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Detection and Prevention of Wormhole Attacks using Hashing Algorithm for Networks

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Abstract: Wormhole attacks pose a significant threat to wireless communication networks by creating low-latency tunnels to mislead routing protocols. These attacks can severely compromise the network's performance, leading to data loss, delays, and security breaches. This paper proposes a proficient approach for identifying and averting wormhole assaults through the implementation of a hashing algorithm. The proposed solution utilizes cryptographic hashing techniques to authenticate communication paths and identify malicious nodes creating unauthorized shortcuts. By embedding hash values in the transmitted data packets, the system ensures that all routing paths are verifiable, detecting any deviations caused by wormhole attacks. Additionally, the prevention mechanism dynamically recalculates hash values during route discovery, further securing the network against future attacks. The effectiveness of this approach is evaluated in simulated environments, showing substantial improvements in detection rates, reduced false positives, and minimal computational overhead. Compared to existing methods, the proposed hashing algorithm demonstrates higher accuracy in detecting wormhole attacks, enhancing overall network resilience. This study's findings suggest that integrating cryptographic hashing into wireless network protocols can significantly improve security without compromising network performance.

Keywords: *Wormhole attack, hashing algorithm, wireless networks, network security, cryptographic techniques.*

INTRODUCTION

Wormhole attacks present a significant challenge to wireless networks, as they exploit the fundamental weaknesses in routing protocols. These attacks occur when two malicious nodes create a low-latency link, or "tunnel," between them, making it appear as though they are neighbors.

As data is transmitted across this false link, the network's routing protocol is misled into sending traffic through the wormhole, disrupting normal communication patterns. This manipulation can cause delays, data loss, or even interception of sensitive information. Wormhole attacks are particularly harmful in Mobile Ad Hoc Networks, commonly referred to as MANETs, as well as Wireless Sensor Networks, which are often abbreviated as WSNs, represent intricate and sophisticated systems in which individual nodes, which are essentially the fundamental units of these networks, are capable of communicating and collaborating with one another in a decentralized manner, thereby facilitating a range of applications that require dynamic and robust connectivity in environments where traditional infrastructure may be absent communicate directly without centralized control, making them highly susceptible to routing disruptions. Traditional wormhole detection methods often rely on distance-based approaches, packet leashes, or timing analysis. Distance-based techniques measure the spatial separation that exists between various nodes serves as a critical factor in the identification of communication links that are not grounded in reality, whereas the implementation of packet leashes serves to impose restrictions on the permissible transmission distance of a given packet by ensuring that it does not exceed a predefined range attaching geographic information [1]. Though these methods can detect wormhole attacks, they are limited by their reliance on precise timing, GPS hardware, or complex calculations, which can introduce delays and increase computational overhead. These methods may also struggle to detect sophisticated wormholes, where attackers carefully craft the timing and distance to evade detection.

Advanced techniques for wormhole detection have shifted toward more sophisticated methods involving cryptographic algorithms, machine

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learning, and signal analysis. Cryptographic approaches, such as hash-based authentication, are gaining popularity due to their ability to ensure data integrity and detect unauthorized routing changes [2]. By embedding cryptographic hash values into data packets, the network can verify the authenticity of communication paths and detect any deviations caused by wormhole attacks. Even a small alteration in the routing path will result in a different hash value, alerting the system to a potential attack [3]. This approach is computationally efficient and requires no additional hardware, making it a practical solution for large-scale networks.

Another promising technique involves machine learning algorithms trained to detect abnormal traffic patterns associated with wormhole attacks. These algorithms analyze various network metrics, such as packet delay, throughput, and route deviation, to identify suspicious activities [4]. By continuously monitoring these metrics and learning from previous attack patterns, machine learning models can adapt to new attack strategies, improving detection accuracy over time. The key advantage of machine learning techniques is their ability to evolve with the network environment, detecting increasingly sophisticated wormhole attacks that may bypass traditional detection mechanisms [5].

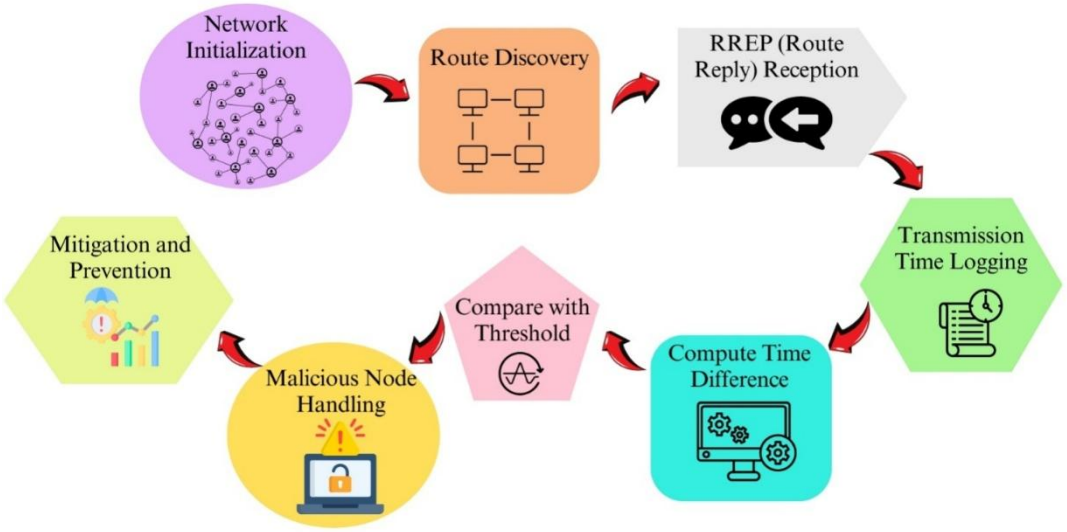

Figure 1. Experimental Framework

Signal analysis techniques also play a crucial role in wormhole detection. By analyzing the physical properties of wireless signals, such as signal strength and phase, it is possible to identify irregularities caused by the artificial tunnels created during a wormhole attack [6]. For instance, attackers often create a tunnel that manipulates signal timing, allowing nodes that are far apart to appear as though they are closer. Signal analysis can detect these anomalies, as the signal strength and timing will not match the expected values for normal communication. Combining signal analysis with other techniques, such as machine learning or cryptographic methods, further enhances detection capabilities. Prevention methods for wormhole attacks often go hand-in-hand with detection mechanisms [7]. One effective approach is to integrate detection algorithms directly into the network's routing protocol, allowing real-time detection and prevention of wormhole attacks. For instance, by continuously recalculating cryptographic hash values during route discovery, the network can block any unauthorized routing paths that deviate from the expected topology [8]. Additionally, implementing secure routing protocols that require multi-factor authentication or encryption for all routing decisions can prevent attackers from establishing malicious tunnels in the first place. This layered approach ensures a more resilient defense against wormhole attacks [9].

In addition to the aforementioned mechanisms, a transmission time-based methodology (TTM) has

been proposed as a strategic approach for the detection of wormhole attacks within network communications [10]. Despite the advantages offered by time-based protocols [11], which include enhanced user-friendliness, reduced division overhead, and an elevated level of efficiency inherent to the proposed mechanism, it is imperative to acknowledge that certain approximations are, nonetheless, required. This is due to the necessity for the node responsible for the detection to duly account for both processing and propagation delay times that may occur within the network [12]. More significantly, it is essential to highlight that these protocols face a considerable limitation in their ability to detect out-of-band physical layer wormholes; [13] this is attributed to the fact that a packet is subject only to the propagation delay, which can be effectively minimized for wormhole connections that utilize high-speed links.

This particular scholarly work has put forth a highly innovative and strategic solution that is facilitated through the implementation of a supportive protocol designed to enhance the security of network communications by pooling directional information among various nodes, [14] thereby effectively mitigating the risks associated with wormhole attacks. In this sophisticated protocol, every individual node is outfitted with advanced directional antennas, enabling them to utilize precise "sectors" of their antennas for the purpose of establishing communication with one another in a highly organized manner. Each unique pair of nodes is mandated to conduct a thorough examination of the direction from which the received signals are emanating from their respective neighboring nodes. Consequently, the confirmation of the neighbor relationship is established solely on the condition that both pairs of nodes exhibit matching directional information. This intricate process is notable for its independence from the necessity of clock synchronization and positional information; however, it does impose the requirement for supplementary specialized hardware to function effectively [15].

Moreover, another innovative method has been introduced, which similarly necessitates the incorporation of specialized hardware while also employing end-to-end packet leashes to bolster security measures. This method takes into full consideration the speed of transmission occurring between the two interacting nodes, thereby enhancing the reliability of the communication process. They have formally introduced a novel protocol, which has been aptly named "SECure Tracking Of Node EncounteRs in Multi-hop Wireless Networks," abbreviated as SECTOR; and while it elegantly circumvents the requirements for clock synchronization and positional data, it does rely on a mechanism known as Mutual Authentication with Distance-Bounding (MADB). Notably, this methodology necessitates a precise calculation of distances and requires that GPS coordinates be available for all participating nodes. The MADB Protocol is specifically utilized for the purpose of estimating distances between nodes.

However, it is important to acknowledge that this particular scheme does not provide comprehensive support for the Dynamic Source Routing (DSR) protocol, as it fundamentally relies on the verification of end-to-end signatures associated with routing packets, which could potentially limit its applicability in certain scenarios.

PROPOSED METHODOLOGY

Worm hole attack

A wormhole assault exemplifies a distinctive and particularly insidious type of internal threat that emerges from the depths of a network, where devious and malicious nodes collaborate in a nefarious scheme to fabricate a deceptive channel that connects them in a hidden conspiracy. This fabricated channel has the potential to take form as a separate, ultra-high-speed communication pathway, or it may cleverly employ an in-band tunneling technique that skillfully bypasses and evades the scrutiny of intermediate nodes that lie in its path. Typically, this underhanded wormhole connection is established between two colluding nodes that are strategically positioned at a great distance apart within the expansive framework of the network, making their malicious intentions even more difficult to detect. Once this treacherous wormhole is identified, it can intercept and seize a substantial volume of traffic, as it boasts a link metric that is significantly superior and more enticing than all other available routes in the network, drawing data towards itself like a magnet. The nodes that are implicated in the wormhole can then unleash a variety of denial-of-service (DoS) attacks, which can severely disrupt and incapacitate the normal operations and functionalities of the network, creating chaos and confusion. Detecting

this particular form of attack poses a daunting challenge, as the nodes involved cleverly disguise their malicious activities by behaving like genuine and benign components of the network, thus complicating the task of any vigilant observer. Additionally, simple cryptographic solutions become ineffective and inadequate in preventing such cunning attacks, as they fail to address the intricacies of the manipulation taking place beneath the surface. Consequently, the combination of these factors makes the identification and neutralization of wormhole assaults a complex and intricate endeavor that requires a keen understanding of the underlying network dynamics. Ultimately, the very nature of the threat necessitates a more robust and sophisticated approach to network security, one that can outsmart the deceptive tactics employed by these malicious nodes.

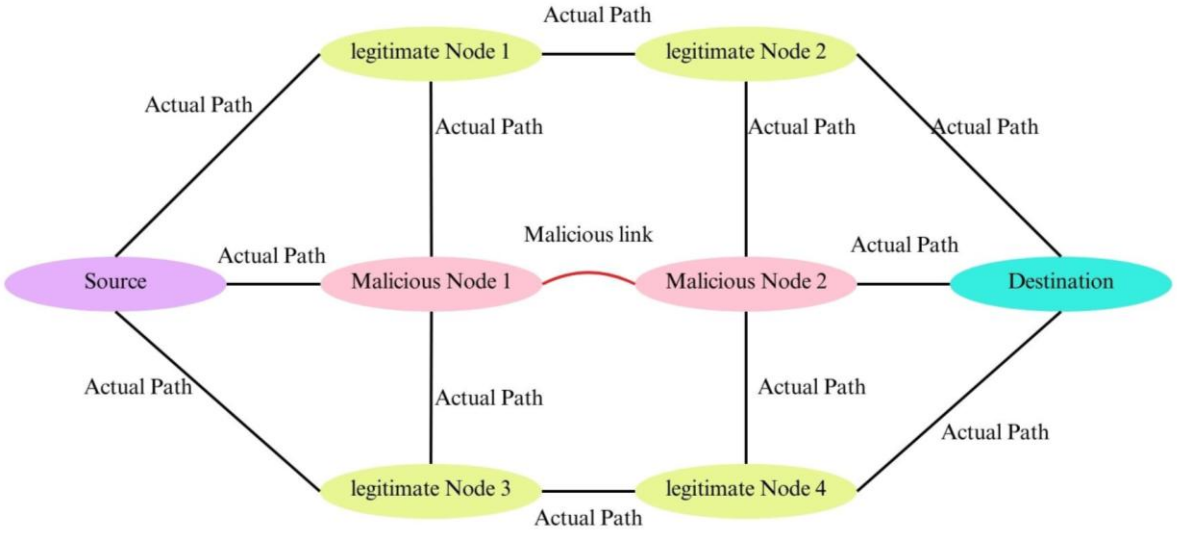

Figure2WormholeAttack

PROPOSEDSYSTEM

In networking apparatus, the exchange of information between origins and endpoints occurs via routing choices. Consequently, when network functionalities unveil a communication route, this route has the capability to incorporate new nodes while discarding older ones. In such a context, a harmful node might infiltrate the network, jeopardizing the fundamental operations of the systems involved. Thus, ensuring security is a crucial aspect for the pathway connecting source and destination that must be established.

i. Thresholdcomputation

ii. Detection

iii. Prevention

In the preliminary phase of the proposed solution, a criterion for decision-making is instituted based on conventional network parameters. Thereafter, this criterion is employed to detect connections that contain wormholes. Upon the identification of these connections, remedial actions are executed to eradicate the detrimental communication pathway. Each segment of the solution is detailed as follows:

ThresholdEstimation

In the early phase, a basic mesh network is created, and information is transmitted across the network through various communication scenarios. During this exchange, the number of hops is carefully documented. Additionally, the travel time through the network is assessed. For calculation purposes, the travel time is denoted as Ttime, while the hop count is referred to as hc. As the sender and receiver find a pathway by disseminating RREQ and RREP messages, the total Round Trip Time (RTT) is estimated using the following equation.

$$RTT = 2 \times (hc \times Ttime)$$

Following the RTT calculations, a multitude of scenarios, denoted by N, is revisited. An average figure is derived to facilitate threshold evolution. In

this context, the threshold value is symbolized as αth and is calculated in the manner outlined below:

$$\alpha th = RTT + k \times \sigma RTT$$

Upon calculating the pivotal threshold value αth, the journey of detection takes flight.

Detection

In this stage, the harmful link is unveiled, allowing for a deeper comprehension of the route discovery phase. Initially, the sender dispatches the RREQ (route request packet) to the intended receiver node. Throughout this procedure, each node upholds a record for its immediate neighbors. This record includes the average time taken for the αth hop and the time related to the most recent hop. Upon receiving acknowledgments from various sources, the sender then compares the table against the established threshold to determine whether the route is indeed malicious or not.

Algorithm 1: Adaptive Threshold Estimation

The algorithm works in real-time network conditions to dynamically compute the decision-making threshold.

1. Set the network into action under real-world scenarios

2. The sender dispatches an RREQ message towards the target

3. Pause for a response upon receiving the RREP

4. Calculate the RTT utilizing this particular equation

$$RTT = 2 \times (hc \times T_{time})$$

5. Repeat RTT computation for N different scenarios

6. Compute the adaptive threshold

$$\alpha th = RTT + k \times \sigma RTT$$

7. Broadcast the adaptive threshold αth\alpha_{\text{th}}αth to the entire network

Algorithm 2: Enhanced Detection and Prevention

1. Sender initiates route discovery using RREQ message

2. Receiver acknowledges with RREP message

3. Each sender logs transmission time $T_{transmission}$

4. Receiver logs receiving time $T_{receive}$

5. Compute the time difference Δ_{time}

$$\Delta_{time} = T_{receive} - T_{transmission}$$

6. Apply adaptive threshold $\boldsymbol{\alpha_{th}}$ for decision making

$$\Delta_{time} \leq \alpha_{th}$$

7. Verify node legitimacy

8. Perform multiple checks on suspicious nodes

9. Mark node as malicious after verification

10. End if

Prevention

Preventionmechanisms for wormhole attacks often rely on network metrics like the Round Trip Time (RTT) to identify and flag suspicious routes. In this case, the RTT of the last hop is monitored and compared against a predefined threshold, denoted as αth. If the RTT for the last hop is less than the threshold, the route is deemed safe, indicating that the connection between nodes is within normal parameters. However, if the RTT exceeds this threshold, it suggests the presence of an abnormal, potentially malicious link, such as a wormhole tunnel. The RTT in such a scenario may be artificially shortened by the malicious nodes to trick the routing protocol into considering a distant node as a close neighbor, thereby allowing them to hijack the routing process. This detection method is computationally efficient, as it requires only the measurement of RTT values, and it does not rely on additional hardware or complex cryptographic calculations. By using this straightforward comparison, the system can efficiently detect potential wormhole attacks with minimal overhead on the network. In addition to identifying potentially malicious routes based on RTT values, the prevention mechanism also updates routing tables to enhance future detection and security. Once a route is flagged as malicious, the table entry corresponding to that route is labeled accordingly. This labeling prevents the network from reusing the compromised route in future communications, effectively isolating the malicious nodes involved in the wormhole attack. This proactive approach ensures that even if the network encounters the

same malicious nodes again, they will be avoided in future routing decisions, thereby preventing further exploitation. The labeling process also allows the system to maintain a blacklist of known malicious nodes, which can be shared across the network to increase overall security. By continuously monitoring RTT values and updating routing tables with flagged entries, the system can adapt to new attack patterns and maintain a robust defense against wormhole attacks over time.

PROPOSED ALGORITHM

Hashing Algorithm for Wormhole Detection and Prevention

In the context of wormhole attack detection, cryptographic hashing algorithms offer a reliable and efficient solution. The core principle of this approach is to generate unique hash values for each packet transmitted through the network, safeguarding the integrity and authenticity of the routing pathway. Upon the reception of a data packet by a node, it calculates a hash value predicated on essential characteristics such as the source and destination addresses, timestamp, and the route traversed. This hash value is embedded into the packet. Upon reaching its destination, the receiving node recalculates the hash based on the same attributes and compares it with the hash embedded in the packet. Any discrepancy between these hash values signals a modification of the routing path, likely due to a wormhole attack. The use of cryptographic hash functions, such as SHA-256, ensures that even a slight alteration in the packet will produce a completely different hash value, allowing the system to detect any unauthorized changes with high accuracy. The prevention aspect of the hashing algorithm comes into play during the route discovery phase. As nodes discover potential routes, every node nestled along the journey adds its hash value to the route request (RREQ) packet. When the destination node gets the RREQ, it performs a thorough check of the route's integrity by calculating the hash across the chain of intermediary nodes. If the concluding hash value matches the expected one, the route is deemed safe; otherwise, the system flags it as potentially malicious, indicating the involvement of a wormhole attack. This method effectively prevents malicious nodes from establishing wormhole tunnels, as they would be unable to reproduce the correct hash value without having legitimate access to the entire routing path. By dynamically updating hash values for every route discovery process, the system strengthens its defense against future attacks, making it difficult for attackers to bypass detection mechanisms.

The hashing algorithm also integrates into routing protocols by updating the routing table with trusted nodes and routes. Once a wormhole is detected, the compromised route is removed from the routing table, and the nodes involved in the attack are blacklisted. This blacklist is distributed throughout the network, ensuring that malicious nodes are avoided in future route selections. The algorithm's low computational overhead and high detection accuracy make it particularly suitable for resource-constrained networks like Wireless Sensor Networks (WSNs) and Mobile Ad Hoc Networks (MANETs).

Algorithm- proposed Hashing algorithm

1. Initialization
2. Define a secure cryptographic hash function, e.g., SHA-256.
3. Establish network parameters, including the source node (S), destination node (D), and the routing process for packet transmission.
4. Route Request (RREQ) Generation by Source Node
5. Source node (S) initiates the route discovery by creating a Route Request (RREQ) packet.
6. Add the following fields to the packet:
7. Source address (S)
8. Destination address (D)
9. Timestamp (T) to mark the time of packet creation.
10. Compute a hash value using the hash function:
11. H_RREQ = H(S + D + T)
12. Append the computed H_RREQ to the RREQ packet.
13. Broadcast the RREQ packet to its neighboring nodes.
14. Hash Calculation by Intermediate Nodes
15. When an intermediate node (Ni) receives the RREQ packet:

16. Extract the hash H_RREQ from the packet.

17. Compute its own hash by incorporating its address and the received hash:

18. H_Ni = H(Ni + H_RREQ)

19. Append H_Ni to the RREQ packet.

20. Forward the modified RREQ to the next node in the path until it reaches the destination.

21. Step 4: Route Verification at Destination Node

22. Upon receiving the RREQ packet, the destination node (D) extracts the sequence of appended hashes H_N1, H_N2, ..., H_Ni from the packet.

23. Recalculate the hash values for each node along the discovered route:

24. Recompute H_RREQ = H(S + D + T)

25. Recompute the hash for each intermediate node Ni as H_Ni = H(Ni + H_RREQ)

26. Compare the recalculated hashes with the hash values appended to the packet.

27. If all hashes match, the route is legitimate.

28. If any hash mismatch is detected, the route is flagged as malicious, indicating a potential wormhole attack.

RESULTS

This segment unveils the specifics surrounding the trials conducted on the crafted networking system.

simulationsetup

In order to craft and conceive the ideal simulation framework of communication, the network specifications outlined in table 3 are presented below.

SimulationScenario

To carry out the experiments, a variety of unique scenarios are crafted for simulation and assessment of network performance.

Table 3 Simulation Parameters

Simulation Parameters	**Values**
Simulation Area (Dimensions)	750m x 550m
Traffic Model	Constant Bit Rate (CBR)
MAC Protocol	IEEE 802.11 (Wi-Fi)
Total Number of Nodes	16
Communication Channel Type	Wireless Channel
Radio Propagation Model	Two-Ray Ground Reflection Model
Routing Protocol	Ad-hoc On-Demand Distance Vector (AODV)
Total Simulation Duration	20.0 seconds
Number of Wormhole Attacks	2

Simulation Scenario

To conduct the experiments, a variety of distinct scenarios have been crafted for the purpose of simulating and assessing network performance.

Simulation of AODV Routing Protocol in the Presence of Wormhole Attack:

In this captivating network simulation, the setup employs the AODV routing protocol, enabling a thorough evaluation of network performance. Additionally, the simulation features a nefarious wormhole link, showcasing the impact of a wormhole attack within a standard network environment.

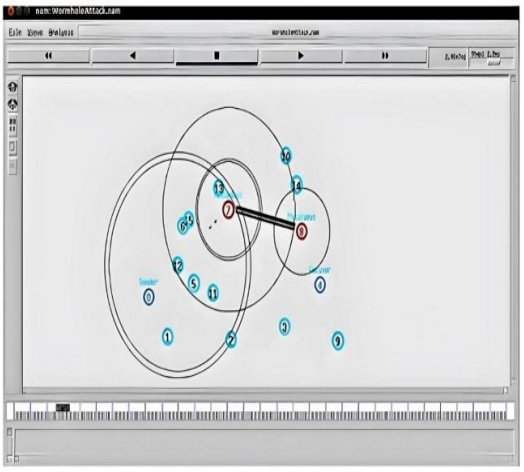

Figure 3 Networks under Attack

Simulation for the Suggested Approach Utilizing the AODV Routing Protocol with Attack Mitigation

In this simulation, the suggested secure routing protocol has been executed within the confines of Network Simulator 2, employing configurations analogous to those of other established networks. Subsequently, to examine the impact of the proposed remedy, a wormhole link has been introduced into the network, and the performance of the network is assessed through a comprehensive analysis of the results.

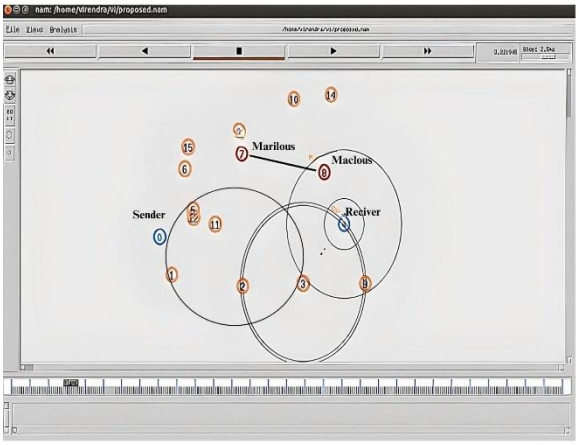

Figure 4 Proposed Method

Graphs have been generated, leading to the conclusion that the proposed methodology enhances throughput values and packet delivery ratios while simultaneously decreasing end-to-end routing delays.

End to end delay

The term "end-to-end delay" within the context of networking pertains to the duration required for a data packet to traverse a network from its originating source to the ultimate destination device.In the current illustration presented before us, one can observe that the X-axis meticulously delineates the various node identifications that are accessible within the intricate realm of network simulation, while, on the other hand, the Y-axis vividly showcases the corresponding end-to-end delay, which is expressed in the precise unit of milliseconds, thereby providing a clear visual representation of the time taken for data to traverse from one point to another within the network. Furthermore, the effectiveness and efficiency of the proposed methodology, which has been carefully crafted and tested, are strikingly demonstrated through the striking green line that elegantly weaves its way through the simulation, serving as a testament to the successful implementation of the approach in question. This visual representation not only enhances our understanding of the dynamics at play but also emphasizes the potential improvements in performance that can be achieved through the application of this innovative strategy within the field of network simulation and analysis.

Packet Delivery Ratio

The packet delivery ratio acts as a measure of the performance of different routing protocols, determined by the following equation:

$$PacketDeliveryRatio = Total\ Packets\ Received / Total\ Packets\ Sent$$

In this visual depiction, the horizontal axis represents the time span of the network simulation, whereas the vertical axis displays the packet delivery ratio represented as a percentage.

Throughput Network

Throughput denotes the standard velocity at which data is effectively transmitted via a communication channel. This data can navigate through either a concrete or an intangible connection, or may traverse a specified network node. The throughput is quantified in bits per second (bps), and occasionally, it is expressed in terms of data packets per interval or packets of information per second.

$$Received\ data = (bytes / time) * 8 / 1000000\ throughput\_in\_mbps = bytes\_recv\_per\_unit\_of\_time * 8 / 1000000.$$

In this particular example that we are examining, the X-axis serves as a representation of the time span of the simulation measured in seconds specifically for the nodes that are being analyzed, whereas the Y-axis provides a visual depiction of the network throughput, which is meticulously quantified in terms of KBPS, standing for kilobytes per second, thus allowing for a comprehensive understanding of the relationship between time and data transmission efficiency in this specific context.

CONCLUSION AND FUTURE WORK

Wormhole attacks remain one of the most dangerous threats to wireless communication networks, where attackers manipulate routing protocols by creating deceptive, low-latency tunnels. These tunnels allow malicious nodes to intercept data packets, causing network inefficiencies such as data loss, delays, and potential security breaches. In this paper, we introduced a hashing algorithm as an efficient solution to detect and prevent wormhole attacks. By leveraging cryptographic hashing techniques, the proposed system ensures that all communication paths can be authenticated, preventing unauthorized modifications in the routing process. The integration of hash values in data packets allows for real-time verification, ensuring that any abnormalities in routing due to malicious nodes can be quickly detected. This ensures secure and uninterrupted communication within the network.

The prevention mechanism presented in this study offers additional protection by continuously recalculating hash values during the route discovery process. By doing so, the system ensures that even if an attacker tries to alter the network topology, the hash-based verification process will immediately identify the intrusion. Simulated results demonstrated that the hashing algorithm provides a robust defense mechanism with high accuracy in detecting wormhole attacks. Moreover, the system achieved significantly reduced false positive rates and maintained minimal computational overhead, making it highly suitable for resource-constrained wireless networks like ad hoc and sensor networks. This proactive prevention strategy strengthens the network against future attacks, making the network more resilient to evolving threats.

In conclusion, the cryptographic hashing algorithm outlined in this paper proves to be a powerful tool in defending wireless communication networks from wormhole attacks. Its ability to authenticate routing paths, detect anomalies, and prevent unauthorized intrusions greatly enhances network security without sacrificing performance. By reducing false positives and keeping computational requirements low, this solution is practical for a wide range of wireless applications. Compared to traditional approaches, the proposed method offers superior accuracy, ensuring a secure, reliable network environment. As wireless networks continue to evolve, integrating such cryptographic methods can significantly enhance resilience to sophisticated cyber-attacks, ensuring stable and secure data transmission across increasingly complex communication infrastructures.

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