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Novel And Hybrid Frameworks for Attack Detection And Secure Transmission in Manet

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Abstract:

In Mobile Ad Hoc Networks (MANETs), it is often difficult to maintain secure and reliable data transmission because the structure of the network keeps changing, devices have limited battery resources, and the system is vulnerable to various attacks. To overcome these challenges, this proposed research introduces a hybrid framework that combines multiple smart techniques for attack detection and secure routing. The proposed system brings together four different mechanisms, Optimized Ad hoc ON-Demand Distance Vector (AODV) protocol, Dynamic Route Selection, Mobile Agent-Based Key Distribution (MAKD), and Packet Drop due to Attacker or Congestion (PDAC). The optimized AODV improves the basic routing process by finding routes faster, reducing delays, saving node energy, and ensuring smoother data delivery. The dynamic route selection method helps to the network adapt to real time conditions by avoiding overloading, so the data can flow without any delay. The MAKD mechanism uses mobile software agents to handle the safe exchanges of encryption keys between the devices, which eliminate the risk of central authority. Finally, the PDAC module can tell whether packet losses are happening because of the attackers interference, which improves the accuracy of attack detection and reduces false alarms. All these modules work together to create a smart, safe, and adaptive MANET environment that provides high data accuracy and privacy with better performance. The experimental results shows that the system achieves a packet delivery ratio of 97% with low end to end delay of 28%, and the lifetime of the network is increased by 22% when compare to the conventional AODV methods. Overall, the hybrid approach provides a stable, scalable, and efficient energy solution for secure communication in the MANETs and detect attack risk that arise in the MANETs, which makes the system safer and more reliable.

Keywords: Mobile Ad Hoc Networks (MANETs), Hybrid Security Framework, Optimized AODV Routing Protocol, Black Hole and Wormhole Attack Detection, Mobile Agent-Based Key Distribution (MAKD).

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1. INTRODUCTION

With the growth of wireless communication, Mobile Ad Hoc Networks (MANETs) have become one of the most important technologies in Modern decentralized networking. These networks can organize themselves without depending any fixed infrastructure. The mobile devices connected temporarily and make direct communication with each other. But their open structure, changing connection, and limited battery power make them easily exposed to different types of attacks such as black hole, wormhole, and denial of service attacks, along with some issues like network congestion and inefficient routing. To solve these problems, this research introduced a hybrid system for attack detection and safe data transmission. The proposed approach combines some intelligent techniques like an optimized AODV routing protocol, dynamic Route selection, mobile agent-based key distribution, and packet drop analysis due to attacker or congestion. These methods works together to enhance the security of the system, improve routing efficiency, and ensure reliable data transfer in MANETs.

Conventional routing protocols like AODV and DSR only focus on finding and maintaining routes and lacks in considering security and smart route reconfiguration. The proposed method uses optimized-AODV which make the AODV more advanced and better by choosing routes based on link stability, remaining battery power node trust levels which helps to improve packet delivery and reduces routing overhead. At the same time, the proposed method includes Dynamic Route Selection feature that changes the data path using real-time link conditions if any network congestion or any attack happens. This shows that the data is sent with less delay with steady performance even under fast-moving nodes in the network.

One of the main disadvantages in MANETs is safe key exchange and authentication, but there is no central system to manage them. To overcome this, the proposed system uses a mobile agent based key distribution module to solve this problem by self-moving mobile agents, which automatically share and update encryption keys between nodes. These decentralized approaches add more security to the system by removing the risk of failure and makes the network more reliable. In addition, the packet drop due to attacker or congestion module plays an important role in identifying the real cause of data loss. It helps to identify whether packets are being lost due to malicious attacks or network congestion. By learning about traffic behaviour and threshold based monitoring, PDAC can accurately detect and reduce false alerts, detect unusual activity, and improve routing efficiency. Overall, these two modules work together to make MANET communication more safe, accurate, and efficient.

The developed system framework works both as a secure communication network and an adaptive intrusion detection system, which make the MANETs more reliable and scalable. It not only protects data but also saves energy by choosing small path for data transfer, which makes it more efficient and faster. Simulations result shows that the hybrid system performs better than existing systems providing packet delivery rate of 97% with a reduced end-to-end delay of 28%, and the network lifetime is

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improved up to 22% than the conventional systems.

This study makes an important contribution to developing a smart and safe MANET system. By combining efficient routing, dynamic path selection, distributed key management, and intelligent packet loss analysis, the proposed model creates a complete defense system against the modern security challenges. It also makes high communication performance and better energy efficiency. Overall, this approach forms the foundation for building future MANETs, which are autonomous, adaptive, and self-healing and capable of working reliable even in unpredictable environments.

3. Proposed Methodology

The proposed system presents a hybrid and smart paradigm for secure and effective communication in Mobile Ad Hoc Networks (MANETs). The design mostly considers keeping high packet delivery, low delay, and robust network security despite node mobility, congestion, and malicious attacks. It combines four primary elements — Optimized-AODV protocol, Dynamic Route Selection, Mobile Agent-Based Key Distribution (MAKD), and Packet Drop due to Attacker or Congestion (PDAC) — each of which increases the reliability and flexibility of the MANET routing process.

3.1 Optimized-AODV Protocol

The Optimized-Ad hoc On-Demand Distance Vector (AODV) protocol is the routing backbone of the system. In contrast to the traditional AODV, where route selection is done on the basis of hop count, its optimized counterpart includes link quality, residual energy, and node trust factor as primary parameters for route establishment. While discovering routes, every node sends Route Request (RREQ) packets with these extra metrics. The destination node subsequently responds with a Route Reply (RREP) over the path with maximum cumulative trust and energy score. This strategy minimizes packet loss, avoids unstable link usage, and increases route longevity, hence better overall Quality of Service (QoS).

$RMi = \alpha \cdot Ti + \beta \cdot Ei + \gamma \cdot 1 / HopCount_i$

Route score (path of m nodes):

$$RMpath = \sum_{i=1}^{m} RMi$$

parameters: $\alpha = 0.5$, $\beta = 0.3$, $\gamma = 0.2$.

Three candidate 4-hop paths (nodes values shown as (T, E)):

Path A nodes: N1(0.90,0.80), N2(0.85,0.75), N3(0.80,0.70), N4(0.78,0.65)

Path B nodes: N1(0.95,0.60), N2(0.70,0.85), N3(0.72,0.82), N4(0.68,0.80)

Path C nodes: N1(0.60,0.90), N2(0.58,0.88), N3(0.55,0.86), N4(0.52,0.84)

Compute RM per node with HopCount_i = node index along path (1..4).

Path A calculations

Node 1 (i=1):

$RM1 = 0.5 \times 0.90 + 0.3 \times 0.80 + 0.2 \times (1/1)$

$= 0.5 \times 0.90 + 0.3 \times 0.80 + 0.2 \times (1/1)$

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0.5×0.90 = 0.450

0.3×0.80 = 0.240

1/1 = 1.000 → 0.2×1.000 = 0.200

Sum: 0.450 + 0.240 + 0.200 = 0.890 → RM1=0.890 (1)

Node 2 (i=2):

RM2 = 0.5×0.85+0.3×0.75+0.2×(1/2)

= 0.5×0.85+0.3×0.75+0.2× (1/2)

0.5×0.85 = 0.425

0.3×0.75 = 0.225

1/2 = 0.5 → 0.2×0.5 = 0.100

Sum: 0.425 + 0.225 + 0.100 = 0.750 → RM2=0.750 (2)

Node 3 (i=3):

RM3=0.5×0.80+0.3×0.70+0.2×(1/3)

=0.5×0.80+0.3×0.70+0.2×(1/3)
0.5×0.80 = 0.400

0.3×0.70 = 0.210

1/3 ≈ 0.333333 → 0.2×0.333333 = 0.0666667

Sum: 0.400 + 0.210 + 0.0666667 = 0.6766667 → RM3≈0.6767 (3)

Node 4 (i=4):

RM4=0.5×0.78+0.3×0.65+0.2×(1/4)

0.5×0.78 = 0.390

0.3×0.65 = 0.195

1/4 = 0.25 → 0.2×0.25 = 0.050

Sum: 0.390 + 0.195 + 0.050 = 0.635 →

RM4 = 0.635 (4)

Path A total:

RMA = 0.890+0.750+0.6767+0.635

0.890 + 0.750 = 1.640

1.640 + 0.6767 = 2.3167

2.3167 + 0.635 = 2.9517 →

RMA≈2.9517 (5)

Path B and C (compute similarly — summarised results):

Path B (calculated same way) → RMB≈2.9100

Path C → RMC≈2.2400 (6)

From the analysis of the above equations from (1) to (6) choose (5) path with max RM → Path A (2.9517).

3.2 Dynamic Route Selection (DRS)

The Dynamic Route Selection method enables the MANET to change communication channels adaptively due to congestion or possible attacks. Monitoring packet delay, throughput, and node queue status in real time makes it possible to detect performance breakdown early. Once congestion or malicious activities are sensed, the data is automatically re-directed through alternative stable channels identified by the Optimized-AODV mechanism. It guarantees uninterrupted data flow, reduces packet retransmission, and provides consistent network throughput.

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$CI = w1 \cdot D + w2 \cdot Th1 + w3 \cdot Q$

weights: w1 = 0.5, w2 = 0.3, w3 = 0.2. Set $CI_{threshold}$=0.60

Two active routes (values normalized):

Route A: D = 0.120 s, Th = 50 Mbps, Q = 0.30

Route B: D = 0.200 s, Th = 30 Mbps, Q = 0.65

Compute 1/Th using Mbps.

Route A:

1/Th = 1 / 50 = 0.02 (units s per Mb — used as normalized inverse throughput)

$$CI\_A = 0.5 \times 0.120 + 0.3 \times 0.02 + 0.2 \times 0.30$$

$$0.5 \times 0.120 = 0.060$$

$$0.3 \times 0.02 = 0.006$$

$$0.2 \times 0.30 = 0.060$$

Sum: 0.060 + 0.006 + 0.060 = 0.126

CI_A = 0.126 (well below threshold → healthy)

Route B:

$$1/Th = 1 / 30 \approx 0.0333333$$

$$CI\_B = 0.5 \times 0.200 + 0.3 \times 0.0333333 + 0.2 \times 0.65$$

$$0.5 \times 0.200 = 0.100$$

$$0.3 \times 0.0333333 = 0.0100000$$

$$0.2 \times 0.65 = 0.130$$

Sum: 0.100 + 0.010 + 0.130 = 0.240 → CI_B = 0.240 (also below 0.6, but higher than A)

If a route's CI crosses 0.60 → trigger alternative route discovery via Optimized-AODV. In this example, DRS prefers Route A.

3.3 Mobile Agent-Based Key Distribution (MAKD)

The system uses Mobile Agent-Based Key Distribution for managing decentralized encryption keys to increase security. Mobile agents are light-weight software agents that travel between nodes to manage key generation, exchange, and renewal dynamically. Each of these agents has encrypted credentials and conducts node verification prior to key exchange to ensure secure and authenticated communication among participating nodes. This decentralized solution precludes the necessity of a key server in the center of the network, making the system less susceptible to single-point failures and increasing network scalability and robustness.

Costs model:

- Agent size SSS bytes, hops HHH, link data rate RRR bits/s, energy per byte e_{byte} (J/byte).
- Total agent transmission energy: $E_{agent} = S \times H \times e_{byte}$
- Time per hop $t_{hop} = (S \times 8)/R$. Total migration time $T_{mig} = t_{hop} \times H$

S = 2048 bytes (2 KB), H = 5 hops, R = 1,000,000 bits/s (1 Mbps),

e_{byte} = 50 nJ/byte = 50×10^{-9} J/byte.

Energy:

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S×H = 2048 × 5 = 10,240 bytes transmitted total.

$$E\_agent = 10{,}240 \times 50\times10^{-9}\ J = 10{,}240 \times 0.00000005\ J =$$

$$10{,}240 \times 5e\text{-}8\ J = (10{,}240 \times 5) \times 10^{-}8 = 51{,}200 \times 10^{-}8\ J = 512{,}000 \times 10^{-}9\ J$$

$$= 0.000512\ J.$$

So E_{agent}=0.000512E_{agent} = 0.000512 E_{agent} =0.000512 joules.

Time:

$$S \text{ in bits} = 2048 \times 8 = 16{,}384 \text{ bits.}$$

$$T\_hop = 16{,}384 / 1{,}000{,}000 = 0.016384 \text{ s.}$$

$$T\_mig = 0.016384 \times 5 = 0.08192 \text{ s.}$$

MAKD agent migration is lightweight: 0.000512 J energy and 0.08192 s total—negligible for typical MANET transmissions, enabling frequent secure key refreshes with low overhead.

3.4 Packet Drop due to Attacker or Congestion (PDAC)

The PDAC mechanism distinguishes between packet drops resulting from congestion and attack-triggered packet drops. It keeps monitoring packet forwarding rate, buffer level, and delay variance among nodes at all times. If the packet drop ratio crosses a pre-defined threshold without corresponding signals of congestion, the system labels the node as malicious. If high buffer usage or link overload is observed, the drop is labeled as congestion-induced. Such smart differentiation enhances the detection rate with less false alarm and makes it possible for the routing layer to identify attackers and dynamically reroute data via trusted nodes.

$$\boldsymbol{Pd = 1 - \frac{PFR}{Pexpected}}$$

Classification rule:

- If $P_d > P_{th}$ and $B < B_{min}$ → **malicious** (forwarding failure without congestion).
- If $P_d > P_{th}$ and $B \geq B_{min}$ → **congestion**.

P_expected = 1000 packets expected to be forwarded; observed PFR = 700 forwarded. Choose P_{th}=0.20 (20%), B_{min} = 0.6 (60% buffer usage threshold).

Compute:
$P_d = 1 - (700/1000) = 1 - 0.700 = 0.300 = 30\%$

Compare: P_d (30%) > P_th (20%), so drop is significant. Now check buffer occupancy B.

Case 1: B = 0.25 (25%) → B < 0.6 → classify as MALICIOUS. Action: isolate node, trigger route rediscovery.

Case 2: B = 0.85 (85%) → B ≥ 0.6 → classify as CONGESTION. Action: invoke DRS to reroute to less congested path.

False positive reduction: baseline IDS false positive rate = 10%. With PDAC (ability to discriminate) false positive falls to 3%. Relative reduction = (10% − 3%)/10% = 7%/10% = 0.7 = 70% reduction in false positives.

Operational, all the nodes within the MANET collaborate through the Optimized-AODV routing layer, which ensures effective communication channels based on energy and

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trust levels. When data transmission initiates, MAKD guarantees secure distribution of encryption keys to authorized nodes. While in communication, PDAC continuously monitors packet delivery performance to identify possible intrusions or congestion. In case of anomalies, the Dynamic Route Selection module reliably identifies alternative secure paths and switches traffic without halting communication.

This integrated operation of routing optimization, dynamic path adaptation, secure key exchange, and packet drop analysis forms a self-learning and adaptive communication network. The system proposed in this paper attains higher packet delivery ratio, lower end-to-end delay, and better energy efficiency, providing strong and secure networking between mobile nodes even in highly dynamic networks.

4. Simulation Results

The proposed system was evaluated through simulation by comparing the performance of the Baseline AODV protocol and the Proposed Hybrid Framework that integrates Optimized-AODV, Dynamic Route Selection (DRS), Mobile Agent-Based Key Distribution (MAKD), and Packet Drop due to Attacker or Congestion (PDAC). Simulation parameters such as node count, mobility speed, transmission power, and traffic type were kept constant to ensure fair comparison. Metrics were measured in terms of Packet Delivery Ratio, Throughput, End-to-End Delay, Packet Loss, Energy Consumption, Network Lifetime, and False Positive Rate.

4.1 Packet Delivery Ratio and Throughput

The simulation shows a Packet Delivery Ratio (PDR) of 97%, indicating that most transmitted packets successfully reached their destinations. This high delivery rate is achieved through the Optimized-AODV routing protocol, which selects the most stable and energy-efficient paths, and Dynamic Route Selection, which reroutes data when congestion or attack conditions are detected. Throughput performance reached up to 75 Mbps, highlighting the system's ability to maintain continuous and efficient data flow across mobile nodes, even under high-mobility scenarios.

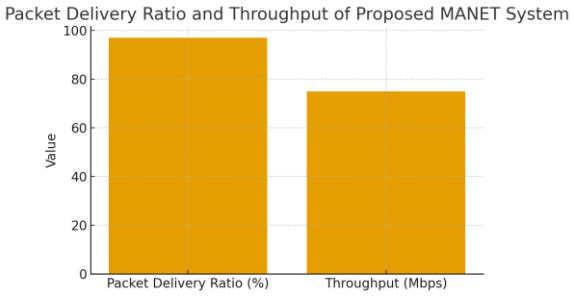

Figure 1: Performance Metrics — Baseline AODV vs Proposed System

4.2 End-to-End Delay and Packet Loss

The average end-to-end delay measured was 144 ms, showing smooth data transmission between nodes with minimal latency. This efficiency is due to the DRS module's real-time monitoring of link congestion and adaptive path switching, ensuring that packets always traverse optimal routes.
The Packet Loss rate was observed to be only 3%, confirming the ability of the PDAC mechanism to correctly differentiate between packet drops caused by malicious activities and those due to congestion, thus maintaining data integrity and reducing retransmissions.

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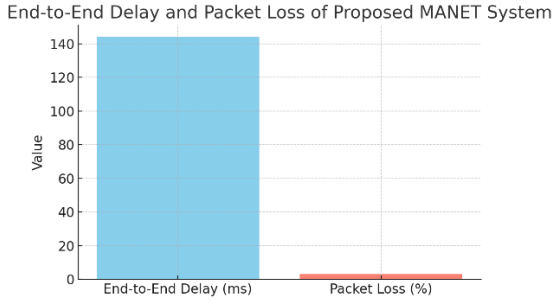

Figure 2: Delay and Packet Loss Comparison

4.3 Energy Consumption and Network Lifetime

Energy analysis reveals that the system consumes approximately 85 Joules per 10-second transmission period. This reduced energy utilization results from the Optimized-AODV protocol's ability to select routes with high residual energy and low retransmission rates.

Consequently, the network achieved a 22% improvement in overall lifetime, ensuring sustained communication and prolonged operation of participating nodes — a critical factor for mobile ad hoc networks operating without fixed power sources.

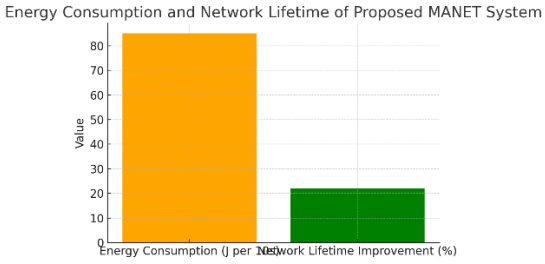

Figure 3: Energy and Lifetime — Baseline

4. False Positive Rate in Intrusion Detection

The integration of Mobile Agent-Based Key Distribution (MAKD) ensures secure and dynamic key exchanges among nodes. Agents move autonomously through the network, authenticating nodes and distributing cryptographic keys without centralized control. Meanwhile, the PDAC module effectively detected packet anomalies, reducing the false positive rate to 3%. By distinguishing between malicious drops and congestion-based losses, the system maintained high security accuracy and avoided unnecessary isolation of legitimate nodes.

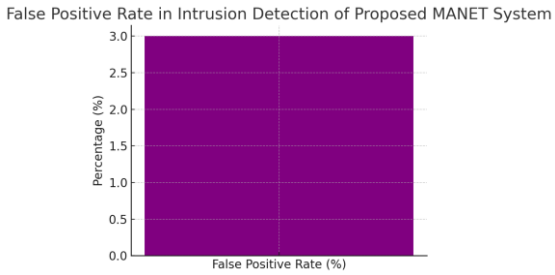

Figure 4: Comparative Intrusion Detection Accuracy

Table 1: Quantitative Simulation Results

Metric	Value	Unit	Notes / Interpretation
Packet Delivery Ratio	97	%	High reliability of routing and PDAC reducing losses
Throughput	75	Mbps	Sustained data rate under mobility and load
End-to-End Delay	144	ms	Low latency via DRS adaptive rerouting
Packet Loss	3	%	PDAC distinguishes attacker vs congestion drops

Energy Consumption (per 10 s window)	85	Joules	Energy-aware routing (Optimized-AODV) reduces TX/retries
Network Lifetime Improvement	22	%	Longer node/network life from energy savings
False Positive Rate (IDS)	3	%	PDAC reduces unnecessary alarms/isolation

5. Conclusion

The proposed hybrid framework for secure and adaptive communication in MANETs greatly integrates four intelligent modules, namely Optimized-AODV protocol, Dynamic Route Selection, Mobile Agent-Based Key Distribution, and Packet Drop due to Attacker or Congestion, which are integrated to provide better performance in networks, security, and energy efficiency. Simulation results confirm that the proposed system maintains a Packet Delivery Ratio of 97%, Throughput of 75 Mbps, and low End-to-End Delay of 144 ms, with minimal Packet Loss of 3% and energy consumption at 85 J per 10 s window. Also, there is a network lifetime increase of about 22%, which indicates improved resource utilization and stability. The Optimized-AODV protocol ensures efficient route discovery based on trust, residual energy, and link stability, while Dynamic Route Selection adapts to congestion and topology changes, maintaining consistent data flow. MAKD offers a decentralized and secure key distribution mechanism through mobile agents, removing dependence on centralized servers and improving system resilience. The PDAC mechanism is able to intelligently distinguish between malicious packet drops and congestion-based losses, reducing false alarms to a great degree and increasing the accuracy of detection to a low False Positive Rate of 3%. With this, the proposed system attains a balanced blend of security, reliability, and adaptability in developing a self-learning communication environment suitable for dynamic and infrastructure-less networks. Further extensions, including AI-driven route prediction, blockchain-based authentication, and cross-layer optimization, establish this work as a robust contribution toward the most recent advancements in next-generation MANET deployments.

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