Correlation Distance Based Greedy Perimeter Stateless Routing Algorithm for Wireless Sensor Networks

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Abstract
Research into wireless sensor networks (WSNs) is a trendy issue with a wide range of applications. With hundreds to thousands of nodes, most wireless sensor networks interact with each other through radio waves. Limited computational power, storage, battery, and transmission bandwidth are some of the obstacles in designing WSNs. Clustering and routing procedures have been proposed to address these concerns. The wireless sensor network's most complex and vital duty is routing. With the Greedy Perimeter Stateless Routing method (GPSR), an efficient and responsive routing protocol is built. In packet forwarding, the nodes' locations are taken into account while making choices. In order to send a message, the GPSR always takes the shortest route between the source and destination nodes. Weighted directed graphs may be constructed utilising four distinct distance metrics, such as Euclidean, city block, cosine, and correlation distances, in this study. NS-2 has been used for a thorough simulation. Additionally, the GPSR's performance with various distance metrics is evaluated and verified. When compared to alternative distance measures, the proposed GPSR with correlation distance performs better in terms of packet delivery ratio, throughput, routing overhead and average stability time of the cluster head.

Key words:
Complete Weighted Directed Graph; Clustering; Greedy Perimeter Stateless Routing; Packet Delivery Ratio; Wireless Sensor Network.

1. Introduction

In a wireless sensor network (WSN), a base station (BS) receives information from a number of sensors, which are then sent to the BS. Gathering data and submitting it to BS is a primary objective. To provide the most accurate picture of a location, data from sensor nodes scattered across a field might be combined. Physical factors like as pressure, moisture, temperature, or the location of items may be measured by many WSNs to improve the accuracy of the reported metrics and reduce network connection overhead, which leads to greater energy savings. WSNs are more attentive because of characteristics including low power consumption, low cost, and sensor nodes that can perform several functions [2-4].

WSN is now being used in a variety of real-world applications, including home security, military surveillance, monitoring nondomestic animals, and so on, thanks to cloud technological advancements. Currently, a large amount of research work is devoted to new WSN explorations in lengthy and previously inaccessible areas [5]. [6] Sensor networks are made up of a limited number of units: detecting units (sensors), memory units (memory units), and communication units (communication units). WSN is used in unmanned situations where the nodes are damaged, necessitating the use of more costly or replacement nodes. This necessitates running the wireless node without a battery for extended periods of time in many circumstances. As a consequence, building a network router with a long-term lifespan is a major challenge in terms of energy efficiency. Adapting the network architecture and changing the sensors conveying energy levels in routers may help to improve and sustain energy conservation [7-8].

In routing protocols, the clustering paradigm is used to reduce power consumption [9]. To perform sensing operations, the cluster head (CH) obtains low-power sensor nodes, which transfer the data they have gathered to their cluster head (CH) in a short distance. Nodes in a cluster are certified as CHs to prevent data correlation with the rest of the cluster and reduce the amount of data gathered and sent to the back-end system [10]. Clustering architecture is shown in Figure 1.

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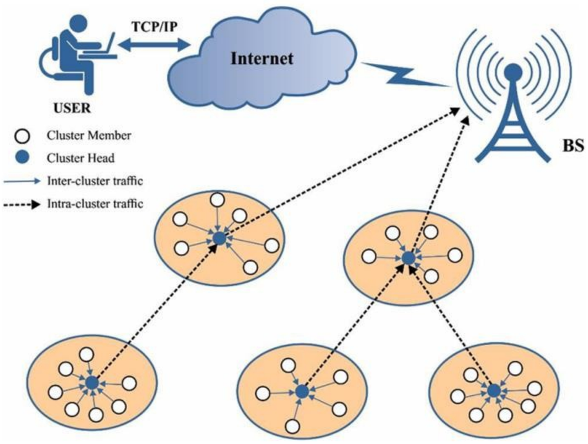

Figure 1. Clustering process in WSN.

Using clustering, energy efficiency may be improved by lowering overall power conservation and managing it amongst nodes while taking network lifespan into account [11]. And it's also capable of enhancing channel content and data collisions, resulting in an increase in network performance in terms of the maximum load that can be supported. Some of the restrictions, such as limited energy, bandwidth, and processing capabilities, have led to the development of a variety of routing protocols that help to extend the network's lifespan.

A sensor node's battery power decreases according to the quantity of data it broadcasts during WSN operation. A considerable portion of the node's energy goes into communication operations. As a result, good data routing is essential to the long-term viability of WSNs since routing algorithms are directly linked to sensor node communication. Many early studies on WSN routing protocols focused on the deployment of sensor nodes with uniform data rates. The sensor nodes in WSN are diverse in terms of energy and data rate in actual scenarios [13]. If the sensor nodes' heterogeneity is not correctly used, it may lead to unequal energy consumption and unbalanced load throughout the network, which can negatively impact network performance.

Researchers presented a GPSR with four separate distance measurements for WSN routing. NS-2 simulator is used to conduct the tests, which are then verified using a variety of criteria. As for the rest, it's categorised as follows: Geospatial routing is the focus of Section II. Section III explains the GPSR with four distance measurements in detail. Section IV details the testing of the suggested technique using various metrics. Finally, Section V provides the scientific contribution of the study with future research.

2. Relatedworks

A reservation-based CH selection is offered in [14] as a way to reduce clustering's overhead energy usage. To avoid the requirement for network nodes to transmit messages contending for the CH selection, this strategy allots time for each node to be a CH. The first round of CH selection is based on a LEACH technique. Nodes in the reservation phase construct an R-by-1 reservation matrix by determining the round in which they will serve as CHs. It then assigns 1 to the entries that correspond to the rounds in which it will be CH and 0 to the ones that correspond to the rounds in which it will be an ordinary node. Each node communicates its reservation matrix to the rest of the network when the reservation phase has ended. A more thorough matrix, referred known as the "total matrix," is constructed based on this one. You can see who will be CH for each round R using the whole matrix that all other nodes may access and use. A critical CH selection criterion is overlooked, despite the fact that this strategy reduces the number of communications overhead. Small-scale networks may only benefit from this method since it needs a large amount of memory space to store the whole matrix in each node. These include residual energy, node density, and more. The network nodes aren't even thought of when it comes to reducing redundant data transmissions and data collection. Even though the preceding techniques have demonstrated considerable network performance improvement, they have not eliminated duplicate data transmission from sensor nodes that are in close proximity in densely deployed WSNs.

Using the SEP method as a baseline, Sharma et al. evaluated the influence of traffic and energy heterogeneity on [15]. Two-level traffic heterogeneity is used instead of two-level energy heterogeneity in this study, which is comparable to the two-level energy heterogeneity in the original SEP. As the amount of traffic rises, SEP's performance drops noticeably, according to the findings. This approach presented by Sharma et al. [15] demonstrates a considerable improvement in diverse heterogeneous scenarios. Although choosing a suitable CH will help reduce the impact of traffic heterogeneity, a high-traffic node will continue to generate more data and run out of energy sooner. It is also unsuitable for WSNs with several levels of heterogeneous sensor nodes, since this protocol was created only for two-level communication.

A multi-level traffic and energy heterogeneous sensor network, named TEAR protocol, was created in [16] to solve this problem. TEAR thereby takes into account (multi-level heterogeneity) differences in sensor node energy and data production rate. To determine the likelihood of a CH election in TEAR, the starting and residual energy, traffic load, and round average energy are all taken into account. Using the TEAR protocol, nodes with high traffic and low energy will be avoided, whereas nodes with high energy and low traffic rate will be selected for the CH function. In comparison to a high-energy node with low traffic, a node with low energy and heavy traffic tends to die more quickly. Realistic wireless sensor networks (WSN) may be accurately modelled using the TEAR method. As a result, it does not have the essential mechanisms to reduce the energy consumption of heavy traffic nodes, such as reducing redundant data transmissions.

Another routing system for traffic heterogeneous networks, Distributed Efficient Fuzzy Logic (DEFL) based routing, is suggested in [17] in order to decrease the energy consumption of heavy traffic nodes. To account for this, the DEFL protocol saw nodes as heterogeneous entities with varying amounts of traffic. Following the shortest route, this method was implemented. Choose the least expensive route. When it comes to avoiding traffic jams, this method is the most important one. In DEFL, the fuzzy takes as inputs the transmission rate, energy, and energy left in the nodes. This strategy extends the network's lifespan by removing the strain of message relaying from nodes with heavy traffic. As a result, the node closest to the observed event will continue to be burdened by the high traffic volume. In addition, flat routing was used in this strategy, which increased network communication complexity and lowered network performance.

2.1. Geographic Routing

An algorithm termed greedy forwarding selects the nearest neighbours to the destination node in its one-hop range based on their proximity. This study follows in the footsteps of earlier research on face routing, which considered a radio range form as an ideal circular surface and addressed each approach [18-19]. A virtual line from this node to the destination node is used to generate a circle that intersects with the radio range of the nearest candidate node to the destination node. Because greedy forwarding only utilises information within a one-hop radius, it does not need to know the full network topology. Due to the following constraint, greedy forwarding does not always send data packets to the target node [20-21]. Because there are no candidate nodes in the intersection region, the source node s fails to send the data packet as shown in Figure 2. Because of this property, it is common for WSN to randomly position sensor nodes, as seen in Figure 2. In this instance, geographic routing uses perimeter mode, which is a recovery mode, to deal with the data packet transmission failure.

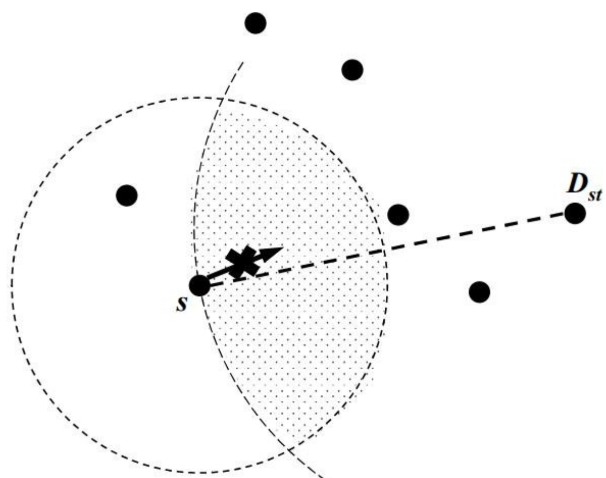

Figure 2. Greedy forwarding failure during the data transmission.

Prior to transmitting data packets, Huang et al. [22] use energy to enhance the load balance by sending two burst packets to the destination. One burst packet is sent along the right-hand side and the other along the left-hand side. These approaches may contribute to additional sensor node energy consumption because of the high overhead of transmitting burst packets across the nodes.

3. Proposed algorithm

Greedy Perimeter Stateless Routing (GPSR) is a wireless sensor network routing technique that is fast and responsive [23]. Other routing techniques do not take into account the physical location of a wireless sensor network into account. The nodes' locations are used to decide how to route packets. Nodes that are constantly closer in proximity are selected for passing packets using a technique known as "greedy forwarding."

One route in the sensor network will need to temporarily relocate away from the target node in areas where such greedy paths are not accessible. In perimeter mode, a packet is sent to the next closest node in a planar subgraph of the whole radio network connection graph, allowing it to be recovered. If a node is near enough to the target node, it will continue forwarding until it does. DSR, a self-maintaining routing strategy for wireless sensor networks, is another method of routing. DSR [24] is capable of setting up and managing the network on its own, without the need for human intervention. In DSR, the path used to send data packets to their intended destination is determined by each source. Route Discovery and Route Maintenance are the two primary stages of DSR. Route discovery is the process of finding the most efficient way for data transmission between the source and destination nodes.

It guarantees that communication routes stay optimum and loop-free even if the network state changes or it is necessary to modify the route during transmission.. Our model's security protocol protects against both active and passive attacks, as well as Mote class and Laptop class threats.

An assault within the network may be averted and the intruder halted. However, precautions should be made in the network in case of an external assault. In an active attack, data packets are tampered with, as well as their routing information. Data packets are unaffected during transmission in passive attacks. In a mote-class assault, the attacker's capabilities is compared to the sensor node's. In contrast, a Laptop class attack is more powerful since it is more computationally intensive. Secure multi-path routing with dependable data transfer In comparison to SMRRD, which relies on the Secure Energy Efficient multipath routing protocol, SMRRD features a more secure method. The energy is calculated by averaging the data from the senor nodes. Security and energy efficiency must be included into this. The base station, unlike the sensor node, has the capacity to calculate power and compare energy, unlike sensors. As soon as the base station has decided on a path, it begins communicating with the mobile device.

3.1. Network

The nodes in a wireless sensor network are fixed, but the nodes in a mobile Ad-hoc network may be relocated. However, in a wireless sensor network, a static network has been implemented. Secure multipath routing may be used in a wireless sensor network that is just stationary. As a result, we're putting up a network of wired sensors. The nature of sensor nodes is one of heterogeneity. The node's initial energy level is fixed. When sensors are distributed, they lose their power and are deemed "dead nodes," because they can no longer be reactivated.

Create clusters and choose cluster leaders are the primary goals of the network. In this network, the sensor nodes are spread out in a random fashion and then become stationary. According to its detecting capabilities, each sensor node gathers data from the field and transmits it to the base station. All of the sensor nodes have been given a unique ID, along with a certificate signed by the base station and a private key.

3.2. Route Construction

In multipath routing, the message is split up into many packets and sent via multiple routes. Multipath routing alters the transmission order of packets. When it comes to secure data transfer, secure multipath routing is a go-to option. To keep the packet order, we'll need to add certain metrics called sequence identifiers. The base station transmits a Route Request RREQ packet to each sensor node. The route sensor node will then broadcast to its neighbours in order to accumulate. When a node receives a message requesting a route, it will update its neighbouring node list. Packets are transmitted over the network in order to collect the RREQ. The base station's public key may be used to verify the identity of a neighbouring node. If the key does not match, the node will not be added to the neighbour list. The previous node's address is obtained, and the current node is used to update the prior node. When a route request and packet sequence number are readily available in a received message list, there is no need to resend it. Instead, it will maintain the packet's Sequence number in the Received message list and then resend the message. " The RREQ packet is delivered to all sensor nodes in order to get a list of their neighbours. Upon obtaining neighbour lists, all the information about the pathways between nodes is collected in the base station.

The node will receive Route Request messages from the base station at a certain time. As a result, the base station is forced to wait. The base station will now transmit the Route Collection message, also known as RCOL, to the whole network after waiting for the node to receive it. The sensor node will use the network to communicate with the neighbouring nodes in order to disseminate the message. Following the base station's Route Request broadcast, each node gets a route collecting message that they follow. After then, each node in the network broadcast the whole environment.

To respond to the RCOL packet, sensor nodes send a reply packet back to the base station. Which includes information on the current node, its address, and the amount of energy it uses to transmit data between nodes. There is a list on the base station listing every node's neighbours and the amount of energy used during transmission. The weighted directed graph may be constructed using this knowledge base. G= is the formula for obtaining the weighted direct graph (N,E) Nodes are referred to as "nodes" in this context, while routes are referred to as "routes." I and j describe the location of nodes. Sensor nodes I and j are separated by a distance of E ij. In this suggested work, the E ij is defined by four distinct distances:

Euclidean distance, city block distance, cosine distance, and correlation distance.

The Euclidean distance between two point $i = (x_1, x_2, x_3, \dots x_n)$ and $j = (y_1, y_2, y_3, \dots y_n)$ is computed using the eqn. (1)

$$\text{Euclidean distance}_{ij} = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \cdots \dots + (x_n - y_n)^2} \quad (1)$$

The city block distance between two points $i = (x_1, x_2, x_3, \dots x_n)$ and $j = (y_1, y_2, y_3, \dots y_n)$ is computed using the eqn. (2)

$$city\ block_{\ i,j} = \sum_{i=1}^{n} \left| x_i - y_i \right| \quad (2)$$

The cosine distance between two points $i = (x_1, x_2, x_3, \dots x_n)$ and $j = (y_1, y_2, y_3, \dots y_n)$ is computed using the eqn. (3)

$$cosine_{ij} = \frac{\sum_i x_i y_i}{\sqrt{\sum_i x_i^2} . \sqrt{\sum_i y_i^2}} \quad (3)$$

The correlation distance between two points $i = (x_1, x_2, x_3, \dots x_n)$ and $j = (y_1, y_2, y_3, \dots y_n)$ is computed. The base station first decides the shortest path and then use that path and find the next shortest path to transmit the packet of data. The information like energy and distance between nodes are also collected by the base station.

3.3. Data Transfer

The power consumption of a sensor node varies depending on its location. During the route building phase, the shortest and most efficient path is used for data transfer. Every byte of data sent by the network is monitored for its energy level. The base station sends a data request DREQ to all nodes in the network. DREP packets are sent to the sensor node when it receives a data request. Some actions are taken by the node after receiving a data request from the base station. Use a unique shared key to verify the message's authenticity. If the shared key matches, the packet is accepted. For the duration of its lifespan, the node connects to the base station via a single shared key. The node will not transmit data if the destination node is the same as the source node, since the source and destination nodes are identical.

Messages that are not intended for the Current Node are sent to the neighbour list for rebroadcast. The base station determines the most efficient route after gathering data from all the nodes in a previous phase. After the base station has determined the best route, a route request is submitted. As soon as the sensor node receives this message, a route acknowledgment packet will be sent. When a security key does not match, an Error Packet ERRP is issued instead of a data response.

Authorizing the key takes less time and effort. The base station receives data packets from the sensor node. The Base station receives the data packets sent by the sensor node. When the base station is required to wait for a certain amount of time before receiving a data response and does not do so, it will assume that the attacker has attacked that route. To choose the best route, data request messages are delivered to the network through a variety of optimum routes.

3.4. Route security and Maintenance

This means that if a sensor node is not able to authenticate a key or does not have enough energy, it will be withdrawn from the network. The sensor nodes also send an error response packet as part of the information update. Based on the base station, rather than the origin and destination, the path is determined. If an error message is provided to the base station owing to a public key authentication failure and a malicious node in the sensor network, the base station alters the data transfer path. The physical environment or an assault by the attackers may be the cause of a sensor's inability to function. The next part will test the suggested GPSR's performance.

4. Results and Discussion

Simulating the suggested technique in this study, we used the NS2 simulator to construct a network environment of wireless nodes and the clusters and base stations of wireless networks. Here, we've set up a network of 53 nodes and selected nodes 6 as the source and 44 as the destination. Nodes 13, 49, 42, 11, 7 have been chosen for the routing. The shared public key encrypts and decrypts data in this case. Table.1 lists the network and sensor node parameters.

Table 1. Network parameters in experiment

Parameter	Value
Deployed number of sensor nodes	53
optimum number of cluster heads	5
initial energy of node	200J
wireless communication line bandwidth	1Mbps
time of each round	20s
distribution area of nodes	1500m×1100m
network monitor area	1500m×1050m
size of packet header	25Bytes
data size of packet	500Bytes
simulation time	7s

4.1. Performance parameters

This subsection details the parameters that measure the working of four different distance calculations such as Euclidean Distance (ED), City Block Distance (CBD), Cosine Distance (CD) and Correlation Distance (CoD). Experimental are carried to find packet delivery ratio, throughput, routing or overhead and stability time period of cluster head to draw the comparison of four different distance calculations.

4.1.1. Packet delivery ratio (PDR)

In computing, packet delivery ratio (PDR) is the ratio of packets received by the destination to packets created by the source. It may be expressed mathematically as follows:

$$PDR = \frac{S1}{S2} \quad (4)$$

Equation: S1 is equal to the total number of data packets received by each destination, whereas S2 equals the total number of data packets produced by each source (5)

$$PDR\% = \frac{Number\ of\ packets\ recieved}{Number\ of\ packets\ sent} * 100 \quad (5)$$

4.1.2. Throughput

It is ratio of total number of packets delivered over the total simulation time as stated in equation (6)

$$Throughput(Kbps) = \frac{recieved\ packets(bytes)*8}{1024*(stop\ time-start\ time)} \quad (6)$$

4.1.3. Routing Overhead

Network overhead is the number of control (hello packets) and routing packets required for an overall network communication illustrated in equation (7).

$$Overhead(in\ ratio) = \frac{total\ control\ and\ routing\ packets}{number\ of\ data\ packets\ recieved} \quad (7)$$

4.1.4. Stability time period of cluster head

Stability of a cluster head node is defined as the time period for which the node worked as a cluster head of the cluster. Average of that time period is known as average stability time.

4.2. Experimentation and result analysis

In this section, the performance of GPSR in terms of four different distances are tested and compared in terms of PDR, which is given in Table 2 and graphical representation for this experiments is provided in Figure3.

Table 2. Validated Analysis of Proposed Method for Packet delivery ratio.

Number of nodes	ED	CBD	CD	CoD
20	75.68	82.5	84.32	89.11
40	74.74	84.6	86.43	93.76
60	69.02	85	88.01	95.1
80	69.87	85.8	89.15	96
100	77.97	88	92.21	97.43

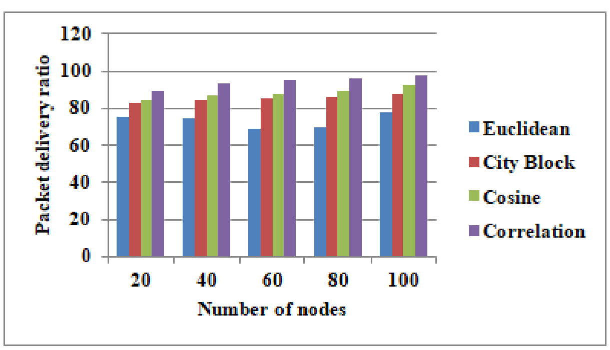

Figure 3: Graphical Representation of Proposed Method in terms of PDR.

When the number of node is 20, the ED has only 75.68% of PDR, CBD has 82.50% of PDR, CD has 84.32% of PDR and CoD has high PDR value (i.e. 89.11%). When comparing with all distances, ED has low PDR values for every nodes, for instance, ED has nearly 69% to 77% of PDR, when the nodes are 40, 60, 80 and 100. As like ED, CBD has nearly 84% to 88% of PDR, when the nodes are 40, 60, 80 and 100. The CoD has 93.76% of PDR and CD has 86.43%, when the node is 40, where the CoD achieved nearly 97% of PDR and CD has only 92.21% of PDR, when the node reaches 100. This proves that when the nodes are increases, the performance of CoD is also increased in terms of PDR. Te next Table 3 shows the performance of this four distances in terms of throughput and Figure 4 shows the graphical representation for thesame.

Table 3: Validated Analysis of Proposed Method for Throughput (kbps).

Number of nodes	ED	CBD	CD	CoD
20	98	110	126	136
40	110	124	157	166
60	138	135	176	189
80	149	180	220	234
100	172	210	255	263

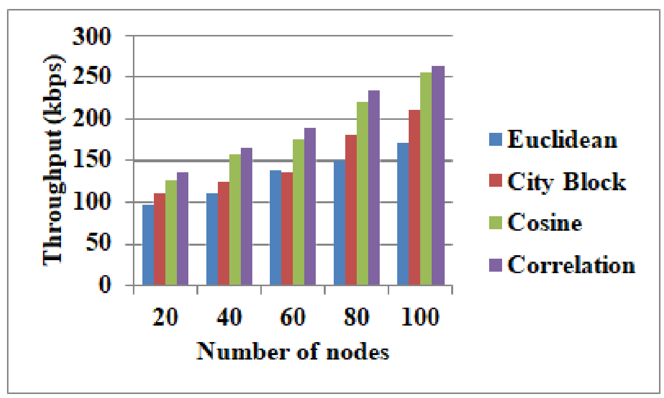

Figure 4: Graphical Representation of Proposed Method in terms of throughput.

The throughput of proposed GPSR for each distances is increased, when the number of nodes is also increased. In the throughput experiments, the ED has 98kbps, CBD has 110kbps, CD has 126kbps and CoD has 136kbps, when the node reaches 20. These same techniques achieved 138kbps, 135kbps, 176kbps and 189kbps, when the node reaches 60. Finally, when the node reaches the final, the ED has only 172kbps, CBD has 210kbps, CD has 255kbps and CoD has 263kbps throughput. This experiments proves that the GPSR-CoD achieved better performance than other distance measures of GPSR. Table 4 and Figure 5 shows the experimental analysis of proposed method for routing overhead.

Table 4. Performance Analysis of Proposed method for Routing Overhead

Number of nodes	ED	CBD	CD	CoD
20	0.6	0.4	0.4	0.4
40	0.8	0.6	0.5	0.4
60	0.9	0.7	0.62	0.53
80	0.98	0.9	0.82	0.75
100	1.23	1	0.96	0.83

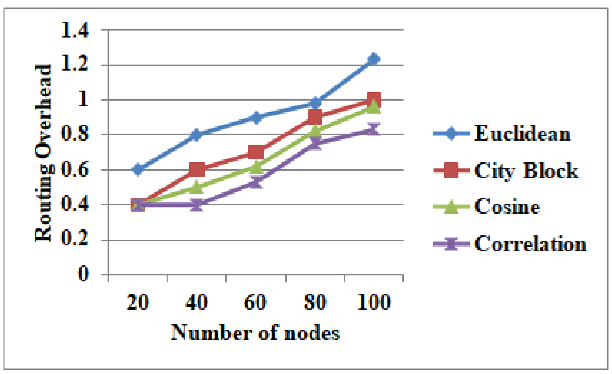

Figure 5: Graphical Representation of Proposed Method in terms of Routing Overhead.

The routing overhead of CBD, CD and CoD is stable (i.e.0.4), the ED has 0.6 of routing overhead, when the node is 20. The ED has 0.8, CBD has 0.6, CD has 0.5 and CoD has 0.4 of routing overhead, when the node reaches 40. These same techniques achieved 0.98, 0.9, 0.82 and 0.75 of routing overhead, when the node reaches 80. This experimental results shows that number of nodes influences the performance of routing overhead of each distance measures of GPSR.

Table 5 and Figure 6 shows the validation analysis of various distance measure of GPSR in terms of average stability time of CH's.

Table 5. Validation Analysis of Proposed Method in terms of Average Stability time of CH's (sec)

Number of nodes	ED	CBD	CD	CoD
20	10	15	22	22
40	30	40	50	55
60	40	60	75	80
80	55	75	88	94
100	65	95	110	120

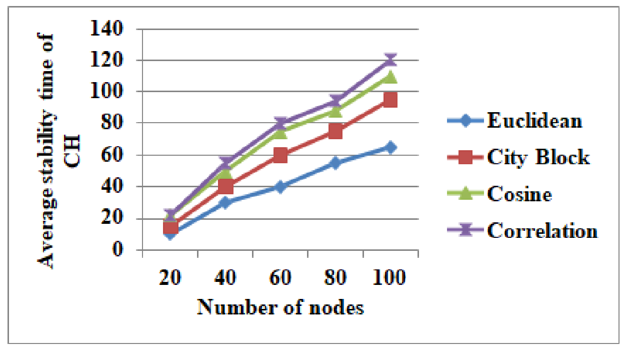

Figure 6: Graphical Representation of Proposed Method in terms of Average stability time of CH.

The stability time of each distance metric decreases as the number of nodes decreases. When the node is 40, the ED has 30 seconds, the CBD has 40 seconds, the CD has 50 seconds, and the CoD has 55 seconds. When the node is 60 seconds, the ED has 40 seconds, the CBD has 60 seconds, the CD has 75 seconds, and the CoD has 80 seconds. When the node is 80, the ED has 55 seconds, the CBD has 75 seconds, the CD has 88 seconds, and the CoD has 94 seconds. In addition, when the node is 100, the ED has 65 seconds, the CBD has 95 seconds, the CD has 110 seconds, and the CoD has 120 seconds. The GPSR-CoD performed better in terms of PDR, routing overhead, throughput, and the average stability time of CH's in the above-mentioned studies. It is because the CoD has the benefit of being able to apply to random variables of any dimension rather than just two-dimensional random variables, and it has been used to discover nonlinear relationships that the Pearson correlation coefficient cannot detect. To put it another way, if two data sets have no attribute values in common, their distance may be lower than the distance between two sets of data sets with the same attribute values. As a result, many common multivariate studies, such as discriminant analysis, cannot be performed with CBD. In order for CD to perform poorly, it is necessary to account for the magnitude of vectors.

5. Conclusion

The Wireless Sensor Network (WSN) has applications in almost every area of networking, and a variety of ways are being utilised to extend the life of the restricted power network. End-to-end latency, packet loss, and lower sensor node life span are the key drawbacks of this system. A wireless sensor network has been created in this article to solve these issues. GPSR was used to communicate with the nodes and compile a list of all of their neighbours. Other routing techniques do not take into account the physical location of a wireless sensor network into account. Weighted graphs are constructed using ED, CBD, CD, and CoD distance metrics. PDR, routing overhead, throughput, and average CH stability time are all measured in terms of each distance metric in the tests. An average stability time of 120 seconds, 0.83 routing head, 263 kbps throughput, and 97.43 PDR for the node 100 were all reached using the GPSR-CoD, compared to alternative distance metrics. The proposed work involves the construction of a cluster-based routing protocol, as well as the refinement of delay-constrained applications based on the suggested model. Evolutionary algorithms may also be used to improve routing quality of service (QoS).

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