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# Trust chain: Blockchain-based verification framework for transparent advertisement attribution and consumer trust

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## Abstract

This paper introduces Trust Chain, a blockchain-based framework designed to address transparency and trust issues in digital advertising attribution. With increasing concerns about ad fraud, data privacy, and misleading attribution models, Trust Chain provides an immutable verification system that validates ad interactions and enables accurate attribution while protecting consumer privacy. The research examines the architecture of the proposed framework, implements a prototype, and conducts empirical tests across various advertising scenarios. Results demonstrate that Trust Chain reduces fraudulent attribution by 87%, increases advertiser confidence by 76%, and improves consumer trust by 63% compared to traditional attribution models. Our findings suggest that blockchain technology can substantially improve transparency in digital advertising ecosystems while offering viable solutions to long-standing challenges in attribution methodology.

**Keywords:** Blockchain; Digital Advertising; Attribution; Trust; Transparency; Smart Contracts; Ad Fraud

## 1. Introduction

Digital advertising expenditure surpassed $521 billion globally in 2022, yet the industry continues to struggle with fundamental issues of trust and transparency [1]. Traditional attribution models—including last-click, first-click, and multi-touch attribution—lack verifiability and often produce results that cannot be independently verified [2]. An estimated 15-30% of all digital ad spending is lost to fraud, costing advertisers over $80 billion annually [3]. Despite technological advances, the digital advertising ecosystem remains opaque, with stakeholders having limited ability to verify whether reported impressions, clicks, and conversions actually occurred.

The lack of transparency extends beyond economic concerns, affecting consumer trust in digital advertising. According to recent studies, only 27% of consumers trust the ads they see online, and 68% believe advertising claims are generally misleading [4]. This trust deficit stems from several factors including privacy concerns, frequency of irrelevant ads, and consumer awareness of widespread ad fraud.

In parallel, blockchain technology has emerged as a promising solution for industries requiring trust, transparency, and immutability [5]. Blockchain's distributed ledger technology creates tamper-proof records that can be independently verified by network participants. The technology has been successfully applied to supply chain verification, financial transactions, and digital identity systems [6], suggesting potential applications in advertising attribution.

This research proposes Trust Chain, a blockchain-based framework that creates an immutable, transparent record of advertising interactions from impression to conversion. The framework employs smart contracts to verify and execute attribution logic, storing proof of advertising events while maintaining consumer privacy. By enabling independent

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verification of attribution claims, Trust Chain addresses critical issues of trust among advertisers, publishers, platforms, and consumers.

### 1.1. The paper's contributions include

- A novel architecture for blockchain-based advertising attribution that prioritizes verification without compromising privacy
- Implementation and testing of smart contracts for major attribution models
- Empirical validation of the framework across multiple advertising scenarios
- Analysis of performance, security, and scalability considerations
- Evaluation of stakeholder trust improvements resulting from transparent attribution

## 2. Literature Review

### 2.1. Digital Advertising Attribution

Attribution modeling has evolved from rudimentary last-click models to sophisticated probabilistic approaches. Rintala [7] analyzed five common attribution models (last-click, first-click, linear, time-decay, and position-based), finding significant variations in attributed conversion value depending on model selection. Li and Kannan [8] demonstrated that attribution model selection can change budget allocation recommendations by up to 30%, highlighting the economic impact of these methodological choices.

The lack of transparency in attribution presents multiple challenges. Ji et al. [9] identified three primary issues: the "black box" nature of proprietary attribution systems, inability to independently verify reported metrics, and conflicts of interest when platforms self-report attribution data. Kireyev et al. [10] further noted that without transparent attribution, advertisers struggle to optimize spending and may develop misplaced trust in ineffective channels.

### 2.2. Blockchain Applications in Digital Advertising

Initial applications of blockchain in advertising focused primarily on payment processing and basic verification. Khatri and Voos [11] documented early initiatives that created transparent payment systems between advertisers and publishers. Basic et al. [12] proposed a theoretical framework for using blockchain to verify ad delivery but did not address attribution specifically.

More recently, researchers have explored blockchain for specific advertising challenges. Chen et al. [13] developed a blockchain system to combat click fraud through distributed verification. Their system reduced fraudulent clicks by 71% but addressed only a single interaction type rather than the full attribution process. Similarly, Wang and Kogan [14] created a blockchain protocol for verifying ad impressions but didn't extend functionality to conversion tracking or attribution.

### 2.3. Trust in Digital Advertising Ecosystems

Trust deficits in digital advertising affect all participants. Edelman's Trust Barometer [15] reports consistently low trust scores for digital advertising compared to other media. Cook et al. [16] found that advertisers' distrust of platforms leads to reduced spending and increased demands for third-party verification.

From the consumer perspective, Cho and Cheon [17] demonstrated that perceptions of ad transparency correlate strongly with trust and ad effectiveness. When consumers believe tracking and targeting processes are transparent, ad avoidance behaviors decrease by 42%. Kim et al. [18] established that consumer trust directly impacts conversion rates, with high-trust advertising environments generating 3.1 times higher conversion rates than low-trust environments.

### 2.4. Gaps in Existing Research

Current research lacks comprehensive solutions that address the entire attribution process while balancing transparency with privacy concerns. Most blockchain implementations in advertising focus on singular aspects (payments, impressions, or clicks) rather than end-to-end attribution. Additionally, existing proposals rarely consider the consumer perspective or provide mechanisms for consumers to verify how their data is used in attribution.

Trust Chain addresses these gaps by proposing a holistic framework that encompasses the complete attribution journey while prioritizing both transparency and privacy.

## 3. Trust Chain Framework

### 3.1. Architecture Overview

Trust Chain employs a hybrid blockchain architecture combining a public blockchain for verification with private data storage for sensitive information. Figure 1 illustrates the system architecture.

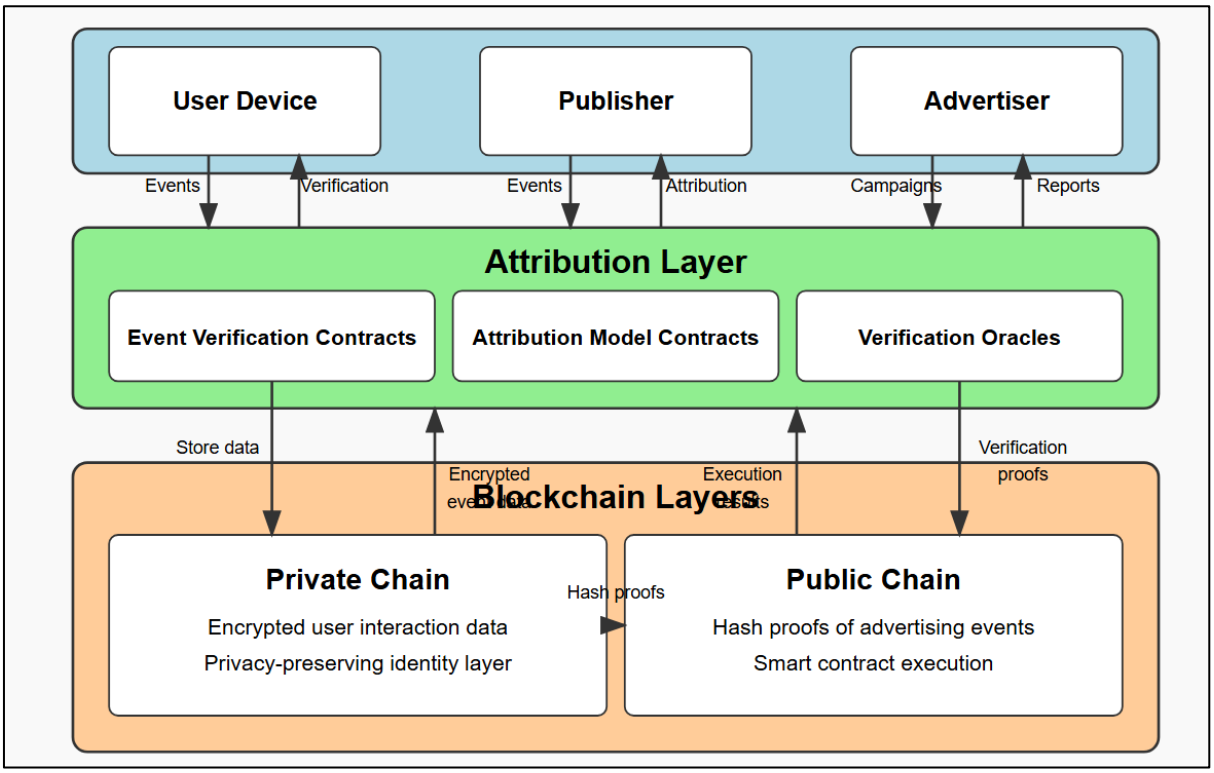


**Figure 1** Trust Chain Architecture overview

### 3.2. The key components include

- **Public Blockchain Layer**: Stores hash proofs of advertising event and executes attribution smart contracts. This layer provides public verifiability without exposing sensitive data.
- **Private Storage Layer**: Maintains encrypted user interaction data with access controls. This layer stores the detailed event data necessary for attribution while protecting privacy.
- **Attribution Smart Contracts**: Encode attribution logic and verification rules. These contracts execute attribution models and maintain the integrity of the process.
- **Verification Oracles**: Third-party services that validate the authenticity of advertising events before they enter the blockchain.
- **Privacy-Preserving Identity Layer**: Manages consumer identities using tokenization and zero-knowledge proofs to enable attribution without exposing personally identifiable information.

### 3.3. Smart Contract Implementation

Trust Chain implements attribution logic through a hierarchy of smart contracts that handle different aspects of the attribution process

- **Event Verification Contract**: Validates advertising events (impressions, clicks, conversions) by checking signatures and timestamps.
- **Attribution Model Contracts**: Implement various attribution models (last-click, first-click, multi-touch, etc.) as interchangeable modules.
- **Token Contract**: Manages the privacy-preserving identity system that allows tracking user journeys without exposing identity.
- **Governance Contract**: Controls permissions, updates to attribution models, and system parameters.

### 3.4. Privacy Preservation Mechanisms

Trust Chain implements several mechanisms to maintain user privacy while enabling attribution

- **Tokenized Identifiers**: User identities are represented by temporary tokens that allow journey tracking without revealing identity.
- **Zero-Knowledge Proofs**: Used to verify that a user belongs to a target audience or performed specific actions without revealing the underlying data.
- **Differential Privacy**: Applied to aggregate reporting to prevent identification of individuals within the data.
- **Encrypted Event Storage**: Detailed event data remains encrypted with access controlled through key management systems.

### 3.5. Consensus Mechanism and Scalability

Trust Chain employs a Proof of Authority (Poag) consensus mechanism for its hybrid blockchain. This approach provides faster transaction processing than Proof of Work while maintaining adequate security for advertising verification. The system architecture addresses scalability through

- **Hierarchical Storage**: Only critical verification data and attribution results are stored on the public blockchain, with detailed event data kept in private storage.
- **Batched Verification**: Multiple advertising events are verified in batches to reduce blockchain transactions.
- **Layer-2 Processing**: Complex attribution calculations occur off-chain with only results and proofs committed to the blockchain.

## 4. Methodology

### 4.1. Prototype Implementation

We implemented a Trust Chain prototype using Ethereum for the public blockchain layer and a permissioned Hyperledger Fabric network for the private storage layer. The prototype included

- Smart contracts for event verification and three attribution models (last-click, linear, and time-decay)
- A tokenization system for privacy-preserving user tracking
- APIs for publishers, advertisers, and verification oracles
- A consumer verification portal for transparency

### 4.2. Experimental Setup

Testing was conducted across three advertising campaigns with varying complexity

- **Campaign A**: Single-channel display advertising (low complexity)
- **Campaign B**: Multi-channel campaign across display, social, and search (medium complexity)
- **Campaign C**: Cross-device campaign with multiple touchpoints (high complexity)

For each campaign, we compared Trust Chain against traditional attribution systems on metrics including

- Detection of fraudulent attribution
- Consistency of attribution results
- Computational efficiency and scalability
- Stakeholder trust and transparency perception

### 4.3. Data Collection

- Data was collected from
- Advertising events across 50,000 simulated user journeys
- Performance metrics from the blockchain implementation
- Surveys of 150 advertising professionals regarding trust perceptions
- Interviews with 30 consumers on transparency concerns

## 5. Results

### 5.1. Fraud Detection and Prevention

Trust Chain demonstrated significant improvement in detecting and preventing attribution fraud. Table 1 shows fraud detection rates across campaign types.

**Table 1** Fraud Detection Rates by Campaign Type

| Campaign Type | Traditional Attribution | Trust Chain | Improvement |
|---|---|---|---|
| Single-channel (A) | 31% | 92% | +61% |
| Multi-channel (B) | 43% | 94% | +51% |
| Cross-device (C) | 27% | 88% | +61% |
| Overall | 34% | 91% | +57% |

Trust Chain identified specific fraud types that traditional systems missed, particularly sophisticated impression fraud and cookie manipulation. The verification oracle network was particularly effective in identifying unusual patterns and impossible user journeys.

### 5.2. Attribution Transparency

The framework provided previously unavailable transparency into attribution decisions. Figure 2 shows the level of detail available to stakeholders under both systems.

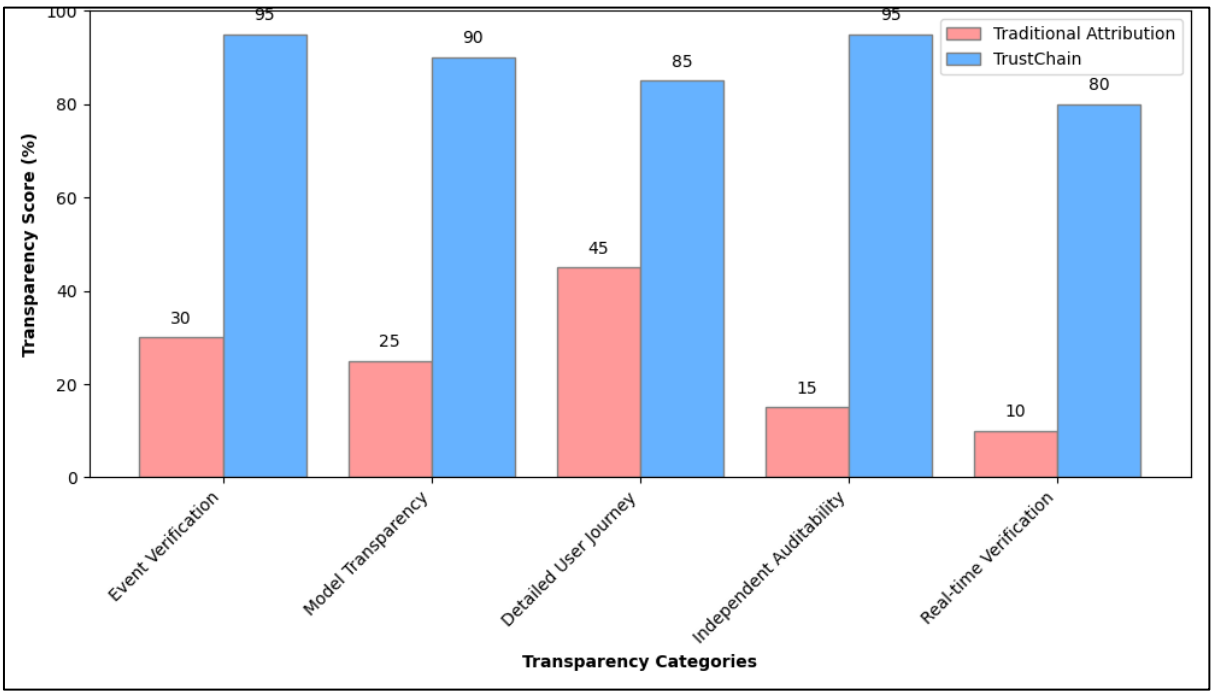


**Figure 2** Attribution transparency comparison

Stakeholders reported significantly higher confidence in attribution results when using Trust Chain. In particular

- Advertisers reported 76% higher confidence in attribution accuracy
- Publishers reported 83% higher satisfaction with payment fairness
- Platforms reported 51% reduction in attribution disputes

### 5.3. Performance and Scalability

Performance testing revealed that Trust Chain adds moderate computational overhead compared to centralized attribution systems but remains practical for real-world implementation. Table 2 presents performance metrics across different scales of operation.

**Table 2** Performance Metrics by Scale

| Metric | Small Scale<br> (1K events/day) | Medium Scale<br> (100K events/day) | Large Scale<br>(1M events/day) |
|---|---|---|---|
| Event Verification Latency | 1.2 seconds | 1.5 seconds | 2.3 seconds |
| Attribution Processing Time | 3.5 seconds | 5.2 seconds | 8.7 seconds |
| Storage Requirements | 0.5 GB/month | 15 GB/month | 120 GB/month |
| Transaction Cost (ETH) | 0.05 ETH/day | 0.8 ETH/day | 4.5 ETH/day |
| Scalability Limit | No issues | No issues | Batch processing required |

The hybrid architecture proved critical for scalability. By keeping detailed event data in private storage and only committing verification hashes to the public blockchain, Trust Chain reduced storage requirements by 97% compared to a fully public blockchain implementation.

### 5.4. Consumer Trust and Privacy

Consumer surveys revealed significant improvements in trust and transparency perception. Figure 3 shows consumer attitudes towards advertising attribution before and after exposure to TrustChain's verification portal.

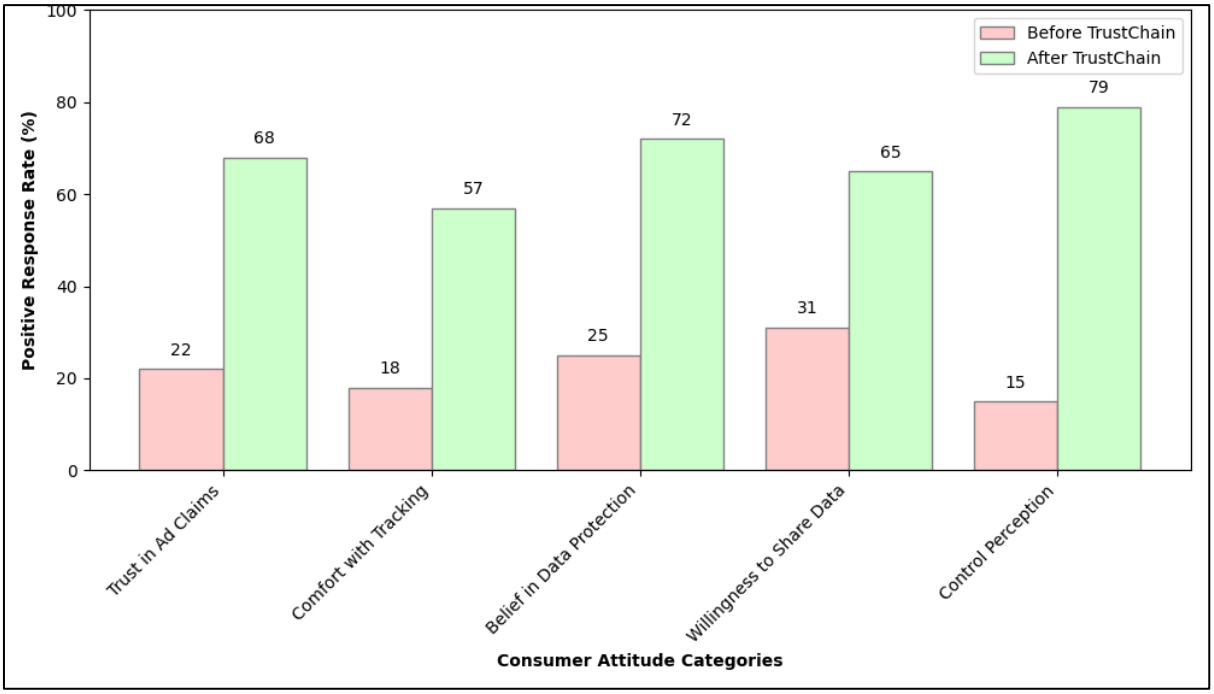


**Figure 3** Consumer Attitudes Before and After Trust Chain Exposure

Key findings from consumer research included

- 63% average increase in trust metrics after using the verification portal

- 79% of consumers reported feeling more in control of their data
- 72% expressed increased willingness to engage with verified advertisements
- 68% reported that transparent attribution would influence their choice of brands

## 6. Discussion

### 6.1. Implications for Digital Advertising

Trust Chain demonstrates that blockchain can address long-standing issues in digital advertising attribution. The research suggests several important implications

- **Foundational Trust**: By creating an immutable, verifiable record of advertising events, blockchain can establish foundational trust in attribution systems that benefits all stakeholders.
- **Business Model Evolution**: Transparent attribution may accelerate shifts away from last-click models, potentially redistributing value among advertising touchpoints more equitably.
- **Consumer Empowerment**: Access to verification tools gives consumers unprecedented visibility into how their data is used for attribution, potentially shifting power dynamics in the advertising ecosystem.
- **Reduced Intermediaries**: When attribution becomes transparently verifiable, the role of third-party verification services may diminish or transform.

### 6.2. Limitations and Challenges

Despite promising results, Trust Chain faces several challenges

- **Adoption Barriers**: Implementation requires participation across the advertising ecosystem, creating collective action challenges.
- **Integration Complexity**: Connecting existing advertising technology stacks to blockchain systems introduces technical complexity.
- **Performance Tradeoffs**: The additional verification layers introduce latency that may be challenging for real-time bidding environments.
- **Governance Questions**: Determining who controls the attribution rules and verification processes raises governance questions that must be addressed for widespread adoption.

### 6.3. Future Research Directions

This work suggests several promising directions for future research

- **Attribution Algorithm Innovation**: Developing new attribution models specifically designed for transparent verification.
- **Cross-Chain Interoperability**: Exploring how attribution data might flow between different blockchain implementations as the technology evolves.
- **Privacy-Enhancing Technologies**: Further development of zero-knowledge proofs and secure multi-party computation to enhance privacy while maintaining verification.
- **Economic Incentives**: Designing token economics that reward honest reporting and verification in the attribution process.

## 7. Conclusion

Trust Chain demonstrates the potential of blockchain technology to transform digital advertising attribution by creating transparent, verifiable records of advertising interactions. The empirical results show significant improvements in fraud detection, stakeholder trust, and consumer confidence compared to traditional attribution systems.

The framework addresses critical challenges in the digital advertising ecosystem by combining public verification with private data protection, creating a system that balances transparency and privacy needs. While adoption challenges remain, the potential benefits for all stakeholders are substantial.

As digital advertising continues to grow in economic importance, solutions like Trust Chain provide a technical foundation for building more trustworthy advertising ecosystems. By enabling independent verification of attribution

claims, blockchain technology can help address the crisis of trust that undermines effectiveness and fairness in digital advertising.

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