

Blockchain in Supply Chain: Journey from Disruptive to Sustainable

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Abstract

“Whereas most technologies tend to automate workers on the periphery doing menial tasks, blockchains automate away the center. Instead of putting the taxi driver out of a job, blockchain puts Uber out of a job and lets the taxi drivers work with the customer directly.” — Vitalik Buterin, co-founder Ethereum and Bitcoin Magazine

Blockchain has evolved to be the most discussed and potentially disruptive technology and is expected to become a driving force for technology-based business innovations. Although blockchain is still in infancy in terms of technological maturity, experimental adoption and customization are already in progress. One of its' early adopters, Supply chain Management is expecting to find fascinating solutions for its most pressing issues like confidentiality and trust, along with those of the inability to share information between supply chain partners, limitations of IT systems and lack of data standards. This paper is an attempt to seek the applicability of blockchain technology in the business process of Supply Chain Management. The Paper provides a comprehensive map for technical feasibility of a blockchain based supply chain through the distributed concepts including proof of work, consensus, and smart contracts.

Keywords:Blockchain, Supply Chain Management, Decentralized Applications

I. Introduction

Its nearly a decade since blockchain based cryptocurrency bitcoin [XXIV] was released and the number of cryptocurrencies available over the internet as of February 14, 2019, is 2017 and growing [IV]. Inspired by the concepts of distributed computing and cryptography blockchain has been referred to as a disruptive technology as it brings benefits like decentralization, transactions security, and anonymity. Blockchain has the potential of displacing an established technology and shakes up the industry or a ground-breaking product that creates a completely new industry [X] and initial trends with the rise of cryptocurrencies has signaled that blockchain has been disruptive for the banking industry and financial services. Cryptocurrency has the potential of shaking a centralized banking system by

eliminating the need to pay fees for using credit or debit cards [XVI][XXV]. Recent Trends have shown that blockchain is turning out to be a sustaining technology rather disruptive and has huge potential in supply chain [XII], healthcare [XX], Internet of Things (IoT) [XIX], education [III] and public services[II].Blockchain has been seen as commercially viable technology(Figure 1) that can help transform existing transaction processing practices. Commercial viability and acceptability of blockchain are on the rise and 3021 patent families related to blockchain applications are divided into four sub-categories based on different types of application like Payments and Transaction systems, Financial services business, Administration and E-commerce.[VIII]

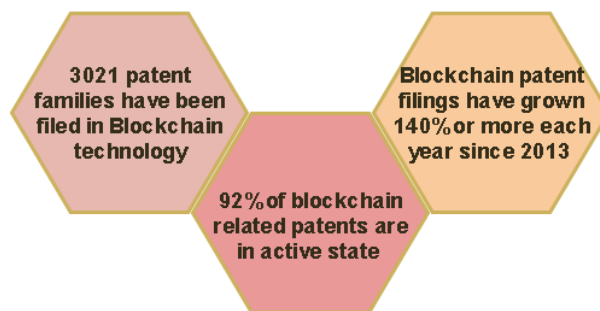


Figure 1: Rise of Blockchain Patents

II. BLOCKCHAIN

Blockchain has exciting features(Figure 2) that makes it a better alternative for business processes. Blockchain enforces trust by making transaction processing transparent and verification process of the transaction with hashing (Merkle tree) makes in immutable.

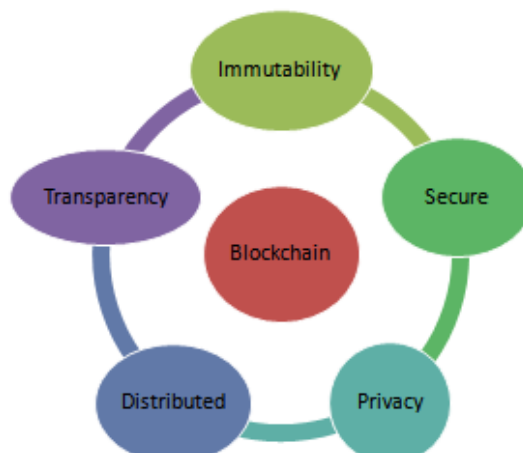


Figure 2: Inherent Features of Blockchain

Blockchain eliminates the risk of single point of failure as it is distributed in nature and all network nodes carry a copy of transactional data. Extensive use of

cryptography and decentralization makes it highly secure. Privacy issues over public blockchains can be addressed by implementing blockchain in a controlled manner(permissioned blockchain).

Blockchains can be classified as public, private or hybrid variants, depending on their application[XXIX]

- **Public** – No one owns Public blockchains, they are fully decentralized and are visible by anyone.
- **Private** – These are also referred to as permissioned blockchains and uses privilege to control who can read from and write to the blockchain.
- **Hybrid** – These blockchains are public only to a privileged group. Consensus process is controlled by privileged servers using a set of rules agreed to by all parties. The network is partly decentralized and copies of the blockchain are only distributed among limited participants.

Although a public blockchain distributes itself in a decentralized peer-to-peer fashion, this isn't necessarily true for a private blockchain. Private blockchains are those used by enterprises to record asset transactions within a limited user base (restricted scope). Hybrid blockchains can be visualized as very small scale public blockchains; they are decentralized only across a limited participant base.

The blockchain is a distributed ledger that records every transaction in chronological order. The records grouped together in the form of blocks and are stored along with hash values that are cryptographically verifiable. Now, these blocks are connected together to form the blockchain that provides a way for information to be recorded and shared by a community. Each member maintains a copy of the blockchain and all members must validate any updates collectively [XXVI]. Figure 3 represents a simplified blockchain.



Figure 3: A simplified blockchain

Blockchain may record transactions, contracts, information assets or practically anything that can be stored in digital form. Blockchain records are permanent, tamper-proof, transparent, and searchable. Each new “block” generated is added to the end of a “chain.” Initiation, validation, storage, and distribution of each new block is managed by a protocol. Blockchain replaces the need of third-party intermediaries and participants of blockchain run complex algorithms to certify the integrity of records in the block.

III. CONSENSUS ALGORITHMS

Consensus algorithms are used to achieve necessary agreement on a single state of the network among distributed processes or multi-agent systems. The consensus is achieved by tallying the hash values of all copies of the chain. This requires the people in the network to spend a lot of computing power to maintain the blockchain. For this provision of reward is required for people to contribute resources for maintaining the network. Following are some popular consensus algorithms:

- **Proof of work (PoW)[XXIV] mechanism.** Miners or participants on the network who run bitcoin nodes gather up recent transactions as a block of data where each block must refer to the previous block. To select a miner who will be assigned to solve a block of transactions, a mathematical puzzle is created that is hard to solve, i.e. it takes a lot of work. Whoever solves the puzzle first gets to mine the block. In exchange for mining the block, the miner receives bitcoin as a reward. After every successful transaction, the puzzle starts increasing in complexity i.e. miners need to look for an even larger hash value. The complexity of the puzzle also depends on the number of miners in the network.
- **Proof of stake[XXVIII]** is a mechanism that requires miners to spend a native currency to perform a transaction i.e. users need to have a stake in the transaction being carried out. For the Ethereum blockchain, the native coin is ether. To achieve consensus, the network participants spend a tiny amount of ether to exercise their vote.
- **Proof of activity[VI]** combines proof of work and proof of stake. A random number of miners have to perform work (solve the puzzle) and sign off on a block using a crypto key (currency) to make a block official.
- **Proof of capacity[XV]** requires miners to allocate a sizable volume of their hard drive to mining while proof of storage requires miners to allocate and share disk space in a distributed cloud.
- **Ripple (XRP) rely on social networks for consensus[XXVII]** where the value of a member in a social network is determined by the number of unique members/nodes it connects to. This type of mechanism is biased where newcomers need social intelligence and reputation to participate. Only authorized member groups to reach consensus. This model allows for corporate style structures to exist with accountability on the blockchain.

IV. SMART CONTRACTS

Smart contracts are computer programs that secure, enforce and execute the settlement of a contract between organizations, people and things. The term Smart contract was coined in 1994 by Nick Szabo, back when it was an idea nowhere to go. Blockchain changed all that. The blockchain enables you to enforce complex smart contracts which require multiple people to approve a transaction by enabling multiple signature protocols. It is also known as multi-sig. Multi-sig could be used in cases of arbitration or a remote shareholder meeting to decide a company's strategy. A set of smart contracts can be bundled together perform complex transactions called distributed apps(a.k.a dApps).

A distributed application (dApp) is a set of smart contracts that stores data and enforces multiple smart contracts on a blockchain. Simple smart contracts require people to sign off on the transactions, however for simple repetitive actions like getting milk delivered every morning and making real-time payments, people might choose to automate the task to a program. We call these autonomous agents. Some autonomous agents could be intelligent, that they could adapt to the state of the system and act accordingly. For example, the system knows that you are on vacation and thereby stops the milk subscription temporarily. At the other end, a collection of dApps can enable companies to craft clever, self-reinforcing agreements. Another case would be when building a product, goods can be micro scheduled to arrive at the factory floor directly from the supplier.

V. BLOCKCHAIN IN SUPPLY CHAIN

The blockchain is gaining acceptability and is expected to become a driving force for business innovation in various fields. Although, there are many challenges in terms of technological maturity. Many projects covering customization are active. Blockchain technology has already started to impact several aspects of businesses and governments [XIV]. The financial industry has been the prime sector for blockchain adoption and several financial institutions are proactively exploring proof of concepts with a number of blockchain pilots through partnerships with financial technology startups, consortiums, and collaborations with regulators; the next fertile area for application of Blockchain technology is proposed to be supply chains [XXII].

With the rise in digitization and process automation organizations need to maintain a competitive advantage by adopting technological enhancements across there process that decrease Turn around time to address speed to market and the ability to rapidly navigate changing business environments.

Supply chains, often defined as the next frontier of competition have evolved through theyears to encompass increased product variety, global sourcing of components, distribution to geographically spread markets while striving for enhanced responsiveness and efficiency [VII].

Supply chains have extensive coordination requirements with multiple stakeholders from different fields including manufacturing, freight and logistics, financial, government entities and several third-party service providers (e.g. freight forwarder,

customs broker, Information technology (IT) firms and so on), supply chains seem to be well positioned in being significantly transformed by blockchain technology.

Supply chain management is to plan, implement and control supply chain operations that spans all movement and storage of raw materials, work-in-process inventory and finished goods from the point-of-origin to the point-of-consumption [IX]. The critical challenge is to find the best supply chain configuration such that operations can be performed in an efficient and responsive way [XXI].

However, supply chains continue to increase in complexity. What contributes to the complexity is increasing product and service complexity, regulatory and compliance requirements, geographically spread supplier and customer networks, outsourcing, risk and security considerations, and the rise of e-business to increase the speed of change in supplier networks and customer expectations [XIII]. In addition, the inevitable increase in the number of players within the chains is also a source for the increase in supply chain complexity [V].

As supply chains become more complex, firms are exposed to a greater volume of data [I]. While it is essential to enhance data visibility and transparency for both existing and newly added layers in supply chains, information obtained from different sources, however, tends to reduce data accuracy[I].

Consequently, maintaining both visibility and quality of data from different stakeholders is one of the critical factors for sustaining efficiency and responsiveness in supply chains. Given that supply chain management spans both internal and external stakeholders, timely and accurate information transfer is vital to achieving improved supply chain performance.

Supply chain involves moving a product from a supplier to the customer that requires effective coordination between human and mechanical inputs. Supply chains need to improve end-to-end visibility, product tracking, fraud, regulatory compliance, delivery speed, and settlements.

A smart contract can be used to automate business rules related to transaction processing in the supply chain. A Smart contract can encode any set of rules represented in its programming language for instance, a contract can execute transfers when certain events happen (e.g. payment of security deposits in an escrow system). Accordingly, smart contracts can implement a wide range of applications, including financial instruments (e.g., sub-currencies, financial derivatives, savings wallets, wills) and self-enforcing or autonomous governance applications (e.g., outsourced computation [XVII]).

A smart contract is identified by an address and its code resides on the blockchain. Users invoke a smart contract in present cryptocurrencies by sending transactions to the contract address. Specifically, if a new transaction is accepted by the blockchain and has a contract address as the recipient, then all participants on the mining network execute the contract code with the current state of the blockchain and the transaction payloads as inputs [XVIII].

The network then agrees on the output and the next state of the contract by participating in a consensus protocol. Ethereum is a popular blockchain with a built-in full-fledged Turing-complete programming language that can be used to create "contracts" that can be used to encode arbitrary state transition functions, allowing users to create any of the systems described above, as well as many others that we have not yet imagined, simply by writing up the logic in a few lines of code. Though blockchain is considered a promising breakthrough technology, research in this field is still evolving. Empirical evidence demonstrating a comparison between blockchain-based and traditional approaches is also nascent. Thus, significant research opportunities arise to contribute to this emerging paradigm, considering the technology and its potential to impact supply chain processes. Blockchain can certainly address supply chain challenges through its features as shown in Figure 4.



Figure 4: Blockchain features for Supply Chain

- **Auditability:** Auditability feature of blockchain can provide a full audit trail of data throughout the supply chain that allows event monitoring to ensure traceability in the supply chain.
- **Immutability:** Immutability feature of blockchain can provide Single timestamped tamper-proof source of data that helps in preserving evidence of Regulatory Conditions compliance to ensure Compliance in a supply chain.
- **Smart Contract:** Smart contract feature of blockchain provide Real-time rule-based verification of multiparty confirmations that facilitates Cost effective adaptation to business environment changes to ensure flexibility in the supply chain.
- **Distributed:** the Distributed feature of blockchain allow Direct Interaction with a Trusted digital signature based peer to peer interactions that ensure Supply chain communication risk reduction and trust building in the supply chain ensuring stakeholder management.

As Blockchain adoption in the supply chain is on the rise, but it can't be ignored that industry adoption of blockchain is still young. Benefit realization needs to be

evaluated to conclude a positive correlation between blockchain adoption and company performance. Following are potential barriers discussed by industry professionals.

- **Standardization of Blockchain Networks:** The rapid pace of blockchain network development by firms in many industries is creating challenges for standardization of blockchain. There is a potential for multiple blockchain networks to be created for a single application within an industry. Blockchain use cases are also evolving at a rapid pace which will delay the standardization process. This will limit the expected benefit realization from blockchain implementation [XI].
- **Latency:** Blockchain networks have been known to be fast –there is a need to evaluate the performance over entire transaction lifecycle on blockchain network. If transaction cycle times are reasonably good, this will lead to strong business case development[XI].
- **Collaboration Challenges:** Firms may not be accustomed to sharing data across their supply chain with their partners.
- **Data Interoperability:** Companies will have agreed upon the structure, format, and meaning of the data each company shares. In addition, companies will have to determine what data they are willing to share with others in the network and what data remain private[XXIII].

VI. Design Process for Blockchain Systems

Blockchain-based systems are developed in a step by step process and Figure 5 represents a systematic design process [XXX] for blockchain application. The process starts with the decision to decentralize trust (authority) – or not.

A blockchain is used in scenarios where no single trusted authority is required and the trusted authority can be decentralized or partially decentralized. Given the limitations of blockchains, the next major decision is splitting computation and data storage between on-chain and off-chain components. After that, a collection of design decisions around blockchain configuration need to be made, like the type of blockchain, consensus protocol, block size and frequency. The arrows only illustrate one of the possible sequences to make design decisions. Some decisions mainly affect scalability (like block size and frequency), security, cost efficiency and performance [XXX].

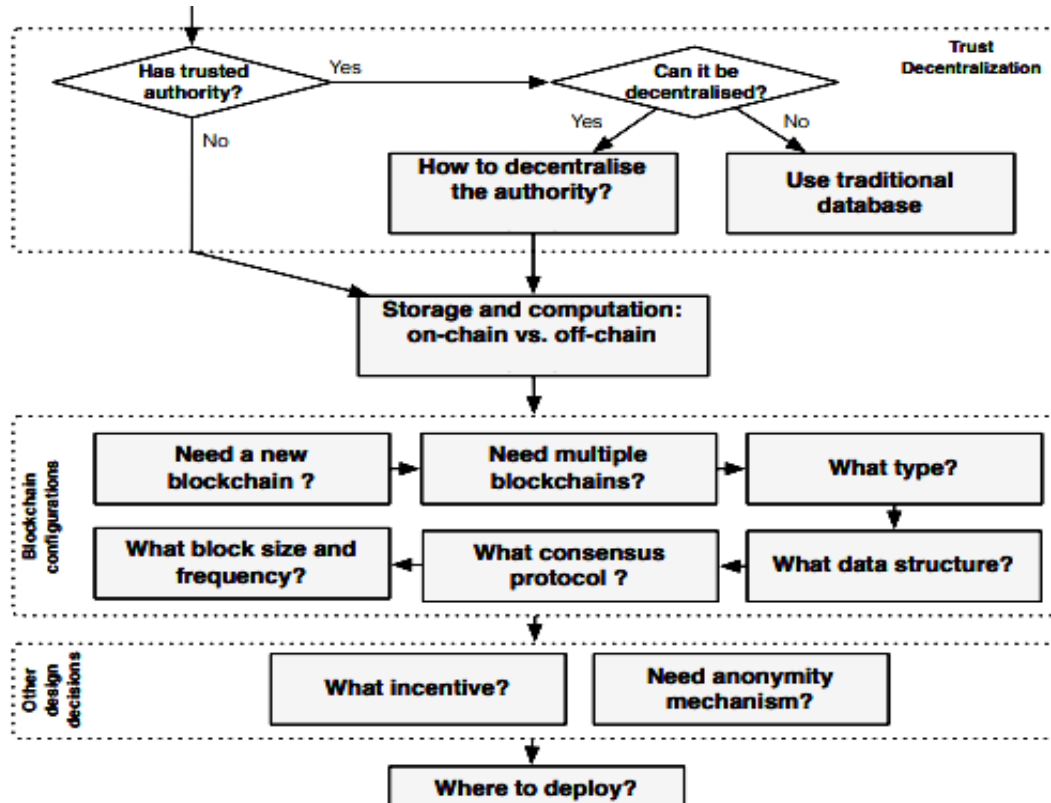


Figure 5: Blockchain design process

VII. Conclusion

To summarize, our review of the literature related to blockchain's consideration in supply-chain reflects positive signs that blockchain can surely address issues and challenges of the supply chain. We further feel that blockchain can be an appropriate alternative to address supply chain issues like traceability, compliance, flexibility, and stakeholder management across multiple industries. This paper discusses the blockchain implementation process. Challenges with existing blockchain practices in the supply chain have also been discussed. Several of these issues require further attention and research with the implementation of smart contracts and appropriate consensus algorithm over permissioned blockchain.

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