An overview of Routing Protocols for Mobile Wireless Sensor Networks

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Abstract- The sensor nodes perform many tasks, including event sensing, data processing, and data communication. The main aim of hierarchical-based routing in MWSNs is saving the residual energy of each sensor node, extending the network lifetime, and ensuring the connectivity among the sensor nodes. Here, we present a detailed taxonomy and classification of the hierarchical-based routing protocols based on different approaches.

Keywords—Hierarchical, MWSN,Lifetime

I. Introduction

Routing protocols for mobile wireless sensor network are complex. Movement can be applied to the sensor nodes and to the sink node in the network. These protocols are divided into hierarchical-based, flat-based, and location-based routing protocols. The hierarchical-based routing protocols exhibits better performance This review paper will act as a guideline for Selection of an appropriate hierarchical routing protocol for specific applications. This overview divides the hierarchical-based routing protocols into two broad groups, namely, classical-based and optimized-based routing protocols. The sensor nodes perform many tasks, including event sensing, data processing, and data communication. Each node has various parts as shown in Figure 1. The first part is a sensing unit that senses a phenomenon and converts sensing data into a digital form using a sensor and Analog-to-Digital Converter (ADC). Processor unit is the second part that processes all data and controls operations of the other parties. The third part is a transceiver unit that is used to transmit and receive data with a limited transmission range. Power unit is the last part that supplies power to all parties. Moreover, a sensor node might additionally have some specific components, such as the Global Positioning System (GPS), mobilize, and power generator units. The power generator unit is responsible for power generation by applying some specific techniques such as solar cell [7].

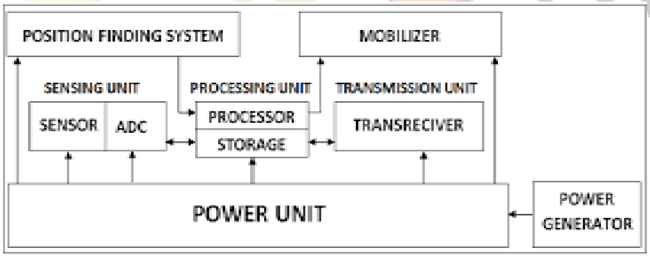

Figure 1-Structure of a node

A sensor node has limited on-board storage, processing, power, and radio capabilities due to its small size. Therefore, MWSNs require effective mechanisms to utilize and resolve the limited resources. Routing is one of these mechanisms that prolongs the lifetime of network by reducing the energy consumption in communication. According to literature [8–16], the hierarchical based routing protocols saves energy extends lifetime and stability of WSNs. The hierarchical-based routing partitions the network into multiple groups. Each group contains one head node and many member nodes (MNs). MN only senses and delivers its sensed data to its related head node, while a head is responsible for collecting and aggregating data of its MNs and then transfers the aggregated data to sink**.**

II. Literature survey

This section summarizes the previous surveys [8–16] of the routing protocols for MWSNs in literature. A survey of routing techniques that are developed for wireless ad-hoc or WSN networks was presented in

[8].This overview helps to identify the routing protocol that can support the mobility of the sensor nodes in static and mobile sensor nodes.
Authors in [9] gave a detailed analysis of the routing protocols on the basis of discovery, data transfer, routing, and motion control. The authors y classified the routing protocols into flat routing and proxy-based routing. In [10], authors analysed LEACH-M, LEACH-ME, CBR-M, ECBR-MWSN, E2R2, 2L-LEACH-M, FTCPMWSN, LFCP-MWSN protocols based on assumptions, CH Selection, location awareness, scalability, and complexity. In [11], the authors classified the flat- and hierarchical based routing protocols of MWSNs depending on their network structure, state of information, energy-efficiency, and mobility. This classification details the advantages and disadvantages of the reviewed routing protocols. This survey provides researcher a foresight for improvement of the existing routing protocols.

A survey of the location-based routing protocols with the sink mobility is presented in [12]. The survey divides the location-based routing approaches into backbone-based and rendezvous-based approaches.This classification considers the network structures and explains advantages and disadvantages of each type. A survey in [13] classified the present routing protocols of MWSNs into delay-sensitive routing protocols and delay tolerant routing protocols on the basis of delay. Authors classified the protocols in centralized and distributed protocols based on the routing decisions,.Based on mobility pattern classified into discretely and continuously based routing protocols .Location-based and topology-based protocols depending on the routing information needed. This survey explained detailed view of each protocol working and mentioned the advantages and disadvantages of each one. Authors in [14] surveyed the distributed routing protocols for mobile sinks. They explained the challenges and the design requirements for a mobile sink based routing protocol. The protocols are compared on parameters like position consideration , sink mobility pattern, virtual structure type, data aggregation, multi sink support, protocol overhead, structure accessibility, and hotspot mitigation.

A survey of more than ten mobile sink-based routing protocols was done in [15]. These protocols are compared on number of mobile sinks, type of protocol, and sink mobility pattern. In [16], a brief overview of the cluster-based protocols for static WSNs, where the sensor nodes are fixed, and for MWSNs, where some or all the sensor nodes are mobile in nature, was presented. The protocols are compared based on the assumptions working environment, advantages, limitations, and working. This survey paper provides a comprehensive review and detailed classification of the existing hierarchical-based routing protocols that were developed in the last ten years for MWSNs. We have reviewed protocols on routing approach, control manner, mobile element, mobility pattern, network architecture, clustering attributes, protocol operation, path establishment, communication paradigm, energy model, protocol objectives, and applications**.**

III. Classification of Hierarchical-Based Routing Protocols

The goal of hierarchical-based routing in MWSNs is saving the residual energy of each sensor node, network lifetime improvement and goodbconnectivity among the sensor nodes. Here, we present a detailed classification of the hierarchical-based routing protocols based on different approaches. These are routing approach, control manner, mobile element, mobility pattern, network architecture, clustering attributes, protocol operation, path establishment, communication paradigm, energy model, protocol objectives, and applications as shown in table 1.

3.1. Routing Approach. The challenge of data routing can have two broad methods, namely, classical-based method and optimized-based method.

(a) Classical-Based Routing. In the classical-based routing, head nodes are selected randomly on the basis of timer function,.This distributes the traffic flow in different head nodes. They are suitable for applications of WSNs, and give variable results for scalability; load balancing, connectivity, coverage, and robustness.

(b) Optimized-Based Routing. Routing in WSNs is considers various parameters .The various classical protocols exhibit moderate fault tolerance, energy-efficiency, connectivity, robustness, and scalability. Researchers have developed improved routing protocols based on optimization algorithms such Genetic Algorithm (GA), and Artificial Bee Colony (ABC), which provide optimal solutions to the various problems. Thus in the optimized-based routing, the head nodes are determined based on various parameters to achieve the requirements of QoS.

3.2. Control Manner. On the basis of control manner, routing approaches of MWSNs can be centralized, distributed, or hybrid approaches.

(a) Centralized Approaches. In the centralized approaches sink/head node requires global information (e.g., energy level, geographical position) of the network/group to control the network/group. This approach organize the network into clusters and assign a head node for each one.

(b) Distributed Approaches. In the distributed approaches, the sensor nodes interact with each other and build routes without e global information of the network. Each sensor node can execute its algorithm and takes the decision of becoming a head node or not. These approaches are used for coordination between the head nodes.

(c) Hybrid Approaches. Hybrid approaches combine the features of centralized and distributed.

3.3. Mobile Element. As the network has number of sensor nodes and sink nodes, the mobility may be applied to the sensor nodes and/or the sink nodes depending on the applications. Therefore, the routing protocols can be classified based on the mobile elements into protocols supporting sink nodes mobility, sensor nodes, and protocols supporting mobility of both sensor nodes and sink nodes.

3.4. Mobility Pattern. One of the main challenges in routing of MWSNs is determining the moving pattern of the mobile element (i.e., sensor nodes or sink node). Depending on the application and network size, there are different mobility patterns.

(a) Predefined Mobility Pattern. In this pattern, the mobile element moves along a predefined path within the sensor field and stops at predefined positions to perform a specific task. This pattern can be used for the mobile sink.

(b) Random Mobility Pattern. The random mobility pattern can be used for the mobile sensor nodes and the mobile sink. In this pattern, the mobile element moves randomly within the sensor field. The standard models are used for simulating the random mobility of a mobile element like Random Waypoint mobility model (RWP) and Reference Point Group Mobility Model (RPGM) [17–19].

(c) Controlled Mobility Pattern. In the controlled mobility, the mobile element is driven on the control of the routing protocol. The movement of the mobile element depend on some factors such as energy level, avoiding energy hole or hotspot problem [20], and connectivity, to achieve better results.

	Strategy	Type
Classification of hierarchical-based routing protocols in MWSNs	Routing approach	Classical-based
		Optimized-based
	Control manner	Centralized
		Distributed
		Hybrid
	Mobile element	Sink
		Sensor node
		Sink and sensor node
	Mobility pattern	Predefined
		Random
		Controlled
	Network architecture	Block-based
		Tree-based
		Chain-based
	Clustering attributes	Inter cluster routing
		Cluster size
		Cluster density
		Cluster properties
		Intra cluster routing
	Sensor capabilities	Homogeneous
		Heterogeneous
	Protocol operation	Negotiation-based
		Multipath-based
		Query-based

		QoS-based
		Coherent-based
	Path establishment	Proactive
		Reactive
		Hybrid
	Communication paradigm	Data centric
		Position centric
	Radio model	First order
		Realistic
	Protocol objectives	Lifetime max.
		Load balancing
		Others
	Applications	Time-driven
		Event-driven
		On-demand
		Tracking-based

Table-1 *Classification of Hierarchical based protocol*

3.5. Network Architecture. The basic basis network architecture plays an important role in the function of the hierarchical routing protocols in MWSNs. Based on the network architecture; the hierarchal routing protocols can be classified into three categories, which are block-based hierarchical routing, tree-based hierarchical routing, and chain-based hierarchical routing.

(a) Block-Based Hierarchical Routing. In the block-based hierarchical routing protocols, the network is divided into groups called clusters. Each one has a head node called Cluster Head (CH) node that is responsible for collecting and aggegration of the data of its MNs and then transfers the aggregated data to the sink node. The main problem with these protocols is how to select CH and the limited range of sensor nodes to connect directly with sink.

(b) Tree-Based Hierarchal Routing. In the tree-based hierarchical routing protocols, a routing tree is formed among all sensor nodes and the sink is the root of this tree. Leaf nodes in the routing tree send data to their parent. Each parent node aggregates the received data and sends it to the next level
parent node towards the sink.

(c) Chain-Based Hierarchical Routing. In the chain-based hierarchical routing protocols, one or more chains are constructed to connect the nodes for data transmission. A head node for each chain called leader is chosen to collect data from the chain members. Data is delivered from the farthest node from sink along the chain until the leader node forwards the final packet toward the sink. However, the data packet reaches the sink via a large number of hops, which increases the packet delay. Moreover, the chain-based routing has less ability of robustness because the failure of one node breaks the chain and data will be dropped.

3.6. Clustering Attributes. The attributes of the clustering process have an important effect on the performance of hierarchical-based routing. The cluster properties and the sensor capabilities are the two main issues in the clustering attributes [21, 22].

3.6.1. Cluster Properties. In the hierarchical-based routing protocols, the characteristics of the formed clusters are used to differentiate between these clusters in terms of saving energy, load balancing, and lifetime.

(a) Cluster Size. From the point of cluster size, the hierarchical-based routing protocols in MWSNs can be grouped into equal and unequal clustering. In the equal clustering protocols, all clusters have the same size, while in the unequal clustering protocols, clusters have different sizes. In general, unequal clustering protocols are used for load balancing and solve the energy hole problem.

(b) Cluster Density. Cluster density is the number of cluster members. Density of cluster affects the energy consumption ofCH. Clustering protocols can be static clustering protocols and dynamic clustering protocols. In the former one, clusters have fixed density, but the cluster density in the second one is variable.

(c) Intracluster Routing. Intracluster routing is the communication between MNs and CH. This communication can be a single-hop or a multihop routing. In the single-hop routing, MNs directly transfer the data to CH. However in the multihop routing, member nodes transmit their data to CH via relay nodes.

(d) Intercluster Routing. Intercluster routing is the communication between the sensor nodes/CHs and sink node. The intercluster communication can be a single-hop or a multihop routing. In the single-hop routing, sensor nodes/CHs send their data directly to sink. While sensor nodes/CHs transmit their data to sink using intermediate nodes in the multihop routing.

(e) Stability. The stability of routing process depends on the cluster density. If the cluster density is fixed, the stability of routing is said to be fixed. Otherwise, the routing stability is considered variable because the cluster density varies
throughout the routing process.

3.6.2. Sensor Capabilities. Based on the resources of the sensor nodes, MWSNs can be classified into homogeneous and heterogeneous networks.

(a) Homogeneous Network. In the homogenous network, all sensor nodes have the same energy, computation, and communication resources. In this type of networks, CHs are assigned according to a random manner or other criteria.

(b) Heterogeneous Network. In the heterogeneous network, sensor nodes have unequal capabilities . Therefore, the role of CHs is specified to sensor nodes that have more capabilities.

3.7. Protocol Operation. Depending on the protocol operation, the hierarchical-based routing protocols are divided into negotiation-based, query-based, multipath-based, coherent based, and QoS-based routing.

(a) Negotiation-Based Routing. In this type of routing, a high level of descriptors is utilized for the negotiation between the sensor nodes which minimize the duplicated information and avoid the redundant data. Generally, this negotiation should be done before real data transmission between the source and the relay node or the sink node.

(b) Query-Based Routing. This type of routing depends upon queries from destination. The source node transmits its data in response to the received query from the destination node.

(c)Multipath-Based Routing. In the multipath routing, multiple paths are constructed between a source and a destination to increase the fault tolerance and enhance the network performance.

(d) Coherent-Based Routing. Different data processing mechanisms are presented to save the processing computations that consume a significant part of the node energy. Coherent and non coherent are the two main data processing approaches that are used to save the consumption energy in data computations. In the non coherent data processing technique, the sensor node processes the data locally and then forwards it to the aggregator. Aggregator is a node, which aggregates the received data from many sensor nodes and forwards the aggregated packets to sink. In the coherent method, a sensor node performs minimum data processing and sends data to the aggregator. After receiving the data, the aggregator is responsible for the major and complex part of processing.

(e) QoS-Based Routing. The used algorithm in this type of routing ensures the QoS parameters of the data. These are reliability, delay, or bandwidth. The task of routing protocol is balancing the dissipated energy while achieving the QoS conditions.

3.8. Path Establishment. The path establishment mechanism is responsible for identifying or discovering routes from a source to the intended receiver. This mechanism can also be used to distinguish between different types of the hierarchical-based routing protocols.

(a) Proactive Routing. This type of routing is also often described as table-driven, because each node selects the best path and forwards its data based on the contents of a routing table. This table contains a list of paths between a node and one or more next-hop neighbors and also cost associated with
each path. In this type of network, nodes periodically switch on their sensors and radios to sense the data and transmit it to the destination via a certain route from the routing table. This routing type is suitable for periodic data monitoring applications like collecting data about temperature change over a particular area.

(b) Reactive Routing. In the reactive routing, the node reacts immediately to sudden changes in the sensing event and does not already have a route established. This type of routing adds delay for discovering the route before transmitting the data. Also, it is well suited for time-critical applications like explosion detection and intrusion detection.

(c) Hybrid Routing. In this routing type, nodes not only react to sudden changes in the sensing event but also send their data at periodic intervals in an efficient method to the destination.

3.9. Communication Paradigm. The communication between the sink and the sensor nodes can be node centric, data centric, or location centric.

(a) Node Centric. In the node-centric protocols, destinations are specified using numerical addresses (or identifiers) of nodes. In this type, sensor node can forward its data to specific destination via its ID.
(b) Data Centric. In the data centric technique, sink forwards queries to a particular area within a sensor field and waits for data of the sensors that are located in the selected region. The source sensors of the selected region send their data to the sink via intermediate nodes. This intermediate sensor nodes aggregate the collected data from multiple sources and forward the aggregated packets to the sink. This process saves the dissipated energy in the redundant data.
(c) Location Centric. In the location-centric routing, the sensor nodes should know their locations in the sensor field. Location information is used to construct best routing, which improves the network performance. Location information is used to construct best routing, which enhances the network performance.

3.10. Radio Model. The major task of the hierarchical-based routing protocols is saving the residual energy of each sensor node and extending the network lifetime. Since the energy consumed by the radio of the sensor node represents the largest portion of the consumed energy [23], the routing protocols can be surveyed according to the model of the sensor radio. The radio of the sensor node is simulated as the first-order model [24] or as the realistic radio model such as CC2420 [25].

3.11. Protocol Objectives. The hierarchical-based routing protocols have been developed to save the dissipated energy and extend the lifetime of MWSNs. Accordingly, the hierarchical based routing protocols of MWSNs can be classified according to the above criteria based on different objectives like data aggregation, load balancing, lifetime maximization, stability period extension, guarantee of connectivity, fault tolerance, avoiding hotspot, and so forth. The routing protocol are developed to achieve one or more objectives at the same time.

3.12. Applications. Since there is not a routing protocol appropriate for all applications, this survey specifies the suitable applications for each hierarchical routing protocol. Applications of MWSNs can broadly be split into event driven, time-driven, on-demand, and tracking-based applications [26]. (a) Event-Driven Applications. Sensor nodes deployed for such type of applications are expected to be inactive most of the time and bursting into activity when an event is detected. Then, the detected event is reported to the sink. This type of application can be found in forest fires, grass fires, volcanic eruptions, and so forth. (b) Time-Driven Applications. In this type of applications, each sensor is expected to constantly produce some amount of data, which has to be conveyed periodically to the sink. The time-driven applications include monitoring the environmental conditions like affecting crops, temperature, humidity, and lighting. (c) On-Demand Applications. In some applications, the sink is not interested in data updates from all the nodes in the network. This is done via sending queries to a set of sensor nodes at different times from different regions. This results in a more energy-efficient use of resources. (d) Tracking-Based Applications. This class is helpful when the source of an event is mobile. The sensor nodes can report the event source's position to the sink, potentially with estimates about speed and direction. The tracking applications combine some of the above three classes. This class can be used in the military application (e.g., tracking an intruder), the environmental applications (e.g., tracking the movements and patterns of insects and birds), and the intelligent applications (e.g., tracking of vehicles).

IV. Conclusion

Recently, many routing protocols are developed for mobile Wireless Sensor Networks. This paper reviews the recently hierarchical-based routing protocols that are developed in the last years for the Mobile Wireless Sensor Networks (MWSNs). In this survey, the hierarchical based routing protocols are grouped into classical-based routing and optimized-based routing. Also, a detailed classification of the reviewed protocols based on different approaches such as control, network architecture, mobile element, mobility pattern, clustering attributes, protocol operation, path establishment, communication paradigm, energy model, protocol objectives, and applications.

V. References

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