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Review of Power-Efficient Gathering in Sensor Information System (PEGASIS) for Network Optimization in WSN

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Abstract- Wireless sensor networks (WSN) consists of small sensor nodes which perform sensing, computation and communication capabilities. These networks collect information from all sensor nodes and send it to the base node for further operations. PEGASIS is a hierarchical based routing protocol which is used for their high energy and good expandability. In PEGASIS high energy nodes are randomly selected for processing and sending data and low energy nodes are used for sensing and sending information to chain heads. This aim of this paper is to facilitate future researches such that several techniques of improving energy efficiency in PEGASIS can be probed quickly.

Keywords- Power-Efficient Gathering in Sensor Information System (PEGASIS), QoS, Wireless Sensor Network (WSN), Energy Efficiency, LEACH.

I. INTRODUCTION

A wireless sensor network (WSN) means a wireless network which consists of spatially distributed nodes that use sensors to monitor physical conditions. These nodes combine with routers and a gateway to create a typical WSN system. Each node has its own processing capability that can include one or more microcontrollers, CPUs or DSP chips ,may contain multiple types of memory , have a RF transceiver (usually with a single Omni-directional antenna), have various batteries and solar cells as a power source, and accommodate various actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. [1]

The features of WSN include: constrained resources (bandwidth and energy), data-centric application and dynamic configuration and so on. There are many technical challenges associated with sensor networks, such as self-organizing algorithm, energy-efficient routing protocols, data aggregation technology and network lifetime improvements. The energy for sensor networks is very important. It is infeasible to replace battery of sensor. Therefore, conserving energy so as to prolong the network lifetime is becoming one of the key challenges. [2]

A. Classification of Routing Protocols in WSN

Different routing protocols are designed to fulfill the shortcomings of the recourse constraint nature of the WSNs. The deployed WSN can be differentiated according to the network structure or intended operations. Therefore, routing protocols for WSN needs to be categorized according to the nature of WSN operation and its network architecture.WSN routing protocols can be subdivided into two broad categories, network architecture based routing protocols and operation based routing protocols.

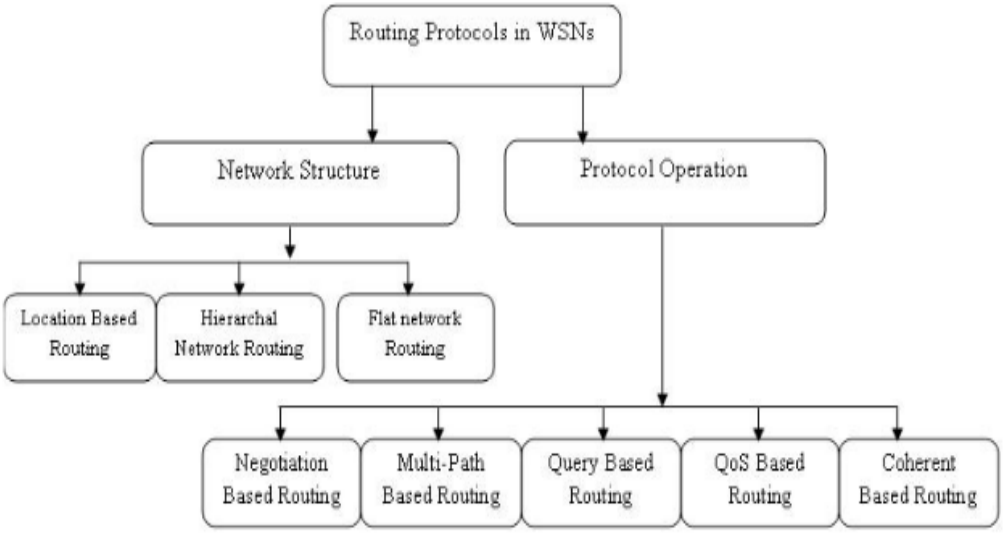

Fig. 1 Classification of routing protocols in WSN [3]

B. Hierarchical-Based Routing

Hierarchical-based routing protocols are used in the applications where their high energy-efficiency and good expandability is needed the most. These protocols work on the basic idea to select some nodes in charge routing in certain regions. The selected nodes posses greater responsibility relative to other nodes of the network which leads to the incompletely equal relationship between sensor nodes. LEACH (Low Energy Adaptive Clustering Hierarchy), PEGASIS (Power-Efficient Gathering in Sensor Information System) is the typical hierarchical-based routing protocols [4].

II. POWER EFFICIENT GATHERING IN SENSOR INFORMATION SYSTEMS (PEGASIS)

PEGASIS is a chain based routing protocol [4]. Unlike LEACH, PEGASIS constructs chain instead of clusters so that the burden of dynamic clustering can be reduced. In PEGASIS all nodes communicates with their closest neighbors and continues their communication until the aggregated data reached the BS. Thus this improves the network lifetime, since it reduces the power consumption required per round.

1) *Chain Formation:* For constructing the chain the PEGASIS protocol starts from furthest from the base station and uses Greedy algorithm to form chain. Each node communicates with its two neighbors to transmit data. Each node aggregates data from downstream node and sends it to upstream node along the chain.

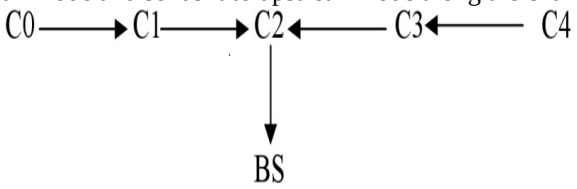

Fig. 2 Chaining in PEGASIS [6]

2) Leader Selection: At the beginning of each round leader node is selected randomly. The benefit of selecting the random node is that if the node dies at random location the network will be robust. To initiate the data gathering a token is sent to the end node from the leader node after the selection of leader node. Passing token also consumes energy but the size of token is so small that the cost for passing is very small.

3) Data Transmission: The node that has the token starts sending its data to its neighbor. The neighbor node collaborates its data with the data sent from the previous node and then passes the data to its neighbor. This process continues till the data reaches the leader node. Then the leader node transmits the collaborated data to the BS. The leader nodes rotate randomly in each round.

III. TECHNIQUES USED TO OPTIMIZE PEGASIS

A. Ant Colony Based Algorithm (ACO)

Unlike PEGASIS, the ACO provides the shortest network nodes chaining, to allow network lifetime extension instead of starting from the furthest node and using Greedy algorithm. The leader role duration for each node is defined on the basis of its required energy to do this role in the established chain avoiding fast node's energy depletion due to which, the network lifetime would be extended. Ant colony optimization is the Meta heuristic optimization technique. The basic idea for using this algorithm is based on the food searching behavior of real ants. As the ants deposit pheromone on the route taken by them, the pheromone concentration on the shorter path will be higher than on the longer path. [7]

B. Particle Swarm Optimization(PSO)

The PSO algorithm is an evolutionary computing technique, modelled after the social behaviour of a flock of birds [7]. In the context of PSO,, a particle is represented as a potential solution and a potential solution is further referred as a swarm to the optimization problem. The aim of the PSO is to find the particle position that results in the best evaluation of a given fitness function. During each generation, each particle uses the information about its previous best individual position and global best position to maximize the probability of moving towards a better solution space that will result in a better fitness. [7]

C. Biogeography Based Optimization (BBO)

Biogeography Based Optimization (BBO) is an evolutionary algorithm (EA) that optimizes a function with regard to a given measure of quality, or fitness function by stochastically and iteratively improving candidate solutions. As BBO includes many variations so it is included in the class of metaheuristics .

D. Genetic Algorithm (GA)

GAs is adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. They signify an intelligent exploitation of a random search that is used to resolve optimization problems. By no means GAs are random, instead they use chronological information to direct the search, within the search space, in the area of improved performance. To simulate processes in natural systems which are necessary for evolution, the basic techniques of the GAs are designed. [12][11]

IV. NETWORK OPTIMIZATION

To optimize the usage of energy resources and share the wireless medium efficiently stand as the important issue in network optimization. The management of power consumption is the most important element to consider due to the energy constraints of battery powered device. The primary objective in PEGASIS design is to maximize network lifetime.

Lifetime optimization provides information about the time period for which the nodes can, but it does not specify a set of routing features as problem constraints [10]. In fact there may exist multiple routing alternatives, for a calculated lifetime [13].

V. PERFORMANCE ISSUES IN PEGASIS

Network optimization in pegasis is carried out by following performance issues:

1) *Energy Efficiency:* Sensor nodes should collaborate with each other in an energy efficient manner for exchange of data so that lifetime of the network can be increased. It is important to note that the battery replacement in the sensors is infeasible since most of the sensors are randomly placed.[8]

2) *Scalability:* Network protocols designed for sensor networks should be scalable to different network sizes, independent of the number of the sensor nodes in a sensor network.[1]

3) *Reliability:* Reliable data delivery should be provided by the network protocols designed for sensor networks even over noisy, error-prone, and time-varying wireless channels. Designing of Error control and correction mechanisms must be donel.[1]

4) *Mobility Adaptability:* The different applications of wireless sensor networks could demand nodes to cope with their own mobility [1], the mobility of the sink or the mobility of the event to sense. An appropriate support by the routing protocols for these movements should be rendered by Routing Protocols.

5) *QoS support:* QoS means that the network should provide some kind of guarantee or assurance about the level or grade of service provided to an application. The QoS is characterized by a certain number of parameters (throughput, latency, jitter and loss, etc.).[9]

6) *Resilience:* Eventuality of unpredictably stopped operations due to environment reasons or to the battery consumption so that when a current-in-use node fails, an alternative route could be discovered.[1]

7) *Autonomy:* It does not stand in wireless sensor networks as it could be an easy point of attack and there should not be any centralized entity to make the routing decision, it proceeds to transfer the network nodes. [1]

8) *Data Latency and Overhead:* They are the important factors that influence routing protocol design. Data latency is cause of Data aggregation and multi-hop relay. Some routing protocols create excessive overheads to implement their algorithms, which are not suitable for serious energy constrained networks.[1]

9) *Node Deployment:* Node deployment is application dependent and affects the performance of the routing protocol. The deployment is self organizing. In these situations, the sensors are manually placed and data is routed through predetermined paths. When the distribution of nodes is not uniform, optimal positioning of cluster head becomes a pressing issue to enable energy efficient network operation.[1]

VI. RELATED WORK

Celalettin et Al [14] in the paper "Analysis of Energy Efficiency of Compressive Sensing in Wireless Sensor Networks" paper compared the conventional approaches to analyze the effects of acquisiton, processing, and communication CS-based measurements on WSN lifetime. Energy dissipation models for both CS and conventional approaches are built. These dissipation models construct for both convetional and CS approaches a mixed integer programming framework that jointly captures the energy costs for computation and communication. By systematically sampling the parameter space (i.e., sparsity levels, network radius, and number of nodes), numerical analysis is performed. In a small coverage region,the result shows that CS approach has better life span for sparse signals for WSNs. [14]

Jamal N. Al-Karaki Ahmed E. Kamal [5] represents the "Routing techniques in wireless sensor networks: A Survey" paper, presents a survey of the routing techniques in wireless sensor networks. In this survey first, a comprehensive survey of different routing techniques is performed followed by the outline design challenges for routing protocols in WSNs. Overall, the routing techniques are classified into three categories based on the underlying network structure: °at, hierarchical, and location-based routing. Furthermore, depending on the protocol operation ,these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, and coherent-based.[5] In every routing

paradigm, we study the design tradeoffs between energy and communication overhead savings. We also highlight the performance issues of each routing technique and advantages . The paper concludes with possible future research areas. [5]

A. Seetharam, A. Acharya, A. Bhattacharyya, M. K. Naskar[8] in "An Energy Efficient Data Gathering Protocol for Wireless Sensor Networks" we propose an energy efficient protocol which enhances the performance of LEACH, PEGASIS. As the individual nodes are deployed randomly in the area under surveillance the base station is located at variable distances from them. Thus each node actually dissipates a different amount of energy during its turn of transmission to the base station. Network performances are poorer if this energy difference between the various nodes keeps on increasing. In our scheme depending on its distance from the Base Station each node takes turns in transmitting to the base station and only communicates with a close neighbour . As compared to LEACH and PEGASIS, this helps to iron out the unequal energy dissipation by the individual nodes of the network and results in superior performance. Extensive simulations have been carried out which shows that significant improvement is over these schemes. [8]

Zeenat [15] in "Efficient Data Forwarding Techniques in Wireless Sensor Networks" proposed three data forwarding techniques. Here, to forward the data to the destination based on different criteria, the source nodes or intermediate nodes select a next node. The process repeats until data reach the destination. In the first technique, considering the distance from sink node as a criterion, neighbor node nearer to the sink is chosen. In the second technique to select the next node remaining energy of the neighboring nodes is used as a criterion. The combination of previous two criteria is considered in the third technique based on Multiple Criteria Decision Analysis. Results are presented in this paper and a comparative study of the performance of these techniques has been carried out .

Tintu et al [18] in "Statistical Analysis of Energy Efficient Hierarchical Routing Protocols in WSN" surveys various energy efficient hierarchical routing protocols for sensor networks and presents a classification and comparative study of the various approaches pursued. Wireless sensor nodes with limited battery power are deployed to collect data from the environment. Initially WSN was developed for military purpose,but now it is extended to wide range of applications. It is critical to operate the network for a long period of time for gathering sensed data in an energy efficient manner. Many protocols have been developed for different applications. [18]

Kajal[19] in "Research on Energy Efficient Routing Protocol LEACH For Wireless Sensor Networks" discussed in recent era of Wireless Technology, latest wireless technologies and energy efficient design have enabled new exciting applications for wireless devices. These types of applications cover a wide range including transfer of large amount of data from one device to another, real time and streaming video and audio delivery. As these applications usually suffer from resource constraints so they require high performance on the network. Because nodes are battery operated, Wireless devices are often having limited energy resource. This makes application with limited bandwidth &making the transfer error prone. In WSNs data fusion is helpful to reduce the amount of data transmitted between sensor nodes and base station, when we need to operate sensor network for a long time. To this problem LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is an appropriate solution. [19]

Joon-Woo [16] in "Ant-Colony-Based Scheduling Algorithm for Energy-Efficient Coverage of WSN" propose an ant colony-based scheduling algorithm (ACB-SA) to solve the EEC problem. Their algorithm is a simplified version of the conventional ant colony optimization algorithm, optimized for solving the EEC problem. A more realistic approach to solve the EEC problem is represented by using the probability sensor detection model and applies their proposed algorithm to a heterogeneous sensor set. Simulation results are performed to verify the effectiveness of the ACB-SA for solving the EEC problem in comparison with other algorithms. [16]

Edwin [17] in "Research Issues in Wireless Sensor Network Applications: A Survey" presents an overview of the various research issues in WSN based applications.Wireless Sensor Networks (WSN) which are used in variety of fields around us viz military, health care, environmental, biological, home and other commercial applications. Embedded computer and sensor technology has done a huge advancement out of all the areas, Wireless Sensor Networks (WSN), which have made a remarkable impact everywhere, is composed of several sensor nodes which are capable of sensing, actuating, and relaying the collected information.[17]

Sunita et al [21] in the paper "A Survey on QOS and energy efficient routing protocols in WSN" surveys recent energy efficient routing protocols for sensor networks, they have summarized current research consequences on energy efficient routing in sensor networks which comes under QOS based category is also incorporated whether the protocol is utilizing flat or multi-hop transmission scheme.[21]

S.Manju Priya1 et al [22] in the paper "An Efficient Clustered Multipath Routing to improve lifespan in WSN" propose a new way by using clustered multipath routing to improve the lifespan of sensor networks. A wireless sensor network, in order to gather data in various environments use a large number of tiny sensor nodes in an effective way. One of the significant challenges in the wireless sensor network is the energy saving and increasing the life time of the network. In order to increase the energy of the nodes it is necessary to implement energy routing algorithms. [22]

Akoijam et al [20] in the paper "A Review on Power Efficient Energy-Aware Routing Protocol for Wireless Sensor Networks" proposed a Power-efficient Energy-Aware routing protocol for wireless sensor networks that saves the energy by efficiently selecting the energy efficient path in the routing process. α is calculated for each route when source finds destination . The value of α is based on both the hop count of path and largest minimum residual energy of the path. Path is selected for routing the data, if a route has higher value of α. If the largest of minimum residual energy of the path is higher and the number of hop count is lower, the value of α will be higher. Data is transferred along the path, once the path is selected. In order to increase the energy efficiency further transmission power of the nodes is also adjusted based on the location of their neighbor. Then transmission range of the node is decreased, if the neighbors of a node are closely located to that node. Therefore for the node to have the transmission power enough to reach the neighbor within that range is necessary. As a result to reduce the energy consumption of the node, transmission power of the node is reduced. Their proposed work is simulated through Network Simulator (NS-2). [20]

Feng et al [4] in the paper "An Improved Energy-Efficient PEGASIS-Based Protocol in Wireless Sensor Networks" proposed an improved energy-efficient PEGASIS-based protocol (IEEPB).IEEPB uses weighting method when selecting the leader node and adopts new method to build chain, In weighting method a weight is assigned to each node so as to represent its appropriate level of being a leader. Residual energy of nodes and distance between a node and base station (BS) are considered as key parameters for selecting a leader. IEEPB has a better performance than EEPB is shown in simulation results, on balancing energy consumption and prolonging lifetime of Wireless Sensor Networks (WSN).[4]

VII. CONCLUSION

In this paper, we presented the modifications in PEGASIS to meet network optimization challenges through focussing on factors such as energy efficiency, scalability, reliability, mobility adaptability, QoS support, resilience, autonomy, Data latency and overhead, Node Deployment. Optimization techniques of Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Biogeographical Based Optimization (BBO), Genetic Algorithm (GA) are explained. In this paper, we also presented PEGASIS protocol to facilitate future researches such that several proposed modifications in PEGASIS routing protocol can be done quickly and easily.

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