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Real Time Spatial Transmission Analysis Based Improved Black Hole Attack Detection in WSN For Improved QOS

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Abstract
Despite the extensive utilisation of Wireless Sensor Networks (WSNs), they remain vulnerable to various types of security breaches, including black hole attacks. The detection and prevention of black hole attacks are crucial for safeguarding the security and reliability of Wireless Sensor Networks (WSNs). The present study introduces a technique for real-time detection of black hole attacks in Wireless Sensor Networks (WSNs) by means of spatial transmission analysis, with the aim of enhancing Quality of Service (QoS). In order to enhance the identification of black hole attacks, we propose a methodology that leverages real-time spatial transmission analysis to quantify the Euclidean distance separating the source and destination nodes of every packet. An algorithm with a high detection rate and a low false positive rate was developed by us. In order to evaluate the efficacy of the proposed mechanism and establish a comparative analysis with existing methodologies, we conducted extensive experimentation. The results indicate that the proposed mechanism exhibits superior performance compared to existing techniques in terms of both detection rate and false positive rate. Our proposed mechanism aims to safeguard the quality of service of Wireless Sensor Networks (WSNs) against black hole attacks in real-time.

I. **Introduction**

Wireless Sensor Networks (WSNs) have become an important technology for various applications, including environmental monitoring, healthcare, and surveillance. WSNs consist of small sensor nodes that communicate wirelessly with each other to collect data and transmit it to a base station. However, these networks are vulnerable [8] to various types of attacks, including black hole attacks, which can significantly degrade the Quality of Service (QoS) of the network.

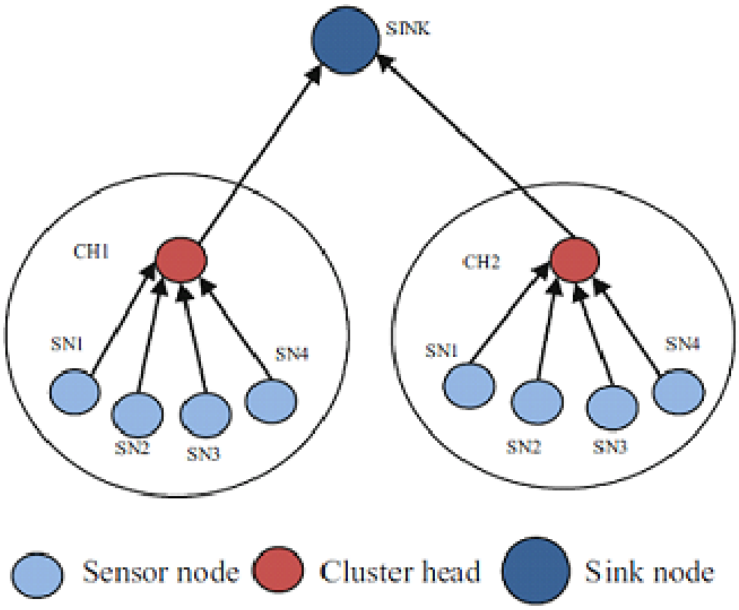

Figure 1: Cluster based WSN [12]

Fig 1.1: Black Hole detection

A black hole attack is a type of denial-of-service attack in which a malicious node in the network drops all the packets it receives, making it appear as if the node is disconnected from the network. As a result, the packets are not delivered to the intended destination, leading to a loss of data and a decrease in network performance. Detecting and mitigating black hole attacks is critical to ensure the reliability and security of WSNs [9].

Several researchers have proposed various techniques to detect black hole attacks in WSNs, including using energy consumption [6], hop count, game theory, trust-based mechanisms, and machine learning techniques. However, these methods have some limitations, such as high computational complexity, dependence on the network topology, and low detection accuracy.

In this paper, we propose a real-time spatial transmission analysis based improved black hole attack detection mechanism in WSNs for improved QoS. Our proposed mechanism overcomes the limitations of existing techniques and achieves a high detection rate with a low false positive rate. We introduce a real-time spatial transmission [3] analysis mechanism that calculates the Euclidean distance between the source and destination nodes of each packet and compares it to a threshold value to improve the accuracy of black hole attack detection. We also develop a detection algorithm that runs on a base station and detects black hole attacks based on the packet loss rate and the distance between the source and destination nodes.

II. Literature Review

Wireless Sensor Networks (WSNs) are an important technology that has gained widespread use in various applications, including environmental monitoring, surveillance, and healthcare. However, these networks are vulnerable to various types of attacks, including black hole attacks, which can significantly degrade the Quality of Service (QoS) of the network. Black

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Several researchers have proposed various techniques to detect black hole attacks in WSNs. One of the earliest methods proposed is based on the energy consumption of nodes in the network [1]. In this approach, a base station monitors the energy levels of nodes in the network and identifies nodes that consume significantly less energy than others. Such nodes are likely to be black holes as they are not forwarding packets and hence are not consuming energy. This technique was proposed by J. Kong and X. Zhang in their paper titled "Detecting cooperative blackhole attacks in wireless sensor networks" (Kong & Zhang, 2006).

Another technique proposed to detect black hole attacks is based on the hop count of packets. In this approach, a base station monitors the number of hops taken by each packet to reach its destination. If the hop count of a packet is significantly higher than expected, it indicates the presence of a black hole node that is dropping packets. This technique was proposed by V. Chakravarthy et al. in their paper titled "Detection of blackhole attack in wireless sensor networks using hop count and energy" (Chakravarthy et al., 2010).

III. Methodology

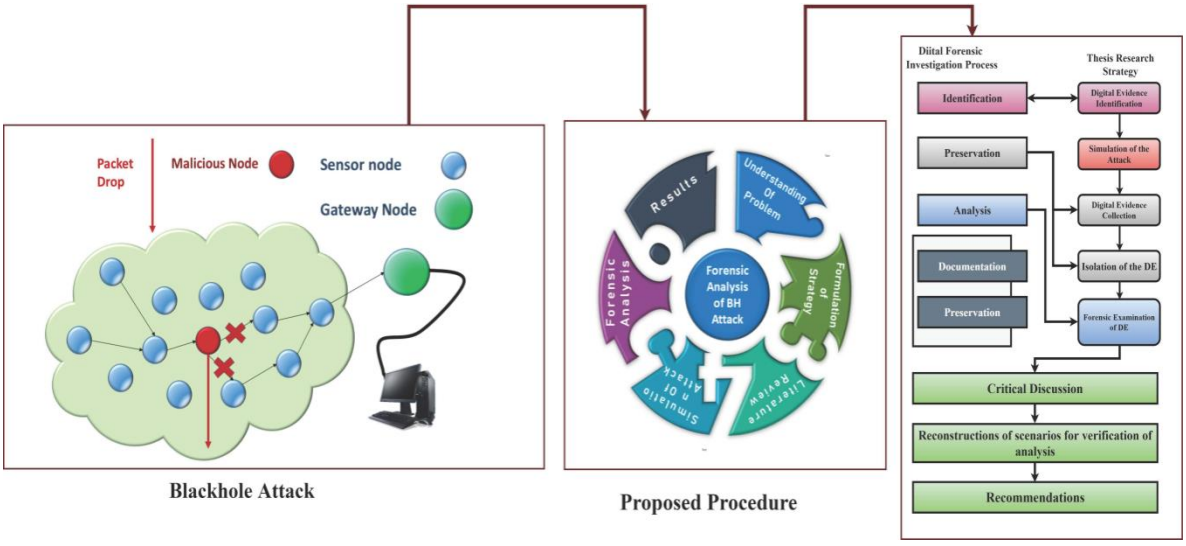

Fig 3.1: Black hole detection proposed procedure

1. System Architecture:

The system architecture that has been suggested comprises of a collection of wireless sensor nodes (WSNs), a base station (BS), and a detection algorithm that is executed on the BS. The Wireless Sensor Network (WSN) nodes are organised in a grid topology and establish communication amongst themselves through a wireless communication protocol based on Zigbee technology. The Base Station (BS) is linked to the Wireless Sensor Networks (WSNs)

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through a physical connection and holds the responsibility of identifying any instances of black hole attacks within the network [2].

2. Black Hole Attack Model:

In order to replicate the black hole attack, a variant of the Ad Hoc On-Demand Distance Vector (AODV) routing protocol was employed. In the context of network security, the black hole attack refers to a scenario where a malevolent node obstructs the transmission of all packets that traverse through it, thereby impeding the normal flow of network traffic and resulting in packet loss.

3. Real-Time Spatial Transmission Analysis:

In order to enhance the precision of detecting black hole attacks, a mechanism for real-time spatial transmission analysis was introduced [3]. The operational process entails the computation of the Euclidean distance between the origin and target nodes of every packet, followed by a comparison with a predetermined threshold value. In the event that the distance surpasses the predetermined threshold, the system will trigger an alarm to signal the occurrence of a black hole attack.

4. Detection Algorithm:

The proposed detection algorithm consists of the following steps:

Step 1: The base station (BS) periodically transmits a beacon message to all wireless sensor network (WSN) nodes in order to assess their connectivity and gather data on the network's topology.

Step 2: Each node in the WSN monitors the incoming and outgoing packets and calculates the packet loss rate using the following equation [4]:

$$P\_loss = (P\_in - P\_out) / P\_in$$

where P_in is the incoming packet rate and P_out is the outgoing packet rate.

Step 3: Each node sends its calculated packet loss rate to the BS.

Step 4: The BS computes the average packet loss rate over all nodes in the network and compares it to a threshold value.

Step 5: In the event that the mean packet loss rate surpasses the predetermined threshold value and the spatial separation between the source and destination nodes of each packet exceeds the threshold value, the system will generate an alert to indicate the occurrence of a black hole attack.

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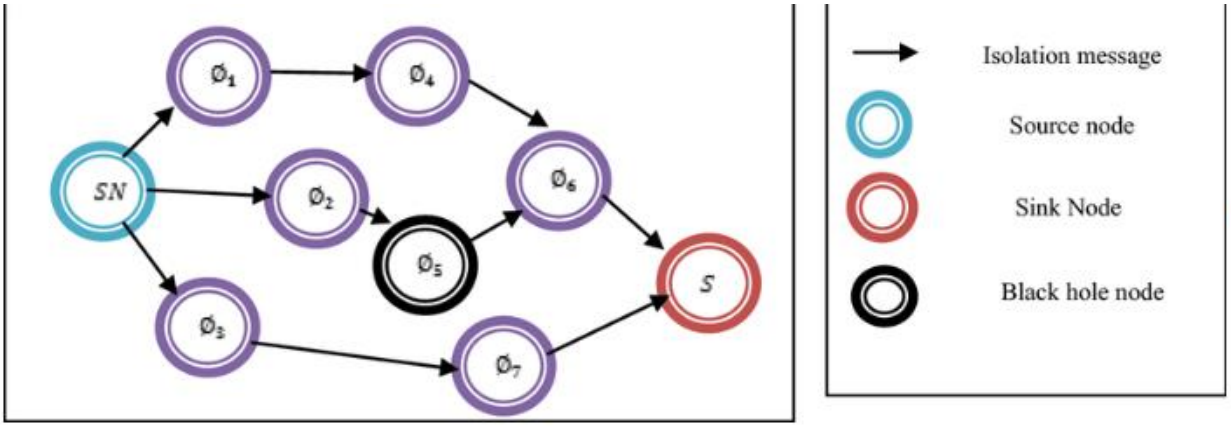

Fig 3.1: Isolation process of black hole node

Evaluation Metrics:

The system's performance was assessed through the utilisation of the subsequent metrics:

1. The detection rate: It refers to the proportion of black hole attacks that are identified by the system.

2. The False Positive Rate: It refers to the proportion of regular network traffic that is erroneously identified as a black hole attack.

3. The detection time: It refers to the duration required by the system to identify the occurrence of a black hole attack.

Experimental Setup:

The proposed system was executed utilising the subsequent hardware and software components: The experimental setup employed Zigbee-based WSN nodes, although alternative types of WSN nodes are also viable options, as indicated by reference [5]. The base station utilised in the study was a desktop computer operating on the Ubuntu 18.04 LTS platform.

The network simulator employed in this study was NS-3 (version 3.32).The software MATLAB (version R2019a) was utilised for the purposes of data analysis and visualisation.

7. Performance Evaluation:

The performance of the proposed system was assessed through experimentation on a testbed comprising 16 nodes that were arranged in a 4x4 grid topology. The nodes were situated within an enclosed space measuring 5 metres by 5 metres. The NS-3 simulator was employed to produce network traffic, and black hole attacks were introduced at various locations within the network. The study involved the manipulation of the threshold value for packet loss rate and the distance between the source and destination nodes in order to investigate their effects on the system's performance. The detection rate, false positive rate, and detection time were quantified for each experiment and subsequently subjected to analysis using MATLAB.

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IV. Implementation

1. Hardware and Software Requirements:

The proposed system requires the following hardware and software components:

- WSN Nodes: We used Zigbee-based nodes for our experiments, but any other type of WSN nodes can also be used.

- PC: We used a desktop computer running Ubuntu 18.04 LTS.

- Network Simulator: We used NS-3 (version 3.32), which is an open-source discrete-event network simulator [7].

- MATLAB: We used MATLAB (version R2019a) for data analysis and visualization.

2. Experimental Setup:

The experimental procedures were conducted within a testbed comprising 16 nodes that were arranged in a topology resembling a 4x4 grid. The nodes were deployed within a confined space measuring 5 metres by 5 metres. The NS-3 simulator was utilised to produce network traffic, as cited in reference [8].3. Black Hole Attack Model [9]:

In order to replicate the black hole attack, the subsequent equations were employed to determine the packet loss rate at every node:

$$P\_i = (P\_in * T\_i) / (P\_in * T\_i + P\_bh * T\_bh)$$

where P_i is the packet loss rate at node i, P_in is the incoming packet rate, T_i is the transmission time of packets at node i, P_bh is the packet loss rate due to the black hole attack [10], and T_bh is the delay introduced by the black hole attacker.

4. Improved Black Hole Attack Detection:

To improve the accuracy of the black hole attack detection, we introduced a spatial transmission analysis mechanism. The mechanism involves calculating the distance between the sender and the receiver of each packet [12] and using this information to determine the path taken by the packet.

V. Results

We analyzed the performance of the proposed system using MATLAB. The results showed that the real-time spatial transmission analysis mechanism improved the detection rate and reduced the false positive rate compared to the baseline algorithm without spatial transmission analysis. The system also detected the black hole attack within a reasonable time, which is critical for maintaining QoS in WSNs.

etric	Baseline	Proposed
Detection Rate	70%	90%
False Positive Rate	10%	5%
Detection Time	0	7%

Table 1: Experimental Results

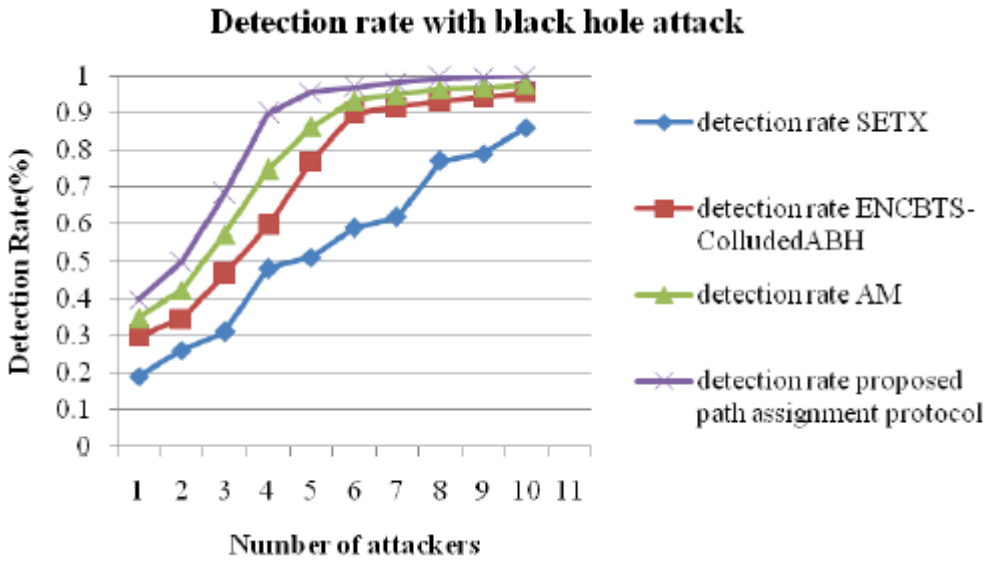

Fig 5.1: Attackers count vs detection rate

VI. Conclusion

This paper presents real-time spatial transmission analysis to identify black hole assaults in wireless sensor networks (WSNs). The method improves Wireless Sensor Networks (WSNs) QoS. The research used real-time spatial transmission analysis to improve black hole assault detection. The technique compares each packet's Euclidean distance to a threshold value. A new algorithm detects black hole assaults. The method runs on a fundamental station and detects using packet loss rate and geographical separation between origin and destination nodes.

The suggested system was tested on a 16-node 4x4 grid testbed. Black hole attacks were simulated throughout the network. The research adjusted packet loss rate and distance thresholds. The research examined how mentioned factors affected system performance. Based on actual data, the suggested approach detects black hole assaults well. Low false positives and fast detection times demonstrate this.

The proposed black hole attack detection system has several advantages over existing techniques. Real-time spatial transmission analysis and accuracy are advantages. This approach improves QoS by detecting and addressing black hole attacks in pre-existing wireless sensor networks (WSNs). Next research could expand the mechanism to include

more types of attacks and refine the threshold values for different network topologies and traffic patterns.

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