A Comparative Study of Energy Efficient Bio Inspired Clustering Methods for Homogeneous & Heterogeneous in WSN

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Abstract— Wireless sensor networks (WSNs) have extensive real time applications such as security, monitoring, tracking, management, learning etc. Energy is critical and limited resource of WSNs; therefore it is necessary to have a energy efficient method for WSNs. Clustering algorithm is widely used approach for saving energy consumption and improving the network performance. In this project we are presenting clustering based innovative routing protocols for both homogeneous and heterogeneous type of WSNs using artificial bee colony (ABC) algorithm and bio inspired approach. This proposed method is called as I-Bee Cup which is extension of recent Bee Cup method. In I-Bee Cup method enhanced ABC algorithm is used rather using existing ABC algorithm for node deployment. This approach has advantage of biologically inspired computation with goal of improving the performance of energy efficiency. This method initially estimates the number of cluster heads as per the scenario of network, then selection cluster is done by using new Improved ABC algorithm.

Keywords—Wireless sensor networks, PSO, GA, ABC, BeeColony, clustering protocols, sensor routing protocols.

Introduction

Wireless Networks

A wireless sensor network (WSN) is a set of small sensor nodes which consumes small amount of energy and route sensed data to a base station. Wireless networks are also connected to computers wirelessly regardless of the sort. The wireless sensor networks have allowed enterprise to minimize costly means of connections between different equipment at different locations. The key part of wireless systems is radio waves and execution occurs at the physical higher level of network structure. It also ensures minimum possibility of network collapse during a disaster which causes physical damage to structural parts of physical network [1].

Wireless technologies vary in different dimensions, most particularly in just how much bandwidth they provide and how far apart communicating nodes can be. The electromagnetic spectrums used and power consumption are also very important aspect of network design. In this section we discuss four prominent wireless technologies: Bluetooth (802.15.1), Wi-Fi (generally known as 802.11), WiMAX (802.16), and third-generation or 3G cellular wireless network [2].

The Wireless sensor networks (WSNs) does not involve use of a specific infrastructure for its implementation. But it creates a problem of scalability, energy consumption and connectivity over time [3], [4], [5]. A model of wireless sensor networks is shown in Fig. 1. Conventional scheme of a wireless sensor network is very vibrant and made for mobile environments, and they must have fault tolerant nodes. Algorithms used for wireless sensor networks must be implemented to avoid single point's failures, to imply self-organization and to increase scalable deployment [6].

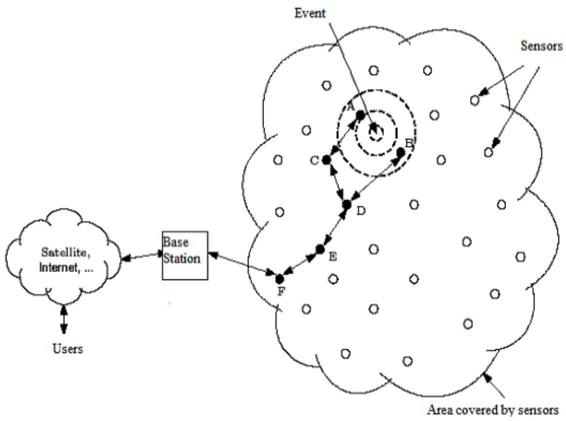

Fig. 1. A model of wireless sensor network

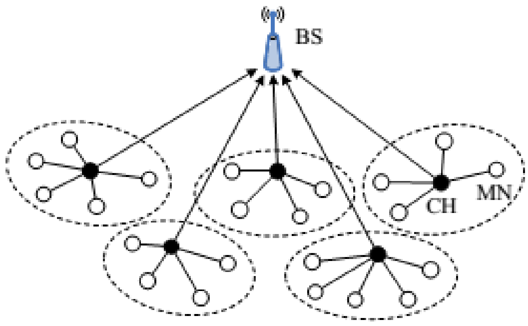

Fig. 2. A simple wireless node clusters with cluster heads as communication mediator between sensors and Base station.

Introduction and Need of Clustering

Self-organization can be characterized as the emergence of a global behaviour from local interaction [7]. Wireless sensor networks have limited bandwidth and energy. Self-organization algorithms that limits the number of message for transmissions and receptions are preferable. The challenge is to arrange dynamic and spontaneous nodes to construct a network and must have increased life-time, which will satisfy the constraints of quality of service. It is therefore essential for self-organizing algorithms to control packet transmission for a least amount of energy and conserve the structure of self-organization for better stability and reliability the network.

How to design an energy efficient protocol to lessen the battery consumption and extend the network lifetime becomes a critical issue. The passive clustering structure is a technique to decrease the energy consumption and can used to carry out data aggregation, the process follows grouping nodes into clusters and select one node as cluster head (CH). CH of each cluster will transmit the collected data to central base station through other CHs. clearly, a great amount of unnecessary transmission can be saved by such clustering and data aggregation method [6].

Here is a small exploration of a number of previous works which consider the wireless sensor network self-organization with clustering mechanisms, a large variety of approaches have been presented such as passive, grid based, Enhanced Uniform Distribution, based on distance and residual energy, recursive clustering, hierarchical clustering, data correlation-based clustering by various researchers [7,8, 9,10,11,12,13,14,15,16].

Routing Protocols

WSN does not have any fixed infrastructure and is highly dynamic [17]. There are mainly two reasons responsible for the dynamic infrastructure. The first reason is the energy; the sensor nodes have restricted energy source in the form of batteries. If the protocol is unable to balance the load among the nodes, the sensor node could die. It leads to the dynamic network structure. The second reason is the mobility; in many scenarios after the deployment, sensor nodes are static but sink can move within the network. It makes the network dynamic, and the protocol that works for static sink may not be applicable for mobile sink [18]. In many applications, sensor nodes are required to know their location information. It is not feasible to enable all nodes with Global Positioning System (GPS) [19]. So the protocol should have to take the help of the techniques like triangulation based positioning [20], GPS-free solutions [21], etc. to get the approximate location information.

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Literature Survey

Arboledaet al. [22] presented a comparison survey between different clustering protocols. The authors have discussed some basic concepts related to the clustering process, such as cluster structure, cluster types, clustering advantages, and analysed LEACH-based protocols as well as proactive and reactive algorithms of WSNs in brief. The main type of these protocols were analysed and the proof where they can be implemented were outlined.

Kumarawaduet al. [23] surveyed the clustering algorithms available for WSNs and classified them based on the cluster formation parameters and CH election criteria. The authors of this survey paper also studied the main design challenges and discussed the performance issues related clustering protocols based on the classification of identity-based clustering algorithms, neighbourhood information based clustering algorithms, probabilistic clustering algorithms and biologically inspired clustering algorithms.

Different clustering methods are discussed by Deosarkaret al. [24], with special importance on their CH selection strategy based on the classification of deterministic technique, adaptive technique and combined metric technique. The overhead of CH selection were compared with respect to cluster formation, distribution of CHs and creation of clusters. Besides, a requirement of more scalable, energy efficient adaptable clustering technique for data gathering in WSNs was put forward.

Jiang etal. [25] discussed a total of three major advantages of clustering methods for WSNs, such as more scalability, less overheads, and easy maintenance, and then present a classification of WSN clustering technique is based on a total eight clustering attributes. The authors have also evaluated altogether six popular WSN clustering algorithms, such as LEACH, PEGASIS, HEED, EEUC, and etc., and compared these WSN clustering techniques, including various attributes.

Maimouret al. [26] considered clustering routing protocols to achieve higher energy efficiency in WSNs and presented a review on clustering algorithms from the data routing point of view.. A simple classification of clustering routing protocols is proposed in the review. Totally nine typical clustering protocols including two classes, pre-established clustering and routing algorithms and on-demand clustering routing algorithms, are summarized in respectively. Besides, some future research directions are presented in the review.

The operations of some clustering protocols were discussed in the survey presented in [27], and the advantages and limitations of each one of these algorithms were analysed in brief. The authors have chosen only seven popular clustering algorithms for WSNs, such as LEACH, TL-LEACH, EECS, TEEN, APTEEN, and etc. Additionally, the survey compared these clustering protocols in terms of energy consumption and network lifetime.

A survey on clustering algorithms for WSNs was presented by Boyinbode *et al.* [28]. The main challenges of clustering algorithms were analysed and altogether nine popular clustering algorithms for WSNs such as LEACH, TL-LEACH, EECS, HEED, EEUC, etc. were simply summarized in the survey. The authors also compared these clustering algorithms based on parameters such as residual energy, uniformity of CH distribution, cluster size, delay, hop distance and cluster formation methodology.

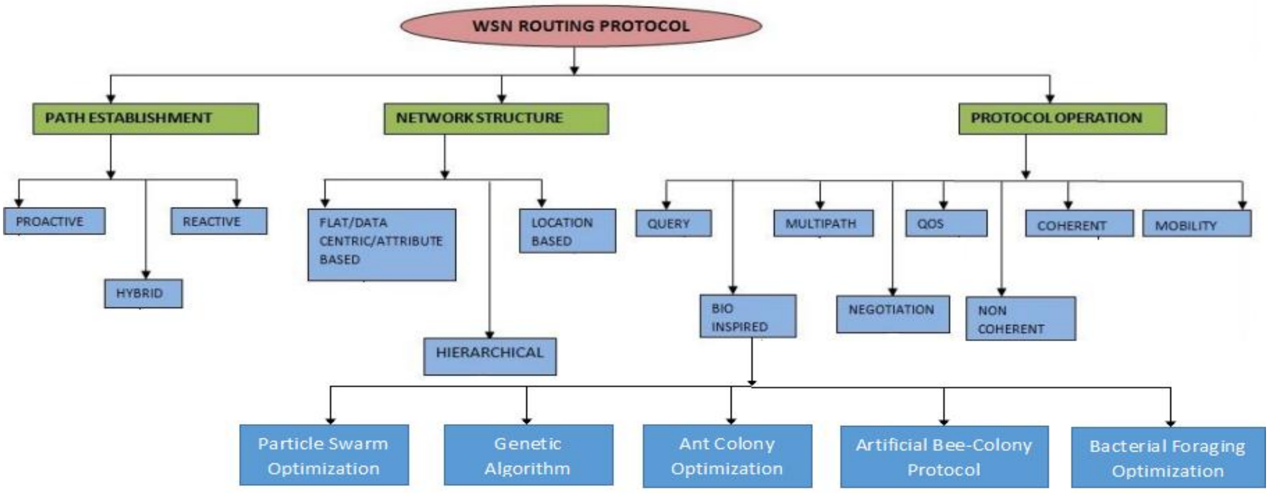

Fig. 3. Classification of protocols for wireless node routing.

A survey of routing protocols for WSNs was presented in [29], whose authors summarized the clustering architecture in WSNs and explained a simple classification based on only three attributes, i.e., parameters used for CH election, presence of a centralized control during clustering, and hops between nodes and CH in intra-cluster communication. In addition, the survey outlined the challenges in clustering WSNs and briefly introduced a few clustering routing techniques.

Classification of Meta-Heuristic Protocols

Meta-heuristic protocols are higher-level procedures or heuristics designed to find and generate, partial search algorithm that may offer a sufficiently good solution to an optimization problem. Here the optimization problem is node routing in a disaster affected wireless sensor network.

The ant system models the way ant colonies complete difficult tasks from the co-operative behavior of a great number of individuals [31]. Ant colony optimization (ACO) is an important class of optimization algorithms that is based on the observation of the collective foraging behavior of ants using stigmergic communication. This can be modeled as a simple distributed, self-organized system consisting of a population of simple agents communicating locally with one another and with their environment. Several papers and text books have explained the ACO algorithm and its application in networking in details [30–34].

Several authors have explained the use of PSO for network clustering: Tillett, Rao and Sahin [35] where the first to use a PSO algorithm for the clustering of nodes in a network. Dong and Qi [36] used a PSO-based clustering algorithm with an enhanced search ability and increased performance.

Latiff, Tsimenidis and Sharif [37] presented an energy-aware clustering for wireless sensor networks using PSO. The performance of the protocol was compared with conventional cluster-based protocols developed for wireless sensor networks, e.g. LEACH (Energy efficient Adaptive Clustering Hierarchy) and variants hereof. Guru, Halgamuge, and Fernando [38] described a number of versions of the PSO algorithm by introducing clustering in a wireless sensor network to minimize the total communication distance of the network and hereby decreasing the energy cost.

Charalambous and Cui [39] used bio-inspired intercellular communication to achieve a compressed cluster via a lateral induction model in a entirely distributed and energy-efficient manner. Initially, the sensor nodes work together to construct a functional cluster via lateral orientation followed by a lateral inhibition phase. Once clusters have been formed, a competitive scenario between nodes is created where nodes compete on which to be active or which nodes to go to sleep. Eventually, one of the active nodes becomes cluster-head as a result of competition.

Proposed System

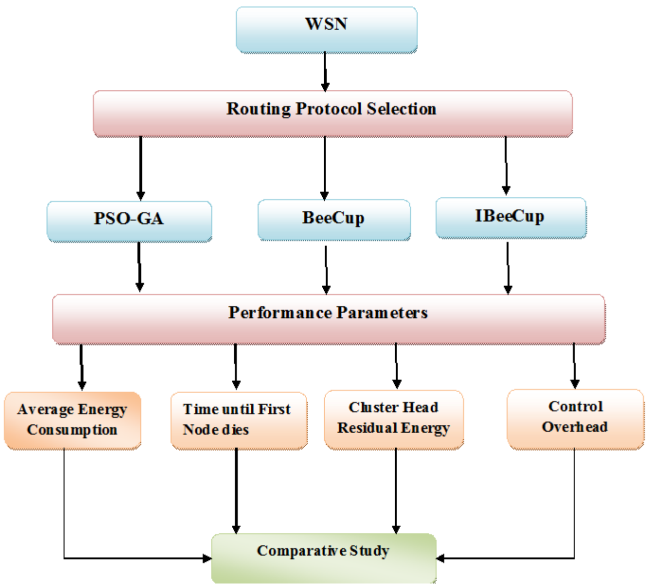

Fig. 4. Structural flow chart of proposed system.

The proposed system uses PSO-GA, Bee Cup (Artificial Bee colony Protocol) and improved Bee Cup. The system will also consist of comparative analysis between these protocols for different size of network and a variable environment.

PSO-GA

Swarm Intelligence (SI) is an pioneering distributed intelligent concept for solving optimization problems that is originally motivated from the biological examples by swarming, flocking and herding phenomena in vertebrates. Particle Swarm Optimization (PSO) integrate swarming behaviors observed in schools of fish, swarms of bees, flocks of birds and even human social behavior, from which the idea is came into sight [40].

The drawback of PSO is that the convergence of swarm may occur before achieving optimal solution. The fundamental principle behind this problem is that, the global best is achieved by converging to a single point, which is on the line between the global best and the personal best positions. This point of convergence is not guaranteed for a local optimum [41].

Another cause of this problem is the fast rate of data flow between particles, resulting in the formation of similar particles with a loss in variety that increases the possibility of being trapped in local optima. To overcome the limitations of PSO, hybrid algorithms with GA are anticipated. Such hybrid approach is expected to have qualities of PSO with those of GA. One advantage of PSO over GA is its algorithmic simplicity. Another obvious difference between PSO and GA is the ability to control convergence [42].

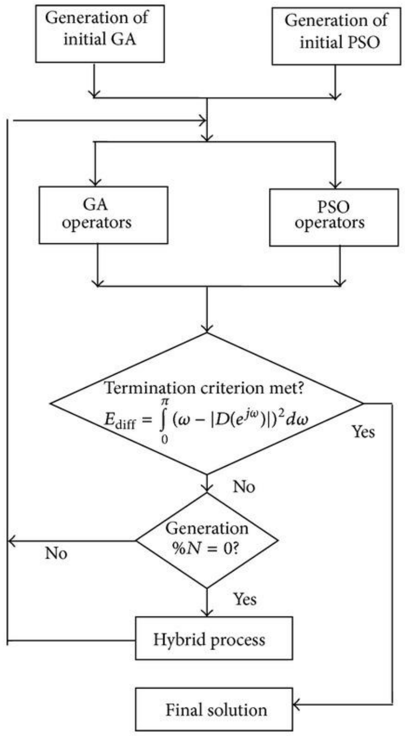

Fig. 5. Flowchart of PSO-GA protocol

Bee-Cup

Bee-Cup protocol contains three main parts. Initially it estimates the number of CHs by taking into account the nodes' mobility, the communication radiuses of WLAN and Bluetooth as well as the maximum cluster size. By dividing the network into K stable areas which have low relative velocity and appropriate number of nodes, we could realize the distribution of the network and how many clusters are suitable. The second part is to select K CHs based on the following constraints:

1) The distances to CHs from their associate nodes and to the base station from CHs.
2) The mobility so as to select K stable CHs.
3) The residual energy in the interim and the number of single-node clusters which have to interact with the base station straight through WLAN.

The Bee Cup protocol also comprise of two cluster maintenance methods during re-clustering intervals: one is local re-clustering if a node is no longer suitable for being a CH due to its low residual energy and the second one is to balance local load by adjusting the RNs. The flowchart of our Bee-cup clustering protocol is shown in figure 6.

Estimating the number of CHs is necessary before clustering the network especially for the randomly distributed network or network with irregular area. Some works manually allot a percentage of nodes to be CHs without fully taking network condition and communication parameters into consideration such as radius and max cluster size. For example, different transmission powers or communication methods may have different communication radii which have an essential influence on the coverage area.

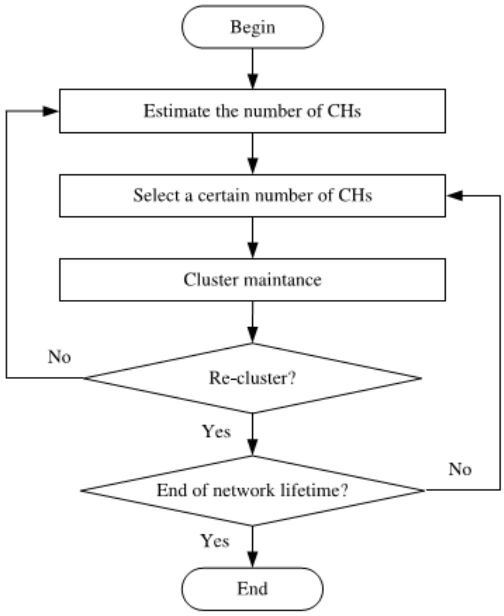

Fig. 6. Flowchart of Bee Cup protocol

Here, we define the fitness function as Eq. (1) using the ABC algorithm to discover a solution with the highest fitness. k represents the CHs from the non-empty cluster which will communicate with the base station by using WLAN. Vi stands for the instant velocity of node i. In order to let the value of the function be as small as possible, we must limit the value of k and choose the nodes with a similar speed as

CHs. ω1 and ω2 whose sum is 1 are used to control the weight of the two factors.

$$CHNumber\_Fitness = \omega_1 \times \frac{k}{n} + \omega_2 \times \frac{1.0}{\sum_{i=1}^{k} V_i + 1.0}. \quad (1)$$

Proposed IBee-Cup

The proposed I-Bee Cup protocol introduces the clustering into mobile learning to save the mobile devices' energy and to enhance the quality of experience and learning effects.

We use the ABC algorithm to adaptively determine the number of clusters rather than manually assigning one. A appropriate fitness function for the scene of mobile learning considering the factors of distance, mobility, energy and number of single-node cluster is also proposed. In addition, proposed protocol also comprise two intelligent cluster maintenance methods to adapt the clusters dynamically before re-clustering.

The proposed algorithm incorporates M-learning which highlights its characteristics on "moving in" learning in network, contextual relevance, and some other new features. It has been deduced that it successfully provide an energy-efficient and load balancing solution for WSN in disaster stricken network areas by using the hierarchical structure, using clustering and routing.

Results

In this section, a comparison in the performance protocols: PSO–GA and Bee Cup for communication of one-to-many and many-to-one as for the application of m-learning is showcased. Unless otherwise specified, the simulation time is 7200 s for each experiment and the re-clustering interval is set to 600 s.

We divide the evaluation of our Bee Cup protocol into following parts:

1. Energy consumption
2. Time before first node dies
3. Average Cluster Head Residual Energy
4. Control Overhead

The calculations are done for number of nodes for varying range of 20 to 180. The Bee Cup protocol outperforms PSO-GA in most of the scenarios and criteria.

Conclusion

The proposed clustering algorithm will maintain the clusters to keep the network stable. The performance of I-Bee Cup has been evaluated under different network sizes and scenes. Our protocol was compared to two other existing protocols: PSO–GA, ABC (Bee Cup).The results show that I-Bee Cup performs better in increasing the network lifetime and hence can improve the superiority of user experience in mobile learning. Furthermore, it is applicable to both homogeneous and heterogeneous networks.

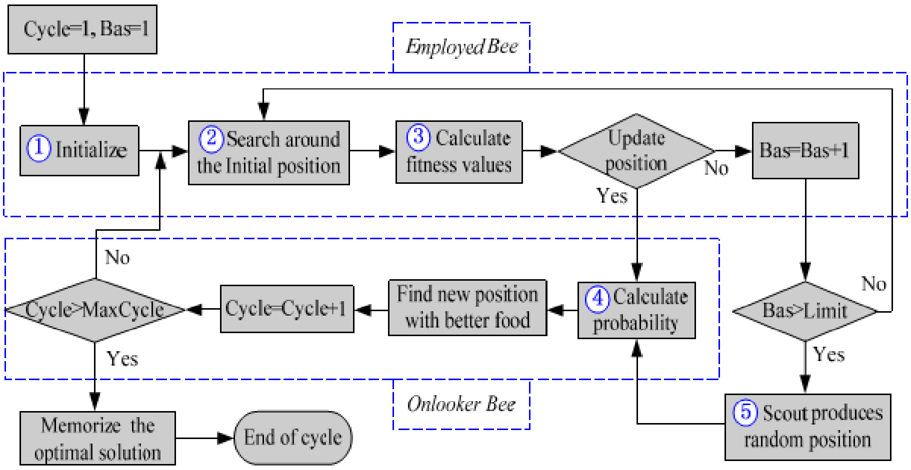

Fig. 7. Flowchart and detailed protocol design of proposed I-BeeCup protocol

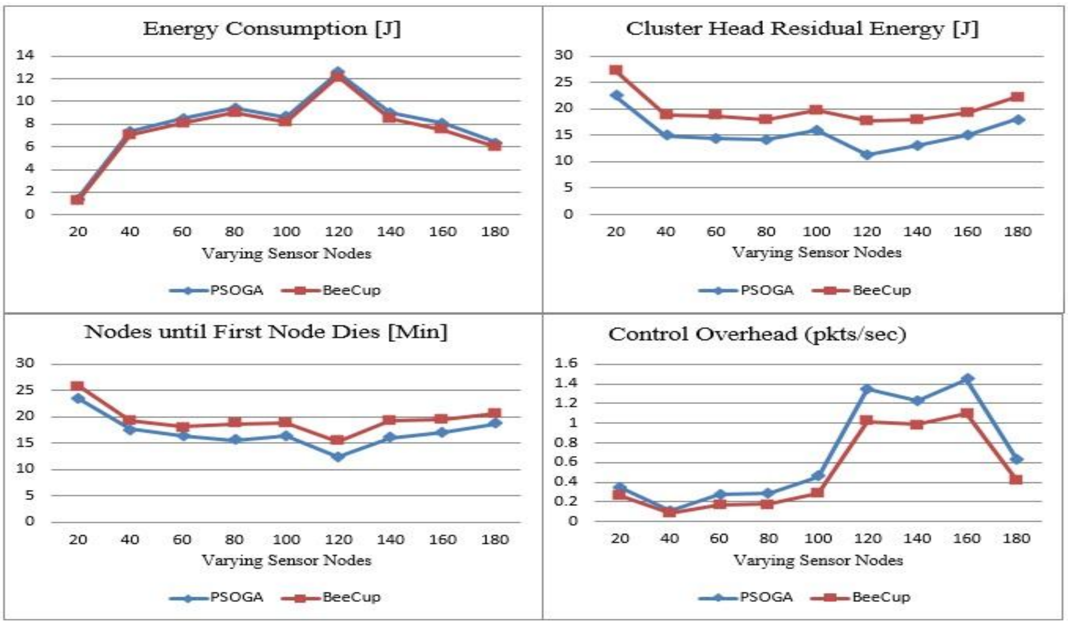

Fig. 8. Graphs showing comparative analysis of protocols in context of (a) Energy consumption (b) Time before first node dies (c) Average Cluster Head Residual Energy (d) Control Overhead

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