

Designing dynamic adjustment approach of event reliability in wireless sensor network

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Abstract

Many industries, such as environmental monitoring, industrial automation, healthcare, agriculture, and more, use wireless sensor networks. A critical requirement for wireless sensor networks (WSNs) is reliable transmission from source to destination. The main challenges for reliable data transmission are network connectivity, coverage optimization, data aggregation, shortest path, congestion, bandwidth, and quality of service. In a static environment, all sensor units transmit maximum data to the sink, dramatically raising their energy utilization and resulting in their early death. A dynamic environment can be utilized to collect data to reduce the amount of energy required to transport lengthy data packets over a wide area while still maintaining sensor node energy usage. The dynamic environment and duplicate packet simulation reflect real-world challenges like changing node positions and the potential for data duplication due to wireless communication issues. This paper introduces a dynamic event reliability protocol (DERP) in which the new positions of the sensor nodes are generated randomly in each event and a mobile sink collects data from every sensor node. The proposed technique consists of four parts, including a network model, a radio and energy model, a proposed approach, and a performance analysis. Our results show that DERP significantly improves energy consumption and unique packet delivery while reducing packet loss and the number of duplicate packets against LEACH and the average k-means clustering approach.

Subject Classification: 68M15.

Keywords: Wireless sensor network, Event reliability, Mobile sink, Dynamic environment, Energy consumption.

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1. Introduction

Many industries, such as environmental monitoring, industrial automation, healthcare, agriculture, and more, use wireless sensor networks. In an environmental monitoring application, temperature, humidity, pollution levels, and other data can be gathered with WSNs [1, 2].

A static wireless sensor network (WSN) is a collection of small, battery-powered sensor nodes equipped with wireless communication capabilities as shown in Figure 1. These sensor nodes are typically stationary and are deployed in a fixed configuration to monitor and collect data from their surrounding environment [3, 4]. Static wireless sensor networks are valuable for various monitoring applications but they have limitations related to coverage, scalability, node reliability, and data duplicacy [5, 6]. A wireless sensor network with dynamic environment is a network in which sensor nodes have the capability to move or change their locations over time. Unlike static WSNs, where sensor nodes are stationary, dynamic WSNs allow for flexibility in node mobility and adaptability to changing environmental conditions. In summary, dynamic wireless sensor networks offer advantages in terms of adaptability to changing environments, extended coverage, efficient data collection, energy efficiency, scalability, fault tolerance, real-time monitoring, and enhanced security [7, 8]. These advantages make dynamic WSNs valuable in applications where flexibility and responsiveness are critical [9]. In this article, we propose a dynamic event reliability protocol (DERP) for WSN in a dynamic environment. DERP simulates the operation of sensor nodes sending data to a mobile sink, which could represent a central data

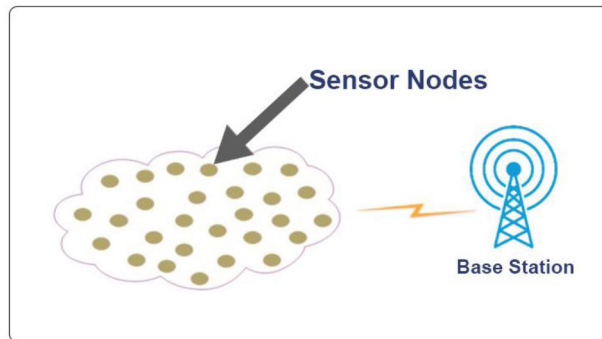


Figure 1
Wireless sensor network architecture

collection point. The dynamic environment and duplicate packet simulation reflect real-world challenges like changing node positions and the potential for data duplication due to wireless communication issues.

2. Related Work

This section describe a thorough study of a wide range of current surveys, comparison studies, and reviews that look at the reliability of WSNs from various angles. For various applications, both the problems and solutions were identified and discussed. An approach to assessing the reliability of WSNs in typical industrial situations has been proposed by researchers. They used a fault tree-based formalism to represent a WSN, taking into account permanent faults that develop in field devices as a result of hardware issues and the lack of pathways to the gateway. The outcomes demonstrate the proposal's value in locating reliability bottlenecks, calculating the necessary level of redundancy, and assisting in network design over its entire life cycle. They create an optimization problem that identifies the ideal sensor set whose sensing and transmission radius is to be changed to offer the necessary degree of coverage by minimizing a cost function made up of energy consumption and achievable accuracy in detection [10, 11]. It is challenging to assess the network stability of wireless sensor networks (WSNs) due to their complexity, multistate, and dynamic features. Authors provide a few evaluation approaches that are transmission-path-based and mission-oriented. Furthermore, researchers claim that when a node fails or the communication environment changes, the dynamic assessment framework is automatically updated and can be customized upon request. The outcome of the simulation demonstrates how accurate and efficient the suggested evaluation methodology was.. A variable number of sensor nodes can cooperate in real time to detect and convey any given event with the aid of this framework. This framework works well and efficiently in terms of energy consumption and processing delays [12, 13]. They developed a brand-new, all-encompassing dependability metric for heterogeneous WSN deployments in this study. They developed a search method that creates the entire set of pathways for a particular deployment in a time-effective manner, addressing the computational challenge involved with assessing the reliability of deployments at realistic scales using the proposed reliability metric. The results show that the level of SN redundancy and the failure risks of the individual SNs that make up the deployment have the biggest effects on a deployment's reliability [14].

According to the author, a WSN's ability to sustain an end-to-end connection in the face of unstable links or node loss is frequently correlated with how dependable it is. They contend that Katz's status index is a suitable gauge of reliability. [15]. The suggested approach gives sensor nodes the option to choose whether they should exchange sensor values to accurately detect events. The technique was used in cargo monitoring systems to track the movement of unattended freight boxes as they were being transported. This approach, which detects spatial events based on shared sensor readings, greatly increases network lifetime, provides accurate event detection, and minimizes data transmissions between surrounding sensor nodes, according to experimental assessment. A mesh topology's reliability use three models, S-RBD, H-RBD, and T-based FTA, are compared, and it is found that S-RBD is the least trustworthy, while H-RBD is the most reliable, and FTA offers intermediate results since it considers the actual weight of each node in the network. The proposed network can be evaluated for system availability and reliability using FTA, but it is not practical to build the entire fault tree of the system when there are hundreds or thousands of nodes [16, 17]. Researchers examine the significance of packet loss consideration (PLC) in a wireless sensor network's inter-node communication. Their evaluation is based on measurements made in the field using the IRIS Crossbow WSN. They suggest a network initiation phase during which all nodes solicit data from all of their neighbors regarding connection packet loss. Each node will use this information to determine the attending cluster head (CH) based on the least amount of packet loss rather than the greatest RSSI. Simulations show that taking packet loss into account when determining the appropriate communication path has a considerable influence on lowering network energy usage and raising network throughput. The author argues that the fundamental LEACH protocol is insufficient for mobile nodes. A type of mobile WSN routing protocol called LEACH-M was developed on the LEACH protocol to maximize node movement. This study extends the concept of on-demand routing to the mobile sensor network by proposing a clustering protocol called Leach-MON based on mobile WSN for the loss of LEACH-M packets. When the nodes' throughput and energy usage were completely taken into account during the simulation using the NS3 Network Simulator, the packet loss was substantially lower than it was for LEACH-M [18, 19]. MWSNs (Mobile Wireless Sensor Networks) place a high priority on reducing packet drops. To deal with the packet drops, numerous techniques are put forth. This method suggests employing volunteer nodes (PDRV) in the MWSN to

reduce packet drops. Volunteer nodes seek to lessen network delays and packet losses. Based on node linkage, energy, communication processing time, and bandwidth, nodes are chosen. Additionally, for sending secure data, PDRV uses an OTK to validate the hash signature. As a result, it lessens the delay as well as the packet loss. The major issue is that different applications' packets have varied QoS requirements when they travel via computer networks. To discover the best weights for the weighted fair round-robin algorithm (WFRR) in this study, we propose employing the particle swarm optimization approach while taking into account the traffic's fluctuating densities. The results reveal that the particle swarm optimization for the weighted round-robin method is more effective than WFRR, especially in high-intensity traffic. The suggested approach to optimize the weights is compared with the conventional WFRR algorithm [20, 21]. Energy balancing, packet loss, and latency reduction are the key problems with cluster-based data aggregation algorithms in wireless sensor networks (WSN). This research proposes a cluster-based data aggregation scheme for WSN packet loss and latency reduction. Aggregation Tree Construction and the Slot Scheduling Algorithm are the two components of the suggested approach. This method decreases waiting and unnecessary retransmissions, which enhances network performance in WSN. Simulation findings demonstrate that the suggested technique boosts the packet delivery ratio and residual energy while decreasing delay and overhead [22].

3. Problem statement and motivation.

A WSN must have reliable data transfer as a key need. There are many causes for unreliable transmission such as redundant data, collisions, packet loss, heavy traffic, delays, or other reasons. The data transported in the network from source to destination must arrive without loss or fault in order to maintain the WSN's reliability [23]. In static WSNs, every sensor unit transmits a heavy amount of data to the sink, substantially increasing their energy consumption, leading to the early death of nodes, and splitting the network topology. As a result, nodes positioned far from the sink won't be able to send data, which will shorten the WSN's lifespan. To reduce the energy needed to send large data packets over a large region while maintaining sensor node energy utilization, data collection can be done in a dynamic environment. Generating new random positions for sensor nodes simulates a dynamic environment to reflect real-world scenarios where sensor nodes may move or change their positions over time. In

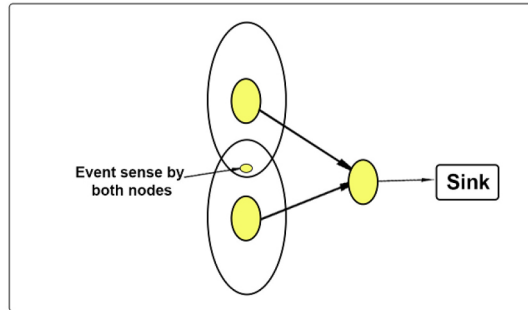


Figure 2

Duplicate event sensing

many wireless sensor network applications, nodes may be deployed in environments where their positions are not fixed. For example, sensor nodes might be placed in agricultural fields, forests, or urban areas where factors like wind, animal movement, or human activities can cause nodes to change their locations. By generating new random positions for sensor nodes in each simulation event, the code introduces variability into the network topology. This variability is an attempt to mimic the changing nature of a real-world environment and its impact on the communication dynamics within the network. Mobility is utilized to cover the largest area of interest in order to obtain maximum coverage in a network. But due to mobility, multiple sensor nodes may have overlapping sensing ranges and detect numerous packets associated with the same event, as shown in Figure 2.

Event duplication is the process of sending data about the same event in two or more packets. Duplicate events can lead to congestion, energy waste, and high bandwidth use. While the sink receives at least one packet with the event's sensed data, eliminating duplicate packets is necessary for event reliability [5, 6].

4. Proposed DERP

Figure 3 shows the steps taken in the code to simulate the DERP protocol in a wireless sensor network with a dynamic environment. Each event simulates the movement of the mobile sink, the updated positions of sensor nodes, and the reception of packets, considering packet loss and duplicates. The final metrics are calculated and displayed to evaluate the protocol's performance. In the dynamic environment simulation, the new positions of the sensor nodes are generated randomly for each event. The position matrix stores the (x, y) positions of the sensor nodes.

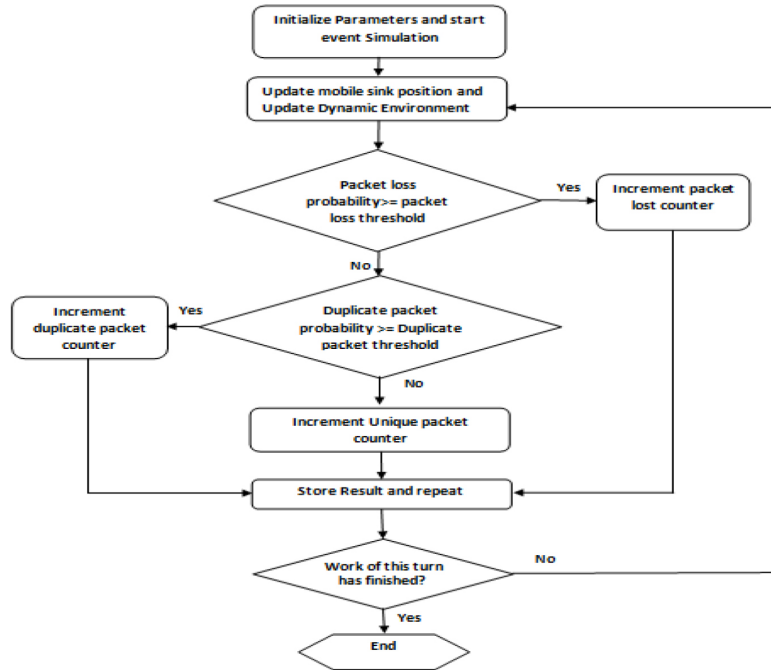


Figure 3

DERP working flowchart

5. System Model and Performance Parameters

5.1 Network Model

Network model assume that all sensor nodes will be randomly placed in an $M \times M$ -square region, and that all of them will interact with the mobile sink using the single-hop communication. The nodes closest to the path of the mobile sink will be chosen through the construction of the shortest path. The mobile sink collects data while travelling at a constant speed along the shortest path. All the other parameters are described as follows:

1. Nodes send data in terms of n bits at regular intervals, otherwise called rounds.
2. Sink movement is performed using the shortest path routing technique.
3. Neighbors and distance is computed using Euclidian formula $D = [(y_i - y_j)^2 + (x_i - x_j)^2]^{1/2}$

4. Equal energy is distributed to all the nodes, and the energy is the same during the transmission between the sender and the receiver in both directions.
5. Each packet assigned a unique id to remove duplicate packets.

5.2 Energy Consumption Model

The network model is shown in more detail in Figure 4, and it is mostly used to estimate how much energy the nodes used during transmission between the source and the destination require [24]. The major sections are transmitter electronics and receiver electronics. At the initial condition, the data packets are transmitted to the transmitter section. There the process of amplification is also carried out. Then it is transmitted to the receiver section. The transmitter and receiver circuits' main consideration is energy, which is strongly related to the quantity of bits (n).

$$E_{elec} = E_{\left(\frac{TX}{RX}\right)} \div n, \quad (1)$$

where, E_{elec} denotes the energy that is taken per bit (n) to start the transmitter (T_x) and the receiver (R_x).

The number of bits (n) and the transmission distance (dt) are taken into account in order to determine the transmitter energy required by the amplifier.

$$E_{temp} = \begin{cases} \varepsilon_{fs} \times n \times d_t^2, & \text{if } d_t < d_{th} \\ \varepsilon_{mp} \times n \times d_t^4, & \text{if } d_t > d_{th} \end{cases}, \quad (2)$$

where d_{th} is a threshold value used to determine the fading model, and the value of d_{th} is denoted as,

$$d_{th} = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}, \quad (3)$$

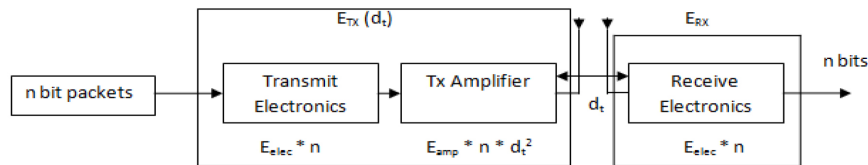


Figure 4
Network energy Model

Hence the total transmission energy is given as, where ϵ_{fs} and ϵ_{mp} are the constant values, those are used to represent the basic models such as free space and multi-path models.

$$E_{TX} = \begin{cases} (E_{elec} \times n) + (\epsilon_{fs} \times n \times d_t^2), & \text{if } d_t < d_{th} \\ (E_{elec} \times n) + (\epsilon_{mp} \times n \times d_t^4), & \text{if } d_t > d_{th} \end{cases} \quad (4)$$

And the receiver energy is given as,

$$E_{RX} = E_{elec} + L. \quad (5)$$

6. Simulation Parameters and Result analysis

We evaluated the performance of the DERP via simulations using MATLAB and compared it with the average K-means clustering and Leach protocol. We simulate six random sensing events occurring periodically. Performance metrics such as packet received, duplicate packet, lost packet, and energy are analyzed. The simulation parameters are listed in Table 1.

Table 1
Simulation Parameters

Parameter used	Value
Number of nodes	100
Transmit range	10 m
MAC Protocol	802.11 collision free
Total Simulation Time	300 s
Grid size	100 × 100 mts
Initial Energy	25 J
Sink node	1
Sink speed	10 m/s

Unique Packet Received:

Figure 5 illustrates the performance of the total number of unique packets delivered at the sink over time. The number of packets received at the sink through DERP Contrasting ERP with LEACH and average K-means clustering, DERP reveals a significantly higher number of unique events reported at the sink. In order to successfully transfer valuable event

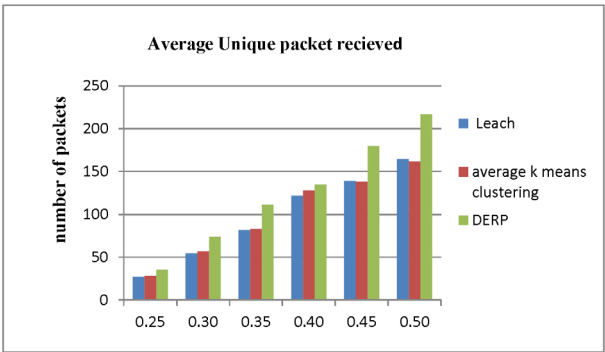


Figure 5

Average unique packet received vs time in second

information to the sink, DERP performs better than LEACH and average K-means clustering.

- **Average Duplicate packets received**

We can also see how DERP helps by reducing the amount of duplicate event packets. In comparison to the current LEACH and average K-means clustering, Figure 6 demonstrates that the amount of duplicate events recorded at the sink in DERP is significantly smaller. This indicates that DERP actually reports a higher number of unique events at the sink than other protocols. In order to successfully convey important event information to the sink, DERP is therefore noticeably superior.

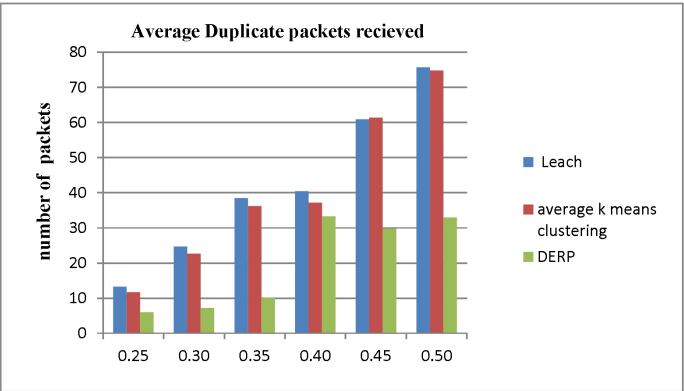


Figure 6

Average Duplicate packets received vs time in second

- **Average packets lost**

By adjusting to changing conditions and maximizing energy economy, the DERP protocol is intended to improve network performance, including lowering packet loss. In comparison to the current LEACH and average K-means clustering, as shown in Figure 7, the number of lost packets recorded at the sink in DERP is significantly lower. This indicates that compared to other methods, DERP performs much better.

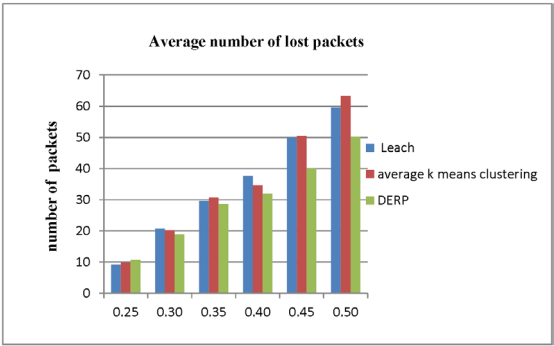


Figure 7

Average packet s lost during transmission vs time in second

- **Average energy consumption**

We can see from Figure 8 that the proposed DERP consumes less energy and increases network lifetime when compared to LEACH and average K-means clustering under the same simulation conditions.

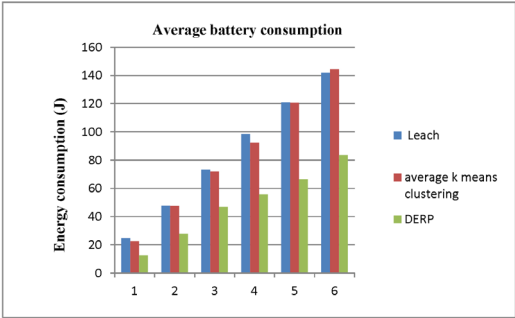


Figure 8

Average energy consumption vs time in second

7. Conclusion

Our research concentrated on measuring the effectiveness of a DERP protocol in WSN. DERP uses the mobile sink's updated position to calculate the distance between sensor nodes. The code then tracks received packets, duplicate packets, and simulate packet loss. Several scenarios were run using various network configurations. The simulation results of the DERP protocol are implemented using MATLAB and compare with the average K-means clustering and Leach protocols. The findings show that the proposed approach greatly minimizes energy consumption and significantly prolongs the life of the network, and DERP has the ability to improve the ideal packet ratio transferred from the sensor nodes to the base station. DERP improves event reliability by minimizing the number of duplicate packets compared to the average K-means clustering and Leach protocol.

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