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WSN-Wireless Sensor Networks: A Review

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***Abstract*—WSN (Wireless sensor network) is a very important area of research and vital partner in contribution in many fields of sciences such as Micro Electro-Mechanical Systems technology, wireless communications and digital electronics. Routing protocols dedicated for WSN have been designed to achieve high performance due to the nature of WSN in terms of the limited source of power supply. This research aims to provide a summary and overview of the routing protocols for WSNs.**

Keywords—WSN; routing protocol

I. INTRODUCTION

WSN is a network where nodes have a certain type of sensors that send information based on conditions and the environment such as humidity and temperature for the purpose of monitoring and controlling. WSN is now an essential part of embedded systems and wireless communications due to its nature and properties of low cost, low power, multi-functional, small size, and communicate over short distances.

WSNs have many practical applications such as military, environmental monitoring, and health.

Nodes' sensors in the WSN sense data from the surrounding environment, then nodes can process data and send it to other neighboring nodes based on multiple hops forwarding (from node to node). [1]

Data sensed by the sensors are conveyed to other nodes that are high in power called sink node(s), which are responsible for complex processing. [2] Different routing protocols are designed for WSN based on the architecture and the applications of WSN. [3] These protocols are dedicated for the nature and requirements of WSN (limited memory, small size, low power consumption, fault tolerance, and low latency). [4]

This research aims to provide literature review about WSN in general and focusing on their routing protocols. The rest of article is designed as follows: section II presents the challenges that face WSN, section III presents different classifications of routing protocols for WSN, and section IV presents a summary of the manuscript.

II. WSN CHALLENGES

WSN faces several challenges in comparison to the traditional networks; nodes are mobile, battery is the only source of power, and most data traffic is in burst. [5] The followings are some of these issues and challenges:

A. Energy and Delay:

Increasing number of nodes and so number of hops can decrease the consumed power because the transmission range is decreased as a whole for all nodes, but packet delay is increased. [6]

B. Bandwidth Limitation:

In order to deal with voice, high quality real time traffic should be used, one way to achieve that is to use number of independent routes to split the traffic and reduce energy consumption. [7]

C. Topology:

WSN consists of three types of nodes; sensor, sink, and monitor nodes, most of the network architectures assume that sensor nodes are stationary, but the sink nodes could be dynamic, sending message to mobile sink nodes can affect rout stability and cause route failure. [8]

Another effect of topology is the deployment of sensor nodes, which could be either deterministic or self-organizing; in deterministic ones, the location of nodes is known and the data is forwarded through a predefined route. While the other type imposes scattering the sensors randomly and there is a need to find the best route to sink node, which consumes more energy. [9]

D. Memory Limitation:

Most of energy is consumed in transmission, and so it is preferable to keep radio devices (transmitters) off most of the time; this can be achieved by receiving data most of the time, then processing that data, and finally turning on the transmitter to send the processed data. But to receive data most of time, significant size of memory (buffer) is needed, while the buffer size of nodes is limited. [10]

E. Transmission of Data:

Different models are used to deliver data to sink node: continuous delivery model; each sensor sends data periodically, event-driven model; the transmission of data is triggered when an event

occurs, query-driven model; the transmission of data is triggered when a query is generated by the sink node, and finally the hybrid model using a combination of the previous mentioned models. The routing and MAC protocols are the most affected by the data delivery model. [11]

F. Nodes Rules:

Each node in WSN has its own tasks. In homogeneous network, all sensor nodes have the same tasks and so the same capabilities (computation, communication and power), but some nodes may have additional tasks based on their capabilities which consumes more energy for example the cluster head node that acts as server. [12]

G. Data Aggregation:

Similar packets from multiple nodes can be aggregated and so the number of data transmission would be reduced. Aggregation of data can be performed by functions such as suppression (eliminating duplicates), min, max and average. [13]

III. WSN Routing Protocols

Routing protocols for WSN are designed based on the real application and the architecture of network; they can be classified (based on the route discovery) into reactive, proactive and hybrid protocols [14]; in proactive ones, sensors are sending data regularly, and so each path to each sink node is known in advance by storing routing information in routing tables in each node, once a node needs a path to a sink node, it can find it in its routing table. While reactive routing protocols do not have routing tables; once a node needs to find a route to sink node, it sends a request searching for the best route to that sink node. And hybrid routing protocols which benefit from the advantages of the previous two types.

Another classification based on the architecture of network is flat, hierarchical and location based protocols [15], but due to the awareness of power consumption of nodes, additional category of routing protocol is considered which is the energy aware routing protocols, see figure 1.

A. Flat Routing Protocols:

Gossiping [16] is an example of flat routing protocol; each neighbor node, that receive message, forwards it to randomly selected neighbor nodes, and so on till the message reaches the destination. Flooding [17] is another example of flat routing protocols; each node sends the message to its neighbor nodes, and so on till the message reaches its destination.

B. Hierarchical Routing Protocols:

Hierarchical routing protocols divide the network into clusters and each node belongs to a cluster which is controlled by a cluster head. An example of this type of routing protocols is PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [18]; it eliminates the overhead of dynamic cluster formation, limits the number of transmitted and received messages and uses only one transmission to the sink per round. LEACH (Low Energy Adaptive Clustering Hierarchy) [19] constructs clusters of the sensor nodes depending on the RSS (Received Signal Strength) and uses local cluster heads as routers to route data to the base station.

C. Location Based Routing Protocols

Location based protocols benefit from the location of nodes to route the message to its destination. GEAR (Geographical and Energy Aware Routing) [20] is an example of location based routing protocols that uses the location and energy levels of nodes in order to forward the message.

D. QoS Routing Protocols:

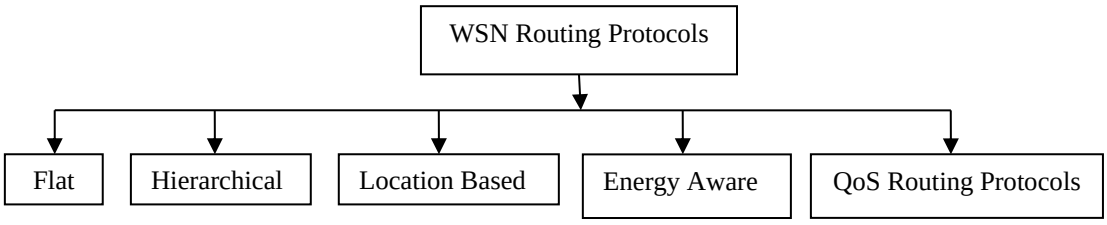

Fig. 1. Classification of WSN Routing Protocols

Additional classification is considered based on the QoS (Quality of Service). QoS aims to find route of minimum cost in terms of energy, routing overhead, and processing. The followings are examples of such

Table 1. Comparison between WSN routing protocols

Routing Protocol	Data Aggregation	Energy consumption	Mobility	Routing approach	Transmission direction	Mulitpath	Location Aware	QoS
Gossiping	No	High	No	On demand	Sensor to sink only	No	No	No
Flooding	No	High	No	On demand	Sensor to sink only	No	No	No
PEGASIS	No	Moderate	Fixed to BS	On demand	Sensor to sink only	No	No	No
LEACH	Yes	Moderate	Fixed to BS	On demand	Sensor to sink only	No	No	No
GEAR	No	High	Limited	Table driven	Bi-directional	No	Global	No
SPEED	No	Low	Limited	On demand	Sensor to sink only	No	Local	Yes
SAR	Yes	Moderate	Limited	Table driven	Sensor to sink only	No	Global	Yes

type of protocols:

SPEED [21] that guarantees a constant delivery speed throughout the network, it uses geographical forwarding to find each path; each node needs geographical information about its neighbors to estimate the end-to-end delay.

SAR (Sequential Assignment Routing) [22] uses routing tables that are created by trees which are rooted to one hop neighbor.

E. Energy Aware Routing Protocols

Pure Energy Aware Routing Protocols that are designed for WSN in order to minimize the power consumption; EMP (Energy-Efficient On-Demand Multicast Routing Protocol) [23] prolongs the network lifetime by introducing a strategy of energy critical avoidance in the process of on-demand construction of multicast routing trees. Nodes of low level of energy are discouraged from involving a multicasting task.

GFTEM (Greedy Forwarding Based on Throughput Energy Aware Multi-Path) routing protocol [24] is based on selection of next hop node that has the highest throughput and closer to destination node.

LEACH-SCH (Topology Based Scheme and Reliable Routing Scheme) [25] is a multi clustering type of routing protocol for some definite wireless sensor network.

[26] proposes an optimized routing protocol for wireless sensor nodes. It constructs an efficient routing spanning tree that minimizes the energy consumption among all nodes in the network and fit for WSN with reduced energy for achieving a longer lifetime. The main idea of this algorithm comes from the MST (Minimum Spanning Tree) graph theory.

And many others such as CHSM-MBC (Cluster Head Selection with multi-hop Balanced Clustering) [27], LCUCR (low-energy consumption unequal clustering) [28].

1) Energy Aware - Directed Diffusion

Energy aware can be sub divided into Directed Diffusion, which aims to save energy by diffusing data through sensor nodes by means of a naming scheme for the data; and so we can get rid of unnecessary operations of network layer routing and save energy [5].

GBR (Gradient-Based Routing) [29] is an example of directed diffusion. It keeps the number of hops when the interest is diffused through the network; and so, each node can discover the minimum number of hops to the sink node.

CADR (Constrained Anisotropic Diffusion Routing) [30]; each node evaluates an information objective and routes data based on the local information gradient and end-user requirements. The information utility measure is modeled using standard estimation theory.

IDSQ (Information-Driven Sensor Querying) [30]; the querying node can determine which node can provide the most useful information while balancing

the energy cost. IDSQ provides a way of selecting the optimal order of sensors for maximum incremental information gain.

2) Energy Aware – Hierarchical Routing Protocols

Other routing protocols that are considered as hierarchical and energy aware are:

TEEN (Threshold sensitive Energy Efficient sensor Network) that [31] that is responsive to sudden changes in the sensed attributes such as temperature; where responsiveness is important for time-critical applications.

APTEEN (Adaptive Threshold sensitive Energy Efficient sensor Network) [32] is an extension to TEEN and aims at both capturing periodic data collections and reacting to time-critical events.

Another classification that merges between location based routing and energy aware:

MECN (Minimum Energy Communication Network) [33] sets up and maintains a minimum energy network for wireless networks by utilizing low power GPS.

Table 1 presents comparisons between the previous routing protocols of WSN.

F. Secure Routing Protocols for WSN:

In the recent years, focus has been given to support a secure, resilient and reliable environment with multi-path routing, because WSN has many applications such as area monitoring, environment monitoring, disaster management, and security surveillance. Several routing protocols have been developed for that purpose such as:

HHCS (Hybrid hierarchical cluster based secure) routing protocol [34], which is a hybrid secure routing protocol that offers a high level scalability, security, cluster formation and cluster head selection, so that the network life time can be increased gradually. TDP (Trust-Distrust Protocol) [35] has four stages; initial stage is topology management, where an improved k-means algorithm is applied. Then the second stage of fitness evaluation of every node in the network. The third stage where a grade point is allotted to every node which is based on the fitness value. And the last stage; the secure path for the routing is determined based on grade point.

E-STAR (Establishing Stable and Reliable) [36] combines payment and trust systems with a trust-based and energy-aware routing protocol in heterogeneous multi-hop wireless networks.

And others such as [37], [38], and [39]

IV. Conclusion

WSN has witnessed a huge interest and a great development due to its real time applications in several fields. WSN faces several issues and challenges that should be considered when designing routing protocols. And so different classifications of routing protocols for WSN have been observed- flat, hierarchical, topology based, energy aware, and secure routing protocols. This research focuses on those categories giving several examples and summarizes them in table indicating their characteristics.

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