A Survey on Different Routing Protocols in Wireless Sensor Networks

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Abstract - *The paper mainly aims to categorize the routing algorithms and examines the routing-related optimization and security problems. Advancement in wireless sensor network (WSN) has given the availability of low-cost sensor nodes with the competence of sensing various types of physical and ecological conditions, data collection with processing and wireless communication. Various detecting capabilities results in abundance findings in multiple application areas. However, the features of wireless sensor networks require more effective methods for data collecting and processing in terms of security and routing. In WSN, the nodes have restricted transmission range, low energy resources in terms of storage and processing capabilities. Routing protocols for wireless sensor networks are in authority for maintenance of the routes in the network and ensure the reliable multi-hop communication under any circumstances. Subsequently, the literature is analyzed based on the Quality of Service (QoS) and the Routing protocols.*

Key Words: **Wireless Sensor Networks, Sensor nodes, Routing Protocols, Security, QoS**

1. INTRODUCTION

In 21st century, Wireless sensor network (WSN) is considered as the most significant technology [1]. This network consists of a bulk number of less power consuming multi-functional wireless sensor nodes for sensing, communicating and computing capabilities [2]. These sensor nodes communicate over a short distance through wireless medium and accomplishes a major task, for example, military surveillance applications [3]. These battery-powered sensor nodes are expected to operate for longer period of time. But in reality, it is very difficult to change or revive batteries. WSNs are characterized by: Dense deployment, highly unreliable, power consuming with limited computation capability and memory limitations. The traditional routing protocols have many faults when applied to Wireless Sensor Networks, which is mainly due to energy-controlled nature [3]. Consider the flooding technique in which given node broadcasts data and control packets in the network. This process is repeated till it reaches its destination node. Flooding technique is not Energy-Restricted but leads to overlap and implosion problems [4,5]. The above mentioned problems are solved using a technique called Gossiping [6].

1.1 Characteristics and Limitations of Wireless Sensor Networks

On Comparing with MANETS and Cellular Networks, WSNs bears its own characteristics and limitations such as:

- Denser deployment
- Battery-operated
- More energy and computation limited
- Decentralized Structure
- Highly Unreliable
- Data redundant
- Mostly Application specific
- Dynamic topology in nature

1.2 Network Design Objectives

- Low -cost design with low power consumption
- Reliable, Scalable, Dynamically Adaptable
- Quality of Service Support
- More Fault tolerance
- More Secured network

1.3 WSN Design Challenges

From [3,7,8], the major design challenges are as follows:

- Data Collection and processing
- Hardware resources are limited
- Different applications need various topology of network
- Nodes are denser in some area and lesser in other area
- Location of sensor nodes.

2. ROUTING PROTOCOLS AND ITS TYPES

Routing in WSNs varies from traditional routing. It is infrastructure-less, hackable wireless links, node failures [9]. The major routing protocols proposed for WSNs may be categorized as shown in Fig 1.

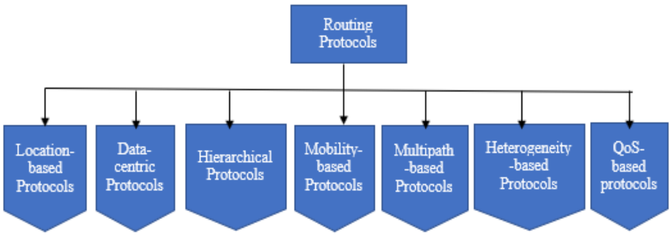

Fig -1 Major Routing Protocols

2.1 Location- Based Protocols

In this type of routing protocol, the sensor nodes are identified using their respective locations. Based on the distance between two nodes, the energy required is calculated. Some of its types are shown in the Table 1

Location- Based Protocols							
MECN	SMECN	GEAR	TBF	BVGF	Span	GAF	GeRaF

Table-1 Location - Based Protocols

2.1.1 Minimum Energy Communication Network (MECN)

MECN [10] is a self-reconfiguring and location-based protocol, which attempts to set up and maintain a minimum energy network with movable sensors. It computes perfect spanning tree rooted at the sink, called **minimum power topology**, which contains the minimum power paths from ach sensor to the sink. It contains two main phases, namely, **enclosure graph construction** and **cost distribution**. For a stationary network, in the 1st phase, MECN constructs a sparse graph, called an **enclosure graph**. In the 2nd phase, non-optimal links of enclosure graph are eliminated and the resultant graph is called **minimum power topology**. Each sensor broadcasts its cost to its neighbor with minimum power that is needed for the sensor to establish a directed path to the sink and it suffers from a worse battery depletion problem when applied to stationary networks. To solve this problem, the enclosure graph and thus the minimum power topology should be dynamic.

2.1.2 Small Minimum-Energy Communication Network (SMECN)

SMECN [11] is an improved version of MECN. This protocol is based on **minimum energy property**. With this protocol, the sensors find its immediate neighbors by broadcasting a neighbor discovery message using some preliminary power and then, a sensor checks whether the imaginary set of immediate neighbors is a subset of the sensors that will respond to that neighbor- discovery message. In this case, the sensor will utilize its corresponding power p to communicate with its immediate neighbors. Or else, it will increment p and rebroadcasts its neighbor discovery message.

2.1.3 Trajectory-Based Forwarding (TBF)

TBF [12] is a location-based routing protocol that needs dense network system. Example, a GPS. In GPS, sensors can position themselves and estimate the distance to their neighbors. Route maintenance in TBF is not disturbed by-means of sensor mobility. The implementation of multipath routing is used in order to increase the reliability and capacity of the network. The interesting application of TBF is securing the perimeter of the network.

2.1.4 Bounded Voronoi Greedy Forwarding [BVGF]

In BVGF [13], a network is designed by *Voronoi* diagram with sites indicating the locations of sensors. In greedy geographic routing, a sensor will always forward a packet to the neighbor that has the shortest distance to the destination. The BVGF protocol chooses the neighbor with shortest Euclidean distance to the destination among all other eligible neighbors. Actually, each sensor has only one next hop to forward its data to the sink. So, any data broadcasting path between a source sensor and the sink will have the same chain of the next hops, which will suffer from battery power exhaustion.

2.1.5 Geographic Adaptive Fidelity (GAF)

GAF [14,15,16] is an energy-aware location-based routing protocol proposed exclusively for MANETs. But due to its low energy consumption, it is used to support WSNs. Geographic Adaptive Fidelity protocol is based on the turning off mechanism of unnecessary sensors. In this protocol, the sensor field is categorized into grid squares. Each sensor uses its location information with the help of GPS. GAF is used to track the sensors that are comparable from the perspective of packet forwarding.

2.1.6 Geographic and Energy-Aware Routing (GEAR)

GEAR [17] is also an energy-efficient location-based routing protocol designed especially for routing queries to target regions. GEAR is an hardware equipped. The sensors know their residual energy and their locations well in advance. It uses a repetitive geographic forwarding algorithm to broadcast the packet within the target region.

2.2 Mobility-based Protocols

The mobile characteristics poses new challenges to routing protocols.

Mobility- Based Protocols			
Joint Mobility and Routing	Data MULES Based Protocol	Dynamic Proxy Tree-Based Data Dissemination	Scalable Energy-Efficient Asynchronous Dissemination (SEAD)

Table- 2 Mobility- Based Protocols

2.2.1 Joint Mobility and Routing Protocol

In [18], Energy sink-hole problem is solved with the help of a mobile sink for gathering sensed data from source sensors. Using shortest path recovery, average load of data routing is reduced when the trajectories of the sink mobility match to concentric circles. One more category is to move the sink in annuli from Trajectory. Hence, such movement can be regarded as a weighted average over the set of concentric circle movements.

2.2.2 Data MULES Based Protocol

In [19], this three-tier architecture protocol guarantees cost effective node connectivity in a sparse network. It is based on mobile entities called mobile ubiquitous LAN extensions (MULE). The architecture has three main layers: top layer, middle layer and bottom layer. The bottom layer is used for sensing an environment. The top layer is responsible for analyzingthe sensed data. The middle layer has mobile entities (MULEs) that traverse through the sensor field and collect sensed data from the source sensors. This architecture design is Energy-Efficient, fault tolerant, no overhead problems and low cost for deployment. But MULE architecture gives high data success rate in case of dense network not in sparse network.

2.2.3 Scalable Energy-Efficient Asynchronous Dissemination (SEAD)

SEAD [20] consists of Dissemination tree (d-tree) construction, data dissemination, and maintaining linkages to mobile sinks. It is a self-unifying protocol that minimizes the forwarding delay to a mobile sink. Source sensor reports its sensed data to other mobile sinks. Sensors know their geographic locations. Each source sensor constructs its data dissemination tree rooted at itself and all the dissemination trees for all the source sensors are constructed separately. SEAD can act as an overlay network on top of a location-aware routing protocol.

2.2.4 Dynamic Proxy Tree-Based Data Dissemination

This protocol [21] consists of stationary sensors and several mobile hosts, called **sinks** and proposed for sustaining a tree that connects a source sensor to multiple sinks that are interested in the source. Each source is characterized by a stationary source proxy and each sink is denoted by a stationary sink proxy. This design of proxies reduce the cost of driving data to and querying data from the source and sinks proxies.

2.3 Heterogeneity-based Protocols

This protocol architecture consists of line-powered sensors and the battery-powered sensors. There is no energy-constraint in case of line-powered sensors unlike Battery-powered sensors. So, the battery-powered sensors have to utilize their energy in an efficient manner.

Heterogeneity- Based Protocols		
Information-Driven Sensor Query (IDSQ)	Constrained Anisotropic Diffusion Routing (CADR)	Cluster-Head Relay Routing (CHR)

Table- 3 Heterogeneity- Based Protocols

2.3.1 Constrained Anisotropic Diffusion Routing (CADR)

This protocol is a general form of Directed Diffusion. It activates sensors close to the event and dynamically adjusts the routes. Routing is based on local information/ cost gradient. This protocol is more energy efficient than Directed-diffusion.

2.3.2 Information-Driven Sensor Query (IDSQ)

M. Chu et. al., [22], X. Du et. al., [23] has discussed about the Energy consumption, latency of sensor nodes, heterogenous characteristics of the network. The algorithm of this protocol makes a few subsets of sensor nodes to be active to communicate and others are at idle state which increases tracking accuracy and minimize detection latency. In IDSQ protocol, leader sensor node is in charge for selecting optimal sensors depending on some information utility measure.

2.3.3 Cluster-Head Relay Routing (CHR)

In [24], CHR has L-sensors and H-sensors. Both are static, randomly distributed and well known about their locations. It partitions the heterogeneous network into clusters with L-sensors and H-sensors. L-sensors are in control of sensing and forwarding data packets in a multi-hop fashion. Whereas, H-sensors are responsible for data fusion and forwarding the collected data packets towards the sink in a multi-hop fashion.

2.4 Hierarchical Protocols

Hierarchical Clustering is an energy-efficient communication protocol which is used by the sensors to report their sensed data to the sink.

Its Types:

Hierarchical Protocols				
Low-energy adaptive clustering hierarchy (LEACH)	Power-Efficient Gathering in Sensor Information Systems (PEGASIS)	Hybrid Energy-Efficient Distributed Clustering (HEED)	Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)	Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

Table- 4 Hierarchical Protocols

2.4.1 Low-energy adaptive clustering hierarchy (LEACH)

In [25,26], LEACH protocol depends on an aggregation technique to communicate with sensors. The cluster head (CH) will directly communicate with Base station (BS) while broadcasting the data. The CH position is randomly selected. It has two phases- a setup phase and a steady-state phase. LEACH is does not require any global knowledge of network. It minimizes the energyconsumption by

- Reducing the communication cost between sensors and cluster heads
- Switching-off the non-head nodes as much as possible [27].

2.4.2 Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [28]

- An extension of the LEACH protocol
- The data is collected and traverses from node to node, aggregated and sent to the base station.
- The chain construction is performed in a greedy way.
- It avoids cluster formation and uses only one node in a chain to transmit to the BS.

2.4.3 Hybrid Energy-Efficient Distributed Clustering (HEED)

Manjeshwar et. al., [29] HEED protocol was designed to attain four prime goals namely

(i) Network lifetime extension,
(ii) Limiting the clustering process,
(iii) Reducing control overhead,
(iv) Well-distributed cluster Heads and dense clusters.

2.4.4 Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

W. Lou et.al., [30], has described about TEEN protocol. The nodes report their sensed data to their current cluster head until it reaches sink. It is based on Hierarchical grouping. It finds applications where an user can have a trade-off among data accuracy and energy efficiency. It is suitable for time critical sensing applications but it cannot generate periodic reports.

2.4.5 Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

APTEEN [31] is an hybrid combination of both LEACH and TEEN. It is also known as extended version of TEEN architecture. It supports three query types:

- Historical query
- One-time query
- Persistent query

2.5 QoS-based Protocols

Apart from Energy consumption constraints, Quality of Service (QoS) is the most important factor to be considered in Wireless Sensor Networks. Its parameters are Jitter, Delay, Throughput and fault tolerance.

Its Types:

QoS- Based Protocols		
SPEED	Sequential Assignment Routing (SAR)	Energy-Aware QoS Routing Protocol

Table-5 QoS- Based Protocols

2.5.1 Sequential Assignment Routing (SAR)

In [32], it is said that SAR is the first QoS based routing protocol. It follows multi-path approach. Local node failure is automatically revived but periodic re-computation of paths will be needed in case of frequent node failures. Its Routing decision [33] is based on three main factors:

- Available energy resources
- QoS on every path
- Level of priority for every packet

2.5.2 SPEED

In [32], SPEED is an Energy-aware protocol that needs to collect information regarding its neighbors and uses topographical forwarding to find the paths. It provides soft real- time end-to-end communication with congestion avoidance. Beacon exchange mechanism gathers information about the nodes along with their location. Delay estimation is computed with the elapsed time when an ACK is received from a neighbor as a response.

2.5.3 Energy-Aware QoS Routing Protocol

In [34], this protocol is both Energy-Aware and provide QoS routing in wireless sensor networks generating real-time traffic by sensors. It finds a flexible less cost-energy efficient path during the connection setup. It is based on class-based queuing model to determine real-time and non-real-time traffic.

2.6 Multipath-based Protocols

All routing algorithms have their own way of finding routes from source to destination. It may be either single-path routing or multi-path routing. In single-path routing, every source sensor computes the shortest path to its destination (sink), whereas in multipath routing every source sensor finds the first *k* shortest paths to its destination (Sink) and splits its load evenly among those paths.

Its types:

Multipath - Based Protocols		
Braided Paths	N-to-1 Multipath Discovery	Disjoint Paths

Table-6 Multipath - Based Protocols

2.6.1 Disjoint Paths

S. Lindsey et. al., [35] has discussed about Disjoint routing protocol as a multipath protocol which finds a small number of alternate paths (paths that are independent of the primary path) along with the primary path. In case of primary node path failure, alternative paths will be used. This type of routing is more resilient to sensor node failures.

2.6.2 Braided Paths

S. Lindsey et. al., [35] has furnished that braided multi-path routing is a partially disjoint routing. The primary path is computed along with best alternative paths which are called idealized braided multipaths. The geographical location of the alternate paths is close to the primary path. So, the energy consumption of both the paths are more or less same.

2.6.3 N-to-1 Multipath Discovery

In [23], the route discovery is based on the simple flooding mechanism. It has two phases namely, branch aware flooding (Phase 1) and multipath extension of flooding (Phase 2). It generates multiple node-disjoint paths for each sensor. Multi-hop routing is intended to handle sensor failures to enhance network reliability.

2.7 Data Centric Protocols

In Data-centric protocols, the source sensors send their data to the sink, intermediate sensors can perform aggregation on the data originating from source sensors and forward the aggregated data toward the sink. This transmission process does not more energy consumption

Its types:

Data- Centric Protocols						
Directed Diffusion	Sensor Protocols for Information via Negotiation (SPIN)	Gradient-Based Routing	Energy-Aware Data-Centric Routing (EAD)	COUGAR	ACQUIRE	Rumor Routing

Table- 7 Data- Centric Protocols

2.7.1 Directed Diffusion

In [36], C. Intanagonwiwat et. al., has discussed Directed diffusion. It is used for sensor query dissemination and processing. It offers energy efficiency, scalability and robustness.

2.7.2 Sensor Protocols for Information via Negotiation (SPIN)

In [38], SPIN protocol was able to calculate the energy need for a successful transmission. So, it is energy-aware and Resource-aware. It overcomes implosion and overlap problems. Thus, they can make informed decisions for efficient use of their own resources. This has two key mechanisms: negotiation and resource adaptation.

2.7.3 Gradient Based Routing

This protocol is an another variant of Directed Diffusion. It consists of a distributed sensor network with limited energy source, sensor devices, short-range radio and on-board processing capability. Each can calculate the height of the node which is the minimum number of hops to reach the BS. The difference between the node's height and its neighbor is called the Gradient of that link. A packet is transmitted on a link with the largest gradient.

2.7.4 Cougar

In [39], This routing protocol views the entire network as a huge distributed database. Network layer process from declarative queries to abstract queries. It introduces a new query layer. The leader node performs the data aggregation and forwards it to sink.

2.7.5 Rumor Routing

D. Braginsky et.al., [40] has discussed about rumor routing which is an efficient protocol and a rational compromise among query flooding and event flooding schemes. It is based on Agent concept.

3. CONCLUSIONS AND FUTURE WORK

In this paper, a survey has been made with various of routing protocols and discussed their characteristics along with merits and demerits. The main challenges in design of routing protocols for WSNs is the security, energy efficiency and Quality of Service (QoS). The main objective is to extend the network-lifetime. Future research will be focused on 3D Sensing Applications.

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