International Journal of Smart Sensor and Adhoc Network

Volume 3 | Issue 3 Article 9

March 2022

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Recommended Citation

Alli, S K Jawed and Senapati, Sudhir Kumar (2022) "An Empirical Analysis of cluster-based routing protocols in wireless sensor network," *International Journal of Smart Sensor and Adhoc Network*: Vol. 3: Iss. 3, Article 9.
DOI: 10.47893/IJSSAN.2022.1224
Available at: https://www.interscience.in/ijssan/vol3/iss3/9

An Empirical Analysis of cluster-based routing protocols in wireless sensor network

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Abstract

Wireless Sensor Networks (WSNs) are utilized for condition monitoring, developing the board, following animals or goods, social protection, transportation, and house frameworks. WSNs are revolutionizing research. A WSN includes a large number of sensor nodes, or bits, in the application. Bits outfitted with the application's sensors acquire nature data and send it to at least one sink center (in like manner called base stations). This article simulates energy-efficient network initialization strategies using simulation models. First, an overview of network initiation and exploration procedures in wireless ad-hoc networks is provided. The clustering-based routing strategy was selected since it's best for ad-hoc sensor networks. The clustering-based routing techniques used for this study are described below. LEACH, SEP, and Z-SEP are used. MATLAB was used to implement and simulate all routing protocols. All protocols were simulated with various parameters like Number of CHs, Number of Alive Nodes, Number of Dead Nodes, Number of packets to BS, and circumstances to show their functioning and to determine their behavior in different sensor networks.

Keywords: WSN, LEACH, SEP, Z-SEP, Cluster Head

1. Introduction

WSN or Wireless Sensor Network consists of many sensors and a base station [1]. Autonomous sensors have battery control, computing capacity, communication range, and memory. They also have transceivers to gather data from their surroundings and send it to a base station, where the observed parameters may be stored. In most cases, sensors characterizing these systems are provided randomly and left unmanaged [5]. Due to its arbitrary construction, WSN node density varies over its territory. Sensor networks require a lot of energy because the individual sensors are so power-hungry. These sensors have small, limited-range communication devices. Both hub density differences throughout the network and sensor hub energy constraints cause hubs to pass on, making the network less dense. It's common to broadcast WSNs in harsh conditions, which destroys many sensors. These systems must be fault-tolerant to minimize maintenance. Network architecture is constantly and violently changing, thus it's not a good idea to add superfluous sensors to replace old ones. Creating routing patterns that work well and use as little energy as possible for node connections is a real and perfect solution. WSN sensor devices report events to the base station. In this method, sensors in the same network area might exchange attribute comparisons.

Both the probable difference of hub density across a few locations of the network and the vitality constraint of the sensor hubs make hubs progressively pass on rendering the network less dense. It is a frequent practice to put WSNs into severe environments, which renders a great number of sensors either inoperable or defective. Because of this, these systems need to be able to tolerate errors in order to reduce the amount of maintenance that is required. In most cases, the topology of the network is dynamically and consistently shifting. Implementing routing protocols for the communication between nodes that are efficient in their operation while using the least amount of power feasible is a true and appropriate solution to this problem. Sensor devices that are part of WSNs keep an eye on the same event and communicate their findings to the base station.This is a terrific technique since it allows for more accurate results. Sensor networks need the use of protocols that are specific, information-centric, capable of information aggregation, and capable of maximizing the exploitation of vitality [1]. The following are some more characteristics that a perfect sensor network needs to have:

- Attribute-based tending is applied rather often in the context of sensor systems. The attribute-based addresses are made up of a set of attribute-value pairs, each of which identifies a particular physical parameter that has to be sensed.
- Being conscious of one's whereabouts is yet another crucial concern. It is advantageous for the hubs to be aware of their position whenever it is required since the majority of the information that is collected is dependent on location.

As technology develops, wireless sensor networks (WSN) are seizing up opportunities for use in mobile relationships [6]. There are two alternative ways to demonstrate adaptability in a mobile wireless sensor network (WSN) (MWSN). The explanation with the least amount of confusion is the one in which the sensor center points remain static while the sink center points are the ones that move. For instance, crops on a farm may contain sensors that make estimations about the temperature or moisture level of the crops, and whenever a farmer moves about, his self-propelled cell functions as a sink center in order to download information about the crops. The second step is to maintain static sinks while ensuring that sensor centers are adaptive to various circumstances, such as when they are attached to animals in subsequent applications. When the animals are inside the sensor's range, the information that follows may be collected by using a static sink, which can be employed in this scenario since the information is put away in the sensor center points. In the end, the two approaches may be combined, which will provide all center points access to the WSN and make the network adaptable. For instance, in a private setting for developed individuals or for persons with deficiencies, sensors that are attached to them may give information to the mobile phones of the partner work constraint [7]. In spite of the fact that coordinating traditions for MWSN presents an extra layer of complication, the capacity to carry waste comes with it the possibility of reducing the number of skips to the sink center point. According to what is shown in [8], the probability of there being something close to a sensor hub in the extent of a sink increases as the correspondence range increases, the speed of the centre point increases, and the number of sinks increases. This results in a reduction in the amount of inactivity that occurs. In any event, situations of great transportability could hinder certain transmissions from effectively passing on messages [9]. Any kind of distant contact, from one point of view, calls for a baseline amount of time to be completed. On the other hand, a capricious coordinating tradition may need the presence of extra robustness constraints in order for a sensor center point to be able to communicate with a sink [10]. The objective of this research work is summarized as follows:

i. To implement cluster-based routing protocols such as LEACH, SEP, and Z-SEP.
ii. To measure the performance of the implemented algorithms by using the number of cluster heads9, alive node, and dead nodes with a different round of iterations.

2. Literature Survey

LEACH, a flexible bunching convention for distributing the system's energy burden across the sensor hubs, was introduced by Burgos et al. [5]. Drain increases the lifespan by using the randomized rotation of the group base stations or bunch heads and comparing groups to distribute energy dispersion evenly among the sensors. The advantages of using bunches for information transmission to the base station include smaller transmitting separations for the overwhelming majority of hubs and the need for just a few hubs to broadcast information across long distances to the base station. By employing flexible groups and spinning bunch heads, it improves the performance of conventional bunching computations, enabling the system's energy requirements. Additionally, each bunch may have a neighborhood calculation performed by this standard, which reduces the amount of data that has to be communicated to the base station. This results in a significant reduction in energy distribution. The author of [9] also suggested M-LEACH, a steering convention for mobile remote sensor systems that is energy efficient. A few LEACH convention features include the selection of the bunch head area to lessen the absolute power weakening. In this convention, each hub provides data, such as locations and energy levels, to the base station during the setup stage. Then, during the transmission stage, each hub sends data at the designated transmission time. Cluster-tree LEACH, which supports single or many cluster systems, has been introduced in [10]. In a multi-bunch organization, each individual group serves as the group head, and these group heads are fixed in each bunch during the course of the system's existence. The lifespan of the system has been increased by approximately half thanks to this practice. The author of [18] introduced PEGASIS, an insatiable chain convention that resolves the problem of distant sensor systems' information collecting. The main problem is that each hub communicate with its immediate neighbours, broadcast to them, and alternate being the transmission pioneer to the base station. This strategy will distribute the energy burden across the sensor hubs in the system fairly. The hubs are first placed arbitrarily in the field, and the sensor hubs are designed to create a chain. This chain may either be grown by the sensor hubs using a voracious calculation starting from some hub, or it can be grown externally. However, the base station is capable of understanding this chain and relaying information to the numerous sensor hubs. All hubs use the insatiable calculation after having access to the system's global information in order to advance the chain. Because this problem is similar to the one with travelling sales representatives, a circle will be constructed to ensure that all hubs have near neighbours. Before starting the first round of communication, the basic approach for constructing the chain is completed. By eliminating the overhead of dynamic bunch generation, reducing the number of transmissions, and using just one transmission to the base station every round, it shows superior performance as compared to LEACH and shows greater progress if the system estimate increases.

PEACH is a bunching convention that Akcan et al. [27] devised in order to extend the lifespan of remote sensor systems. Sensor hubs can reduce information bundles by collecting information on WSN thanks to bundling standards. By hearing (for instance, sensing) the surrounding hubs in distant sensor arrangements, a hub may determine the source and the destination of bundles broadcast. In order to provide a flexible staggered grouping, this is meant to function on probabilistic guiding conventions. Compared to the present grouping conventions of the remote sensor systems, it is often more adaptive and efficient to the various settings because of the convention structure. This concept may be used to distant sensing systems that are both aware of their surroundings and unaware of them. When no hub's area data is available on the system, the area ignorant convention may be used. By reducing the size of the information packages, WSN's communication costs are reduced, and bunching conventions extend the life and maximizethe energy efficiency of distant sensor systems. When compared to the existing grouping rules, PEACH has no overhead on bunch head determination and constructs adaptable staggered bunching. The first convention made for receptive systems was suggested by Manjeshwar and Agrawal in [7], and it is called Youngster. In this, the bunch leader interacts with its members at the time of each group change. By allowing hubs to broadcast only when the detected characteristic is within the range of interest, the hard limit seeks to reduce the number of communications. The delicate limit eliminates any transmissions that may have typically occurred when there was practically no alteration in the detected feature with the hard limit, thus reducing the number of broadcasts. The main drawback of this scheme is that if the requirements are not met, the hubs won't ever communicate, the client won't get any information package from the system, and they won't be remembered in the event that they pass away. As a result, this strategy isn't suitable for applications where the client must get information routinely. A realistic implementation would need to ensure that there is an impact-free group, which is another problem. To save transmission energy, the author of [11] developed a SOP standard that combines a bunch design of Drain with multi-bounce direction. Multiple WSNs get multi-jump steering. As a result, a hub is created that must provide data to a target hub, as well as one or more intermediary hubs. Each hub communicates with the others until the information bundles succeed in their aim. In essence, the information bundles move across the system's hubs a few times. The primary advantage of this technology is the reduction in transmission energy use. However, as the system becomes less active, the delay of information packages will increase. The multi-bounce steering may sometimes result in good energy efficiency even in the absence of rigid requirements on inactivity. When groups are sorted out according to this norm, the bunch heads create a multi-bounce steering spine. For communication purposes, the group leader receives information from each hub in the group. While a multi-bounce directive is received for communications between the group head and the base station in order to save transmission power and keep the disparity in energy use among all hubs in the system to a minimum. Crash evasion tools have been introduced to the CSMA Macintosh convention in order to reduce the chance of crashes during setup. It is more pertinent to WSN in this regard. The assumptions are considered in the same way as a Filter seeing the system display as a pursuit. This means that all hubs may use control to change their transmission control and go. In the meanwhile, each hub has sufficient preparation capability to support various conventions and flag handling tasks. With the use of guiding calculation, Huang et al. [19] enhanced system execution and the hand-off hub situation plot for remote sensor systems. This practice is especially helpful in cases where sensor hubs cannot be reached or replaced properly. In the suggested technique, a multi-hop Stack structure with the transfer, source, and sink hubs is used.

3. Methodology

3.1 Leach Protocol

Low Energy Adaptive Clustering Hierarchy was the name given to the progressive routing computation for sensor systems that was introduced by Heinzel man and colleagues [6]. (LEACH). LEACH sorts the hubs in the system into smaller groups and selects one of those bunches to serve as the leader of the group. The hub first determines whether or not it has succeeded in its mission, and then it relays the pertinent information to the bunch leader. After that point, the leader of the group will tally up all of the information obtained from each of the hubs, pack it up, and transmit it to the base station. When compared to other hubs, the hubs that are selected to serve as the group head emit a greater quantity of energy. This is because it is necessary to transfer information to the base station, which may be located in a remote location. Therefore Filter makes use of an uneven turn of the hubs that are needed to be the bunch heads in order to fairly transmit the amount of energy that is being used in the system. Following a series of reenactments carried out by the designer, it was determined that just 5% of the total number of hubs are required to function in the capacity of bunch heads. Macintosh TDMA/CDMA is used to reduce the effects of both the effects between groups and the effects within groups. This pattern is used in situations where regular monitoring by the sensor hubs is necessary since information accumulation is centralized (at the base station) and only takes place on occasion. The LEACH protocol works in two different phases as described below:

- ***The establishment of the cluster:***Once the cluster headers have been selected, they use the Macintosh convention in order to send ADV news to the various hubs. ADV news consists of a hub ID and a parcel header, both of which are employed as identifying news. The hub makes the decision to join with the bunch based on the flag quality that it receives, and it then sends an invitation (Join-REQ) to the comparing group header using the Macintosh protocol. The Join-REQ query takes into account the hub ID, the bunch header ID, and the parcel header. After bunch creation is done, group header sets up TDMA mechanism, and warns their portion hubs of information transmission schedule opening. The TDMA component effectively ensures that the information transfer inside the cluster will be fluid, and it avoids the correspondence conflict that may occur within one group.
- ***The Phase of Data Transmission:***This stage lasts for a considerable amount of time in the distant sensor network. However, the remote collector of bunch header should always keep open so that it can get the information sent by part hubs all at once. Each hub will only send information when there is enough space, and when there isn't enough space, it will close the communication module and go into a dormant state. To prevent this interaction, any communication that took place inside the group would inevitably have an effect on the people immediately around it. The bunch hubs that

are not part of a single group all participate in the CDMA transmission process. When a single hub is about to take on the role of group header, it will first choose one code from a code arrangement to serve as the header for the group as a whole, and then it will deliver that code together with the TDMA space table. When the component hubs are in possession of the data, they will transmit it employing this code. This will guarantee that their communication with the group will not impact the activities of other groups. Part hubs deliver the collected information to the bunch header, and the bunch header intertwines the information to kill information connection and packs it into a successful information that has the base limit, and then the group header finally sends the combination information to the base station.

3.2 Stable Election Protocol (SEP)

The term "Stable Election Protocol," often known by its acronym "SEP" [4,] refers to a system in which both normal and advanced nodes are deployed in a haphazard manner. If a significant number of typical nodes are placed in a site that is quite a distance from the base station, those nodes will have to use more energy in order to relay data to the base station, which will lead to a decrease in both the stability period and the throughput of the network.Nodes that are further away from the base station, such as those in the network's corners, require more energy to transmit data. As a result, these nodes are given more energy and are referred to as advanced nodes. This is in contrast to nodes that are closer to the base station, which are known as normal nodes and send data directly to the base station. The acronym for the procedure known as the Stable ElectionProtocol (SEP) describes how it works to improve the stable region of the clustering hierarchy process by making use of the characteristic parameters of heterogeneity. These parameters include the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (). The SEP makes an effort to keep the constraint of well-balanced energy consumption in order to make the stable zone last for a longer period of time. Intuitively, advanced nodes have a greater obligation to take up the role of cluster head than regular nodes do. This obligation is analogous to a fairness limit placed on the amount of energy used.

3.3 Zonal Stable Election Protocol (Z-SEP)

The SEP protocol was expanded, which resulted in the creation of the abbreviation ZSEP, which stands for Zonal Stable Election Protocol. It is a hybrid protocol in which the network field is divided into three zones depending on the energy level and the Y coordinate of the network area. These zones are separated from one another by the energy level. The names given to each of these zones are zone 0, zone 1, and zone 2, in that order. There will be a randomized deployment of normal nodes in zone 0; half of the advanced nodes will be deployed in head zone 1; and the remaining advanced nodes will be deployed in head zone 2. ZSEP employs not one, but two distinct approaches in order to transmit data to the base station: the first of these approaches is direct communication, and the second is transmission via the cluster head. Direct communication is a method in which regular nodes situated in zone 0 detect and gather data of interest, which they then send directly to the base station after having done so. In the second scenario, a cluster head is chosen from the nodes in both head zone 1 and head zone 2; after this has been done, the cluster head will detect and collect data, then it will aggregate this information before sending it to the base station. When sending data to the base station, Z-SEP makes use of two different methods. Techniques are:

- ***Direct Communication:*** The nodes in Zone 0 communicate their data to the base station in a direct manner. The environment is sensed by normal nodes, which then collect data of relevance and transmit it straight to the base station.
- ***Transmission via Cluster head:*** The nodes in Head zone 1 and Head zone 2 use a clustering technique to transfer data to the base station. The cluster head is chosen from among the nodes in either the Head zone 1 or the Head zone 2 zones. The cluster head is responsible for collecting data from the member nodes, aggregating it, and sending it to the base station. The selection of the cluster head is of the utmost importance. As can be seen in Figure 1, advance nodes are placed in both Head zone 1 and Head zone 2 in a random fashion. Only the most advanced nodes will form the cluster.

4. Empirical Analysis

These minuscule sensor nodes have limited vitality and memory, thus directing conventions that have the ability to simplify the directing complexity are quite appealing. This may be accomplished in a number of ways, one of which is to use a topology that is not the same as a conventional flat topology, assign the steering responsibilities to a small number of nodes, and then periodically rotate this. In this section, we will provide a little prologue to the sensor organize demonstrate, which will serve as the foundation for the protocols that we have developed. We take it for granted that each of the nodes in the system is identical and that they all begin with the same amount of initial vitality. The BS has the bandwidth to transmit directly to the sensor nodes, which provides a rapid means for the down-connect to take place. In spite of this, the sensor hubs often are unable to do this due to the restricted power supply they have, which results in an incorrect correspondence. Due to the severe energy requirements, hierarchical clustering has emerged as the model that proves to be the most viable option for wireless sensor networks.

This group head adds up all of the information that was supplied to it by the whole of its members and then forwards it to its higher dimension group head (hub 1) and so on and so forth until the information reaches the BS. As a result of the fact that CHs execute functions that need a greater amount of energy, and in order to appropriately equalise the CHs' usage of energy, groups exist for a period of time referred to as the bunch time frame T, and then BS regroups the groups. This takes place at the same moment at what is termed the bunch change time. The following are the primary distinguishing features of such a design:

- Each of the hubs must communicate simply to their fast bunch head in order to save energy.
- Only the quick bunch head is required to carry out further computations on the information, such as conglomeration, and so on. As a result, there is a moderation of energy.
- The bunch members from a group are often next to one another and detect similar information. This information is collected by the CH.

- The CHs at higher levels in the chain of command are required to convey information across distances that are typically farther apart. In order to ensure that this use is distributed evenly, each hub takes turns acting as the CH.
- The complexity of the steering process is simplified as a result of the fact that only the CHs need to be aware of how to direct the information towards its higher-level CH or the BS.

The number of Cluster Head:

A hierarchical protocol is one in which the majority of the nodes send their transmissions to the cluster heads, and then the cluster heads aggregate, compress, and send the data on to the base station (sink). Because large volumes of data need to be sent throughout the conversation, and the Cluster Head is wholly responsible for delivering the packets to where they are supposed to go in their proper form. The overcrowded state of the Network is caused by the haphazard and unequal deployment of cluster heads in Leach. Because LEACH is done via proactive routing, there is an equal chance that any given node will take over as the cluster head. However, as TEEN is a reactive network, the decision of which node should serve as the cluster head will be based on the amount of data flow. So the quantity of cluster head will fall substantially.

The total number of alive nodes:

This measure provides information on the total lifespan of the network. First and foremost, it provides an indication of the geographic coverage provided by the network throughout the course of time.

Since LEACH is a proactive routing system, in contrast to TEEN, it maintains a greater number of active nodes in its network than does the latter. In LEACH, each node must be actively participating in the transmission of the packet. TEEN, on the other hand, is a reactive routing protocol, which means that only the needed number of nodes that are aware of the destination node will participate in the connection. When compared to the other algorithms, the number of active nodes in APTEEN will be much higher due to the fact that it operates on hybrid networks. MODTEEN, on the other hand, is a protocol for pure reactive networks that extends the life of hubs for longer.

The total number of dead nodes:

The term "dead node" refers to any gaps in the routing that are present in the communication line. A routing hole occurs when a node that normally participates in the flow of communication becomes inactive during the process of sending or receiving a packet. When compared to the number of nodes that take part in communication using the TEEN protocol, the number of nodes that take part in communication using the LEACH protocol is much larger. When compared to the TEEN protocol, APTEEN has a higher number of dead nodes than MODTEEN does, but TEEN has fewer dead nodes overall.

The total number of packets sent to the Base Station

The base station is represented by a single node that is located beneath a cluster head. As a result of the proactive aspect of the LEACH protocol, the data packets will be sent to an extremely large number of base stations. On the other hand, as a result of the reactive nature of the TEEN protocol, the data packets will be sent to a much smaller number of base stations. When using APTEEN, a greater number of nodes are involved in the communication; as a result, a greater number of packets are passed to the BS. When using MODTEEN, this number drops significantly.

Matlab Simulator was used for the LEACH and TEEN WSN routing protocols. A simulated environment consisting of 50 nodes and 100 nodes arranged in a flat grid of 500 by 300 was generated using random positions.

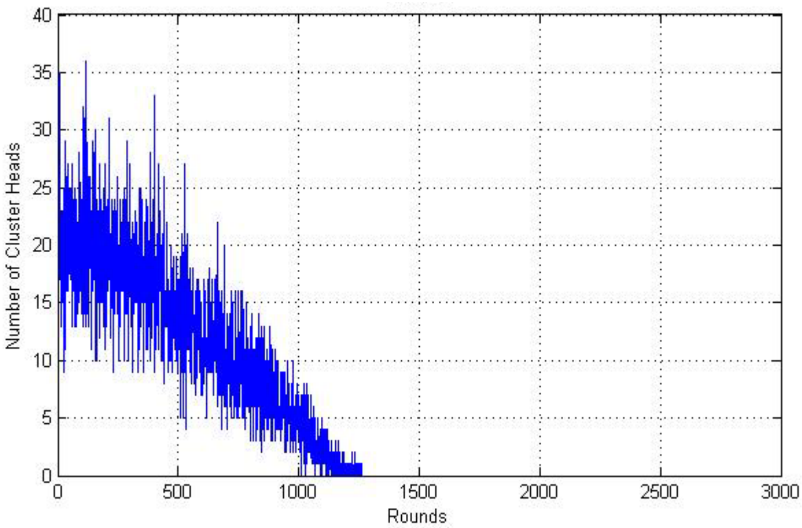

Fig 1: Number of CH of SEP

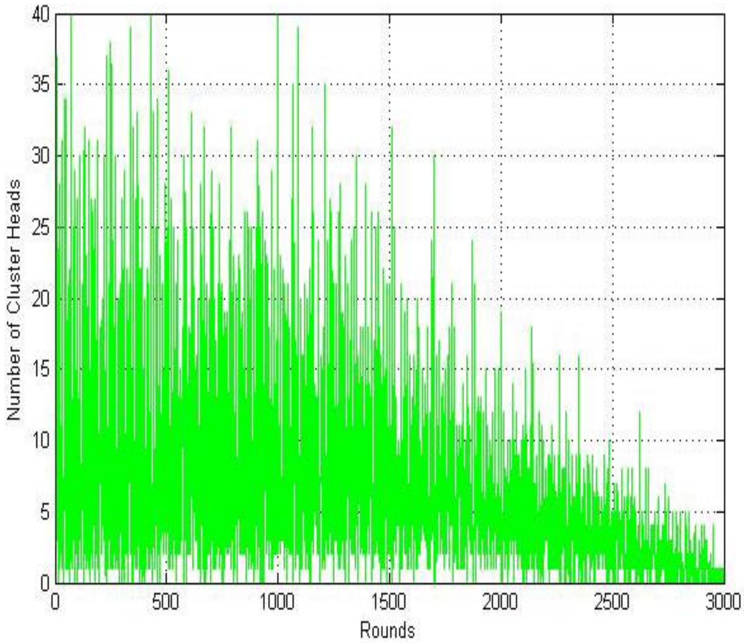

Fig 2: Number of CH of LEACH

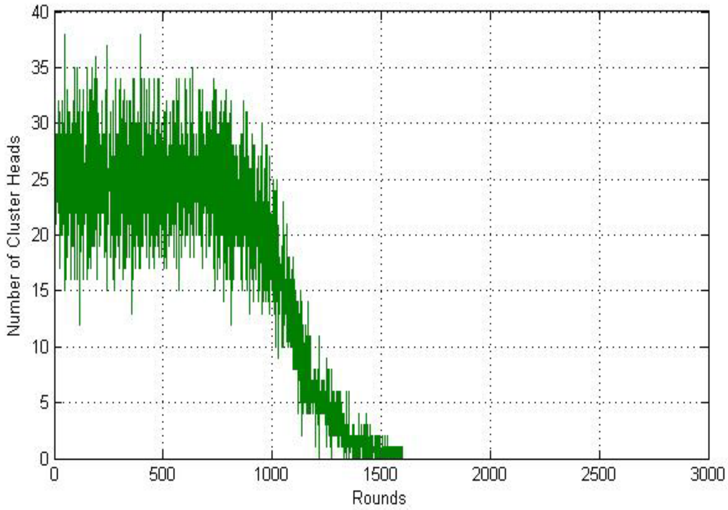

Fig 3: Number of CH of Z-SEP

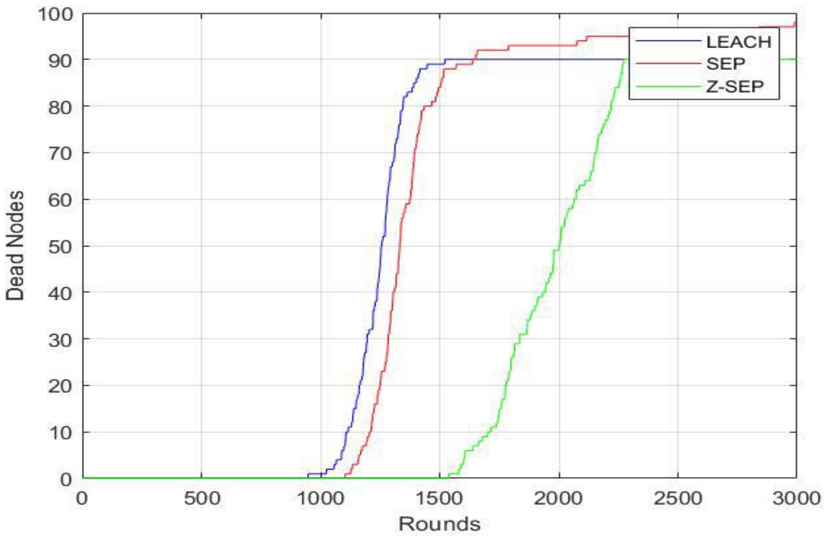

Fig 4: Number of Dead Nodes in LEACH vs SEP vs Z-SEP

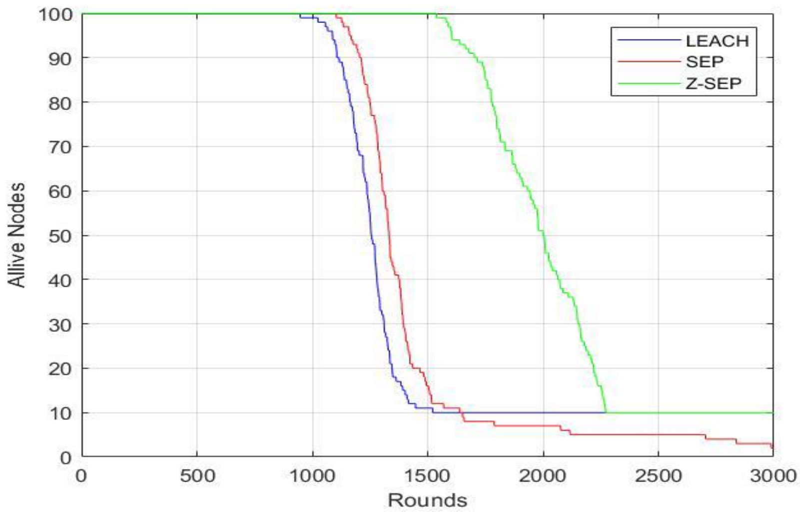

Fig 5: Number of Alive Nodes in LEACH vs SEP vs Z-SEP

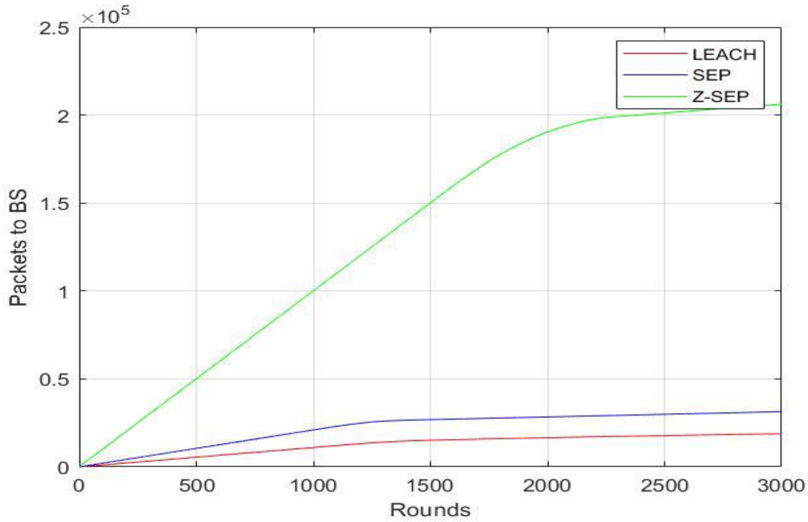

Fig 6: Number of packets to BS in LEACH vs SEP vs Z-SEP

5. Conclusion

When initial network energy is raised without changing network area, protocol performance suffers. As the number of rounds rises, so does each protocol's stability. Each cycle brings more packets to the base station. ZSEP outperforms LEACH and SEP, however SEP transfers more packets to the base station. It concludes that network protocols and initial energy should be synchronised. In the same context, not all protocols function equally. Zone 0, Head Zone 1 and Head Zone 2 divide the field. Normal nodes are only placed in zone 0 to save energy and relay data straight to the base station. Half of advanced nodes are installed in Head zone 1 and half in Head zone 2 and employ clustering to relay data to base station. By deploying various types of nodes in different zones according to their energy needs, the stability period is enhanced by around 50%. Z-throughput SEP's is higher than LEACH and SEP. It's important to pick a wireless network protocol based on the environment's needs.

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