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Energy-Efficient Control Methods in Heterogeneous Wireless Sensor Networks: A Survey †

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Abstract: Due to the advancement of sensor gadgets and telecommunication technology, wireless sensor networks (WSNs) have drawn a lot of observations in the recent period. Inaccessible terrain, disaster zones, or polluted conditions are typically where they are deployed at random, making battery replacement or recharge challenging or even impossible. Network lifespan is therefore extremely important to a WSN. An abundance of power-effective strategies in a diverse wireless sensor network are surveyed in this paper. We first provide an overview of the fundamental network radio representation and how it may be utilized to analyze different trade-offs between network deployment costs and an energy-efficient clustering approach. We also highlight a few protocols that can be utilized in heterogeneous networks that are energy efficient.

Keywords: heterogeneous; protocols; network lifespan; cost; energy conservation

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1. Introduction

As batteries have a limited power capacity, they are often used to power sensor nodes in a WSN, and they are tough or even impossible to be put back or to restore. Therefore, energy control is required to effectively utilize the scarce energy ability in order to reduce the energy spent by the sensor nodes and thereby extend the lifespan of the network. To achieve this, power efficiency needs to be taken into account at every step of the network system and work not only for the transmission between specific sensor nodes, but also for the network as a whole. Energy conservation and management are the fundamental guarantors of network performance, which includes delay and throughput. In this paper, we provide a survey of the schemes and protocols which have been utilized in heterogeneous networks. Therefore, our intention is to help people better understand the problems that are now being faced in this new field of the conservation of energy.

Consumption of Power

Since it is an electronic device, the cellular detector network junction can only be powered by a little amount of power. Figure 1 depicts the traditional four main parts of a node structure: a sensor, a refining, a transmission, and an energy unit. As a result, the battery health of a few nodes has a remarkable effect on the lifespan of the detector junction, which might result in major topological change and need packet re-routing and network reorganization. Consequently, power management and conservation gain extra significance in the utility grid, islanded mode, which refers to an autonomous operation as described in the below sections.

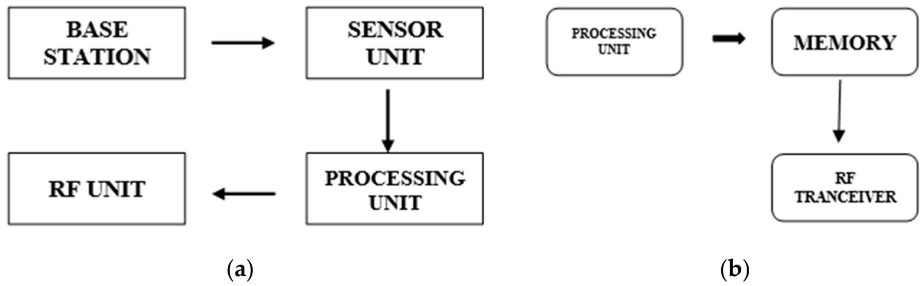

Figure 1. (**a**) Structure of sensor node. (**b**) Processing unit.

These factors are the driving forces behind academics' current focus on the creation of sensor network protocols with energy awareness and algorithms.

2. WSN Heterogeneous Model

Most protocols created for WSNs make the assumption that all detectors have the same repository, processing, observing, and communication abilities, which should be homogeneous. A set of detectors in these networks would have the same lifespan if their rates of energy consumption were the same. However, in some applications of sensing, we use detectors of different potentiality in which the network should be heterogeneous. The supposition of homogeneous sensors may not be realistic in the real world since sensor advantages require the heterogeneous sensors in the form of sensory and conveying potentiality to improve the stability and connectivity of the network. Additionally, even though the sensor has ideal hardware, the transmission and nodes related to the sensor could differ from time to time [1]. In actuality, we cannot ensure that the set of sensors node on the identical platform will have the exact identical physical characteristics. This pathology concentrates on heterogeneity during the map-out phase, as the sensors are created with different capabilities to fulfill the unique requirements of sensing applications [2].

Therefore, we will introduce a WSN of a heterogeneous model and discuss the resources based on the heterogeneous model in this part of the paper. In a sensor node, the human sources of the resources' heterogeneity in a sensor node can be classified as energy heterogeneity [3]. Computational heterogeneity differs from other heterogeneities by its larger memory and its potential microprocessor. Link heterogeneity is the heterogeneity in which the heterogeneous node has a high bandwidth and a long-distance network transceiver when compared to that of the ordinary junction. This can supply further reliable data transmission [4]. Power heterogeneity is the kind of heterogeneity in which the heterogeneous node is line-generated, or else its power unit is interchangeable. The energy heterogeneity among the aforementioned three kinds of assets of heterogeneity is the most symbolic since both calculation heterogeneity and connect heterogeneity will require further power assets [5]. Without power heterogeneity, calculation and connect heterogeneity will have a negative effect on the entire sensor network, shortening its lifetime.

2.1. Effect of Heterogeneity in Wireless Sensor Networks

The following three benefits can be achieved by adding a few heterogeneous junctions to the detector network:

2.1.1. Prolonging Network Lifetime

A packet's average power consumption for sending on from the usual junctions to the drop will be much lower in a heterogeneous wireless detector system than in a homogeneous detector network [6].

2.1.2. Enhancing Data Communication Reliability

It is well known that the reliability of a detector system connection is often small. The end-to-end transportation rate is also dramatically decreased with each hop. There will be fewer hops between the conventional detector junction and the drop with heterogeneous nodes [7]. Therefore, compared to a homogeneous sensor network, a heterogeneous detector system can achieve a considerably greater end-to-end delivery rate.

2.1.3. Reducing Data Transmission Latency

The processing delay of nearby nodes can be reduced due to computational heterogeneity. Additionally, the amount of time transmission queues must wait can be decreased via link heterogeneity [8]. Another advantage of fewer hops between the sensor and sink nodes is lower forwarding latency.

2.2. Performance Measure

Here, we outline the metrics that can be used to gauge heterogeneous systems' effect.

2.2.1. Lifespan of Network

This is the period of time from the beginning of the sensor network operation until the demise of the first live node.

2.2.2. Number of Cluster Heads per Round

This immediate measurement represents the number of nodes that would communicate data collected from their bunch members immediately to the sink [9].

2.2.3. Throughput

Track the total data transfer rate across this network, the data convey rate from bunch heads to sinks, and the data transfer rate from node to cluster heads.

2.2.4. Enhancing Data Communication Reliability

It is well known that the reliability of the detector system connection is often small. The end-to-end transportation rate is also dramatically decreased with each hop. There will be fewer hops between the conventional detector junction and the drop with heterogeneous nodes [10]. Therefore, compared to a homogeneous sensor network, a heterogeneous detector system can achieve a considerably greater end-to-end delivery rate.

2.2.5. Reducing Data Transmission Latency

The processing delay of nearby nodes can be reduced due to computational heterogeneity. Additionally, the amount of time transmission queues must wait can be decreased via link heterogeneity [11]. Another advantage of fewer hops between the sensor and sink nodes is lower forwarding latency.

3. Strategies for Power-Aware Power Control in Heterogeneous Networks

A detector network consists of many sinks and detector junctions, and base stations typically act as gateways to other systems [12]. It supplies powerful data refining, repository capabilities, and bandwidth approve points to the network's sensor nodes. Detector junctions observe their surroundings, gather perceived information, and send it to the base station (Figure 2). However, they have physical, computational, and memory limitations [13]. Deploying several heterogeneous nodes is effective in extending the life and reliability of a wireless sensor network. Figure 2 discusses many energy-efficient heterogeneous plots.

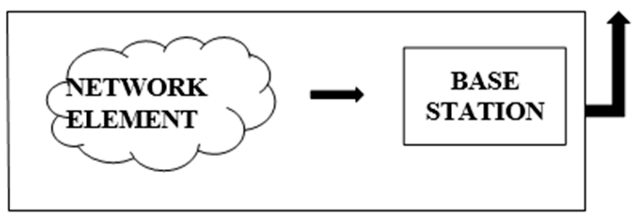

Figure 2. Base station unit.

3.1. Cluster-Based Approach

In a hierarchical system, detector junctions are grouped into a bunch, with the bunch heads acting as a pass on for the data transmission to the sink while the cluster members provide their data to them [12]. To conduct the detecting operation and convey the detected data to its bunch head across a small duration, a junction with reduced power can be employed, while a bunch head might be chosen from a node with more energy to working data from bunch members and specified data to the sink [13]. This process allows you to even out the amount of traffic, reduce the amount of energy consumed for communication, and develop ascendable as the system grows. The main problems in bunching are the cluster leader selection and cluster establishment [14]. In this case, a variety of clustering algorithms can be applied. Figure 3 represents the classification of efficient energy strategies. It is possible to categorize and separate WSN clustering algorithms based on a number of distinct characteristics [15].

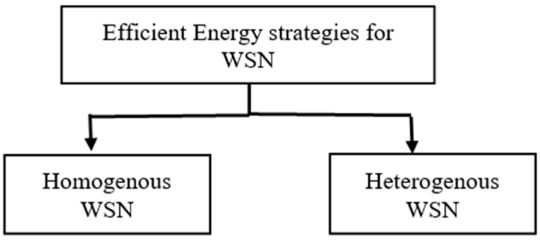

Figure 3. Classification of efficient energy strategies.

The following CH node traits identify several clustering strategies:

- Mobility: The membership of the sensors changes as a CH is travelling, necessitating constant cluster maintenance. However, stationary CH often results in stable bunches and makes managing intra- and between-bunch networks easier [16].
- Node types: Only a subset of sensors used is called in some configurations, while CHs are granted access to an excessively high number of computing and communication resources in other settings.
- Role: A CH can either collect or fuse the sensor data it has collected, or it can easily act as a relay for the congestion generated by the detector in its bunch. When targets or phenomena are discovered, a CH may occasionally act as a base station or sink to carry out directives. Various clustering techniques have been put forth, depending on the approach and purpose [Figure 3].

To balance the power consumption of the detector junction in the system, LEACH chooses a small number of nodes at random to serve as bunch heads and rotates this function. Data coming from nodes inside the appropriate cluster are combined and gathered by the bunch head junction [17]. In order to lessen the amount of data and transmission of duplicate data, bunch heads also send accrued data to the drop. Data gathering is done on a regular basis and is consolidated to the sink. The setup phase and the steady-state phase are the two main phases of the LEACH operation. Clusters are arranged and cluster chiefs are chosen during the setup process. The actual sending of the data to the drop takes place during the quiet phase. The next round will start after the steady-state phase.

After receiving this announcement message, each non-bunch head junction chooses the bunch to which they will belong for this round [18]. The strength of the advertisement messages' received signal is taken into account when making this choice. The bunch head creates a TDMA schedule, receives all messages from nodes wanting to join this cluster, then allocates each node lot when it has time to send and calculates the number of junctions in the bunch. The sensor nodes can start sensing and sending information to cluster heads during the steady-state period [19]. Each non-cluster head node's radio can be disabled until the designated transmission time. After receiving all the data, the cluster heads aggregate it before passing it to the sink. In order to minimize intervention from the junction belonging to the other bunch, each cluster head communicates using a unique set of CDMA codes.

3.2. Approach Based on Chain

Each node in PEGASIS (power generating system for use in space) [20] is supposed to accept from and transmit to its instantaneous neighbors while as an alternative serves as the transmission figure head to the base station, which is the main idea in PEGASIS. The network's sensor nodes will receive an equal share of the energy load using this method. The i-th junction is situated at an arbitrary position, since the nodes are first distributed randomly around the play area [21]. The organization of the nodes to form a chain can be done in one of two ways: one is by the sensor junction which uses a greedy algorithm method with starts with some nodes.

As an alternative, the base station can figure this out. As the greedy algorithm steadily increases the neighbor distances because nodes previously on the chain cannot be revisited, we begin with this node to make sure that nodes afar from the base station have close neighbors.

Each node collects data from its neighbors in one round, fuses it with its possessed data, and then sends it to the next neighbor in the bonds. To node c2, node c0 will send its particulars [22]. Node c4 will send its data to node c2 once node c2 passes the token to it after receiving data from node cl.

4. Proposed Model

The protocols are suggested for heterogeneous networks. It is necessary to either establish new protocols or make further improvements to these ones. These protocols can be expanded to handle nodes of more than three different types and to accommodate hierarchies with more than two levels.

The heterogeneity among detector junctions is not only in the energy available, but also in the working power and power expending of data refining.

Future research may examine related information in query-driven and event-driven sensor network types, as well as multi-hop clustering and fault-tolerant mechanisms that may be employed in heterogeneous sensor networks.

In contrast, sensor nodes are aggregated into a cluster-based routing protocol, effectively sending captured data to drop. Bunch heads are sometimes chosen because they are special junctions that are more power efficient. How to create clusters that maximize modern communication metrics like latency and energy consumption is the most important research question surrounding such protocols. Future research should focus on the variables influencing cluster formation and cluster head communication. Additionally, a number of energy-saving techniques have been emphasized. There are still numerous demands and problems that need to be resolved even though many of these protocols seem promising.

Additionally, the process of data fusion and aggregation within clusters is a fascinating issue to research. The combination of sensor networks and wired networks is another area that could be studied in depth in routing protocol research in the future (i.e., Internet).

Although these protocols' energy efficiency performance is encouraging, more study is still required to address problems like the quality of service posed by video and imaging detectors and real-time applications.

5. Conclusions

This article provided a comprehensive overview of a heterogeneous network in wireless detector models. The study attaches great importance to energy efficiency to improve network longevity, development costs, stability, and all parameters. Many solutions under cluster-based and chain-based approaches have been suggested.

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