Mobile Wireless Sensor Network: Routing Protocols Overview

Maha Al-Sadoon, Ahmed Jedidi, and Hamed Al-Raweshidy

Abstract Wireless sensor Networks (WSNs) became in one of the important technologies in our days in which it is applied in many applications and domains. Further, most of these applications are under the umbrella of the Internet of things (IoT) and that required a particular Quality of Service (QoS). Recently, many vital applications need mobility, which Mobile WSNs (MWSN) subscribes in these needs. However, the low-cost technology of the MWSNs is the first obstacle to improve performance in these applications. The usual methods of routing algorithm cannot be applied in MWSNs. In addition, security has become a primary concern to provide secure communication between wireless nodes, with additional challenges related to the node's computational resources. Particularly, the wireless ad-hoc communication adopted by the sensor nodes communication makes WSNs more susceptible to different types of security threats and attacks. In this paper, we present the specification of MWSN, and based on that we describe the different routing protocols used. Second, we discuss the performance of these protocols and propose a new technique to improve MWSN performance.

Keywords Mobile Wireless sensor network · Routing Algorithm · Genetic Algorithm · LEACH · Cluster Head

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1 Introduction

Wireless Sensor Network (WSN) is presented as a promoting technology in various domains. According to the low-cost technology, WSN became the backbone of Internet of Things (IoT) and many other applications, which the performance of the network presents one of the high priorities and importance criteria. IoT is defined as the connection between the physical environments and the digital one. Recently, IoT involves in various areas industrial, militarily and ecosystem, which it takes place more and more indispensable. In addition, these areas required a high quality of service (QoS), particularly: security, efficiency and energy consumption [1].

One of the major advancements in the WSN field is the introduction of the Mobile Wireless Sensor Network (MWSN) being much more versatile than static WSNs as the deployed sensor nodes have to adapt to the changes in the network's topologies. Examples of applications of MWSNs are military surveillance, habitat monitoring, agriculture applications, healthcare management, industrial monitoring, and environment monitoring [2, 3] some of these applications illustrated in Fig. 1 [4]. However, MWSNs have major design challenges such as the hardware cost, system architecture, memory and battery size, processing speed as shown in Fig. 2.

Mobile sensor nodes consist of a microcontroller, various sensors (i.e. light, temperature, humidity, pressure, mobility, etc.), a radio transceiver powered by a battery [5]. Usually the sensor nodes are deployed on land, underground, under water environments, and can be classified into heterogeneous or homogenous [6].

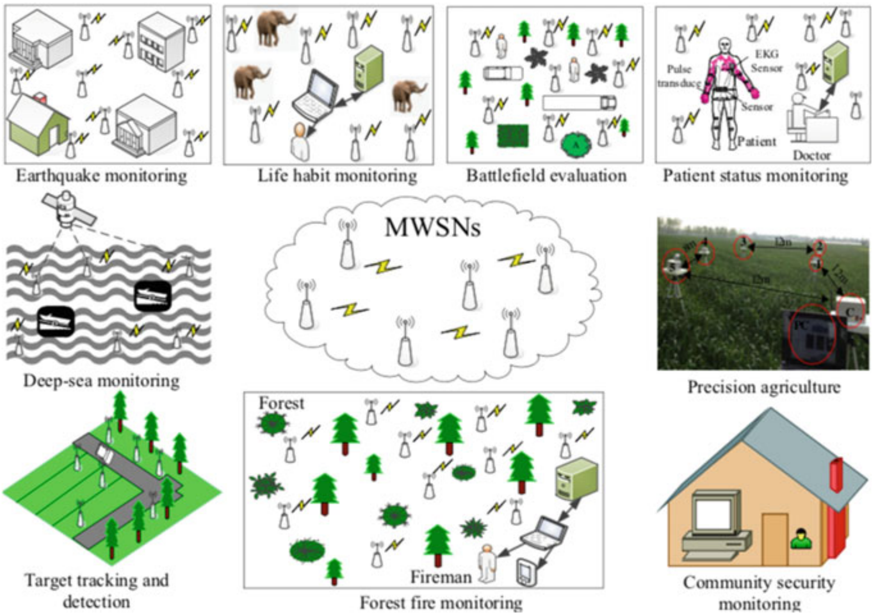

Fig. 1 Some application of MWSN [4]

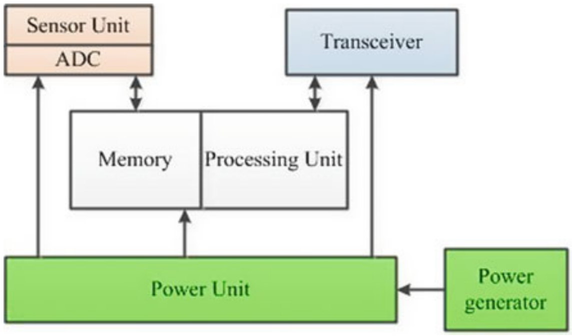

Fig. 2 Inner structure of sensor node

The heterogeneous nodes in MWSNs consists of sensor nodes that have unequal properties, but the homogenous MWSNs consist of identical sensor nodes according to the resources of the sensor nodes such as battery power, memory size, computing power, sensing range, transmission range, and mobility, etc. [7].

The unique characteristic of MWSNs imposes extra challenges on the design of an efficient routing protocol that considers the dynamicity of the network's topology, node's mobility, and other node's related constraints such as energy, computation complexity, resource availability, storage, and bandwidth. Therefore, this article presents the most famous routing protocols used in MWSN, which we discuss, the advantage and disadvantage for each one. Further we propose a new technique based on genetic algorithm to improve the MWSN performance.

The rest of paper is organized as follow. The second section will present the specification of MWSN and the different challenges of this technology. The third section will describe the various routing protocols used in MWSNs and a discussion will be hold in section fourth to compare between these protocols. Finally, we will propose a brief description of our new routing algorithm based on genetic algorithm.

2 MWSN Specification and Challenges

MWSNs introduce mobility in two approaches, either by having static sensor nodes while the sink devices are moving, while in the second approach the sink device is static, and the sensor nodes are mobile [4]. Examples of the first approach include crops on a farm deploying sensors and sending measurements about the humidity and temperature to the farmer's smartphone as he/she walks in the field. The second approach is clarified by static sink that can be used to collect tracking information stored in sensor nodes when the animals are in its range. The two approaches can be combined to have all nodes mobile such as in assistant personnel systems.

2.1 Mobility and Topology in MWSN

The reliable communication, full coverage network connectivity, sensor node mobility, data collection, and network topology management representing the success of large-scale mobile wireless sensor networks [5]. Therefore, designing efficient routing protocols for MWSNs indicates the accuracy of modelling sensor mobility and topology management. The mobility represents the sensor nodes behaviour through their movement pattern, whereas the network topology provides a reliable network and higher QoS in terms of traffic, and end-to-end connectivity [8, 9].

Network topology management is the task responsible for managing the membership of sensor nodes group by managing the new and withdrawn members. Depending on the nature of the MWSN, in order to achieve the best performance and to ensure reliable data gathering, different types of network topologies are deployed. The network topologies can be categorized into several types such as flat or unstructured, tree, clustered, chain, mesh, and hybrid [5–10]. Another proposed classification of network topology also available as follows:

- Distributed topology: In this topology there is no central node to manage the network, hence the network consists of homogenous sensor nodes so all of sensor nodes have an equal role and without prior infrastructure imposed before the network start running.
- Hierarchical topology: The senor nodes in this topology are organized in several levels, and the role of sensor nodes can be different, some nodes will act as cluster head while the others can act as cluster members also some of the sensor nodes might be consider as relay nodes in some cases. WSNs are more manageable and scalable in this hierarchical topology.
- Centralized topology: All the sensor nodes in this topology have the task of sensing the area of interest and collecting the data and then sending it to central node for processing. However, the main problem of this topology when the central node depletes its energy is a single point of failure.

On the other hand, the modelling of node's mobility predicts the future positioning of the sensor nodes. Thus, it brings the opportunity of reducing the number of hopes to the sink nodes, which results in a reduction of the latency. However high mobility scenarios can reduce the successful transmission of data to the sink nodes, therefore, increasing the complexity of the routing protocols [11–13]. Here, different mobility models can be applied to the sensor nodes or sinks depending on the application of the MWSN, by characterizing the mobile sensor movement patterns either in an independent or dependent approach. Mobility models can define the movement of the sensor nodes using both analytical or simulation-based models [14]. The analytical models usually provide simple mathematical models for the change in node's movement. In contrast, the simulation-based models provide more realistic mobility scenarios by introducing more complicated solutions. The mobility can further be classified into (a) trace models: a deterministic mobility pattern of real-life systems; (b) syntactic models: represents the movements towards/ away mobile sensor nodes realistically.

Another classification based on mobility patterns and histories such as directional, random and habitual mobility models. Generally, the various models available in the literature can be classified into four major categories including: random, temporal dependency, spatial, and geographic-restricted models.

2.2 MWSN Challenges

The mobility aspect of wireless sensors in MWSN increases the challenges of designing the MWSN. The following are some of those challenges [15]:

1. Dynamic Network Topology: due to the sensor nodes movement, the network structure is frequently changing. Therefore, the routing has to be adjusted to cope with the new position of sensor nodes. This adjustment can be done, by operating the location look up table, which contains the updated position of each sensor node in MWSN.
2. Localization: identifying the location of each sensor node within the wireless network is mandatory. In static WSN, the localization of all the sensor nodes is done once since the deployment and remains fixed. While in MWSN the sensor nodes are changing their location dynamically. So using some rapid localization techniques, the sensor nodes location has to be updated. This process consumes more energy and time.
3. Power Consumption: the sensor nodes scarce in power i.e. embedded with battery of low power capacity, the life of the wireless network is mainly affected by the energy depletion, which caused by mobility of sensor nodes that requires energy beside localizing sensor nodes also consumes extra power. Also routing these mobile nodes after changing their position also has energy overhead. All these processes leading to additional power consumption in MWSN. The sensor nodes already restricted with embedded battery of low capacity.
4. Network Coverage: One of the major influences in the MWSNs is the coverage area of interest design and application where the sensor coverage measured by the whole area that the network is currently monitoring. The quality of service that the network provides is part of sensor coverage measurements, and it will drop if case of sensor failures or undesirable sensor deployment and consequently will affect the critical application when initial deployment is far from having a full coverage area. Moreover, natural constrains and external harsh environments (e.g., wind, fire) affect the lifetime of whole networking.

Although MWSN is a special type of mobile ad hoc network (MANET) which designed to cope with mobile environments. However, there are varying in the following aspects [16, 17]:

- WSNs are mainly used to sense and collect data while MANETs are designed for distributed computing i.e. no sensing ability.

- The density of SNs in a WSN is relatively high comparing with the density of nodes in a MANET.
- The size of SNs is small, while the size of the wireless ad hoc is quite large with dimensions of laptop.
- SNs primarily employ the broadcast communication paradigm; on the other hand, MANET used a point-to-point communication.
- The data flows from the SNs toward the sink node whereas in MANETs, the flows of data are irregular.
- SNs resources are limited comparing to MANET recourses. SNs memory size is limited to 8-bit to 16-bit while with ad hoc the memory size is in the range of gigabyte to terabyte. Power resources of SNs are small batteries embedded into the sensing device with limited capacity because of their cost and mostly not rechargeable however nodes in ad hoc can be recharged.
- SNs are much more limited in their computation and communication capabilities (3–30 m) than their ad hoc (10–500 m) due to their low cost and prone to failures.
- SNs could be placed in harsh environments by helicopter or chopper plane, but not the case with MANET.

3 Routing Protocols in MWSN

To establish routing paths from the source nodes which response to sense the data to the destination that is a sink node, MWSN routing protocol relies on the geographic data of the sensor nodes deploy in the target area. Many routing protocols have been proposed in the art-of-state that uses position parameter for routing decisions. It is assumed in this type of protocols, sensor nodes have access to location information by using low power GPS module, or it use distributed localization schemes based on the received signal power (RSSI), signals time of arrival, etc. Therefore, in position-based protocols [18, 19], sensor nodes usually identified the position of their neighbour nodes through periodic "Hello" messages, hence, reducing the communication overhead resulting from flooding. However, obtaining the location information of nodes is a costly process due to message transfer overhead and energy consumption especially in case of mobile nodes. Examples of position-based routing protocols are:

- Geographical Energy Aware Routing (GEAR) [20]: This approach uses energy-aware metric in order to select the associated nodes for each cluster. GEAR is aims to balance the energy consumption and extending the network lifetime. The protocol calculates the value of the cost function for reaching an associated node based on node location and residual energy.
- Geographical Adaptive Fidelity (GAF) [21]: this protocol organized the area into geographical grid that comprises of cells, each grid contains multiple cells, with only one active node at a time. GAF purposes to prolong the network lifetime and reduce energy consumption.

- Adaptive Face Routing (AFR) [22]: This an ad hoc routing protocol that is based on the Euclidean planar graphs, AFR will divide the nodes and edges of a plane into regions called faces. This protocol used face routing to traverse the faces in a controlled way, the protocol repeated the same process using eclipse of double size when the face routing fails to deliver the data to the destination.
- Mobility Aware Routing (MAR) [23]: It is a hierarchal position-based routing protocol, in this network the area is organized into geographic grid with cluster heads that serve the area based on the mobility metric. This approach selects cluster heads that have less mobility metric without considering the energy level of the selected node and this represent the main weakness of MAR protocol.
- Geographic Robust Clustering (GRC) [24]: This protocol uses hierarchal-based routing protocol, based on two parameter which are nodes position, and energy levels it will select the cluster heads. To recover the packet loss this protocol, implement inter-cluster communication phase.
- Minimum Energy Communication Network (MECN) [25]: MECN is an energy-efficient routing protocol with objective of reducing the energy exhaustion of the entire network with help of low power GPS. The idea behind MECN protocol is to transmit the data packets through intermediate nodes _rely node instead of direct transmitting data to the sink node since direct communication consumes more energy than transmitting data through multiple hops using several relay nodes.

4 The Proposed Routing Protocol

In this section we propose a new clustering algorithm based on energy efficient incorporate dynamic Genetic Algorithm, is proposed to extend the lifetime of whole network. The idea is suggested to deploying homogenous mobile wireless sensor nodes randomly in the area of interest. This networking area is divided into five balanced cluster divisions, while the number of sensor nodes are not equal due to mobility with a constrain. Each cluster division has one cluster head that is response of collecting and aggregate the data sent by the cluster members associated with each cluster head. The selection of cluster head is based on a novel dynamic genetic algorithm. The fitness objective is form of weighted parameters, the first represent the position of the sensor node toward the centre of the cluster division whereas the second parameter indicates the residual energy of the sensor node.

5 Conclusion

The revolution of technologies since past few years that adding mobility features to the WSNs puts new challenges especially in design efficient routing protocols. According to some researchers, hierarchical based routing protocol outperform than the flat based and location-based routing protocols particularly in preserving energy, and prolong the lifetime of MWSNs as reviewed in this paper.

Several hierarchal routing protocols were suggested in many research papers. Some requirements for the routing protocols may conflict. Therefore, when picking the shortest path towards the sink node causes the in-between sensor nodes to deplete their energy fast, and consequently result in reducing the network lifetime. At the same time, it might result in less network delay and minimum energy consumption. Since the routing objectives are tailored according to the application, several routing protocols have been suggested for different applications.

Moreover, this survey highlighted the main challenges that affect the performance of MWSN beside the obvious different between the stationary WSN, MWSN and ad-hoc. The proposed technique in this survey focuses on develop an optimized routing-based protocol with help of evolutionary algorithms such as genetic algorithm to acquiring long lifetime of MWSN. And to attain that, a new selection approach for the cluster head with homogenous mobile sensor nodes is proposed. The parameters that employed in this work to formulate the fitness objective are the outstanding energy in addition to the position of each sensor nodes within the cluster division. The extensive description of this method will be discussed after we done with MATLAB simulation of MWSN and develop a fair comparative with recent available hierarchal based routing protocols then analyzed the performance of the proposed approach on the basis of energy efficiency, scalability, lifetime.

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