Blockchain-Based Automotive Traceability Research

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1. Research Objective

This research explores a blockchain-based solution for enhancing automotive traceability by leveraging decentralized, tamper-proof records. The primary goal is to enable comprehensive tracking of vehicle-specific quality data — from OEMs to Tier 1 (and in future Tier 2) suppliers — including torque values, leak test outcomes, and alignment parameters for suspension subassemblies. This system aims to improve root-cause analysis, streamline warranty claim validation, and reduce the operational impact of vehicle recalls.

2. System Architecture

The solution utilizes a Solidity smart contract deployed on the Ethereum testnet. A Node.js client or command-line script is used to record and retrieve traceability events. Each record stores VIN-level quality checkpoints across multiple manufacturing and testing stations. Key data points include torque test results, leak test pressures, and alignment metrics, each associated with the respective station, timestamp, and pass/fail status.

3. Smart Contract Data Model

Field	Type	Description
vin	string	Unique Vehicle Identification Number
stationId	uint	Station identifier (e.g., 5034, 5065)
testName	string	Type of test (Torque, Leak, Alignment)
value	string	Test value (e.g., torque = 48 Nm)
timestamp	uint	Epoch timestamp of test data
status	string	Result: Pass or Fail

4. Primary Use Case

The most impactful application of this system is during vehicle recalls or warranty claims initiated at the OEM level. In such cases, manufacturers can trace specific failed VINs backward through the production history — identifying the exact test results and supplier-level subassemblies involved. For instance, if a vehicle fails a suspension alignment test at the OEM's End-of-Line (EOL) station, this blockchain-based solution can reveal whether torque application at a Tier 1 supplier’s station was out of specification, or if leak test anomalies occurred further upstream. This facilitates faster and more precise root-cause analysis — saving cost, time, and enhancing compliance.

5. Security and Tamper Resistance

Each data entry is permanently recorded on the Ethereum blockchain via smart contracts. Once committed, the records cannot be altered or deleted — ensuring high-integrity audit trails across the supply chain. This provides value for both OEMs and suppliers by mitigating disputes and reinforcing compliance in quality control processes.

6. Performance & Scalability

The system is deployed on a public Ethereum testnet for demonstration. In real-world applications, transaction batching and Layer-2 solutions like Polygon or Optimism would significantly reduce latency and gas costs. For enterprise adoption, permissioned chains like Hyperledger Besu could be explored for high-throughput environments.

7. Future Work

- Develop a dashboard UI for plant quality teams to monitor traceability data in real-time. - Integrate PLCs at stations for automatic test data capture. - Extend traceability down to Tier 2 suppliers using hierarchical smart contracts. - Simulate real-world warranty scenarios and demonstrate compliance trace flows to auditors.

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