Exploration of the Application of Blockchain Technology in E-commerce Supply Chain Management

Jiaqi Wen

Communication University of China, Beijing 100024, China

Abstract: With the rapid development of the e-commerce industry, traditional supply chain management faces challenges such as lack of transparency and low efficiency. To break through these limitations, blockchain technology has emerged. By leveraging core elements such as distributed ledgers and smart contracts, blockchain deeply integrates into various aspects of the e-commerce supply chain, including building transparent information networks, precise traceability, ensuring data security, optimizing processes, promoting multi-party collaboration, and innovating business models. Through the analysis and practical application of real cases, results show that blockchain effectively enhances supply chain transparency and efficiency, reduces costs, and strengthens trust. The application of this technology is of significant importance to the e-commerce supply chain, providing an innovative path and solid support for the sustainable development of the industry.

Keywords: blockchain; e-commerce supply chain; data security; supply chain optimization; traceability

1. Introduction

In the surging era of e-commerce, supply chain management stands as the cornerstone of the e-commerce edifice, and its importance is self-evident. However, traditional supply chains are mired in challenges, with information shrouded in mist and trust among parties as thin as ice, while efficiency bottlenecks act as shackles. At this moment, blockchain technology emerges like a beacon cutting through the night, bringing its unique distributed architecture and encryption algorithms to the forefront. How will it transform the stage of e-commerce supply chain management, making fuzzy information clear and transparent like a magician? And how will it reinforce the bridge of trust among all parties like a fair referee? Let us witness the marvelous journey of blockchain in e-commerce supply chain management, where it plays the role of a reformer and innovator, staging a spectacular play of reshaping and revolution.

2. Blockchain Reshaping the Core Architecture of E-commerce Supply Chains

2.1 Distributed Ledger: Building a Transparent Information Network

Taking the globally renowned e-commerce company Amazon as an example, after introducing blockchain distributed ledgers into some of its product supply chain management, detailed data from every stage — from raw material suppliers to producers, warehouse logistics providers, and sales terminals — such as the origin of raw materials, production dates, transportation routes, and storage conditions are accurately recorded at each node. These data are encrypted and form a chain structure, ensuring the integrity and immutability of information. Numerous participants can query in real-time, significantly reducing decision errors and inefficiencies caused by information asymmetry. This effectively enhances the overall visibility and coordination of the supply chain, making the commodity circulation process transparent and laying a solid foundation for the efficient and stable operation of the e-commerce supply chain.

2.2 Smart Contracts: Automating Transactions and Rule Enforcement

In some product transaction scenarios on the large e-commerce platform JD.com, when a consumer places an order to purchase a certain product, a pre-set smart contract automatically activates. It will automatically verify order information, check inventory levels, calculate prices and discounts based on the rules set in the contract[1]. Upon confirmation, it triggers payment instructions, notifies the merchant to ship the goods, and arranges logistics distribution. The entire process requires no human intervention, greatly improving the speed and accuracy of transactions. Additionally, smart contracts precisely enforce rules for returns, exchanges, and quality inspections within the supply chain. If a product has quality issues, smart contracts will automatically handle refund or exchange processes according to predetermined terms, protecting consumer rights while standardizing responsibilities and obligations of upstream and downstream enterprises in the supply chain, reducing default risks, and promoting the automation and intelligentization of the e-commerce supply chain.

3. In-Depth Application of Blockchain in Key Aspects of the E-commerce Supply Chain

3.1 Precise Traceability: Ensuring Product Quality and Reliable Sources

JD Fresh leverages blockchain technology to enhance the traceability and transparency of its agricultural product supply chain. Each participant, from farmers to packaging plants and logistics providers, uploads detailed data at every stage to a secure, immutable ledger. Consumers can scan a QR code on product packaging to access comprehensive traceability information, such as the orchard's name, geographic location, fertilizers and pesticides used, harvest times, and environmental conditions during packaging.

For example, when scanning a QR code for a specific brand of oranges, consumers can trace the product back to a mountainous orchard in Sichuan, where organic fertilizers were used and the fruit was harvested at optimal ripeness. The oranges are then packaged within 24 hours at a certified plant and transported via cold chain logistics to maintain freshness. In case of quality issues, the blockchain allows for quick identification of the responsible parties, ensuring rapid corrective action.

This system not only ensures product quality but also fosters trust with consumers by providing verifiable information about the origin and handling of the produce. It also promotes sustainable practices among farmers, improves market access for SMEs, and upholds environmental and social responsibility throughout the supply chain.

3.2 Data Security Protection: Resisting Information Risks and Tampering Threats

Taking Alibaba, a globally renowned e-commerce giant, as an example, the company employs advanced blockchain encryption algorithms and distributed storage mechanisms to safeguard its extensive product transaction data, supplier information, and user privacy. For product transaction data, each order detail—including product names, prices, quantities, buyer and seller information—is meticulously encrypted and stored across multiple nodes on the blockchain. This distributed ledger system ensures that even if one node is compromised by hackers, accessing complete, unencrypted order details remains impossible due to the decentralized nature of blockchain technology. Furthermore, any attempt at tampering with the data is instantly detectable through blockchain's hash algorithm. The hash value of altered data will not match the original record, thereby triggering an immediate alert and allowing for timely intervention.In terms of supplier information, critical data such as supplier qualifications, production capacities, credit ratings, and other vital metrics are securely recorded on the blockchain. This immutable ledger prevents malicious competitors from stealing or altering this crucial information. It ensures that the exchange of information between upstream and downstream enterprises within the supply chain remains secure and credible. By implementing these measures, Alibaba significantly mitigates business risks associated with data leakage or tampering, fostering a stable and trustworthy e-commerce supply chain environment.

Alibaba implements robust security measures for blockchain transactions using advanced encryption and decentralized storage. Before uploading transaction data to the blockchain, it is encrypted using cryptographic algorithms like AES (Advanced Encryption Standard) or RSA (Rivest–Shamir–Adleman). This ensures that even if data is intercepted, it remains unreadable without the decryption key. The encrypted data is then split into smaller chunks and distributed across multiple nodes in the blockchain network. Each node stores only a portion of the data, making it difficult for hackers to reconstruct the full information. Additionally, each piece of data is paired with a unique hash value generated by functions like SHA-256 (Secure Hash Algorithm 256-bit). This hash serves as a digital fingerprint, ensuring that any change to the data will alter the hash, signaling potential tampering and ensuring the integrity of the blockchain.

Consensus Mechanisms: To validate transactions and add new blocks to the chain, Alibaba utilizes consensus mechanisms like Proof of Work (PoW) or Proof of Stake (PoS). These processes require significant computational power or staked resources to approve changes, ensuring that only legitimate transactions are recorded[2]. Smart Contracts: For automating complex workflows and ensuring compliance with predefined rules, Alibaba employs smart contracts. These self-executing contracts automatically enforce agreements when certain conditions are met, reducing the need for manual oversight and minimizing human error. Audit Trails: Every action taken on the blockchain, whether it's adding a new block or updating existing information, is logged with a timestamp and linked to the specific user or entity responsible. This creates an unalterable audit trail that can be traced back to its source, providing transparency and accountability. Supplier Onboarding: When integrating new suppliers into the ecosystem, Alibaba conducts thorough background checks and verification processes. Once approved, supplier credentials are then recorded onto the blockchain, where they remain accessible yet protected against unauthorized modifications.

Real-Time Monitoring: Continuous surveillance systems monitor the blockchain for unusual activities indicative

of potential breaches or attacks. In case of anomalies are detected, immediate actions can be taken to mitigate risks and protect sensitive data.Regular Updates: To stay ahead of emerging threats and vulnerabilities, Alibaba regularly updates its blockchain infrastructure with the latest security patches and enhancements. This proactive approach helps maintain high levels of security and resilience against evolving cyber threats.User Privacy Protection: Personal identifiable information (PII) collected from users during transactions is handled with utmost care. Only necessary details required for fulfilling orders are shared with third parties, and all communications involving PII are encrypted end-to-end.By adopting such comprehensive measures, Alibaba not only safeguards its own operations but also sets a benchmark for other companies looking to leverage blockchain technology for enhancing their supply chain management practices. The result is a more secure, efficient, and transparent e-commerce ecosystem that benefits both businesses and consumers alike.

3.3 Supply Chain Process Optimization: Improving Efficiency and Reducing Costs

Taking the cross-border e-commerce platform AliExpress as an example, the platform deeply collaborates with logistics companies like DHL using blockchain technology. This collaboration begins with the integration of blockchain into the logistics tracking system. When goods are dispatched from the seller's warehouse, key information such as warehouse in/out times and location updates during transportation are recorded on the blockchain. This data is then shared in real-time with the e-commerce platform, sellers, and buyers, ensuring transparency at every stage of the shipment process.

For instance, when a buyer purchases an electronic product from abroad, the blockchain system can arrange local delivery resources in advance based on the real-time location and estimated arrival time of the goods. This involves coordinating courier allocation and distribution center goods assignment through smart contracts embedded within the blockchain network. As a result, the overall delivery time is significantly shortened from the traditional average of 15-20 days to about 10-15 days.In terms of inventory management, AliExpress integrates blockchain with supplier systems to track product inventory levels and restocking needs in real-time.

For a clothing brand sold on multiple e-commerce platforms, sales data and inventory situations from various platforms are continuously updated on the blockchain ledger. This allows the brand to adjust production plans dynamically based on current demand and inventory levels. By leveraging blockchain technology, the brand can avoid overstock or stockouts, thereby reducing inventory costs and improving customer satisfaction.Furthermore, the immutability and transparency of blockchain ensure that all transactions and inventory adjustments are securely recorded and easily auditable. This not only enhances trust among all parties involved but also facilitates efficient operation and cost control of the e-commerce supply chain.

4. Blockchain Driving Collaboration and Innovation in E-commerce Supply Chains

4.1 Multi-Entity Collaborative Cooperation: Breaking Down Information Barriers and Silos

Taking the Xiaomi ecosystem as an example, it encompasses numerous entities such as hardware manufacturers, software developers, logistics providers, and sales channel partners. Before the introduction of blockchain, information flow among these entities was sluggish. For instance, hardware manufacturers were unaware of real-time market feedback on product functionalities, leading to delayed product iteration and optimization; logistics providers struggled to accurately estimate the delivery needs for different products, resulting in resource wastage and delivery delays.With the adoption of blockchain technology, a unified information sharing platform was established. Hardware manufacturers can upload real-time information on product development progress and component supply conditions to the blockchain network. This data is then accessible to all stakeholders in the ecosystem. Software developers use this data to create more compatible applications that align with the latest hardware specifications.

Logistics providers can also benefit from this transparent system by planning delivery routes and warehouse arrangements in advance based on production plans and sales order data recorded on the blockchain. For example, during the production process of the Xiaomi Mi Band, the manufacturer records information such as chip supply status and assembly progress on the blockchain. Sales channel partners can then estimate market launch volumes and provide feedback for demand adjustments.This collaborative effort shortens the average cycle from R&D to market launch by about 20%, significantly enhancing the efficiency of the entire supply chain. It breaks down information barriers and silos between entities, achieving efficient integration and utilization of resources.

4.2 Innovative Business Models: Injecting New Vitality into the E-commerce Supply Chain

Taking Pinduoduo's "New Brand Plan" as an example, the plan leverages the traceability and immutability of blockchain. In this program, numerous small and medium-sized manufacturing enterprises deeply collaborate with the

Pinduoduo platform. When consumers purchase goods, they can view the complete production process of the products through blockchain, including raw material sources and detailed production processes[3]. This allows some lesser-known but high-quality small and medium-sized manufacturing enterprises to gain more trust and market opportunities.

Based on the smart contract functionality of blockchain, an innovative profit distribution model is realized. For a participating clothing manufacturing enterprise, once product sales reach a certain quantity, the smart contract automatically triggers, distributing a portion of profits to raw material suppliers according to a preset ratio, incentivizing them to provide higher quality materials; another portion of profits is invested in the company's research and development and environmental upgrades.This innovative business model not only stimulates the innovation vitality of small and medium-sized manufacturing enterprises, giving them new momentum in the e-commerce supply chain, but also provides consumers with more cost-effective and trustworthy product choices. It promotes the development of the e-commerce supply chain towards a more vibrant and sustainable direction.

5. Conclusion

At the level of information exchange, distributed ledgers have completely broken the closed and lagging nature of traditional supply chain information, constructing a comprehensive, real-time transparent information ecosystem that allows data from various links to flow smoothly and be precisely shared. Smart contracts transform cumbersome manual operations and ambiguous rule judgments into automated, standardized processes from the perspective of transactions and rule execution, greatly reducing human errors and disputes. Precise traceability is not only about controlling product quality and origin but also about establishing a monument of trust in the hearts of consumers, making every shopping decision based on a clear product history. Data security protection acts like a solid fortress, resisting various risks of the information age, ensuring the integrity and confidentiality of supply chain data assets. Supply chain process optimization fundamentally reshapes resource allocation and operational rhythm, reducing costs while enhancing response speed. Multi-entity collaborative cooperation promotes deep integration among all participants in the supply chain, and innovative business models inject continuous vitality and creativity into the industry. Looking forward, as blockchain technology continues to evolve and improve, e-commerce supply chain management will undoubtedly undergo more profound changes. More innovative application scenarios will continue to emerge, further enhancing the resilience and flexibility of the supply chain, thereby helping e-commerce enterprises stand out on the global commercial competition stage with superior supply chain management advantages, creating a more efficient, intelligent, and sustainable new business ecosystem, and propelling the entire e-commerce industry to a new development height.

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Author Bio

Wen Jiaqi (November 2003-), male, Han ethnicity, from Kunming, Yunnan, with a bachelor's degree, research direction: digital economy, big data.