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Hybrid meta-heuristic optimization based energy efficient protocol for wireless sensor networks

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ABSTRACT

Energy efficiency has recently turned out to be primary issue in wireless sensor networks. Sensor networks are battery powered, therefore become dead after a certain period of time. Thus, improving the data dissipation in energy efficient way becomes more challenging problem in order to improve the lifetime for sensor devices. The clustering and tree based data aggregation for sensor networks can enhance the network lifetime of wireless sensor networks. Hybrid Ant colony optimization (ACO) and particle swarm optimization (PSO) based energy efficient clustering and tree based routing protocol is proposed. Initially, clusters are formed on the basis of remaining energy, then, hybrid ACOPSO based data aggregation will come in action to improve the inter-cluster data aggregation further. Extensive analysis demonstrates that proposed protocol considerably enhances network lifetime over other techniques.

1. Introduction

With the advent of Wireless Sensor Networks, inaccessible environments can be easily monitored. It is a powerful tool to gather data in many applications like military surveillance, battle-field, forestry, oceanography, temperature, pressure, humidity, etc. [1]. WSNs contain number of sensor nodes which are connected together and to a base station. WSNs include sensing of data through sensor nodes, processing of data, and transmission to base station. Charging and reinstallation of sensor nodes do not possible in difficult environments. So, energy conservation is a big challenge in WSNs. Recently, researchers gave a solution to this problem by organizing the nodes into clusters and enhance the life-time of WSNs [2]. Further, routing protocols are implemented in cluster WSNs to guide the selection of Cluster Heads (CHs) and discover best route to save the energy of nodes [3]. A typical cluster based wireless sensor network is shown in Fig. 1.

Nayak and Anurag Devulapalli [4] utilized fuzzy logic based clustering technique to reduce the energy consumption rate further. In this method, size of cluster is optimized through Fuzzy inference engine (Mamdani's rule). The appropriate selection of CHs reduces the energy consumption and enhances the life of network. Gong et al. [5] designed a routing protocol ETARP (i.e., Energy Efficient Trust-Aware Routing Protocol for Wireless Sensor Networks) to reduce the energy consumption and increase the security during communication among nodes in WSNs. The selection of route between sensor nodes is based on utility theory. Shi et al. [6] addressed the issue of mobile sinks like route maintenance in WSNs by introducing dynamic layered routing protocol. The distribution frequencies and scopes of routing updates are minimized using the combination of dynamic anchor selection and dynamic layered Voronoi scoping.

Leu et al. [7] utilized Regional Energy Aware Clustering with Isolated Nodes (REAC-IN) algorithm to select CHs based on weight. Weight is calculated considering each sensor's residual energy and regional average energy of every sensor in all clusters. Shen et al. [8] solved the problem of delay in message transmission in underwater WSNs using Location-Aware Routing Protocol (LARP). In this method, position knowledge of sensor nodes is used to facilitate message transmission. Bouyer et al. [9] used fuzzy C-means (FCM) algorithm to create optimum number of CHs in LEACH algorithm to reduce the energy and prolong the network life-time. Cai et al. [10] proposed Bee-Sensor-C routing protocol inspired from

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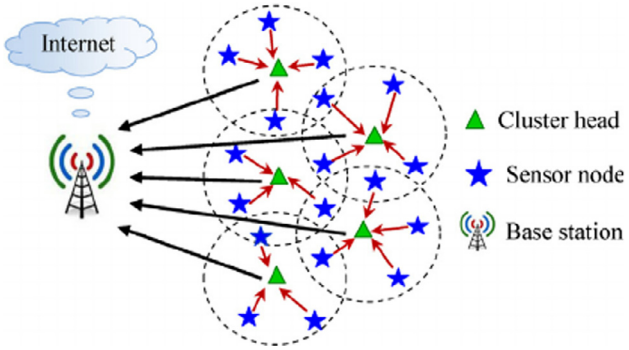

Fig. 1. Typical clustering environment of wireless sensor network.

BeeSensor (i.e. bee-inspired routing protocol) that can form clusters dynamically and transmit the data in parallel fashion.

Shankar et al. [11] used hybrid Particle Swarm Optimization (PSO) and Harmony Search Algorithm (HSA) to select CH efficiently utilizing minimum energy. Zahedi et al. [12] presented the problem of uneven distribution of CHs, unbalanced clustering, and their scope to limited applications of WSNs. They used fuzzy c-means clustering algorithm to create balanced clusters and Mamdani fuzzy inference system to select suitable CHs. Fuzzy rules are optimized through swarm intelligence algorithm based on firefly algorithm.

Sabet and Naji [13] implemented the multi-level route-aware clustering (MLRC) technique to save energy in decentralized clustering protocols. The main advantage of this protocol is that it creates a cluster and routing tree, simultaneously, to reduce an unnecessary generation of routing control packets.

Naranjo et al. [14] presented Prolong- Stable Election Protocol (P-SEP) to elect the CHs among heterogeneous nodes in fog-supported WSNs to increase the life of network. Xenakis et al. [15] utilized simulated annealing technique to control the topology by maximizing the network coverage and lifetime of WSNs as objective functions. Nayak and Vathasavai [16] utilized type-2 fuzzy logic in WSNs to make a decision for CH efficiency. Ouchitachen et al. [17] implemented IMOWCA (Improved Multi-Objective Weighted Clustering Algorithm) for the selection of CHs. Residual energy is used to select the best performing node for further communication with BS. Base Station Genetic Algorithm is utilized to balance the energy among different clusters.

Elshrkawey et al. [18] addressed the issues of LEACH protocol like improper selection of CH, formation of unbalanced clusters, and continuous transmission of updating data. They used threshold value to elect CHs, sensor nodes send their updated data in their allotted time, and modified TDMA scheduling is utilized to break steady state phase. Rani et al. [19] used E-CBCCP protocol to cache the data at CH and relay node to evade the communication of same data packets. Control packets are used to inform all sensor nodes that data packets are same and do not transmit the data packets. Laouid et al. [20] designed an approach to select the best route based on hop count and residual energy of each sensor node to maximize the life of network.

Ez-zazi et al. [21] utilized adaptive coding scheme considering channel state and distance between inter nodes to scrutinize the trade-off between energy efficiency and reliability. Huang et al. [22] used public transportation vehicles as mobile sinks to gather data. To balance the energy consumption, an energy-aware routing and energy-aware unequal clustering algorithms are used.

In this paper, we have proposed a hybrid meta-heuristic optimization based energy efficient protocol. Because, GSTEB protocol routing tree is manufactured where tree centered routing is performed to transmit knowledge to the bottom section. In case, if the parent node dies the topography must be repair again that'll consume a lot of power and there might be loss of knowledge also. To prevail around the problem of sign delay and knowledge reduction in the system because of the nodes disappointment in the root to sink, cluster based aggregation process can be utilized. In big system, well- organized sign of knowledge to the sink requires obtaining the maximum route according to how many trips; therefore, knowledge can be aggregated at cluster head which needs to be transmitted to the bottom station. The clustering strategy may minimize knowledge redundancy and reduce the congestive routing traffic in knowledge transmission. Following the clustering tree centered routing at the cluster-heads it is required to obtain the shortest route between the source and the sink, but the smallest route issue is NP-Hard in nature [22].

Contribution: Following are our main contributions in this research paper:

i. First of all, we have evaluated the performance of some well-known existing energy efficient protocols for WSNs.
ii. Based upon the comparative analysis we have found that effective inter-cluster data aggregation using metaheuristic techniques can improve the network lifetime further.
iii. We have designed and implemented a well-known hybrid ACO-PSO based clustering GSTEB protocols to enhance the results further.
iv. Extensive analysis has also been done to evaluate the effectiveness of the proposed technique.

Rest of the paper is organized as follows: In Section 2, network energy model is described for WSNs. Section 3, describes the proposed technique with suitable mathematical formulation. Experimental set-up and results are described in Section 4. Concluding remarks are discussed in Section 5.

2. Network energy model

In this research work, we have randomly deployed WSN with "N" sensor nodes in M∗N network field. All nodes even including the sink are stationary in nature. Each node has its own unique identification number. Each node monitors the given environment and communicate data with sink. Whenever communication is done given node have to spent some energy based upon the distance (D) with sink. All the communication links are symmetric in nature.

2.1. Energy model

Whenever a node sends or receives sensed information it has to spend some energy based upon two channel propagation models

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