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Review Article

Recent Study on Energy Efficient Cluster Based Algorithms for Wireless Sensor Network

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Abstract

Wireless Sensor Networks (WSNs) are made up of micro-sensor nodes with limited energy with processing capability in a constrained environment. WSN monitors physical and environmental conditions of many applications (e.g., health, military, home). Dense numbers of sensors are deployed to operate autonomously in different conditions of the environment. The main problem of WSN is maintaining network lifetime for a long time using low battery Sensor Nodes (SNs). Sensor nodes are frequently organized into distinct, non- overlapping groups termed clusters to provide high scalability with improved data aggregation. The pathways for data transfer in Wireless Sensor Networks (WSNs) are chosen in such a way that the total energy consumption is reduced to optimize network lifespan. We review advancements in clustering, classification of clustering properties and prominent cluster-based algorithms.

Keywords: LEACH; Clustering; Cluster Head; CH Selection; Wireless Sensor Network; Energy Efficient; Network Lifetime

Introduction

A Wireless Sensor Network (WSN) consists of a large number of Sensor Nodes (SNs) called "tiny devices" for monitoring areas. The data is processed at Cluster Head (CH) and then sent to the Base Station (BS) where a user can connect to the internet. The Low power consumption, dynamic topology, low energy, node failure, mobility, short-range broadcast communication, multiple hop routing, and a massive deployment scale are significant characteristics of a WSN [1]. The node consists of five basic components: the sensor unit, the ADC, the CPU, the power unit, and the communication unit [2]. A sensor node is a Micro-Electro-Mechanical System (MEMS) [3] that responds to changes in physical conditions like temperature and pressure. Many applications use sensors to gather information with a specific purpose. Sensors are being used in medical devices, home appliances, and even the military. In military targeting systems, sensor networks play a significant role in communications, computing, intelligence, and surveillance. It is easier to monitor and assist handicapped patients. The WSNs are self-organizing, quick to deploy and fault tolerant.

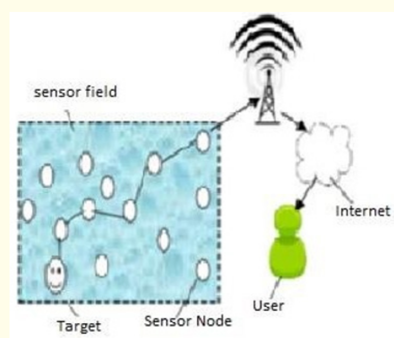

Figure 1: Architecture of Wireless Sensor Network.

The construction of WSN is shown in Figure 1 where SNs are spread out in sensor fields and connected for gathering data from the environment and then sending it directly to the Base Station. A sensor node collects data based on its sensing mechanisms observation and transmits aggregated data packets to the base station. The Base Station may be placed at a considerable distance from the sensor nodes.

Direct transmission requires more energy so the preferable strategy is to select fewer nodes for transferring data to the BS. These nodes are called aggregator nodes in WSN.

The Sensors are limited in capacity for sensing, computing, communication performance and power so several SNs are deployed across the different regions to gather information in a WSN. These nodes may connect to send or receive data directly or through intermediary nodes in a network. The sensors act as routers [4] for each other in a network. There is a central hub called the Base Station (BS) through which every sensor nodes communicate and delivers acquired data through direct communication routing protocols.

A routing protocol [5] explains how sensor nodes communicate with each other and share data so that they can determine the best path between any two nodes on the network. Each router maintains routing information and is quickly disseminated among local neighbor SNs.

As a result, the topology and configuration of the network are made available to the routers. Furthermore, sensors are energy-constrained, and their batteries are not rechargeable so implementing an energy-aware algorithm becomes a critical aspect of increasing sensor lifespan [6]. Figure 2 explains the classification of routing protocols in WSN.

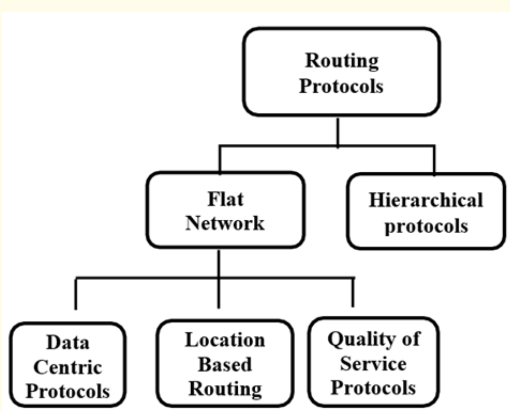

Figure 2: Classification of routing protocol in WSN.

To improve network scalability, researchers are working hard on clustering sensor nodes.

The distribution of energy is maintained equal among the nodes in the cluster by rotating the cluster-head node often in the network.

Most clustering techniques try to spread energy evenly across all nodes so that the network life can increase as long as possible.

Clustering

Clustering is the process of grouping sensors together for saving both time and energy. There is several different routing strategies are developed to increase the overall network's lifespan of the certain critical application.

For example, network clustering divides a network into small clusters with a cluster head node in charge of monitoring and controlling. Information from these CHs is transmitted to the base station employing a direct connection (BS). At first, data from all of the sensors is collected and sent to the BS via CHs. The CHS collects data from several SNs and then aggregates and communicates directly to the BS in a single hop. Therefore CH must be formidable in energy near to cluster centroid with low mobility and very less vulnerable.

The following factors should be considered before choosing a CH.

- **Battery power remaining:** Evidently, the sensor node with the highest battery level will become the CH.
- **Distance between a node and the sink:** The BS specifies how far apart each node is from the sink in terms of distance. The greater the likelihood that a node will become CH, the closer it is to the sink.
- **Mobility:** An important factor in the network's longevity is the mobility of its nodes. As a result of the high mobility of the nodes, the network's topology will change rapidly and need to choose CH frequently in the network.
- **Vulnerability index:** This metric indicates how susceptible a certain node in the network is. If it's too high, the node won't be chosen as the CH. A detailed discussion of this factor can be found in [8].

The design of a generic Cluster-Based WSN is shown and ob-

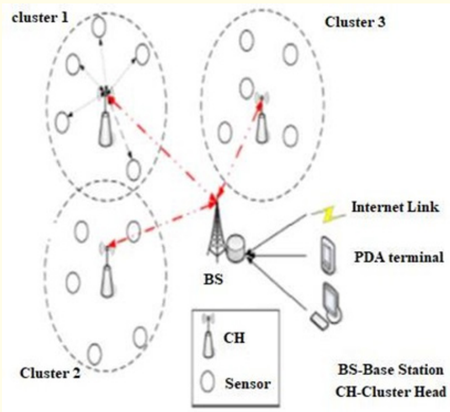

Figure 3: General Cluster-Based WSN Architecture.

served how the clustering phenomena.

- **Sensor Node:** The WSN's basic component is the Sensors. Each Sensor node in a network can perform a variety of functions, including basic sensing, data management, data transmission and data analysis.
- **Clusters:** WSNs' organizational units are clusters. The dense sensor nodes of WSN must be divided into clusters to ease management and reduce the consumption of energy.
- **Cluster Heads:** The cluster's organizational leaders and commonly responsible for organising events in the cluster. The responsibilities include data aggregation and scheduling of communications.
- **Base Station:** In a hierarchical WSN, the BS is at the top level, it establishes a path between the end-user and the sensor network, allowing the exchange of information among sensors.
- **End User:** A sensor network's data can be utilized for several purposes. Thus, desktop computers can access network data via application software that runs on the network.

The results of a sensor network query (where the required data is gathered from a query sent through the network).

Clustering attributes taxonomy

In the following section, we present a list of the characteristics that can be used to categorize and identify clustering approaches for WSNs. The characteristics are as follows:

Cluster properties

Clustering techniques are typically intended to create clusters with specified features. They are linked to the internal structure of clusters or interactions with other clusters. The following are the relevant characteristics of clusters:

- Cluster count: The numbers of clusters are predetermined in certainly published methodologies, hence the number of CHs is also predetermined in WSN. Several approaches are developed to get a more accurate count of clusters in WSN. Choosing CHs at random from deployed sensors typically results in a varying number of clusters.
- Stability: Adaptive clustering refers to a clustering approach in which the number of nodes in a cluster varies and the membership of each node changes over time. The number of sensor clusters in a network and their position is fixed throughout their existence in the network.
- Intra-cluster topology: Several clustering approaches employ a direct link between a sensor and the CH in each round. When the sensor's communication range or the numbers of CHs are restricted, it is often essential to link sensors to CHs through several hops.
- Inter-CH connectivity: When the CH doesn't have enough long-distance communication for connecting to the BS. As a result, the clustering system must ensure that an inter-CH path can be built from each CH to the BS.

Cluster-Head capabilities:

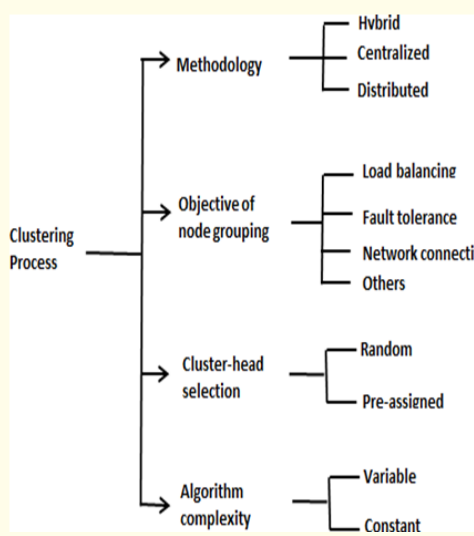

Figure 4: Cluster Properties.

The CH node has the following abilities in thenetwork.

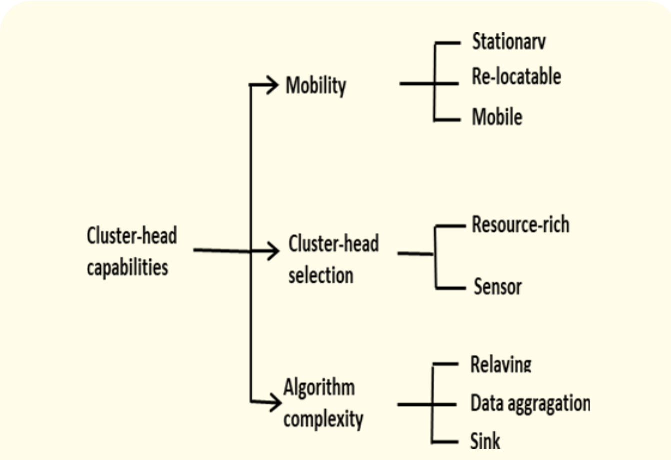

Figure 5: Cluster Head capabilities.

- **Mobility:** Sensor membership varies constantly when a CH moves, demanding constant maintenance of sensor clusters. The stationary CH tends to produce stable clusters and enables inter- cluster network management while dynamic CH is more likely to produce unstable clusters. Occasionally, CHs can travel short distances to improve network performance.
- **Node types:** The subset of deployed sensor nodes are labeled as CHs and certain CHs are provided with much higher processing and communication capacity.
- **Role:** Depending on the type of data collection performed by the CH, it can either act as a basic gateway within the cluster, or it can perform consolidation and integration of data gathered by sensors in the cluster. A CH is sometimes used as a sink or base station that responds to an event or target in the network.

Clustering process

Clustering systems differ substantially in their ability to integrate the complete clustering process as well as in their algorithmic characteristics. The clustering process depends on the following factors:

- **Methodology:** In a few techniques, the nodes are partitioned and the cluster membership is controlled by a centralized Base Station.
- **Cluster-Head selection:** Once the connection between nodes that have been set up, CHs can be pre-assigned or chosen at random from the list of nodes.
- **Algorithm complexity:** Different clustering algorithms have been presented depending on the purpose and technique. Algorithm complexity and convergence rate depend on the number of CHs and sensors, which might be either fixed or variable.

Comparison of algorithms

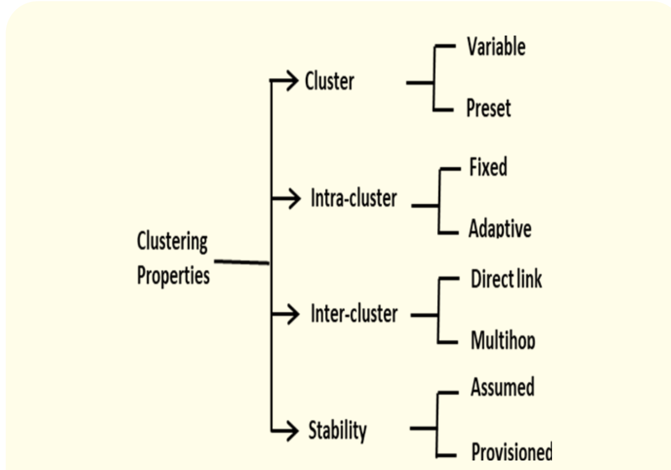

Figure 6: Clustering Process.

Energy-Efficient Communication Protocol for Wireless Microsensor Networks

For WSNs, this research proposes the clustering- based protocol LEACH (Low-Energy Adaptive Clustering Hierarchy). Using the random rotation of Cluster-Heads, it distributes the energy load across all sensors uniformly, making it extremely energy efficient [9]. The goal of the experiment is to demonstrate a LEACH can balance energy among the sensors to increase the lifespan of the network. The energy consumption level and network lifespan of LEACH are compared with the existing direct communication protocol and minimum energy routing protocol.

Comments

A result shows that LEACH reduces the consumption of energy and prolongs the lifespan of the network. LEACH is a widely used cluster- based routing system that has become something of a de facto standard among researchers.

LEACH with deterministic cluster-head selection

Two new algorithms are proposed and LEACH is enhanced by adding a deterministic component to the CH selection process. Any node that has not been selected as a cluster leader in the last 1/P rounds could be brought into consideration for future revisions because of the factor that raises this threshold. As a result of these alterations, the micro-sensor networks' lifespans can be extended by 30%.

Comments

An improvement to LEACH's technique for determining a threshold has been made in this paper by altering the algorithm. Simulation attempts to compare the energy usage of the original with the first, and second modified LEACH algorithms. Increasing the cutoff value will cause the network to crash after a few iterations.

HEED: A hybrid, energy-efficient, distributed clustering approach for ad-hoc sensor networks

HEED [11] is a clustering algorithm that chooses periodic cluster leaders based on the residual energy of each node and the "communication cost" inside the cluster. To choose new CHs, clustering depends on every clustering process duration, TCP and network operation interval, and TNO. The clustering procedure must be iterated for each CH selection. The inter-cluster organization is determined depending on the network application. The clustering performance of HEED is compared with the weight-based clustering protocol for quasi-stationary ad hoc networks in terms of the number of cluster iterations and number of clusters. The HEED can asymptotically connect clustered networks with the right number of nodes and transmission range limits.

Comments

Several researchers have proposed new routing protocols inspired by the HEED cluster-based routing protocol and it is more reliable than LEACH.

A biologically-inspired clustering protocol for WSNs

This research [12], proposes a novel application of collective social actors that will lead to a sufficient number of clusters with well-balanced membership. This work introduces TANT, a dynamic clustering methodology inspired by ant- colony optimization. In a simulation of T-ANT clustering, clustering fitness, CH election fitness, residual energy distribution, and network lifetime were evaluated in a simulation. LEACH and HEED are used to compare the findings. The results reveal that TANT outperforms the competition in terms of energy savings.

Comments

In this paper, the ant colony optimization algorithm is applied to WSN routing. Using a spread-out method makes sure that CHs are evenly spaced.

A clustered wireless sensor network model based on log-distance path loss

This study discusses a cluster-based wireless sensor network with a longer range and lowers power consumption. Long–distance path loss [13] and a loss exponent are used in this study to simulate communication at distances greater than a crossover distance. In this study, free space propagation is used to simulate communication at distances less than the crossover distance. This experiment's goal is to determine the optimal distance between the CH and BS. For a given network architecture and number of nodes, the distance between nodes and the amount of non- linear compression determine the best number of cluster heads.

Comments

This work proposes a routing algorithm that takes into account path loss for WSN communication over long distances.

A distributed algorithm for energy-aware clustering in WSN

The one-hop neighbours of the SNs are used in messaging in the network. By studying WSN networks of varying sizes, the optimal number of CHs will be determined. A comparison of the proposed algorithm with LEACH and HEED is also presented, but no experiments or quantitative results are included.

Comments

The paper describes in detail how cluster heads are selected without using distributed messaging. It would be advantageous to carry out more experiments that demonstrate its advantages over other clustering-based routing protocols, such as LEACH.

A dynamic clustering and energy efficient routing technique for sensor networks

Researchers have developed a dynamic clustering algorithm [15] that consumes less energy for large-scale sensor networks. Cluster heads are selected based on the number of active nodes in the cluster. Consequently, clusters require less power to communicate with one another.

EPA's [16] real-time estimation algorithm is checked for correctness and compared with LEACH's and HEED's clustering energy consumption. Then, EEPA is evaluated and compared with the other algorithms in terms of its lifetime, routing overhead and end-to-end package delay. An efficient and scalable clustering and routing approach is demonstrated by running simulations over a different number of sensors.

Comments

The proposed algorithm is better suited for large- scale WSN applications than LEACH and HEED.

A proposed energy-efficient distance based Cluster Head (DBCH) Algorithm: An Improvement over LEACH

The node distance from BS and residual energy is used to establish a new threshold [17,18].

The threshold value can be calculated as this paper to propose a distributed algorithm [14] for clustering them. For choosing CHs, energy levels of nodes are used instead of distributed

$$T(n)=\frac{p}{1-p(r \bmod \frac{1}{p})}+(1-p)\frac{D_{max}-D_{i\ to\ BS}}{D_{max}-D_{min}}\left(\frac{E_R}{E_0}\right)$$

The remaining and initial node energy are represented by E_r and E_i correspondingly. The cluster head will be chosen based on nodes which are closest to the base station along with other factors like remaining energy and distance. This upgrade compares and finds the maximum and minimum distance between the CH and the Bs. Threshold [19] can be calculated using residual energy and distance.

Comments

To improve on the original LEACH method, the study suggests including the distance between the node and the preceding node as a metric of change.

Energy efficient algorithms for enhancing lifetime in wireless sensor network

In this research [20], a variety of methods were used to select CH at different rounds to maximize the WSN's lifespan. The linear programming problem is solved using a polynomial-time technique. A strategy for extending network lifespan is presented for each half-life and end-of- Sensor nodes can organise themselves as well as gather information about the phenomenon and transmit data to the sink via neighbouring A fixed location node with an opportunity to associate sensor networks to existing external networks the unique characteristics of WSNs imposes difficult requirements on the prototype of the foundational techniques. sensors. life of sensors.

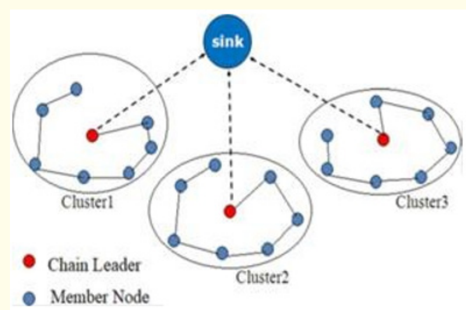

Figure 7: Chain-based topology.

Numerous extensive research projects in academic and commercial are aimed at developing communication protocols that meet these standards for sensor networks.

Comments

Since energy is the primary resource for power consumption, energy-efficient routing schemes should be developed by considering wasteful power consumption, and power-efficient, unmanaged data transfer schemes should be implemented in multiple models.

Power consumption leads to loss of power, resources and causes sink node power hole problems. Throughout the WSN, the power hole affects the network lifetime.

SSEER: segmented sectors in energy efficient routing for WSN

Segmented sector networks [21] have been proposed in this study to help extend the network's lifespan. Heterogeneity in sensor nodes is a feature, where normal nodes transmit data through direct diffusion, and advanced nodes participate in clustering. When networks are segmented, direct diffusion and clustering are used to maximise the longevity and stability of the network. In the proposed protocol, NN and AN form a two-tiered heterogeneous system. These nodes are randomly dispersed across the entire network, but the randomness is dependent on sectors. As illustrated in Figure 8, the network is separated into five sectors: sector 1, sector 2, sector 3, sector 4, and sector 5. There are 18 NNs and 2 ANs in each of the five sectors, each of which is portrayed in a distinct colour. NNs are denoted by a tiny circle (∘), while ANs are denoted by (a).

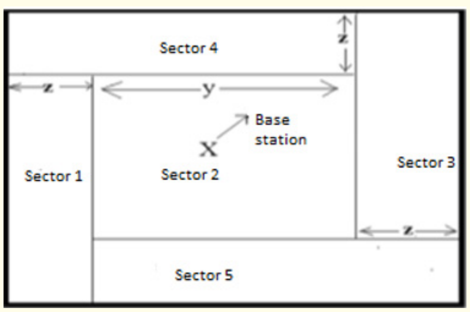

Figure 8: Selection of sector regions.

The indented network field is divided into five sectors by the suggested protocol. The distant region from BS is defined by four network region boundaries, whereas the near region is defined by the BS, which is located in the square region's centre.

Five sectors are formed by four edges of the square region and one central region. Clustering from four sides of the region increases the effectiveness of the network's four sectors, while direct diffusion increases the efficiency of the network's fifth sector, which is located in the middle region. The lifetime from the outside of the desired region can be increased due to clustering among nodes, and the intermediate region can increase the lifetime by employing a direct connection near BS.

Comments

For heterogeneous wireless sensor networks, Segmented Sectors in Energy-Efficient Routing (SSEER) is proposed for energy-efficient routing. Divide the network territory into five sectors, labelled sector 1, sector 2, sector 3, sector 4, and sector 5. The network region is divided into five sectors. All of the sectors have the same number of normal nodes and advanced nodes. As a result, SSEER exhibits variability on two levels. In this protocol, three different network scenarios are considered, namely, network sizes of 50 × 50, 100 x 100, and 200 x 200, with the BS remaining fixed at the centre of the network in all three cases. The outcome demonstrates that a smaller network can nonetheless operate admirably. It extends the network lifetime, increases throughput, and improves network stability when compared to LEACH, SEP, and Z-SEP for lower network sizes.

Conclusion

Energy efficiency is one of the major issues in the design of protocols for WSNs because of the limited energy resources of sensors. The main purpose is to prolong the network lifetime by maintaining the sensors functional as long as possible. In this paper, researchers reviewed and analysed current studies that were primarily concerned with the energy-efficient hierarchical cluster-based routing algorithms for WSNs. This study has briefly discussed examples of routing protocols. The protocols covered in this study each have their own benefits and drawbacks. The protocol and routing algorithms can be used depending on the topology.

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