

# Reliability Analysis of Wireless Sensor Networks in a Static and Dynamic Environment

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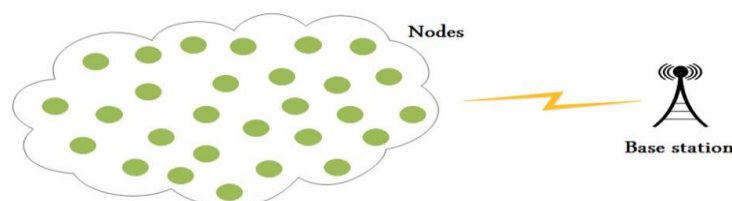
## ABSTRACT.

WSNs have enabled a new control and monitoring paradigm for information detection in a large geographical area. In a WSN, sensor units collect data from the surroundings and transmit this raw data to the sink. The sink refines this raw data with predefined methods and procedures and sends it to the base station. In a static WSN sensor nodes and sinks are fixed at their respective positions. Sensor nodes do not move and cannot change their respective positions. So huge number of sensor nodes are deployed to cover the monitoring area for data sensing and transmitting purposes. In a dynamic environment, nodes can move during their lifetime. A movable sensor node is used to improve or enable communication and sensing coverage. In this paper, the reviewed research works are classified into static and dynamic environments. The analysis is focused on whether a static or dynamic environment is employed and whether nodes are static or mobile. This paper also explores the features and key considerations of both static and dynamic environments.

**Keyword:** wireless sensor network, event identification, static and dynamic environment

## 1. INTRODUCTION

WSNs are low-cost systems made up of a large number of small sensor nodes and sinks, as shown in **Fig. 1**. Sensor nodes are commonly placed in dense clusters to fulfill complex tasks through close collaboration. WSNs are used in various applications due to their compact size and low cost [1, 2]. Reliability in Wireless Sensor Networks (WSNs) refers to the network's ability to consistently and dependably perform its intended tasks despite challenges and uncertainties. Reliability is a fundamental requirement in many WSN applications, such as environmental monitoring, healthcare, industrial automation, and more, where the accuracy and consistency of data collection and transmission are critical [3, 4].



**Fig. 1.** Wireless sensor network architecture

## 2. RELATED WORK

WSNs have enabled a new control and monitoring paradigm for information detection in a large geographical area. In a WSN, sensor units collect data from the surroundings and transmit this raw data to the sink. The sink refines this raw data with predefined methods and procedures and sends it to the base station [6, 7]. WSNs are used in different application areas to identify an event. An event may be anything from environmental monitoring to fire detection. A variety of sensors, such as light and temperature sensors, microphones, accelerometers, and cameras, can be used depending on the application. While designing an application, some constraints are also to be considered so that the application can perform in a better way. Designing an energy-efficient protocol is one of the most important necessities to maximize the longevity of the network via energy-efficient techniques [8, 9]. The major challenges in WSNs with limited resources are how to achieve a high degree of reliability to provide efficient transmission of sensing events in monitoring and control systems. The majority of current research focuses on achieving event reliability in a static environment, ignoring the use of a dynamic environment to enhance event reliability. A dynamic environment with reliable event detection will reduce unreliability and inadequacy in terms of transmission accuracy, network connectivity, coverage optimization, data aggregation, path finding, congestion, bandwidth, and quality of service [10, 11]. A traditional WSN is made up of static sensor nodes and a static sink that are positioned inside the monitored area. Battery power utilization is a critical factor for sensor nodes because it is difficult to replace batteries in large-scale networks. In practice, each node works with restricted battery power, where the maximum energy is exhausted on event detection and transmission processes. In multi-hop static WSNs, all sensor units transmit maximum data to the sink, dramatically raising their energy utilization and resulting in their early death and network topology partitioning. As a result, nodes placed far away from the sink will not be able to send data to the sink, which will decrease the life span of the WSN. Mobile sinks are recommended as a solution for data collection from a large geographical area, which maintains energy utilization along with the sensor [12, 13]. A mobile sink is a mobile device with moving capability in a sensing region to collect data. In such systems, the mobile sink increases network flexibility, the convenience of data collection, and the lifetime of the WSN. In a dynamic environment, a mobile sink can use any type of predefined mobility, such as random, fixed, or controlled mobility, for data collection approaches and energy efficiency [14].

## 3. ENVIRONMENT CLASSIFICATION FOR WSN:

Sensor nodes monitor the field of interest, communicate with other nodes for data exchange, and process data to make local decisions about monitored phenomena. There are two environments in a WSN for event identification.

### 3.1 Static Environment

In a static WSN, sensor nodes and sinks are fixed at their respective positions. Sensor nodes do not move and cannot change their respective positions. A huge number of sensor nodes are deployed to cover the monitoring area for data sensing and transmitting purposes. A central sink receives raw data from the sensor nodes, processes this raw data, and forwards refined data to the base station. Because of the limited resources in WSNs, especially power limitations, it is always desirable to minimize the network traffic in a WSN and only transmit the packets that are needed for the application [15, 16].

### 3.2 Dynamic Environment

In a dynamic environment, nodes can move during their lifetime. The mobility of nodes can be divided into two different areas:

**Sensor Node Mobility:** A movable sensor node is used to improve, or enable altogether, communication and sensing coverage. In this model, the sensors move into locations to provide maximum coverage and reduce the energy cost of transmitting data streams to the sink [17].

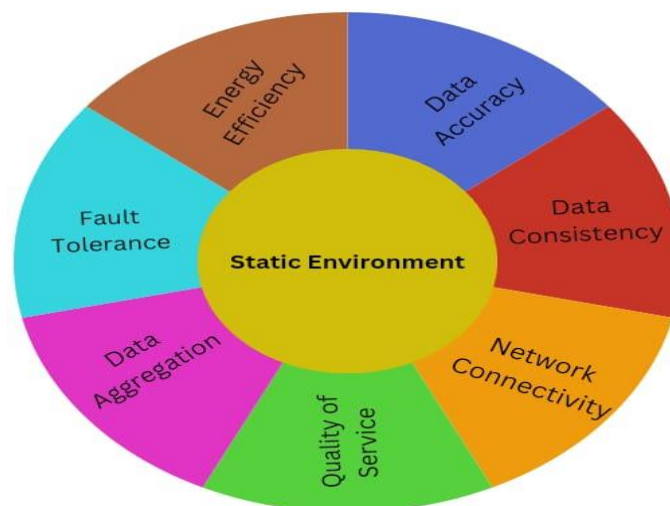
**Sink Mobility:** In this network model, a mobile sink is used to move into the sensing region to collect sensing information from sensor nodes. In such systems, the mobile sink increases network flexibility and the convenience of data collection. . With the use of predefined mobility patterns (random, fixed, or controlled), a mobile sink can collect data reliably and efficiently from sensors [18].

## 4. RELIABILITY CLASIFICATION

Achieving reliability in WSNs is a multidisciplinary challenge. It involves designing robust communication protocols, optimizing energy usage, ensuring fault tolerance, and addressing challenges like interference, node failures, and network scalability. We can classify reliability under static environment and dynamic environment.

### 4.1 Reliability of WSN in a static environment:

Reliability in wireless sensor networks (WSNs) within a static environment primarily focuses on ensuring dependable data collection and transmission in scenarios where sensor nodes and the monitored environment remain relatively unchanged over time. In such settings, the challenges related to reliability are often tied to factors like data accuracy, consistency, and network robustness. Some classification of reliability in WSNs within a static environment are data accuracy, data consistency, network connectivity, and fault tolerance, quality of service, energy efficiency, and data aggregation as shown in **Fig. 2**.



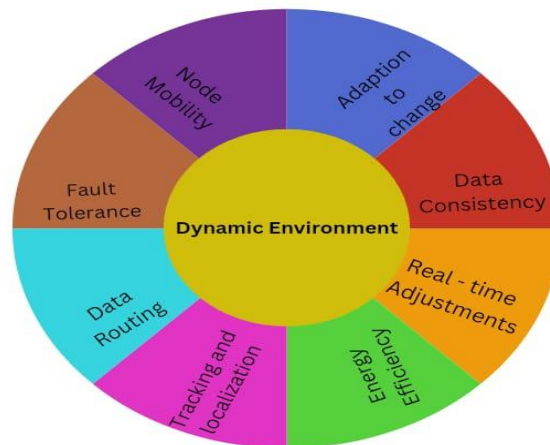
**Fig. 2.** Key Considerations in a Static Environment

Reliability in a static WSN is particularly important in applications like environmental monitoring, precision agriculture, and infrastructure monitoring, where consistent and accurate data is required over extended periods. Achieving reliability in such scenarios often involves the design of specialized communication protocols, energy-

efficient algorithms, and network management strategies tailored to the specific requirements of static environments.

**4.2 Reliability of WSN in a Dynamic Environment**

Reliability in Wireless Sensor Networks (WSNs) within a dynamic environment involves ensuring consistent and dependable data collection and communication in scenarios where the environment and the sensor nodes themselves experience frequent changes and movement. Some classification of reliability in WSNs within dynamic environments are node mobility, data continuity, adaptation to changes, fault tolerance, data routing, energy efficiency, tracking, and localization as shown in Fig. 3.



**Fig. 3.** Key Considerations in a Dynamic Environment

To handle a dynamic environment in a WSN, it's important to design the network and its algorithms with adaptability in mind. This could involve dynamic routing protocols that can quickly adjust to changing paths, algorithms to handle node failures and replacements, and strategies to adjust sensing schedules based on changing conditions. Such adaptations can help the WSN maintain its functionality and achieve its monitoring objectives even in the presence of a changing environment.

**5. SALIENT FEATURES OF DIFFERENT RELIABILITY APPROACHES**

Each of the reliability schemas has unique features which are reviewed in this study are elaborated in the following table:

**Table 1.** Salient Features of Reliability Approaches

S. No	Protocol/ Approach	Environment	Simulation Tool	Findings	Gaps
1.	MTCLM[16]	Dynamic	MATLAB	Use a dynamic environment to maximize the number of covered targets.	Energy use, transmission accuracy, and future challenges were not addressed.
2.	CNE [21]	Static	NAM	Provides a better result in packet delivery ratio,	Lack of event reliability and data aggregation.

				end-to-end delay, and energy consumption.	
3.	DS-EERA[22]	Static	MATLAB	minimize energy consumption while also extending the network lifetime	Lack of Dynamic environment and data aggregation.
4.	RTGOR [23]	Dynamic	ONE	Improve energy consumption and provide more convergence.	Lack of data aggregation is not suitable for large networks.
5.	Multifactor Strategy [24]	Static	NS2	Increasing the packet delivery ratio and securing packet transmission.	Nodes use a lot of energy to increase the packet delivery ratio.
6.	EEEC [25]	Static	OMNET++	Clustering approach for event reliability in homogeneous WSN.	Lack of a dynamic and heterogeneous WSN environment.
7.	EAAER [26]	Dynamic	MATLAB	Minimize duplicate packets, improve energy efficiency,	Not suitable for large WSNs
8.	EDHRP [27]	Static	NCTUNS6.0	Increase efficiency in terms of power utilization, end-to-end delay, congestion control,	Not suitable for heterogeneous WSN consisting of nodes of different capabilities.

Table 1 presents the features of the different schemes discussed in the previous sections. Each scheme aims to achieve energy-efficient, reliable WSN by using different reliability approaches.

## 6. CONCLUSION

WSN architectures in the past assumed that the network was dense and that any sensor node could connect with the sink via multi-hop transmission without any mobility. This type of environment was called a static environment, in which all sensor nodes and sinks were fixed at their positions and could not move. In a dynamic environment, mobile nodes are used for data collection. In this paper, the reviewed research works are classified into static and dynamic environments. The analysis is focused on whether the environment is static or dynamic and whether nodes are static or mobile. This paper also explores features and key considerations of both static and dynamic environments.

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