A COMPREHENSIVE ANALYSIS OF ENERGY EFFICIENT WIRELESS SENSOR NETWORK (WSN) PROTOCOLS

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Abstract: Wireless Sensor Networks (WSNs) include many tiny and low energy and cheaper nodes in different areas for measuring the environmental parameters like temperature and humidity. Hence, the usage of WSNs has become an adaptable means of data transfer across different fields due to the advancement of wireless technology. It is noted that these networks, which use nodes for event detection and identification, gather information by means of simple calculations and send it to a particular Base Station (BS) via gateway nodes. The applications of WSNs can be classified into monitoring and tracking, which are used in areas such as environmental monitoring, health diagnostics, military surveillance, and many others. Energy consumption is still a major issue of concern, sensor nodes in particular, use energy in sensing data and transmitting it. Energy savings techniques like clustering and routing protocols are important for increasing the life time of the network. Thus, this research aims at analysing the different aspects of improving energy efficiency and network performance, especially in the context of the clustering algorithms, such as the Multi-level Stable and Energy Efficient Clustering (MSEEC) protocol. The paper discusses major issues and suggests some new combined routing approaches for WSNs with the problems connected with fault tolerance, topology, scalability, and power consumption.

Keywords: Energy consumption, sensor node, power consumption, clustering, secure, and network lifetime.

Introduction

Wireless Sensor Networks (WSNs) are made up of hundreds of tiny, typically battery-powered sensors for measuring and transmitting data on environment parameters like temperature, humidity and light. These nodes are planned as low-cost and low-power devices, which can be used in such applications as environment monitoring, military surveillance, and others. WSNs include many kinds of nodes and they are divided based on their functionality such as sensing nodes, processing nodes and transmitting nodes. To the collected data is transmitted to the central Base Station (BS) through intermediate gateway node. Due to the portability and cheapness of WSNs, they have been used in many areas such as health monitoring, habitat monitoring, and structural monitoring.

WSNs are broadly classified into two application categories: accounting and reporting. Monitoring applications are characterized by the constant observing of the environment and sending intermittent data to the BS. Tracking applications are oriented towards target recognition and tracking, for example, cars or people. Every application type requires a certain degree of data matching as well as delivery accuracy in varying extents.

The problem of energy consumption is one of the main issues that can be met in WSNs. Since the sensor nodes are powered by batteries, energy conservation is important in increasing the network's lifetime. The energy consumption of sensor nodes is primarily influenced by two tasks: Data acquisition also commonly referred to as data sensing, and Data communication also known as data transmission. Sensing energy consumption is predictable and remains almost constant while the transmission energy consumption is slightly unpredictable and highly dependent on the network structure and location of the BS. Nodes that are closer to the BS are usually dead sooner because they deal with many data than their counterparts far from the BS.

In order to overcome these challenges, different types of routing protocols and clustering mechanism have been developed. Clustering for example clusters nodes into clusters, which will have a leader referred to as the Cluster

Head (CH). The CH collects and forwards information of its cluster to the BS which minimizes the total energy of the network. Other protocols like the Multi-level Stable and Energy Efficient Clustering (MSEEC) focuses on conserving energy by choosing nodes that have high energy levels to act as CHs, this helps in improving the efficiency in transmitting data and scalability of the network.

Besides energy management, the design of WSN has to take into account issues such as fault tolerance, topology reorganization, scalability, and hardware limitations. Fragments: Fault tolerance is used in the networks to continue working without nodes while topology control deals with changes in the nodes such as mobility and failure. In large networks there are a lot of nodes and scalability is a major issue in order to manage all the nodes, and about hardware there are compromises between size of the node, power and processing capabilities. This work explores ways to enhance energy conservation in WSNs, which are the clustering algorithms and the hybrid routing mechanisms. Thus, the research objectives are to improve the cluster formation and data transmission with an intent to address the optimization challenge and provide recommendations as to how the WSNs can be made more efficient and long-lasting.

Challenges in the Design of Wireless Sensor Networks

The following problems must be considered throughout the design and implementation of WSN algorithms. These are the primary requirements for achieving efficiency in WSN operations [6].

Fault tolerance: Node failure in WSN can occur anytime because of battery depletion, interference, or physical damage. The ability of a network to continue operating after the failure of specific sensor nodes is known as fault tolerance. The sensor network should be structured so that the failure of a few sensor nodes does not impact the network's functionality.

Topology: The network topology is modified when sensor nodes fail. The movement of the nodes in mobile WSNs causes topological changes as well.

Scalability: WSNs are numerous sensor nodes that may vary depending on the application. The number of sensor nodes in some applications may exceed a million. In these circumstances, scalability becomes a critical factor that needs to be considered while designing the System. The ability of a sensor network to meet performance requirements as the sensor nodes increase is also known as scalability.

Hardware constraints: A sensor node's core components should fit into a matchbox-sized module. The sensor nodes contain limited energy supply and storage capacity due to their smaller size. Additionally, the sensor node's processing and communication capabilities are limited. The sensor nodes in WSNs have bandwidth restrictions compared to nodes in wired networks.

Power consumption: The sensor nodes use energy to detect, process, and communicate data to the sink. Communication will drain during these three tasks.

Transmission channel: The sensor nodes communicate over an unstable wireless connection. The radio, infrared, and optical frequency ranges are used for wireless communication channels.

Node cost: WSNs have many sensor nodes compared to typical wired networks. Individual sensor node costs should be maintained low so that the WSN's overall cost is equivalent to a regular wired network.

Clustering in WSN

Clustering is required to reduce the System's energy consumption and increase stability. The network is grouped into clusters during clustering. Every cluster has a leader known as the cluster head, abbreviated CH [8]. The primary responsibility of the cluster head is to collect data from nodes, aggregate it, and then connect it with the base station or sink. Cluster heads serve as a conduit between base stations and sensor nodes. Clustering significantly lowers the amount of energy used. Other ideas, including mobile sinks and rendezvous nodes, contributed to the direction of energy savings and clustering. In clustering, the central node is called the cluster head, and all other nodes are members.

Members of the cluster submit data to the CH, which then aggregates the data, eliminates duplicated data, and performs additional tasks. Once filtered, CH transmits it to the base station.

Objectives of Clustering

Enhancing the network's lifetime: - In contrast to mobile systems, where portable devices (such as phones) may be recharged when their battery runs out, energy management is a secondary concern. WSN's battery life is constrained. Consequently, increasing network lifespan is a growing concern and one of the main concerns while developing WSNs. To address this problem, clustering aids in lowering energy usage and lengthening the lifespan of WSNs.

Fault-tolerance: - The problem of node failure is addressed in various ways. When a node fails or has reduced transmission energy, proxy cluster heads address the problem, or CH rotation may be the answer. One of the key goals when building a clustering method is fault tolerance.

Literature Review

Sanjeevi, P. et al. (2020) [9] Agriculture and farming are now part of a precision sensor network thanks to recent advancements in the Internet of Things (IoT). The Internet of Things (IoT) wide-area network, built on wireless sensor networks (WSNs) and cloud computing, can be useful for the agriculture and farming industry in a remote place. The authors of this research described a scalable wireless sensor network architecture for internet-of-things-based remote farming and agriculture monitoring and control. In precision agriculture and farming, managing water resources and using water efficiently (PAF) is crucial. Resources. Achieving proper water irrigation control can be done by combining WSN technology with IoT. IoT is utilized in agriculture to facilitate the productive communication of numerous wireless sensors and boost farmer output. Writers have looked at the WSN topology regarding throughput maximization, delay reduction, high signal-to-noise ratio (SNR), minimal mean square error, and expanded coverage area. The results of the studies have shown that the suggested methodology performs better than more conventional IoT-based farming and agriculture. The farming system and IoT-based precision agriculture can both attest to their great value. For farmers because both much and insufficient irrigation is beneficial to agriculture. Based on the state of the agricultural field, the parameter values of sensor conditions such as temperature, humidity, and wetness might be fixed. The solution under discussion will create an efficient use of resources and address the issue of inadequate irrigation. The significance performance of WSN is better represented graphically than by prior technologies that could retrieve and display graphics.

Bhasin, Vandana et al. (2020) [10] An effective combination of sensing, processing, and communication are sensor networks. Small, affordable sensor nodes with limited processing power and radio ranges are used to build these networks. They direct themselves toward various applications while simultaneously running into severe energy limitations and a lack of memory resources. The hardware design of these nodes is also directly impacted by the sophisticated personalities of sensor networks. Numerous hardware platforms, including Crossbow, Intel, and Inmate, have been developed to investigate research-community theories and to put applications into practice across all branches of science and technology. Due to the sheer number of applications created in this field, security issues are of the utmost significance. This article surveys security architectures at the link layer and network layer, the two layers of the network stack.

Balaji, Subramanian et al., (2019) [11] A wide-area monitoring tool known as a wireless sensor network supports low-power tiny sensors used in scientific research. Memory, compute power, bandwidth, and energy are finite resources used by WSNs. The wireless sensor network's Cluster Routing protocol offers the highest levels of energy economy. Cluster Routing Protocols are employed to create the cluster (CH) when choosing a cluster head. Data packets are finally being sent from one CH to another and then forwarded, reaching the base station. During the setup stage, Chs is chosen. This System looked into a multichip transmission in which data packets are delivered between each hop. After then, the completed data packets are sent to the base station; transmitted. The cluster head moves the packets from the source sensor to the wireless sensor network base station. For fuzzy logic type 1, three factors are used, including the trust and distance factors. Fuzzy logic predicts the nodes that are close to the base station and have high trust. Type 1 fuzzy logic will select CH as the best forwarder. It will decrease network overhead while directly increasing the network lifetime.

Goyal, Nitin et al. (2019) [12] Although the oceans and rivers are still uncharted territories, experts have taken a particular interest in underwater surveillance because disasters and calamities frequently occur there. Underwater Wireless Sensor Networks (UWSN) are designed as an aquatic medium for various uses, including collecting oceanographic data, managing or preventing disasters, assisting with navigation, defending against attacks, and monitoring pollution. Like terrestrial Wireless Sensor Networks (WSN), Unmanned Wireless Sensor Networks (UWSN) comprise sensor nodes that gather data and transmit it to sinks. Water-based medium Mobile sensor nodes, lengthy propagation delays, constrained network capacity, and numerous message receptions are a few of these difficulties. This book presents a thorough overview of challenges relating to underwater sensor networks. The accessible test beds, routing protocols, experimental projects, simulation platforms, tools, and analyses are described by the authors. Oceans, seas, and other water bodies comprise around 96% of the world's water.

The development of networks or procedures to interpret data from a broad undersea environment has always been difficult for researchers. However, UWSN has been built with unique features to gather, transform, and store the massive amounts of data found underwater. UWSN has been a fascinating area of study in the struggle to perform like terrestrials in the challenging environment of aquatic medium. The UWSN functions differently from electromagnetic or radio waves utilized in land-based WSNs—acoustic waves, which have their restrictions. Several unresolved issues in UWSN need to be investigated, including creating energy-efficient routing methods, constrained battery depletion, and accessible bandwidth. These difficulties must be overcome for effective and dependable data conveyance in various applications, such as aided navigation, pollution monitoring, mine detection, offshore exploration, disaster management, and tactical surveillance. The authors in this work have provided the communication architecture of the UWSN to illustrate how the network functions. There is also a discussion of the current quality of service, energy efficiency, and fault tolerance challenges. The comprehensive analysis of WSN is given in Table 1.

Table 1. Analysis of WSN Techniques

Routing Protocol	Classification	Energy Efficiency	Location Awareness	Data Aggregation	Scalability	Quality of service	Fault Tolerance	Load Balance	Disadvantages
HCEH-UC [13]	Classical	Moderate	No	No	Yes	Yes	No	No	The performance of the approach is moderate, which necessitates further enhancement.
Fuzzy-based Energy Efficient Routing Protocol (E-FEERP) [14]	Classical	Moderate	No	No	Yes	Yes	No	No	The clustering process met the convergence at the early stage, where an efficient technique is needed for CH selection.
BSR [15]	Classical	Moderate	Yes	No	Yes	Yes	No	No	The network is prone to attack.
RRS [15]	Classical	Moderate	Yes	No	Yes	Yes	No	No	The topology needs improvement
ANS [15]	Classical	Moderate	Yes	No	Yes	Yes	No	No	The proposed work needs to be enhanced in handling the

									network overhead.
LEACH-SWDN [16]	Classical	Good	No	Yes	Limited	No	No	Yes	Network overload is not considered due to the data transmission overhead
ASLPR [17]	Classical	Good	No	Yes	Moderate	No	Yes	Yes	When the network is large, and the data transmission necessitates multi-hop routing
Q-LEACH [18]	Classical	Good	Yes	No	Limited	No	No	Yes	The protocol is not effective in handling mobility and large-scale network.
ERP [19]	Classical	Good	No	Yes	Limited	No	No	Yes	Fitness is not effective, and the protocol is not stable.
C-RPL [20]	Classical	Good	Yes	Yes	Moderate	Yes	No	Yes	This is not effective for distributed context.
OZEEP [21]	Classical	Very Good	Yes	Yes	Very Good	Yes	Yes	Yes	Re-clustering and clustering are not effective.
MTPCR [22]	Classical	Very Good	No	No	Very Good	No	Yes	Yes	Awareness of quality of service is absent
EAODV [23]	Classical	Good	No	Yes	Limited	Yes	No	Yes	The protocol is not strong enough to handle large-scale data transmission.
PHASeR [24]	Classical	Good	Yes	Yes	Very Good	No	Yes	Yes	The channel fading influences the performance of the proposed approach

Conclusion

Wireless Sensor Networks (WSNs) are becoming one of the most popular solutions for various monitoring and tracking purposes due to it's flexibility and low cost. The problem of demand management for energy is still at the core of the functioning of these networks. By means of clustering and using routing protocols, for example, Multi-level Stable and Energy Efficient Clustering (MSEEC), it is possible to enhance the parameters of energy consumption and increase the network's lifetime. Clustering lightens the energy weight on each node of the network with respect to data aggregation by allotting this responsibility to the cluster heads, thus prolonging the duration of operation of the network. But energy consumption problems are still present, and affected by the factors including the working distance between the nodes and the base station and the network structure.

The study reveals that there is a need to come up with a mixture of routing methods more so in the enhancement of WSN performance. To make the sensor networks more efficient and reliable, it is important to also work on the issues related to fault tolerance, scalability and the hardware limitations. Such issues are likely to remain as research and development advances as WSN technology moves forward; it is as a result of such advancements that the effectiveness of WSNs in several applications will be boosted. This, therefore, calls for further development of energy-efficient routing and clustering techniques due to the increasing needs of WSN applications.

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