JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Investigation of Various Energy-based Routing Protocols in WSN and Compare the Communication Efficiency

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Abstract: In recent years, several academics have shown significant interest in energy-efficient cluster routing in wireless networks (WSNs). Wireless networks are the intelligent networks of small sensor nodes for data processing, sensing, wireless transmission, memory, and energy constraints. During the existing time, many energy-efficient routing protocols for wireless sensor networks were suggested to extend the network life of the minute sensor node, but due to their transforming behaviour into modified, higher, or poorer performance scenarios, conventional techniques cannot be observed without doubt. Its primary aim is to assess energy-efficient routing protocol performance in WSNs based on overhead, delay, packet delivery ratio (PDR) and energy consumption congestion and network life. The present study effort may be used to guide the design of protocols, to choose the application-specific protocol and to modify existing routing protocols in wireless sensor networks. Cluster-based data collection protocol (ECDGP) and cluster-based Selective Flooding Routing Protocol (SFRP) simulations confirmed their findings over the periods overhead, delay, packet delivery and congestion over energy consumption and network life.

Key Word: WSNs, delay, packet delivery ratio (PDR) and energy consumption

I. INTRODUCTION

WSN comprises of many ad hoc sensor nodes to interact with the physical environment. Each node has certain elements: "sensors, controllers, power and transceivers." Sensor nodes may be consistently or randomly distributed (installed manually). The sensing area is the region in which sensors are installed. Sensors gather, handle, and send data from the area of interest to base station (BS) or to other nodes wirelessly [2]. WSNs have limitations including limited energy, short communication range, poor bandwidth, and restricted processing. The definition of: size, distribution strategy and network architecture [3] is important to the environment.

Energy consumption is a major element in the design of WSN. When sensor nodes are deployed in a complicated setting, replacing or recharging batteries is extremely challenging ('or not feasible'). The unit costs are greater than the sensing and processing in WSNs. Energy saving by means of the optimum data transmission method is thus required in order to divert data from nodes to BS to prolong the lifespan of the network [1]. Clustering is a significant energy saving method. Nodes are organized into clusters in this approach. The cluster nodes are termed "cluster members" and chosen from them Cluster Head (CH) [1].

A broad variety of applications were discovered using sensor nodes while forming a linked network known as the Wireless Sensor Network (WSN). A WSN has a wide range of applications such as border control, civil surveillance, health services, environmental monitoring such as temperature, sound, vibration, pressure, movement, pollution levels, moisture, wind speed and direction and others, farm monitoring such as water, infection by insects, household use applications, industrial process control etc. Without effort, all this variety of applications cannot be achieved. These attempts are called

WSN challenges. WSN thus has a wide range of problems, such as sensor node deployment, energy efficiency, sensor node routing, data security, sensor node design, kind of sensor node, energy distribution among data collecting sensor nodes etc. So the routing protocol discovers the appropriate route from the source node to the destination sensor node or base station or sink for data transfer. The process of choosing the correct route is not that simple since it relies on other variables such as network type, channel feature, etc. The sensed data transmits to the base station where it may be linked to another network where it is evaluated, and action based on sensed data is performed.

However, the wireless sensor network has a distinct situation than the wireless network, which makes it extremely difficult to construct. These are the difficulties

1. Because sensor node deployment is unpredictable, making it impossible for a consistent sensor node address system.

2. Since we have several sensor nodes that have detected data and sent them to the base station, or to any other sensor node, we need an efficient network.

3. As the base station receives data from a range of sensor nodes, the base station has data redundancy which causes difficulties to decide correctly.

4. Since we randomly deploy the sensor node and have a limited battery life, it is extremely difficult to replace the sensor node battery.

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A network of electronic devices, designated as the sensor nodes, may be characterized as a wireless sensor network (WSN), sensing the surrounding area, and transferring information gathered from the environment through wireless connections. The data gathered is transmitted to a separate site known as a base station (BS) or a sink or centre unit through one hope or many hops. The dish or BS may be in the network or linked through a gateway to other networks (e.g., the Internet). As illustrated in the Figure, the sensor nodes may be categorized by hardware, location, use, energy, and mobility. 1. The sensor node is categorized as below in hardware

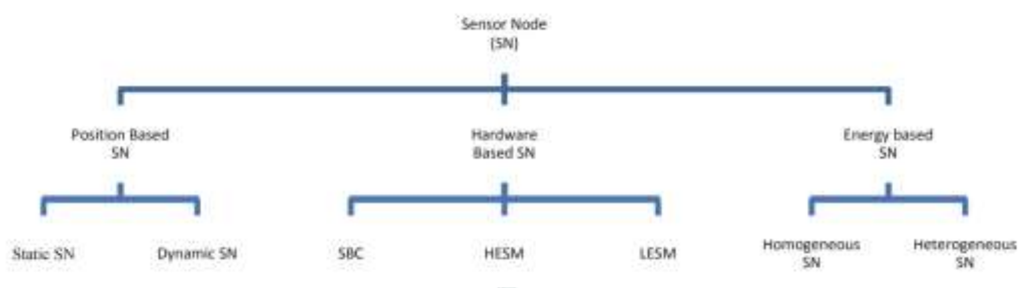

Fig .1. Types of SN

Single Board Computer: These sensor nodes are intended to have adequate computer energy and to run comprehensive systems like Windows, Linux, etc. The power usage may vary based on the system utilized. They rely on external power source such as solar energy etc. during the deployment of such sensor nodes in the field [5].

Embedded Sensor Module: Such built-in sensor nodes are high-end sensor nodes. Such sensor nodes are built into components such as computing power CPU, RAM for internal storage, external storage flash & many other peripherals such as analogy to a digital converter, digital to analog converter, input/output general purposes, RF etc have enough peripherals to run for various operating systems. Such sensor nodes use enormous power and will last for a few weeks or months [6].

Low-end Embedded Sensor Module: Such built-in sensor nodes are low ended. These sensor nodes are intended for months and years of extended life on batteries. These sensor nodes are intended for low energy consumption and inexpensive microcontrollers such as TI CC2538, Freescale MC13234 and so on [7] which are implemented using the standard IEEE 802.15.4 protocol. These nodes need efficient operating systems like Tiny OS and so forth. Such devices usually use power on the range of a few mW[8].

Low-end Sensor Embedded Module: Such nodes of the integrated sensors are low. These sensor nodes are intended for months and even years to operate on batteries. These sensor nodes have been intended to use little power and have inexpensive microcontrollers like TI CC2538, Freescale MC13234 and so on [8] integrated as a standard IEEE 802.15.4 protocol. These sensor nodes need operating systems as optimized as Tiny OS etc. The power consumption of this equipment is usually on the range of a few mW[9].

II. Wireless Sensor Network Components

The fundamental element of the wireless sensor node consists of four main units: sensor, computer, communication, and power unit. Furthermore, there are three alternative components to be coupled with the sensor node: location system, mobilizer, and electricity generator. The components of a typical wireless sensor node [4] are shown in Figure 1.

1) Sensing unit: It is responsible for the physical phenomena's sensing and generates the ADC analog signals to convert them to digital data and transmit them to the computer.

2) Computing Unit: This unit is utilized for the management and management of sensing, communication, and self-organization instructions. It consists of a CPU chip, active short term storage memory for sensing data, internal flash memory for program instructions and an internal time timer.

3) Communication Unit: It is responsible for all sensor node transmission and acquisition of the transceiver circuitry.

4) Power Unit: This unit is the most important component of the wireless node. It provides the other components with the electricity required.

Another component inside WSN's is a power generator and a mobilizer, such as a location system.

a. Localization System

It is essential that the wireless sensor node works for a 1-place detection system since many WSN applications need it. The routing algorithms and sensing coverage algorithms are needed that require information about the position of the wireless sensor nodes. The position finding system consists of a Global Positioning System (GPS) or an algorithm to determine the placement of the wireless sensor nodes utilizing distributed computing.

b. Mobilizer

In many applications the mobility function is occasionally required to move the wireless sensor node from one place to another in order to complete a particular job in WSN. So, for such applications the mobilizer system has to be equipped with the wireless sensor node. High energy consumption is required to support and effectively support the mobility in the wireless sensor node. The movement of the wireless sensor node with the collaboration of the sensor and computer unit is controlled by the mobility function.

c. Power Generator

Many WSN applications must run for a longer period, and it is thus important to supply the wireless sensor node with an extra power source to extend the network life.

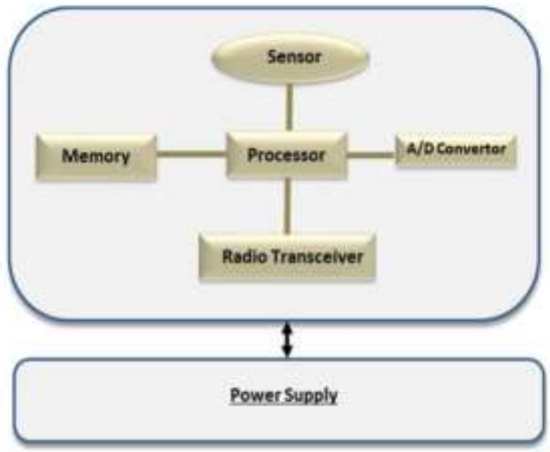

Figure 1. Components of WSNs

III. Background

Gupta, P., Tripathi, S., & Singh, S. (2021), Efficient energy consumption is still important to improve network life, no matter how advanced the Wireless Sensor Network (WSN) is. In real time applications, the network lifespan depreciates owing to battery limitations of sensor nodes. One approach is cluster-based heterogeneous WSN (HetWSN) combined with optimization methods to alleviate an energy depletion issue. For optimisation, technology such as IoT, machine learning, and neural networking may be very important. This article addresses a thorough literature analysis of cluster-based routing procedures along with their advantages and disadvantages for HetWSN spanning the 2009–2019 timeframe. Furthermore, based on different clustering characteristics also compare briefly energy based and hybrid clustering method for static and mobile HetWSN. As a result of their evaluation, they offer a statistical survey that will guide researchers in proposing a new energy-efficient procedure in future. Finally, the article presents open problems in WSNs followed by some debate and conclusion.

Daanoune, I., Abdennaceur, B., & Ballouk, A. (2021), Wireless Sensor Network (WSN) has been an active study field in the past several years, owing to its widespread usage of this technology in many applications, including military applications, healthcare, automation, etc. WSN oversees physical characteristics in cases of difficult or impossible human action. The WSN is a collection of numerous sensor nodes placed in a certain area. These nodes constantly detect data and record values and transmit these data to the Base Station (BS) through other sensor nodes. Various problems are found in the WSNs, such as energy consumption, sensor node deployment, routing algorithms, energy efficiency, cluster head (CH) selection, resilience, etc. In order to overcome these limitations, several academics have created routing protocols and suggested many optimization methods to determine the optimum route between the transmitter and the receiving node. Hierarchical routing methods improve network life by improving network performance. LEACH (Low Energy Adaptive Clustering Hierarchy) is the most common hierarchical technique that aggregated sensor nodes into clusters. Each cluster is made up of standard nodes and managed by a CH chosen by members of the cluster to gather their data and to transmit them to the BS. The LEACH technique reduced WSN energy usage. They provide an in-depth analysis of LEACH descendant clustering methods in this survey. This research is the first in which LEACH-based routing methods have been classified into CH selection, data transmission and CH selection and data communication. This survey is compared with other current surveys. In order to assess these protocols, they examine several criteria, such as CH selection, communication mechanism, scalability, energy efficiency, mobility, node localisation, etc. They offer a comparative study of various clustered routing methods according to these criteria. This survey also examines the merits and drawbacks of each LEACH methodology. The article concludes with suggestions on future areas of research in the WSN.

Vadicherla, P., & Vadlakonda, D. (2021), Due to the constraints related to Wireless Sensor Network strength and characteristics during network transmission, cluster-based and energy efficient routing technologies are gaining prominence. Wireless sensor networks are about the utilization of energy (WSNs). WSNs have a limited lifespan, therefore it is difficult to maintain them. Heterogeneous Wireless Sensor Networks (HWSN) routing protocols have just received a large press release. Several HWSN routing methods have been suggested in order to improve the efficiency of HWSNs. Among these protocols, hierarchical HWSN routing protocols may significantly improve network efficiency. In this post, they can test three hierarchical HWSNs. EDFCM, MCR and EEPCA are three newly suggested new routing protocols, LEACH and LEACH+. SEP., they focus on the round at which the first node dies (also known as the secure period) and the number of packets delivered to the sink. This is an important factor to note while evaluating the control capacities of a protocol. They do several tests and simulations. MATLAB has been used to analyse the outcomes of the five routing methods.

Lodhi, A. K., Rukmini, M. S. S., & Abdulsattar, S. (2021), Wireless Sensor Network (WSN) consists of autonomous sensor nodes to gather environmental status. These nodes have limited batteries. The batteries of the nodes cannot be recharged or replaced during the operation, since applications of the WSNs include underwater and mountain-driven forests. Objective: Therefore, the energy provided must be used efficiently. Energy efficient routing is one of the main energy management sources. WSN cluster-based routing is a common way of achieving network performance and energy efficiency. In literature, the number of energy efficient routing protocols based on clusters and their road selection measure are dependent on the remaining node energy status. This measure nevertheless leads some intermediary nodes to drain energy immediately. This scenario leads intermediate nodes in wireless networks to become a bottleneck node and causes deterioration of performance in terms of efficiency and packet delivery. The study thus attempts to develop a cluster-based routing protocol to avoid creating a bottleneck node. They provide a new routing measure for the bottleneck issue termed "ranking status." Findings: The results show that the proposed routing protocol avoids the formation or improvement of the network intermediate bottleneck node.

Gupta, S. K., Kumar, S., Tyagi, S., & Tanwar, S. (2020), The Wireless Sensor Network is a network of wirelessly linked sensor nodes. The sensor node may detect, analyze and transmit data to a separate location known as the base or sink or destination sensor node. The goal of the sensor node is to sensing and sending data to a sink; however, data transmission is important depending on how it is routed. Energy is another element affecting the sensor network. These two variables are thus extremely important for WSN.

Almazaideh, M., & Levendovszky, J. (2020), This article proposes new energy-conscious and dependable routing methods. The objective is to optimize the life of Wireless Sensor Networks (WSNs) according to pre-defined confidence limitations via multi-hop routing methods in which the source node transfers the packet to the base station through other nodes, including relays. Energy efficiency is achieved in the first suggested protocol by maximizing the least residual energy in the route subject to specified reliability limitations. The second procedure is an optimized lifetime and complexity variant of the first. The optimum route is one in which the residual energy distribution of the path nodes is as near as feasible and the packet reaches the base station with a certain chance of success. They utilize an entropy-like metric to quantify the homogeneity of the residual energy distribution. The current energy status of the network is kept through a search database from which optimum routes are calculated on the BS. After each packet transmission cycle, the BS broadcasts updated optimum routes to each node.

Li, X., Keegan, B., Mtenzi, F., Weise, T., & Tan, M. (2019), Wireless Sensor Networks (WSNs) are a kind of self-organizing networks with reduced capacity for energy provision and communication. The adoption of an energy-efficient routing protocol to extend the network life is one of the most critical problems in WSNs. They thus present the new WSN energy-efficient load balancing algorithm (EBAR). EBAR uses a pseudo-random path discovery method with enhanced pheromone path updating to balance the sensor nodes' power consumption. To improve route setup, it employs an efficient, heuristic updating method based on a greedy anticipated energy cost measure. In order to minimize the overhead control energy consumption, EBAR uses an energy-based opportunity broadcasting system. In various application situations, they simulate WSNs to assess EBAR for performance measurements such as energy consumption, energy efficiency and projected network life. The findings of this thorough research indicate that EBAR is much better than the state-of-the-art EEABR, SensorAnt and IACO methods.

Ganesh, J., & Dhulipala, V. S. (2019, September), Resource restriction, such as power, reliability, wireless network storage and computing (WSN), which is a problem in current development in sensor network research. In WSN, the battery usually operates Sensor Nodes (SN), thus it is difficult to replace or recharge the battery in unattended settings. These may be addressed by using appropriate routing methods. This study provides a short survey based on the parametric analysis of routing methods in WSN.

Banerjee, I., & Madhumathy, P. (2019), The sensor nodes in the Wireless Sensor Network (WSN) have a limited battery life and are thus very careful with energy consumption in WSN. The routing protocols are the main field of study for working on network quality such as network life, scalability, energy consumption, overhead packets etc. Given that the sensor node has a limited battery life, the effective usage of nodes without losing connection on the network becomes an important problem when developing routing protocols. The grouping of sensor nodes into small clusters and the selection of a cluster head appears to provide more benefits than in other network architectures in order to achieve more scalability, stability, and end-to-end data transmission. In this article the many energy-efficient routing protocols for the clustering of sensor nodes, their advantages, demerits, and applications have been addressed and examined.

Ameen, N., Jamal, D. N., & Raj, L. A. (2019), The Wireless Sensor Network (WSN) was deemed a formula for addressing different needs such as surveillance, healthcare, traffic monitoring and military systems. In support of the needs for the wireless sensor network, the efficient energy consumption and secure communication regions for WSN have been investigated. Introduction of the Optimized Dynamic Secure Multi-Path Routing Protocol (ODMRP) for Ant Colony Optimization, WSN improved its energy efficiency, performance, strength, and scalability. This article proposes an optimization method based on the optimized dynamic safe multi-way routing protocol (ODMRP-ACO) for the transmission of data in the WSNs. This facilitates the transfer of data through WSNs. The shortest way between the source node and the target node is evaluated via the ACO-based colony cooperation. The ACO-based routing protocols have several routing protocols: Energy-aware and Secure Trust routing (ESRT-ACO), Split Multipath Protocol-Ant Colony Optimisation (SMR-ACO), Light Weight Trust Based Routing Protocol (TLB-AODV), and AODV Routing Protocols. They deal with the end-to-end delay, delivery rate, overhead routing, performance, and energy efficiency. The data analysis findings have shown efficient in comparison with the other WSN-designed routing methods. That is why the total ODMRP-ACO is 96.98 percent better than the current ODMRP-ACO. The simulation platform utilized for the newly designed ODMRP-ACO protocol is NS2 simulation software.

Zhang, Y., Zhang, X., Ning, S., Gao, J., & Liu, Y. (2019), The sensor nodes in the Wireless Sensor Network (WSN) have a limited battery life and are thus very careful with energy consumption in WSN. The routing protocols are the main field of study for working on network quality such as network life, scalability, energy consumption, overhead packets etc. Given that the sensor node has limited battery life, the effective usage of nodes without losing connection on the network is a big problem in the development of routing protocols. The grouping of sensor nodes into small clusters and the selection of a cluster head appears to provide more benefits than in other network architectures in order to achieve more scalability, stability, and end-to-end data transmission. In this article, they reviewed and examined the many energies efficient routing algorithms for the clustering in wireless network sensor nodes, their merits, demerits, and applications.

Mohamed, R. E., Saleh, A. I., Abdelrazzak, M., & Samra, A. S. (2018), Wireless Sensor Network (WSN) is a collection of tiny power nodes that collect and transmit data to the base station (BS). These nodes encompass a wide area of interest (ROI) in accordance with the application need for various reasons. The initial issue with WSNs is how to properly cover ROI and transmit monitoring information to the BS. Although the energy injected during the setup phase and the violation of the energy fairness restriction of dynamic topology routing, they achieve excellent network coverage and connection performance. In this article they classify WSN applications based on several characteristics to illustrate the main problems of protocol design. The energy efficiency of the current proactive routing algorithms is thus examined from many perspectives. Every protocol has thoroughly evaluated the energy overhead and energy fairness. Studied and analyzed the most powerful routing methods for homogenous proactive networks, the research difficulties and current issues in this field are highlighted. The findings showed that the most effective elements of network life and network efficiency are energy overhead and route choice.

Bhushan, B., & Sahoo, G. (2017), Numerous, small, multipurpose sensor nodes (WSNs) are available for the gathering of data and information from different target regions or sensing domains. WSNs may be utilized for many purposes like medical surveillance, military research, space exploration, environmental surveillance, disaster management, etc. These are also helpful for applications that do not allow the deployment of conventional wireless and wired networks. Transmission of data in WSNs is not a simple job because of resource restricted nodes, limited battery life, poor transmission power, etc. Energy for sensing and sending sensed data to a sink is a key element in WSNs. In hostile and distant areas, WSNs are installed to make them susceptible to different kinds of security assaults. The design of WSN routing protocols must thus consider different routing difficulties and design concerns. The study covers several methods to data gathering and efficient routing algorithms to decrease the energy consumption of networks. The article discusses several routing problems and the constraints of WSNs. The report also gives a comprehensive description of four fundamental kinds of routing protocols: location-based, information-centric, hierarchical, and cross-path routing. Some open-ended research topics and the conclusion are also mentioned.

Khandnor, P., & Aseri, T. C. (2017), The development of energy-efficient routing methods is thus a significant issue for the wireless sensor network, since sensor nodes are battery powered. Few sensor nodes in the heterogeneous wireless sensor network have greater processing and communication capabilities. This article proposes the reactive energy-efficient protocol for heterogeneous cluster-based routing. Finally, the performance of the proposed protocol is compared with current routing methods based on heterogeneity. The performance of the suggested protocol in terms of network life and energy efficiency is superior than the current protocols.

Solayappan, A., Frej, M. B. H., & Rajan, S. N. (2017), The underwater remote sensors transmit signals at a range where no human interaction is feasible. It is tough to change the battery in an acoustic environment to maintain energy. In addition, solar energy cannot be utilized to recharge batteries because of the environment. These sensors must remain awake for a long time, bearing in mind that their energy limits are restricted. One of the problems with submerged remote sensor systems is the unequal use of energy resources. This will ultimately reduce the lifespan of the sensors in the submarine networks. Underwater Wireless Sensor Networks (UWSN) has a hostile environment compared to conventional wireless sensor networks, which may result into high energy restrictions, limited bandwidth, reduced transmission, and delayed propagation. The distance between the anchor node and the normal node is more significant in multi-hop communication; this results to higher energy usage. On the other side, the distance is longer and leads to a signal attenuation and a frequency loss of power. The deep ocean sound speed should be considered as the depth of the ocean rises. The difference in sound speed leads to this loss. When the combined attenuation and noise are mixed, there is a typical power spectral density. This resulted in a decrease of 18 dB over 10 years. Physical UWSN norms are defined in the layers of the auditory sensor network in a way that compensates for energy consumption. The energy usage must be lower or balanced when packets are sent, else energy holes would be formed. In these situations, energy efficiency, longevity and performance are increased. In this article, we summarize most of the existing routing methods based on energy. The information given may be helpful in analysing and designing protocols for wireless submarine sensor networks by decreasing energy usage.

IV. Comparison table

S. No.	Author	Year	Network-Protocol	Output
1	Gupta, P., Tripathi, S., & Singh, S.	(2021)	WSN	energy-based and hybrid clustering algorithm for static and mobile HetWSN on the basis of various clustering attributes
2	Daanoune, I., Abdennaceur, B., & Ballouk, A. (2021),	2021	WSN-LEACH	study of LEACH descendant clustering protocols. This survey is the first study to classify LEACH-based routing protocols into CH selection, data transmission, and both CH selection and data transmission techniques.
3	Vadicherla, P., & Vadlakonda, D. (2021),	2021	HWSN, EDFCM, MCR, and EEPCA	To boost the efficiency of HWSNs, various HWSN routing protocols
4	Lodhi, A. K., Rukmini, M. S. S., & Abdulsattar, S. (2021),	2021	WSN	design a cluster based routing protocol to prevent the creation of intermediate bottleneck node
5.	Gupta, S. K., Kumar, S., Tyagi, S., & Tanwar, S. (2020),	2020	WSN	different IEEE standards related to WSN.
6	Almazaideh, M., & Levendovszky, J. (2020),	2020	WSN	maximize the lifespan of wireless sensor networks (WSNs) subject to predefined reliability constraints by using multi-hop routing schemes

V. Conclusion and future work

A wireless sensor network (WSN) comprises of independent space dispersed sensors for reliable monitoring of various civic and military settings and the collaborative transfer of data to the central location via the network. Routing methods have an important effect on total sensor network energy usage. Appropriate energy-efficient routing algorithms for the intrinsic properties of these network topologies are necessary. Due to resource restrictions in wireless sensor networks, it was quite interesting to extend the network's lifespan. Most sensor node energy is used to transmit data to the base station.

It thus causes them more quicker to exhaust their energy. In this article we examine and evaluate the many communication protocols that may have a substantial effect on the energy dissipation of these networks.

References

1. Gupta, P., Tripathi, S., & Singh, S. (2021). Energy-Efficient Routing Protocols for Cluster-Based Heterogeneous Wireless Sensor Network (HetWSN)—Strategies and Challenges: A Review. *Data Analytics and Management*, 853-878.
2. Daanoune, I., Abdennaceur, B., & Ballouk, A. (2021). A comprehensive survey on LEACH-based clustering routing protocols in Wireless Sensor Networks. *Ad Hoc Networks*, 102409.
3. Vadicherla, P., & Vadlakonda, D. (2021). Study on energy efficient routing protocols scheme in heterogeneous wireless sensor networks (network & mobility). *Materials Today: Proceedings*.
4. Lodhi, A. K., Rukmini, M. S. S., & Abdulsattar, S. (2021). Energy-Efficient Routing Protocol for Network Life Enhancement in Wireless Sensor Networks. *Recent Advances in Computer Science and Communications (Formerly: Recent Patents on Computer Science)*, *14*(3), 864-873.
5. Gupta, S. K., Kumar, S., Tyagi, S., & Tanwar, S. (2020). Energy efficient routing protocols for wireless sensor network. In *Handbook of Wireless Sensor Networks: Issues and Challenges in Current Scenario's* (pp. 275-298). Springer, Cham.
6. Almazaideh, M., & Levendovszky, J. (2020). Novel reliable and energy-efficient routing protocols for wireless sensor networks. *Journal of Sensor and Actuator Networks*, *9*(1), 5.
7. Li, X., Keegan, B., Mtenzi, F., Weise, T., & Tan, M. (2019). Energy-efficient load balancing ant based routing algorithm for wireless sensor networks. *IEEE Access*, *7*, 113182-113196.
8. Ganesh, J., & Dhulipala, V. S. (2019, September). Optimum Energy Based Routing Protocols for Wireless Sensor Network: A Short Review and Analysis. In *International Conference on Intelligent Data Communication Technologies and Internet of Things* (pp. 381-390). Springer, Cham.
9. Banerjee, I., & Madhumathy, P. (2019). Study on Energy-Efficient and Lifetime-Enhanced Clustering Algorithm-Based Routing Protocols in Wireless Sensor Network. In *Emerging Research in Computing, Information, Communication and Applications* (pp. 87-98). Springer, Singapore.
10. Ameen, N., Jamal, D. N., & Raj, L. A. (2019). Comparative analysis of energy based optimized dynamic source multipath routing protocol in WSNs. *Indonesian Journal of Electrical Engineering and Computer Science*, *16*(1), 441-455.
11. Zhang, Y., Zhang, X., Ning, S., Gao, J., & Liu, Y. (2019). Energy-efficient multilevel heterogeneous routing protocol for wireless sensor networks. *IEEE Access*, *7*, 55873-55884.
12. Mohamed, R. E., Saleh, A. I., Abdelrazzak, M., & Samra, A. S. (2018). Survey on wireless sensor network applications and energy efficient routing protocols. *Wireless Personal Communications*, *101*(2), 1019-1055.
13. Bhushan, B., & Sahoo, G. (2017, July). A comprehensive survey of secure and energy efficient routing protocols and data collection approaches in wireless sensor networks. In *2017 International Conference on Signal Processing and Communication (ICSPC)* (pp. 294-299). IEEE.
14. Khandnor, P., & Aseri, T. C. (2017, March). Reactive energy efficient heterogeneous cluster based (R-EEHC) routing protocol for WSN. In *2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)* (pp. 1442-1445). IEEE.
15. Solayappan, A., Frej, M. B. H., & Rajan, S. N. (2017, May). Energy efficient routing protocols and efficient bandwidth techniques in Underwater Wireless Sensor Networks-a survey. In *2017 IEEE Long Island Systems, Applications and Technology Conference (LISAT)* (pp. 1-7). IEEE.