E. (1995). Particle swarm optimization. In Proceedings of the IEEE International Conference on Neural Networks, 1942-1948.
17. J. Kulik, H. B. L. B., W. R. Heinzelman. (2002). Negotiation-based protocols for disseminating information in wireless sensor networks. Wireless Networks, 8 , 169-185.

18. Karaboga, B. B., Dervis. (2008). On the performance of artificial bee colony (abc) algorithm. *Applied soft computing*, 8 (1), 687–697.
19. Karaboga, D. (2005). An idea based on honey bee swarm for numerical optimization. Tech. Rep. TR06, Erciyes University, Engineering Faculty, Computer Engineering Department.
20. Luis Cobo, S. P., Alejandro Quintero. (2010). Ant-based routing for wireless multimedia sensor networks using multiple qos metrics. *Computer networks*, 54 (17), 2991–3010.
21. M. Chu, F. Z., H. Haussecker. (2002). Scalable information-driven sensor querying and routing for ad hoc heterogeneous sensor networks. *The International Journal of High Performance Computing Applications*, 16 .
22. M.Dorigo, A. C., V.Maniezzo. (1996). Ant system: optimization by a colony of cooperating agents. *IEEE Transactions on Systems, Man, and Cybernetics*, 26 , 29-41.
23. Muhammad Saleem, M. F. (2012). Beesensor: A bee-inspired power aware routing protocol for wireless sensor networks. In *Applications of evolutionary computing* (pp. 81–90). Springer.
24. Muhammad Saleem, M. F., Gianni A. Di Caro. (2011). Swarm intelligence based routing protocol for wireless sensor networks: Survey and future directions. *Information Sciences*, 181 , 4597-4624.
25. N. Ding, P. X. L. (2004). Data gathering communication in wireless sensor networks using ant colony optimization. *Proceedings of IEEE International Conference on Robotics and Biomimetics*.
26. Ossama, S. F., Younis. (2004). Heed: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. *IEEE Transactions on Mobile Computing*, 3 (4), 366–379.
27. Palvinder Singh Mann, S. S. (2016). *Energy-efficient hierarchical routing for wireless sensor networks: A swarm intelligence approach*. *Wireless Personal Communications*, Springer .
28. P. Guo, J. L., W. Cheng. (2011). Global artificial bee colony search algorithm for numerical function optimization. *Seventh International Conference on Natural Computation*, 3 , 1280-1283.
29. P. Larranaga, J. L. (2001). *Estimation of distribution algorithms: a new tool for evolutionary computation*. Kluwer .
30. P Lucic, D. T. (2001). Bee system: modeling combinatorial optimization transportation engineering problems by swarm intelligence. *Triennial Symposium on Transportation Analysis*, 441-445.
31. Prasenjit Chanak, I. B. (2013). Energy efficient fault-tolerant multipath routing scheme for wireless sensor networks. *The Journal of China Universities of Posts and Telecommunications*, 20 , 42-48.
32. Pratyay Kuila, P. K. J. (2014). Energy efficient clustering and routing algorithms for wireless sensor networks: Particle swarm optimization approach. *Engineering Applications of Artificial Intelligence*, 33 , 127–140.
33. R. Apostol, M. A. M. (2003). Sum of square of distance in m-space. *The Mathematics Asso. of America*, 516-526.
34. Rui Zhang, C. W. (2011). An artificial bee colony algorithm for the job shop scheduling problem with random processing times. *Entropy*, 13 (9), 1708– 1729.
35. Sangho Yi, Y. C. J. H., Junyoung Heo. (2007). Peach: Power-efficient and adaptive clustering hierarchy protocol for wireless sensor networks. *Computer communications*, 30 (14), 2842–2852.
36. S Deng, L. S., J Li. (2011). Mobility-based clustering protocol for wireless sensor networks with mobile nodes. *Wireless Sensor Systems, IET*, 1 (1), 39–47.
37. S Mao, W. C.-I., Song Zhao. (2011). Unequal clustering algorithm for wsn based on fuzzy logic and improved aco. *The Journal of China Universities of Posts and Telecommunications*, 18 (6), 89–97.
38. Storn R, P. K. (2010). Differential evolution-a simple and efficient heuristic for global optimization over continuous spaces. *Journal of Global Optimization*, 23 , 689-694.
39. Swagatam Das, P. N. S. (2011). Differential evolution: A survey of the state-of-the-art. *IEEE Transactions on Evolutionary Computation*, 15 .
40. T. Camilo, J. S.-F. B., C. Carreto. (2006). An energy-efficient ant-based routing algorithm for wireless sensor networks. *Proceedings of the 5th International Workshop on Ant Colony Optimization and Swarm Intelligence*, 4150 , 49- 59.
41. V. Gonuguntla, K. C. V., R.Mallipeddi. (2015). Differential evolution with population and strategy parameter adaptation. *Mathematical Problems in Engineering*.