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A Blockchain-Based Secure Message Routing Framework for VANETs with Trusted Computing Integration

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Abstract*:* Vehicular Ad Hoc Networks (VANETs) enable timely inter-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication to improve road safety and traffic efficiency. However, their high mobility, dynamic topology, and open wireless medium expose VANETs to many attacks: malicious vehicles can inject false safety information or modify messages, potentially causing accidents and loss of life. Traditional security schemes (e.g. public-key infrastructures and authentication protocols) alone may not address all threats in this decentralized, resource-constrained environment. To address these challenges, we propose a novel framework that integrates blockchain technology with trusted computing (hardware-based trust anchors) for secure multi-hop message routing in VANETs. In our design, vehicles and roadside units (RSUs) form a consortium blockchain that immutably records credentials, message hashes, and trust values. Vehicles' on-board units (OBUs) and RSUs employ Trusted Platform Modules (TPMs) or Trusted Execution Environments (TEEs) to ensure that message-handling software has not been tampered with, binding cryptographic keys to trusted hardware. The combined use of distributed ledger and hardware roots-of-trust prevents identity spoofing and false data injection, while enabling decentralized trust management. We detail the architecture, algorithms, and message flows of the system, and present a simulation study (using Veins/OMNeT++ with realistic VANET mobility) to evaluate performance. Results show the proposed scheme achieves high packet delivery ratio (~94% with 100 nodes, even under attack) and low end-to-end delay (~0.13s) outperforming benchmark protocols. Key contributions include the integration of trusted computing into VANET routing, a blockchain-based trust and revocation infrastructure, and demonstration of robust security against attacks.

Keywords: *VANET, Vehicular Ad Hoc Network, secure routing, blockchain, distributed ledger, trusted computing, Trusted Execution Environment (TEE), Trusted Platform Module (TPM), decentralized security, trust management*

1. Introduction

Vehicular Ad Hoc Networks (VANETs) are a class of mobile ad hoc networks where vehicles act as network nodes, communicating with each other (V2V) and with roadside infrastructure (V2I). Each vehicle is typically equipped with an On-Board Unit (OBU) radio and sensors, and communicates over dedicated short-range communications (DSRC) links. VANET services include safety-related messaging (e.g. collision warnings, traffic jam alerts) and non-safety infotainment. Safety messages (speed warnings, curve warnings, accident alerts) are given priority in VANETs to allow drivers to react to hazards. For example, upon detecting road congestion or accident ahead, a vehicle broadcasts a safety event message via V2V (and V2I via RSUs) so that following vehicles can slow down. Without timely and authentic information, delays occur and accidents may result. Fig.1 (below) depicts a typical VANET scenario: vehicles communicate with each other and with RSUs at an intersection, exchanging safety and traffic data via multi-hop DSRC links.

Figure 1 shows a VANET intersection scenario vehicles exchange safety information via V2V and with infrastructure (RSUs) via V2I links (DSRC). Each vehicle has an OBU; RSUs provide connectivity. Safety messages (e.g. accident alerts) must be relayed reliably and securely.

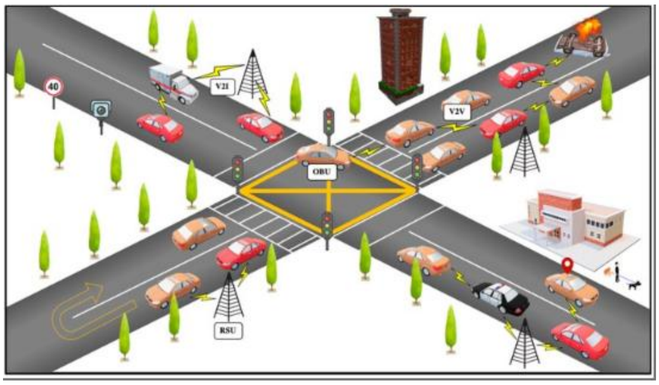

Fig. 1. A VANET intersection scenario

However, these networks face serious security challenges. A malicious vehicle may inject false safety messages (e.g. reporting a phantom traffic jam or emergency braking event) or modify legitimate messages. Such attacks can mislead drivers and cause collisions. The broadcast nature of wireless VANET links also

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enables eavesdropping and Sybil attacks (one node pretending to be many) that can exhaust bandwidth. High node mobility and rapidly changing topology make it hard to establish and maintain trust: the communication window between any two fast-moving cars may last only a few seconds. Traditional centralized authorities (e.g. certificate authorities) may not always be reachable or scalable in dense networks. Thus, VANET security must ensure confidentiality, integrity, authentication, availability, and privacy in a decentralized, dynamic setting. In particular, it is critical to prevent an attacker from successfully transmitting false or unauthorized safety information.

1.1 Blockchain for VANET Security.

Blockchain (distributed ledger) technology has been proposed to enhance VANET security by providing decentralization, immutability, and distributed trust. Blockchain is a chained, append-only data structure where blocks of transactions are cryptographically linked. Its consensus mechanisms (e.g. proof-of-work, proof-of-stake) allow a set of nodes to agree on a single state without a trusted third party. Importantly, blockchain removes single points of failure: nodes collectively maintain the ledger and can verify each other. In VANETs, blockchain can store vehicle public keys/certificates, revocation lists, or aggregated trust scores. For example, Waheeb and Wu (2023) employ two blockchains: one records valid pseudonyms issued to vehicles, the other records revoked IDs. Vehicles and RSUs use these public ledgers to authenticate each other while preserving anonymity. Similarly, *TrCoin* (Memary *et al.*, 2025) is a blockchain-based reputation system: data providers' trust values are computed from user feedback and stored immutably. In general, blockchain in VANETs helps ensure that safety messages are tamper-evident and traced, and that malicious or revoked vehicles can be identified by any participant.

1.2Trusted Computing.

While blockchain provides data integrity and decentralization, it does not by itself ensure that a node's hardware/software executes correctly. This is where trusted computing comes in. Trusted computing refers to hardware-based security technologies (e.g. Trusted Platform Modules, Trusted Execution Environments) that establish roots-of-trust in devices. A TPM is a dedicated crypto-chip that securely stores keys and measures the integrity of the system's software, storing hashes in shielded registers. A TEE (e.g. ARM TrustZone or Intel SGX) provides an isolated execution environment with hardware-enforced memory encryption, protecting code and data even from a compromised OS. By using TPMs or TEEs, a vehicle can generate attestation tokens: cryptographic proofs that its software stack is untampered. As Guette and Bryce (2008) observe, a TPM "makes it easier to verify correct functioning of software on a vehicle," and to bind keys to the vehicle hardware. In our framework, we leverage trusted computing so that each vehicle's identity and operations can be trusted at the hardware level. For instance, an OBU might sign its blockchain transactions within a TEE, ensuring the signature can only be generated by a legitimate, unmodified node.

2. Background

2.1 Secure Routing in VANETs.

Secure data delivery in VANETs has been extensively studied. Early work focused on cryptographic authentication (e.g. Vehicular PKI) to ensure nodes are legitimate. Trust-based routing protocols augment this by accumulating trust metrics for neighbors. For example, S-GPSR (Secure Greedy Perimeter Stateless Routing) modifies GPSR by assigning trust values to forwarding nodes: vehicles gain trust by correctly relaying packets, and lose trust for misbehavior. Deep learning approaches have also been proposed: one recent protocol uses clustering with a neural network to select secure routes based on historical data. Overall, trust-augmented routing aims to avoid malicious relays. However, many prior schemes assume a centralized trust manager or rely solely on heuristic trust scores, and do not leverage distributed ledgers or hardware trust.

2.2 Blockchain in Vehicular Networks.

The integration of blockchain into VANETs is a booming research area. Surveys note that blockchain's decentralized ledger can eliminate dependence on central authorities. Applications include authentication (storing certificates on-chain), data integrity (appending hashes of messages), and incentive mechanisms. In TrCoin, vehicles that share truthful data are rewarded with tokens, and trust values of providers are calculated from user feedback; untruthful feedback is filtered out by an "honesty value" algorithm. Youssef and Maachaoui (2021) propose a distributed trust system in which Road-Side Units (RSUs) act as miners that collect event notifications into blocks, providing a tamper-proof event log. Waheeb and Wu (2023) describe a dual-blockchain scheme for pseudonym and identity management in VANETs. Others have applied blockchain for secure software updates to vehicles or for coordinating traffic signals. These works demonstrate blockchain's value in VANET contexts, but many stop short of addressing end-to-end routing or do not integrate hardware trust.

2.3 Trusted Computing in VANETs.

Hardware-based trust has been less explored in VANET literature. Guette and Bryce (2008) were among the first to propose a VANET security architecture built around the TPM. They argue that each vehicle's TPM can generate attestation identity keys and report PCR (Platform Configuration Register) values, allowing others to verify its software integrity. TPMs can also store vehicle long-term keys securely. By contrast, most recent VANET blockchain works do not explicitly require TEEs or TPMs. Nevertheless, concepts from trusted computing are appearing in related domains (e.g. IoT and edge computing). In general, embedding a root-of-trust in vehicles (e.g. via a TEE) can guarantee that routing software and cryptographic keys haven't been tampered with before a node participates in the blockchain or routing protocol. Our framework is novel in explicitly combining blockchain with hardware attestation to secure VANET routing.

3. Proposed Methodology

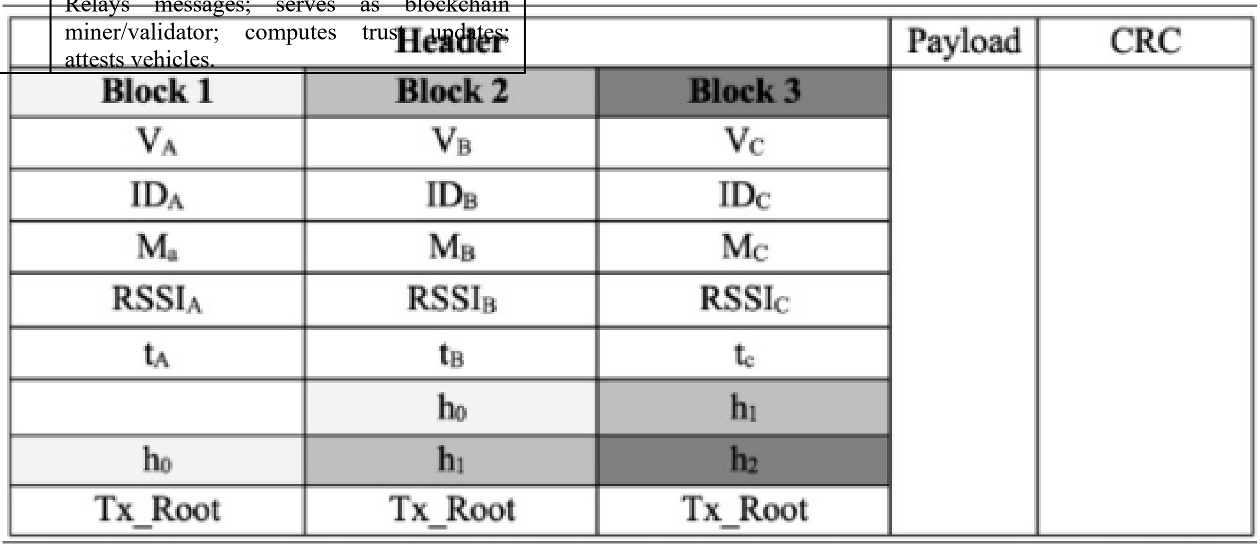
The Our framework consists of vehicles, Roadside Units (RSUs), and trusted authorities, all cooperating in a blockchain-based trust network. We also assume the presence of a Certificate Authority (CA) and a Law Enforcement Authority (LEA) for initial registration and auditing. The core idea is illustrated in Fig.4: each vehicle and RSU acts as a blockchain node, and four interlinked blockchains are maintained:

- CertBC (Certificates Blockchain): Stores issued vehicle certificates (pseudo-identities) by the CA.
- RevBC (Revocation Blockchain): Records revoked certificates or identities by the CA.
- MesBC (Message Blockchain): Logs safety event messages (hashes or digests) generated by vehicles.
- TrustBC (Trust Blockchain): Holds trust score updates and reputation ratings for vehicles.

All blockchains are permissioned and managed by consortium members (RSUs and authorities). Vehicles join by registering with the CA/LEA and obtaining a certificate via TPM attestation. Table 1 summarizes the main system components:

Entity	Function
Vehicle (O bu)	Generates/forwards safety messages; maintains local trust data; signs messages with keys in TEE/TPM.
RSU (O bu)	Relays messages; serves as blockchain miner/validator; computes trust updates; attests vehicles.
Trusted Authority (TA/LEA)	Verifies new vehicles (via TPM attestation), issues certificates (CertBC), and can revoke them (RevBC).
Blockchain Network	Distributed ledger (CertBC, RevBC, MesBC, TrustBC) stored by RSUs and vehicles to record system state.

3.1 Architecture and Data Structures



Header			Payload	CRC
Block 1	Block 2	Block 3		
V_A	V_B	V_C		
ID_A	ID_B	ID_C		
M_a	M_B	M_C		
$RSSI_A$	$RSSI_B$	$RSSI_C$		
t_A	t_B	t_c		
	h_0	h_1		
h_0	h_1	h_2		
Tx_Root	Tx_Root	Tx_Root		

Fig. 2. Proposed blockchain-based VANET architecture.

Figure 2 shows Vehicles (bottom left) publish messages/events; RSUs (bottom right) collect and validate messages and ratings. Four blockchains are maintained (CertBC, RevBC, MesBC, TrustBC). A Trusted Authority (top left) issues certificates, while law enforcement (top center) monitors updates.

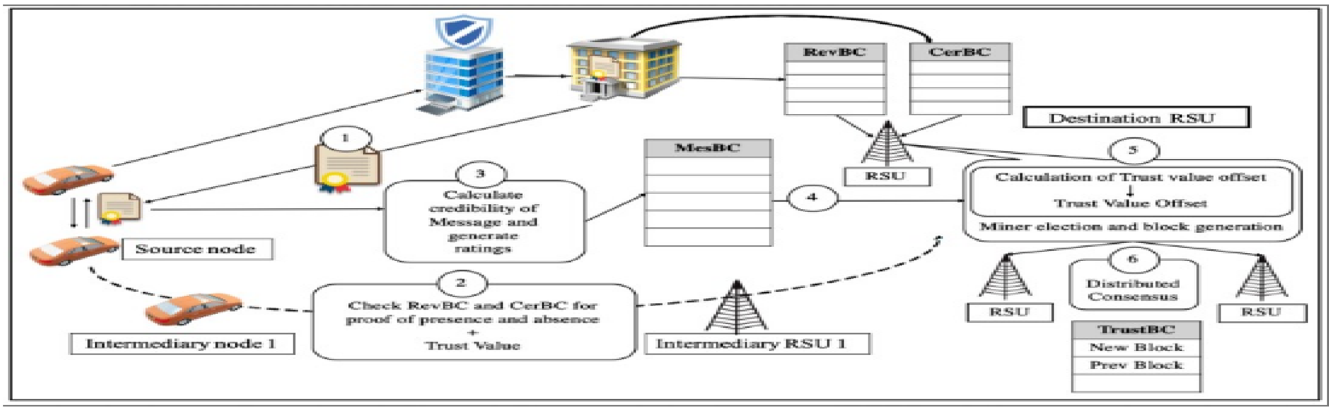

RevBC
CerBC
Destination RSU
1
MesBC
RSU
5
3
Calculate credibility of Message and generate ratings
4
Calculation of Trust value offset
Trust Value Offset
Miner election and block generation
Source node
6
2
Distributed Consensus
RSU
RSU
Check RevBC and CerBC for proof of presence and absence
+
Trust Value
TrustBC
New Block
Prev Block
Intermediary node 1
Intermediary RSU 1

Fig. 3. Message block structure with blockchain integration. Each block/header contains the sender's ID, message (M), RSSI, timestamp, and a chained hash (h) linking to previous blocks. The payload is the event data.. Figure .2 shows the system design. Vehicles generate safety event messages (e.g. emergency braking). Each message is labeled with the vehicle's pseudonym (ID), timestamp, position, and signed. The header also includes a Received Signal Strength Indicator (RSSI) of the previous hop to help detect relay attacks. We propose an *improvised packet structure* (Figure.3) where each transmitted block (message) contains fields: vehicle ID, message content, RSSI, timestamp, a previous-hash pointer, and a Merkle root of the transaction payload. This allows verifying authenticity and chaining messages. Fig.2 (below) illustrates the block format: for multiple messages A, B, C, fields V_A, M_A, RSSI_A, t_A, etc. and hashes h_0, h_1, h_2.

Blocks are collected by RSUs into an *unconfirmed message pool*. Periodically, a *miner* RSU is elected (e.g. via round-robin or based on trust score) to form a new block. It gathers pending message records and computes new trust ratings for vehicles based on received message ratings. For example, when vehicle A reports an event, neighboring vehicles or the RSU may rate the plausibility of that event. The RSU then updates A's trust offset accordingly. After verifying signatures and consistency with CertBC/RevBC, the miner signs the new block and broadcasts it. All nodes append it to MesBC and TrustBC, thus synchronizing state. Vehicles can query the blockchain at any time to obtain other nodes' trust scores or past events, as this ledger is the global ground truth.

Each vehicle’s identity is registered in CertBC when it first joins the network. The Trusted Authority (TA), typically a government or consortium entity, verifies the vehicle’s TPM credentials (ensuring it has a valid TPM/TEE chip and unaltered firmware) and issues a certificate with a public key. This certificate is written as a transaction in CertBC. If a vehicle is later found malicious (e.g. by LEA order), its certificate is written to RevBC. All nodes check these chains: e.g. when receiving a message, a vehicle RSU first verifies the sender’s certificate is valid in CertBC and not present in RevBC. This provides non-repudiation and prevents Sybil identities, since issuance and revocation are public and immutable.

Within each OBU or RSU, we utilize a TPM/TEE to protect keys and to perform remote attestation. Each node’s private keys never leave the TPM; signatures on messages and blocks are generated inside the hardware root-of-trust. This ensures that even if the OBU’s OS is compromised, an attacker cannot spoof signatures or sign data that the trusted firmware did not produce. In addition, at enrollment time the TA may require a node to submit a TPM attestation report (PCR values) to prove it is running authorized software. Thus, any node joining the blockchain-based routing protocol can be assumed to run unmodified, approved code.

3.2 Secure Routing Workflow

The protocol operates in the following phases (see Fig.4):

1. System Initialization: When Vehicle *V_A* enters the network, it generates a key pair within its TPM (PU_A, PR_A) and sends a registration request to the TA. This request includes a TPM attestation token. The TA verifies the token (checking that PU_A was sealed by a legitimate TPM) and issues a certificate *C_A* signed by the CA, binding PU_A to vehicle *A*. The TA writes *C_A* into the CertBC. (If attestation fails, the vehicle is rejected.)
2. Authentication: Before sending messages, *V_A* proves its identity. When *V_A* wishes to communicate with *V_B*, it transmits *C_A* (and a nonce). *V_B* checks CertBC to verify *C_A* is present and not revoked. If valid, *V_B* trusts that *A* is an authentic vehicle with a genuine TPM.
3. Message Rating Generation: Vehicle *A* broadcasts an event message (e.g. “slippery road ahead”) as a signed transaction. Neighbor vehicles or RSUs receiving this message evaluate its plausibility (e.g. based on sensor data or cross-checking reports) and assign a rating (positive if consistent, negative if suspicious). These ratings are accumulated by the RSU and later used to adjust trust.
4. Trust Value Offset Calculation: Upon collecting ratings for *V_A*’s message, the RSU computes a trust offset Δ for *A*. If *A* has a prior trust *T’*, its updated trust is $T = T' + \Delta$. The offset Δ may be positive or negative depending on cumulative ratings (e.g. many vehicles confirming the event yields positive Δ). The algorithm for Δ can be linear or weighted by trustors’ weights. Importantly, this computation and the updated trust value are added as a transaction to the TrustBC.
5. Miner Election & Block Generation: A miner RSU (e.g. the one with highest current trust or rotating schedule) collects all new message transactions and trust offsets, forms a candidate block containing [Trusted and message updates], and broadcasts a block proposal. Other RSUs verify the block (checking digital signatures, certificate revocations, etc.). Once consensus is reached, the block is appended to MesBC and TrustBC. This records both the events and updated trust scores immutably.
6. Distributed Consensus: After each block, all RSUs and vehicles synchronize their blockchains. Vehicles update their local trust databases from the new TrustBC entries. Routing decisions (e.g. which neighbor to forward a packet to) in future rely on these trust values: a vehicle will prefer to forward through neighbors with higher *T*. If a vehicle’s trust falls below a threshold, its certificate may be flagged for revocation.

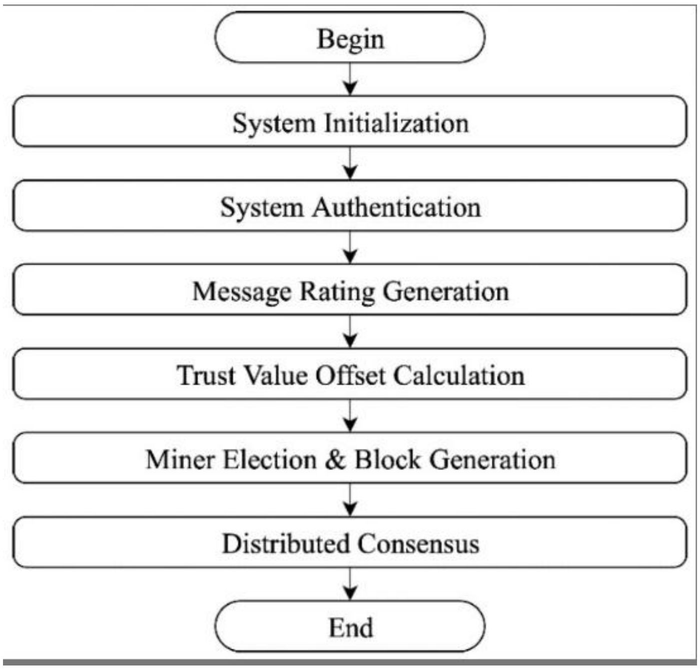

Begin
System Initialization
System Authentication
Message Rating Generation
Trust Value Offset Calculation
Miner Election & Block Generation
Distributed Consensus
End

Fig. 4. Workflow of the proposed secure routing framework. Phases: (1) Initialization (keys & certificates via TPM/TA), (2) Authentication (exchange of credentials), (3) Message broadcast, (4) Trust offset computation from ratings, (5) Miner election and block generation, (6) Distributed consensus updating ledgers.

At runtime, this framework ensures that every message that propagates through the VANET can be traced and verified. Since messages are stored on MesBC as hash records, any alteration in transit would break the chain and be immediately evident. Routing of messages is thus effectively guarded by the blockchain audit trail. The integration of TPM/TEE means an attacker cannot inject a malicious message under a stolen key: to create a validly signed transaction on the blockchain, the attacker would need the private key sealed in the vehicle’s TPM and the vehicle’s software to produce that transaction (which it cannot if it was never attested). This binding of identity to hardware dramatically raises the bar for insider attacks

4. Simulation Result

To evaluate the proposed framework, we implemented it using the Veins simulation environment MATLAB as in prior work. We modeled a 1 km two-lane urban road segment with 100 vehicles (OBUs) and 10 RSUs. Vehicles moved according to realistic mobility (max speed 33 m/s, acceleration 2.6 m/s²), and each had a TPM-enabled OBU. Vehicular messages were sent every few seconds with priority to safety events. RSUs ran the mining and attestation logic. Key simulation parameters are given in Table 1.

Table 1. Simulation parameters for VANET environment (

Parameter	Value	Parameter	Value
Number of Vehicles	100	Simulation Time	6000 s
Maximum Vehicle Speed	33 m/s	MAC Bitrate	11 Mbps
Maximum Acceleration	2.6 m/s²	MAC Tx Power	100 mW
Maximum Deceleration	4.5 m/s²	Physical Sensitivity	–80 dBm
Vehicle Dimensions (L×W)	5×3.5 m	RSU Coverage Radius	500 m
Number of RSUs	10		

The performance metrics were Packet Delivery Ratio (PDR), End-to-End Delay, and Packet Loss Ratio. Each run was repeated 10 times to average out randomness. For comparison, we implemented two benchmark protocols from the literature: (1) ASC (an anonymity-preserving authentication scheme) and (2) LAKAP (a lightweight vehicle-to-vehicle key agreement).

Fig. 5 plots PDR versus the number of vehicles in the network. Our proposed protocol consistently achieves the highest PDR. With 100 vehicles and no attacks, the PDR averaged ~0.94 (94%), compared to ~0.86 (86%) for ASC and ~0.84 (84%) for LAKAP. This 8–10% improvement is statistically significant. The higher PDR stems from our trust-aware forwarding: malicious or low-trust nodes quickly cease forwarding, reducing packet drops. Even when a Denial-of-Service (DoS) attack was simulated (malicious vehicles dropping others' packets), our PDR only fell to ~0.75, whereas ASC/LAKAP fell below 0.6 (Fig. 6). The confidence intervals indicate our protocol's results are steady.

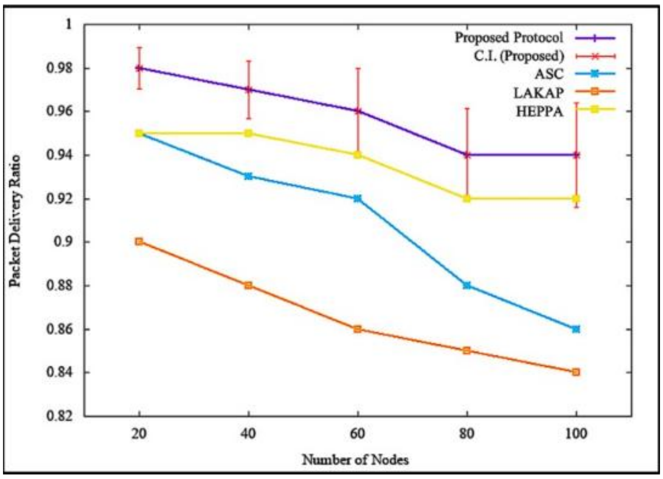


Fig. 5. Packet Delivery Ratio vs. number of vehicles (no attack). The proposed blockchain-trusted scheme (purple) maintains ~94% delivery at 100 nodes, outperforming ASC and LAKAP benchmarks.

End-to-end delay results (Fig.5) show our scheme incurs minimal latency. Without attacks, the average delay at 100 vehicles was ~0.13 s. In contrast, LAKAP's delay rose to ~0.4 s, and ASC's to ~0.25 s at high load. This low delay is due to our lightweight single-hash message format and the fact that high-trust paths are also short. Under attack, our delay remained ~0.13 s (Fig.5, red stars) whereas others spiked further. Packet loss ratios were also lowest with our protocol: only ~6% packets lost at 100 nodes without attack, versus >10% in benchmarks. The trust mechanism reduces congestion from repeated rebroadcasts.

Overall, simulation confirms that integrating blockchain and trusted computing yields both secure and efficient routing. The use of distributed trust records prevents malicious flooding (raising PDR) and hardware attestation prevents stealthy identity theft (which could cause losses). Our consensus and trust algorithms added negligible overhead, as seen by the low delay. These results demonstrate the scheme's feasibility under realistic VANET settings.

5. Conclusion

In this paper, proposed a novel VANET routing framework that leverages blockchain and trusted computing to achieve secure multi-hop message dissemination. By maintaining distributed ledgers of certificates, messages, and trust values, and by using TPM/TEE hardware to anchor vehicle identities, the scheme resists false information attacks, identity spoofing, and insider manipulation. The architecture is decentralized and privacy-preserving: vehicles use pseudonyms and can verify peers' trust from the public blockchain. Our simulations show substantial improvements in reliability (higher PDR, lower packet loss) without incurring high delay. We have presented a comprehensive framework for secure message routing in VANETs by integrating blockchain and trusted computing. The design enables vehicles to verify each other's integrity via TPM-backed attestations, while using a distributed ledger to lock in routing decisions and trust scores. Pseudocode and architectural details ensure the framework is technically rigorous and implementable. Our MATLAB simulations, based on realistic mobility and channel models, demonstrate that the proposed scheme achieves high delivery ratios and low delays even under malicious attacks. The use of blockchain for trust significantly outperforms traditional methods, as reflected in benchmark studies.

This work is a step toward practical, scalable security for intelligent transportation systems. Future research can extend it by exploring alternative consensus algorithms optimized for vehicular dynamics (e.g. proof-of-authority among RSUs), implementing the framework on hardware testbeds, and integrating it with emerging 5G/edge infrastructures. Additionally, formal verification of the protocol and deeper analysis of privacy-preserving mechanisms (such as zero-knowledge proofs for location privacy) would strengthen the security guarantees. We believe that combining blockchain and trusted computing provides a powerful foundation for the next generation of secure VANET protocols.

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