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Survey of Energy Aware Routing Algorithms in Wireless Sensor Networks

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Abstract- The Wireless Sensor Network (WSN) consists of several devices called sensor nodes that communicate with each other to detect the parameters of the environment in which they are used. The sensor nodes communicate with each other using wireless communication techniques, and these techniques are managed by existing routing algorithms. Traditional routing algorithms cannot be used on the WSN due to the inherent nature of the WSN, which is different from other wireless networks. Performance of the Wireless sensor network depends on the routing algorithm hence an extensive survey of the challenges and issues faced during the design of the routing algorithms such as energy-based, optimization-based and hop count based algorithms are presented in this paper.

Keywords – Wireless Sensor Networks, Routing, Energy, Optimization, Hop Count

I. INTRODUCTION

WSN can be defined as a collection of self-organized minute devices, named as sensor nodes. All deployed sensor nodes are dispersed in a random manner based on ad-hoc infrastructure, to gather the sensory data over the entire network field. Unlike other wireless communication technologies, the WSNs pose unique constraints on the communication protocols because of constrained resources [1]. Routing protocols in traditional networks are designed in a way to improve network performance in terms of data delivery and network latency. On the other hand WSNs mainly emphasis on how to progress energy preservation while slightest communication overheads [2]. Over the conventional networking approaches [3], scalability, minor costs, correctness, consistency, and easiness of distribution are focal advantages of WSN applications. Due to limited constraints of in WSN scenarios [4], energy utilization is a rare source and has to cope intelligently with improving network lifetime and routing performance. Traditional and single-tire routing solutions are not feasible for sensor-based applications, because of the dynamic behavior of sensor nodes [5]. Thus, recently, different researchers focus on the development of adaptive and robust routing protocol for the improvement of energy efficiency and appropriate routes discovery towards the endpoints [6].

The architecture diagram of the sensor node is shown in figure 1. A node consists of mainly four units: a tiny sensor, a microprocessor, a power supply unit, a memory, and a radio receiver to communicate with the whole network. Because of the inherently limited energy resources, processing capacity and data transfer bandwidth, effective routing becomes a significant concern in wireless sensor networks.

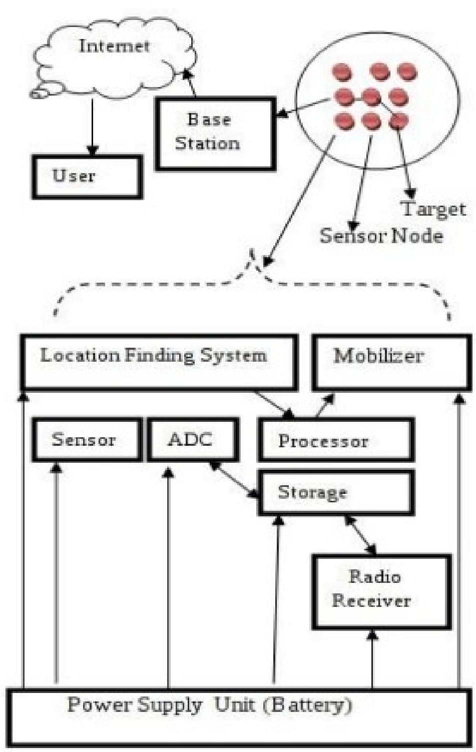

Fig.1. Architecture of sensor node in WSNs

The location of the event or the node location to obtain information is the important information in the monitoring message of sensor nodes. Moreover, the monitoring of data without location information is always meaningless. Then, the location information of sensor nodes is very important for wireless sensor networks [7]. Therefore, the design of the localization system and algorithm suitable for the characteristics of wireless sensor networks has become a research hotspot in the field of wireless sensor networks. In view of a few nodes with known locations, the localization of sensor nodes is to determine their own locations according to a certain localization mechanism. Based on whether it needs to measure the distance or angle between nodes in the location process, the existing location algorithms can be divided into two categories: location algorithm and distance-free location algorithm [8]. ADistance-based algorithm has high location accuracy; however, it has a very high requirement for hardware resources. Moreover, it requires strict clock synchronization among its nodes and leads to high cost. In contrast, distance-free location algorithm has better practicability because it does not need measuring distance.

In the past few years, intensive research that addresses the potential of collaboration among sensors in data gathering and processing and in the coordination and management of the sensing activity were conducted [9]. However, sensor nodes are constrained in energy supply and bandwidth. Thus, innovative techniques that eliminate energy inefficiencies that would shorten the lifetime of the network are highly required. Such constraints combined with a typical deployment of alarge number of sensor nodes pose many challenges to the design and management of WSNs and necessitate energy-awareness at all layers of the networking protocol stack [10]. For example, at the network layer, it is highly desirable to find methods for energy-efficient route discovery and relaying of data from the sensor nodes to the BS so that the lifetime of the network is maximized. Wireless sensor networks havea great potential which is not yet reached because of various challenges faced in designing and deploying them. These challenges have become subjects of research interest and few of them are listed below:

- Energy: First and foremost challenge is to reduce the energy consumption of sensor nodes as they run on the limited battery. Energy must be conserved to increase the lifespan of the sensor nodes. Energy is required by the sensor node to sense, collect, communicate and process data. Batteries when depleted can be replaced or recharged. The most important task in WSNs is to design and implement various energy-efficient hardware and software protocols to manage limited battery life efficiently 11].

- Routing: Owing to the unstructured nature of WSNs traditional routing protocols are not suitable. Routing protocols in WSNs must be lightweight because of the limited network resources. Routing protocols in WSNs are classified as greedy forwarding, energy- oriented, data-localization and flood based. Greedy forwarding forwards packets to neighbors close to the destination. Data-centric protocols are attribute-based protocols, they use compression and aggregation to route the packets. Energy efficient protocols choose a neighbor with a high energy level to route the packet [12]. Localization based protocols use GPS or any other localization model to localize the neighbors in the network and to decide the route. Flooding is a technique in a node which a broadcast data or control packets' for route determination.

The rest of the paper is organized as follows. Section II gives a brief discussion of various challenges and issues in routing design. Section III shows the comparative analysis with parameters of each routing algorithm. Section IV identifies the problem from the existing work. Section V concludes with the summary of proposed routing algorithm.

II.VARIOUS CHALLENGES AND ISSUES IN ROUTING DESIGN

A. Energy Based Routing Algorithm

Ding et al., [13] presented a tree-based aggregation algorithm for improving the energy efficiency of WSN. The construction and maintenance of the network tree are initiated by BS and known as the root node. During data aggregation and forwarding to BS (Base Station), each source node determines its next-hop based on residual energy and hop-count parameters. However, this process takes a lot of time for data routing and increases the end-to-end ratio. Furthermore, the constructed routes are not evaluated in terms of link quality that arise frequency of re-transmissions.

Kumar et al., in [14] presented Enhanced Threshold Sensitive Stable Election Protocol (ETSSEP) for heterogeneous networks. The proposed protocol improved network lifetime as it changed the cluster head selection process based on a dynamic probability function. The selection process of the cluster head has exploited the factors of residual energy and the number of clusters per round. Although, the routing paths are non-optimal and link evaluation is overlooked, which results in decreasing data delivery performance and network reliability.

P. Bhondekar et al., in [15] different models of energy for WSN and proposed energy retrained routing protocol for energy saving to increase the stability period, where it considers heterogeneous based routing to achieve optimal utilization of the resource. It is founded that increase in traffic heterogeneity, by increasing nodes' packet lengths, increases the effective number of bits per round for communication. This increases the WSN energy consumption per round and reduces the WSN lifetime and the stability period.

A. Ahmed et al., in [16] proposed an energy awareness routing protocol that uses distribution based trust model for detecting and isolating the nodes which have misbehavior and faults, the results came inversely with low packet delivery ratio. Moreover, a multi-facet routing strategy helps to balance out energy consumption among trusted nodes while routing data using shorter paths.

Amairullah Khan et al., [17] proposed a metric based routing protocol with efficient energy to elaborate systems lifetime by selecting a proper route with the consideration of reactively the status of an intermediate node. Which computes the route finding metric based on the current energy condition of an intermediate node. The results of the simulation, it concludes that the proposed routing protocol is well suited for the various applications of WSNs. Moreover, it elaborates the lifetime of the system as well as accumulates the energy of the node.

Luo et al. [18] have addressed these problems by presenting a virtual routing protocol that not only balances the energy dissipation of the nodes but also tries to reduce data latency and loss. Their scheme is based on discrete mobility of the sink where the sink pause time is greater than its mobility time in the sensor field. One potential drawback of their scheme is that whenever the sink moves, routing paths need to be updated. Moreover, when the sink pauses at any point along the boundary, then the scenario becomes equivalent to that of a static sink case that leads to increased data loss in the vicinity of the sink.

Kim et al., in [19] propose a new energy-efficient routing protocol for Wireless Body Area Networks where the nodes are static. They use a routing approach by using the intersection of the nodes and find a path to the sink without flooding. Three different stages are used in the proposed scheme where in the first stage the nodes prepare a route and send the advertisement to the neighbors, in the second stage neighboring nodes decision of whether to reply is done and finally, in the third stage, the information is passed from source to the selected sink node. They claim that the proposed protocol shows better results. But additional hardware requirement of GPS is needed for the nodes to be aware of their current location and that of the sink. Besides that it is assumed all the nodes are aware of their energy levels.

B. Optimization Routing Algorithm

Ho et al. [20] proposed an ACO (Ant Colony Optimization)-based ladder diffusion algorithm to solve the energy consumption and transmission routing problems in WSNs. The algorithm consists of two phases, namely the ladder diffusion phase and the route-choosing phase. The ladder diffusion creates a ladder table for each sensor node, and the route-choosing phase integrates ACO to select and construct the route from a sensor node to the sink node. The proposed algorithm greatly reduces the energy consumption compared to the previous work by properly assigning the transmission route using the ACO. However, the algorithm has a main flaw that it does not consider the sensor nodes' residual energy when choosing the relay node. So the algorithm is easy to face in the "Hot Spot" and "Energy Pole" problems.

Cheng et al.,[21] proposed an ant colony variant Energy Aware Ant Colony Algorithm (EAACA) that considers shortest distance neighbor and energy consumption in a balanced manner. Nodes with average lesser energy consumption are selected for routing in the shortest path. Theoretical analysis and simulation results showed that the traditional Ant Colony Algorithm (ACA)for the routing of the wireless sensor network, EAACA routing protocol balances the energy consumption of nodes in the network and extends the network lifetime

X.Liu proposed [22] Optimal Distance-based Transmission Strategy (ODTS) to prolong the network lifetime. ODTS is an optimization technique based on an ant colony that depends on balancing factors of energy and distance aware neighbor selection methods. The novelty of this strategy is threefold. Firstly, by introducing two notions, "most energy-efficient distance" and "most energy-balanced distance", a local optimal-distance achievement mechanism is presented for not only high energy efficiency but also good energy balancing in WSNs; Secondly, by working out a network lifetime evaluation method, a global optimal-distance acquirement scheme is developed to achieve energy depletion minimization for sensor nodes with maximal energy consumption throughout the network.

Camilo et al [23] proposed Ant Colony Optimization based Energy Efficient Ant Based Routing (EEABR)algorithm to improve the energy efficiency of the network. EEABR relies on ant updates for neighbor selection and packet transmission. The ants produce an optimal path for transmission with distance and energy awareness.

Sonia et al., [24], Bat algorithm is used to find the position of the sensor nodes. The goal of localization is to find the geographical coordinates of the sensor node with the help of anchor nodes. In many applications node location is inherently one of the system parameters. Node localization is required to report the time of events to happen, where to report the events, assist group querying of sensors, routing and to answer questions on the network coverage.

Regina et al.,[25] suggested Enhanced optimized energy-efficient routing protocol (E-OEERP) is proposed to prevent the formation of residual nodes. This is achieved by using particle swarm optimization (PSO) and gravitational search algorithm (GSA). During cluster formation, some of the nodes are not a member of any cluster. Such nodes are called residual nodes or individual nodes that require high energy for data transmission or it may send many control packets to find the optimal routing path. In E-OEERP, PSO is responsible for cluster formation and cluster head election. GSA is responsible for finding the next best hop by considering the parameters like the position of the node, velocity and force between the cluster heads.

Caputo et al., [26] address the problem of network lifetime. They proposed a new hybrid technique based on evolutionary algorithms to optimize the issues in WSN. In this paper genetic algorithm and particle swarm optimization is combined and produces a new hybrid technique called Genetical swarm optimization (GSO) technique to maximize the network lifetime. GSO is a hybrid evolutionary algorithm which combines the properties of GA and PSO to overcome the premature convergence.

C. Minimal Hop Routing Algorithms

Chiang et al. [27] established routing tables for sensor nodes using a technique similar to the classical flooding method. In each node's routing table, it includes its neighbor nodes. They are marked as parent nodes, sibling nodes or child nodes respectively by recording their hop count values, together with their ID numbers, energy levels and time slots. A node's parent nodes are whose hop counts are one less than this node itself, sibling nodes are who have the same hop counts with this node itself, and the child nodes are whose hop counts are one more than this node itself. Based on the routing table, in accordance with the priority of the parent nodes and the sibling nodes, each sensor node can determine the best next-hop node which has the highest energy level. The proposed data routing protocol reduces some redundant data transmission by providing a next-hop node selection approach.

DalongXueet al.,[28] proposed an improved Distance-vector hop (DV-Hop) algorithm based on hop thinning and distance correction whereas it is based on minimum hop which is corrected by introducing received signal strength indication (RSSI) ranging technology, and the average hop distance is corrected by the weighted average value of hop distance error and estimated distance error. Subsequently, the overall improvement in the location performance of the Hop-DV location algorithm is realized, and the location error is reduced. Under the Matlab simulation environment, the simulation experiment on the improved algorithm is carried out. The experimental results showed that the improved algorithm reduces the location error and has higher location accuracy.

OnurYilmazet al.,[29] proposed a novel distributed shortest hop multipath algorithm for WSNs in order to generate energy-efficient paths for data dissemination or routing. The proposed algorithm generates shortest hop braided multipath to be used for fault-tolerance or load-balancing. It guarantees the BFS tree and generates near-optimal paths in message complexity and O(D 2) time complexity regarding the communication costs towards the sink after the termination of algorithm.

Jianhua Huang et al., [30] suggested improved multi-hop routing protocol (IMHRP) for homogeneous networks. It is based on the distances to the BS; the CH nodes are divided into internal CH nodes and external CH nodes. The set-up phase of the protocol is based on the LEACH protocol and the minimum distance between CH nodes is limited to a special constant distance, so a more uniform distribution of CH nodes is achieved. In the steady-state phase, the routes of different CH nodes are created on the basis of the distances between the CH nodes. The energy efficiency of communication can be maximized.

Hana Rhim et al., [31] proposed a multi-hop graph-based approach for an energy-efficient routing (MH-GEER) protocol in wireless sensor networks that aims to distribute energy consumption between clusters at a balanced rate and thus extend networks' lifespan. MH-GEER deals with node clustering and inter-cluster multi-hop routing selection. The clustering phase is built upon the centralized formation of clusters and the distributed selection of cluster heads similar to that of low-energy adaptive clustering hierarchy (LEACH). It improves the network's lifetime and stability compared with single-hop conventional LEACH protocol.

III. COMPARATIVE ANALYSIS OF ROUTING ALGORITHMS

Table-1 Comparison of energy based routing algorithm

Author	Technique	Energy Consumption	End to end Delay	Throughput
Ding et al.,	A tree based aggregation algorithm	Low	Moderate	High
Kumar et al.,	Enhanced threshold sensitive stable election protocol	Very low	High	Moderate
A. Ahmed et al.,	Energy awareness routing protocol	Low	Very high	High
Luo et al.	Energy dissipation routing protocol	Moderate	Low	Very low
Kim et al.,	energy efficient routing protocol	Low	Moderate	High

Table-2 Comparison of optimization routing algorithm

Author	Technique	Energy Consumption	Network Lifetime	Packet Delivery Ratio
Ho et al..,	ACO-based ladder diffusion algorithm	Moderate	High	Very high
Cheng et al.,	Ant-colony variant EAACA	Low	Moderate	Moderate
X.Liu et al.,	Optimal Distance based Transmission Strategy (ODTS)	Very low	Low	Low
Sonia et al.,	Bat algorithm	High	Very high	Very low
Regina et al.,	Enhanced optimized energy efficient routing protocol	High	Low	High

Table-3 Comparison of minimal hop routing algorithms

Author	Technique	Average Hop Count	Energy Consumption	Packet Delivery Ratio
Chiang et al.	Classical flooding method	Low	High	Moderate
DalongXue et al.,	Distance vector hop (DV-Hop) algorithm	Moderate	Very high	Low

OnurYilmaz et al.,	Novel distributed shortest hop multipath algorithm	Very low	Very high	High
Jianhua Huang et al.,	Improved multi-hop routing protocol (IMHRP)	Low	Moderate	High
Hana Rhim et al.,	Multi-hop graph-based approach for an energy-efficient routing (MH-GEER) protocol	Low	High	Very high

IV.PROBLEM IDENTIFICATION

To summarize, the energy consumption of the nodes in the network can be minimized in two ways; by minimizing the total amount of energy consumed during the idle time with the hop-alert method and minimizing the number of communications per node with a load fair routing mechanism.

- There is no mathematical tool, in which maximum lifetime routing problem and effect of hop alert on network lifetime investigated so far.
- Existing techniques did not determine the optimum total amount of packets to be routed on each link of the network for maximum network lifetime by considering idle mode energy consumption.
- A clear tradeoff exists for every sensor nodes in the field, on one hand, it should be activated to provide more sensing abilities; on the other hand, it should be kept in an inactive for the longest possible time to save energy.

IV.CONCLUSION

Wireless sensor networks are increasingly being used in military, environmental, health and commercial applications. The problem of relaying data from remote sensor nodes to a central base station is of paramount importance in such applications. Severe resource constraints in the form of limited computation, hole and energy make the problem of routing interesting and challenging. Sensor networks are inherently different from traditional wired networks as well as wireless ad-hoc networks. However, routing algorithms for sensor networks have borrowed liberally from the existing algorithms for ad-hoc networks. In this paper, we have tried to explore the space of sensor network energy aware routing algorithm. An attempt has been made to summarize many of the proposed routing algorithms. The routing protocols have been classified into distinct categories and their parameters have been discussed.

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