Grenze International Journal of Engineering and Technology, Jan Issue

A Novel Clustering and Optimization Strategy for Network Lifetime Enhancement in Wireless Sensor Network

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***Abstract*— A Wireless Sensor Network (WSN) is a collection of distributed, specialised sensors that can analyse, communicate, and sense data from a base station known as the sink. WSN is essential when a network connection is needed immediately, such as in cases of emergency surveillance, remote monitoring, healthcare, military field communication, home automation, or industrial automation. Usually, sensor nodes are positioned in inaccessible or challenging-to-reach locations. Gathering data from sensor nodes and sending it to a sink is the WSN's main duty. In essence, the sensor nodes are clustered using the clustering approach. A sensor node designated as the Cluster Head (CH) in each cluster has the power to add and remove Cluster members. The gateway (GW) node in WSNs links to many clusters for multi-hop communication. The communication overhead for multi-hop communication is kept to a minimum and the quickest path between the source node and the sink is carefully chosen. Because the CH and GW nodes were carefully chosen, the WSN's lifespan is increased while the VI sensor nodes' energy consumption is reduced. The key challenge for cluster-based routing is choosing an efficient CH and GW node. For this reason, the REAS (Residual Energy Aware Angle-based Routing Protocol for Cluster-based Wireless Sensor Networks) is recommended for the strategic selection of the CH and GW nodes, leveraging elements such as the node's residual energy and the angle and distance between the node and the sink. The setup phase and steady-state phase of REAS are used to ensure efficient information routing from the source node to the sink. When the clusters are constructed using the CM, CH, and GW nodes, the shortest routing path is determined. During the steady-state phase, data are collected from the CMs and transferred to the sink. While evaluating REAS performance, end-to-end latency, remaining energy, longevity, packet delivery ratio, and energy efficiency are all taken into account. The REAS protocol's intended platform is Network Simulator 2 (NS2) version 2.34. The performance of the SEECH (Scalable Energy Efficient Clustering Hierarchy) and ARPEES (Adaptive Routing Protocol with Energy Efficiency and Event Clustering for Wireless Sensor Networks) protocols is compared with that of the REAS protocol by varying the number of rounds. The simulation results demonstrate that, in terms of residual energy, lifetime, packet delivery ratio, energy efficiency, and end-to-end latency, the REAS protocol is superior than the ARPEES and SEECH protocols.**

***Index Terms*— Internet of Things, a wireless sensor network, a clustering protocol, energy use, and network longevity.**

I. INTRODUCTION

Nowadays, Wireless Sensor Network (WSN) is developing because of the development in embedded systems and

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wireless network technology [1]. WSN has a wide range of applications at our workplace, environment, locality, community, and beyond [2]. Both personally and professionally, it provides new sources of inspiration and convenience. WSNs comprise one of the core next-generation application fields, including civil engineering, environmental monitoring, medical monitoring, industrial automation, home security, military systems, and transportation. A WSN normally contains many sensor nodes that can sense and communicate wirelessly to send gathered sensory data to a destination for further processing. Figure 1.1 presents the concept of WSNs [3]. While evaluating REAS performance, end-to-end latency, remaining energy, longevity, packet delivery ratio, and energy efficiency are all considered. The REAS protocol's intended platform is Network Simulator 2 (NS2) version 2.34. The performance of the SEECH (Scalable Energy Efficient Clustering Hierarchy) and ARPEES (Adaptive Routing Protocol with Energy Efficiency and Event Clustering for Wireless Sensor Networks) protocols is compared with that of the REAS protocol by varying the number of rounds. The simulation results demonstrate that, in terms of residual energy, lifetime, packet delivery ratio, energy efficiency, and end-to-end latency, the REAS protocol is superior than the ARPEES and SEECH protocols. SNs are typically organized in unattended as well as hostile environments to monitor wild forests, battlefields, nuclear reactors, chemical plants, and, among other things [5]. A lot of research has been done on data collection, processing, and routing among sensors in recent years [4]–[6]. As a result, replacing or charging the battery becomes a difficult task. Not only does the sensor node sense the environment, but it also sends information to the base station (BS). A BS is a high-capacity device with unrestricted power, storage, and communication. Depending on the applications and scenarios, it could be a static or a mobile SNs. The BS collects data from SNs and sends it to the user via existing communications systems.

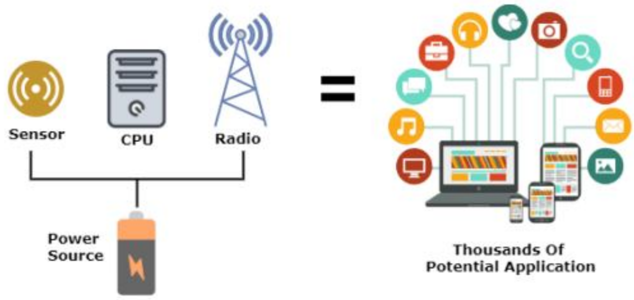


Figure 1 Concept of wireless sensor networks.

The communication in a WSN is shown in Figure 1.1. To detect environmental factors crucial to the applications, such as temperature, ambient humidity, soil moisture, and air quality, sensor nodes are randomly placed across the surroundings.

Purple and yellow hues on the WSN's display of the SNs show which SNs have joined or have not entered the communication line, respectively. Every piece of data on the energy and location of each sensor node (SN) in the WSN is gathered by the base station (BS). BS calculates the total number of cluster heads for a network with several clusters (CHs). Nonetheless, because the SNs are not connected, the number of CHs varies from round to round. Depending on the requirements of the system application, WSNs are configured as either mobile or static networks. By positioning sensor devices in preset places, a static WSN is produced [7]. Multi-hop communication is employed if the transmission range of the sensor node is exceeded.

A routing protocol aids in transmitting the data from the SNs to the BS successfully [8]. Static WSN, on the other hand, cannot adequately monitor applications with intrinsic mobility. Sensor nodes may need to be connected with the phenomena being monitored in applications where animals or humans are examples of mobile phenomena that are being monitored. A MWSN or dynamic WSN is a network that uses sensor devices. Like static sensor networks, MWSN nodes cannot create a stable routing structure [9].

II. RELATED WORKS

WSNs operate in terrain that people cannot access. To efficiently convey data from sensor nodes, energy-saving technologies are required. Cluster-based routing in WSNs aims to increase network lifetime while reducing energy consumption. This chapter delves deeply into the research initiatives conducted by multiple authors for successful cluster-based routing in WSN. The three categories listed below may be used to categorise the CHs, GW nodes, and routing path selection in cluster-based approaches discovered in the literature survey:

i. Clustering and cluster head selection approach

ii. Gateway node and routing path selection approach
iii. Mobile sink-based routing and data gathering approach.

A. Clustering and Cluster Head Selection Approach

Routing protocols in cluster based WSNs depend on clustering and the CH selection. Hence, it is the basic and the most important service that helps in finding the efficient routing path to reach the sink. A survey on the CH selection for cluster based WSNs is discussed below. The development of clustering mechanisms is essential for WSN energy efficiency. Basic clustering methodology for WSNs has been proposed by Heinzelman et al. (2000) and is known as LEACH (Low Energy Adaptive Clustering Hierarchy). It is the most well-liked distributed cluster creation energy-efficient clustering protocol. This system's primary goal is to improve energy efficiency by reducing energy consumption and ensuring that the load is distributed evenly among all of the sensor nodes. There are rounds in the LEACH protocol function. The two phases of a round are: both the initialization and steady-state phases. Clusters are constructed, nodes are deployed, and cluster chiefs are chosen during setup. Based on the predetermined value p, the cluster head is selected (the desired percentage of cluster heads in the WSN). Each node in this stage might either be a cluster member or the cluster leader. A number between 0 and 1 is chosen at random by each wireless sensor node. The node whose random number is below the specified threshold value T is chosen as the cluster head for that round (n).

Heinzelman et al. (2002) created the LEACH-C (Centralized-LEACH) protocol, which uses a centralized clustering mechanism to build the clusters. Each node transmits to the sink information about its position and energy level in respect to the other nodes in the network, according to this scheme. Based on this data, the sink determines the number of clusters, and the CH is determined by the cluster's centre node. The energy of the sensor nodes is drained early in the setup phase to obtain global information in this approach. This scheme is not robust and has a relatively high overload. A new approach suggests the formation of clusters only once and they are fixed. The sink node decides the CH selection based on the rotation among the various nodes within the cluster. This leads to the node’s flexibility in the cluster. Dhawan et al. (2014) have analyzed LEACH-F (Fixed-LEACH). In this scheme, the next CH selection is based on the status of all the nodes in the cluster. This scheme is the same as LEACH and LEACH-C.

This protocol is made up of two segments: the setup phase and the data transfer phase. During the setup step, clusters are created, and cluster heads are chosen. The cluster head is chosen in the same way as LEACH is, but the threshold value is computed based on the quantity of energy left in the node and the number of neighboring nodes. The order of events and the shortest path to the sink are critical considerations in the data transmission phase. It has given a better network lifetime compared to LEACH, but the direct routing between the cluster head and sink has drained the energy easily as there is no relay node usage which has created high energy consumption among the nodes thereby leads to an inefficient routing scheme. An unequal clustering mechanism is an effective way of establishing large number of nodes by uniformly distributing the load. Mao Ye et al. (2005) have presented EECS (Energy Efficient Clustering Scheme) for periodical data gathering applications for WSN.

B. Gateway Node and Routing Path Selection Approach

In multi-hop communication, the sensed data need to be routed over a long distance to reach the sink which reduces the strength of the information and consumes more energy. Hence the GW nodes are required to send the information efficiently to the sink using multiple hops. The routing path selection is an important factor for achieving energy consumption in WSN, since the link or path failure causes large number of packets drops in the network. Hence the dynamic path selection is required for the achievement of a high packet delivery ratio. The following section analysis the various reviews based on GW node selection and dynamic routing path selection. A link-aware clustering method (LCM) has been presented by Wang & Chen et al. (2013) to enable energy-efficient routing for cluster-based WSNs. This protocol uses a carefully chosen combination of cluster heads and gateways, along with a foreseeable high transmission count, to achieve energy efficiency (PTX). The dependability and energy efficiency of this method are achieved, however the optimal cluster head or gateway node in the WSN cannot be chosen using the CH selection criteria, which only take into account the node's residual energy and distance[10-12]. A Passive Clustering (PC) scheme for WSN has been developed by Kwon & Gerla (2002). This mechanism describes all the nodes in the network with their own state. The receiver node changes its state depending on the sender node state and all the nodes update the new state to their neighbors, with the knowledge of the current cluster state. This passive clustering technique has reduced additional load by reducing the control packets in the network. This passive clustering uses the random CH selection procedure to reduce the battery power very quickly making the CH selection and the routing scheme inefficient.

C. Mobile Sink-Based Routing and Data Gathering Approach

In mobile sink-based WSNs, the position of the mobile sink is always in an ad-hoc manner, making the routing and data gathering more challenging. Hence the following section presents a survey of the 48 mobile sinks based WSNs. Zahhad et al. (2015) have proposed (MSIEEP) which avoids the energy hole problem by minimizing the total dissipating energy in communication. The above scheme uses AIA (Adaptive Immune Algorithm) in order to reduce the communication overhead control packets in the network and optimizing the required number of CH in the network. AIA identifies the location of the CH and also the mobile sink [13] which leads to the reduced energy consumption while communicating between the CH and mobile sink. Rani et al. (2016) presented a BDEG (Big Data Efficient Gathering Algorithm) for real time data gathering using RSSI (Received Signal Strength Indicator) data communication methodology. The static approach is followed, for determining the clusters. The CH and the relay node selection considers the residual energy of the node. The data gathering in various nodes is indicated through RSSI. This scheme achieves load balancing and increases the lifetime of the sensor nodes. In this scheme, the CH selection is based only on one parameter and the total distance for data transmission is high leading to an inefficient mobile sink-based routing scheme for WSN. Takaishi et al. (2014) have proposed a methodology which describes the sink mobility utilization to assist data gathering in a densely distributed WSN. This scheme describes the modified maximization technique and the cluster optimization for reducing energy consumption [14]. This algorithm groups the nodes based on their communicating ability.

III. Solution Proposed

A Wireless Sensor Network (WSN) is a self-contained network of specialised, geographically separated sensors that can identify, evaluate, and communicate using radio signals. Environmental characteristics including temperature, sound, pollution levels, humidity, wind speed, and others may be monitored and measured using it. To reduce the energy consumption of the sensor nodes, which is the main issue in the WSN and has a significant impact on the network's functioning, the data collected from various sensor nodes is transferred to the sink. One method for utilising WSNs with minimal energy consumption is cluster-based routing. The basis for the CH selection processes in cluster-based routing is frequently random selection or the node's residual energy. But this is an inefficient methodology since some nodes contain high energy but the distance from the node to the base station is high, which results in early depletion of energy. In the random selection procedure, the node that contains minimum energy which is selected as the CH quickly drains the energy level, thereby reducing the lifetime of the network. In the GW node selection procedure, the nearest node to the sink is frequently selected as the GW node. But that node receives heavy messages compared to other nodes, which minimizes the energy of such nodes easily 59 leading to error-prone situations in WSNs. So the GW node is also very important and requires careful selection. Hence, the CH and the GW node selection is an important issue in the energy efficient cluster-based routing protocol for the WSN. In this chapter REAS protocol is proposed for WSN through strategic selection of the CH, GW node and the shortest path from the source node to the sink.

To improve the energy efficiency in WSN, the routing protocols use the cluster-based routing. Different cluster-based routing protocols have been used for minimizing energy consumption through efficient selection of the CHs and GW nodes. The CH or GW node was chosen in prior conventional cluster-based routing protocols either at random or depending on the remaining energy. suggested the SEECH protocol, where the node location is used to determine which CH and GW nodes are chosen. The GW nodes are chosen to be closer to the sink than the CH nodes, which are chosen to be farthest from the sink. The selection of CH and GW nodes must consider many parameters. These problems serve as the impetus for the suggestion of a cluster-based routing protocol with an effective CH and GW node selection, considering variables like the residual energy of the 60 node and the angle and distance between the node and the sink in order to increase the energy efficiency in the system.

The REAS protocol achieves energy efficiency by carefully selecting the CH and GW nodes along the shortest route from the source to the sink. REAS has two steps in order to provide successful routing: setup and steady state. During setup, clusters are built using CM, CH, and GW nodes, and the shortest routing path is determined. During the steady-state phase, data is collected from the CMs and sent to the sink via the CH and GW nodes. The protocol assumes that each sensor node has its own ID, that all sensor nodes have the same energy levels, and that the sink is stationary and remote from the sensing field. Each sensor node has a GPS device fitted so that they may track their own geographic location. The 61 sensor nodes may be switched between sleeping and inactive states. Each round contains a complete cycle for constructing clusters, selecting CH and GW nodes, and transferring data to the sink. Every sensor node has the same energy and rate. The REAS protocol block diagram is shown in Figure 3.1. The parts that follow go over the many aspects of the REAS protocol, such as cluster setup, REAS message formats, how the protocol operates, and intra- and inter-cluster routing. The CH selection phase, the CH selection algorithm, the GW node selection phase, the GW cluster formation algorithm, and the GW route selection algorithm are covered in this procedure.

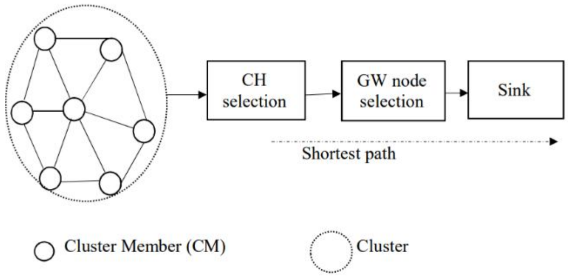


Figure. 2 Block diagram of REAS protocol

Cluster Head Selection Mechanism In cluster-based routing, CH which is the backbone of the cluster performs all the required functions in the network, such as cluster formation, CM insertion, CM deletion and communication. As a result, the CH must be chosen with care. In the REAS protocol, CH selection factors include the angle and distance between the node and the sink, as well as the node's residual energy. The network area is dotted with n sensor nodes. The source node is CH selection GW node selection Sink Shortest path 62 considered as the tentative CH (TCH) for each round. All the sensor nodes execute a CH selection algorithm to select the CHs. For example, consider node j to be the CH. Then node j calculates CHn which determines its chance for being a CH.

The CH sends the CH advertisement message CHn (j) to all the sensor nodes within the region. The nodes receive the message and reply with the join message (JOIN_MSG) to that particular CH. After successfully receiving the join message from the sensor nodes in the network, the CH accepts the nodes as CMs for that particular CH. The CH sends the reply message (REP_MSG) to all CMs. Each CM sends the sensed data to the corresponding CH. The CH searches for the shortest path towards the sink and transmits all the gathered data to the sink using single-hop or multi-hop routing through the GW nodes.

The various steps involved in CH selection process are described below.

Step 1: When all the sensor nodes are randomly put in the defined location, networks are formed.

Step 2: The source node is first chosen as the tentative CH (TCH).

Step 3: To choose the CHs, each sensor node calculates its residual energy, angle, and distance from the sink.

Step 4: The node which contains the maximum value becomes the CH in the network for that particular region.

Step 5: The selected CH sends the CH advertisement message to all the sensor nodes within the region in the network.

Step 6: The sensor nodes in the network receive the CH advertisement message

Step 7: The sensor nodes respond with a reply message (JOIN_MSG) to the CH.

Step 8: CH receives the JOIN_MSG from the various sensor nodes within the region and forms the clusters and CMs.

Step 9: The CH sends the reply message (REP_MSG) to all the CMs.

Step 10: The CM respond to the selected CH and sends the sensed data to the CH.

Step 11: The CH gathers all the data and sends it to the sink using the shortest path.

VI. Simulation Report

The main results of the suggested methodology are described in this section as they appeared after being applied to the NS tool. To establish the study's significance and reliability, we employed two phases of assessment in this study, the first of which is given below. The ground station has no resource constraints in terms of energy, memory, or computing capabilities. The ideal network protocol was based on a WSN with a base station that was located outside the network and nodes distributed at random inside a two-dimensional square region of length (M, M). The network also makes the following assumptions: After deployment, and both nodes and the base station remain immobile.

Nodes all start with the same amount of energy and are physically inaccessible. As a result, these nodes couldn't be refilled.

- The identify of each node is known to the base station.
- Determine node behavior, the radio energy consumption model is employed.
- Nodes are aware of their location in the world.

A. Comparison Packet Delivery Ratio

By dividing the total number of data packets sent from sources by the total number of data packets arriving at targets, the packet delivery ratio can be calculated. The total number of packets received at the destination is divided by the total number of packets broadcast from the source to arrive at the packet delivery ratio.

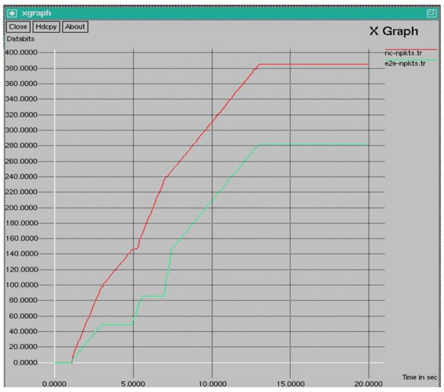
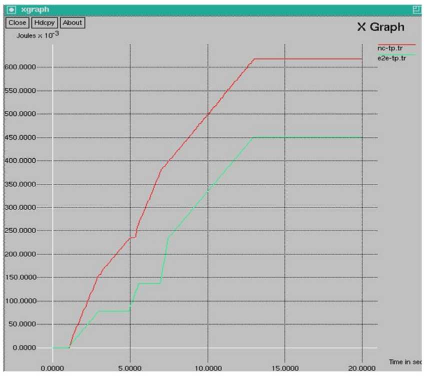


Figure 3. packet delivery ratio

B. Comparison Of Throughput

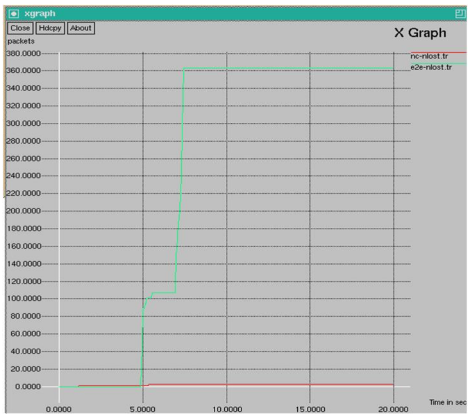
The rate at which a certain amount of data may be transferred between two sites is measured in bits per second (bps), megabits per second (Mbps), and gigabits per second (GB/s) .



• Figure 4. throughput

C. Comparison of Overhead

Each transmission contains "overhead" data required to route the data to the desired location. Network overhead may be calculated by sending a fixed-size data transfer through the network and then computing the additional bytes of data transmitted to complete the operation.



• Figure 5. overhead

D. Comparison Of End-To-End Delay

Network latency is a telecommunications service productivity and network design factor. It is the length of time it takes for a piece of data to move from one transmission endpoint to the next across a network. It is referenced frequently in fractions or tenths of a second.

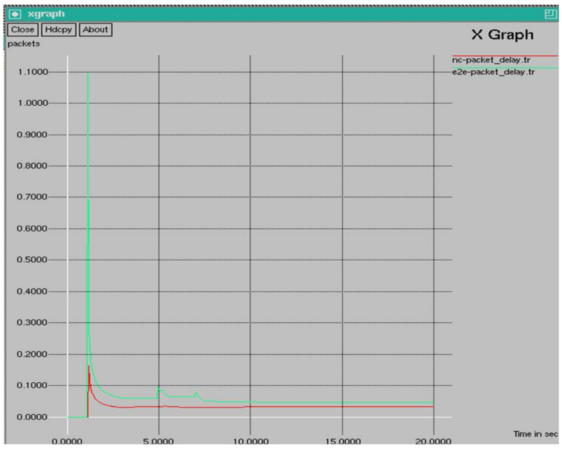


Figure 6. End-to-End delay

E. Comparison of energy consumption

It is critical to determine how much energy is consumed by various tasks. Each procedure necessitates a certain amount of electricity for a specific length of time. Sensor nodes are being researched to lower their energy consumption while retaining a wide communication range.

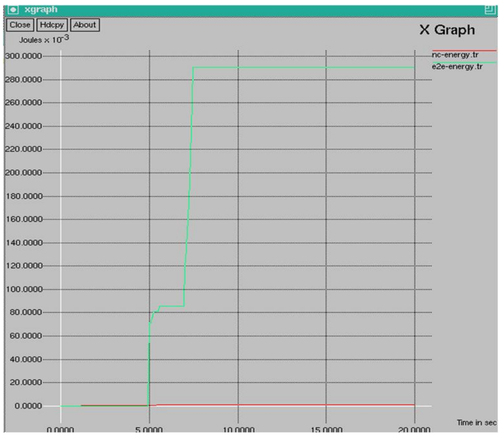


Figure 7. energy consumption

V. CONCLUSION

Now-a-days, WSNs are essential for mankind finding versatile and challenging applications in various fields, such as monitoring and tracking. Cluster-based WSN is an emerging research area with great challenges, especially in routing. Energy efficiency is the major issue in WSNs due to various factors, such as sensing, computation and especially routing. Although several cluster-based routing mechanisms have been proposed, some routing issues still have to be addressed, based on the CH selection, GW node selection, routing path selection and routing with mobile sink in the network. Furthermore, because different cluster-based routing algorithms pick CHs and GW nodes based on parameters such as residual energy or random selection, the nodes' energy consumption is optimised, depleting the energy of the network's sensor nodes. As a result, an efficient cluster-based routing protocol that decreases the energy consumption of the sensor nodes through effective selection of the CH and GW nodes based on variables such as the angle and distance between the node and the sink, as well as the node status, is required. This is believed to be the key contribution of this work.

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