Performance evaluation of Energy Efficient algorithm using Spatial Trusted and Energy Aware Trusted Distance routing in WSN

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Abstract. Energy efficient routing is the most important design criterion for WSN (Wireless Sensor Network) as the nodes are either powered by batteries, or by other external power sources. In a Sensor network, the nodes communicate with each other in a multi-hop fashion. The availability of each node is equally important to the proper functioning of the network. The power failure of nodes greatly affects the overall performance of the network. The Quality of Service (QoS) has been measured using the parameters of data quality, energy utilization and position of the sensor nodes. In this paper Energy efficient routing algorithm called Location and Energy Aware Trusted distance source routing (LEATDSR), Energy-aware Spatial Trusted Routing algorithm (ESTR) and Intelligent Weighted Fuzzy Cluster based Secure Routing Algorithm (IWFCSRA) were analyzed in term of energy efficiency performance. This paper implements LEATDSR, ESTR and IWFCSRA by using NS2 simulator. Energy Consumption and Security Analysis are used to evaluate LEATDSR, ESTR and IWFCSRA routing protocols performance analysis in WSN

Keywords: Energy Utilization, Quality of Service, Cluster Formation, Sensor nodes, Energy, Wireless Sensor Network.

1. Introduction

Numerous wireless availability standards and advancements have been developed over the most recent couple of years. The transfer of data or power between at least two points that are not associated by an electrical conductor is known as Wireless communication. Wireless sensor networks (WSNs) are the most versatile wireless technologies, nowadays as wireless communications and networking occupy center stage in research and development [1].
The two important factors that lead to an efficient sensor network design are (i) Power Consumption and, (ii) the Quality of Service (QoS). Power Consumption deals with the Distribution of energy among all the nodes throughout the network and QoS depends upon high routing efficiency under multi-hop transmission scenarios [2]. Therefore, for designing such type of networks, researchers must focus on both the energy consumption and routing efficiency.

The Wireless Sensor Network is a highly distributed network consisting of small lightweight battery powered electronic motes that are heavily deployed to monitor the environment or system through physical parameter measurements like temperature, pressure, humidity, etc [3]. The sensor mote is the basic electronic building unit of the WSN that consists of three main functional units sensing, computing and communication, packaged in a single unit of about an inch diameter. Wireless Sensor Networks are used in many applications including habitat monitoring, military applications, environmental monitoring, health sensing and so on.

Therefore, energy conservation in sensor networks is of utmost importance due to the limited energy availability in the wireless devices. Since wireless devices consume a significant amount of energy, it is important to minimize the energy consumption cost for communication by practicing efficient energy-aware routing strategies.

The energy-aware routing strategies increase network lifetime by utilizing limited energy sources. However, the execution of the protocol affects the energies spent during the transmission of the data. The Wireless Sensor Networks (WSNs) generally consists of many sensor nodes [4]. Each sensor node can process and collect sensitive data and communicate via the nodes in the network. Each sensor node includes a microcontroller that processes data and also controls the functions of other parts of the sensor node to facilitate the sending and receiving of data for the external memory and power supply for storing data. The limitations of size and cost-based sensor nodes lead to some limitations such as memory, communication bandwidth, energy, and computational speed.

Recently, trust management system which is a system that is also widely used in many applications including data aggregation, data packet routing in networks, access control mechanisms in the process of data access, and the decision making process in intrusion detection systems [5]. The term Trust Management System (TMS) is also utilized together with the processes of trust score calculation and the reputation score calculation. These two processes are important and also playing crucial roles in trust management systems.

2. Literature Review

In [6] the author proposed a narrative perception for hierarchical heterogeneous WSNs with regards to mobile sensor nodes named MEACBM routing protocol. Further, based on this new implemented probability equation, the CHs were selected. In this, only the sensor nodes were chosen as CH that poses larger energy between other sensor nodes. Here, the hierarchical heterogeneous clustering was assumed with sensor nodes having three levels; sensor node connectivity inside the entire network area and multi-hoping for inter-cluster communication.

In [7], the authors proposed an energy-efficient fuzzy logic-based clustering technique for WSN, which makes use of five parameters to determine the strength of the nodes. Accordingly, the proposed solution selects the nodes for the role of cluster heads.

In [8] the author addressed stated Energy efficiency as the initial problem in WSNs. These sensor nodes become lifeless over time as they were battery powered. Therefore, the enhancement in data dissipation within energy efficiency was considered as the promising issue in improving the sensor
device’s lifespan. The prolonged analysis has stated the considerable improvement in the network lifespan among the proposed model.

In [9], the authors proposed a secure and reliable communication for next-generation networks in smart cities, which aims to decrease the quantity of unnecessary traffic flow between the edges by relying on node-to-node transmission protocol. Moreover, the integration of fog and cloud layers ensures secure communication. However, the proposed solution does not evaluate its routing performance in terms of energy efficiency and network overheads. The authors in [10], proposed Secure Routing in Multi-hop IoT based Cognitive Radio Networks under Jamming Attack, which aims to improve the data delivery performance and secure the routing path from source to destination. However, the routing decision is not optimal by considering the significant network parameters. Moreover, the performance of the proposed solution is only analyzed based on the packet delivery ratio and overlooked other network metrics.

In [11] the author examined an optimum node degree for minimum energy consumption. The node degree of the Degree Constrained Tree (DCT) in homogeneous WSN with only one BS was adopted for their study. The degree of the nodes, in turn, affects the lifetime of the network. Consequently, the paper proposes a Collaborative Distributed Antenna (CDA) routing protocol in terms of transmission energy to provide node distribution. The experimental results show that the optimal node degree doubles the lifetime of the network. Further, DCT with CDA proves enhancement in network stability.

The authors [12] proposed a novel security protocol for WSN using cooperative communication, which aims to improve the performance and resiliency and data reliability against cyberattacks. The proposed solution provides a data security MAC protocol that implements a hash function to verify the message integrity along with the simple key distribution mechanism to authenticate the network entry. It improves network security, however, it is appropriate with a small number of sensor nodes, and routing performance is overlooked.

Authors in [13] proposed an enhanced hierarchical clustering approach for mobile sensor networks using fuzzy inference systems, which aims to reduce the energy conservation and packet loss rate between mobile sensor nodes. The simulation-based experiments revealed that the proposed solution improved the performance for network lifetime and cluster deviation than other work.

In [14] suggested Bluetooth Low Energy (BLE) method for optimizing energy consumption in IoT based Wireless sensor networks. They used a hybrid topology to decrease the energy consumption and minimize the cost. Here, Authors compared Zigbee and RF wireless networks with Bluetooth low energy model for low power applications to improve the functionality of the network and costing low energy.

In [15] author proposed delay and energy-sensitive routing protocol to ensure enhanced quality of service. The main objective of the paper includes minimization of delay and energy consumption. The WSN and actuator network are considered. It composed of both sensor and actuator nodes. These networks are organized in clusters, which are supervised using CH. The CH was elected based on connectivity and energy capability.

In [16] the author presented a routing approach GECR and genetic algorithm-based energy efficient clustering for prolonging the life cycle of network and enhancing energy efficiency. The optimal solution that attained from the earlier network round has been added to the prime population for the present round, by which the search efficiency has been enhanced.
In [17] the author exploited a new load balancing protocol for managing the energy consumed by the sensor nodes in the WSN. The simulation was done using MATLAB, the performance comparison was evaluated using two protocols namely LEACH and SEP. Thus, finally it proved its superiority.

The authors [18] proposed an adaptive competition-based clustering approach (ACCA) for WSN, which provides multi parameters for the selection of cluster heads. The factors are residual energy, the centrality of the nodes, and the distance between the cluster heads. The distance factor among cluster heads is exploited in the proposed solution to distribute the clusters with suitable sizes.

In [19], the authors proposed novel predictive efficient energy consumption reclaim PEECR-based clustering routing approach for WSN. The proposed solution presents an energy-efficient routing approach based on clustering distance between nodes, degree of nodes, and nodes residual energy. The proposed solution is based on the swarm colony optimization algorithm to achieve data routing. The authors in [20], proposed a particle swarm optimization (PSO) based routing protocol. The proposed solution aims to conserve the energy consumption of the gateway nodes for improving network lifetime and routing. The simulated results illustrated better performance than the existing solutions, however, it lacks the security consideration and also links integrity is overlooked in routing decision.

In [21] the author suggested Media-based Surveillance system (EAMSuS) method for an Efficient Algorithm in IoT Smart city system. They propose the routine security system that will assure a lighter and more secured transmission for rapid media sharing among the people of the smart city, for instance, in the case of a cybercrime social cloud; they achieved low memory consumption at the WSN of IoT assisted smart city management.

Shortest based algorithms [22, 23] causes’ energy loss and intrusion will increase transmission overhead. By using route massage and neighbor based forwarding reduce energy over the node. Node compromised is one of the threats mostly in hello and sinkhole attack. Sometime these will leads to selective forwarded. Sen-SDA [24] proposed secure data aggregation which used to filter the false data and minimize the energy. Active trust based routing method is proposed to detect block hole attack. It reduces energy and will provide trust.

3. Energy Efficient algorithm based on Spatial Trusted and Energy Aware Trusted Distance routing

3.1. Location and Energy Aware Trusted Distance Source Routing (LEATDSR)

The LEATDSR is an energy aware routing and reactive protocol methods which are able to save energy and also works based on the location. Here, it discovers the active path in the network. In addition, the on demand routing procedure that is working mainly based on the source-routed on-demand routing which is used for improving the network lifetime. For this purpose, a sensor node establishes a route and it always modifies the routing table with caching. The sensor nodes are similar in nature to store the data, capability of sensing and data transmission for the proposed methodology.

The sensor nodes have been framed by the groups to produce the data collection; the decision manager is accountable for gathering the information about the Energy of the sensor nodes, the temporal and spatial details of all the sensor nodes. The routing procedure is the key module to construct the secured routing that the cluster is framed by electing the cluster head and the trust model. The trust model is used to perform the secured routing in the network. Fig 1 represent the LEATDSR architecture.

3.2. Intelligent Weighted Fuzzy Cluster based Secure Routing Algorithm (IWFCsRA)

In Fig 2, IWFCsRA system architecture is shown. It has seven important components namely Pre-processing phase, Clustering Module, Fuzzy Rule Manager, Decision Manager, Knowledge Base, Trust
Computation Module, Weight Assignment Agent and Routing Module. The role of pre-processing phase in this work is to identify the contributing nodes by selecting the outlier nodes in the network scenario.

Clustering module is forming a cluster based on the pre-processing phase recommendation and the energy level of the current nodes. Weighted Fuzzy rules are stored in a knowledge base. Fuzzy rule manager is communicating with weight assignment agent for framing fuzzy rules. Decision manager helps to select the suitable nodes for the cluster and cluster head nodes. Trust computation module is responsible for calculating the trust scores for the respective nodes in dynamic topology. Routing module is responsible for selecting the trust paths with the help of decision manager recommendation. The decision manager is responsible to control all the components of the proposed system architecture. It takes decision over the clustering, trust computation and routing process in the network.

![Flowchart](image)

Figure. 1 LEATDSR architecture
3.3. Energy-aware Spatial Trusted Routing algorithm (ESTR)

The proposed ESTR contains the elements like sensor nodes, data gathering, energy utilizer, temporal analyzer, spatial allocator, decision supporter, trust formation and secure routing procedure. The sensor nodes which contains several nodes having minimized energy level that are contributed in the WSN. Information gathering is dependable for gathering data to the decision supporter. It acts as an overall coordinator in the framework.

The decision supporter has gathered the relevant information from information gathering module and it computes the trust value according to the behavior of the nodes according to the temporal and position of the relevant sensor nodes. Additionally, it computes the choice that all the nodes that are to be discovered as the dynamic nodes in WSNs.

The routing based decision will be taken by the decision supporter with the trust level of the sensor nodes. The energy utilizer contains the components of threshold, limitations for balancing the elements of secured routing. The trust formation contains the components of data transmission value. The values are computed animatedly allocated to the position of the sensor nodes. The components of cluster based components and trust values to perform the routing procedure according to the energy based trust values dynamically.

4. Experimental approach

The proposed algorithms were constructed and implemented with NS2 tool. The efficiency of the proposed ESTR, IWFCSRA and LEATDSR algorithm were analyzed by doing the experiments with the parameter metrics like Energy Consumption and Security Analysis. The all three proposed methodology is compared with one another to find the best energy efficient routing algorithm. The simulation metrics are demonstrated in Table 1 in detailed manner.

**Figure 2. IWFCSRA Architecture**

![IWFCSRA Architecture Diagram](image-url)
Figure 3 shows the packet delivery ratio analysis between ESTR, IWFCRA and LEATDSR Energy and Trust based Secure Routing Algorithms. Here, five different mobility speeds from 10 m/s to 50 m/s have been considered for conducting five experiments in this work. When the number of nodes increases then the packet delivery degrades gradually. From the figure 3 it clear that the performance of ESTR is higher than the other algorithms.

Energy-aware Spatial Trusted Routing algorithm (ESTR). This is due to supporter has gathered the relevant information from information gathering module and it computes the trust value according to the behaviour of the nodes according to the temporal and position of the relevant sensor nodes.

Figure 4 shows the energy consumption analysis between the proposed algorithms like ESTR, IWFCRA and LEATDSR. Here, five different experiments have been conducted by considering five different mobility speeds. From figure 4, it can be seen that the energy consumption of the proposed LEATDSR is less when it is compared with the ESTR and IWFCRA algorithms. This is due to on demand routing procedure that is working mainly based on the source-routed on-demand routing which is used for improving the network lifetime.

| METRICS                        | VALUE   |
|--------------------------------|---------|
| Time for simulation            | 490s    |
| Monitoring range               | 275 x 275 m |
| Total amount of sensor nodes   | 1000    |
| Attackers%                     | 25%     |
| Distributed of node model      | Random model |
| Initial energy                 | 19J     |
Figure 4 shows the security level analysis for ESTR, IWFCSRA and LEATDSR. Here, five experiments have been conducted with different number of nodes in the network scenario such as 100, 200, 300, 400 and 500 for analyzing the security level of the proposed work. From figure 5, it can be observed that the performance of the proposed LEATDSR is high when it is compared with the ESTR and IWFCSRA. This is due to the use of outlier detection, intelligent fuzzy rules, effective trust mechanism and consideration of mobility and energy during the decision making process over the routing process.

Figure 5. Security Analysis

5. CONCLUSION
In this paper, a novel energy efficient routing protocols for WSN like ESTR, IWFCSRA and LEATDSR where implemented and analyzed for effective performance. While Analyzing packet delivery ratio, ESTR has the higher performance than LEATDSR and IWFCSRA. Moreover, when analyzing energy consumption, LEATDSR has less consumption rather than ESTR and IWFCSRA. When looking over security analysis, LEATDSR has high security feature rather than ESTR and IWFCSRA. In further implementation of Machine learning with Energy and Trust based routing algorithm will be feasible.
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