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Optimizing the core business processes of financial asset management companies using blockchain technology

Nick van de Luijtgaarden s1471791

Supervisors:

Dr. T.K. Cocx (LIACS) & M. de Heus (Company) & C. de Vries (Company)

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Leiden Institute of Advanced Computer Science (LIACS)

Abstract

Our current financial system is built on a model of centralized trust, where most financial activity is required to flow through and be validated by national financial institutions that provide the market with security and stability. However, the problem is that these processes are time and cost consuming and a high level of trust is needed in a single central body acting as the "middle man", especially in the asset management industry.

Thanks to advances in computing such as networking, processing power and storage facilities, a new technology called blockchain is emerging, that can eliminate these intermediaries in the financial industry. The aim of this study was to look at how blockchain technology can be used for the core business processes of an asset management company and what the best tools are to set up a blockchain.

This study followed a qualitative and quantitive case study research methodology at a small to medium sized asset management company. Interviews were conducted to provide insight in the business processes and programming was done to review the blockchain platforms. In addition, a framework was provided to review blockchain platforms and business processes. Results showed that blockchain platforms were still immature, but did offer solutions that can be interesting for the financial industry. Also, misinformation between participants was one of the biggest causes for errors in the business processes.

This paper argued that Corda was the best blockchain platform because of scalability, auditing for regulators and offering a specific consensus between firms. However, it was evident that blockchain platforms are still in constant development, thus it is important to use the framework provided in this study to evaluate blockchain platforms in a changing industry.

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Chapter 1

Introduction

The amount of monetary transactions that is carried out digitally in modern society is growing at an accelerating pace; digital technology is transforming the financial-services industry [15, 16, 19]. From 2010 till 2014 an average growth of 10% has been measured in global non-cash transaction volume every year, reaching 387.3 billion in 2014 [28]. Furthermore, banks are automating their servicing processes and migration of front-end activity to digital channels, and contactless payment methods such as Paypal and Bitcoin are getting more popular [20, 22, 24].

Our current financial system is built on a model of centralized trust, where most financial activity is required to flow through and be validated by national financial institutions [10]. These intermediaries provide the market with security and stability through services such as fraud detection, recordkeeping and exchange of funds. However, the problem is that these processes are time and cost consuming and a high level of trust is needed in a single central body acting as the "middle man".

Thanks to advances in computing such as networking, processing power and storage facilities, a new technology called blockchain is emerging, that can eliminate these intermediaries in the financial industry [10, 11, 27, 36]. According to D. Biondi, T. Hetterscheidt and B. Obermeier [10], "In simple terms, blockchain is the technology that creates a distributed ledger of transactions on a network that is secure, tamper-proof, and easily accessible. It is a shared record of transactions, distributed over a network of users". One of the most widely known cryptocurrencies called Bitcoin [11] is based on this underlying infrastructure.

Participants in the financial markets know distributed ledger technology is coming; 80% of financial market participants say blockchain technology will be transformative and expect their firms to adopt it by 2020 [14]. Blockchain is seen as the currently emerging paradigm for this decade, see Figure 1.1, following the social media and the internet [12, 25, 27]. According to Goldman Sachs [36], from 2012 till 2015 venture capital firms have invested almost a billion dollars in the technology, with about half of that amount invested in 2015 alone. Still, nearly 40% of executives admit they know little or nothing about blockchain [25].

It is easy to see a use case for blockchain technology in financial asset management. Within the financial asset
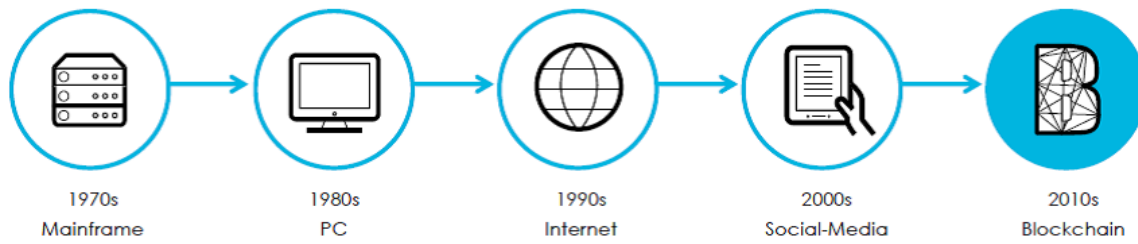
Figure 1.1: Disruptive compting paradigms [27]

management industry, business processes often involve many parties. Currently, these parties constantly have to wait for each other to receive the information they need to respond with the right action, resulting in long waiting times, high transaction fees and slow reporting to clients [29]. In addition, all of these parties keep their own records on a centralized database and there is a lack of interoperability between these systems [12,29].

Using blockchain technology, data can be shared between consenting parties, thus allowing the parties to work with the same data set and reducing the need for duplicative data collection. Sharing instructions and messages between parties by posting them to a distributed ledger reduces the chance for tampering with the data and makes documentation processing more efficient [13].

Currently, there are many different tools available that can be used to set up and deploy a blockchain platform, but almost no research has been conducted yet to find out which one is best fit for use [26]. Because a lot of asset management companies are now just starting to get to learn more about blockchain technology, it is difficult to find the right platform for their common needs, but it is important for these companies to join in on this trend as soon as possible, because it could possibly have have great impact on their current business model [12,29].

This paper discusses the core business processes of an asset management company and how they can be improved using blockchain technology. In addition, this research will review the currently most widely used and accepted tools to set up a distributed ledger based on blockchain technology and the challenges that can be faced here. Moreover, this study will discuss the requirements that need to be met to improve these business processes. The main research question for this paper is "What are the best tools to set up a distributed ledger based on blockchain technology for the core business applications of an asset management company?". Using a case study methodology, the research will be performed at a small to medium sized financial asset management organization with international presence.

As mentioned previously, many parties are involved in the core business processes of an asset management company. The scope of this study will mostly be limited to the role of the asset managemement company in these processes. Only some exploratory research will be conducted to provide insight in the roles of the other parties involved.

This paper starts with an introduction to blockchain technology and a discussion of the current most widely used tools to set-up and deploy a blockchain platform. Thereafter, the asset management industry and the core business processes of an asset management company will be considered. Next, our research design and

methods that were used in this study will be explained. Finally, this paper discusses the results of our research and draw conclusions.

Chapter 2

Background

This chapter will review the relevant literature related to our research. In the first section the background and definitions regarding blockchain will be discussed, and in the second section an introduction to the core business processes of an asset management company will be given.

2.1 Blockchain

This section discusses what a distributed ledger is and how it is related to blockchain technology. In addition, the way in which a central authority can be eliminated in a blockchain while still maintaining a secure system will be examined. Therafter, the most used application of blockchain technology called Bitcoin [11] will be considered. Finally, the use of "smart contracts" in a blockchain will be elaborated on and an analysis of the tools that are currently in the industry to set-up your own blockchain will be given.

2.1.1 Distributed ledgers

A ledger is a database for recording transactions and keeping track of who owns a specific asset [37]. Currently, financial institutions keep their systems and databases internal and do not share them with other parties [38]. As a result of this, these systems have overlapping functionality and are regularly in conflict, and require slow, expensive and difficult reconciliation.

A *distributed* ledger is a database that can be shared across a network and all participants can have their own identical copy of the ledger [33]. No central administrator or centralised data storage is needed; every copy of the ledger is updated automatically when new transactions occur, and the ledger is maintained by a group of peers, rather than a central agency [12, 34, 46]. However, ensuring the integrity of the ledger can be difficult, because the system no longer relies on a central authority validating all transactions; this topic will be discussed in section 2.1.5 [46]. The security of the assets in the distributed ledger is maintained

cryptographically through the use of keys and signatures, which will be further elaborated on in section 2.1.6 [33].
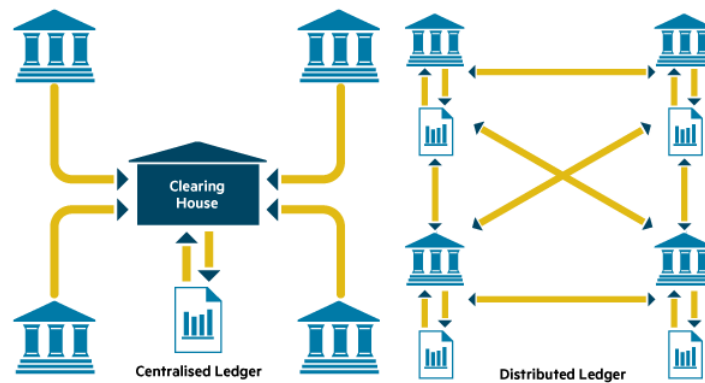
Figure 2.1: Centralised ledgers and distributed ledgers [31]

In Figure 2.1 the difference between centralised ledgers and distributed ledgers in our financial system is illustrated. A centralised ledger tracks asset movements within the financial system between institutions and is maintained by a clearing house that provides the market with security and stability [31]. Conversely, in the case of a distributed ledger, the need for central authority is eliminated and financial insitutions can communicate directly with each other. A distributed ledger could potentially be used in financial markets to settle trades for any given set of assets and their holders [29].

2.1.2 Blockchain technology

According to D. Biondi, T. Hetterscheidt and B. Obermeier [10]; "In simple terms, blockchain is the technology that creates a distributed ledger of transactions on a network that is secure, tamper-proof, and easily accessible. It is a shared record of transactions, distributed over a network of users. A blockchain is made up of a series of data blocks, each of which contains a set of transactions". Transactions that are recorded are added to the chain as a block, and each block contains a timestamp and a link to the previous block [30]. Once a block is added to the chain, the data of this block cannot be modified in any way. Blockchain and distributed ledgers can be two confusing terms to use together. To clarify, all blockchains are distributed ledgers, but not all distributed ledgers are blockchains; blockchain is a type of distributed ledger [39].

Server Based Network   **Peer to Peer Network**
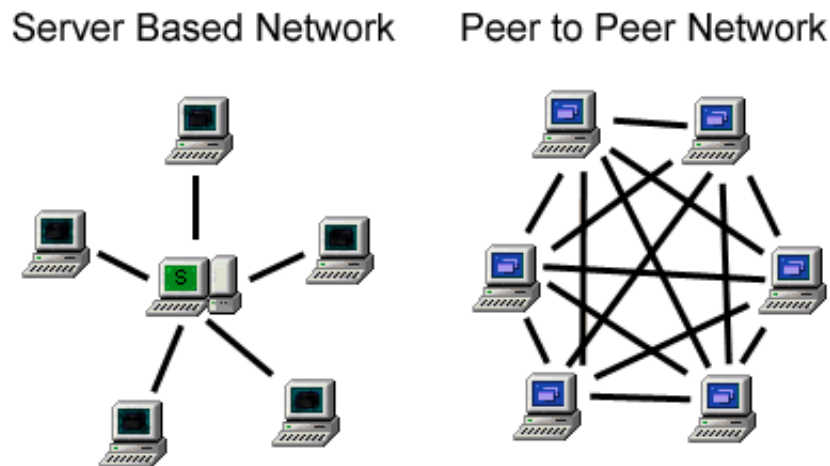
Figure 2.2: A server-based network and a peer-to-peer based network [32]

As discussed before, a blockchain does not store data on a centralized database or server. Instead, it makes use of a network architecture called Peer-to-Peer [40]. R. Schollmeier [5] discusses that "a distributed network architecture may be called a Peer-to-Peer (P-to-P, P2P, ...) network, if the participants share a part of their own hardware resources (processing power, storage capacity, network link capacity, printers, ...). These shared resources are necessary to provide the Service and content offered by the network (e.g. file sharing or shared workspaces for collaboration). They are accessible by other peers directly, without passing intermediary entities".

In Figure 2.2 the difference between a server-based network and a peer-to-peer based network is illustrated. It can be seen that in a server-based network, all commmunication is done via a central server where all clients are connected to. In a peer-to-peer based network, all clients communicate directly with each other and there is no central point of control. This means that in a blockchain, the ledger is hosted and maintained by interested parties and when changes are entered in one ledger, all other copies are updated [40].

How a blockchain works

1 A wants to send money to B

2 The transaction is represented online as a 'block'

3 The block is broadcast to every party in the network

4 Those in the network approve the transaction is valid

5 The block then can be added to the chain, which provides an indelible and transparent record of transactions

6 The money moves from A to B
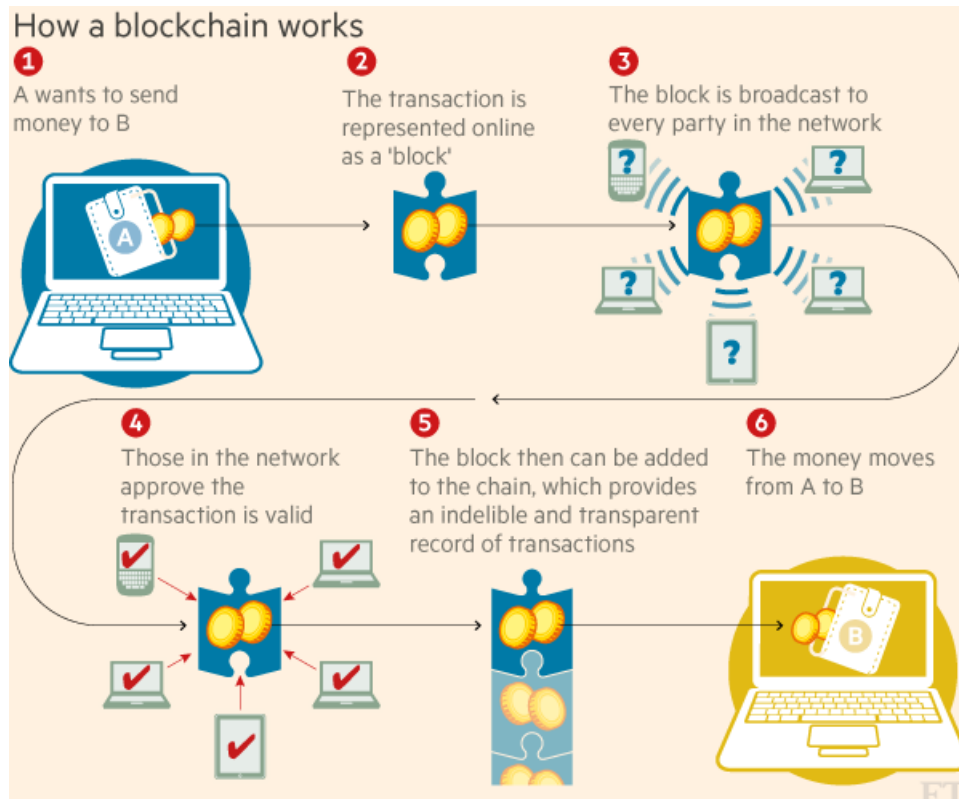
Figure 2.3: A trade between two parties using blockchain technology [35]

Figure 2.3 shows a trade between two parties using blockchain technology. Party A sends money to party B, and together with transactions done by other parties, it is configured into a block. Before party B received its money, the transaction must be validated first [35]. The block containing transactions is broadcasted to other parties in the network who will then validate these transactions. How the validation of transactions done on a blockchain works will be discussed in section 2.1.5. When the parties have reached a consensus and have approved the transactions, the block will be added to the blockchain and the money is sent to party B. All transactions that were configured into this block now become irreversible and visible to others on the blockchain.

One of the main benefits of blockchain technology is that the ledger itself can be programmed to trigger transactions automatically using "smart contracts" [12, 45]. M. Iansiti and K. R. lakhani [40] explored the applications of smart contracts and found that "for example, a smart contract might send a payment to a supplier as soon as a shipment is delivered. A firm could signal via blockchain that a particular good has been received–or the product could have GPS functionality, which would automatically log a location update that, in turn, triggered a payment". The topic of smart contracts will be further elaborated on in section 2.1.8.

2.1.3 Public-key cryptography

As stated before, a blockchain offers a high level of transparency, because all transactions carried out on the distributed ledger are visible to others. An issue that can be identified here is that of privacy; especially in the financial world, people are secretive about their transactions and assets [56]. Blockchain technology solves this problem by making use of public-key cryptography [54].

When someone carries out a transaction on a blockchain, they are not using the real name of a person but they are actually sending them to their public account address [57]. This address is a hashed version of what's known as the "public key". According J. van Oerle and P. Lemmens [12], "Hashing is the process of running a computer algorithm over content in order to create an alphanumeric character that cannot be back-computed into the original content". A public key is generated when you create a new account on the blockchain and is a long, random-looking string of numbers [54].
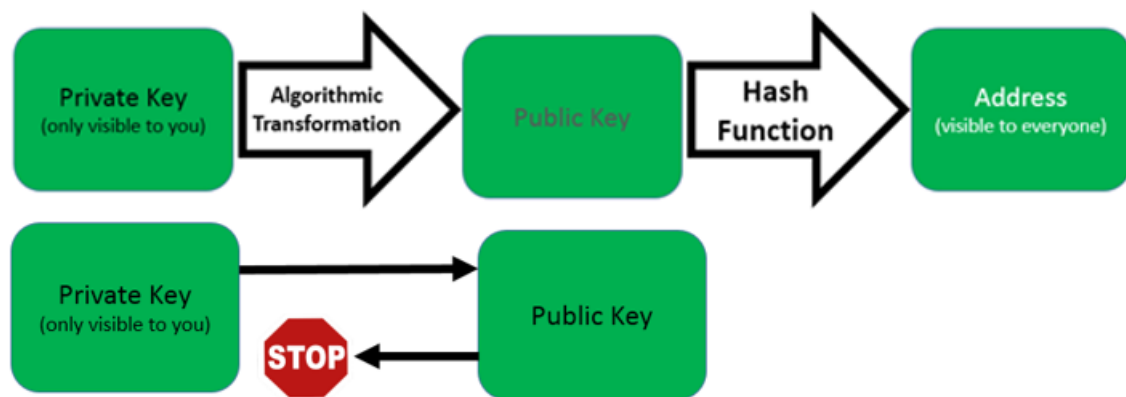
Figure 2.4: Relationship between a public key, a private key and an address [57]

To access the assets of an account, a "private key" has to be used. A private key is a randomly generated string of numbers that gives you access to your account on the blockchain [57]. This key is used to mathematically generate your public key, see Figure 2.4. Private keys "sign" a transaction and create a digital signature, proving that the sender controls the address associated with those funds [114].

Using a person's public key and digital signature, it can be verified that the signature has been created with the correct private key. The public key is only revealed to the validators whenever you spend money, because it is necessary for validating the transaction. Hashing the public key to a public address on the blockchain adds an extra level of security; if the cryptography between the private and public key would fail, it would still be difficult for a hacker to find your public key.

However, if a public key is found, wouldn't there be any way to find someone's private key using this public key? This problem is solved by using a complicated mathematical algorithm to generate a public key [57]; this algorithm makes it easy to generate a public key from a private key, but nearly impossible to reverse this process. Because of the decentralized character of blockchain, there is no customer service for password recovery or any private key backup [27]. If you lose your private key, you lose your assets. According to M. Swan [27], "this could be an indication that blockchain technology is not yet mature enough for mainstream

adoption".

2.1.4 Public, Private, Permissioned and Unpermissioned Blockchains
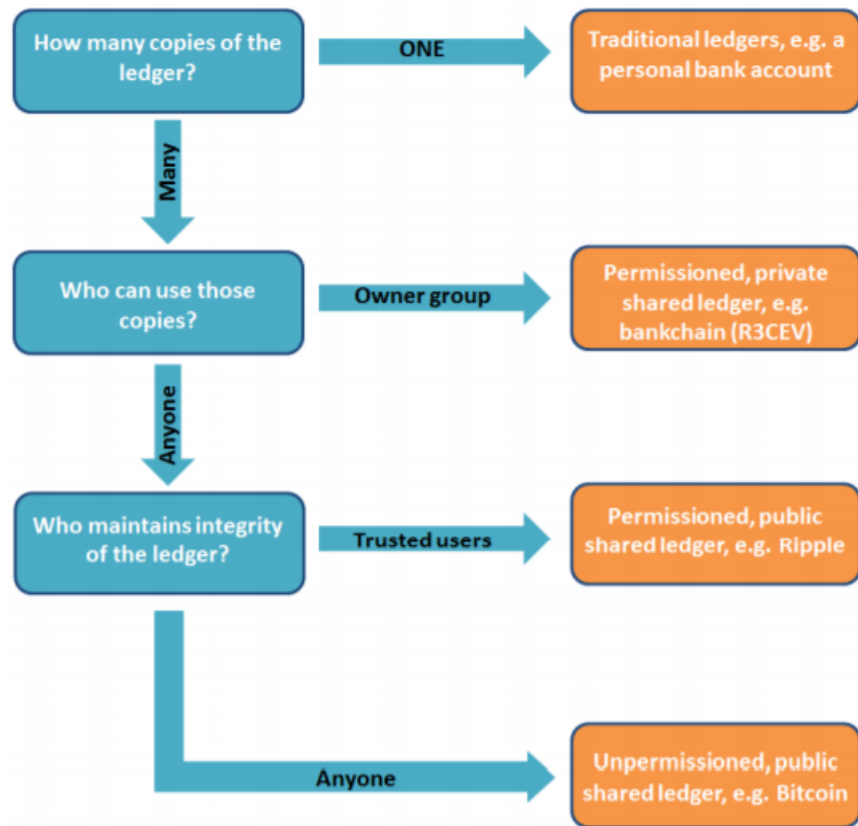
Figure 2.5: Public vs. Private vs. Permissioned vs. Unpermissioned blockchains [12, 33]

As can be seen in Figure 2.5, there are different kind of distributed ledgers available in the industry. Bitcoin, for example, is an unpermissioned ledger which means that anyone is allowed to validate the ledger's integrity. Bitcoin is also a public ledger; public ledgers allow anyone to contribute to the ledger, while in private ledgers only certain groups are allowed to enter the blockchain.

In a permissioned ledger, the ledger's integrity is checked by trusted actors, which makes maintaining the records in the ledger much easier [33]. J. van Oerle and P. Lemmens [12] argue that in the financial sector, parties such as banks or asset managers want to be the trusted actors that can check the ledger's integrity and allow members to participate, see the permissioned and private ledger in Figure 2.5.

In a private and permissioned ledger, validators are known and can be trusted to be well-connected, which makes any manual interventions much easier and prevents the risk of malicious users manipulating the blockchain [111]. This is important in the financial sector, because clients want their money to be safe. Despite the differences, public and private blockchains have many similarities; each participants still maintains a replica of the ledger, a consensus is used for validation and the immutability of the ledger is guaranteed [110].

2.1.5 Consensus

The essential feature of a distributed ledger is that the need for a central authority can be eliminated. One issue, however, is that transactions still need to be validated in some way to avoid the 'double spending problem'. The double spending problem occurs when someone is able to spend a single digital token twice; this can happen when a distributed ledger is not updated in time [12]. A common solution for this problem is to have a trusted central authority that validates every transaction for double spending. However, the problem here is that the fate of the entire system depends on this company, because every transaction flows through it [11].

Blockchain technology has shifted this responsibility to the group of peers that are using the distributed ledger; any member of this group can add records to the ledger, but they are only accepted when the group agrees that this record meets all the ledger's requirements [46]. The process that these parties use to come to an agreement if a transaction is valid is called the consensus process. According to A. Koster [47], "a consensus algorithm does two things: it ensures that the next block in a blockchain is the one and only version of the truth, and it keeps powerful adversaries from deraiing the system and successfully forking the chain".
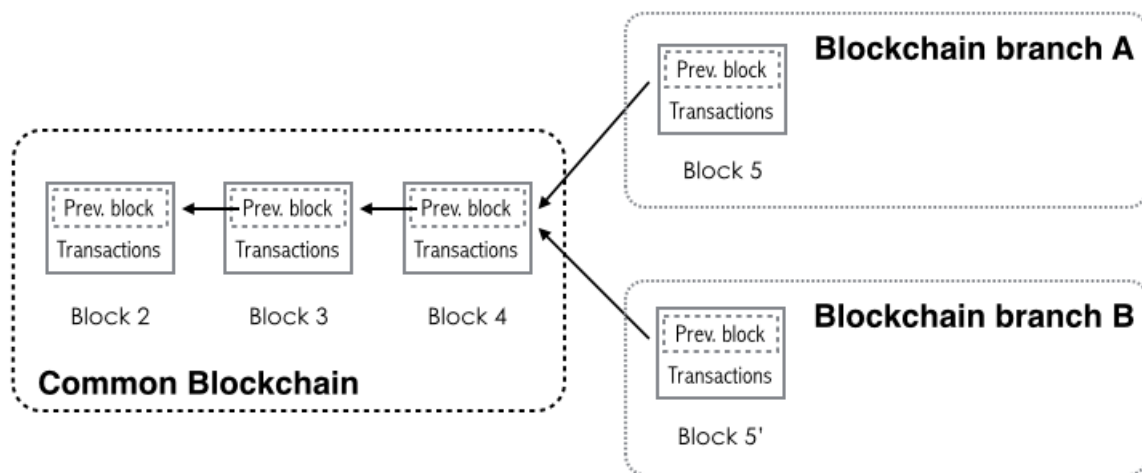
Figure 2.6: A blockchain fork [107]

Sometimes, validates cannot agree on the common rules of the consensus, which leads to the blockchain diverging into two potential paths [104]. This behaviour of a blockchain is called a "fork", see Figure 2.6. Because of this, users of the blockchain have to show support for one choice over the other. Most forks are small and resolved on their own, but sometimes the network can split, creating two blockchain histories and separate currencies.

Ethereum Classic is a cryptocurrency that was split from an existing cryptocurrency called Ethereum [108]. In Ethereum, a hacker made use of a bug in the code, which caused him to earn around $30 million dollars through smart contracts. This led to a fork, because people wanted to reverse the blocks that had these transactions on the blockchain. However, a big group of users did not support this fork; they argued that transactions that are carried out on the blockchain should be immutable and never changed. This led to a network split, and these users that did not support the fork are now using Ethereum Classic.

When establishing this consensus, it is important to remember that some of the peers can provide incorrect data to the ledger and manipulate the trust in the blockchain to their advantage. Especially in public and unpermissioned blockchains the incentive to be malicious is high, because anyone can declare the truth of the ledger and some people have an incentive to make the ledger more beneficial to themselves [48]. This problem of maintaining a consistent set of records where different parts of the system give conflicting information to each other is defined as the *Byzantine Generals Problem* [3].
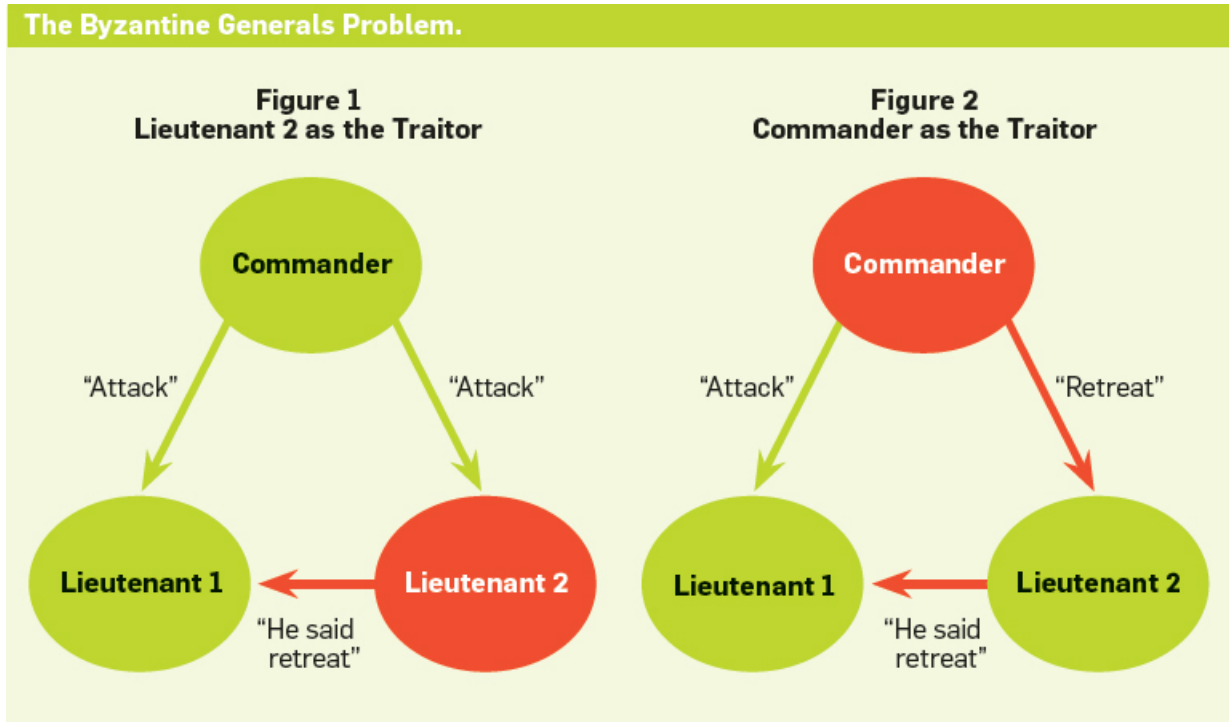
Figure 2.7: The Byzantine Generals problem [1]

In Figure 2.7 you can see an illustration of the Byzantine Generals Problem. According to L. Lamport, R. Shoshtak and M. Pease [3] this problem is formulated as "reliable computer systems must handle malfunctioning components that give conflicting information to different parts of the system. This situation can be expressed abstractly in terms of a group of generals of the Byzantine army camped with their troops around an enemy city. Communicating only by messenger, the generals must agree upon a common battle plan. However, one or more of them may be traitors who will try to confuse the others. The problem is to find an algorithm to ensure that the loyal generals will reach agreement. It is shown that, using only oral messages, this problem is solvable if and only if more than two-thirds of the generals are loyal; so a single traitor can confound two loyal generals. With unforgeable written messages, the problem is solvable for any number of generals and possible traitors. Applications of the solutions to reliable computer systems are then discussed".

2.1.5.1 Proof-of-Work vs. Proof-of-Stake

There are many different mechanisms that can be used to establish a consensus, with the two most popular ones being Proof-of-Work and Proof-of-Stake, see Figure 2.8. Proof-of-Work is currently being used by Bitcoin

and Ethereum. However, Ethereum is preparing to move to Proof-of-Stake by the end of 2017 [105]. According to M. Swan [27], these two cryptocurrencies "are created as a reward for computational processing work, known as *mining*, in which users offer their computing power to verify and record payments into the public ledger". The technical process of how computing power is used to verify payments is beyond the scope of this paper.
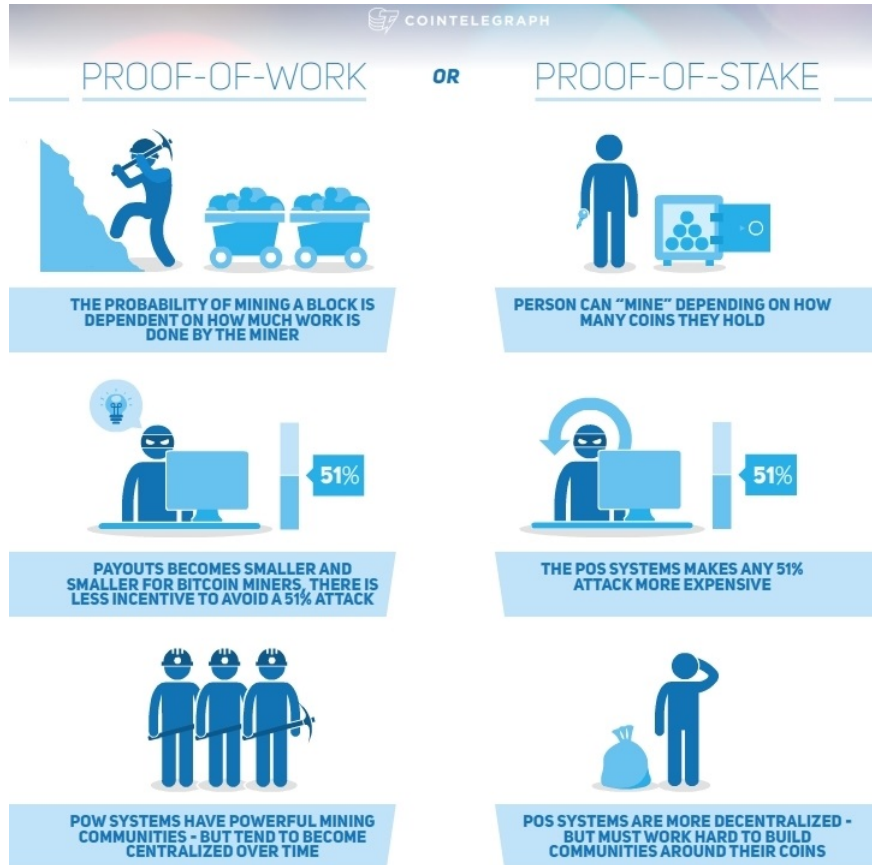
Figure 2.8: Proof-Of-Work vs Proof-Of-Stake [58]

In Proof-of-Work, all participants in the blockchain can offer their computing power to validate payments. However, the probability of mining a block is dependent on how much (computing) work is done by the miner [58]. This means that if users can combine their computing power together for mining, they can make money much faster. People noticed this, and companies known as "mining pools" were started that mine in exchange for money, and give a part of the block back as a reward. Because of this, 50% of the "mining power" for Bitcoin is divided between four companies, as can be seen in Figure 2.9. This is a big problem, because the blockchain could become centralized. In addition, there is more chance for a "51% attack" to occur, which will be elaborated on in section 2.1.6.
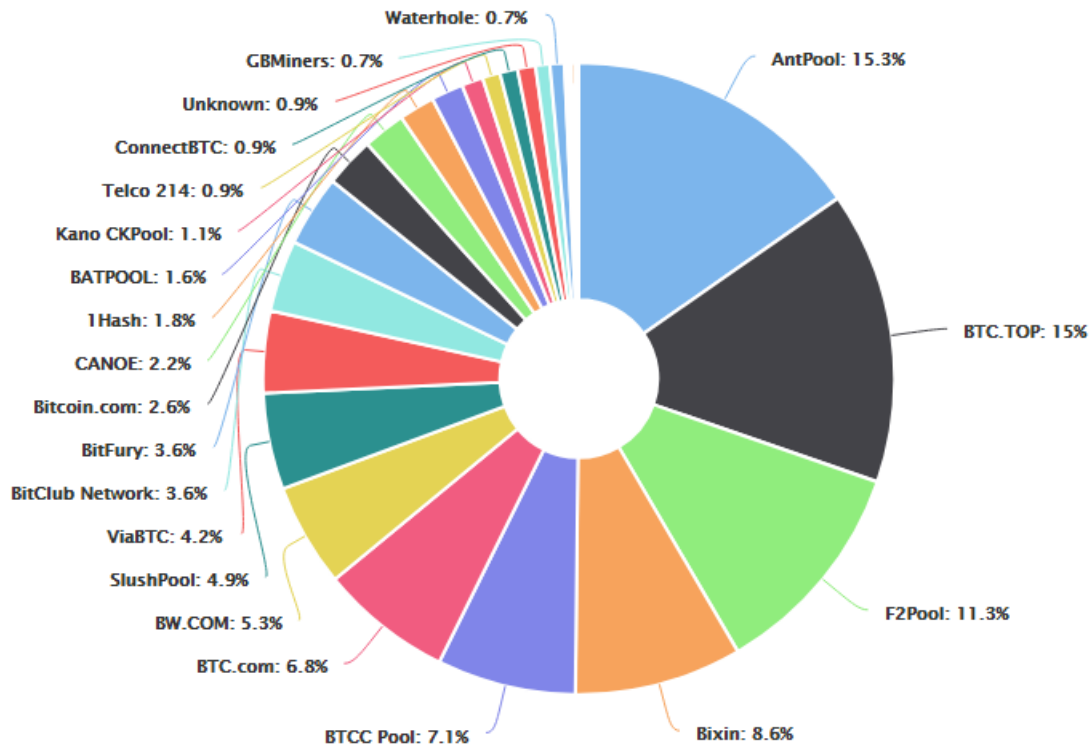
Figure 2.9: Distribution of mining pools [102]

The centralization of the mining power led to the creation of a new consensus algorithm: Proof-of-Stake. According to Blockgeeks [103], "Unlike the proof-of-Work, where the algorithm rewards miners who solve mathematical problems with the goal of validating transactions and creating new blocks, with the proof of stake, the creator of a new block is chosen in a deterministic way, depending on its wealth, also defined as stake". This means that a person can mine depending on how many coins they hold, thus making the blockchain more decentralized. However, not all users who hold coins are involved in mining, so it will be hard to build communites that validate around the coin [58].

2.1.6 Security

Security is an important aspect of blockchain technology, because all participants in the distributed ledger have access to the ledger through their own copy and there is no central authority safeguarding the data in the blockchain [46]. The security of the users is protected using public-key cryptography, as discussed in section 2.1.3. This also protects the privacy of the user, because no personal information is saved on the ledger. However, to prevent money laundering, terrorist financing and market manipulations, recently new users have to give their personal information to companies that sell cryptocurrencies [97].

This paper defines the security of a blockchain as the way in which the privacy of the participants and its governance is maintained and how the ledger is protected against forks and malicious attacks to steal or

modify data. As discussed in section 2.1.5,the distributed consensus mechanism of a blockchain prevents hackers from modifying data in the chain, because each transaction must be verified by the group of peers using the ledger, leaving fraudulent transactions unable to get into the chain [52]. Malicious users will have no chance of inserting fraudulent blocks into the ledger, since it immediately will be noticed by others.

Still, in public blockchains such as Bitcoin [11] and Ethereum [53] that use a Proof-of-Work mechanism as their consensus, it can be possible for malicious users to manipulate the blockchain using a technique that is called a "51% attack". A 51% attack may occur when a single user controls more computational resources than the rest of the network nodes, meaning that this user can manipulate the trust in the blockchain to his advantage, because it can act as if the majority of the peers agree to a transaction being validated [52].

Malicious Attack	Definition	Defensive & Preventive Measures
Double Spending	An individual makes more than one payment using one body of funds.	The complexity of the mining process
Record Hacking	Records in the ledger are modified or fraudulent transactions are inserted into the ledger.	Distributed consensus
51% Attack	A single miner node with more computational resources (51%) than the rest of the network nodes dominates the verification and approval of transactions.	Detection techniques; wide adoption of the blockchain technology
Identity Theft	The private key of an individual is stolen.	Identify and reputation blockchains
Illegal Activities	Parties transact illegal goods or commit money laundering.	Detection techniques; laws and regulations
System Hacking	The programming codes and systems that implement a blockchain are compromised.	Robust systems and advanced intrusion detection methods

Figure 2.10: Malicious attacks to blockchain and defensive measures [52]

In large blockchains such as Bitcoin it is very expensive to own 51% of the networks' computational power, but in smaller blockchains the risk does exist [27]. Currently, research is being conducted to improve the Proof-of-Work algorithm so it prevents centralization and reduces the risk of a 51% attack [8]. Figure 2.10 shows more forms of malicious attacks and their corresponding defensive & preventive measures.

2.1.7 Bitcoin

Bitcoin is the first decentralized currency developed by a person or group under the pseudonym S. Nakamoto in 2008 [11]. The biggest innovation of this decentralized currency was the solution to the double spending-problem; Proof-of-Work. Bitcoin introduced a peer-to-peer version of electronic cash that allows payments to be sent directly to another party without going through a financial institution. Almost all other current cryptocurrencies are based on bitcoin's open source code [9].
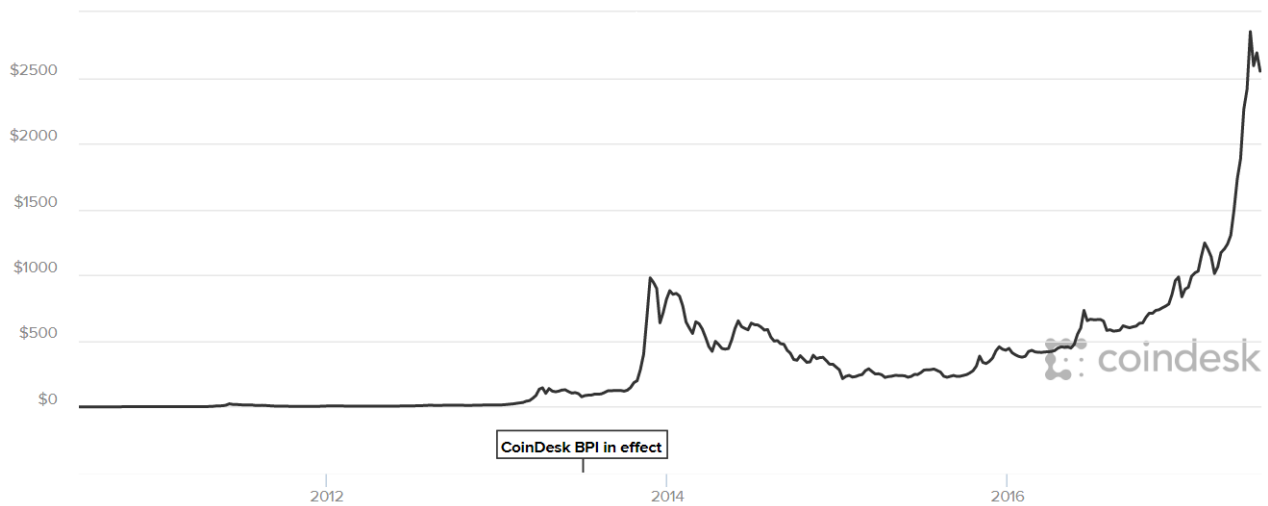
Figure 2.11: Bitcoin closing price from 2011 till 2016 [21]

2.11 illustrates the increase of the price of bitcoin from 2011 till 2016. The price has fluctuated considerably with the peak in 2014 being the most interesting one. Research has identified that the Bitcoin has a relationship with other fiat currencies such as the Chinese Yuan and the US dollar [27]. For example, the peak in 2014 was caused by the Cyprus banking crisis that drove a great deal of demand and by heavy trading done in China. Currently, still almost 85% of Bitcoin trading is done in China [18]. Other factors that can explain the high growth of Bitcoin are the widespread adoption of cryptocurrencies and governments trying to match up Bitcoin to their existing regulatory structures [27].

2.1.8 Smart contracts

One of the main benefits of blockchain technology is that the ledger itself can be programmed to trigger transactions automatically using "smart contracts" when conditions are met [12, 45]. C. D. Clack et al. [96] define a smart contract as "an automatable and enforceable agreement. Automatable by computer, although some parts may require human input and control. Enforceable either by legal enforcement of rights and obligations or via tamper-proof execution of computer code".
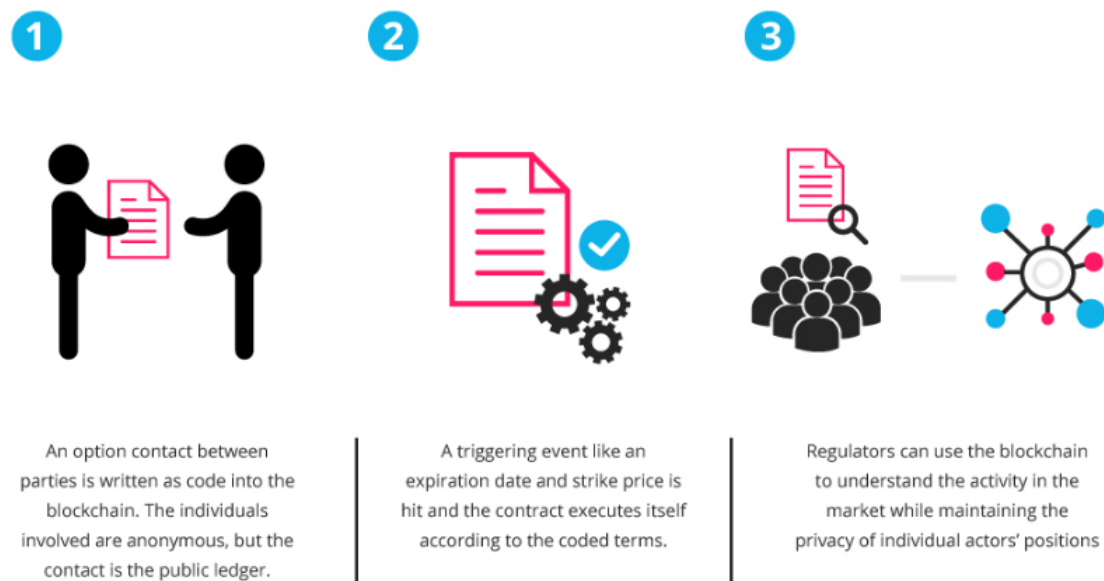
Figure 2.12: An application of a smart contract between two parties [41]

A smart contract is autonomous; once it is specified and running there is no need for anyone to check that process [12]. In addition, it is decentralized because of the blockchain, so it is not stored on one central database. The smart contract can connect with either internal input from the blockchain or with information from the external world, such as account balances or share prices [44]. Figure 2.23 describes an example of an application of a smart contract between two parties.

However, despite smart contract venture capital-related deals totalling $116 million in the first quarter of 2016 and accounting for 86% of blockchain venture funding, smart contracts are still in its early stages [43, 44]. Challenges that can be identified are scalability and interoperability with legacy systems [44]. In addition, because of the legal aspect of smart contracts, there are many regulatory challenges because governments still need to adapt to blockchain technology. Smart contracts are also not as flexible as real-world contracts yet and they cannot be fully governed yet.

Research has identified use cases for smart contracts in (overseas) supply chains, insurance and in the financial sector [44, 45]. In Figure 2.13 the lifecycle of a smart contract in the financial sector is illustrated. It can be seen that in the financial sector, regulators and validators are involved and data needs to be provided for compliance and reporting.
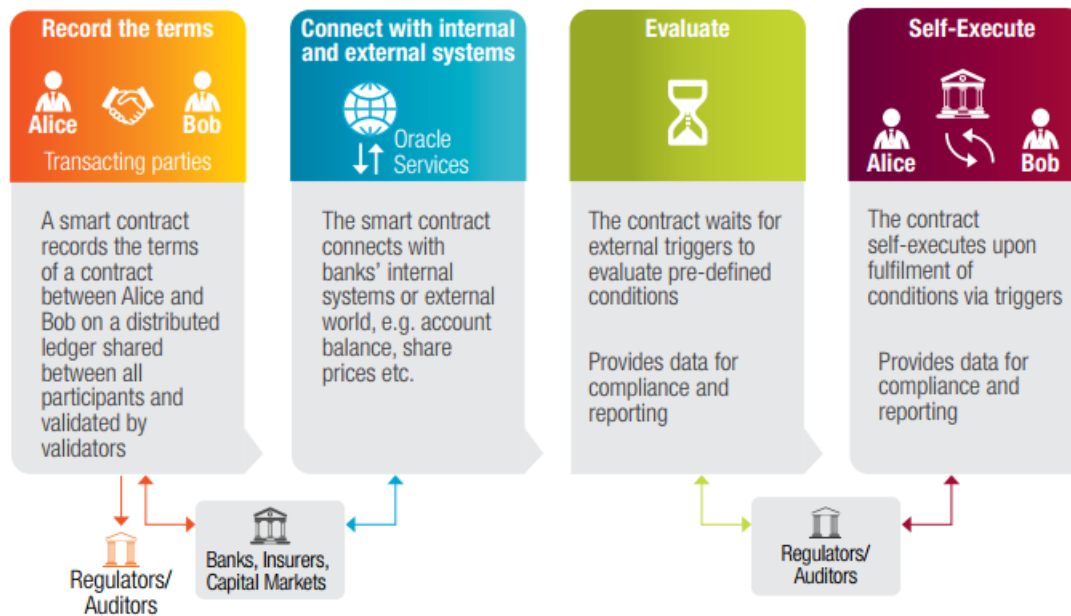
Figure 2.13: Smart contract lifecycle for the financial sector [44]

Recently, UBS conducted one of their first experiments with smart contracts in the financial sector resulting in the development of a so called "smart bond" [42]. They built an application on the Ethereum platform that can recreate the issuance, interest calculations and coupon payments of a bond. The issuer of the bond makes up a smart contract that is connected to the blockchain and specifies when coupon payments are made and for what amount [12]. Buyers can then allocate money to this bond by paying cryptocurrency to the bond address. When the bond is completely filled, the bond goes live and the smart contract triggers all payments of coupons on the coupon dates of the bond, without the need for any manual input. In addition, the value of the bond is automatically transferred to the issuer and the bond has the right to withdraw money from the account of the issuer to fulfill the coupon payments.

2.1.9 Blockchain platforms

This section discusses the current most widely used blockchain platforms in the industry to set-up a distributed ledger based on blockchain technology. This study has looked at tools that can set-up a private and permissioned blockchain and offer support for smart contracts. This is because in preliminary research, it was evident that these are important properties for the financial sector [12, 44]. In addition, this paper has looked at how these blockchain platforms are used by other companies in the financial sector, because as of now, different blockchain platforms do not integrate with each other. For example, a distributed ledger set up using Corda cannot interact with a distributed ledger that was created using Ethereum, because both have a very different technical implementation of blockchain technology.

At the end of 2016, Coindesk published their yearly report on blockchain technology. In this report [51] they provide a detailed analysis of blockchain platforms that provide solutions to create private and permissioned blockchains. Below, the results of this report are summarized. Section 3.4 discusses how this information has

been used to select the blockchain platforms for our research.

1. **Ethereum**. Ethereum is known from the public blockchain, but they also offer software to build your own private and permissioned blockchain. The organisation is mature (started in 2013), and some developers behind it are very much involved in research on blockchain technology and are known in the blockchain world. Many projects are already made on this blockchain platform and the open source community is huge. In addition, many giant organizations such as J.P. Morgan, microsoft and Intel have united to build business-ready versions using this software.

2. **Chain**. Chain provides permissioned and private blockchain services for enterprise businesses. Milestones last quarter were Visa introducing international B2B payment solution built on this technology and Chain launching the open source developer platform. Privacy and confidentiality is important on this blockchain and is provided by a special type of encryption. The organization is not as mature as other blockchain platforms such as Ethereum.

3. **Digital Asset**. Digital Asset is a blockchain software provider focused on distributed asset settlement. Milestones last quarter were the release of a detailed white paper of their platform and them patenting a method to trade a wide range of assets on a distributed ledger. The platform uses a special language to help enterprise blockchain frameworks improve smart contract services and the white paper reveals that the platform reduces risk, cost and capital requirements involved in processing financial transactions. The organization is not as mature as other blockchain platforms such as Ethereum.

4. **Hyperledger**. Hyperledger is an open-source cooperative managed by the Linux Foundation creating permissioned distributed ledger platforms to help financial institutions mitigate settlement risk and lower cost. Milestones last quarter were them having a 105 partner organization, 30% member growth and 28 media mentions. In addition, they provide different blockchain frameworks developed by growing communities from the entire industry. One of them is Hyperledger Fabric; it enables confidentiality and scalability in business environments, which is important for the financial industry. The project started at around 2015-2016, so the organization is not very mature yet.

5. **Ripple**. Ripple allows banks to offer real-time cross-border payments to their customers. In addition, you can use this technology to build your own private and permissioned blockchain. The code is open-source and there are many contributors. Many banks are cooperating with Ripple so that this technology can be used for cross-border payments between banks. This technology is primarily focused on payments between banks, dramatically reducing cost and settlement time. Ripple is a mature organization and has been working on distributed ledger technology since 2012.

6. **R3 Corda**. Corda is a permissioned and private blockchain technology made by R3, a company that is leading a consortium of 70+ financial institutions. They are currently open-source and have a lot of media mentions. R3 is working on many proof-of-concepts with financial institutions, such as a know-your-customer identity registry system. Corda is made for the financial sectors, with the focus on enforcing business and financial agreements between companies through smart contracts. In addition,

regulation and governance is very important to R3. Corda became open-source at the end of 2016, so the community has not grown very large yet. R3 itself has been working on blockchain technology since 2014.

2.2 Asset management

This section will review the relevant literature related to asset management. First, definitions regarding asset management will be discussed an an overview of the industry will be given. Then, key trends and drivers for its powerful growth in the last decade will be identified. In addition, the core business processes of an asset management company will be considered.

An asset management company manages the assets of individuals, pensions or corporations and uses these assets to generate a greater return than regular savings through investments and trades in stocks, bonds and other investment vehicles [77]. In addition, the company also fulfills the needs of clients who want to pursue banking and investment options themselves, with access to a financial advisor and no transaction fees. Asset management companies have dedicated researchers, investors and portfolio managers as well as access to detailed equity related research which should give them an advantage over regular investors [78]. They usually charge a fee or take a percentage of the profits for their service.

2.2.1 Asset management industry

The asset management industry is growing rapidly; the global assets under management (AuM) have increased at an annualized pace of 5.9% since 2005, reaching $63.9 trillion in 2013, see Figure 2.14 [70]. In this highly competitive and mature industry, the firms vary and range from large independent asset managers to commercial banks, insurance companies and brokerages, all offering asset management services [4].

Figure 2.14: Growth of the gobal assets under management [70]

Research has highlighted major trends that can explain this large growth in the asset management industry. Demographic trends have had a transformative impact; emerging markets continue to drive almost all of the global industry's flows [71]. In addition, pensions have been a great opportunity for asset managers because

of the diminishing role of governments concering pensions and social securities. Also, driven by smaller instutional investors, many investment alternatives have arised for the asset management industry. However, in the aftermath of the financial crisis in 2008, regulation has increased drastically, leading to higher costs because of more strict compliance procedures, slowing the effect of all these trends [72].

According to research done by PricewaterhouseCoopers [73], "Global investable assets for the asset management industry will increase to more than $100 trillion by 2020, with a compound annual growth rate of nearly 6%". They discuss that AuM in the South America, Asia, Africa and Middle East (SAAAME) will grow faster than developed countries and retirement assets will continue to represent a great amount of the AuM. However, asset managements commercial costs will rise and and fees earned by asset managers will be under continued pressure. [73].

J. van Oerle and P. Lemmens [72] discuss socio-demographic trends that can impact asset management, see Figure 2.15. The blue outer circle represents the demographic changes that can have a positive impact on the asset management industry and the orange inner circle represents the social trends. These social trends can either support or counter demographic developments. An example would be the increasing influence of the developing worlds in combination with cultural differences; the asset itself shifts towards developing countries, but in emerging markets the attitude towards investing is very different than in the developed world [72]. Investing is sometimes seen as gambling and not as a tool to accumulate long-term wealth.

Figure 2.15: Socio-demographic trends impacting asset management in the coming years [72]. The blue outer circle represents the demographic changes that can have a positive impact on the asset management industry and the orange inner circle represents the social trends. These social trends can either support or counter demographic developments.

Investments in technology and data management will also need to be maintained to benefit from new technologies and to cope with the increasing demand for regulation and reporting [73]. In addition, trends

such as Big Data and cloud computing can deliver a lot of value for asset managers in the future. Currently, the asset management industry is ahead in developments in the processing of data, but it is far behind in using technology to better interact internally and externally with clients [72]. Asset managers have to watch out for the FinTech industry; companies and startups that use new technology and innovation in order to compete with traditional financial institutions [82]. 60% of asset managers fear losing part of their business to these companies [74].

2.2.2 Business processes

According to M. Hammer and J. Champy [75], a business process is defined as "a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer". In this paper it is important to make a distinction between different types of business processes, because its scope is limited to the *core* business processes of an asset management company. Literature discusses three types of business processes [7]:

1. **Management processes**. These are processes that govern the operation of the system and coordinate the activities of the operational and supporting processes strategically and do not provide value directly to the customer.

2. **Operational processes**. These are the core processes that create the primary value stream and are the primary means by which an organization enables the business it is in. They provide value directly to the customers and reflect the core competencies and value adding-activities of an organization [76].

3. **Supporting processes**. These processes support the core processes and don't provide value directly to the customer, examples are HR and accounting.

2.2.3 High level model

Figure 2.16 below shows a generic, high level business function model of an asset management company divided into front office, middle office and back office functional areas; this model has been used to find the core business processes of an asset management company [79]. The blue parts in this figure refer to the supporting processes of the company and are thus not in our scope. However, some of these processes very important for an asset management company are considered important for the asset management company [69]. In the red squares in Figure 2.16, the processes that have been looked at in this research are illustrated. This study limits its scope to these business processes because through preliminary literature research and talks with people in the blockchain team inside the case company it has been evident that these processes can deliver the most value to an asset management company using blockchain technology [12, 29, 69].
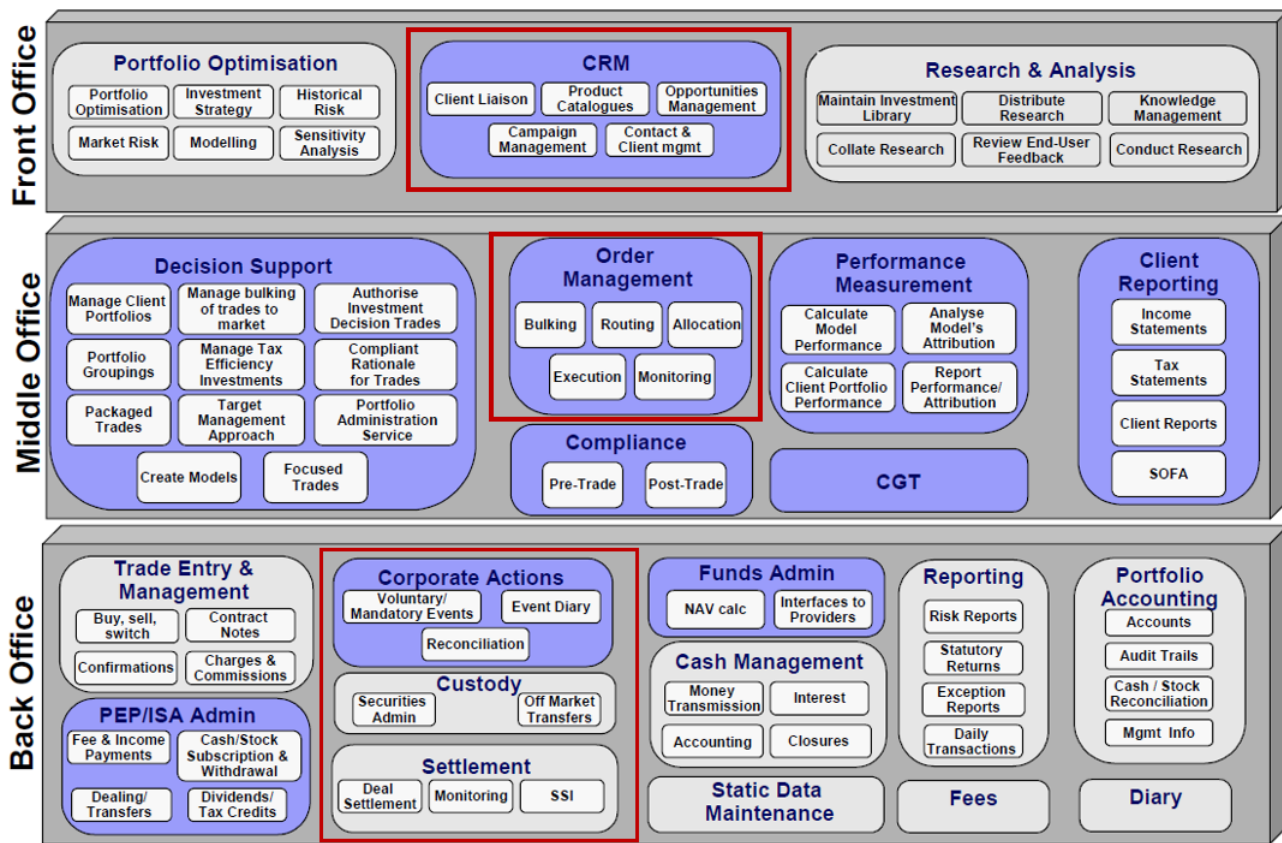
Figure 2.16: Asset Management: High-level functional model [79]

The definitions of front, middle and back office vary between organisations. The front office is the interface with the market where the trading happens; all pre-trading and trading execution activities are done here [80]. The middle office is sometimes categorized under the back office and is mostly composed of risk management, they calculate profit or loss of each deal transacted by the front office [81]. The back office monitors and processes all transactions. Back office processes include confirmation, payment, settlement and accounting; they provide support services to the employees at the front office.

2.2.4 Trading

All of the processes in Figure 2.16 support the core business of an asset management company; managing assets in such a way to maximize the return of trading. In Figure 2.17 the required actions in trading of an asset management company are illustrated; the pre-trading and execution occurs in the front and middle office and the post-trading in the back office. The efficiency of the information systems used in this process is measured by the Straight Through Processing rate (STP). This is the rate of the amount of transactions that processed with little or no manual intervention [80].
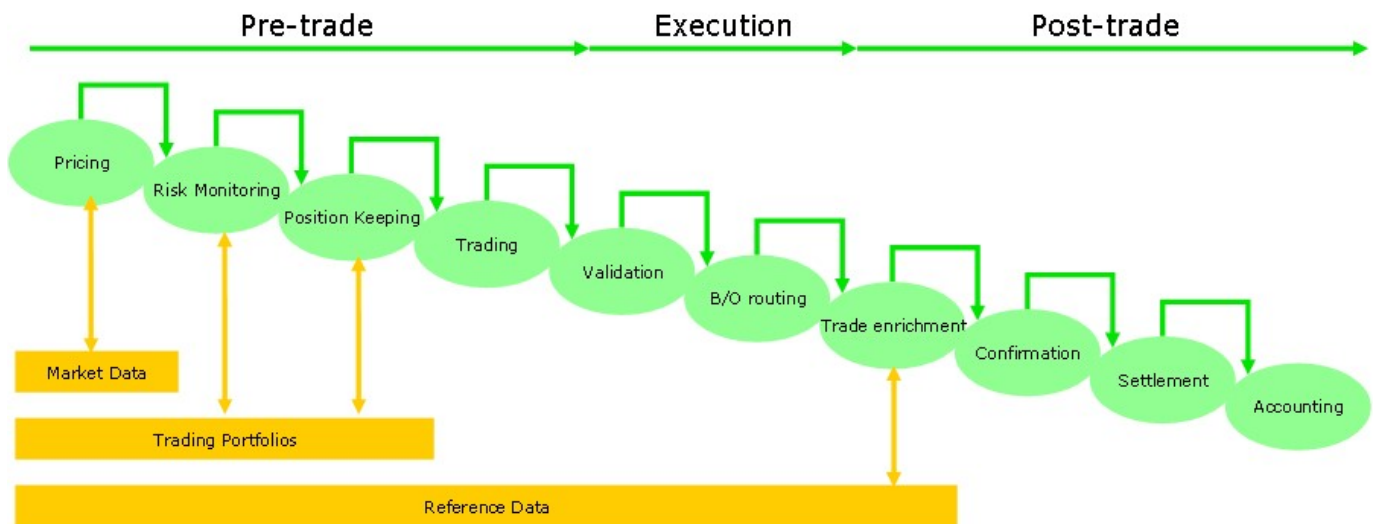
Figure 2.17: Required actions from pre-trade to post-trade [80]

This paper will now dive deeper into this trading process and identify important processes and parties involved here. However, this study will not discuss the identified processes in too much detail and its scope will mostly be limited to the role of the asset management company. In Figure 2.18 a high level view of the trading process of securities including relevant parties is illustrated. A security is defined as "a financial instrument that represents an ownership position in a publicly-traded corporation (stock), a creditor relationship with governmental body or a corporation (bond), or rights to ownership as represented by an option. A security is a fungible, negotiable financial instrument that represents some type of financial value" [84].

The process begins with with the asset management company taking on the role as either the seller or the buyer; the seller wants to sell a security and the buyer offers something in return. However, how does a seller find a buyer or a buyer find a seller? This happens on a trading venue; buyers and sellers come here together in one place to maximize the chance of matching them with each other [83]. Buyers and sellers do not want to travel to a London or New York stock exchange market themselves whenever they want to make a trade. As a result of this, brokers were introduced; people that go to the stock market on your behalf to get the best deal for you [83]. This overall process of people finding a deal for their trade is called the *trading process*.
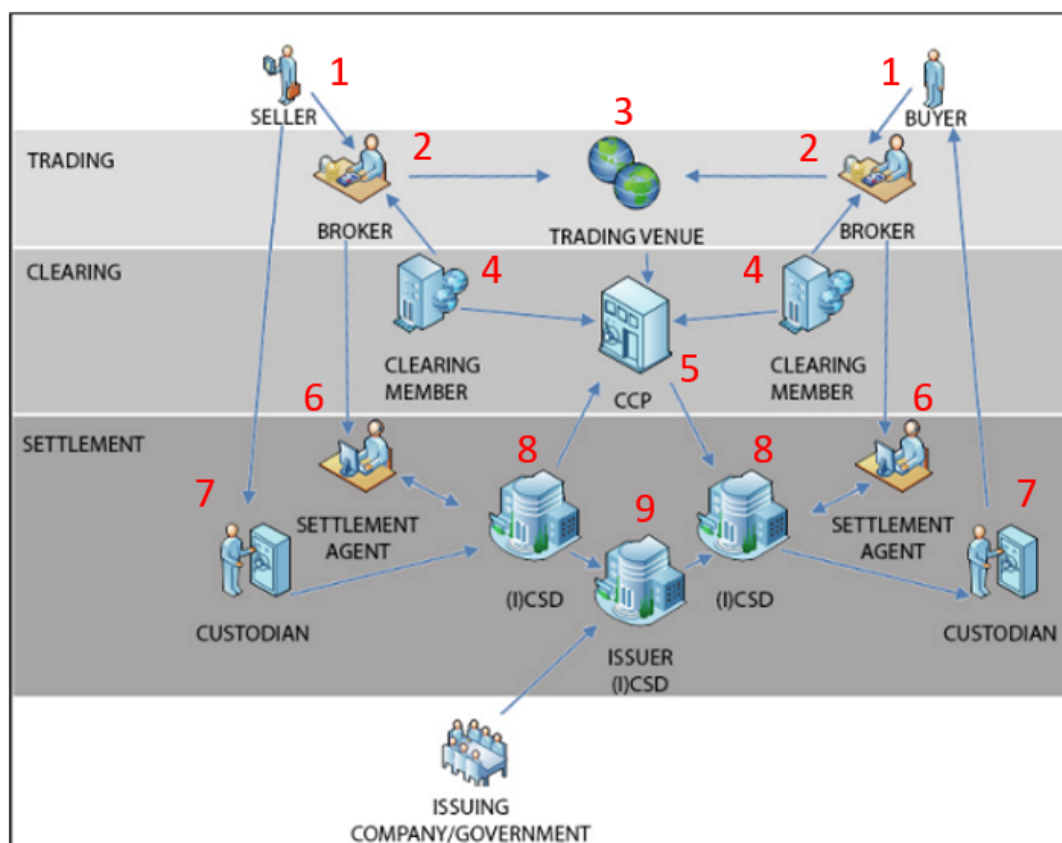
Figure 2.18: Trading processes including relevant parties [29]

At this moment, the broker is trusted with our certificate of the security and that he takes the right receipt of the financial assets from the buyer. In addition, this broker has been trusted to correcly respond to corporate actions such as collecting and reporting about issued dividends by the stock company; section 2.2.6 will further elaborate on the topic of corporate actions [83]. Because of the above reasons, custodians and settlement agents were introduced; they look after the accounting, book-keeping, security and reporting of a company's securities. This process of delivering the securities to the right place at the right time is called the *settlement process* [29]. There are many different companies that act as a custodian. Therefore, central security depositories (CSD) are utilized by the securities to make sure the shares move properly between custodians [83].

It can be chaotic and difficult for brokers, who are making trades all the time, to completely agree on the details of a trade and make sure they have matching settlement instructions [83]. In addition, the broker needs to know for certain that the seller can lay their hands on the shares and the seller wants to make sure that the buyer has got enough assets available for payment.

Clearing members solve these problems; after a trade is matched, the information is sent to the clearing house and they will get everything ready for the settlement process. The clearing house will now be fully responsible for the trade and if, for example, the seller turns out to be a fraud, it's now the clearing house's problem. Thus, it can be seen that the clearing house acts as a central counterparty (CCP). We call this overall process the *clearing process*. The clearing house instructs the brokers of all the obligations and the broker makes sure the settlement agents and custodians get the securities to the right place [29].

25

It is evident that this is a complicated process and a lot of intermediaries are needed. Of course, all of these intermediaries ask for a fee for their services, limiting the profit of the asset manager. In addition, this whole process takes about two days at best, because all of these intermediaries keep their own records on a centralized ledger and there is a lack of interoperability between these systems [12, 29].

A. Pinna and W. Ruttenberg [29] consider a scenario for blockchain technology in the trading process where institutions embrace the new technology to improve efficiency, leaving business practice "as it is". Because of the highly regulated market, they argue this will be a likely scenario where the existing business arrangements can be imagined to be replaced by a system made up of different *internal* distributed ledgers, with little effect on the institutions involved, see Figure 2.19. The only breakthrough here will be that the change in ownership of a security will be processed near real-time using the distributed ledgers.
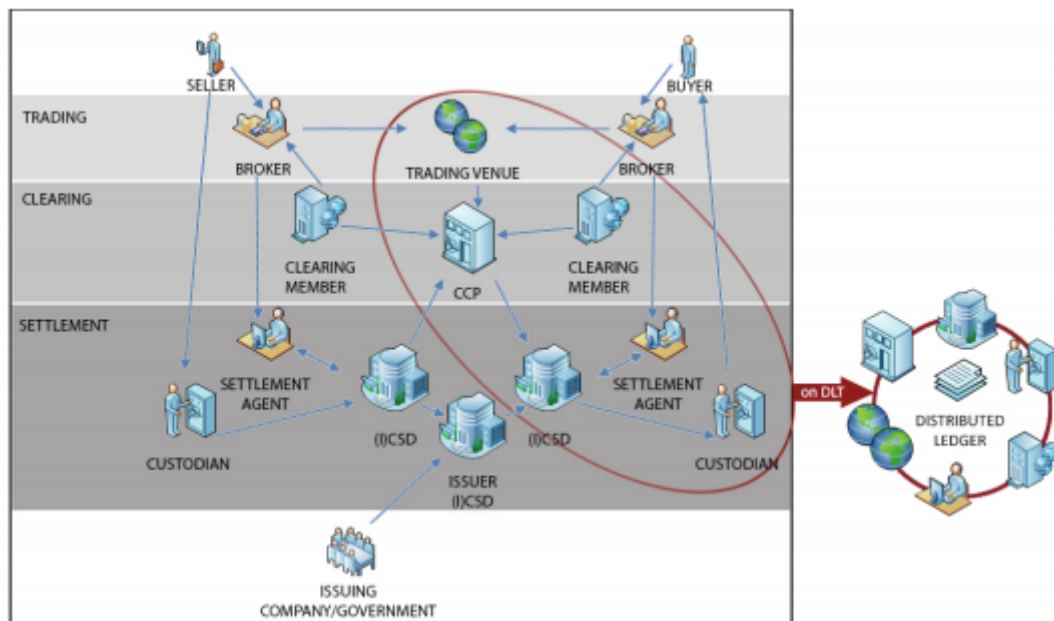
Figure 2.19: How a distributed ledger may affect the trade process on the buy-side, assuming current business practice continues [29]

2.2.5 Know your customer

Because an asset management company manages the financial asset of their clients for trading, it is important for them to know the wishes of their client in detail; there are many different strategies that a trader can follow, depending on the client's risk tolerance and profit target [85]. This process of analyzing the wishes of your clients and knowing detailed information about their risk tolerance, investment knowledge and financial position is known as the *Know Your Customer (KYC) process* [86]. Financial institutions are required to perform this process before engaging in financial transactions with their clients [88].

In addition to getting to know your customers wishes, asset management companies must use their KYC process to make sure that the client's money is legitimate and not acquired from crime or corruption [88]. They have to be sure that they are not involved in money laundering; the process by which criminals attempt to

hide and disguise identity, source or origin and ownership of the proceeds of their criminal activities, with aim of avoiding prosecution, conviction and confiscation of the criminally acquired funds [89]. See Figure 2.20 for an example of an overview of a KYC and AML process.
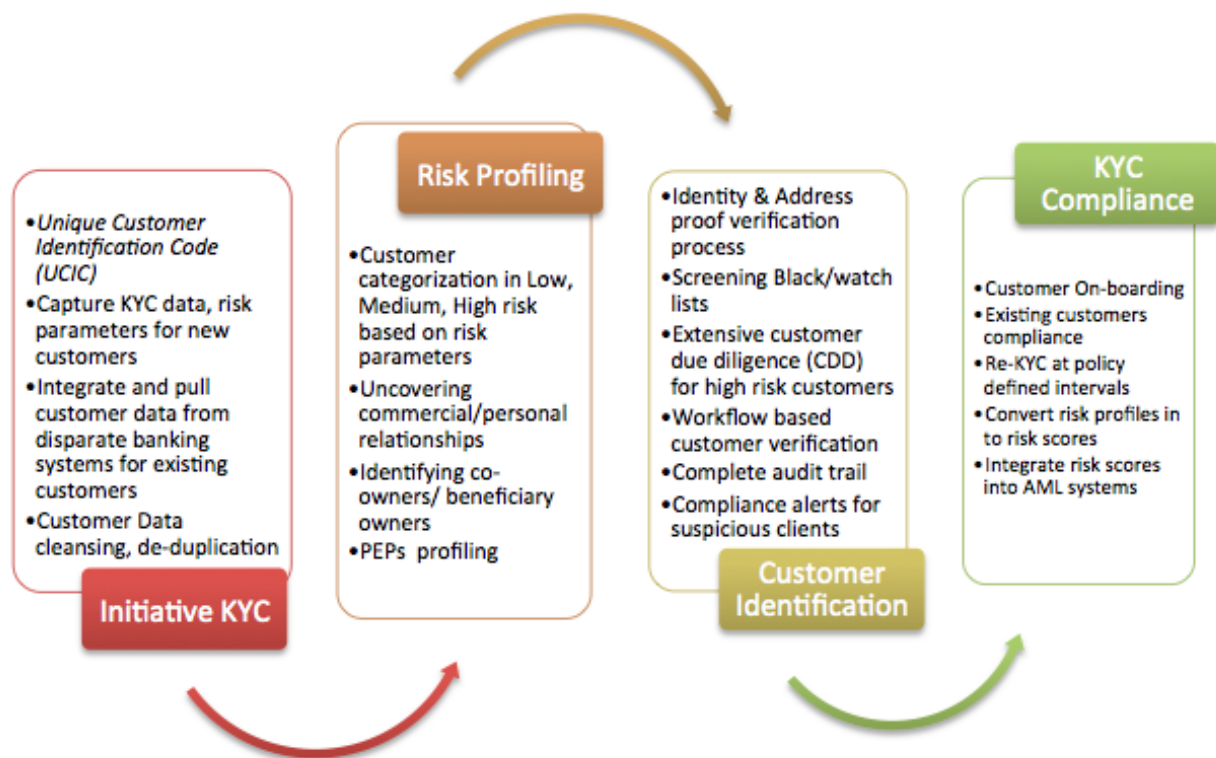
Figure 2.20: Example of a Know Your Customer process [91]

KYC and AML regulations have increased in the last years, leading to longer client onboarding times and increased resources needed by the asset management company to collect, verify and maintain KYC and AML records [87]. In addition, there is no standardized KYC policy across asset managers and each of them interprets it differently.

KYC and AML can take long; some requests can take between 30 and 50 days to complete and involve a lot of double work at different organizations [92]. Also, in 2014 it was estimated that the AML compliance costs alone were estimated to be $10 billion [93].Below, the current challenges in the KYC process found by J. Plein, chief operating officer at Fullerton Fund Management [87], are summarized.

- KYC and AML workflows are mostly paper-based and not digitized
- No standardized policy across banks and asset managers
- KYC and AML is done many times on a single client by different firms
- Growing concern about sensitive client data; who can access it and how it is protected

Preliminary research on blockchain technology in the trading process has shown that there are potential benefits for asset managers, see Figure 2.21. J. van de Velde et. al. [112] from Oliver Wyman, a global consulting company, argue that "many clients (particularly on the buy side) will expect to accrue the most benefit, from the reduction in costs of capital markets dealing and securities servicing. Retail and wholesale investors may

transact more among themselves, now with guaranteed execution on open markets"; in this case the clients are asset management companies.

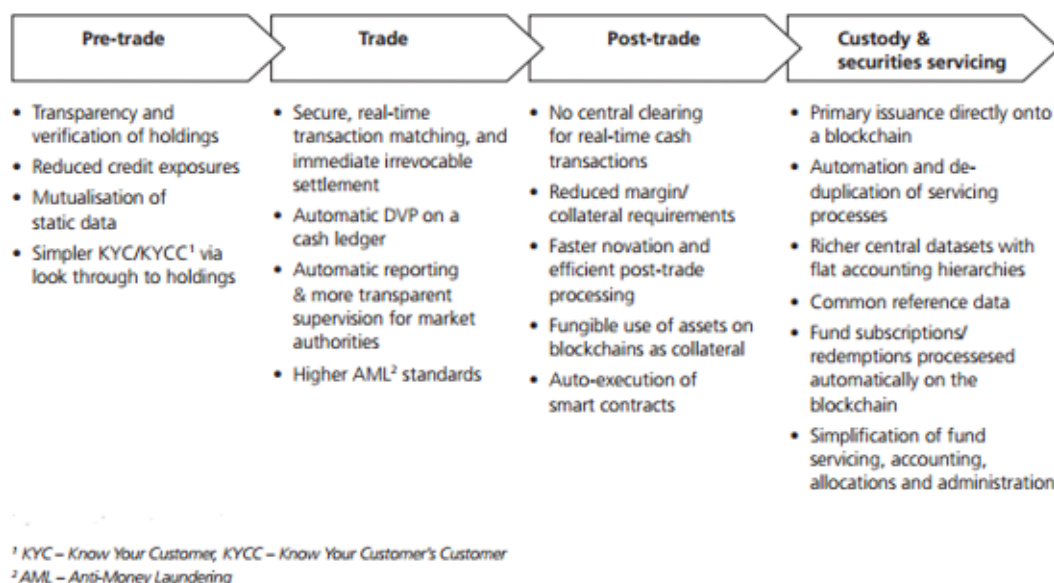| Pre-trade	Trade	Post-trade	Custody & securities servicing
• Transparency and verification of holdings • Reduced credit exposures • Mutualisation of static data • Simpler KYC/KYCC[1] via look through to holdings	• Secure, real-time transaction matching, and immediate irrevocable settlement • Automatic DVP on a cash ledger • Automatic reporting & more transparent supervision for market authorities • Higher AML[2] standards	• No central clearing for real-time cash transactions • Reduced margin/ collateral requirements • Faster novation and efficient post-trade processing • Fungible use of assets on blockchains as collateral • Auto-execution of smart contracts	• Primary issuance directly onto a blockchain • Automation and de-duplication of servicing processes • Richer central datasets with flat accounting hierarchies • Common reference data • Fund subscriptions/ redemptions processesed automatically on the blockchain • Simplification of fund servicing, accounting, allocations and administration

[1] KYC – Know Your Customer, KYCC – Know Your Customer's Customer
[2] AML – Anti-Money Laundering

Figure 2.21: Benefits of blockchain adoption [112]

2.2.6   Corporate actions

Section 2.2.4 discussed that collecting and reporting about issued dividends by the stock company is an example of a corporate action. However, there are many more corporate actions that can be identified in the world of trading. A full overview of all sixty types of corporate actions is beyond the scope of this study; Only the most common corporate action types for an asset management company will be identified [99]. According to J. Femia and C. Wyle [94], "A corporate action occurs when changes are made to the capital structure or financial position of an issuer of a security that affect any of the securities it has issued".

Corporate actions are one of the most manual and complex back-office operations and information received may be conflicting, confusing and incomplete, because it must wind its way through many firms [94]. In 2013, B. Farrel, executive vice president of Sungard, a financial services and solution company, estimated the amount lost through missed or mismanaged corporate actions events to be one billion dollars annually [98].

In 2004 the amount of corporate actions that took place was estimated to be around one million [95]. Given that each corporate action may affect thousands of stakeholders and that processing these actions involves several organizations, you can see that corporate actions require huge effort [100]. A survey by SWIFT [101] found that almost 25% of asset managers reported an increase in employees needed to process corporate actions in the period from 2012 to 2015. Research classifies three categories of corporate actions [95]:

1. **Mandatory actions**. For these actions, such as cash dividend and interest payments, no action is required by the investor or its intermediaries.

2. **Mandatory actions with options**. These actions are mandatory, but a choice needs to be made, for

example, if you want to receive dividends in the form of further units of the security or in cash.

3. **Voluntary actions**. The investor has the choice of whether they want to participate in the action.

In Figure 2.22 a high-level view of the information flow in the *corporate action process* is illustrated. The process starts with the issuer, also known as the stock company, that issues a corporate action, for example, a cash dividend. The CSDs, custodians and other external data providers (companies that specialize in corporate action information) will receive this information and insert it in their systems in their own format. They will send this information to the broker which will then send the information to the asset management company that owns the stock [106].

Currently, this process can take several days to complete and it is estimated that missed or mismanaged corporate actions events cost the industry one billion dollars every year [113]. A lot of these processes still have to be done manually and in a recent survey by SimCorp [109], 78% of respondents said manual processing of corporate actions was the top reason for corporate actions failure. Also, there is no standard for delivering information about corporate actions; the data is delivered in different formats by different custodians [113].

Sometimes, the stock company changes the cash dividend the day after it was issued. However, because some custodians are still processing the old issued cash dividend at the time the issuer changes it, the asset management company receives old information about the corporate action. Because all of the participants in the corporate action chain have their own internal systems, the asset management company will receive different information from their custodians, not knowing which amount of cash dividend is the truth [69]. A distributed ledger could help here by presenting one "golden source" of information that all the participants in the corporate action chain can access.
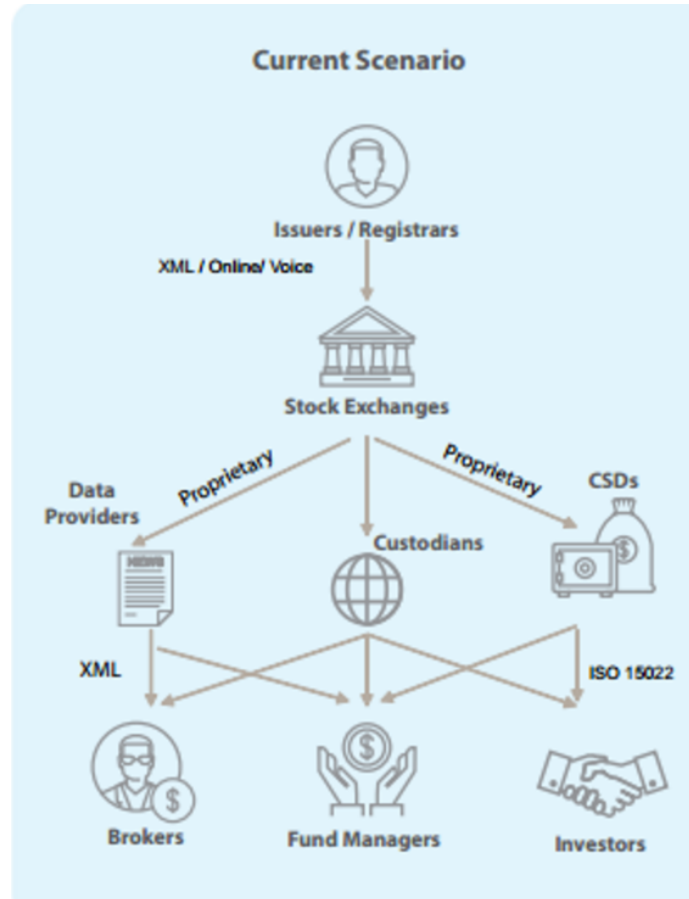
Figure 2.22: Market participants involved in the corporate action chain [106]

Internal data and research identified the three most common types of corporate actions processed by the case company [69], see Figure 2.23. The top three corporate actions are described below in more detail.

1. **Cash Dividend**. A cash dividend is an amount of cash distributed to the shareholders depending on their equity holding [100]. This is a mandatory action.

2. **Dividend Reinvestment**. A dividend reinvestment allows investors to use their dividends to buy additional shares instead of receiving the cash [100]. This is a voluntary action.

3. **Exchange Offer**. This is an offer of one security for another, typically this happens when a takeover occurs and the acquirer wants to have all of the securities of the company that he is taking over [100]. This is a voluntary action.

Figure 2.23: Amount of corporate actions processed by the asset management company since January 2016 [69]

2.2.7 Summary

This section provides an overview of all the business processes that have been discussed, see Table 2.1.

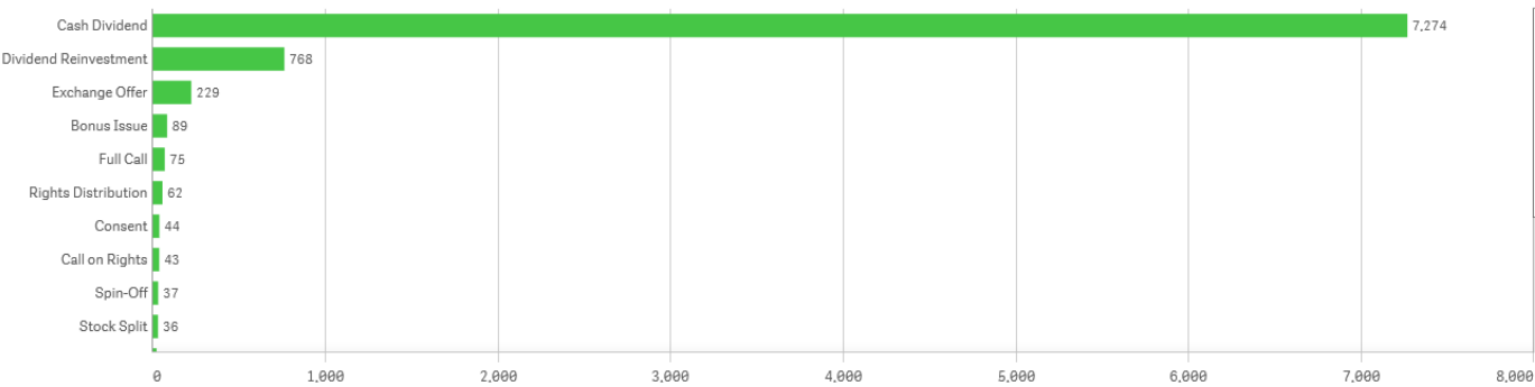| Business Process	Description	Challenges and issues
Trading/matching process	This is the process of brokers coming together on a trading venue and finding a deal for their trade.	• Seller and buyer have to communicate with each other through several intermediaries, which costs time [83]
Settlement process	The process of custodians and settlement agents, together with the asset management company and the brokers, delivering the securities and financial assets to the right participants at the right time [29].	• Many intermediaries are needed [12] • This process, together with the clearing process, takes about two or three days at best [12] • Lack of interoperability between systems of participants [29]
Clearing process	Clearing members help brokers, who are making trades all the time, to completely agree on the details of a trade and make sure they have matching settlement instructions; this is called the clearing process [83].	• Lack of interoperability between systems of participants [29] • This process, together with the settlement process, takes about two or three days at best [12]
Corporate actions	According to J. Femia and C. Wyle [94], "A corporate action occurs when changes are made to the capital structure or financial position of an issuer of a security that affect any of the securities it has issued".	• Many manual operations [94] • Information received by parties may be conflicting, confusing or incomplete [94] • The process can take several days to complete [113] • Mismanaged corporate actions cost the industry one billion dollars every year [113]
Know Your Customer	Analyzing your client's wishes making sure their money is legitimate [86,88].	• Paper-based process and no standardized policy [87] • Growing concern about sensitive client data; who can access it and how it is protected [87]

Table 2.1: Summary of the discussed business processes

Chapter 3

Approach

This chapter describes the research design and approach of this paper. In addition, the research methodology and techniques that were used for our data collection will be explained.

3.1 Research method

This paper followed a qualitative and quantative case study research methodology at a small to medium sized asset management company. Case study research enables the researcher to perform the study in a natural environment, and gain knowledge of the business processes in an organization and create theories from practice. Because not a lot of research had been conducted yet on blockchain and it still was an immature technology, as indicated by the Gartner's hype cycle, a case study research was approriate [6,61]. This approach enabled us to get answers on the "which" and "how" questions in order to explore and comprehend the complex processes that come from blockchain technology and the asset management industry [2].

For its data collection, this study made use of semi-structured interviews with people from different departments to get a better understanding of the core business processes inside an asset management company. A semi-structured interview is defined by a pre-set of questions and aims to provide in-depth findings through informal discussions with participants [60]. For this method was chosen because blockchain is still an immature technology, and therefore some people do not have a lot of knowledge about it. Interviewees would likely provide interesting data in different areas of the case company, but it was not sure who whould provide which information.Therefore, this study started the interviews with a list of topics that needed to be discussed, but explored interesting areas that came up during the interview in more detail.

In addition, this study made use of quantitative experiments and simulations inside this case study to review the tools that can be used to set up a distributed ledger. Using criteria as will be discussed in section 3.4, the best blockchain platform is that can be used for the core business processes of an asset management company have been determined.

3.2   Case study

This has been conducted at an international asset manager offering an extensive range of active investments, from equite markets to government bonds. The company believes strongly in sustainability investing, quantitative research techniques and adding value for clients through innovative investment techniques. In addition, this company has a broad and deep knowledge in quantitative research, especially investments. The company manages up to 137 billion EUR (December 2016) and employs 879 people at sixteen offices worldwide.

3.3   Research design

The main research question for this paper is "What are the best tools to set up a distributed ledger based on blockchain technology for the core business applications of an asset management company?". Clearly, this question has an IT and a business perspective; the study needs to look at the technical side of blockchain, but also thoroughly understand the core business processes of an asset management company.
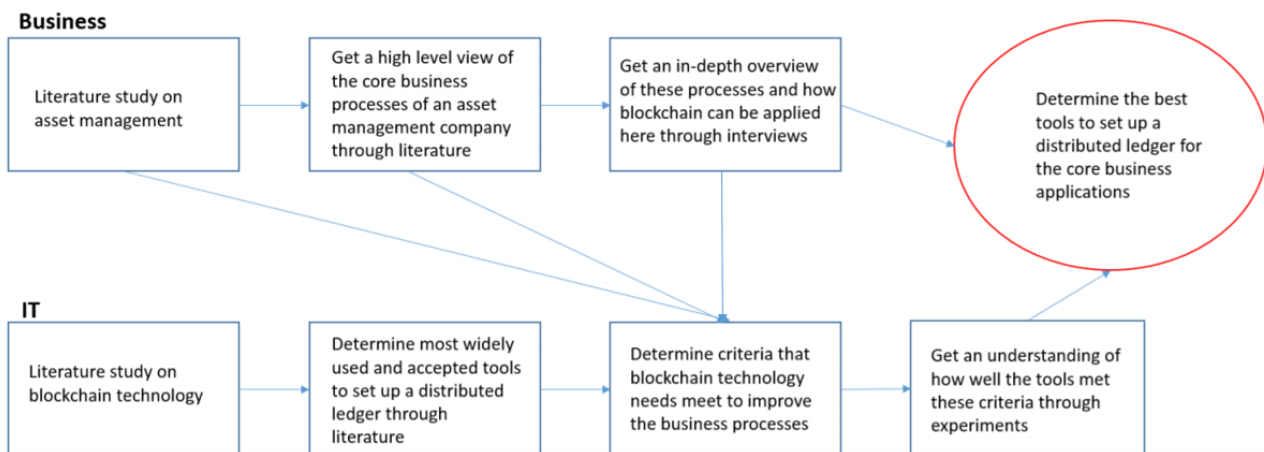
Figure 3.1: Research design

As can be seen in our research design in Figure 3.1, this study started with a literature study on blockchain technology and the core business processes of an asset management company. On the business side, a scope was first determined through literature study to find what the core business processes of an asset management are. Thereafter, a deeper understanding of how these processes work and how blockchain can be applied here was needed. section 3.5 will further elaborate on this topic.

On the IT side, a scope had to be determined of what the most widely used and accepted tools are to set up a distributed ledger, because experiments had to be conducted with them in a later phase. After this, the knowledge that was gathered on the business side had been used to determine criteria that blockchain technology needs to meet to improve the business processes of an asset management company. Once this had been determined, simulations were performed and experiments were conducted with these tools to get a better understanding of how they meet the determined criteria. Section 3.4 will further elaborate on this.

3.4 IT

This section discusses the configuration of our experiments. In addition, the blockchain platforms will be discussed that were taken into our scope and criteria that blockchain needs to meet to improve the business processes of an asset management company will be determined.

3.4.1 Scope

In section 2.1.9 we have discussed the current most widely used blockchain platforms in the industry to set-up a distributed ledger based on blockchain technology. In this study, we have chosen to limit our scope to three blockchain platforms, because this narrow scope allows us to analyze the blockchain platforms in great detail. One of the most important factors we took into consideration when evaluating a blockchain platform was the usage of the platform by other financial institutions. This is because we have seen that different blockchain platforms do not integrate well with each other, and for a distributed ledger to work, all participants in the business process need to work together. For example, a distributed ledger set up using Corda cannot interact with a distributed ledger that was created using Ethereum, because both have a very different technical implementation of blockchain technology.

In this study, we have decided to look at Ethereum [53], R3 Corda [63] and Hyperledger Fabric [62]. We have chosen for Ethereum because the organisation is very mature and many projects are already built on this project. In addition, large institutions have united together to build business-ready versions of this software. We did not decide to use Chain or Digital Asset for our study, because the organizations are not as mature yet and not many other financial institutions are using it.

Hyperledger was very interesting for our research, because of the large partner organization and their focus to help financial institutions mitigate settlement risk and lower costs. We decided to choose the Hyperledger Fabric framework, because it enables confidentiality and scalability, which is important for the financial sector. In addition, Hyperledger Fabric offers many tools to make good use of smart-contracts.

Ripple is a very mature organization and has many partners. However, the technology is focussed on transactions between banks, while our study primarily focussed on processes involving asset management companies. Corda is perfect for our study, because of the high amount of media mentions and the many financial institutions that are joining in. This platform is made for the financial sector and has a focus on enforcing financial agreements between companies through smart contracts.

3.4.2 Experiment configuration

We have created an application for these blockchain platforms, implementing the same functionalities for each of them. This way, we can compare the different blockchain platforms and analyze their behaviour for each

functionality. In Table 3.1 you can see all the functions that we want to implement for each blockchain platform and in Figure 3.2 and 3.3 you can see the design for our web page.

Function	Description
init()	This function will initialise the connection with the blockchain.
getTransactions()	This function will retrieve the five latest transactions that were carried out on the blockchain. It should return the receipt address, sender address, blocknumber, timestamp and the amount that was sent.
getBlocks()	This function will retrieve the five latest blocks that were added to the blockchain. It should return the blocknumber, timestamp and transactions that are linked to this block.
getBlock(blockNumber)	This function will take a blocknumber as input, and retrieve the information about this block. It should return the blocknumber, timestamp and transactions that are linked to this block.
getInfo()	This function will retrieve information about the blockchain. It should return whether the network is online, the total amount of money in the chain, the latest blocknumber and the current time.
getBalance(accountNumber)	This function will take an accountnumber as input and should return the balance of this account.
getTransactionHistory(accountNumber)	This function will take an accountnumber as input and should retrieve the receipt address, blocknumber, timestamp and the amount sent of the five latest transactions.
sendTransaction(fromAddress, toAddress, privateKey, Amount)	This function will send a transaction to a user from a given account. Using the private key of this account, we can confirm that this is the owner of the account and send the transaction.
setAccountNumber(accountNumber)	With this function we can set an accountnumber as the default account in our webserver, so it can be remembered when executing other functions.

Table 3.1: Functions to be implemented for each blockchain platform

There are many different functions that can be executed on a blockchain; in the case of Ethereum, there were over a hundred functions available [68]. Many of these functions are only useable for smart contracts, which

is not in our scope of this research, because this takes too much time to implement. The other functions mostly focus on validating, retrieving and sending transactions. However, in this research we focus on the retrieving and sending transactions functions, because the validation can be done automatically by nodes on the blockchain server.

We wanted to create an interface for the end-user, people from the business or clients, which have nothing to do with validating blocks, but do want to see an overview of the blocks and transactions in the blockchain and experiment with sending transactions. Research has shown that user interfaces that can enable applications of blockchain solutions without any coding skills skills are an important aspect if blockchain is to go mainstream [17].

All of the blockchain platforms that we have experimented with are open-source, meaning their source code is made available to the public, and have an application programming interface (API) that can be used for building applications [67].

Figure 3.2: GUI design of the Admin page
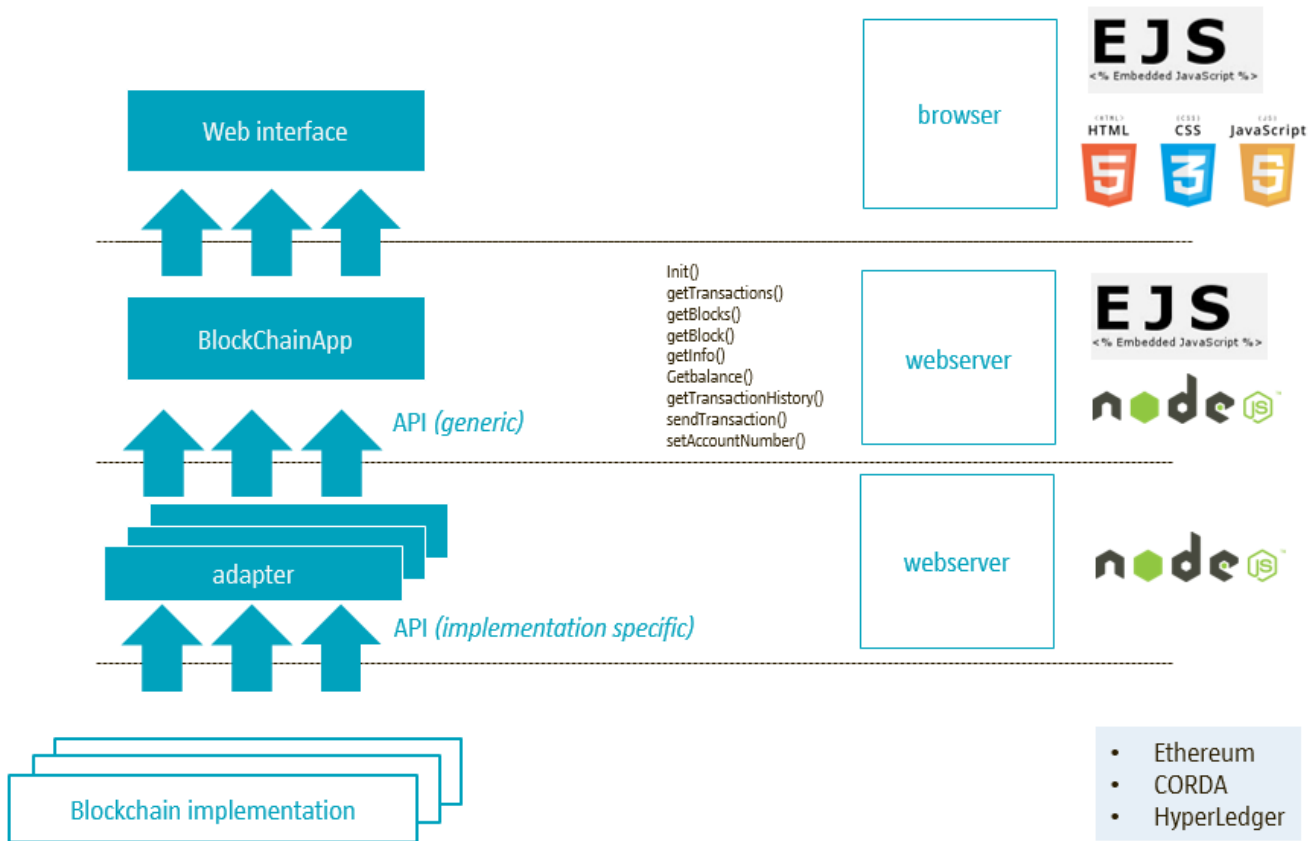
Figure 3.3: GUI design of the Wallet page

Figure 3.4: High-level overview of our blockchain application

For an overview of the software architecture of our experiments, see Figure 3.4. Using Node.js [64] we have created our own web server, which was needed to communicate with the API from the specific blockchain. From our web page, we could then make calls to this web server so we could execute our functions. This server could then communicate with the web server from the specific blockchain implementation.

We used EJS [65] and Jquery [66] to make sure we could communicate properly with our web server. Using a software architecture as illustrated in Figure 3.4, made it easy for us to add new blockchain implementations to our application, because we only had to connect a different adapter to our generic API and there is no need to change any other files or server settings. To summarize, we created a generic web interface where the user can execute several functions such as sending a transaction on the specific blockchain implementation with ease.

For each of our blockchain implementations we also needed a server to run the blockchain network on. We needed to run an instance of the specific blockchain platform locally or on a cloud server, so we could have access it. Some blockchain platforms offered their own cloud services that you can easily configure the blockchain on, but for others you had to find a server and configure it yourself.

3.4.3 Blockchain criteria

In this study we have determined criteria so we could review the blockchain platforms that we will experiment with. These criteria were organised in several categories by importance. Using these criteria, we could get a better understanding of how well the selected blockchain tools perform in our experiments. These criteria have been determined based on talks with people in the blockchain team inside the case company and by consulting relevant literature regarding the most important properties of blockchain technology [13, 29]. In addition, we have made use of a document with requirements that an application of an external vendor needs to meet if the vendor wants to work together with the case company [69].

We have divided the criteria into four categories: technical, blockchain aspects, security, the blockchain organization and the case company. The technical category is primarily about the code and what tools they offer, while the blockchain aspects category looks at the blockchain itself and how things such as the consensus algorithm and data governance are managed. In addition, we conducted research on the blockchain organization to find out how developed they are and how they managed the security of their blockchain. Finally, we looked at the perspective of the case company and what important criteria were for them.

Technical
- Ease of API usage
- Scripting languages for interacting with the API
- Scripting language for contracts
- Ease of setup/installation
- Documentation
- Stability
- Supported operating system
- Client graphical user interface
- Implementation language
- Open source
- Blockchain explorer available
- Standard cloud offering available
- (when open source). Is there a commercial version of the open source tooling available
- Turing complete

Blockchain aspects
- Consensus mechanism
- Public vs. private vs. unpermissioned vs. permissioned
- Data governance
- Support for smart contracts
- Scalability
- Cryptocurrency

Blockchain organization
- Organization behind the implementation/Business model
- Functional + technical roadmap
- Service
- Change and release management
- Maturity
- Development team
- Striking succesful implementations

Security
- Security against hacking
- Responsibility (incident management)
- Encryption

Case company
- Support of counterparties
- Cost
- Usage in asset management industry

Importance
- Not really essential
- Important
- Vital

Figure 3.5: A summary of the determined criteria to review the blockchain platforms

In Appendix A, we have defined the criteria that we have used to review the blockchain platforms in more detail. In Figure 3.5 you can see a summary of the determined criteria. For each criteria in Appendix A we marked the importance: 3 is vital, 2 is important and 1 is not really essential. This helped us prioritize which criteria are important while experimenting and conducting research on the tools. In addition, for each criteria

we described how we measured it and what our measurement end result was.

3.5 Business

This section describes the approach for the business component of our research. First, we discuss the core business processes that we have looked at in this research and what departments inside the asset management company we have conducted our interviews at. We will then explain our interview questions and the goal of our interviews in more detail. Finally, we describe what we have done with the interview results.

3.5.1 Scope

Below, we have defined our scope of the business processes that we have looked at in this research and what departments we have conducted our interviews at. We have decided not to look at the trading/matching process, because in our preliminary research we have seen that on the short term, most value can be achieved in the post-trade clearing and settlement process [12, 29]. In section 2.2 we have defined these business processes in more detail.

- **Post-trade clearing and settlement process**. We have looked at how blockchain can make the post-trade process more efficient. Inside the asset management company, the clearing and settlement process combined are often referred to as the post-trade process, so we have decided to take these two together. We wanted to conduct one or more interviews with people who work in the back-office and have experience with the post-trading process.

- **Corporate Actions – Cash Dividend**. In Figure 2.23 we have seen that cash dividend makes up for more than 80% of all corporate actions. Because of this, we have decided to limit our scope in this research to only this corporate action. Inside the asset management company, a department is located exclusively for the processing of corporate actions. At this department, we wanted to conduct interviews with one or more people that have experience with processing cash dividend corporate actions.

- **KYC and AML**. Inside the asset management company, we wanted to conduct one or more interviews at people who work at the client on-boarding department. They have experience with getting new clients and what process they have to go through.

3.5.2 When is a blockchain appropriate?

Before we started off with describing our interview questions, it was important to define when a blockchain is appropriate and can have the most impact on a business process. In addition, we had to look at the most important properties of blockchain technology. We had to specify in what situation we could get the most potential out of blockchain technology in order to devise our interview questions. Research discusses several

factors that contribute to an environment where blockchain technology can make a lot of impact. When these factors are met, a distributed ledger can have a lot of impact on a business process.

1. **Much redundancy in systems of different participants**. A blockchain creates a shared database that is distributed and replicated across participants [13]. This distributed ledger provides near real-time access to accurate data across multiple parties; instead of using their own database that lacks interoperability with systems of other parties, they can use blockchain technology to remove the redundancy in their systems [29].

2. **Regulation**. In the financial landscape, regulation has become more important, and this could heavily disrupt the potential of blockchain technology [29]. This is because many authentication processes are required by regulators to make sure compliance requirements are met, which means that some intermediaries will still be necessary. However, using smart contracts, many regulation and compliance measures can be automated; this means that a high amount of regulation in a business process could actually be beneficial for blockchain technology. Thus, the influence of this criterium will be dependent on the business process. In addition, regulators have real-time access to information about transactions that are done on the distributed ledger, which means that they do not have to work with data from 1-2 days ago.

3. **High amount of participants and intermediaries**. The higher the amount of participants is in a business process, the more participants can make use of the distributed ledger. In addition, removing many intermediaries by using blockchain technology can save a lot of costs and time, because currently these participants have to update and communicate with each other to reflect changes in each other's records [13,29].

4. **Low amount of transparency**. Because all parties have a copy of the ledger, and many of them can verify records, a distributed ledger provides a high degree of transparency to a business process [33]. Blockchain technology provides a "golden record" with a comprehensive and transparent audit trail of transactions [13,29]. In addition, blockchain offers a high level of transparency because governance can be configured on the ledger.

5. **Trust between parties and intermediaries is low**. Transactions on a distributed ledger are validated by all or many peers that are using the ledger, using a specific consensus mechanism, to assure the right version of the ledger and correct order of transactions [13]. This ensures that participants do not have to constantly check each other to make sure there is no misinformation and the correct actions will be executed.

6. **Smart contracts**. An important property of blockchain technology is the ability to make use of smart contracts, being able to automatize actions on the blockchain based on internal and external information. A distributed ledger makes sure that centralized systems of participants in a business process can now be combined. This means that a smart contract has access to information of all participants and things can be automized between several organisations, instead of only automizing in one organisation.

3.5.3 Interview goals and results

As stated before, the main goal of the case interviews in this research was to get an in-depth overview of the business processes and how blockchain can be applied here. We have divided this main interview goal into three smaller subgoals. In the first place, we wanted to get insight in the current state of the business process and how it is executed at the case company. In addition, it was important to look at where most mistakes occur in the process and what the consequences are of these errors.

In the second place, we wanted to get a picture of the future of the business process. We needed to look at what other innovations are currently entering the market, because there may be a more suitable technology than blockchain for this business process. In the third place, we wanted to see what the interviewee themself thinks of blockchain technology and how it can be applied on the business process. However, we only asked this to people who have knowledge of blockchain technology.

The amount of interviews we have done in this study depended on how much information we could get for each interview process. We have defined a "researched business process" as a business process where we could get an answer to all of the interview topics defined in section 3.5.4.

In Figure 3.6 our approach for the interviews is illustrated. We started with one of the core business processes that we found and selected a department that is responsible for it. Inside this department, we chose one or more persons to conduct our interviews with. Inside the results of this interview we could identify two or three sections, depending if the interviewee had knowledge on blockchain technology. We could then compare the insights gained from the current process with the factors for a good blockchain implementation and find out if the current process is appropriate for blockchain technology. Finally, we compared this with the other results from the interview and conclude whether blockchain is the solution for this process.
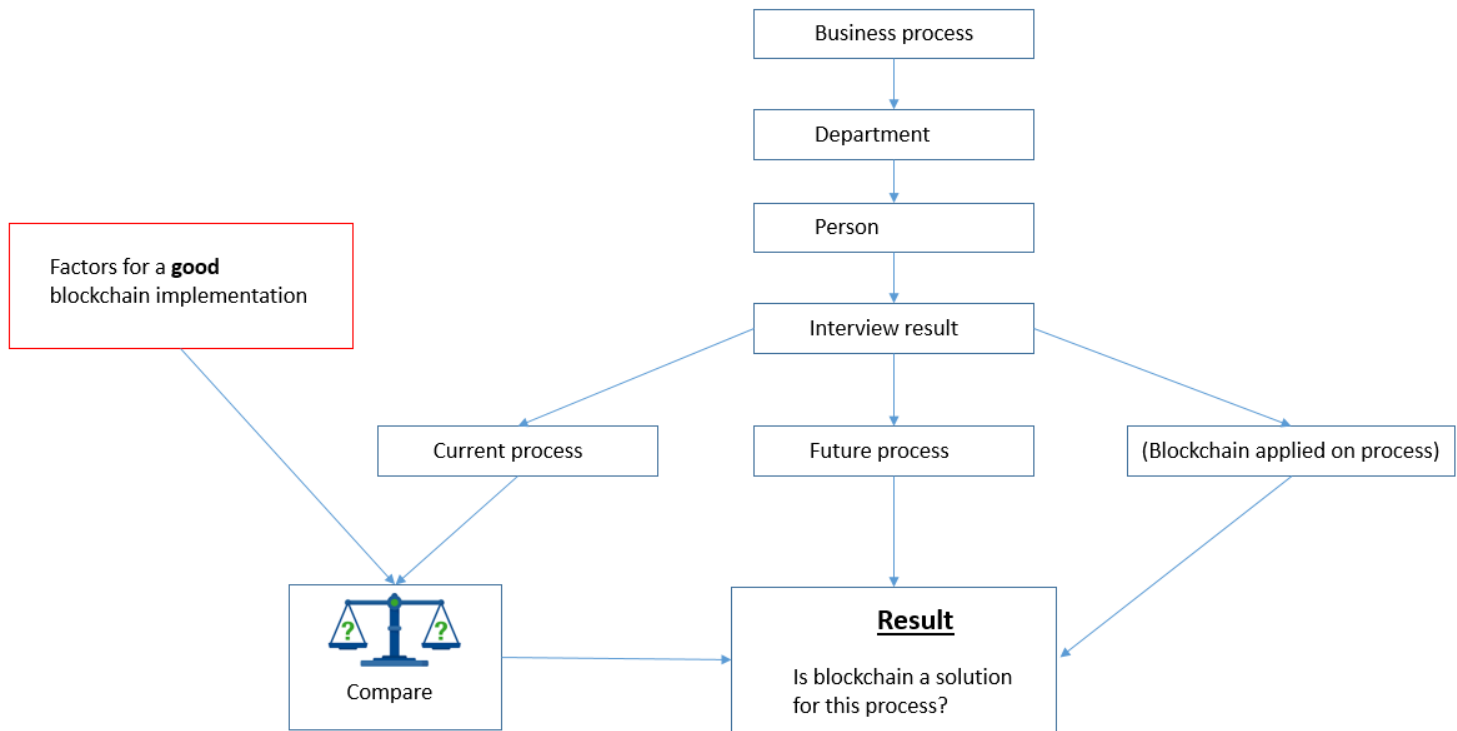
Figure 3.6: The approach for our interviews

In section 3.5.4 we discuss the topics that we will cover in our interviews. For each business process, we have summarized the results per interviewee topic. After this, we compared these results with the properties of blockchain technology and discussed how blockchain can be applied.

3.5.4 Interview topics

Below, we have described the topics that we will discuss in our interviews. Because in this study we have chosen to make use of semi-structured interviews, we have not made up any interview questions or specific order of questions beforehand.

Current process:

- **General overview of the process.** We wanted to have the same view of the process as the interviewee. In addition, this question helped us get more insight in the current process and helped identify us whether the process has a high amount of participants and intermediaries, one of the criteria for a good blockchain implementation.

- **Errors in the process and their consequences.** This helped us get insight in the current process and analyze whether blockchain technology can help reduce these errors.

- **Communication and trust between parties.** This helped us identify misinformation in the process and whether a lot of redundant data is sent back and forth between participants. In addition, we could identify

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if many checks and confirmations need to be done between participants, which gives us information about the level of trust in this business process.

- **Transparency and governance.** Blockchain technology can add a high level of transparency and governance to a business process. Also, it is important to find out whether transparency is important to the user.

- **Usage of current systems.** We wanted to know how current systems are used because this could help us identify the level of redundancy of data and other redundant business processes.

- **Important flows of information.** We wanted to know if blockchain technology can help improve the most important parts of the business process.

- **Regulation.** We have seen that a distributed ledger's effect can be influenced by the amount of regulation.

Future process:

- **Innovations in the market and the asset management company.** It was important to look past blockchain technology and identify other solutions that are entering the market. For example, a new technology may be coming up in the next years that everyone will use for this process, thus making blockchain technology unnecessary.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.** We wanted to know how the interviewee thinks the process can be made more efficient from the perspective of an asset management company.

- **Effect on the participants of the process.** We wanted to know how the role of participants in the process changes and which ones will become unnecessary.

- **Biggest implementation challenges.** This question could help us identify what issues of blockchain technology and the business process still need to be fixed or improved before implementing it.

- **Effect on users inside the asset management company.** Blockchain technology can make people or even departments inside the asset management completely unnecessary, so it was important for us to analyze this aspect.

3.6 Combining IT & Business

As discussed before, our main research question for this paper is "What are the best tools to set up a distributed ledger based on blockchain technology for the core business applications of an asset management company?". To answer this question, we have combined the results that we get from section 3.4 and section 3.5. At the end of our research, we will have a list of criteria about properties of the investigated blockchain tools and the

company behind it. For example, we could find that Corda offers great tools for transparency and governance, but does not have good support for configuring a consensus algorithm.

From the business perspective we will have an explanation for each business process of how blockchain technology can be applied here and what properties of a blockchain are needed most. For example, we could find that in the post-trade process transparency is an important issue, because of the high amount of regulation that is needed in this process.

From these two examples we can see that Corda offers great tools for transparency, and the post-trade process needs a lot of transparency. Thus, we can now conclude that this is the ideal tool for this process. Because in our research we identified what blockchain properties are most important for a business process, it was easy for us to find what tool suits a business process the best.

Chapter 4

Results

This chapter discusses the results of this research. Thereafter, we describe the results of our experiments that were done on the blockchain tools. After this, we will summarize the results of our interviews and discuss how blockchain technology can be applied here.

4.1 IT

In this section we discuss the results of our experiments with Corda, Ethereum and Hyperledger Fabric. First, we will shortly talk about the end design of the web interface that we have created. After this, we will discuss the results of our criteria that we have determined in section 3.4.3 in separate subsections for each of the blockchain platforms. Each subsection starts with an overview of the architecture of the blockchain platform and ends with a discussion of the summarized results that are shown in a mindmap. In Appendix B the detailed results of our criteria can be found. The results of these criteria were determined through our own experiments and by conducting the white papers or documentation of the blockchain platforms [115–120].

4.1.1 Web interface

Figure 4.1: The admin page

In Figure 4.1 you can see the interface of the admin page of the blockchain application that we created. In this page an overview of all activities done on the blockchain is shown, such as the latest blocks and the latest transactions. In addition, we can see what the current block is and what the total amount of money is that is currently on the distributed ledger. The 'Transactions" button of a block can be clicked and this shows all transactions that are linked to this block. The user can also search for a block address, and this shows a lot of information about the block, as Figure 4.2 shows.

Figure 4.2: Retrieving information about a block

In Figure 4.3 you can see the interface of the wallet page of the blockchain application that we created. In this page, the user fills in his account number, and when submitted, information such as transaction history and the balance of the user is shown. In addition, the user can send money to another account using the private key linked to his account.

Figure 4.3: The wallet page

4.1.2 Ethereum
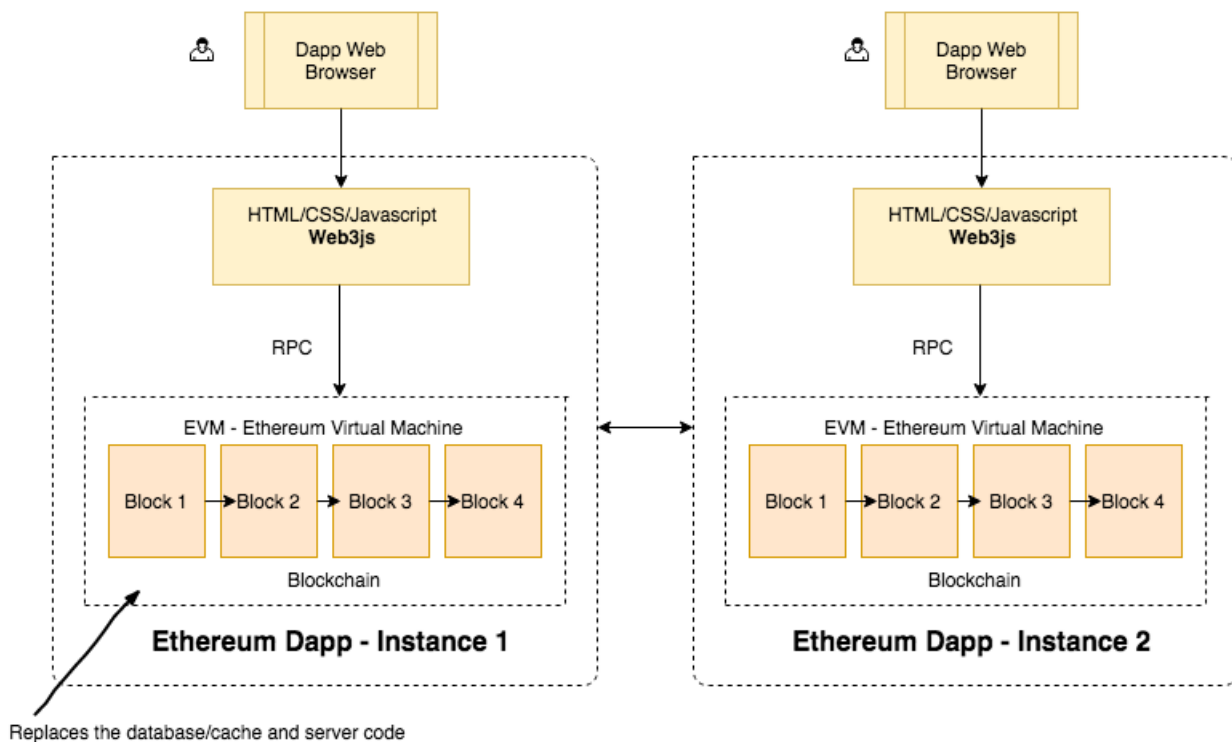
Figure 4.4: High level view of Ethereum Dapp architecture

Ethereum offers a protocol for building decentralized applications with ease through smart contracts [119]. The main focus of the organization is to give a lot of options to developers to build applications using their decentralized architecture. An application that has its back-end code running on a decentralized ethereum network and their front-end code making calls (in any language) to the back-end is called a "DApp". Figure 4.4 shows a high level view of the Etereum Dapp architecture; the web browser (front-end) makes a call to the back-end Ethereum API (Web3js). Web3js then makes the calls to the Ethereum blockchain server and retrieves the correct values from the decentralized ledger. In Figure 4.5 you can see the results of our criteria for Ethereum in a mindmap.
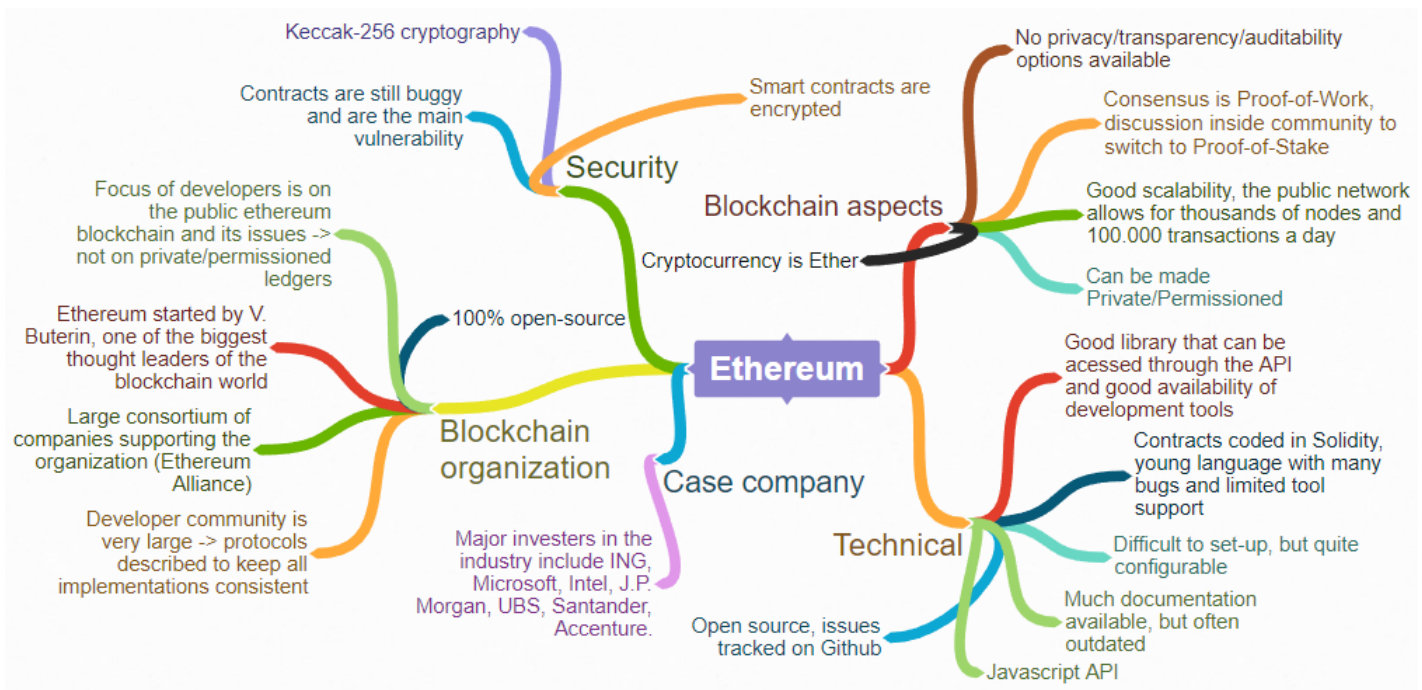
Figure 4.5: Ethereum criteria results summarized in a mindmap

The API that can be used to communicate with the Ethereum blockchain is extensive and many tools are offered to support it. However, currently this API can only be used in Javascript. Contracts are the main issue for Ethereum, because in the past we have seen that they are buggy and can be hacked.

The distributed ledger's scalability is excellent and allows for many validation nodes and transactions a day. However, there are no transparency or auditing options available on the blockchain, and there is no option to switch to another consensus. Transactions are not encrypted, only data on smart contracts is. This ledger uses a cryptocurrency called "Ether"; this means that to trade on the blockchain, you first need to swap currencies. For large financial companies this is not useful, because this adds another layer of exchange rates.

The organisation is started by one of the biggest thought leaders in the blockchain world. However, the main focus of the developers is on the public blockchain and not so much on new features regarding private and permissioned blockchains. The developer community is very large, as opposed to Hyperledger Fabric and Corda. Ethereum is backed by companies from the asset management industry.

4.1.3 Hyperledger Fabric
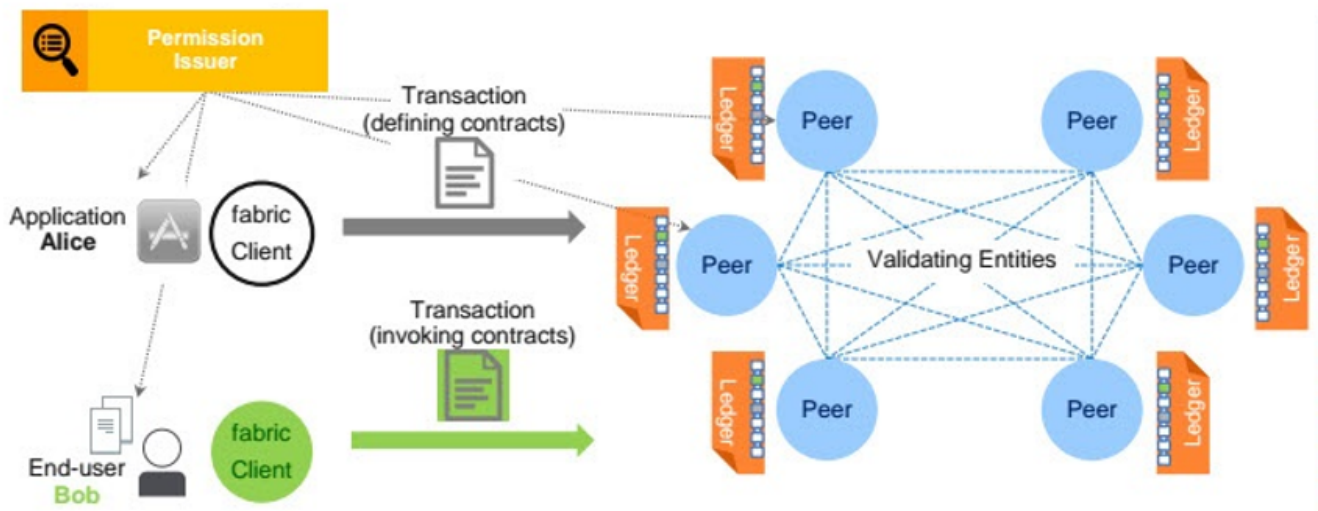
Figure 4.6: The Hyperledger Fabric model [118]

According to the white paper of Hyperledger [117], "blockchain has fallen short of meeting the multitude of requirements inherent in the complex world of business transactions. Scalability challenges, and the lack of support for confidential and private transactions, among other limitations, make its use unworkable for many business-critical applications". Hyperledger intends to improve this and is designed not only for the financial industry, but for other industries too such as supply chains.

Hyperledger *Fabric* is one of the blockchain projects within Hyperledger and offers more options concerning the protection and privacy of sensitive data [118]. Figure 4.6 shows the Hyperledger Fabric model. You can see that the system has a permission issuer which acts as the regulator and audits all transactions and contracts for compliance. Users can deploy their transactions through smart contracts on the ledger. In Figure 4.7 you can see the results of our criteria for Hyperledger Fabric in a mindmap.
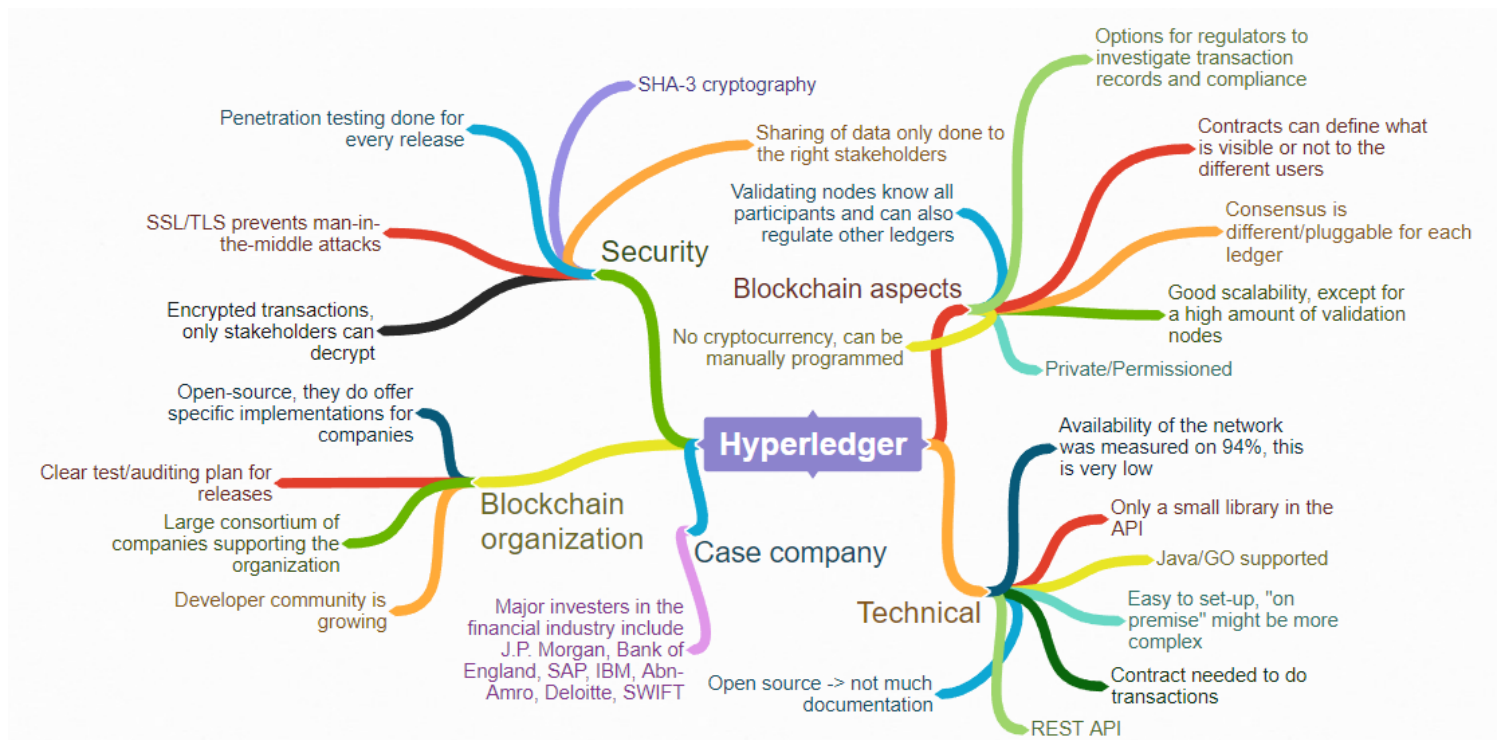
Figure 4.7: Hyperledger criteria results summarized in a mindmap

The main issue on the technical side is the availability of the network, as it was measured on 94%. The API is also still in its beginning stages. The network does offer good scalability, except for a network where there are many different regulators. However, many options are available for regulators to investigate transactions and verify users.

As opposed to Ethereum, the consensus can be chosen for each distributed ledger, depending on the business use case. All transactions are encrypted on the blockchain and penetration testing is done for every release, which leads to a good level of security. Because the contracts are written in a known languages, there is a small change of any bugs occurring in the source code.

The developing community is growing, but is not as large yet as Ethereum. The company does have a clear test and auditing plan for releases, and they offer much insight into new features. The company is backed by many financial companies from the asset management industry.

4.1.4 Corda
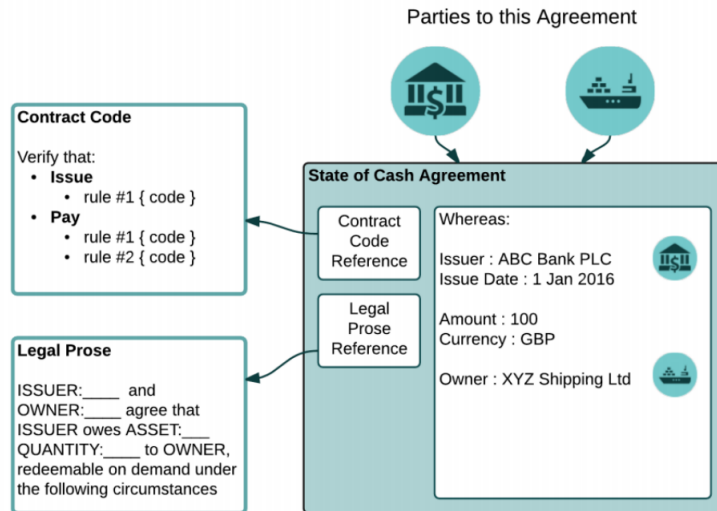
Figure 4.8: A financial agreement between two parties accompanied by its governing legal prose and its contract code [115]

As defined in the Corda whitepaper [115], "Corda is a distributed ledger platform for recording and processing financial agreements". These financial agreements between companies are made possible through the use of smart contracts. One of the main features of Corda is that these smart contracts can be made legally enforceable, through linking business logic and business data to associated legal prose [115].

In Figure 4.8 you can see an example of a financial agreement between two parties where a shipping company owns a cash claim of £100 against a bank. This "agreement" is enforced by a legal prose where all legal related business rules are written in and by a smart contract where all the business logic is written in. This architecture provides the trust that is needed in the financial industry and allows a flow between firms without any central party in between. Figure 4.9 shows the results of our criteria for Corda in a mindmap.
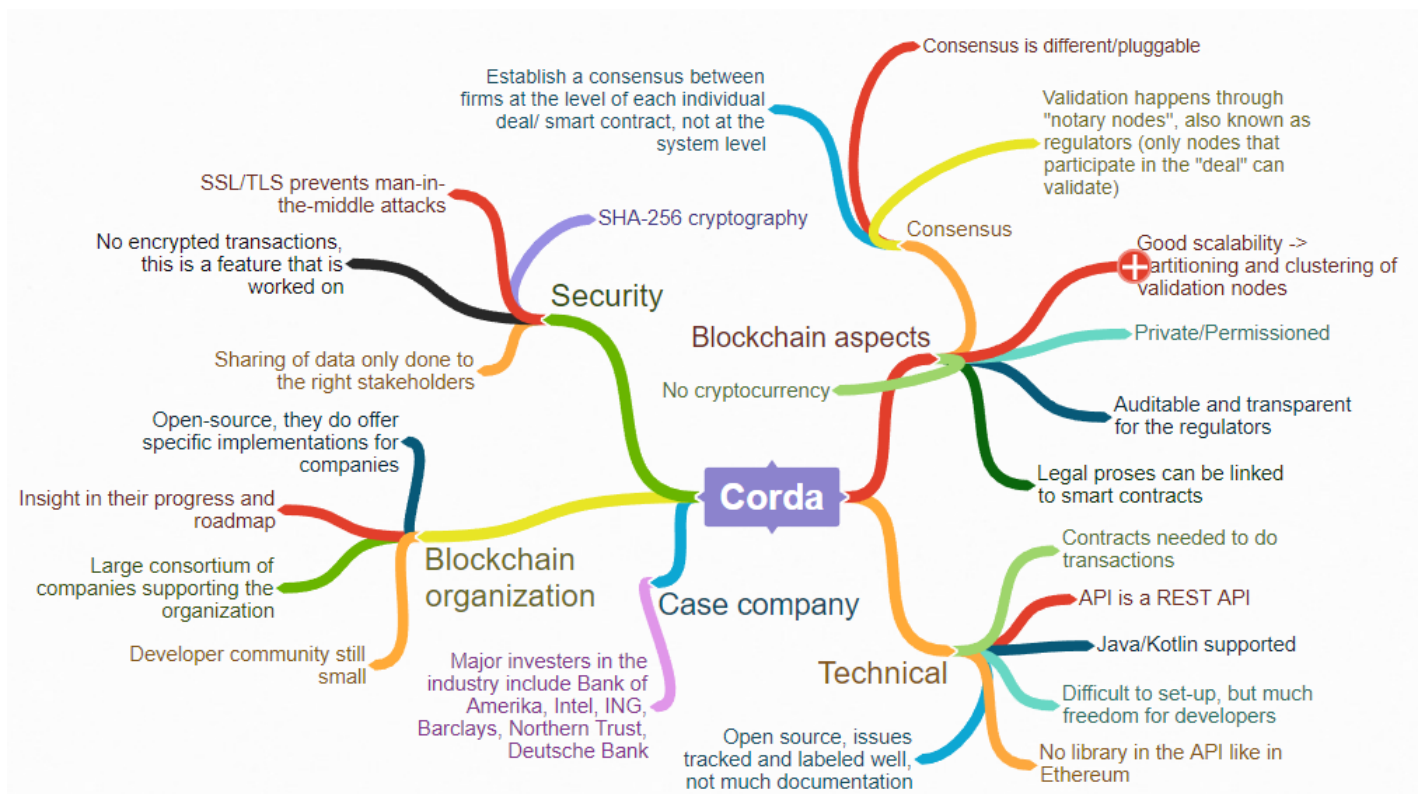
Figure 4.9: Corda criteria results summarized in a mindmap

On the technical side, we have noticed that the company is still young; it does not offer an extensive API as Ethereum does and the documentation is minimal. Also, it was difficult to set up the blockchain. On the other hand, the language where the smart contract is written in is Java and Kotlin, and these languages are very stable and popular, which means there is a large community that can offer support.

The Corda distributed ledger is transparent and auditable for regulators and has good scalability because the performance is not affected by the amount of users. Consensus is not chosen on a network level but at the level of each deal or smart contract, which means that on a ledger, different consensuses can be used. For example, party A and B may want to use "Practical Byzantine Fault Tolerance", while party B and C use "Proof-of-Stake".

There is some room for improvement regarding the security of the blockchain; transactions are not encrypted as is being done in Ethereum and Hyperledger Fabric. In addition, no penetration testing is done by Corda. However, they do offer load testing to check the behaviour of nodes when they are being stressed and encrypting transactions is a feature they are working on.

The blockchain organization offers a lot of insight in their progress and roadmap of new features. Nonetheless, the developer community is still very small, but they do offer help if you are experiencing any issues. R3 Corda is supported by a large consortium of companies that are in the industry of an asset management company.

4.2 Business

In this section we will discuss the results of our interviews. Each subsection starts with an overview of the business process as described by the interviewees. After this, the results will be summarized per interview topic in a mindmap and we will explain how blockchain technology can be applied on this process. Finally, we will discuss the results of our interviews in more detail and compare them with properties of blockchain technology and with the criteria that we have defined in section 3.5.2. In this study we have conducted a total of five interviews with people inside the asset management company. All of these interviews lasted an hour and all except one interviewee had knowledge of blockchain technology.

4.2.1 Post-trade process

For this business process we have conducted one interview with a person that has 15+ years experience in the post-trading process. In addition, this person has a lot of knowledge of blockchain technology and has worked on some blockchain projects inside the asset management company.

4.2.1.1 Current process
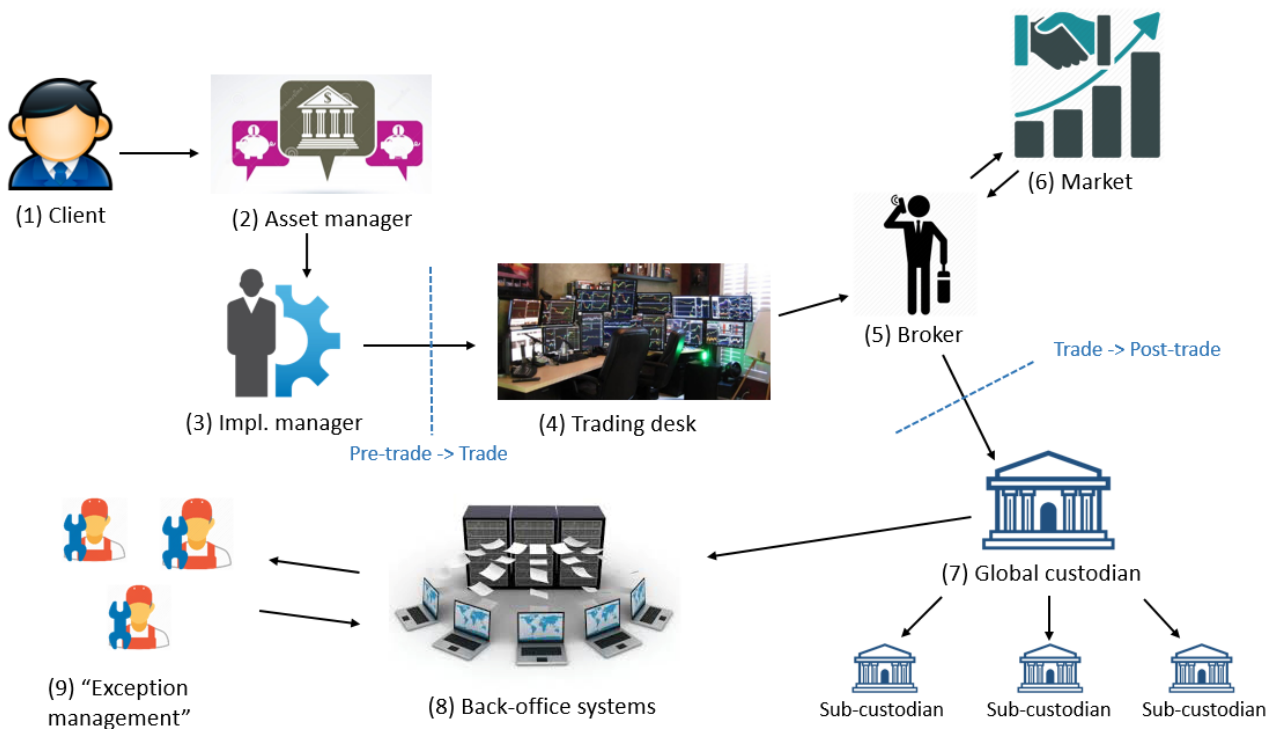
Figure 4.10: The trading process

Figure 4.10 shows an overview of the trading proces as described by the interviewee. The process starts with a client from an asset management company who has a specific risk profile. Based on this risk profile, the implementation manager determines a strategy and prepares transactions that he wants to make. This manager

then sends these instructions to the trading desk and these traders find a match for this transaction on the market through their broker.

When a match is found between two traders, the post-trade process starts. The information is sent to the systems of the asset management company and they send it to the custodians. As can be seen in Figure 4.10, the asset management only communicates with two participants; a custodian and a broker. However, this global custodian has got several local sub-costodians, located in specific regions or sectors of the market. This means that a lot more participants are involved in this process than is immediately observable. In the back-office systems the asset management company can check the status of the transaction and whether it has been settled or not.

Until now, everything done after the trading desk has been automated and no manual actions need to be performed. However, when an error occurs in the process through miscommunication with custodians, a lot of manual interventions need to be done. This is called "exception management"; the management of behaviour that breaks the normal flow of actions and needs manual interference. Many people are needed for exception management inside the asset management company, because it occurs regularly. The post-trade process takes about two days to complete on average. In Figure 4.11 you can find the results of our interview summarized in a mindmap. A detailed analysis of our interview can be found in Appendix C and a condensed version in section 4.2.1.3.
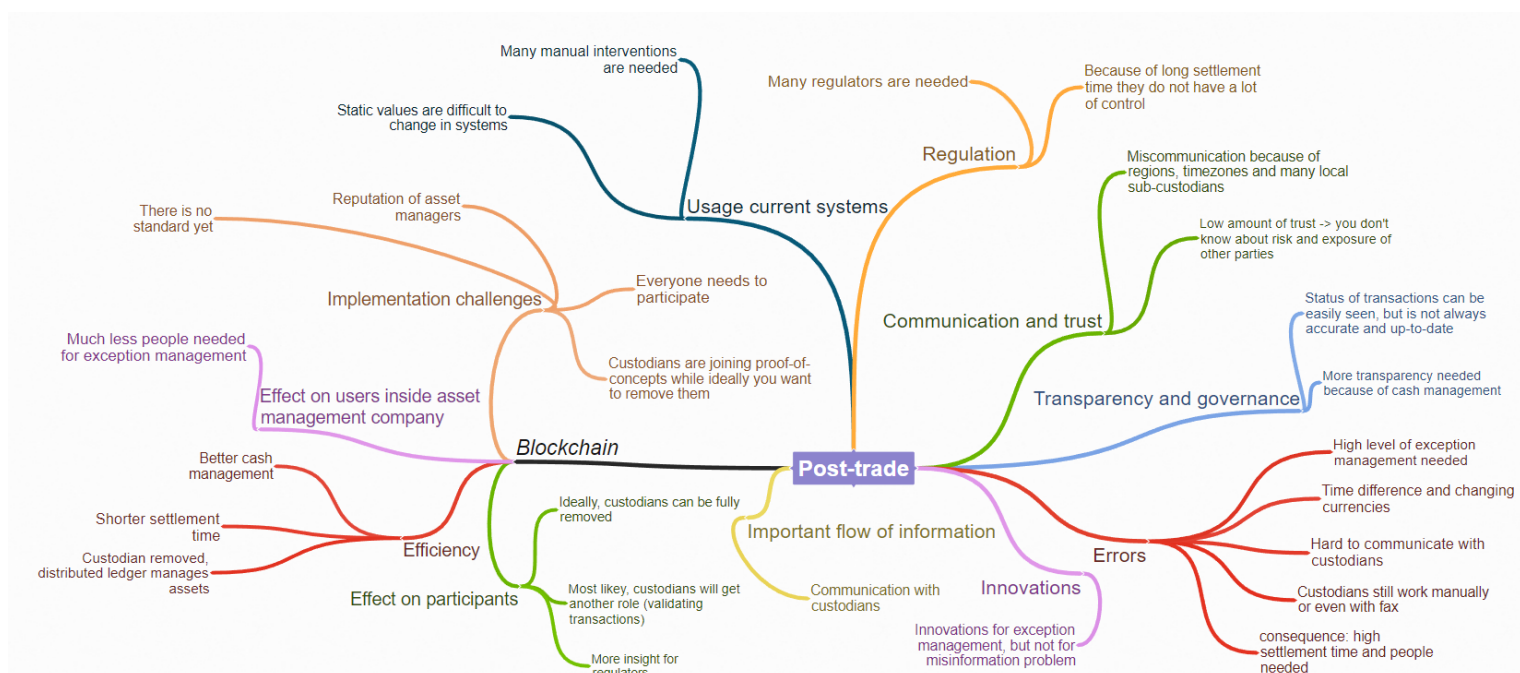
Figure 4.11: Post-trade interview results summarized in a mindmap

4.2.1.2 Blockchain scenario
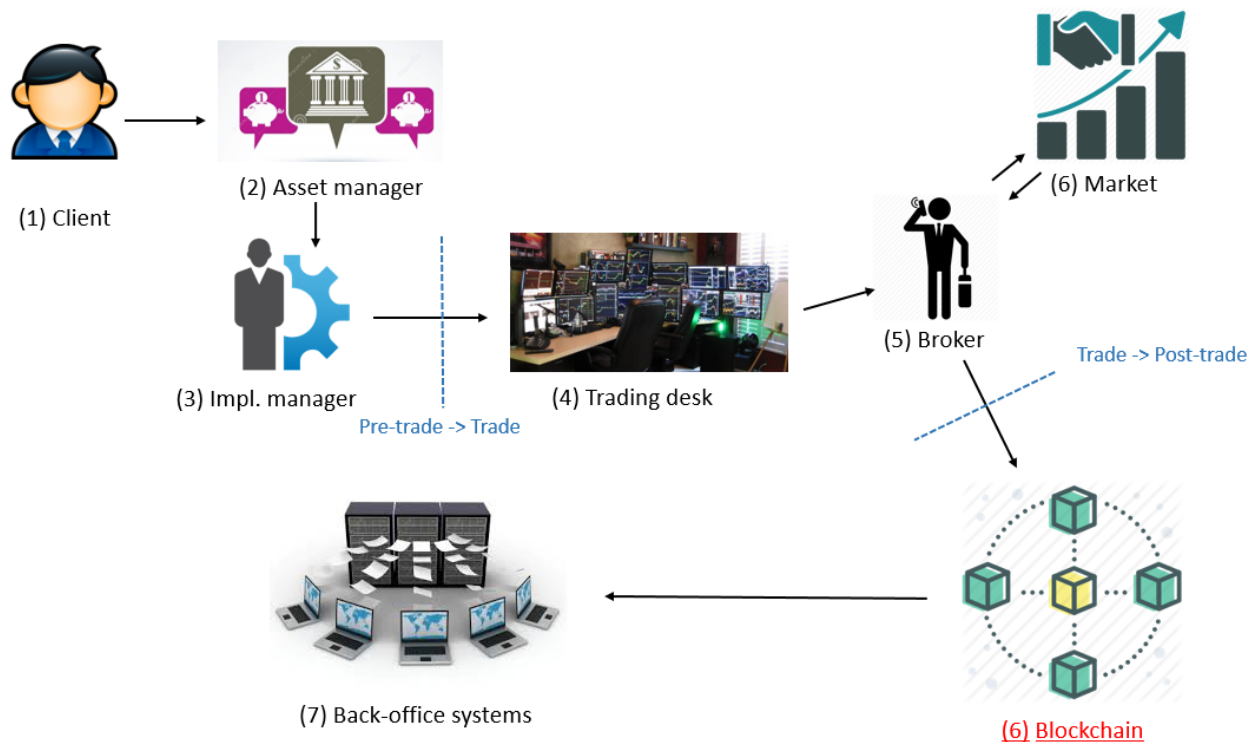
Figure 4.12: The trading process using blockchain

In Figure 4.12 can be seen how we suggest blockchain technology should be applied on the process. The process from the client to the broker is already executed fast and efficient, and the settlement phase is where all errors occur. A distributed ledger can be used to manage the securities, instead of all custodians using their own systems and databases. The broker of the buyer and the seller can both send the information about the trade to the blockchain.

The back-office systems can be linked to the distributed ledger and all information about transactions can be seen real-time. As you can see, custodians become unnecessary in this scenario, because they do not need to manage the securities anymore. This is the ideal scenario, because we have seen that most errors in the process occur because of the custodians. However, we do not think this will be the case, because these participants are already fully established in the infrastructure.

In addition, these custodians are joining proof-of-concepts regarding blockchain technology, so they will try to find a different role for themselves in the business process. Still, even with the custodians, the process will still improve for the asset manager, because exception management can be improved using smart contracts since we now have access to external information from custodians. Using this information, we can already see if a transaction breaks the normal flow of action, and immediately respond to it, instead of waiting two days to receive the information.

Using a distributed ledger, cash management for the asset management company will drastically improve, since you now always have a real-time value of your assets and you do not have to wait 1-2 days for the transaction to settle. Regulators will also have a much better control of the business process since they have access to real-time data on the blockchain.

To summarize, blockchain technology enables the asset management company to see information about transactions in real-time and thus improve cash management. Also, settlement time can drastically be reduced and exception management will not be necessary anymore, so much less people will be needed inside the asset management company to maintain the back-office systems.

4.2.1.3   Condensed interview results

Current process:

- **Errors in the process and their consequences.**

  - Exception management, settlement time of two days, custodians work manually or even with fax, time difference and currency changes.

- **Communication and trust between parties.**

  - Different regions and timezones of custodians, no risk exposure known of other parties so low trust,

- **Transparency and governance.**

  - Transparency is needed for cash management.

- **Usage of current systems.**

  - Manual interventions still needed.

- **Important flows of information.**

  - Communication with custodians.

- **Regulation.**

  - Regulators have no real-time control.

Future process:

- **Innovations in the market and the asset management company.**

  - No solution for misinformation.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.**

  – Custodian can be removed, leads to good cash managemnt and real-time values.

- **Effect on the participants of the process.**

  – Insight for regulators and custodian most likely other role.

- **Biggest implementation challenges.**

  – Reputation asset manager, trust in technology, custodians joining proof-of-concepts, no standard.

- **Effect on users inside the asset management company.**

  – Much less people needed for exception management.

4.2.1.4   Detailed blockchain comparison

- **Errors in the process and their consequences.** We can see that the errors are mainly caused by the custodians, because a lot of misinformation occurs in the communication. A distributed ledger can help here, because the securities can be managed in a ledger, instead of all the custodians updating their own systems, thus removing a lot of redundancy in the process. In addition, on a blockchain only one token is used, thus removing the necessity to change currencies. Blockchain can also help manage exceptions that occur in the process using smart contracts, because we now have access to external information from custodians. Using this information, we can already see if a transaction breaks the normal flow of action, and immediately respond onto it, instead of waiting two days for us to receive the information.

- **Communication and trust between parties.** See above. In addition, transactions on a distributed ledger are validated by a consensus mechanism, which means that participants do not have to constantly check on each other, thus improving the trust between parties, which is now really low.

- **Transparency and governance.** In a distributed ledger the status of your transaction can easily be tracked and you do not constantly have to communicate with the custodian about it. This is needed in this process, because your cash management is much better since you know the real-time value of your assets.

- **Usage of current systems.** The main problem in the current system is that many manual interventions are still needed to manage exceptions which costs time and people. Using smart contracts, we can automatize many of these actions, as we have explained earlier in this section.

- **Important flows of information.** The most important flow of information is the communication with custodians. A distributed ledger can drastically improve this communication because instead of using their own system that lacks interoperability, the asset management company can access the shared database which means it does not have to contact the custodian that often.

- **Regulation.** Regulators currently do not have good control of the business process because of the long settlement times. We think that the most gain will be achieved in the fact that on a distributed ledger the

regulator has access to real-time data, because it will still take a long time before compliance measures will be automized, especially in this process where the transaction volume and amounts are high.

4.2.2 Corporate actions

For this business process we have conducted two interviews with a total of four persons inside the asset management company. In the first interview we talked with two persons who worked on an application that offers a lot of insight in data about corporate actions, such as the error rate and amount of manual interventions needed. In this interview, the interviewees only had a small amount of knowledge about blockchain technology. In the second interview we talked with two persons who are responsible for processing corporate actions inside the asset management company. In addition, these two persons had a lot of knowledge about blockchain technology.

4.2.2.1 Current process
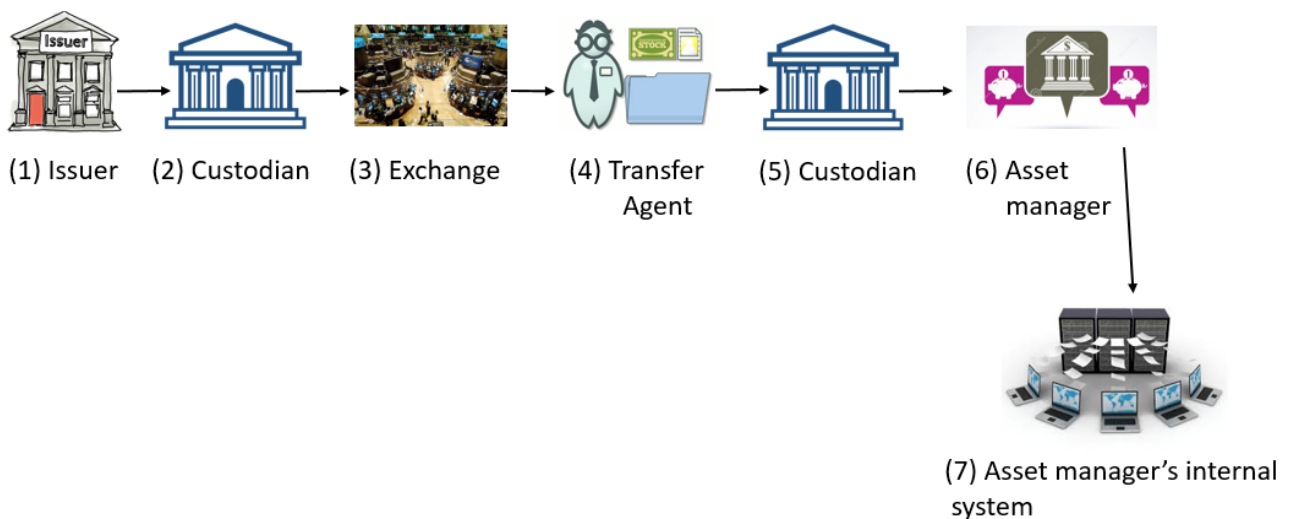
Figure 4.13: The corporate actions process

In Figure 4.13 an overview of the corporate actions process as described by the interviewees is shown. As stated before, we limit our scope of this process to cash dividends. First, the issuer issues a cash dividend on the exchange market of their stock. Most of the time, they send this information about the pay date and amount of cash dividend through their custodian bank. On the other side of the exchange market, the transfer agent retrieves this information and processes it in their own system. This transfer agent works on behalf of the custodian, and once it is processed in their own systems, they send it to the custodian. This custodian then processes the information and delivers it to the asset management company.

However, an asset management company has several custodians that he communicates with, so he will receive this information from a lot of different custodians. When the asset management company receives the information, they process it in their back office systems for administration. On the pay date, the asset

management company needs to check whether the dividend received is equal to the dividend that they processed in their internal system when they received the information from the custodians; this is called the matching process. In Figure 4.14 you can find the results of our interview summarized in a mindmap. A detailed analysis of our interview can be found in Appendix C and a condensed version in section 4.2.2.3.
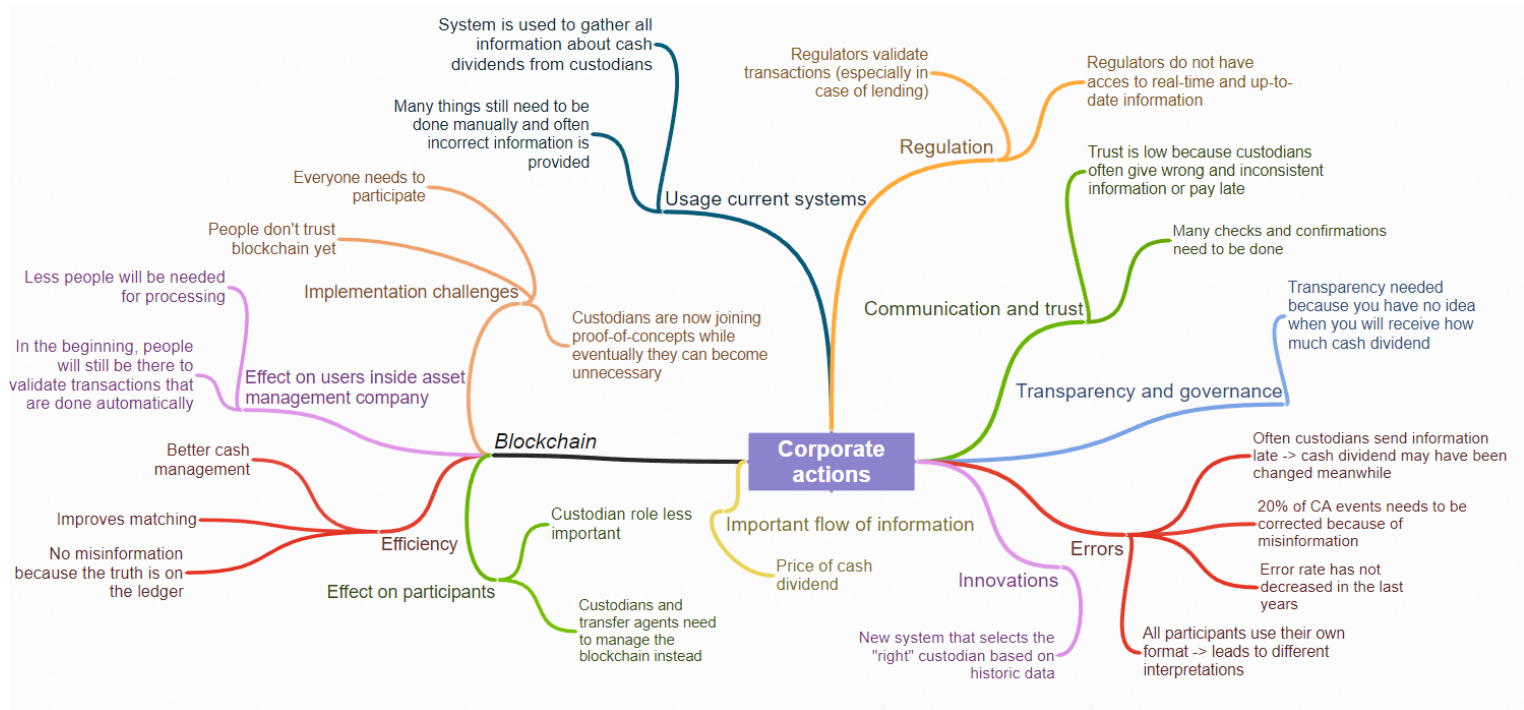
Figure 4.14: Corporate actions interview results summarized in a mindmap

4.2.2.2 Blockchain scenario
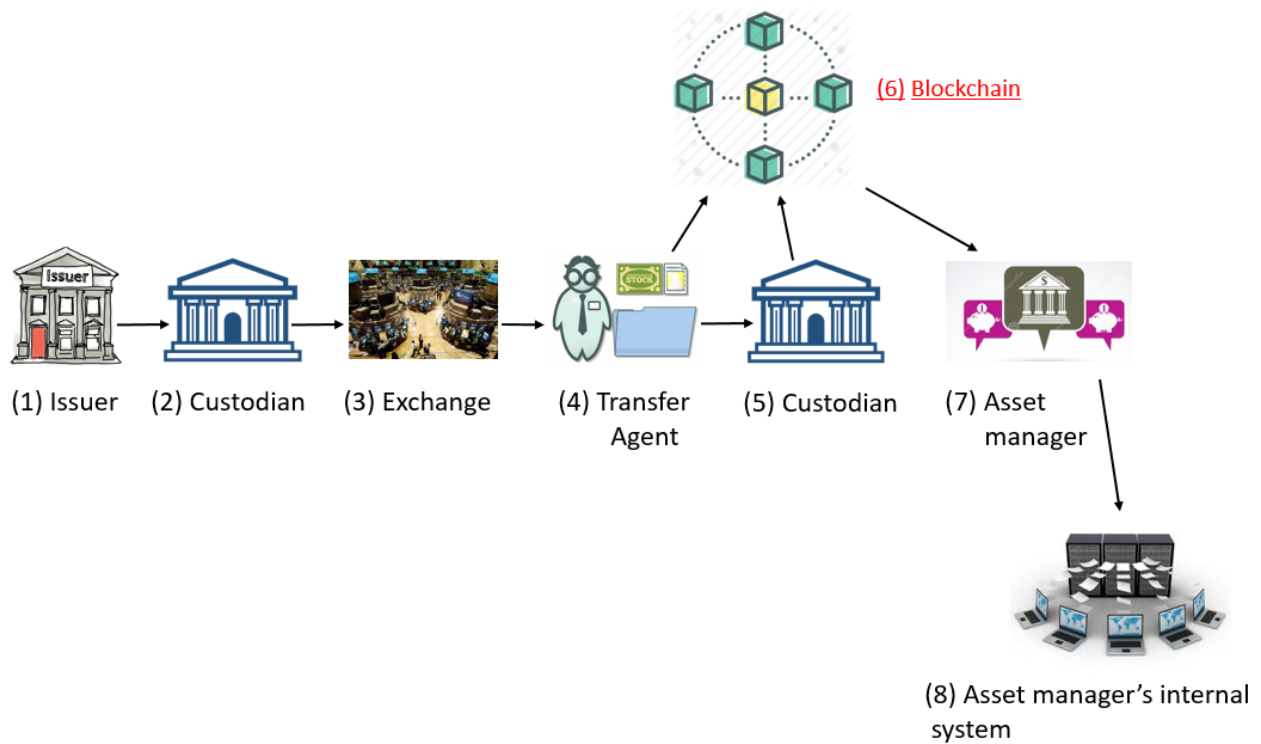
Figure 4.15: The corporate actions process using blockchain

For this business process a scenario is suggested where a distributed ledger is used between the transfer agent, custodian and asset manager, see Figure 4.15. A distributed ledger creates a shared database that all custodians and transfer agents can access and where they can submit their information. Whenever the transfer agent and custodian receive information from the exchange market, they can share it on the blockchain. Because a transfer agent finds information on behalf of the custodian, the transfer agent and the custodian will both be sending information to the ledger, depending if the custodian allows the transfer agent to send information the distributed ledger.

Including all the issuers in the distributed ledger would not work, because everyone needs to participate in the blockchain for it to work and there are many different issuers. Our research suggested that there are a few custodians that are dominating the market in the financial industry. In this scenario it is assumed that once these larger custodians will join the ledger, the smaller custodians join as well. This is because the large custodians will set a standard in the market, which makes it easier for the smaller custodians to participate in the blockchain. Therefore, it is important to initiate blockchain proof of concepts with these larger participants. They will be interested because a distributed ledger can make their internal processes much more efficient, since they do not have to communicate with all the asset managers in the industry; they only have to send the information about the cash dividend to the distributed ledger.

On the distributed ledger only one standard format is used and all changes of the cash dividend are tracked, which means less different interpretations and misinformation. This leads to a much more transparent process, because as an asset manager you can find on the ledger when you will receive how much cash dividend. This transparency also helps regulators be more in control of the process.

We suggest that the role of the custodian and transfer agent will change from communicating with the asset managers to maintaining and validating the distributed ledger. This is because companies will still not trust the technology at the beginning and regulators will still want someone to maintain the validity of the ledger. To summarize, a distributed ledger can provide a "golden record" of information about the cash dividend, which means that an asset manager does not constantly have to wait on custodians to send the information, but they can find the information about the cash dividend in real-time on the ledger.

4.2.2.3 Condensed interview results

Current process:

- **Errors in the process and their consequences.**

  - Custodians have long manual internal processes, different formats in the process.

- **Communication and trust between parties.**

  - Trust is low because of inconsistent and late information.

- **Transparency and governance.**

  - Transparency is needed, no insight in current dividend.

- **Usage of current systems.**

  - Manual actions needed in current system.

- **Important flows of information.**

  - Price of cash dividend.

- **Regulation.**

  - All transactions need validation, but regulators have no insight in real prices.

Future process:

- **Innovations in the market and the asset management company.**

  - New system in progress that chooses right dividend.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.**

  - System connected to other participants, more easily matching, one truth.

- **Effect on the participants of the process.**

  - Custodian less important role, no misinformation for asset manager

- **Biggest implementation challenges.**

    – Trust in technology, everyone needs to join, custodians joining proof of concepts.

- **Effect on users inside the asset management company.**

    – Much less people needed because less errors occur.

4.2.2.4   Detailed blockchain comparison

- **Errors in the process and their consequences.** Errors mainly occur because of custodians sending wrong information or sending information too late. This is because their internal processes are still manual and they receive data in many different formats and have to convert it to the format in their own system. A distributed ledger creates a shared database that all custodians and transfer agents can access and where they can submit their information. This provides a "golden record" of information about the cash dividend. In addition, changes that occur on the blockchain can easily be tracked and the data on the ledger is in one standard format. This means that an asset manager does not constantly have to wait on custodians to send the information, but they can find the information about the cash dividend in real-time on the ledger.

- **Communication and trust between parties.** See above. In addition, trust can be improved because there is only one truth on the distributed ledger, and no additional checks need to be done.

- **Transparency and governance.** A distributed ledger provides a transparent audit trail.

- **Usage of current systems.** Much less manual interventions will be needed because almost no misinformation will occur.

- **Important flows of information.** With a distributed ledger you improve the most important flow of information; the price of the cash dividend.

- **Regulation.** Regulators can more easily validate transactions, because they have real-time access to accurate data across multiple parties and through the transparent audit trail that the distributed ledger creates.

4.2.3   Know Your Customer

For this business process we have conducted two interviews with a total of two persons inside the asset management company. In the first interview we talked with a person who has experience with the products of the asset management company and in the second interview with someone who works together with the sales department to identify clients. Only in the first interview did the interviewee have knowledge of blockchain technology.
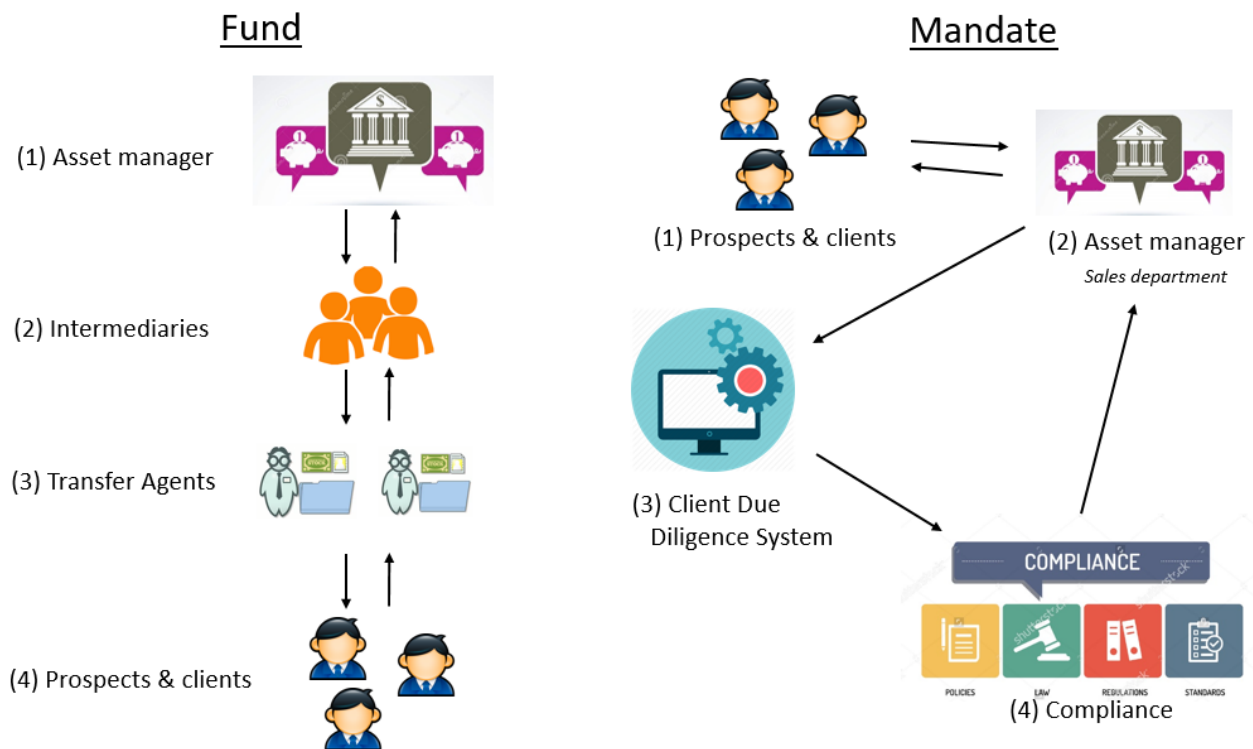
Figure 4.16: The know your customer process

In Figure 4.16 you can see an overview of the know your customer process as described by the interviewees. We can identify two key subprocesses inside this process; funds and mandates. For funds, individual and institutional investors place money in a fund at the asset management company which it uses to invest. In the case of mandates, you are investing for an individual, with a different strategy and risk aversion based on the client. For both of these components, there are some small differences in communication and the participants involved. However, because they are still so alike, we combine the results of both subprocesses in section 4.2.3.3 and specify if any big differences occur.

For funds, you do not communicate directly with the client as an asset manager. The transfer agents will try to get clients for your fund and you can communicate with these transfer agents through many participants (for simplicity, we did not include all the participants in our model).

For mandates, you do communicate directly with the client as an asset manager. The sales department talks with clients and identifies their wishes and risk aversion. When the sales department has made a deal with a client, he has to perform the know your customer and anti-money laundering process. This is done in the client due diligence system; the sales department has to fill in information about the client or the company and this leads to a specific risk level.

Based on this risk level, the sales department has to submit several documents about the client or company and these documents will be sent to the compliance department. They screen all of these documents and give

an advice to the sales department whether this client can be trusted or not. In Figure 4.17 you can find the results of our interview summarized in a mindmap. A detailed analysis of our interview can be found in Appendix C and a condensed version in section 4.2.3.3.
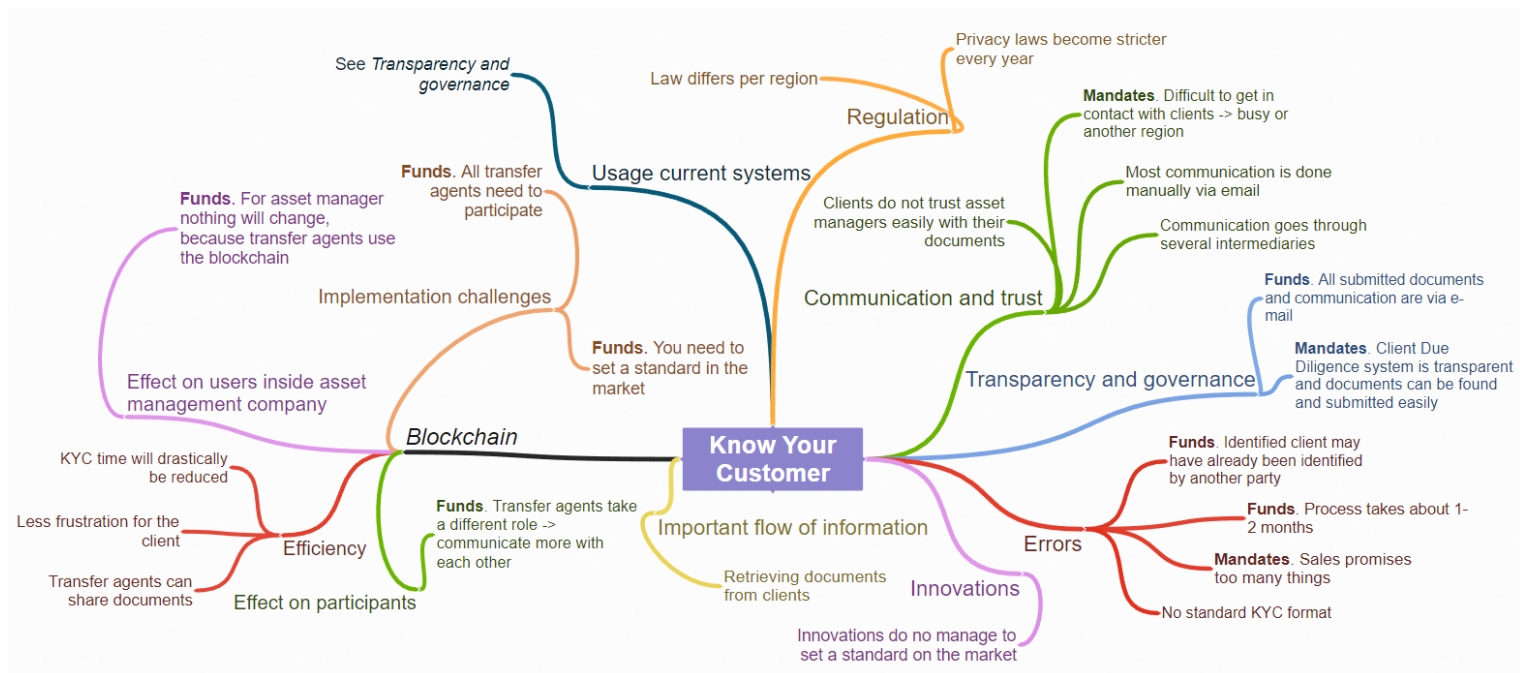
Figure 4.17: Know your customer interview results summarized in a mindmap

4.2.3.2 Blockchain scenario
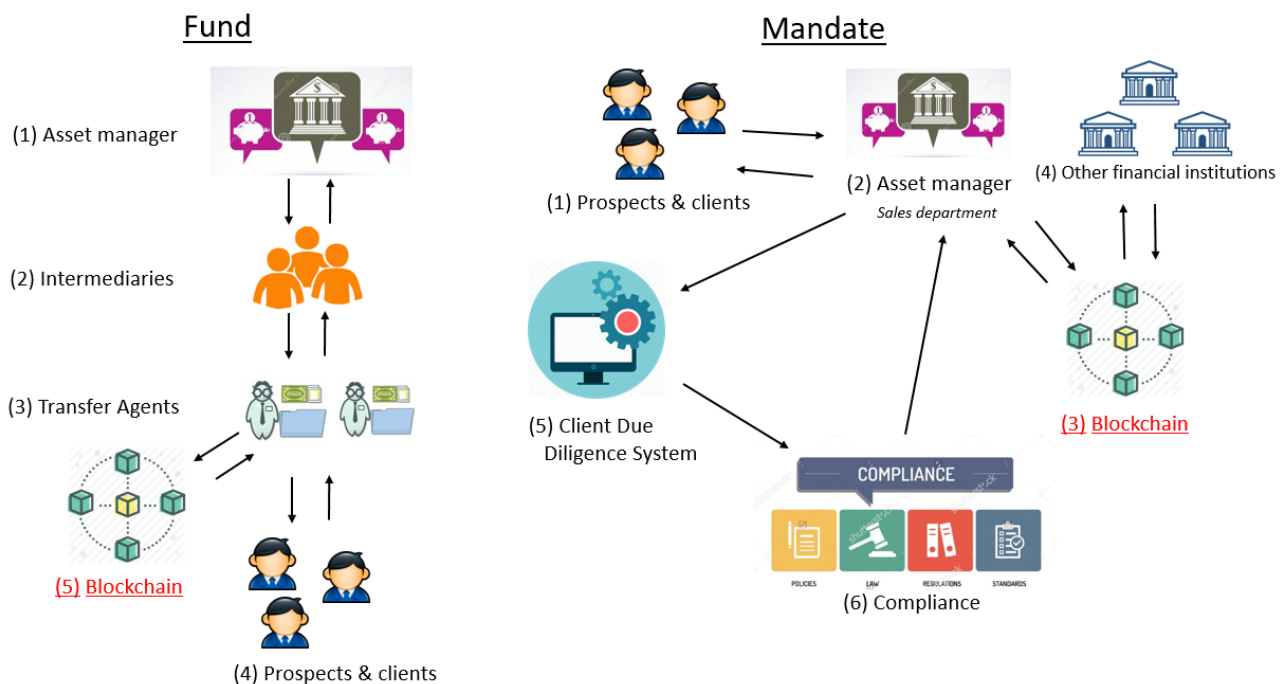
Figure 4.18: The know your customer process using blockchain

For both funds and mandates a scenario is suggested where a distributed ledger is used between the transfer agents and financial institutions, see Figure 4.18. In this scenario the transfer agents or financial institutions retrieve documents from clients, and they can share these with other participants in the ledger that need these documents for their client identification processes. This is because almost all errors in the know-your-customer process occur in the retrieving of documents of a client, while he may have already been identified by another company before. Transfer agents and other financial institutions will be interested in this technology, because it saves them a lot of redundant client identification time.

One of the main implementation challenges that was found in this research is regulation. There are very strict laws regarding client documents, because the documents contain very private client data. A distributed ledger can offer an encrypted shared database that provides a transparent audit trail and has no single point of failure. In addition, any requests that are done for documents on the ledger are continually being validated for identity and permissions through the consensus mechanism. Nonetheless, it can be difficult for clients to trust that this system maintains their privacy, because blockchain is still a relatively new technology. Also, the distributed ledger should be able to be continually updated regarding new privacy laws and governance should be able to be configured.

In the case of funds, we suggest that the role of the asset management company will not change, because only the transfer agents are in contact with clients. Transfer agents will need to communicate more with each other to maintain the ledger, instead of only communicating with clients. Clients will not be interacting with the distributed ledger, only the transfer agents will.

For mandates, the asset manager will need to connect the distributed ledger to their systems, to make sure that all documents can be retrieved properly. Just like with funds, the client will not interact with the distributed ledger, only the financial institutions will. A distributed ledger provides a system where client documents can be shared to parties that need it for their know-your-customer processes. In this scenario it is suggested that the implementation will be easier for funds because only transfer agents are involved. In the case of mandates, many more financial institutions are involed, thus making it harder to have everyone participate and set a standard in the market.

4.2.3.3 Condensed interview results

Current process:

- **Errors in the process and their consequences.**

  - **Funds**. Transfer agents identify the same client many times, process takes 1-2 months, no standard.

  - **Mandates**. Many promises by sales department.

- **Communication and trust between parties.**

  - **Mandates**. Hard to get in contact with clients, clients don't trust asset manager.

- – Funds. Difficult communication with transfer agents.

- **Transparency and governance.**

  - **Mandates**. Internal System is very transparent.

  - **Funds**. No system or transparency, only e-mail.

- **Usage of current systems.**

  - See above.

- **Important flows of information.**

  - Retrieving documents from the client.

- **Regulation.**

  - Laws regarding privacy become stricter every year.

Future process:

- **Innovations in the market and the asset management company.**

  - No, they don't manage to set a standard.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.**

  - **Funds**. Blockchain between transfer agents to share documents, limited participants, less frustration for client and reduced time.

- **Effect on the participants of the process.**

  - **Funds**. Transfer agents need to maintain the ledger.

- **Biggest implementation challenges.**

  - **Funds**. All transfer agents need to participate and market needs a standard.

- **Effect on users inside the asset management company.**

  - **Funds**. Nothing for asset manager.

4.2.3.4 Detailed blockchain comparison

- **Errors in the process and their consequences.** For both funds and mandates the errors occur between the client and the transfer agent or sales department, because it takes a long time to retrieve documents, while the client may have already been identified by another company. This is because the amount of

trust is low in this process, since the documents concern very private client data. A distributed ledger can help here, because it provides a transparent audit trail, has no single point of failure and data can be encrypted. In addition, any requests that are done for documents on the ledger are continually being validated for identity and permissions through the consensus mechanism.

- **Communication and trust between parties.** See above.

- **Transparency and governance.** Governance can be configured on most blockchains and this is very important, since not everyone should have access to a client's data.

- **Usage of current systems.** Current systems will still be necessary, but the documents can be submitted much faster.

- **Important flows of information.** Retrieving documents of clients will almost be unnecessary, because many clients have already been identified by other companies.

- **Regulation.** The distributed ledger should be able to be changed a lot based on new laws regarding privacy and handling with client data.

Chapter 5

Conclusion & Discussion

This chapter will describe the conclusion and discussion of this paper. First, we will give a summary of the research done and answer our research question. Thereafter, we discuss future work and the implications of the answers of our research question. Finally, we consider the limitations of this research.

5.1 Conclusion

This thesis followed a qualitative and quantative case study research methodology to study how the business processes of an asset management company can be optimized using blockchain technology. Our main research question for this paper was "What are the best tools to set up a distributed ledger based on blockchain technology for the core business applications of an asset management company?". Clearly this question had an IT and a business perspective; we had to take a technical look at the blockchain tools, but we also needed to thoroughly understand what the core business processes of an asset management company were.

To conduct our research on the core business processes of an asset management company, we made use of semi-structured interviews with people from different departments inside the case company. In addition, we have made use of quantitative experiments and simulations inside this case study to review the tools that can be used to set up a distributed ledger. This paper argued that the core business processes of an asset management company consist of the post-trade clearing and settlement process, corporate actions (cash dividend) and the know-your-customer process. Research identified several factors that contribute to an environment where blockchain technology can make a lot of impact, and based on these factors we defined our interview topics [13, 29].

We have seen that a distributed ledger can be used to manage the securities in the post-trade process, instead of all custodians using their own systems and databases. In the ideal scenario, the custodian should be removed from this process, but we did not think this would be the case, because these participants are already fully established in the infrastructure. For the corporate actions cash dividends process, we suggested a scenario

where a distributed ledger is used between the transfer agent, custodian and asset manager. We discussed that the transfer agent and custodian share information on the blockchain, whenever they receive information from the exchange market. Their role will change from communicating with the asset management company to maintaining and validating the distributed ledger.

Inside the know-your-customer process we identified two key subprocesses: funds and mandates. For funds, we have seen that the role of the asset management company will not change. A distributed ledger will be used by the transfer agents to submit client data, so they can share it with each other, instead of going through the long process of retrieving the documents from a client. For mandates, we suggest that financial institutions will use a distributed ledger to share client data. The main implementation challenge for the know-your-customer process is regulation, because there are very strict laws regarding client documents.

In this study we have decided to look at Ethereum, R3 Corda and Hyperledger Fabric in our quantitative experiments and simulations. Factors we took into consideration when choosing these blockchain platforms were the usage of the platform by other financial instutions in the industry and the support for smart contracts. To review these blockchain platforms, we have defined criteria such as security, data governance, consensus mechanism, ease of API usage, striking succesful implementations.

At this moment, we have seen that Ethereum failed to offer good support for smart contracts because the coding language is still very young, and did not bring any options to change consensus. However, scalability was excellent and allowed for many validation nodes, but there were no transparency, auditing or privacy options available on the blockchain.

Hyperledger Fabric currently provided encrypted transactions and many options for regulators to investigate transactions and verify users. Nevertheless, they did not offer the scalability and availability of the Ethereum network. As opposed to Ethereum, a consensus could be chosen for each distributed ledger.

Just as in Hyperledger Fabric, Corda provides many options for regulators to check transactions for compliance. However, they could not provide the level of security as Hyperledger did, but they do offer better scalability. Corda does offer the option to choose a consensus at the level of each deal or smart contract, instead of only choosing it on the network level.

5.1.1 What are the best tools to set up a distributed ledger based on blockchain technology for the core business applications of an asset management company?

We will now answer our main research question of this paper; "What are the best tools to set up a distributed ledger based on blockchain technology for the core business applications of an asset management company?". For all of the business processes we will try to argue what the best blockchain platform is that can be used to set up a distributed ledger.

First of all, we suggest that Ethereum should not be used for the business processes of an asset management company. This is because we have seen in our interviews that regulation is a very important aspect; they will

always have to be there to validate transactions. In addition, it was evident that more insight into real-time and up-to-date information for regulators could improve the business processes. Ethereum offers no tools at all that can provide this information for regulators. We do not expect ethereum to release any of these tools in the near future, because the focus of the developers is on the public ethereum blockchain and its issues, and not on private and permissioned ledgers. Finally, smart contracts in Ethereum were still not fully developed yet and have led to security vulnerabilities in the past.

Corda and Hyperledger are very much alike; both are focussed on the financial industry, offer many tools for regulators, a consensus can be chosen, API is still in its early phases and are supported by many investors. Nonetheless, We can identify some differences; Corda provides the ability to establish a consensus between firms at the level of each individual deal/contract and has better scalability, while Hyperledger provides a more secure ledger. However, one thing to note is that Corda is working on a new feature that brings encryption to transactions.

This paper argues that Corda is the best tool to set up a distributed ledger for the core business processes of an asset management company. The only disadvantage compared to Hyperledger is that transactions are not being encrypted. However, we have seen that in Corda sharing of data only done to the right stakeholders, which means that encryption is not necessary, because there is no chance that a node can access the data if they are not part of the deal.

The most important aspect of Corda is that the consensus can be chosen for each individual deal between firms. This is especially important in the know-your-customer process, because laws differ per firm and region, which means that some of them may want to adopt a different consensus. We have discussed before that one of the main implementation challenges for all the business processes is that there is no standard yet and everyone needs to participate. A consensus between individuals and firms makes sure that there will be no debate in the industry about this, because a firm can adopt a different one if he wants. Finally, Corda offers better scalability regarding validation nodes (regulators); in all of the business processes there are many regulators, and we do not want this to affect the performance.

5.1.2 Future work

A topic for future work that can be looked at is integrating smart contracts in the quantitative experiments of our research. This enables the researcher to look at smart contracts from a technical perspective and measure its performance. Moreover, it can be interesting to look at the perspective of other participants in the business processes through interviews with regulators, custodians and transfer agents, and ask them how they think their role in the business process would change. Also, it can be worth looking into initiating a proof of concept with other participants in a business process for our blockchain scenario; a proof of concept allows the researcher to test our scenarios in great detail.

5.2 Discussion

In this study an answer to the research question of what the best blockchain platform is for the core business applications of an asset management company was provided. We have seen that it is important for participants in the business processes to use the same blockchain platform, because as of right now, different distributed ledgers cannot be integrated with each other. This research gives asset management companies the ability find the same tool for their common needs and thus set a standard in the market.

However, in our study it was evident that the companies behind the blockchain platform are still immature. Moreover, the blockchain platforms are in constant development and many new features are being worked on. Our answer to the research question was based on an image of the current blockchain industry and can change as other tools in the industry improve their weaknesses. However, in this research we have provided a framework of how a blockchain tool can be evaluated and what criteria are important, which can be used by asset management companies themselves when the blockchain industry changes.

5.2.1 Limitations

One of the limitations of this research is the generalizability of case study. The case study was done at one organization and the interviews were done with only a few participants, which means that the sample is very small and does not represent the asset management industry as a whole. Further, the subjective bias of the researcher because of the exposure in the environment of the case study is an issue, as well as the answers of the interviewees could be interpreted differently. Time limitation can also be considered an issue, because the research lasted only five months in total.

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Appendices

Appendix A

<u>Technical</u>

- **(3) Ease of API usage**. For our experiments we have defined functions that we want to implement for each blockchain platform. It is import to measure the ease of the usage of the API, because to connect the blockchain implementation properly to the systems of the asset management company, we have to make a lot of use of the API.

  - **How do we measure it?**. How fast are the functions executed (2pt)? How long did it take us to implement them (3pt?) Did we experience any issues/bugs (3pt)? Was it easy to install the API (1pt)?

  - **Measurement end result**. 1-10.

- **(2) Scripting languages for interacting with the API**. The scripting language that must be used to communicate with the API. This can be important, because companies often use specific scripting languages for all their systems and this means that not every language is compatible with their systems. In addition, developers often have a lot of experience some specific languages and less with others.

  - **How do we measure it?**. Check scripting language in code/documentation/white paper of the blockchain platform.

  - **Measurement end result**. Scripting language.

- **(2) Scripting language for contracts**. Same as above.

  - **How do we measure it?**. Check scripting language in code/documentation/white paper of the blockchain platform.

  - **Measurement end result**. Scripting language.

- **(2) Ease of setup/installation**. ow difficult is it to set-up the blockchain, do you need to do a lot of coding yourself or is it very easy to change any settings, can you install the nodes on the server that validate the block with ease etc. This is important to know, because current systems in asset management can already be very complex, so any way to make it easier will definitely help.

- **How do we measure it?**. How much scripting did we need to do ourselves (3pt)? Do you have a lot of configuration options (3pt)? How long did it take us to set it up (3pt)?

- **Measurement end result**. 1-10.

- (2) **Documentation**. A good documentation makes sure that we know how to configure the blockchain properly and communicate with the API. In addition, it is important to get insight into how the blockchain works using models and diagrams, so developers know how to connect it to their current systems.

  - **How do we measure it?**. Do we need to ask for help on forums (3pt)? Could we easily get help on forums (3pt)? Can we develop our application by only using the documentation (3pt)?

  - **Measurement end result**. 1-10.

- (2) **Stability**. In the most advanced scenario's DLT environments will become the backbone of the asset management company. When this is the case the underlying software and infrastructure must be rock solid.

  - **How do we measure it?**. Did we experience any (unexplainable) issues, For instance with failing nodes or connectivity issues(4pt)? When there were issues, how easy was it to reset and restore the configuration (5pt)?

  - **Measurement end result**. 1-10.

- (2) **Supported operating system**. The supported operation system (OS) can be vital, because if the servers at the company do not run the supported OS, you cannot use the specific blockchain platform. Of course, the company can acquire new servers, so we do not rank this as important as some others, but this will cost time and money.

  - **How do we measure it?**. Check supported OS in code/documentation/white paper of the blockchain platform.

  - **Measurement end result**. OS.

- (1) **Client graphical user interface**. A graphical user interface (GUI) is important for the end-user of the blockchain; people from the business and our clients. If a GUI is not available, this means that we will have to create it ourself which will take time.

  - **How do we measure it?**. Check whether it has a GUI in code/documentation/white paper of the blockchain platform.

  - **Measurement end result**. Yes/No.

- (1) **Implementation language**. The language where the blockchain is written in can be different, for example Python, C++, Java etc. Useful to know if the platform is open-sourceand we want to make changes to the code.

– **How do we measure it?**. Check implementation language in code/documentation/white paper of the blockchain platform.

– **Measurement end result**. Implementation language.

- (1) **Open source**. An open source blockchain platform means that we can adjust the code to our needs and wishes. However, an open source platform means that other people could have made small changes to the code which have not been checked and tested properly.

  – **How do we measure it?**. Is it open source (y/n)? how are current issues tracked and solved (9pt)?

  – **Measurement end result**. Yes/No, 1-10.

- (1) **Blockchain explorer available**. A blockchain explorer can be used to get detailed information about the status, blocks, addresses and transactions on the blockchain. It is good to have the option to have an overview like this, so you can have insight in the blockchain and keep control.

  – **How do we measure it?**. Blockchain explorer is available or not.

  – **Measurement end result**. Yes/No.

- (1) **Standard cloud offering available**. The blockchain has to run on some sort of server, and if there is no standard cloud offering available, we will have to set it up ourselves. A standard cloud offering will cost us more, but makes sure that the blockchain will be setup properly. Depending on the ease of set-up/installation, a company can make the decision whether they want to let the vendor do it or themselves.

  – **How do we measure it?**. Check whether blockchain offers a cloud solution at the company website.

  – **Measurement end result**. Yes/No.

- (1) **(when open source). Is there a commercial version of the open source tooling available**. A lot of organizations do not like to use open source software. In some cases vendors offer commercial wrappers arround open source. Examples; Redhat Linux or Hortonworks Hadoop. If a commercial variant of the blockchain implementation is available, this might mitigate a numer of implementation and maintance risks.

  – **How do we measure it?**. Check if there is a commercial implementation of the open source code available on Github or blockchain's website.

  – **Measurement end result**. Yes/No.

- (1) **Turing complete**. A Turing Complete systems means a system in which a program can be written that will find an answer to any computation given enough time and space. A turing complete system is ofcourse useful because this means that developers are not restricted in their programming.

  – **How do we measure it?**. Check turing completeness in documentation.

– **Measurement end result**. Yes/No.

<u>Blockchain aspects</u>

- (3) **Consensus mechanism**. It is important to know the consensus mechanism in the blockchain, because this will determine how the transactions are validated. Depending on the consensus mechanism, there are certain malicious attacks that you need to protect yourself against, for example a '51% attack'. Depending on the business use case of the blockchain and the parties involved, the company may prefer certain consensus mechanisms.

    – **How do we measure it?**. Check consensus that blockchain implementation uses in code/documentation/white paper of the blockchain platform.

    – **Measurement end result**. Consensus, how good it is depends on the business use case.

- (3) **Public vs. private vs. unpermissioned vs. permissioned**. Especially in the financial sector, safety of a person's assets on the blockchain is vital. In public and unpermissioned ledgers, all peers in the ledger can validate the transactions. This means that the blockchain is exposed against attacks such as a '51% attack'. A financial company will never be allowed to join a ledger without any trusted actors, so it is important for such companies to have a permissioned and preferably private ledger.

    – **How do we measure it?**. Check whether it is public, private etc. in code/documentation/white paper of the blockchain platform.

    – **Measurement end result**. Public/Private, Unpermissioned/Permissioned.

- (3) **Data governance**. It is vital from a security and compliance perspective that it is clear who has which permissions in the blockchain. A trader from company A should never be allowed to see the assets of Company B and this needs to be auditable. Especially in the financial sector there are a lot of rules regarding the management of a client's assets that companies need to comply with; a blockchain needs to be able to show that these rules are followed.

    – **How do we measure it?**. Can you configure who can see what (3pt)? Is this auditable (4pt)? Can you give certain users more permissions (3pt)?

    – **Measurement end result**. 1-10.

- (2) **Support for smart contracts**. Smart contracts, if properly implemented, are one of the most essential features of blockchain technology. Smart contracts enable (financial) companies to automate a lot of processes that currently take up a lot of time. Without smart contracts, processes can still be made more efficient, but much less.

    – **How do we measure it?**. Are smart contracts supported? How difficult is it to program using these contracts (4pt)? What is the performance of these smart contracts (5pt)?

    – **Measurement end result**. Yes/No, 1-10.

- (2) **Scalability**. How many transactions/second can the blockchain process, how fast are transactions sent, how many users can be added to the blockchain and how long does it take for them to be validated? These questions will not be important for a blockchain if a business process involves a couple of parties and two hundred transactions a day, but they do if the blockchain gets much larger. Depending on the business process, this criterion can get really important.

    – **How do we measure it?**. How many users can be added (2pt)? How many transactions/second can be send (2pt)? Does it take long for transactions to be validated (3pt)? How does the performance scale with the amount of users (2pt)?

    – **Measurement end result**. 1-10.

- (1) **Cryptocurrency**. Does the blockchain use it's own cryptocurrency, or is it linked to the national currencies. If a cryptocurrency is used, there needs to be a proper way to convert your virtual money to the currency you want it in.

    – **How do we measure it?**. Check cryptocurrency in code/documentation/white paper of the blockchain platform.

    – **Measurement end result**. Yes/No.

Security

- (3) **Security against hacking**. Can tests be provided by the blockchain to ensure securities such as protection against hacking, can any penetration testing be done by the company or the vendor.

    – **How do we measure it?**. What protection is implemented against hacking (3pt)? Is any penetration testing done (3pt)? Is it allowed by the company to do penetration testing themselves (3pt)?

    – **Measurement end result**. 1-10.

- (3) **Responsibility (incident management)**. When an incident occurs, how is this managed? This is important in the financial sector because so much money is involved in the process.

    – **How do we measure it?**. Does the company manage who is responsible for what when something goes wrong (4pt)? Did they think of proper responds to certain incidents (5pt)?

    – **Measurement end result**. 1-10.

- (3) **Encryption**. How is the data on the blockchain encrypted/hashed? If a man-in-the-middle attack occurs, how much information can they "steal" from the user? This is especially important in the financial sector.

    – **How do we measure it?**. What encryption method is used (5pt)? What cryptography method is used (4pt)?

    – **Measurement end result**. 1-10.

- (2) **Organization behind the implementation/Business model**. How is the organization behind the blockchain implementation structured, is it ran one or many companies? Does it have a commercial consortium (meaning that they earn money per transaction you make) or is everything open source? What is their business model? This is important because depending on the business model and the business process the blockchain implementation can cost a lot of money. Also, if e.g. the company is from the United States, you have to comply with certain rules that their government can ask for your data at any time.

  - **How do we measure it?**. How is the organization behind the blockchain implementation structured, is it ran one or many companies (2pt)? Does it have a commercial consortium (meaning that they earn money per transaction you make) or is everything open source (4pt)? What is their business model (3pt)?

  - **Measurement end result**. 1-10.

- (2) **Functional + technical roadmap**. What are the plans of the organization for the future? Do they have a clear roadmap for the future of what features and functionalities they want to implement and what is their philosophy regarding the future of blockchain? This is important because we want a company that has plans for the future and responds to new changes in their environment and also has the same vision of the future of blockchain as us.

  - **How do we measure it?**. What are the plans of the organization for the future (2pt)? Do they have a clear roadmap for the future of what features and functionalities they want to implement (5pt)? What is their philosophy regarding the future of blockchain (2pt)?

  - **Measurement end result**. 1-10.

- (2) **Service**. Are there any services provided by the organization if problems occur? This is especially important in the financial sectors, where small problems can cost a lot of money if they are not solved quickly.

  - **How do we measure it?**. Any service provided? How good is this service (9pt)?

  - **Measurement end result**. 1-10 (level of service, 1 is NO service).

- (1) **Change and release management**. Is there any insight in how the organization manages changes and releases of software, do we know if any auditing is done, what has changed in new versions, how the tools are tested, what software development framework they use (Agile/Waterfall)?

  - **How do we measure it?**. Is there any insight in how the organization manages changes and releases of software (2pt)? do we know if any auditing is done (3pt)? how the tools are tested (2pt)? what software development framework they use (Agile/Waterfall) (1pt)?

  - **Measurement end result**. 1-10 (level of service, 1 is NO service).

- (1) **Maturity**. Some blockchain platforms have been in the market for several years, but many startups not even a year. We can say that a blockchain platform where people have worked on for a long time, is more stable and also has a more mature organization and management.

    - **How do we measure it?**. How "old" is the blockchain implementation?

    - **Measurement end result**. How old.

- (1) **Development team**. How many people are working on the blockchain platform? This often determines the pace of the development.

    - **How do we measure it?**. Check amount of developers.

    - **Measurement end result**. Amount.

- (1) **Striking succesful implementations**. Has the organisation implemented a blockchain platform at any other organisations? If they have a large history of (succesful) implementations, you know they have a lot of hands-on experience with implementing blockchain technology in practice.

    - **How do we measure it?**. Check amount of succesful implementations.

    - **Measurement end result**. Amount

Case company

- (3) **Support of counterparties**. Are any of the case company's "counterparties" using/supporting it (regulator, custodians, swift, brokers, asset managers)? This is very important, because if none of our counterparties support this blockchain implementation, we can only use blockchain for our internal processes. One of Robeco's goals for blockchain is to use this technology for their core business processes such as trading and corporate actions, but for this to work we need our partners to support it as well.

    - **How do we measure it?**. Communicate with the blockchain team inside Robeco about this and look at the blockchain company's website.

    - **Measurement end result**. Yes/No, which ones.

- (2) **Cost**. Open source blockchain implementations are essentially free, but a financial company is probably looking for a more secure solution. However, permissioned ledgers often have a price, so it is important how high this price is.

    - **How do we measure it?**. Check sales or look at other blockchain implementations in similar companies.

    - **Measurement end result**. (average) price.

- (1) **Usage in asset management industry**. Is this blockchain implementation used in the asset management industry? If so, we can later check how it is implemented and if if it is working properly.

– **How do we measure it?**. Consult other companies in the industry, through Robeco blockchain team or by looking on the company's website.

– **Measurement end result**. How many and which companies.

Appendix B

<u>Technical</u>

- (3) **Ease of API usage**. How fast are the functions executed (2pt)? How long did it take us to implement them (3pt?) Did we experience any issues/bugs (3pt)? Was it easy to install the API (1pt)?

  – <u>8</u> **Ethereum**. API was fairly easy to use and install (1pt). It can be used via Node.JS which is easy to setup and use Furthermore a number of usefull tools are available like MetaMask wallet which is a plugin for Chrome that communicates directly to a Etherum instance. Execution time is OK, sending transactions did take long (1pt). There were some issues regarding sending transactions, but for the rest it was fine (2pt). Didn't take too long too implement (3pt).

  – <u>7</u> **HyperLedger**. API was easy to use (1pt). We used HyperLedger Fabric implementation on IBM BlueMix. This provides API acces via Swagger based GUI that enables us to test the API directly from the BlueMix console. Calling the APIs from NodeJS was also easy. Still there were some small issues/bugs, while it looked really clean and simple (2pt). e.g, for transactions to send, you had to make use of smart contracts. Executed fast but long to implement because of contracts (2pt + 1pt).

  – <u>6</u> **Corda**. It is easy to connect to the API (1pt). However, instead of having a library with functions like getBlock(), you have to implement all of them yourself, which takes a long time (0pt). You can say that this offer some freedom, but in Ethereum you have a library but you can add functions yourself too if you want. Function executing is good (2pt), because in corda everything is setup such that not all nodes need to validate a transaction. Setting up the API took some time, there were some issues (2pt).

- (2) **Scripting languages for interacting with the API**.

  – **Ethereum**. <u>Javascript</u>. Ethereum offers a library (web3JS) that is only compatible with javascript. This makes it easy to integrate with NodejS.

  – **HyperLedger**. <u>REST API</u>. The API is a REST API. It can be called from any language or tool that supports REST. We used Javascript.

  – **Corda**. <u>REST API</u>. The API is a REST API. It can be called from any language or tool that supports

REST. We used Javascript.

- (2) **Scripting language for contracts**.

    – **Ethereum**. <u>Solidity</u>. Solidity is by far the most used contract language in Ethereum. Solidity is created specifically for Ethereum and is thus a fairly young language with small userbase, limited tool support and a number of bugs. Other languages are Serpent and Viper (derived from Python).

    – **HyperLedger**. <u>Java/GO</u>. Contracts (in Fabric called chain code) can be implemented in Java or GO. Our test setup on BlueMix only supported GO.

    – **Corda**. <u>Java/Kotlin</u>. Contracts are written in Kotlin or Java.

- (2) **Ease of setup/installation**. How much scripting did we need to do ourselves (3pt)? Do you have a lot of configuration options (3pt)? How long did it take us to set it up (3pt)?

    – **Ethreum**. <u>6</u>. Ethereum is not really easy to setup, took long (1pt). There is a lot of documentation available but a great part of the documentation is outdated. Furthermore, Ethereum is quite configurable with lots of different parameters to tailor the implementation to suit your needs (3pt). It requires quite a lot of reading and experimenting to get Ethereum working (1pt, to let it work good you have to script yourself). We also configured an Ethereum setup on Microsoft Azure. This installation went realy smooth as it hides all technical details. On the other hand; after installation we had some issues connecting to the nodes because that specific technical detail was left out of the documentation.

    – **HyperLedger**. <u>7</u>. The initial setup on BlueMix was very easy, in a number of mouseclicks a network with 4 validating peers was created (3pt + 3pt). Connecting to the network went very smooth. Setting up a network ""on premise"" might be more complex (0pt, not much configuration).

    – **Corda**. <u>6</u>. For the initial setup we could follow the guide on the website, but still it took us a lot of time to set it up (1pt). In addition, if you want to configure anything, you have to dive into the code and change it yourself (1pt). This does offer many options for developer, but it takes some time (3pt).

- (2) **Documentation**. Do we need to ask for help on forums (3pt)? Could we easily get help on forums (3pt)? Can we develop our application by only using the documentation (3pt)?

    – **Ethereum**. <u>7</u>. There is a lot of Ethereum documentation. In fact, there is too much documentation. A great part of the documentation is outdated as Ethereum evolves realy fast. We did needed to ask some questions on the forum, but we did get help really fast (2pt + 3pt). Using only documentation to develop it would be difficult, because so much is outdated (1pt).

    – **HyperLedger**. <u>5</u>. There is not as much documentation on HyperLedger as there is on Ethereum (1pt). The concepts of HyperLedger are different from Ethereum. It took us a while to notice and fully understand these differences, difficult without any help (1pt). Example: HyperLedger

Fabric does use the concept op transactions but these are different transactions than those used on Ethereum. Fabric initialy does not come with cryptocurrency that can be transferred between wallets. Everything has to be coded in ChainCode. This allows for more freedom but this concept was not clear to us from the beginning. Not many forums to ask help (2pt).

– **Corda**. 7. There is a forum where you can ask questions to the developers of Corda, but this is the only forum where you can find information about it, they do offer help very fast (2pt + 2pt). The documentation on the Corda website is good, but still too complicated and it is hard to find something. They do make use of many diagrams and models to explain the concepts (2pt). Concepts do differ from Ethereum, because all functions such as getBlock() have to be coded yourself, while in Ethereum they have a library for this. In addition, just like HyperLedger, you need a smart contract to do transactions. This concept allows for more freedom, but was not clear from the start.

- (2) **Stability**. Did we experience any (unexplainable) issues, For instance with failing nodes or connectivity issues (4pt)? When there were issues, how easy was it to reset and restore the configuration (5pt)?

  – **Ethereum**. 9. Once set up we did not experience many issues (4pt). Connectivity issues focus mainly on the uses of non-standard ports. Within a financial organization that causes challenges with security features (proxies, firewalls). But those are "one off" during installation/configuration. When a node should "malfunction" it is easy to add another node to the network and synchronize so that all blocks are available on the new node (4pt).

  – **HyperLedger**. 4. Availability of network on BlueMix was measured by IBM on 94%, that is way below required availability levels. The reasons for the issues were not clear (1pt). For a production environment we would need extra measures to reach better. availablity (2pt).

  – **Corda**. 8. Some nodes did randomly fail, but for the rest we did not notice any unexplainable issues (2pt). We could restart the blockchain easily if anything went wrong (5pt).

- (2) **Supported operating system**.

  – **Ethereum**. Windows/Linux. You can run it in geth console.

  – **HyperLedger**. Windows/Linux/Mac. Docker needs to be installed.

  – **Corda**. Windows/Linux/Mac. IntelliJ needs to be used.

- (1) **Client graphical user interface**.

  – **Ethereum**. No.

  – **HyperLedger**. Yes. Yes, on BlueMix.

  – **Corda**. Yes.

- (1) **Implementation language**.

- **Ethereum**. Python/Go/Java. The Ethereum foundation creates the specification for Ethereum clients (the nodes). Reference implementations for those clients in different languages exist for instance in Python, Go and Java.

- **HyperLedger**. Java/Javascript.

- **Corda**. Java/Kotlin.

- (1) **Open source**. Is it open source (yes/no)? how are current issues tracked and solved (9pt)?

  - **Ethereum**. Yes, 7. Ethereum is 100% opensource, issues are tracked well. However, some issues take really long to solve as they are placed at the end of the roadmap, and open source developers don't pick them up (7pt).

  - **HyperLedger**. Yes, 8. HyperLedger Fabric was donated to the HyperLedger community bij IBM. It is 100% open source. Issue tracking is handled in Jira, the developer's Agile/Scrum application (8pt).

  - **Corda**. Yes, 8. Corda was first developed by the developers only, but later became open source. Current issues are tracked and labeled well. In addition, people can make changes to the code, which the corda developers will check for their quality management (8pt).

- (1) **Blockchain explorer available**.

  - **Ethereum**. Yes. Yes. Multiple explorers for the public blockchain are available. However, when running a private network a blockchain explorer must be manually implemented on the prive chain.

  - **HyperLedger**. Yes. There is a Hyperledger incubation project call HyperLedger Explorer. We have not tested it.

  - **Corda**. Yes.

- (1) **Blockchain explorer available**.

  - **Ethereum**. Yes. Cloud instance is available for instance on Microsoft Azure. We actually used this Azure variant for our experiments.

  - **HyperLedger**. Yes. HyperLedger Fabric is available on IBM BlueMix. At this moment in a beta variant.

  - **Corda**. Yes. Yes, you can deploy it on Azure.

- (1) **(when open source). Is there a commercial version of the open source tooling available**.

  - **Ethereum**. No. No, not as far as we have seen. There is an Ethereum installation available on Microsoft Azure but Microsoft does not offer any guarantees on the software. A new alliance (Enterprise Ethereum) of many big companies is working on making Ethereum available for businesses. Maybe this could lead to a commercial offering.

- **HyperLedger**. <u>No</u>. HyperLedger Fabric is available on IBM BlueMix. At this moment in a beta variant. Not for full fledge commercial use.

  - **Corda**. <u>No</u>. No, they do have stable milestone releases, but it is still in beta.

- (1) **Turing complete**.

  - **Ethereum**. <u>Yes</u>. Yes. The smart contract programming languages (Solidity, Serpent, etc.) are advanced enough to call Ethereum Turing Complete. Although we must mention that the "immaturity" of Solidity may still be an issue.

  - **HyperLedger**. <u>Yes</u>. Yes. Smartcontracts (Chaincode) can be created in Java or GO. This makes HyperLedger turing complete.

  - **Corda**. <u>Yes</u>. Yes, contracts are turing complete because of Java and Kotlin.

<u>Blockchain aspects</u>

- (3) **Consensus mechanism**.

  - **Ethereum**. <u>Proof-of-Work</u>. Proof-of-Work, it is discussed within the Ethereum community to switch to Proof-of-Stake, no choice for any other consensus.

  - **HyperLedger**. <u>Different/Pluggable</u>. Different/pluggable, Practical Byzantine Fault Tolerance (P)BFT by default. This means that for each business use case, a specific consensus can bechosen.

  - **Corda**. <u>Different/Pluggable</u>. Different/pluggable, Byzantine Fault Tolerance or Raft by default. Consensus is specific per contract, so not for the whole system. A consensus occurs between participants in deals (smart contracts), and not for all participants. This means that for each business use case, a specific consensus can be chosen, and even for specific deals between customers, a consensus can be chosen. Regulators are also included in the consensus process, to gain more insight.

- (3) **Public vs. private vs. unpermissioned vs. permissioned**.

  - **Ethereum**. <u>Both</u>. A public unpermissioned Ethereum platform exists. But the Ethereum technology can also be installed/configured private/permissioned.

  - **HyperLedger**. <u>Private/Permissioned</u>. Private / Permissioned. HyperLedger Fabric is intended to serve small dedicated DLTs. There is no public variant up-and-running.

  - **Corda**. <u>Private/Permissioned</u>. Private / Permissioned. Corda is intended to serve small dedicated DLTs. There is no public variant up-and-running

- (3) **Data governance**. Can you configure who can see what (3pt)? Is this auditable (4pt)? Can you give certain users more permissions (3pt)?

– **Ethereum**. 4. Ethereum in itself is completely open/public. All participants can see all accounts and all transactions. Adding privacy must be coded in smart contracts on top of the Ethereum blockchain. The Ethereum community is think about different options to add privacy but as far as we could see those are not implemented yet (3pt + opt + opt). To summarize, you will have to program it all yourself if you want.

– **HyperLedger**. 8. HyperLedger is not intended/created as a public blockchain. HyperLedger offers the technology that must be installed by the user. This allows for creating private permissioned blockchains. The functionality actually running on the blockchain is defined by the chaincode that is deployed on the blockchain. Within the chaincode the programmer can define what is visible or not to the different users (3pt + 2pt + 2pt).

– **Corda**. 9. Corda's main focus is on the financial industry, and this means that everything has to be auditable and well governed (4pt + 2pt). For example, company C cannot see any transactions done between company A and B, because it does not have the rights to see. Regulators are included in the consensus process, to gain more insight and for audits, and they can give users permissions (2pt).

- (2) **Support for smart contracts**. Are smart contracts supported? How difficult is it to program using these contracts (4pt)? What is the performance of these smart contracts (5pt)?

    – **Ethereum**. 3-8. Smart contracts are supported. The userfriendlyness of the contracts is not very good (2pt). It is quite a task to create and run a smart contract. We have no experience with performance of the smartcontracts.

    – **HyperLedger**. -. Smart Contract are supported. Infact, without smart contracts Fabric will no nothing. You must deploy the functionality in the form of ChainCode to the Blockchain in order to get any functionality running. No info about performance or difficulty.

    – **Corda**. 8. Supported good. Transactions can only be done using a contract, just like Fabric. Corda is made to link financial and legal agreements to contracts, so that works really well, contracts are still a bit difficult to implement because corda is still in beta phase (32pt). Cordas most important feature is its ability to establish a consensus between firms at the level of each individual deal, not at the system level (5pt).

- (2) **Scalability**. How many users can be added (2pt)? How many transactions/second can be send (2pt)? Does it take long for transactions to be validated (3pt)? How does the performance scale with the amount of users (2pt)?

    – **Ethereum**. 9. "The Ethereum network allows for thousands of nodes (2pt). Each nodes can have as many clients/users as the node's infrastructure can handle. The public Ethereum network has 10.000 nodes. Peaks in number of transactions are around 100.000 transactions a day (2pt). This holds for the public Ethereum network. A private network will have other characteristics. The numbers shows what the technology is capable of (2pt). Proof-of-Stake validation not optimal yet (1pt).

– **HyperLedger**. 7. The current performance goal for Hyperledger Fabric is to achieve 100,000 transactions per second in a standard production environment of about 15 validating nodes running in close proximity (2pt + 3pt). The team is committed to continuously improving the performance and the scalability of the system. The consensus mechanism limits the number of nodes because it requires that a node interacts with all peers (1pt) . In a large network (documentation says ¿20 nodes) this will become a bottleneck (0pt).

– **Corda**. 8-10. Scalability is good, because nodes only encounter transactions if they are involved in them, thus many nodes do not need to process transactions, very efficient (3pt validation). In addition, multiple consensus services can be used, so not all transactions must be processed by the same consensus (for each business use case, the appropriate consensus can be chosen, depending on scalability). Performance does not decrease with the amount of users, because of the many scalability features such as partitioning, clustering of the validation nodes (2pt +2pt). number of active nodes does not have effect on volume/traffic/latency. No info about transactions per second it can handle (0pt).

- (1) **Cryptocurrency**.

    – **Ethereum**. <u>Yes</u>. Yes. Ether. Ether for the public Ethereum network costs real money. Ether for a private network does not cost real money.

    – **HyperLedger**. <u>Depends</u>. No, Hyperledger Fabric is different from for instance Bitcoin network or Ethereum. Fabric uses Practical Byzantine Fault Tolerance instead of a mining protocol. This can do without crypto currentcy. It is possible to create a crypto currency in the chaincode on Fabric.

    – **Corda**. <u>No</u>. No. Practical Byzantine Fault Tolerance is used, there are "notary nodes" that validate transactions.

<u>Security</u>

- (3) **Security against hacking**. What protection is implemented against hacking (3pt)? Is any penetration testing done (3pt)? Is it allowed by the company to do penetration testing themselves (3pt)?

    – **Ethereum**. <u>4-10</u>. There are a number of options to "hack ethereum", however, for a private and permissioned blockchain the only danger can lie in smart contracts. The public Ethereum chain consists of thousands of nodes and is visible for every one. It is relatively easy to become a node in the blockchain. The biggest "hack-challenge" lies in the risk that a hacker(group) may "own" as many nodes in the network that they can influence the blocks and insert false transactions. Getting control of this amound of nodes could be done by adding nodes to the network or by taking over control of existing nodes. On top of Ethereum lie the smart contracts. Ethereum smart contracts are coded in Solidity a relative new programming langues in which you can code logic and interact with the underlying blockchain. Hackers can exploit vurnerabilities in the programming language. This in fact was done in the big DAO hack that almost caused the end of Ethereum and led to the

infoumous Hard-Fork. Crypto exchanges convert "real" money into Crypty currency as Bitcoin or Ether. Crypto exchanges are business with the same weaknesses as all other businesses. We have seen a number of hacks on crypto exchanges in which a large number of ether was stolen. This type of hack has nothing to do with the Ethereum blockchain. Solidity is a real vulnerability as the DAO hack proved. The DAO hack also showed that openess of the Ethereum blockchain community quickly identified the hack and solved it.Attacking the chain by taking control over the majority of the nodes is very expensive. It is not very likely to happen. The Ethereum community is constantly looking for ways to improve the consensus mechanism and protect the chain against hacks". Hacks not likely on private network (3pt), no info about penetration testing.

– **HyperLedger**. 7-10. As HyperLedger is intended for private chains, protection against hacks is not an intrinsic topic for the blockchain to solve. The consensus mechanism requires the majority of the nodes to be trustworthy otherwise the mechanism will fail but within a private network this will be easier to uphold than in a public network (3pt). Penetration testing is done for every new release (3pt). Man in the middle attacks are solved using SSL/TLS. No info about company penetration testing.

– **Corda**. 4-10. Blockchain is intented for private use, so the validating nodes can be trusted, thus no danger of a 51% attack (3pt). Corda does offer the option for load testing, to check the behaviour of nodes when they are stressed. No information on any penetration testing. Encryption is being worked on, but man in the middle attacks are solved using SSL/TLS.

- (3) **Responsibility (incident management)**. Does the company manage who is responsible for what when something goes wrong (4pt)? Did they think of proper responds to certain incidents (5pt)?

    – **Ethereum**. 4pt. Ethereum is open source. No incident management by "a company". The Ethereum community could be considered as the incident management group (2pt + 1pt). For the Ethereum Alliance, we do think there will be incident management.

    – **HyperLedger**. 3pt. There is no enterprise ready or fabric-as-a-service solution available. Maybe for proof-of-concepts at companies they do offer this (2pt).

    – **Corda**. 3pt. There is no enterprise ready or fabric-as-a-service solution available. Maybe for proof-of-concepts at companies they do offer this (2pt).

- (3) **Encryption**. What encryption method is used (5pt)? What cryptography method is used (4pt)?

    – **Ethereum**. 7. cryptography is keccak-256 (4pt). Smart contracts are encrypted. They are working on new privacy and encryption methods for normal transactions (2pt).

    – **HyperLedger**. 9. cryptography is SHA3 (4pt). Transactions are encrypted, only stakeholders in the transaction can decrypt it (4pt).

    – **Corda**. 8. crytpography is SHA-256 (4pt) . No t encryption, however, sharing of data is only done to the stakeholders (3pt). Encryption is a new feature that is being worked on.

- (2) **Organization behind the implementation/Business model**. How is the organization behind the blockchain implementation structured, is it ran one or many companies (2pt)? Does it have a commercial consortium (meaning that they earn money per transaction you make) or is everything open source (4pt)? What is their business model (3pt)?

  - **Ethereum**. 9. Ethereum is opensource. The standard is guarded by the Ethereum Foundation There are commercial offerings, for instance via Microsoft Azure (2pt). Also the Enterprise Ethereum consortium was founding; a large number of tech firms and financials working together to create a enterprise ready Ethereum setup. However, the main focus of the developers (such as V. Buterin) is on the public (!) ethereum blockchain and its issues, and not on creating private and permissioned blockchains. Currently, only funding is through investmens or crowdfunding, no business model (3pt + 3pt).

  - **HyperLedger**. 8. HyperLedger is open source. Hyperledger is adopted by the Linux Foundation (2pt). They don't have a commercial consortium, but get their money through funding or doing specific implementations for companies (3pt + 2pt).

  - **Corda**. 8. Open source, companies can use it themselves to program, not commercial or anything (3pt + 2pt). However, R3 does offer specific implementations for companies, and this together with funding is where they get their money. Made by R3 that launched a consortium of many companies so they could create Corda (2pt).

- (2) **Functional + technical roadmap**. What are the plans of the organization for the future (2pt)? Do they have a clear roadmap for the future of what features and functionalities they want to implement (5pt)? What is their philosophy regarding the future of blockchain (2pt)?

  - **Ethereum**. 9. Ethereum was devised by Vitalik Buterin who is seen as one of the thought leaders for the entire DLT world. Furthermore the Ethereum community is very active. There is a roadmap with planned releases and the features that will be contained in those releases (4pt + 2pt). They have a philosophy of the future of blockchain that is supported by almost the entire DLT community (2pt).

  - **HyperLedger**. 8. HyperLedger is open source. It is backed by the Linux Foundation and a large number if tech fims and financials. Version 1.0 will be releases somewhere mid 2017. A large number of extra projects and features are listed to follow version 1.0 (2pt + 3pt). Philosophy is for financial worlds and contracts (2pt).

  - **Corda**. 8. On Github, information can be found about new features, not that much (3pt). In addition, they do offer insight into their Agile Scrum application, so you can see their progress (2pt). They want it for the financial world, big company behind it. Their philosophy is to have their technology be used for the financial world (2pt).

- (2) **Service**. Any service provided? How good is this service (9pt)?

  - **Ethereum**. 4. No service (except for the open source community and the large number of nodes running in the public network).

  - **HyperLedger**. 1. No service.

  - **Corda**. 6. The developers do offer help if any issues are found, they have a website for this. However, at this moment an enterprise-grade support service for Corda implementations is coming.

- (1) **Change and release management**. Is there any insight in how the organization manages changes and releases of software (2pt)? do we know if any auditing is done (3pt)? how the tools are tested (2pt)? what software development framework they use (Agile/Waterfall) (1pt)?

  - **Ethereum**. 7. This is somewhat a difficult question for Ethereum. Within the Ethereum community there is quite some discussion on the change and release policy. More particular on the Hardfork policy On the software development side, the Ethereum community uses the open source development process and tools like GitHub, etc. (1pt). Another interesting aspect is the fact that Ethereum describes a protocol. The protocal is implemented by a number of teams leading to multiple node implementations in different programming languages. This adds to the robustness of the entire network (2pt). Tests done on github and they use agile (2pt + 1pt).

  - **HyperLedger**. 8. It's open source As there is no public network, there are no ""world wide issues"" like the hard fork discussion on Ethereum. They do have a clear test / auditing plan for releasing (2pt + 1 pt). They use Agile (1pt). Tests provided on github (3pt).

  - **Corda**. 8. Open source, but you do have access to their Agile scrum application from the developers, so much insight in their releases and current features (1pt + 2pt + 2pt). In addition, they do offer many (automizedd) tests in their Corda application (2pt).

- (1) **Maturity**.

  - **Ethereum**. -. Pretty mature, one of the first, but also still a long way to go

  - **HyperLedger**. 8. It looks OK but less mature than Ethereum

  - **Corda**. 6. Have been working on it for some years, but only since a half a year they are open source.

- (1) **Development team**.

  - **Ethereum**. 140. Many developers, 140 developers on the github.

  - **HyperLedger**. 92. Community seems active, 92 on the github, including developers from IBM.

  - **Corda**. 40. Community is growing, but not many yet, around 40 contributors including developers from R3.

- (1) **Striking succesful implementations**.

- **Ethereum**. -. A lot of proof-of-concepts are carried out and are claiming successes. As far as we know it, there are no mainstream production implementations of Ethereum within financial institutions

- **HyperLedger**. -. In march 2017 Hyperledger announced to be "PRODUCTION READY". We have not seen/heard any PROD successes yet.

- **Corda**. -. Financial institutions are working on implementations, and are claiming to be succesfull thus far.

Case company

- (3) **Support of counterparties**.

  - **Ethereum**. -. No implementations operational as far as we know it. The Ethereum Alliance (a consortium to build enterprise blockchains using ethereum) includes members such as ING, Microsoft, Intel, J.P. Morgan, UBS, Santander, Accenture.

  - **HyperLedger**. -. No implementations operational as far as we know it, major investers include J.P. Morgan, Bank of England, SAP, IBM, Abn-Amro, Deloitte, SWIFT.

  - **Corda**. -. No implementations operational as far as we know it, major investers include Bank of Amerika, Intel, ING, Barclays, Northern Trust, Deutsche Bank

- (2) **Cost**.

  - **Ethereum**. 8. No specific info, our estimate the cost of underlying infrastructure (couple of hundred EUR / month) + the costs for installing and maintaining Ethereum clients + costs for creating and maintaining the actual smart contracts.

  - **HyperLedger**. 8. Same as above.

  - **Corda**. 6. Same as above.

- (1) **Usage in asset management industry**.

  - **Ethereum**. -. No implementations operational as far as we know it. The Ethereum Alliance (a consortium to build enterprise blockchains using ethereum) includes members such as ING, Microsoft, Intel, J.P. Morgan, UBS, Santander, Accenture.

  - **HyperLedger**. -. No implementations operational as far as we know it, major investers include J.P. Morgan, Bank of England, SAP, IBM, Abn-Amro, Deloitte, SWIFT.

  - **Corda**. -. No implementations operational as far as we know it, major investers include Bank of Amerika, Intel, ING, Barclays, Northern Trust, Deutsche Bank

Appendix C

Current process:

- **Errors in the process and their consequences.**

    – Settlement time is currently two days. This is because it is hard to communicate with custodians: they still have to do a lot of things manually or even work with fax. This leads to a lot of uncertainty and miscommunication.

    – Time difference and changing currencies make communicating with custodians difficult.

    – A lot of people inside the asset management company are still needed because of exception management.

- **Communication and trust between parties.**

    – Because of all the local sub-custodians, different regions and timezones, communication is difficult and misinformation occurs often. This uncertainty and misinformation leads to longer settlement times because participants have to factor in some time to prepare for such errors.

    – Participants do not know much about the risk and exposure of other parties, so they do not have a high amount of trust in each other.

- **Transparency and governance.**

    – From the perspective of the asset management company the process is transparent, because in the back-office systems you can easily see the status of a transaction. However, this status is still not always accurate and up-to-date.

    – A lot of transparency around the value of their securities is wanted by the asset management company. Currently, you never know the real-time value of all of your securities and where they are. Because of the long settlement time, you always work with a value from one or two days ago, which means that you cannot estimate your portfolio properly as a trader.

- **Usage of current systems.**

  - A lot of things can be automatized by current systems, but still manual interventions are needed to manage exceptions.

  - When a static value such as an account number of a custodian needs to be changed, a lot of things need to be changed in the system and this is where a lot of mistakes occur.

- **Important flows of information.**

  - Communication with custodians.

- **Regulation.**

  - A lot of regulation is needed in this process. However, these regulators currently do not have good control because of the long settlement times, which means that they do not work with any real-time value.

Future process:

- **Innovations in the market and the asset management company.**

  - There are some initiatives that are automizing the exception management part. However, these solutions do not solve the misinformation problem.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.**

  - The custodian can definitely be removed in this process, because using a distributed ledger you can manage your securities. However, it will probably be the case that custodians will get another role in his process. The custodians currently account for a lot of errors in this process, so it would be better to fully remove them.

  - Using a distributed ledger, your cash management is much better because settlement is shorter and you have a real-time value of your securities.

- **Effect on the participants of the process.**

  - Custodian can be fully removed, but they will most likely end up having a validating role; validating all transactions on the ledger.

  - Regulators will have much more insight in the process and can perform their compliance better.

- **Biggest implementation challenges.**

  - All participants need to trust the technology and have to participate.

  - Reputation of asset managers; if something in the blockchain goes wrong, their clients will not see them as reputable anymore.

- Currently, custodians are joining all the post-trade blockchain initiatives, because they want to prevent them being removed in the process. This means that they will most likely search for a blockchain solution that still includes them in the business process, even when it is less optimal for the client.

- There is no standard yet; there are too many different blockchain tools.

- **Effect on users inside the asset management company.**

  - Much less people are needed inside the asset management company.

Corporate actions

Current process:

- **Errors in the process and their consequences.**

  - Many custodians still do a lot of their internal processes manually, which leads to them sending information very late. In this time, the cash dividend may have been changes by the issuer, which means that the custodian is sending wrong information. This leads to a lot of conflicts in the matching process.

  - Of all corporate actions that are processed inside the asset management company, about 20% needs to be corrected manually because of miscommunication with custodians. This number has not been decreased in the last years.

  - Every issuer, custodian and transfer agent uses a different format to represent the corporate action that is issued, which leads to many different interpretations of the event.

- **Communication and trust between parties.**

  - Trust is low, because custodians often give wrong information to the asset management company, so you do not know which custodian speaks the truth. In addition, there are a lot of confirmations and checks that need to be done when exchanging information and custodians often pay late.

  - The asset manager only communicates with the custodian, but because there are so many different custodians, the information you receive is very inconsistent.

- **Transparency and governance.**

  - A lot of transparency is needed in this process, because as an asset manager you have no idea what the real cash dividend is and when you will receive the cash from the custodian.

- **Usage of current systems.**

  - Currently, one system is used inside the asset management company where all information about the cash dividend of a stock from the custodians is gathered. However, this system still cannot show what the correct cash dividend is, so still a lot of things have to be done manually.

- **Important flows of information.**

  - Most important part of the process is the information about the price of the cash dividend and this is also where most errors occur.

- **Regulation.**

  - Regulators need to validate all transactions that are done, especially in the case when you are lending your securities to another company. You have to tell the regulators that you lend your securities to another company and that you have to receive the cash dividend from them.

  - Currently, it is difficult for these regulators to see what the real price is of the cash dividend of a stock; they do not have acces to real-time and up-to-date information.

Future process:

- **Innovations in the market and the asset management company.**

  - Currently, the asset management company is working on a new sytem that automatically selects the right information from the custodian about the cash dividend, based on historic data.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.**

  - Current system is only for internal use, and a blockchain can be connected to other participants as well. It will be difficult to connect all the issuers to a blockchain. However, the most likely scenario will be that a blockchain will be used between the transfer agent, custodian and asset manager. The transfer agent can insert the information from the exchange market onto the blockchain, and the custodian and asset management company can retrieve the information from here.

  - Matching can be done more easily, because on the blockchain we can immediately identify from which custodian we will get the cash dividend and there will be no misinformation about the amount.

- **Effect on the participants of the process.**

  - The custodian will have a much less important role, because if a blockchain is used, the asset management company can already find all the information they need.

  - For the asset management company, there will be much less misinformation problems, because there is one "golden source" of truth available with all the information about the cash dividend.

- **Biggest implementation challenges.**

  - Not much knowledge about blockchain technology yet, people do not trust it.

  - All participants have to join the blockchain for it to work well.

- Parties such as custodians are now joining a lot of proof-of-concepts. However, these parties may slow the blockchain progress down, because eventually they will be unnecessary when a distributed ledger is used.

- **Effect on users inside the asset management company.**

  - In the beginning, people working at the corporate actions processing department will still be there to validate transactions done automatically by the blockchain.

Know-your-customer

Current process:

- **Errors in the process and their consequences.**

  - **Funds**. Many transfer agents ask for information from a customer, while he may have already been identified by another transfer agent.

  - **Funds**. Communication with the transfer agent about all the contracts and other arrangement takes a long time. KYC process takes about 1-2 months.

  - **Mandates**. The sales department often promises a lot of things that cannot be done by the asset management company, which leads to a lot of changes in the contract.

  - There is no standard or format that everyone uses for this process.

- **Communication and trust between parties.**

  - **Mandates**. It is difficult to get in contact with clients because often they are very busy or in other regions.

  - Most communication is still done manually and goes through many participants and persons, especially in the case of funds.

  - Participants do not trust each other, so many double identifications need to be done on clients. In addition, clients from certain regions do not want to submit documents about their company because they do not trust the asset management company.

- **Transparency and governance.**

  - **Mandates**. The client due diligence system is very transparent and it is easy to see the status of submitted documents of clients. In addition, documents can be found really easily in the customer relationship management system of the asset management company.

  - **Funds**. There is no system for this subprocess used at the asset management company and all communication is done via email.

- **Usage of current systems.**

– See above.

- **Important flows of information.**

  – Retrieving documents from the client.

- **Regulation.**

  – The laws on privacy and handling with client data differs per region and becomes stricter every few years. Based on these laws, the client due diligence system constantly needs to change.

Future process:

- **Innovations in the market and the asset management company.**

  – There are some small innovations going on in the market, but they do not manage to set a standard on the market.

Blockchain applied on the process:

- **How can blockchain make the process more efficient.**

  – **Funds**. Blockchain should be seen as an infrastructure that can be used by the transfer agents. The asset management company will not do anything with the distributed ledger, but the transfer agents will use it to share documents and information about previous identified clients. A blockchain between the transfer agents will be the (first) most likely scenario because here the amount of participants is limited, which makes it easier to set a standard. Biggest benefit is reduced time and less frustration for the customer.

- **Effect on the participants of the process.**

  – **Funds**. Transfer agents will likely take a different role, because they do not have to perform as many know your customer processes as they used to do. They will communicate more with transfer agents instead of with clients.

  – **Funds**. The role of the asset management company will not change.

- **Biggest implementation challenges.**

  – **Funds**. You need to set a standard in the market. For example, for the internet to work, a standard had to be set, which is now called HTML.

  – **Funds**. All transfer agents need to participate in the blockchain.

- **Effect on users inside the asset management company.**

  – **Funds**. For the asset management company nothing will change, because it will be the transfer agents that will use the blockchain.