Optimization techniques for Routing in Wireless Sensor Network

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Abstract-Recent developments in wireless communications led to the development of low-cost, low-power wireless sensor networks (WSN) which is widely used these days. Minimizing energy consumption and hence maximizing the lifetime of the network are key requirements in the design of sensor networking protocols. Several routing protocols with different objectives have already been proposed for WSN. Several optimization techniques are present, which are used to improve the performance of the network.In this paper we briefly discussed about WSN, various routing challenges in WSN, various optimization techniques like GA, PSO, ACO and ABC. Advantages and the application areas of various techniques are also discussed.

Keywords- WSN, Routing, optimization, GA, PSO, ACO, ABC.

I INTRODUCTION

A WSN typically has little or no infrastructure. A sensor network consists of a large number of sensor nodes, densely deployed either inside the monitoring environment or very close to it. Unlike traditional networks, a wireless sensor network has its own design and resource constraints. Sensor nodes have very limited processing and communication capabilities. As a result, while traditional networks focus more on achieving high quality of service (QoS), sensor network protocols have to focus mainly on network lifetime issues. Various resource constraints that affect the network are low bandwidth, short communication range, limited processing and storage in each node.

All the above mentioned issues are directly related to the optimization problem. Maximizing the lifetime, meeting the QoS requirements along with providing security is not an easy task. Often these three issues contradict with each other. If we want to ensure energy efficiency, then QoS and security is comprised. If QoS is assured, then the other two issues may lack proper awareness. So, from the optimization point of view of WSN, the right choice of the optimizer or algorithm for WSN problems is very important. The algorithm which is chosen for an optimization depends upon various factors like the nature of the algorithm, the type of the problem, the desired quality of solutions, the available resources, time constraints, *etc.* The nature of an optimizer determines if it is appropriate for a particular type of problem.

II ROUTING CHALLENGES IN WIRELESS SENSOR NETWORK

Factors that influence the design of routing protocol in WSN are summarized below:

- Node Deployment: Sensor nodes are densely deployed in the area of interest depending upon the application which affects the performance of routing protocol. Nodes can be deployed either manually or randomly. When nodes are manually placed data is routed through pre-determined paths. In self organizing systems, sensor nodes are scattered randomly creating a topology in an ad hoc manner.

- Network topology: It must be maintained even with high node density.

- Data aggregation: It is a combination of data from different sources .Similar packets from multiple nodes can be aggregated to reduce transmission.

- Transmission media: Generally, communication takes place through wireless media, which is affected by fading which affect the operation of WSN.

- Node Capability: Depending on the application, a sensor node can have a different role or capabilities such as relaying, sensing and aggregation if all these functions are performed by the same node the energy of that node would be drained more quickly. Different capabilities of sensor nodes raise multiple issues related to data routing and makes routing more challenging [1].

- Scalability: The deployment of sensor nodes is dependent on the nature of the application. Sensor node deployment varies with respect to the demand of the application, therefore the number of sensor nodes can be hundreds, thousand or even more. To handle network scalability, routing algorithm should have the capability to cope with scalable network.

III OPTIMIZATION TECHNIQUES

Many optimization algorithms have been developed based on nature-inspired concepts. Evolutionary algorithms (EA) and swarm optimization algorithms are two categories of nature inspired algorithms. EA attempts to simulate the phenomenon of natural evolution. In natural evolution, each species search for beneficial adaptations in an ever changing environment. Genetic algorithms (GA) and differential evolution (DE) algorithms are the example of EA. Swarm optimization algorithms include Particle Swarm Optimization, Ant Colony optimization and Bee Colony Optimization.

3.1 Genetic Algorithm

GA can be viewed as an optimization method which is based loosely on the Darwinian principles of biological evolution, reproduction and "the survival of the fittest". The population consists of a collection of strings known as chromosomes, where a chromosome represents different points in the search space. The representation of each chromosome in GA is in the form of binary strings or real numbers. A fitness or objective function is used to reflect the goodness of each chromosome in the population. At first, the initial population is randomly generated. New populations are created in subsequent generations through the use of four fundamental mechanisms: selection,

crossover, repair and mutation operations [2]. Selection mechanism selects individuals (parents) for crossover and mutation. Crossover is another important technique that causes the exchange of genetic materials between parents to produce offspring, whereas mutation incorporates new genetic traits in the offspring. GA maintains this population and repeatedly modifies it to produce a new generation of chromosomes. This procedure is repeated until convergence is reached or until a maximum number of generations are achieved.

Advantages

- It can solve every optimization problem which can be described with the chromosome encoding.
- GA is not dependent on the error surface, so we can solve many problems of multi-dimensional, non-differential, non-continuous, and even non-parametrical nature.
- Genetic algorithms can be easily transferred to existing simulations and models.

3.2 Particle Swarm Optimization (PSO)

Swarm Intelligence is a branch of Artificial Intelligence (AI) that focuses on the collective behaviour and properties of self-organized and decentralized systems with a social structure, such as bird flocks, ant colonies. These systems consist of simple interacting agents organized in small societies, called swarms, which exhibit traits of intelligence, such as the ability to react to environmental threats and decision making capacities. Particle Swarm Optimization (PSO) was invented by Kennedy and Eberhart in 1995. PSO provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO, particles fly around in a multidimensional search space. During flight, each particle uses its own experience, and the experience of a neighboring particle, to adjust its position by considering the best position encountered by it and its neighbor, a PSO uses both local search methods as well as global search methods.

Advantages

- It is easy to implement.
- Only few parameters need to adjust.
- It is efficient in global search.
- Good quality solutions are possible because of its ability to escape from local optima.
- It has quick convergence [3].

3.3 Ant Colony Optimization (ACO)

The ant colony algorithm is used for finding optimal paths from a source to food that is based on the behaviour of ants searching for food [4]. At first, the ants move randomly. When food source is found, ants walks back to the colony leaving "markers" (pheromones) that show the path has food. When other ants come across these markers, they are likely to follow the same path with a certain probability. If they do, they then populate the path with their own markers as they bring the food back. The path gets stronger as many ants follow the same path. Because the ants drop pheromones every time they bring food, shorter paths are more likely to be stronger. In the meantime, some ants are still randomly searching for closer food sources. A similar approach can be used to find near-optimal solution to the travelling salesman problem. Once the food source is depleted, the route has no longer pheromones and slowly starts decaying. Examples of such systems include computer networks, and artificial intelligence simulations of workers.

Advantages

- Inherent parallelism
- It can be used in various dynamic applications.
- Positive Feedback leads to rapid discovery of good solutions.
- They react quickly to the changes in the environment.

3.4 Artificial bee colony optimization (ABC)

The Artificial Bee Colony (ABC) algorithm was proposed by Karaboga in 2005. Artificial Bee Colony (ABC) algorithm is a swarm-based artificial intelligence algorithm which is inspired by the intelligent foraging behavior of honey bees. The ABC algorithm consists of three bee groups and food sources. The position of a food source denotes a possible solution to the optimization problem and the nectar amount of a food source represents the quality (fitness) of the associated solution. The three types of bees are onlookers, scouts, and employed bees [5]. The bee which carries out random search is known as a scout. The bee which is going to the food source which is visited by it previously is employed bee. The bee which is waiting on the dance area is an onlooker bee. The onlooker bee with scout is also called unemployed bee.

Advantages

- It has few control parameters, i.e. population size, limit and maximum cycle number.
- It is simple, flexible and robust.
- It has fast convergence speed.
- It can be easily used with other optimization algorithms .

IV COMPARISON

PROBLEM DOMAINS	PSO	ACO	GA
Optimal Node Deployment	Centralized nature of PSO minimizes the area of coverage holes of stationary node positioning.	Distributed nature of ACO is better in solving mobile node deployment issues.	Good for random as well as for deterministic node deployments.
Data Aggregation	It is quite suitable for PSO.	In case of large scale and dynamic WSN it can perform better.	Suitable in finding the minimum number of aggregation points while routing data to the BS.
Energy Efficient Clustering and Routing	PSO shows better performance in selecting the high energy node as CHs in each round and can find an optimal route effectively.	Performs better in maximizing both network lifetime and data delivery to the base station.	GA is used in the formation of a number of pre-defined clusters, which helped in reducing the overall minimum communication distance.

V CONCLUSION

Routing in sensor networks has attracted a lot of attention in the recent years and introduced unique challenges compared to traditional data routing in the wired network. In this paper, we presented an overview of the factors that are a challenge in implementing the routing in a WSN. We have discussed various optimization techniques which can be used to improve the performance of the network. Their advantages and disadvantages are discussed and compared. We have also highlighted the problem domain where these optimization techniques can be useful.

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