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Load Balancing in Wireless Mobile Ad Hoc Networks

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Abstract

Ad hoc networks are made up of groups of similar nodes, such as computers or embedded devices. Each node works on its own and talks to the others through a wireless channel. Networks like these are made up of groups of nodes that are either next to each other or connected by another wireless node. Nodes are grouped together along their wireless links to make clusters. Nodes that can talk to other nodes in their transmission range are called cluster heads. This can use cluster heads to send packets to the right nodes in your cluster. In an Ad Hoc network, the idea behind it is that nodes don't always move in the same way. Cluster Heads are picked by different algorithms in different ways. Some of these rules make it clear that some nodes are more important than others. Because of the extra work and faster energy loss that could happen because of more contacts, these nodes may be taken out of the network. Load-balancing across Cluster Heads is necessary to make sure that every node has a fair chance to be a Cluster Head. We Proposed that a number of changes should be made to current algorithms in order to fix the uneven spread of nodes among Cluster Heads and make nodes in a network that uses the fuzzy algorithm last longer.Load balancing in Wireless Mobile Ad Hoc Networks (MANETs) ensures equitable distribution of network traffic among nodes and resources. Due to the ongoing mobility and dynamic nature of nodes in MANETs, this aspect holds significant importance.

Keywords: Ad hoc networks, Routing, Mobile computing, Quality of service.

1. INTRODUCTION

The lack of fixed network nodes—like routers and gateways—and the freedom of movement of such nodes define an ad hoc network. Clusters, made up of interconnected wireless mobile devices (such as computers or embedded devices) that can communicate with one another efficiently, are a common way for ad hoc networks to function [1]. Using the existing nodes as routers, repeaters, or gateways allows the infrastructure to be automatically established.

The time it takes for an Ad Hoc network to go from being operational until one of its nodes stops working because its battery becomes low is called its lifespan. Depending on the chosen settings, many nodes may serve as cluster heads when clusters are created in the network [2]. Keeping in touch with every other node in the network is the job of the cluster head. This node quickly loses connectivity to the network due to its battery dying from the increased amount of communications required to maintain the communication links, as compared to a regular node. This shortens the time that the network is operational. This study takes a look at several clustering methods and shows how to tweak them such that a single cluster head may distribute nodes more effectively [3].

The conventional load balancing problem involves the shift of load units from underutilized processing elements to overloaded processing components. The process entails making a migration decision, namely determining which load unit(s) should be migrated, followed by the actual migration of the load unit to different nodes [4].

MANETs, or Wireless Movable Ad Hoc Networks, are networks that don't have a central authority and are made up of movable nodes that are linked together wirelessly. MANETs are different from regular networks because they don't need permanent hardware or centralized management to work. Instead, they rely on nodes to work together and make network topologies on their own. Because MANETs are flexible, they can be used for many things, such as military activities, disaster recovery, and short-term event networks.

Load balancing is important in MANETs because the network is always changing and mobile nodes have limited resources like battery life, processing power, and bandwidth. Load balancing is an important part of Mobile Ad hoc Networks (MANETs). Its main goal is to spread data flow evenly across the network so that no single node becomes a bottleneck. It is possible to improve network speed, reduce packet loss, and make the network last longer by taking these steps.

1.1. MOTIVATION

Maximizing the network's lifetime requires optimizing clustering. Furthermore, compared to the other nodes, the Cluster Head has a faster battery drain. So, this node will leave the network before its time if there are more nodes under one Cluster Head than under any other Cluster Head. The departure of the cluster head drastically shortens the network's lifetime. Therefore, it is critical to reduce the amount of energy used when doing things like creating clusters, communicating with different nodes in the network, and checking to see whether any nodes are active. One way to accomplish this is to make sure the Cluster Head initiates communications as often as possible. One way to accomplish this is to make sure that each Cluster Head has roughly the same amount of nodes under its control by distributing the nodes fairly among them.

To ensure that no single node in a network experiences an overload, load balancing distributes processing and communication duties evenly among all nodes. Using load balancing, several computers, network lines, CPUs, hard drives, or other resources can have their burden distributed more or less evenly. Optimal resource utilization, increased throughput, decreased reaction time, and prevention of overload are the goals of load balancing.

Moving load units from unused to used processing elements is the standard approach to the load balancing problem. The first step is to decide which load units to transfer, also known as a migration decision. Then, the load units will be physically moved to other nodes.

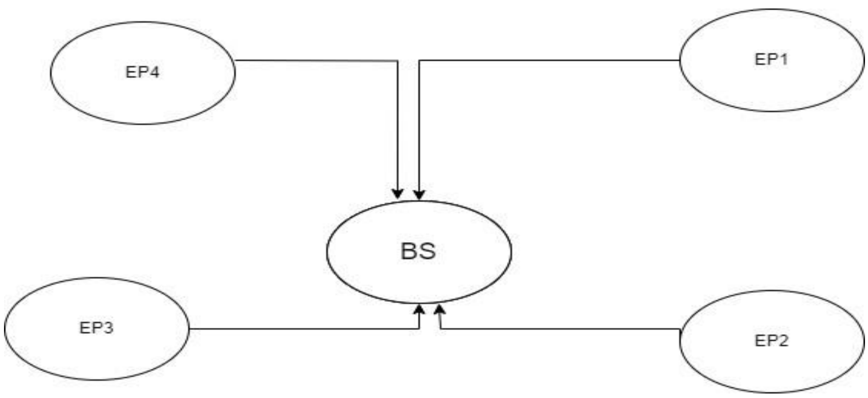

Figure 1. Wireless Sensor Network

1.2. CLUSTERS

The term "cluster" [9] refers to a group of related devices that operate as one virtual node due to their close proximity and interconnection. While there may be some instances where wired connections are used instead of wireless ones, in general, components of a cluster are linked together in this way. In comparison to using a single computer, clusters not only improve performance and availability but also reduce costs when compared to buying individual machines of the same speed and availability. They are also like a group of loosely coupled computers that work together.

Types of Clusters:

A. **High-availability clusters -** Implementing what is also called Failover Clusters [5] primarily aims to make the services offered by the cluster more available. If one component of the system were to fail, the other could take over and continue functioning normally because of the redundant nodes.

B. **Load Balancing Clusters** - Using multiple networked computers to do different computations or function as a single virtual machine is known as load-balancing [4]. There is only just one virtual computer there, even though it looks like there are multiple of them. To process user requests, the several computers that comprise the cluster coordinate their efforts. Hence, the numerous computers in the cluster may divide up the computational tasks equitably.

2. RELATED WORK

A dynamic architecture is used for communication in ad hoc networks. The establishment of a wireless infrastructure is critical to the facilitation of successful communication [10]. When nodes move around in a network, it changes the topology, which means the backbone needs to be adjusted. When selecting the backbone, efficiency and speed should be given precedence because battery-powered mobility nodes will be incorporated.

Clustering can resolve the issue mentioned above. The development and maintenance costs of clustering are higher. To maximize efficiency with the scarce resources of the nodes, existing clustering methods require enhancement.

New metrics for assessing ad hoc networks are introduced in the study: the load index and the bandwidth usage ratio. These metrics can be used to evaluate a network's performance and find ways to make it more efficient by distributing tasks more evenly. They can predict the maximum amount of demand that can be accommodated without causing any problems with congestion or overflow. The efficient load balancing method is also introduced as a new load balancing routing system in the study. By using this approach, network operations are improved and an unprotected medium can be better managed [11] [12].

By increasing scalability and making data collection more convenient, a Wireless Sensor Network (WSN) with multiple sinks is better able to manage large-scale applications. However, finding the most economical route for each sink with a consistent path length becomes more challenging when there are a lot of sinks introduced. This makes it harder to eliminate differences in energy consumption among sensors. Prior approaches to the NP-Hard problem of routing in large networks have primarily focused on reducing path length or energy consumption. This study introduces a new method, Q-GEMS, that uses a genetic algorithm influenced by quantum mechanics to distribute multiple sinks so that the energy consumption of sensors is balanced and the network lifetime is extended. The Q-GEMS can anticipate sensor failures and external influences, and it can also adapt to changes in planned topologies. Its resilience is an engineering feature. Altering the Q-bit population, assigning sensors, installing sinks, and evaluating solutions are all approached with new methodologies [13] [14].

2.1 Highest Connectivity Algorithm

The Highest connectivity algorithm [6] [7] utilizes the degree of connectedness between the two nodes to determine a cluster leader. Therefore, the node with the most robust connections to the other nodes is assigned the role of the cluster head once the process starts executing. The next cluster head is chosen from the remaining set of nodes based on identical circumstances and features.

An important problem occurs when one node is assigned a much greater amount of responsibility compared to the rest; nonetheless, the HC method facilitates the quick identification of the cluster head.

3. PROPOSED ENHANCEMENT

By utilizing algorithms and integrating fuzzy logic [10] and the concept of load transfer, we suggest an improvement to the clustering process by determining the Cluster Head.

The process of clustering is comprised of three distinct phases: Cluster Head Election, Cluster Head Selection, and Load Transfer between Cluster Heads [8].

A. **Selection of the Cluster Head:** The selection of the Cluster Head is based on a Fuzzy decision made by the nodes that will be coming under different Cluster Heads. For this fuzzy selection we use a few more parameters, namely work budget left and number of nodes under the Cluster Head. Based on these two values the node will decide its Cluster Head.

B. **Load Transfer:** This aspect of the improvements is implemented to mitigate the impact of increased workload when a new node is added to the cluster. The aforementioned process functions effectively, however, if a node attempts to join at a subsequent stage, the Cluster Heads tend to reassign this node to another Cluster Head that is comparatively less burdened.

C. **Compute Clusters**: Clusters are typically not designed to manage IO-oriented processes like databases or web services, but rather to perform computational tasks. Computational models of weather or car accidents, for example, could be supported by a cluster. The degree to which nodes in a compute cluster are connected to one another is the main differentiator. In the case of a single compute job that necessitates frequent communication across nodes, for example, this would indicate that the cluster is homogeneous, has densely located nodes, and shares a dedicated network. The Beowulf Cluster is the common name for this type of clustering [9].

D. **Grid Clusters**: On the other hand, there are cases where a compute job only employs a small number of nodes and requires minimal or no communication between them. The latter group is occasionally referred to as "Grid" computing [10]. Grid computing is most effective when processing a large number of separate tasks, or "packets of work," that do not require any shared data. Grids are useful for managing the distribution of tasks to computers, which can then do those tasks autonomously from one another [15].

3.1. Multi – Clusters Architecture

Most hierarchical clustering topologies for mobile radio networks are based on the concept of a Cluster Head. The Cluster Head acts as a local mediator for communication inside the cluster.

The concept of this system differs from the base station concept in existing cellular networks in that it does not necessitate specific hardware. Instead, it is selected dynamically from a collection of stations. Nevertheless, it carries out supplementary functions in contrast to typical stations, which may potentially make it the constraining element of the cluster. Our technique tackles these difficulties by eliminating the requirement for a Cluster Head and instead employing a fully decentralized mechanism to establish clusters and facilitate communication within them.

Cluster-based systems involve the partitioning of network nodes into many groups, as outlined in reference [9]. In each group, one node is selected as the cluster head, while the other nodes take on the function of regular nodes. The size of the cluster is governed by the transmission power of the cluster head, which corresponds to its communication range. The Cluster Head has the responsibility of overseeing and coordinating transmissions within the cluster. Additionally, it oversees the transmission of data between distinct clusters and guarantees the successful delivery of all packets designated for the cluster. In addition, the Cluster Head can communicate with nodes that act as gateways to wired networks. The durability of the network in cluster-based network topologies is directly linked to the incidence of Cluster Head failure. Cluster Heads experience increased energy consumption and exhaust their energy reserves more quickly than normal nodes.

The procedure of cluster formation consists of two phases:

1. Cluster-head election
2. Assignment of nodes to cluster-heads.

The allocation of nodes to a Cluster Head is a critical determinant of the network's lifespan. Furthermore, it is crucial to balance the load by distributing the number of nodes serviced by the Cluster Head after assigning them.

3.2. Types Of Load Balancing Algorithms

The fundamental concept of load balancing is to achieve load equilibrium across all computers by redistributing loads to idle or heavily burdened systems. Load-balancing algorithms can be categorized into three broad types. [11].

A. **Static Algorithms:** Static algorithms use a priori system knowledge to hardcode load-balancing judgments. In static algorithms, the overhead is practically nonexistent.

B. **Dynamic Algorithms:** To balance the loads at each node, dynamic algorithms look at the current condition of the system. Since dynamic algorithms can take advantage of the system's short-term variations to boost performance, they may be able to surpass static algorithms. But there is overhead when they gather, store, and analyze the system state.

C. **Algorithms that adaptively:** One subset of dynamic algorithms, adaptive algorithms modify their execution in real time to account for changes in the system's state.

3.3. Proposed Enhancement

The Simulation values:

- Unit areas measuring 250 × 250 square units.
- The cluster's size is unknown.
- The total number of nodes is {25, 50, 75, 100}.
- The time interval used for sampling is 100 milliseconds.
- The node range is set at 25 units.
- The work budget is set at 5000 units.
- The programming language used is Java.

The simulator is an application that runs on the Java platform. A dynamic network topology is the foundation of the virtual ad hoc network. A 250-unit-long and 250-unit-wide square constitutes the topology. Every node in the network is randomly placed. There is an initial allocation of 5000 units of energy (Work Budget) for all network nodes. For every node, the program asks for a range of 25 units. Nodes can travel at speeds between zero and half their communication range.

A. Selection of the Cluster Head

The selection of the Cluster Head is based on a Fuzzy decision made by the nodes that will become under different Cluster Heads. For this fuzzy selection we use a few more parameters, namely work budget left and number of nodes under the Cluster Head. Based on these two values the node will decide its Cluster Head.

B. Fuzzy Input Variables:

- **Work Budget Left**: This parameter represents the remaining capacity or resources of a potential CH to handle an additional workload. It can include aspects like energy reserves, processing capability, and communication bandwidth.
- **Number of Nodes Under the Cluster Head**: This indicates the current load or the number of nodes already associated with a potential CH. It helps prevent overloading a single CH.

After the initial selection of potential CHs using the LID algorithm, employ a fuzzy logic system to refine the selection based on additional parameters like energy, mobility, work budget left, and load. This combination leverages the simplicity of LID and the adaptability of fuzzy logic.

4. CONCLUSION

Clustering, which entails constructing the network properly, is one of the main challenges in an ad hoc system, as it includes making good use of limited energy resources. There are a few algorithms that try to solve this problem, but they don't provide a complete answer to how to make a network that uses less power.

When it comes to clustering, the LID approach is more efficient. The node with the lowest physical ID that is visible is chosen to be the cluster head and all the nodes that are within direct communication range are added to the cluster. This identification-based selection is simple and clear, reducing room for misunderstanding. A single node can be designated as the cluster head using this method. On the other hand, the average cluster head duration is reduced, making this election type disadvantageous.

A node is always chosen as the cluster head is the one with the physical ID . If another cluster head is not currently servicing any nodes in the entire sample region, this node will likewise be the first to disconnect from the network.

The existing clustering methods are rather inefficient, especially when looking at the average Cluster Head time, hence we have proposed a solution to this problem. By redistributing the network load to a less stressed Cluster Head, the suggested enhancements hope to boost the performance of the current LID method. The remaining work budget and the number of nodes served by the cluster head are two critical elements of the ad hoc network that must be monitored to achieve this. Changes to the election and selection process and the repositioning of nodes in response to post-system-operational node additions are responsible for the improvement in the network's operational duration. Because all the Cluster Heads are under more strain when the number of nodes in the sample region increases, the network lifetime decreases. As the number of nodes in a network grows, though, the decline in lifetime becomes more consistent.

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All authors contributed to the article and approved the submitted version.

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Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

[1] T. Na, H. Ryu, T. Kim, J. Park, S. Hong and P. Park, "Dynamic Load Balancing Mechanism in Mobile Gateway with Heterogeneous Network," (ICTC), Jeju, Korea (South), 2018, pp. 1549-1554, doi: 10.1109/ICTC.2018.8539667.

[2] A. Mohammed, Q. S. Mahdi, A. Alkhayyat, F. H. Abbas and N. Faisal, "Traffic and Energy Aware Load Balancing Routing Protocol for Multipath Mobile Ad-Hoc Networks," (IICETA), Al-Najaf, Iraq, 2023, pp. 863-866, doi: 10.1109/IICETA57613.2023.10351353.

[3] S. Rai, A. Mewada, M. A. Ansari and D. Kumar, "Optimizing Wireless Sensor Networks: Dynamic Load Balancing Strategy with AOMDV Routing," (PARC), Mathura, India, 2024, pp. 350-355, doi: 10.1109/PARC59193.2024.10486598.

[4] K. Boyana, V. R. Gurrala, and B. K. Babu, "Implementation of EPSORR Technique for Efficient Data Transmission in Ad HOc Networks," (ICAAIC), Salem, India, 2024, pp. 1665-1669, doi: 10.1109/ICAAIC60222.2024.10575291.

[5] M. Ismail et al., "Line-of-Sight-Based Coordinated Channel Resource Allocation Management in UAV-Assisted Vehicular Ad Hoc Networks," in IEEE Access, vol. 12, pp. 25245-25253, 2024, doi: 10.1109/ACCESS.2024.3356009.

[6] L. H. Binh and T. -V. T. Duong, "Load balancing routing under constraints of quality of transmission in mesh wireless network based on software defined networking," in Journal of Communications and Networks, vol. 23, no. 1, pp. 12-22, Feb. 2021, doi: 10.23919/JCN.2021.000004.

[7] ArnabMaji, "Load Balancing in Wireless Mobile Ad Hoc Network". National Institute of Technology, Rourkela

[8] G. Pathak and K. Kumar, "Traffic Aware Load Balancing in AOMDV for Mobile Ad-Hoc Networks," in Journal of Communications and Information Networks, vol. 2, no. 3, pp. 123-130, Sept. 2017, doi: 10.1007/s41650-017-0012-z.

[9] Soumitri Mohanty,AsitArunavMohapatra,ShaktiPinakiMisra , "Load Balancing in Wireless Sensor Network using Divisible Load Theory", National Institute of Technology, Rourkela

[10] Jiaxing Wang, Lin Bai, Jianrui Chen, Jingjing Wang, "Starling Flocks-Inspired Resource Allocation for ISAC-Aided Green Ad Hoc Networks", IEEE Transactions on Green Communications and Networking, vol.7, no.1, pp.444-454, 2023.

[11] Manisha Rathee, Sushil Kumar, Kumar Dilip, UpasanaDohare, Aanchal, Parveen, Towards energy balancing optimization in wireless sensor networks: A novel quantum inspired genetic algorithm based sinks deployment approach,Ad Hoc Networks, Volume 153, 2024, 103350, ISSN 1570-8705, https://doi.org/10.1016/j.adhoc.2023.103350.

[12] A. Keerthika, V. Berlin Hency, Reinforcement-Learning based energy efficient optimized routing protocol for WSN, Peer-to-Peer Networking and Applications, 10.1007/s12083-022-01315-6, 15, 3, (1685-1704), (2022).

[13] Li, X.; Bian, X.; Li, M. Routing Selection Algorithm for Mobile Ad Hoc Networks Based on Neighbor Node Density. Sensors 2024, 24, 325. https://doi.org/10.3390/s24020325

[14] Ehtisham, M.; Hassan, M.u.; Al-Awady, A.A.; Ali, A.; Junaid, M.; Khan, J.; Abdelrahman Ali, Y.A.; Akram, M. Internet of Vehicles (IoV)-Based Task Scheduling Approach Using Fuzzy Logic Technique in Fog Computing Enables Vehicular Ad Hoc Network (VANET). Sensors 2024, 24, 874. https://doi.org/10.3390/s24030874

[15] Juston, M.F.R.; Norris, W.R. Ad Hoc Mesh Network Localization Using Ultra-Wideband for Mobile Robotics. Sensors 2024, 24, 1154. https://doi.org/10.3390/s24041154