Industrial Engineering and Management
Prof Dr Omid Fatahi Valilai

Bachelor Thesis

Blockchain Application in Supply Chain

Data Tracking and Tracing in Last Mile Delivery

Supervisor: Prof Dr Omid Fatahi Valilai

Handed in by:

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Syed Muhammad Hussain Haider Tirmazi (Hussain Tirmazi)
College Ring 7
28759 Bremen
30002505

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1 Introduction

Logistics is very important for companies because it is concentrated in several service support. The aim of logistic is serving the production area and the customer's demands. Logistics services must be performed in the right time, from the right place, right products, in the right condition, to the right user and with reasonable costs. Business organizations around the world have found it of ever-increasing importance that they employ an effective Supply Chain (SC) conductive to putting themselves on the map of the global market. Rapidly changing customer as well as technological requirements have compelled companies to employ a competitive SC that can adapt to, and process the change in a swift approach i.e an agile approach. A well-managed SC is what scales up a company's profits and scales down its cost, vis-à-vis customer satisfaction and a lower cost of doing business/operation costs[1]. An example of how costs are mitigated with changes in SC strategy is how in 2010, Walmart decided to lay-off intermediaries for sourcing, as it came to realize that intermediary sourcing providers came with increasing costs. Walmart then managed sourcing itself, and in doing so, it got to have direct contact with the suppliers and ensured that it got the right quality[2]. Such a big move is indeed profitable to Walmart, but the question that needs to be asked is: How well can they manage the SC on such a large scale after such a revolutionary change vis-à-vis data and information management.

Information is an important constituent of SC. It provides the bedrock of decision making in SC Management. Information technology can provide means to garner information, process it and act upon it, improving the SC performance as a result. Information is a foremost attribute to SC performance because it is an attribute that integrates other attributes, resulting in coordination. SC managers are unable to do their job without obtaining information on customer demand, inventory level, and production planning. In a nutshell: Information is key to SC visibility and transparency[3].

[1] János Juhász and Tamás Bányai, "Last Mile Logistics: An Integrated View," 2018.
[2] "Walmart to Centralize Global Sourcing, Reduce Use of Middlemen," accessed June 25, 2022, https://www.scdigest.com/assets/On_Target/10-01-06-1.php.
[3] Suni Chopra and Peter Meindl, *Supply Chain Management: Strategy, Planning, and Operation*, 2000.

From the afore mentioned information, it can be concluded that the integration of data systems for parties that share a SC is imperative for better performance corporately. Looking back at history, SC information sharing has developed significantly since the 1990s, when companies such as Walmart and Proctor and Gamble decided the use of Enterprise Resource Planning (ERP) system[4]

The unique solution to information, data tracking and traceability in the SC touched on in this thesis is Blockchain Technology (BCT). The technology has been revolutionary in the world of finance and trading, and it now goes beyond those fields. It has become a comprehensive technology that is reliable and can create an integrated technological system. This technology was first widely introduced in 2009 when Satoshi Nakamoto published his white paper[5] on the digital currency Bitcoin. It is based on a peer-to-peer system of transactions which means there is no intermediary involved. As it is a cryptographic technology, it can be deduced that this technology enables an anonymous way of data sharing. Since the technology is open source, it was allowed for the technology to be copied and implemented in other systems/fields[6]. Studying Blockchain can be categorized into three: Digital Currency, Application of Blockchain in other fields that are not digital currencies and studying the underlying/existent BCT[7]. SC is the field of interest for this thesis, and Blockchain is a promising technology to be adapted and embedded in SC to prepare for SC Management 2.0 (SCM 2.0)[8] in parallel with Industry 4.0. SC Management is becoming more complex by the day[9] with ever-increasing world population and resource scarcity[10]. The implementation of BCT as a medium for data sharing indicates to be secure and efficient .

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[4] Vishal Gaur and Abhinav Gaiha, "Building a Transparent Supply Chain," *Harvard Business Review*, May 1, 2020, https://hbr.org/2020/05/building-a-transparent-supply-chain.

[5] Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008, 9.

[6] Andrew M. Hanna, "THE IMPLEMENTATION AND EXPANSION OF BLOCKCHAIN TECHNOLOGY IN THE CONSTRUCTION INDUSTRY," May 6, 2021, https://www.frantzward.com/news-blog/june-2021/the-implementation-and-expansion-of-blockchain-tec.

[7] Du Mingxiao et al., "A Review on Consensus Algorithm of Blockchain," in *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 2017, 2567–72, https://doi.org/10.1109/SMC.2017.8123011.

[8] "We Need A New Supply Chain Management Definition," accessed June 25, 2022, https://thegemba.com/article/supply-chain-management-definition.

[9] "Why Supply Chains Are Getting More Complex – And Why This Is Not Necessarily a Problem - Inventory & Supply Chain Blog," February 9, 2015, https://www.allthingssupplychain.com/supply-chains-getting-complex-not-necessarily-problem/.

[10] "As Earth's Population Increases, Resources Turn Scarce," accessed June 25, 2022, https://www.delmarvanow.com/story/opinion/2016/10/16/overpopulation-resources/92072626/.

1.1 Thesis Research Question

As this thesis aims to tackle inefficiency in data sharing and traceability, the following research questions are to be asked:

- How necessary is it to use Blockchain for data tracing in LMD (Last Mile Delivery)?

  This question signifies how important or beneficial Blockchain could be as a SC embedment. As long as it can provide considerable and revolutionary changes to SC Management, it is something of inevitable consideration.

- Who are the stakeholders, how exactly are they defined vis a vis how BCT would affect them financially or convenience-wise?

  This thesis, of course, has to be read by people (stakeholders) concerned with SC Management, who are looking for innovation and solutions. BCT must provide appeal to them with regards to their financial benefits thus the question addressed is an important one to answer.

- What is the main component of Blockchain medium that would influence the SC?

  In essence the component of BCT that must be of consideration is what affects tracking and traceability. So, that is talked about through the research journey.

- In what way can a smart contract be embedded in Blockchain with its defined components.

  Smart contracts are contracts that are sub products of BCT, and this thesis will touch on what they are in detail, what component of them is of SC Management's concern and how they can be made use of, to deliver SC Management efficiency.

All these questions are detrimental to ensure the success of the BCT to be further studied and considered. Time should be carefully utilized to obtain the correct information which in turn determines the current implementation.

1.2 Problem Description and Analysis

SC transparency basically means a firm's ability to keep track of its SC at every stage and is able to communicate information within the firm as well as to other partners that are concerned[11]. It is a common case in the more mainstream SCs that there is a considerate amount of inefficiency related to data transparency between stakeholders in a SC. The mainstream SC consists of independent and centralized data systems for each stakeholder. This set up of data systems is an obstacle to data transparency and trust between the concerned parties. The stakeholders involved would want to enquire the attributes/description of each product at any time. One of the conventional ways to tackle this problem is the Internet of Things (IoT) technology connected to a cloud where various devices are inter-connected and share data over a communication network. But one needs to consider that each partner's independent data system becomes limited with incremental data coming in. The following are issues are obstacles to tracking and traceability[12]:

- Centralized Data/Independent Databases: The conventional SC has multiple parties involved with their own centralized databases. Data sharing between stake holders via several data bases is complicated as the different data bases cannot always be integrated with each other's functions.
- Lack of cooperation between stakeholders: Collaboration between several businesses/firms and customers involved in a business process is key for the successful and smooth passage of the business process. In the conventional way of data sharing in SC there is little collaboration between companies.
- Data loss: The different centralized systems involved in conventional SC cannot always manage to retain the incoming and outgoing information. The consequence is frequent cases of data loss where stakeholders lack the shareable data demanded by other concerned parties. Furthermore, that data is imperative for the stakeholder itself for the sake of keeping track of accounts and figures.

[11] QIMAone, "Qimaone.4-Important-Benefits.Open-Graph.Title," accessed June 28, 2022, https://www.qimaone.com/resource-hub/benefits-of-supply-chain-transparency.
[12] Houssein Hellani et al., "On Blockchain Integration with Supply Chain: Overview on Data Transparency," July 2, 2021.

- Data security: Security and confidentiality is key for a company to maintain its position in the market and strive for comparative advantage. Conventional internalized data systems are susceptible to breaches such as cyber-attacks and eavesdropping.

Companies spend fortunes hiring security professionals to maintain security and confidentiality of their data. Consequently, companies must bear the associated costs.

Another problem is how small businesses suffer due to the lack of trust in the conventional SC. For small businesses with hardly any reputation, there is going to be significantly less cliental compared to big companies. Completely because of trust issues, the manufacturer will tend to go for large companies with a history of customers and a good precedent rather than small new businesses that have limited record or reputation[13].

Because of the afore mentioned points, bottlenecks are brought about in the SC and the firms that can convincingly implement BCT, inclusive of all other stakeholders it deals with, can bear the fruit of competitive advantage i.e. customer satisfaction and decreased costs.

1.3 Research Aim and Methodology

The general aim of this thesis is to give a well-structured and in-depth description of how BCT could be embedded into SC Management, particularly LMD. The thesis takes into account comprehensive ideas from published material. Finally, an understanding of the technology and its integrability is derived and an in-depth description of the technology's integration to SC Management is provided to the reader. The goal is to persuade users of all fields in a universally comprehendible way.

1.4 Research Gaps

There are some considerable challenges to good illustrations for this Thesis. BCT is mostly used by big companies. About 85 of the top 100 companies have adapted BCT as of September 2021[14]. While it is true that they have quite a lot of resources available on their internet platforms

[13] Siraj Raval, "Blockchain for Supply Chain Management," https://www.youtube.com/watch?v=Z6HS1bSZzHk&ab_channel=SirajRaval.
[14] Michelle Lim, "81 of Top 100 Companies Use Blockchain Technology, Blockdata Research Shows," September 24, 2021, https://forkast.news/81-of-top-100-companies-use-blockchain-technology-blockdata/.

on how they use the technology, one cannot go further into questioning about their implementation other than what they have published, unless he/she gets to have access to internal company operations. But the general idea of implementation of BCT is still available for access and that is a limited amount of information that will be grasped and explained as much as it can be for the reader of this thesis to understand and consider. What this thesis focuses on is specifically the integration of an appropriate version of BCT in LMD for shipment tracking and tracing, and hence deliver customer satisfaction on shipment information. Not a lot of in-depth research has been provided for this case on the publications available online.

1.5 Theoretical and Practical Relevance

The globe is developing rapidly in all fields associated with business and trade. There is never a lack of problems associated with each stage of development and advancement. SC Management was worth USD 10.1 Billion in 2020, and is expected to increase to USD 19.3 Billion by 2028, with its growth at CAGR 9.02% between 2021 and 2028[15]. These figures are due to tech advancements, adaptation of cloud-based SC management and increasing demand for better visibility in SC. SC Management is a dynamic field, and it gets more complex by the day with ever-increasing consumerism, e-commerce, and global connectivity. There is always room for change and development to smoothen this significant part of industry. As the world steadily transitions towards Industry 4.0 businesses need to make sure they catch up with the new problems and have novelty in their approach to solve these problems.

BCT is a game changer with the accurate way to applying it in the SC. The technology cannot work unless it is unanimously applied by all stakeholders. So, the more papers there are to persuade the business population, the more writers can help in advancing this technology to Industry 4.0.

[15] Verified Market Research, "Supply Chain Management (SCM) Market Size Worth $ 19.3 Billion, Globally, by 2028 at 9.02 % CAGR: Verified Market Research®," accessed July 9, 2022, https://www.prnewswire.com/news-releases/supply-chain-management-scm-market-size-worth--19-3-billion-globally-by-2028-at-9-02--cagr-verified-market-research-301540702.html.

2 Literature Review

2.1 Last Mile Logistics

The "Last Mile" is described as the last geographical distance that needs to be covered to deliver products to customers. The route is from the order penetration point to the customer/consignee's provided destination of delivery. This route is often seen as the costliest stage (up to half of the total logistics operations costs[16]) with organizational difficulties and substantial operations costs. The stakeholders in Last Mile Logistics include private enterprises, public administrations, and the general public[17]. There are several issues that need to be considered:

1. Delivery to homes, retailers and offices comes with incremental costs, carbon footprint and additional transportation
2. Door to Door delivery comes with finding empty routes

There is also the security aspect to deliveries wherein signatures are required for the reception of packages.

In the conventional SC, the LMD process consists of products, that are shipped to distribution centers, and are then destined for either direct delivery to customers or to company retail stores. There are 4 types of SCs that in turn bring about the 4 types of LMDs:

- **Semi-extended SCs**: Where an ordered product is redeemed at a retail store by customer and the store is taken to be the warehouse/distribution center (i.e indirect reception)
- **Decoupled SCs**: Where distribution centers are used but home direct deliveries do not occur i.e indirect delivery from distribution centers.
- **Fully extended SCs**: Where the retail store is taken to be the distribution center and from there, the product is delivered directly to homes.
- **Centralized Extended SCs**: Where distribution centers are used, and they deliver directly to homes

[16] T. Vanelstander, L. Deketele, and D. Van Hove, "Commonly Used E-Commerce Supply Chains for Fast Moving Consumer Goods: Comparison and Suggestions for Improvement," 2013.
[17] Marta Viu-Roig and Eduard J. Alvarez-Palau, "The Impact of E-Commerce-Related Last-Mile Logistics on Cities: A Systematic Literature Review," 2020.

There are several benefits associated with exploring and studying Last Mile Logistics for solutions. SC managers have a higher degree of ability to make the process of LMD efficient with regards to saving time, data control, security, reducing baneful effects to the environment, increasing service level, increasing mobility, customer satisfaction by measuring it in LMD, and manufacturing[18]

It is agreed by numerous scholars that the LMD component of a SC is the most critical activity from all. Customers are highly demanding of a haste, punctual and flexible delivery. At the same time, they are unwilling to pay a high amount for the service[19]. In the race to tackle the LMD problem, innovative solutions come in three classifications: organizational, technology-enabled and data-technique enabled[20]. An example of the organizational solution would be crowdsourcing[21]. For data-technique enabled solutions there is the approach of mapping customer behaviour[22]. The content of this thesis focuses on the technology-enabled solutions, BCT to be precise. Other technological innovations include innovative vehicles that help save time and mitigate transportation costs[23].

2.2 Distributed Ledger and BCT

A Distributed Ledger Technology is generally described as a log of cryptographically stored asset/transactions that is distributed to multiple parties that have collective access to a database, with a copy of data obtained by each party. All changes/additions to the data are noted and discerned by all parties[24].

BCT is a version of Distributed Ledger Technology with additional features that consists of a decentralized database shared between several parties. A Blockchain can be visualized as

[18] János Juhász and Tamás Bányai, "Last Mile Logistics: An Integrated View," 2018.
[19] Riccardo Mangiaracina et al., "Innovative Solutions to Increase Last-Mile Delivery Efficiency in B2C e-Commerce: A Literature Review," *International Journal of Physical Distribution & Logistics Management* 49, no. 9 (January 1, 2019): 901–20, https://doi.org/10.1108/IJPDLM-02-2019-0048.
[20] Vincent E. Castillo et al., "Crowdsourcing Last Mile Delivery: Strategic Implications and Future Research Directions," *Journal of Business Logistics* 39, no. 1 (2018): 7–25, https://doi.org/10.1111/jbl.12173.
[21] Castillo et al.
[22] Shenle Pan et al., "Using Customer-Related Data to Enhance e-Grocery Home Delivery," *Industrial Management & Data Systems* 117, no. 9 (January 1, 2017): 1917–33, https://doi.org/10.1108/IMDS-10-2016-0432.
[23] Masa Slabinac, "Innovative Solutions for a 'Last-Mile' Delivery - A European Experience," 2015.
[24] UK Government Chief Scientific Adviser, "Distributed Ledger Technology: Beyond Block Chain," 2016, 88.

consisting of a chain of blocks which can be characterized as data bundles. All new data is added in the form of a block to the Blockchain. The chained blocks hence contain all the past data bundles with all transaction history. Each block in a Blockchain has 5 attributes: **Hash value of the previous block, List of transactions, Time Stamp, Nonce (Number Only Used Once), and the Unique Hash Value of the block itself**. Thus, a Blockchain is a securely distributed database that is made up of a network of computing devices storing "blocks" (i.e data bundles) in a way that is secure and fool-proof. Changing any block in the chain would in-effect change the hash value (fingerprint of a digital data) of the block, and this process prevents any irregularities. It is also imperative to verify legitimate transactions in a reliable, robust, and secure manner[25]. For this, there exists the **consensus mechanism** which is a way to achieve consistent agreement on a single piece of data on a shared database between different parties. Conventionally, intermediaries are an important aspect for a transaction to take place as they are a trusted party that verify legitimacy and ensure compliance. The aspect that creates more efficiency as well as data security in a Blockchain is disintermediation i.e circumvention of intermediaries required to validate transactions. In business terms, this allows a direct relationship between a customer/client and the supplier[26]. The use of BCT confirms to a one-time transfer of a valued unit through miners, eliminating the double spending problem via preventing reproduction of a digital asset[27].

To sum it up, the iterative process is: A transaction is requested, it is then broadcasted on a peer-to-peer network of Blockchain, it is stored in the Blockchain for an amount of time, it is then validated by a network of nodes based on the consensus mechanism, the transaction then becomes part of the ledger, visualized as a block added to the Blockchain, and subsequently the transaction is complete and immutable[28].

The vital components that make the Blockchain mechanism possible are Nodes, Timestamp server, Cryptography, Consensus Mechanism.

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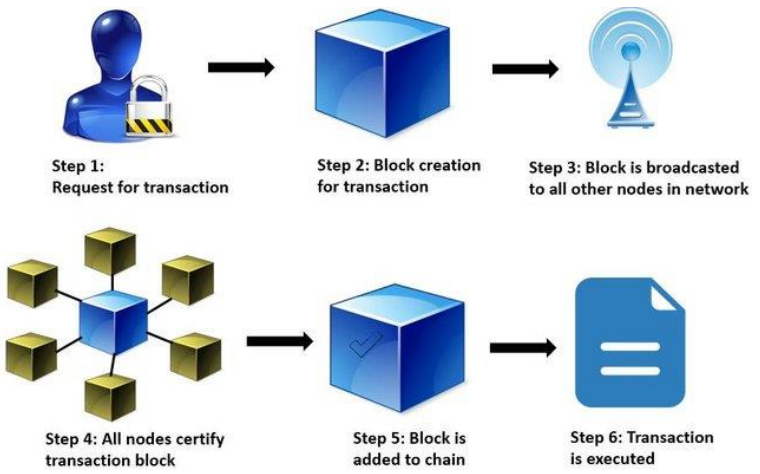
[25] Michael Nofer et al., "Blockchain," *Business & Information Systems Engineering* 59, no. 3 (June 2017): 183–87, https://doi.org/10.1007/s12599-017-0467-3.
[26] Stefan Tönnissen and Frank Teuteberg, "Analysing the Impact of Blockchain-Technology for Operations and Supply Chain Management: An Explanatory Model Drawn from Multiple Case Studies," *International Journal of Information Management* 52 (June 2020): 101953, https://doi.org/10.1016/j.ijinfomgt.2019.05.009.
[27] Dmirty Efanov and Pavel Roschin, "The All-Pervasiveness of the Blockchain Technology," 2018.
[28] Nofer et al., "Blockchain."

Figure 1: A comprehensive visualization of the basic BCT process



Source:(Sara Nadeem)[29]

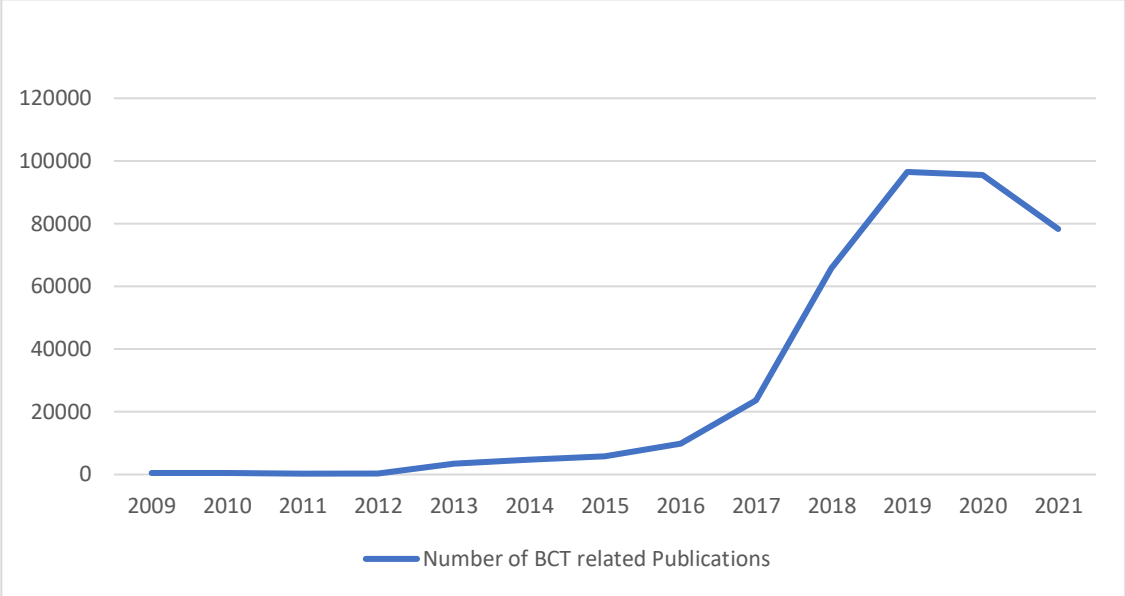
The very concept of securing data and making it immutable in a distributed database goes back to 1991 when cryptographer Stuart Haber and physicist W. Scott Stornetta introduced the idea of time-stamping digital documents[30]. Advancing towards the technology, in 2002 David Mazieres and Dennis Shasha conceptualized storing data in the form of blocks[31]. The closest idea and the first attempt at developing a currency aligned with a decentralized ledger was put forth by Nick Szabo in 2005 dubbed as "Bit Gold"[32]. The focal point in BC's history lied on Bitcoin's popularity which was described by Reuben Grinberg in 2011 as the "flourishing" bitcoin economy. He also talked about its legal status as it was a relatively new digital currency[33] (just two years at that time from when Satoshi Nakamoto published his white paper[34])

The amount of research and interest in BCT has grown almost exponentially over the years since its introduction. Numerous industries have sought its deployment in their business processes under the umbrella of security, privacy, and trust. Industries including Financial

[29] Sara Nadeem et al., "Securing Cognitive Radio Vehicular Ad Hoc Networkwith Fog Node Based Distributed Blockchain CloudArchitecture," 2019.
[30] Haber Stuart and Stornetta W. Scott, "How to Time-Stamp a Digital Document," 1991.
[31] Mazieres David and Shasha Dennis, "Building Secure File Systems out of Byzantine Storage," June 2002.
[32] Szabo Nick, "Bit Gold," 1998.
[33] Grinberg Reuben, "Bitcoin: An Innovative Alternative Digital Currency," 2011.
[34] Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System."

Institutions, Logistics, Energy, Education, Healthcare, and even governments are set to reap the benefits of this innovative technology[35].

Figure 2: Number of BCT Publications by year



Source: (Google Scholar)

2.2.1 Blockchain Network: Nodes

A peer-to-peer network is a distributed network architecture where the participants share their hardware resources with each other. Unanimous sharing is essential to keep the content/service provided by the network running. They are available for every participant on the network bypassing intermediaries. It is also a hard and fast definition that a pure peer-to-peer network would not suffer from any deprivation if a randomly selected participant were removed from the network[36].

A BC is also a distributed database and peers contributing to this database can be referred to as "nodes" where each node is involved in the verification process for security and integrity of

[35] Ahmed G.Gad et al., "Emerging Trends in Blockchain Technology and Applications: A Review and Outlook," 2022.

[36] R. Schollmeier, "A Definition of Peer-to-Peer Networking for the Classification of Peer-to-Peer Architectures and Applications," in *Proceedings First International Conference on Peer-to-Peer Computing*, 2001, 101–2, https://doi.org/10.1109/P2P.2001.990434.

incremental blocks of data into the peer-to-peer network. With a lack of a third-party verification authority, the verification process exists via distributed trust between the nodes[37].

2.2.2 Blockchain Cryptography

Cryptography is an imperative property to verify the BC network. The unique terminology for cryptography in BC is "Hashing". The Hash function is a mathematical conversion to encrypt information which then provides a digital fingerprint. It maps data of an arbitrary size to a fixed-size data[38].

Each block in a BC has the attribute of having its own hash value and the hash of the previous block. Consequently, a chain of blocks is produced with the hash linkage visualized. The result is a substantially secure network i.e Blockchain. As the hash value is the mathematical conversion of the existing data, any tampering with the data will automatically change the hash value and cause the tampered block of data to be labelled as illegitimate and hence ruled out[39]. The Nonce is a randomly assigned number that exists to authenticate and confirm that old digital data is not repeated[40]. The time-stamp protocol for each hash exists to prove merely that the piece of digital information existed at the time. Every timestamp includes the prior timestamp and its hash and thus forms a chain in which each incremental timestamp is strengthening the former[41]. This mechanism confirms the security and immutability of a BC.

The Public Key Infrastructure is the important element in BCT that ensures encryption and authentication. It is consisted in the form of two pair of keys provided to an individual: Public and Private. The pair of keys have a complex mathematical relationship. The Encryption mechanism is theorized as having a ciphertext that is created via another unit's public key which can then only be decrypted by the paired private key. Consequently, this allows multiple units to share encrypted information/text. The Authentication mechanism is recognized as the "Digital Signature" which is created via encrypting a clear text by using an entity's own private

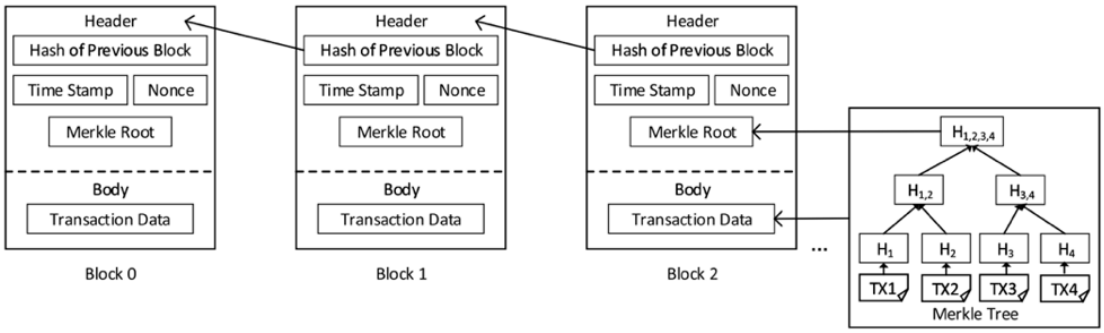
[37] Atin Angrish et al., "A Case Study for Blockchain in Manufacturing: 'FabRec': A Prototype for Peer-to-Peer Network of Manufacturing Nodes," 2018.
[38] Swathi Edem, G. Vivek, and G. Rani, *Role of Hash Function in Cryptography*, 2016, https://doi.org/10.22161/ijaers/si.3.
[39] Nofer et al., "Blockchain"; Edem, Vivek, and Rani, *Role of Hash Function in Cryptography*.
[40] Phillip Rogaway, "Nonce-Based Symmetric Encryption," n.d., accessed August 5, 2022.
[41] Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System."

key. The encrypted message is then sent to other intended units and the receiver units can simply decrypt the message through the sender's public key and in turn authorize it[42].

2.2.3 Blockchain Structure and Transactions

The Blockchain structure consists of blocks that are chronologically ordered by the hash-linkage beginning from the very first block i.e "genesis block" that was ever mined. The chain is incremented with blocks at consecutive time periods via the validation mechanism[43]. Each block is structured as containing a "header' and "body". The header is comprised of the hash of the previous block and the body is comprised of all the transaction data denoted by the block. The Merkle Root can be described as the hash for the collective hashes of data that exist in a block, which form the Merkle Tree[44].

Figure 3: Visualization of a Blockchain



Source: (Ying-Chang)

2.2.4 Consensus Mechanism

The consensus mechanism in conventional BCT involves the "majority dominance" principle for nodes, where the nodes also adhere to set rules. There are two problems that must be solved for one BCT to be applicable: the Double-Spending Problem and the Byzantine Generals Problem. Briefly, double spending is a re-usage of the digital currency for two separate transactions and BCT prevents that by verification via several distributed nodes. The Byzantine

[42] Joel Weise, "Public Key Infrastructure Overview," n.d., accessed August 5, 2022.
[43] Nofer et al., "Blockchain."
[44] Liang Ying-Chang, *Dynamic Spectrum Management: From Cognitive Radio to Blockchain and Artificla Intelligence* (Springer Open, 2019).

Generals Problem is when a decentralized database faces hindrance on reaching a unanimous agreement on a single truth, and this is prevented through the nodes' collective ability to tell apart tampered and non-tampered data, hence delivering consistency. And all this stems from a robust consensus mechanism[45].

2.2.4.1 PoW (Proof of Work)

This is the classic and mainstream consensus mechanism presented by Nakamoto. The concept originally introduced in 1993 by Cynthia Dwork and Moni Naor in their paper[46] is of a consensus mechanism that requires peers on a network to work on solving random complex mathematical problems. They then broadcast this effort to the other participants who verify the effort with the systematic ease of verification. Satoshi Nakamoto described PoW in BC as the act of looking for a value which gives a starting number of zero-bits when hashed. The nonce in the block of a BC is added until the specific value, that delivers the zero-bit hash, is found. For someone to tamper with an existent block, the person would need to redo the complex PoW for it along with all the next blocks. The process of adding a block via solving complex mathematical problems is called Mining. The mining node that manages to add the new block is rewarded with a digital asset (a bitcoin for example). Hence this incentive policy keeps the network running. The proof of work mechanism is understood to be a costly mechanism due to the enormous amount of computing power and capability required by miners.[47].

2.2.4.2 PoS (Proof of Stake)

This is an example of novelty in the consensus protocol after the introduction of BCT. PoS is a modified consensus mechanism that was introduced a few years later after the introduction of Bitcoin in the form of "Peercoin". The mechanism was discussed in-depth by Sunny King and Scott Nadal in their paper where they provided it as a way to diminish the high energy consumption vis-à-vis the PoW mechanism. Briefly, it is a non-competition-based mechanism where a limited number of peers are selected based on the "stake" they hold with regards to a digital asset. They are then designated as validators who then mine/validate a block[48].

[45] Mingxiao et al., "A Review on Consensus Algorithm of Blockchain."
[46] Cynthia Dwork and Moni Naor, "Pricing via Processing or Combatting Junk Mail," 1992.
[47] Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System."
[48] Sunny King and Scott Nadal, "PPCoin: Peer-to-Peer Crypto-Currency with Proof-of-Stake," 2012, 6.

2.2.4.3 Other

There have been other consensus mechanisms as well, most of which are named as "Proof of" something[49].

2.2.5 Smart Contracts

Nick Szabo in his paper proposed the idea of smart contracts as a computerized transaction mechanism that helps adhere to and bring about the terms of the contract[50]. Vitalik Buterin then went on to found Ethereum which is an open-source BC that provides the function of a smart contract. Vitalik provided an in-depth mechanism of the smart contract vis-à-vis BCT[51]. In essence, a smart contract uses the feature of BCT to remove the need for a trusted third-party associate, mitigating costs and time associated with it. The contract has digitally written clauses that are executed the moment the defined conditions of the clauses are adhered to. Usage of a smart contract is illustrated in relation to SC in the paper. It involves a rapid execution mechanism for services solely based on peer-to-peer confirmation and payment through crypto-currency. Risks are mitigated through the immutability of the contract via BCT. Administration and service costs are mitigated via bypassing third-party mediators. Process efficiency is scaled up due to solely peer-to-peer dealing. A smart contract is also a source to digitize real world information into a BC[52].

At the same time there are some drawbacks related to privacy and technological vulnerabilities related to smart contracts[53].

2.2.6 Consortium BCT (Hyperledger Fabric)

For the case of industry where there is no full trust between participants and a few number of nodes and regulations deviating from Cryptocurrency, BCT needs to be permissioned and for that case, the consortium BCT is put to work. The single most utilized version of this technology

[49] Andrey Averin and Petr Cheskidov, "Review of Existing Consensus Algorithms Blockchain," 2019 International Conference "Quality Management, Transport and Information Security, Information Technologies," 2019.
[50] Nick Szabo, "Smart Contracts: Building Blocks for Digital Markets," 1996.
[51] Vitalik Buterin, "A NEXT GENERATION SMART CONTRACT & DECENTRALIZED APPLICATION PLATFORM," 2014, 36.
[52] Abdeljalil Beniiche, "A Study of Blockchain Oracles" (arXiv, 2020), http://arxiv.org/abs/2004.07140.
[53] Zibin Zheng et al., *Future Generation Computer Systems: An Overview on Smart Contracts: Challenges, Advances and Platforms*, 2020.

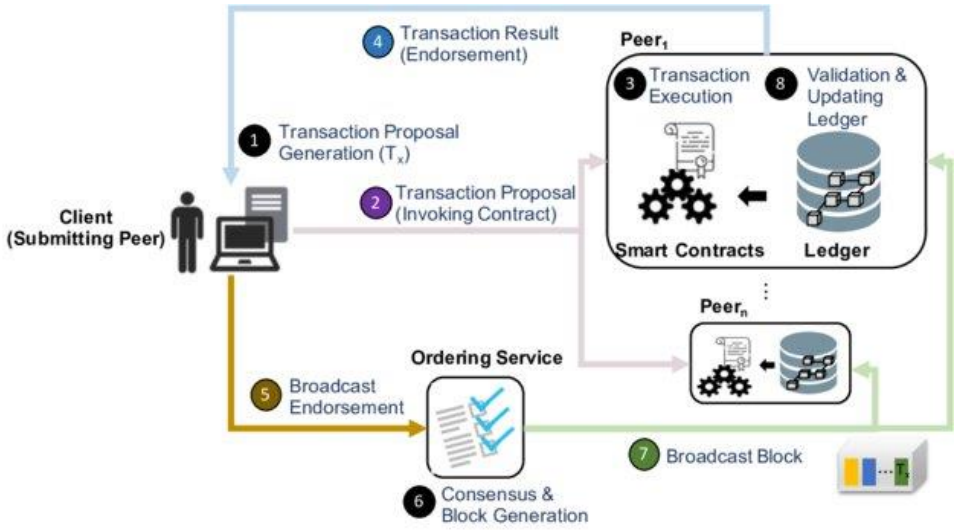
is the Hyperledger Fabric, due it being open source, a permissioned BC, having access control and high-level performance. This BCT also bypasses the need for high energy-consuming consensus mechanisms in public Blockchains such as Proof of Work. A Hyperledger is shared only among specific organizations which possess a Fabric Certificate authority, and the organization is allowed to have several individual peers (nodes) under its name. All nodes in a network have an ID provided by the Membership Service Provider (MSP). The individual peers are designated to operate on behalf of the organization, such as endorsing proposed transactions, execute smart contracts (chain code). There are three nodes at work in the Hyperledger Fabric Consensus mechanism: the client node, Peer/Endorser node, and the Order-Service node.

To communicate with the permissioned BC, an external entity interacts with the client node and relays information in the form of a chaincodes (a version of smart contracts used in Hyperledger Fabric). The client node then sends the chaincode to the endorsing nodes. The endorsing nodes verify if the client node is allowed to perform the transaction, sign the transaction, and send it back to the client node. The endorsing nodes' signatures are then verified by the client node, and it broadcasts the transaction with peers' channel ID to the ordering node in the form of a signed "envelope". A channel is the private BC on the Hyperledger. The subsequent process is the ordering protocol where the orderer node then collects all the envelopes, orders them via Total Order Broadcast[54], then creates a signed chain of blocks for the envelopes, then the blocks of envelopes are delivered to the committing peers that are existent on the channel, which validate the blocks and add the new block to channel of BC. The validation of the transactions is done via a customized consensus mechanism agreed upon by the channel parties.Both invalid and valid transactions are added to the BC, and the client is informed of the appendment. This ensures that validity of transactions and clients is identified[55].

[54] Xavier Defago, Andre Schiper, and Peter Urban, "Total Order Broadcast and Multicast Algortihms:*Taxonomy and Survey," 2004.

[55] Elli Androulaki et al., "Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains," in *Proceedings of the Thirteenth EuroSys Conference* (EuroSys '18: Thirteenth EuroSys Conference 2018, Porto Portugal: ACM, 2018), 1–15, https://doi.org/10.1145/3190508.3190538; João Sousa, Alysson Bessani, and Marko Vukolic, "A Byzantine Fault-Tolerant Ordering Service for the Hyperledger Fabric Blockchain Platform," in *2018 48th Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN)*, 2018, 51–58, https://doi.org/10.1109/DSN.2018.00018.

Figure 4: Hyperledger Fabric Mechanism



Source: (Akos Hajdu)[56]

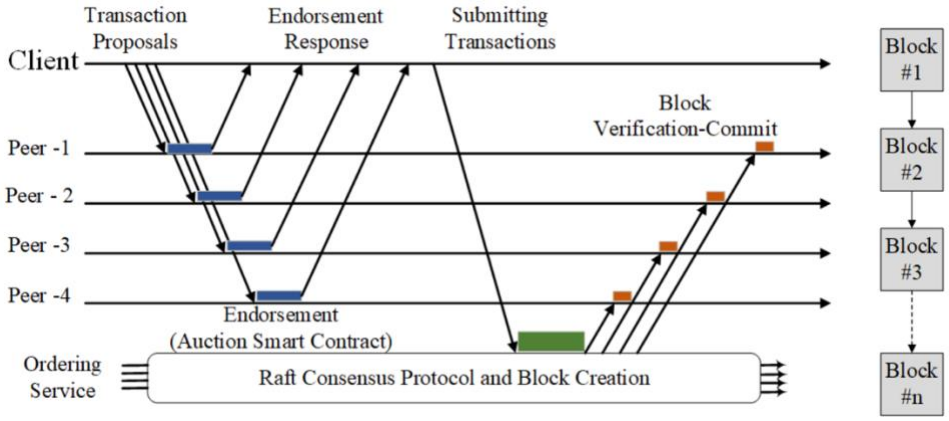
2.2.6.1 RAFT Consensus Mechanism and Ordering protocol

Hyperledger allows its participants to choose the consensus mechanism they want to be implemented in the ordering service. One of the applicable consensus algorithms is the RAFT ordering protocol. It has the attribute of Crash Fault Tolerance i.e tolerating certain fractions of system failures, such as the loss of a few ordering nodes. This ordering protocol uses an election-based approach where the ordering nodes (consenter set of nodes) elect a leading node. The leading node is relayed to with data updates for the ledger, which it then relays to all the other nodes. The other nodes copy the message and reply to the leading node. When the leader receives replies from the majority of the nodes, it relays the data update in the ledger. The transaction is broadcasted to all the participating nodes which then validate and replicate it without any individual validation from their side and hence update the ledger. The deployment

[56] Akos Hajdu et al., "Using Fault Injection to Assess Blockchain Systems in Presence of Faulty Smart Contracts," 2020.

of the RAFT protocol is considered more manageable, less resource-consuming and non-complex[57].

Figure 5: Comprehensive Visualization of the RAFT consensus protocol



Source:(Honar Pajooh)[58]

2.3 The Internet of Things and Blockchain

IoT refers to the communicative network between consumer goods consisting of computing devices as well as other digital and mechanical devices. They are inter-connected over communication networks such as the internet and exchange data via low-cost and pervasive sensors. The idea was introduced by British Entrepreneur Kevin Ashton in 1999. As of today, the number of devices connected to a common network exceed the human population. Furthermore, the IoT has advanced due to the integration of novel technologies such as widely accessible computers, useful sensors, powerful embedded systems as well as machine learning. The three defining features of IoT are context, omnipresence, and optimization. Context means any information that can be used to characterize the situation of an entity eg: location, condition, or atmospheric condition. Omnipresence means a universal existence of the required computing objects. Optimization is the unique capability each object has that is utilized. With the ever-

[57] Houshyar Honar Pajooh et al., "Hyperledger Fabric Blockchain for Securing the Edge Internet of Things," 2021; Diego Ongaro and John Ousterhout, "In Search of an Understandable Consensus Algorithm," 2014, 18.
[58] Honar Pajooh et al., "Hyperledger Fabric Blockchain for Securing the Edge Internet of Things."

increasing innovation and advancement in networking such as 5G, IoT seems to be a promising tool to further integrate into Supply Chain 4.0. IoT provides operational efficiency such as instant information exchange which helps reduce time and resource wastage caused by the Bullwhip effect. IoT also helps reduce the risk of black-market trade such as counterfeits via security features provided by physical products. The three areas of SCM where IoT can be confidently employed are Warehousing, Production and Transport [59].

BC and IoT can work together vis-à-vis continuity of information, accessibility of information, provide linkage between physical and information flows, and integrity retainment. With the case of information, BCT provides immutable and ascending information, hence a platform for the global stakeholders to share and access massive amounts of information from the one single source of truth. Via IoT, information path of the physical entities at each stage of the SC can be made available on the BC. With the necessary technology, integrity and regulations can also be maintained[60].

2.4 Blockchain Oracles

For Blockchain application in a variety of industrial uses, real-world data needs be relayed and recorded to the ledger. A BC itself cannot access off-chain data and thus needs a medium to transfer real-world information in the form of transactions to a BC ledger. The medium should investigate the external realm information, verify it and then authenticate it. A medium should also exist to relay BC ledger data to the external realm. That external realm data also needs a smart contract to call it. And data on a smart contract needs to be relayed to the external realm through a medium. To enable this process, oracles were introduced in versions that deal with the afore mentioned problems. Oracles take into account the data source, direction of the data being relayed, and trust of data.

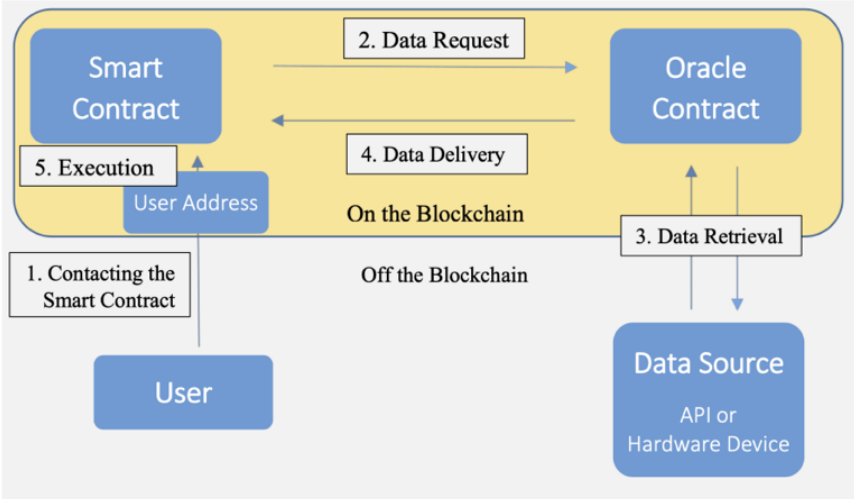
- Software Oracle: Could be for inbound or outbound data related to online sources of information. Inbound data from centralized or decentralized sources are relayed to a

[59] Junyan Hu et al., "Fault-Tolerant Cooperative Navigation of Networked UAV Swarms for Forest Fire Monitoring | Elsevier Enhanced Reader," 2022, https://doi.org/10.1016/j.ast.2022.107494; Abderahman Rejeb, John G.Keogh, and Horst Treiblmaier, "Leveraging the Internet of Things and Blockchain Technology in Supply Chain Management," July 20, 2019.
[60] Deloitte, "Using Blockchain & Internet-of-Things in Supply Chain Traceability," n.d., 24.

smart contract via one or several inbound oracles and outbound data from the ledger could be relayed to the external realm via one outbound oracle.

- Hardware Ledger: Used for inbound data from physical realm. The information can be communicated via IoT sensors etc. The hardware oracle interprets real world occurrences into digital data comprehendible to Smart Contracts[61].

Figure 6: Comprehensive Visualization of Oracle Mechanism



Source: (Beniiche)

2.5 Tracking and Traceability in LMD

Tracking and tracing a product through the SC flow is imperative to ensure compliance and customer satisfaction. It is providing customer with transparency and the an individual story to each product. Tracking involves using traceability record to locate an item through SC flow from the origin of the product to the end customer. While traceability involves using the record to obtain the entire movement story of a product through the SC. In LMD the SC flow of a product is from the nearest distribution canter to the receiver's house. And this process is of utter importance for a company to maintain competition. Modern solutions such RFID, GPS, Barcodes and IoT are already under use and have scalability to some extent. BCT is a relatively novel approach for an even more accurate information and transparency of SC flow[62].

[61] Beniiche, "A Study of Blockchain Oracles."
[62] Leena Wanganoo and Anukul Patil, "Preparing for the Smart Cities: IoT Enabled Last-Mile Delivery," in *2020 Advances in Science and Engineering Technology International Conferences (ASET)*, 2020, 1–6,

3 Methodology

3.1 Approach

With regards to tracking vis-à-vis BCT there have been numerous research papers published with the aim of enhancing tracking and tracing in SC. It was rare to find publications specifically talk about package tracking in LMD. So, a qualitative approach is taken where data was derived from the relevant literary resources to make a framework specific to tracking and traceability of products in LMD. BCT is a relatively new, 21st century, technology. Its applications so far have been limited mostly (or sometimes synonymous) to cryptocurrency. For this thesis the most relevant literature to the thesis problem is referred to for a systematic analysis and data extraction for application to the model.

Once again, the problem definition of this thesis is to do with SC tracking and traceability in LMD. It solely focuses on the last geographical distance to be covered for a product to reach its end-customer. And it is a common phenomenon that a lot of e-commerce customers complain of inefficiency in Last Mile tracking of their ordered product. The stakeholders with regard to the integration of BCT are the supplier (or online retailer), the customer and third-party logistics service providers. The supplier owns the products before they reach the customer but lacks physical control over the products when involving third-party logistics service providers. The third-party logistics service provider does not own the products but obtains physical control over them. Before reaching them, the customer neither has control nor ownership of the goods, yet they require real-time information related to the product's delivery progress. The research that is done is intended to give a robust solution to this widespread problem and hence give a solution for better geographical and physical tracking of products on the move in the SC.

The process visualization of the problem was as follows. It was taken into consideration whether the industry dealt with in this thesis is monetarily of high significance. Then the problem was

https://doi.org/10.1109/ASET48392.2020.9118197; Laurent E. Cartier, Saleem H. Ali, and Michael S. Krzemnicki, *The Journal of Gemology: Blockchain, Chain of Custody and Trace Elements: An Overview of Tracking and Traceability Opportunities in the Gem Industry*, 2018.

analysed according to data obtained about how significant the problem is in the eyes of consumers.

After looking up on the web, the monetary value and growth of the SC industry was realized[63]. It was also realized that Tracking in LMD was a determining factor in customer satisfaction[64]. Hence the research was gone ahead with.

3.2 Collection of Data

To conclude the final model for this thesis, a thorough reading of comprehensive and relevant publications was done. While analysing literature, the classic sources of information were prioritized such as using Nakamoto's paper[65] to comprehend BCT. The final model's architecture was derived from secondary sources and the existent models projected in the publications. The legitimacy and feasibility of the publications was studied and compared to the classic firm-based publications along with an iterary process of looking up multiple sources for the same idea, scanning the writings relevant to this thesis and aligning them together for a composite communication of ideas to the reader of this thesis. The idea of tracking and traceability via BCT was vastly discussed on internet sources including well-known firms like Amazon, Deloitte and IBM, so secondary data was considered sufficient to go forward with the research. Nevertheless, had there been one-on-one interviews conducted with firms where the specific case of package tracking and tracing in LMD was asked about, it would have been much clearer to picture, analyse and deduce the final model and conclusion.

3.3 Obstacles

With a vast number of publications on BCT, the technical aspect of it was substantially difficult to perceive. A lot of the publications talked about in-depth technicalities of BCT which was hard to comprehend at first. It was important to look at the recent developments in BCT and take into consideration all the new versions introduced and talked about in the abundance of

[63] Research, "Supply Chain Management (SCM) Market Size Worth $ 19.3 Billion, Globally, by 2028 at 9.02 % CAGR."
[64] "Customer Survey: Realtime Order Tracking Makes the Difference With Customers," OptimoRoute, January 22, 2021, https://optimoroute.com/customer-order-tracking/.
[65] Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System."

publications present. Each individual BCT needed to be understood and then a final list of options for each version of BCT was put to the table. All options were weighed according to an economical aspect, customer satisfaction and security. Hence the appropriate version was chosen to apply to solve the thesis problem.

4 Model

4.1 Consortium BCT

Via the novelty introduced in BCT by Linux and IBM[66], this thesis propagates that for the purpose of LMD, it is best to use a consortium BCT, Hyperledger fabric to be precise. As Last Mile Logistics is already the costliest phase of SC, it is optimal to use a BCT that bypasses the energy-inefficient mining mechanism, is fast, as well as ensuring privacy on customer information only between the concerned parties i.e stake holders.

4.2 The Architecture

A robust mechanism, ensuring privacy and efficiency is introduced where customers are provided with indirect interaction with the client node provided by a company.

4.2.1 External Source of Data and Oracle.

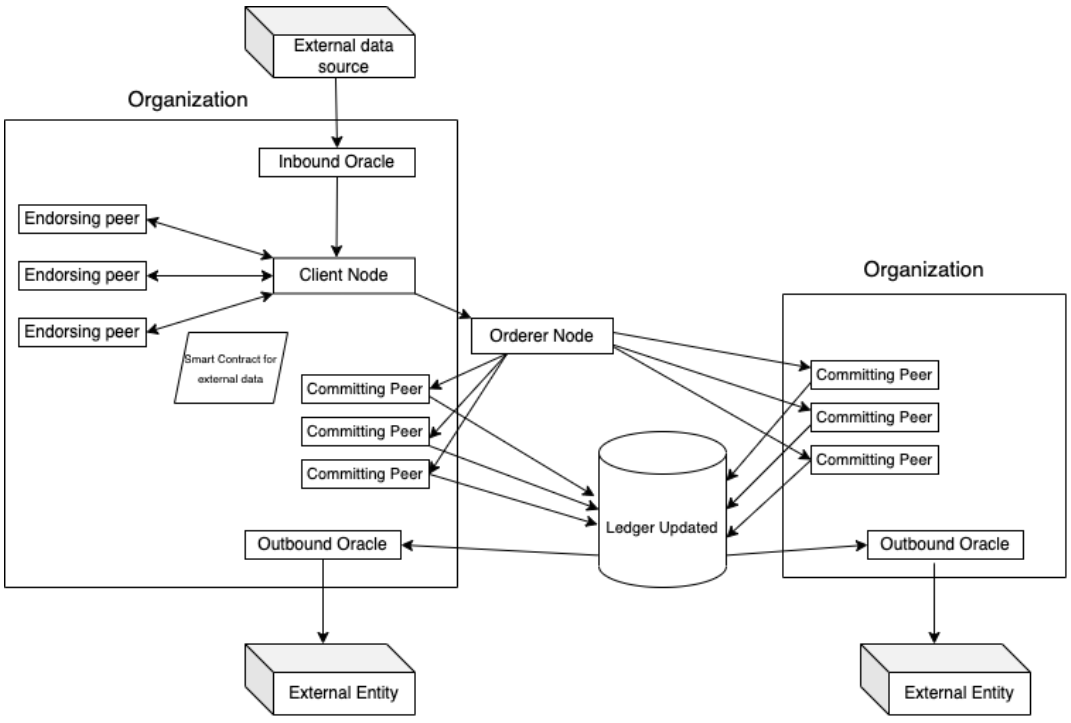
An external data source in the SC provides data to an inbound Oracle. The data might be physical data or registered data from an online source. The Oracle interprets the data to a smart contract. The smart contract, in the form of a chaincode, is then conveyed to a client node provided by the organization the individual is communicating and directly dealing with. The smart contract may contain ID, payment terms, data on real-time physical occurrences or obligations of all the involved organizations to each other. If other organizations are needed to be involved to execute customer request, the data is relayed via the BC on a private channel only between the concerned parties. To provide the external entity with feedback, an outbound oracle is installed.

[66] Androulaki et al., “Hyperledger Fabric.”

4.2.2 BCT Architecture

When the smart contract reaches from the oracle to the client node, the client node conveys the transaction to the endorser nodes which then simulate it, place a digital signature on it, and send it back to the client node. After verifying the endorsers' signature, the client node conveys the transaction to the ordering node which then broadcasts the transaction to the concerned organizations' committing nodes. The transaction is verified via consensus mechanism using RAFT ordering protocol. After reaching consensus on the validity of the transaction, a genesis block is created on a private channel/ledger on the network. This ledger is specific to the external entity's request/order.

Figure 7: A Data Flow Diagram to illustrate Model Mechanism



4.2.3 Consensus Mechanism between Stake Holders

As Hyperledger Fabric allows its participants to agree on a specific consensus mechanism's implementation, this model is set to follow the RAFT consensus mechanism in the ordering service, which in essence, is a leader-follower protocol among the ordering nodes in the ordering service. To make the consensus mechanism efficient among the limited number of parties, the involved parties' orderer nodes in a Hyperledger channel agree to dynamically elect a leading orderer node. The leading node then single-handedly verifies the transaction, which is then automatically validated and replicated by the committing peers on the network. Electing an orderer node is considered to be a fair way among all the stake holders to diverge in their collaboration of data sharing.

In RAFT, the majority of the total number of ordering nodes is needed to forward a transaction. Hence, it is important to configure the appropriate number of ordering nodes. There needs to be a system where a loss of a certain number of nodes could be tolerated by the system. This thesis proposes five ordering nodes to be deployed. The logic behind this specific number is that if a maintenance process is undergoing, one node is already lost, and it can also be supposed that at the same time another node is lost due to any sudden unexpected reason, there would still be three nodes functioning in the system, which can follow the RAFT mechanism of election protocol amongst the functioning nodes. Lastly, five is the minimum number of nodes that can be used to ensure the afore mentioned scenario, hence reducing costs for ordering nodes deployment.

4.2.4 Smart Contract Mechanism

This inter-organizational model for Hyperledger Fabric has a comprehensive Smart Contract logic. Where all statements and obligations are digitally noted down in the "if-then" logic visualization i.e incremental transactions are executed if pre-conditions are met. The pre-conditions may include payments, confirmations, and deliveries etc, all of which are composite between the parties involved.

5 Case Study: Using Low-Cost Trackers for Smart Tracking of Products embedded with BCT

This case study deals with a scenario where LMD and LMD tracking are made more efficient. This particular process involves an online product order request from an e-commerce customer which directly deals with an online retailer (such as Amazon and eBay). The retailer in turn deals with two other entities, the third-party supplier, and the third-party logistics provider. The process, in this case, is assumed to be under a Fully Extended SC atmosphere where in the LMD, the supplier has a retail store which is considered to be the distribution center and the Logistics Firm picks up the package from there for direct delivery to the end-customer. All three parties have a contractual agreement to work together for this version of customer order execution. The case study technology is derived from T-System's low-cost sensors service[67] available and briefed about on their website. The trackers are energy-efficient devices and are attached to the shipment and are programmed to keep track of the location and other physical information on the shipment. For this case study, the technology is embedded with the BCT Hyperledger Fabric, rather than a cloud database. Data on geographical information is readily made available to customers via BCT. Data on physical conditions and occurrences of goods is immutable on the BC and this bypasses the need for any independent auditing for any cases of damage etc. Hyperledger Fabric is chosen because of the limited number of parties to a request which must be dealt with due corporate privacy. Apart from that all three parties have an intra-company database.

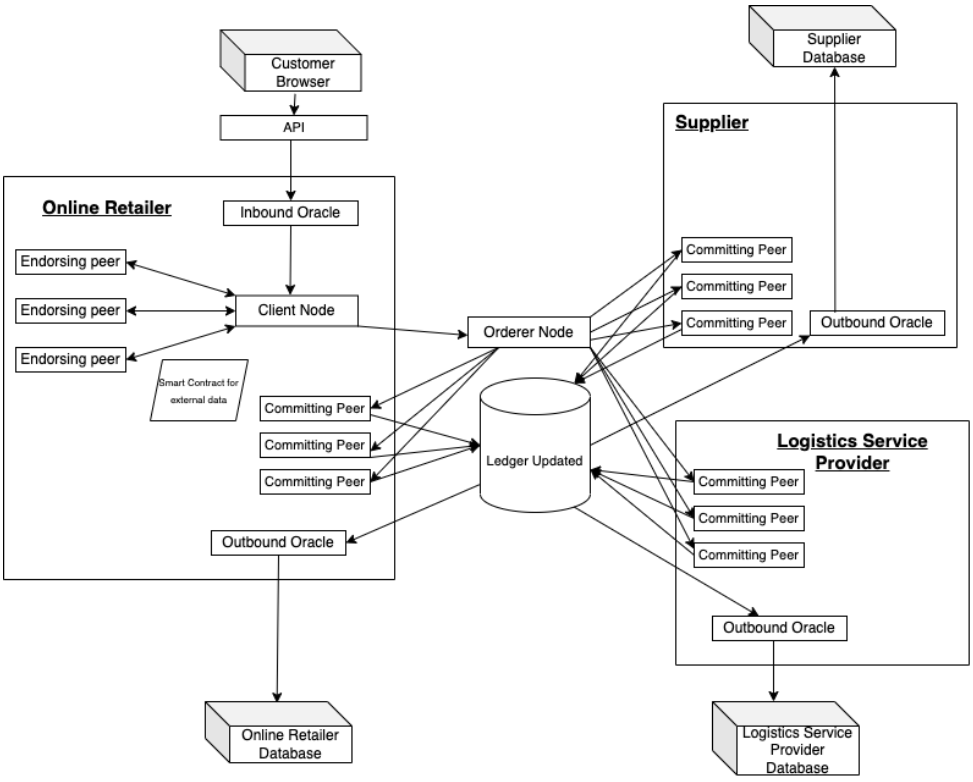
5.1 Customer Order Mechanism vis-à-vis BCT

A customer logs into an online retailer website using his/her credentials. The customer fills in geographical details of the delivery site, personal information, the chosen product, and payment details. After finalizing the order, the customer clicks on the "Buy Now" button, consequently the data is swiftly relayed to an inbound software oracle via a Web API. The oracle embeds the customer information, obligations and inter-company terms on a smart contract which is then relayed to a client node in the form of a chaincode on the Hyperledger. The client node, after

[67] "Low Cost Tracker," accessed August 22, 2022, https://www.t-systems.com/us/en/digital/iot-and-smart-technologies/track-and-trace/low-cost-tracker.

getting the digital signature from the endorsing peers, relays the smart contract to the ordering node. The transaction is validated by all peers under the RAFT consensus mechanism, and a block is appended to the private channel for the three parties in the Hyperledger Network. The data on the order is also relayed to the independent data bases of the individual companies.

Figure 8: Customer Order Data Flow

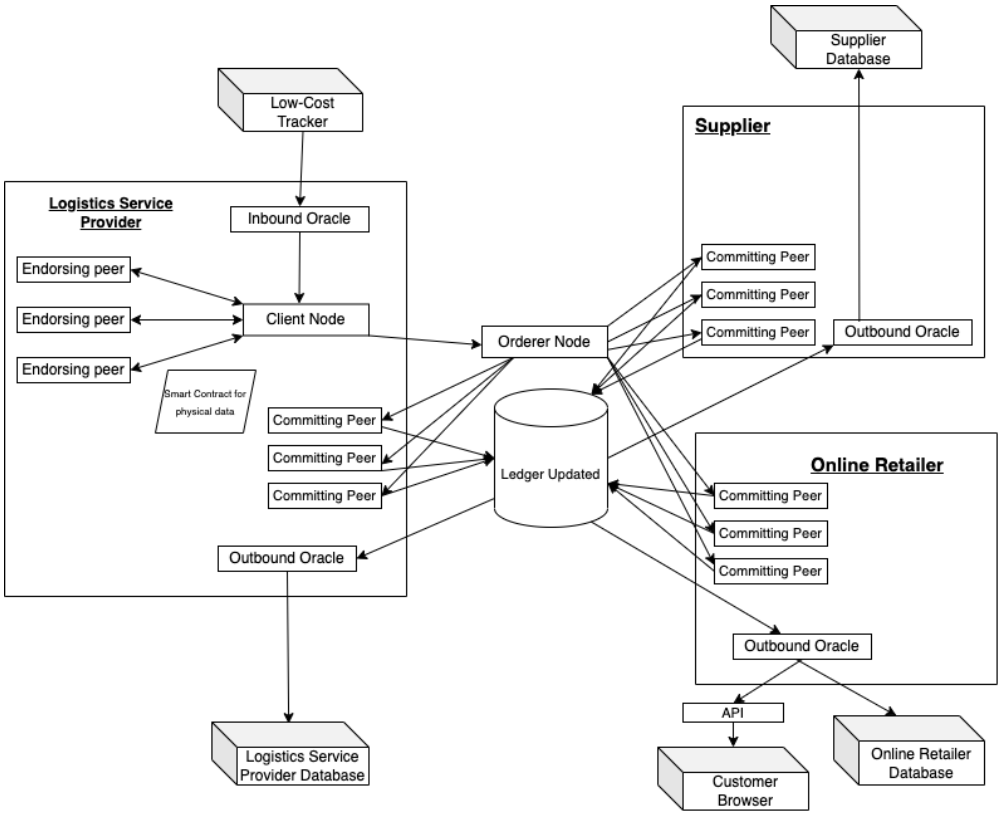


5.2 Tracker Device Mechanism Vis-à-vis BCT

As soon as a shipment is handed over to the logistics firm, the shipment is checked for any prior damage and the firm is obliged to attach the low-cost tracking device on the shipment. During the Last Mile journey, the tracker provides continuous real time tracking data on the physical situation of the shipment. The tracking device communicates the information to an inbound hardware oracle. The oracle translates the physical information to a digital one on a smart contract and conveys it to the client node. The client node then follows the Hyperledger Fabric

mechanism and subsequently adds continuous blocks of data to the private ledger between the three parties. At outbound oracle belonging to each party relays the data to their private databases. The retailer's outbound oracle, via an API, provides continuous real time tracking information to the customer on the retailer's browser.

Figure 9: Tracker Physical Data Flow



5.3 Smart Contract Logic

The smart contract agreed upon by all the involved parties has a logic mechanism where it can be visualized as "if-then" statements between parties. Some of the assumed terms in the proposed smart contract executed for an order request follow the below logic:

- If the customer provides the payment details, then the order is processed and relayed to the involved parties.
- If the online retailer authorizes the payment to the supplier, then the order is arranged and prepared.
- If the Logistics firm confirms availability for the shipment, then the shipment is processed.
- If the package reaches the end-customer, then the payment is processed.
- If the customer returns order, then the payment is refunded.

5.4 Conclusion

After a careful journey of exploration for BCT, a comprehensible model was derived and to prove its legitimacy, there was the need to illustrate a clear application of the model. T-System's provided solution of low-cost trackers was in-line with the research of this thesis project and was considered for this case study as soon as it was realized to fit into the model. Consequently, merging T-System's technology, a considerable solution in LMD for shipment tracking and tracing was provided in this case study. A practical implementation would bring about visualizable results.

6 Final Consideration

6.1 Results and Critical Reflection

Looking back at the research done on BCT: its history, development, and industrial applications, it was realized that the technology has a dynamic manifestation of an uber-efficient future in SC Management. The several characteristics of BCT make it a substantially promising technology in SC Management. While information sharing is a widespread and significant component of all industries in the 21st century, SC management is the field that particularly needs a boost in the swift decision-making process of professionals involved in the field. There was always a need for a decentralized data sharing, hence solutions like Cloud Computing were introduced, that already being an advancement, an advancement from that advancement has to be a technology with revolutionary features such as BCT.

Specifically proposing Hyperledger Fabric had a reasonable background. It is energy efficient. The technology providers a secure ledger, inaccessible to random parties. Furthermore, within the Hyperledger network of an organization, there can be private channels. In-effect, this version of BCT provides organizations incentives with an economical version of BCT, which is also friendly to corporate privacy regulations.

Despite the existent buzz, among tech-savvy people, around BCT and its imminent (or inevitable) application in the near future, the lack of awareness of this technology, along with its complex nature has been a deterrent in a wide-scale application of the technology. The biggest application of BCT, cryptocurrency, is yet to be made universally utilized. Even in the case of this thesis, it required an arduous journey of research to comprehend the technology, and yet not every version and attributes of this technology have been wholly appreciated.

6.2 Implications for further Research

This project has quite a few shortcomings with regards to research. It is solely based on secondary sources of data. There is no hands-on review of the technology being applied actively, so there is no sureness whethere the model derived by the secondary sources has any technical discrepancies. The assumption taken was that as long as the data obtained was in-line with previously made available versions of the data, as well as the classic version, the model should have a significant degree of accuracy. Unfortunately, there is no empirical evidence provided for the model in this thesis. A substantially reasonable and accurate model would have been provided, had there been primary data i.e hands on insight into firms that apply the technology and allow the technology to be used to test the project model's practicality.

As SC requires multi-party collaboration, a financial research needs to be done with regard to the unanimous investment of SC parties (big or small) in the application of BCT into their business operations. If there is a conflict of economic interest in applying the technology, the technology cannot in practice be applied, as it requires a multi-party approach.

With regards to advancement of research vis-à-vis BCT, reverse logistics could be a diverging point of interest for organizations dealing with sustainability in Logistics. The implementation of BCT and smart contracts to track and trace recycled products can use the immutable data

attribute of BCT and provide insurance for environment-friendliness to concerned organizations.

6.3 Implications for Practice

BCT's revolutionary application was propagated in a rigorous manner. SC professionals realize the power of information as being a fundamental metric in SC management. A lot of major world SC firms have already begun the integration of this novel technology. A lot of the Key Performance Indicators of SC service are directly related to information and the rest are related to the response on that information. Real-time immutable data is what BCT is about, and that is an essential part of what an efficient data system is.

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Matriculation number	30002505
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