DNB Working Paper
No. 718 / June 2021

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DeNederlandscheBank
EUROSYSTEEM

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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

Working Paper No. 718

June 2021
Update October 2021

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Governance in systems based on distributed ledger technology (DLT)[1]

A Comparative Study

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Abstract

The (experimental) use of DLT is growing, also in the financial sector. DLT systems themselves advocate the fact that they use (consensus) algorithms and cryptography to create a leaderless system (horizontal). How is it possible to ensure that decisions in these DLT systems are in the interest of all stakeholders and the public interest, including supervisory authorities? Given the popularity of the Bitcoin and Ethereum blockchains, for example, it is not inconceivable that a part of the FMI will be based on a public DLT system in the future. It is therefore important to gain a better understanding of the governance of such DLT systems, and what the risks are for FIs when using DLT.

This paper compares the governance of financial institutions (FIs) and financial market infrastructures (FMIs) on the one hand with the governance of systems based on distributed ledger technology (DLT systems), on the other, to discover how they differ, and where potential risks and benefits lie for their future use, also in the financial markets. We answer two questions: i) What are the differences in governance between traditional FIs, FMIs and DLT systems? and ii) What are the consequences of decentralized governance of DLT systems for supervisory authorities?

Key words: Comparative study of governance in DLT systems, Managerial and operational governance, Horizontal and vertical governance, tipping point, Public DLT Systems and Private DLT Systems

JEL Codes: G3, M15, M4

[1] This paper sets out our personal views, these are not necessarily representative of DNB's or AFM's policy views.

Executive Summary

This paper compares the governance of financial institutions (FIs) and financial market infrastructures (FMIs) on the one hand with the governance of systems based on distributed ledger technology (DLT systems), on the other, to discover how they differ, and where potential risks and benefits lie for their future use, also in the financial markets. We answer two questions: i) What are the differences in governance between traditional FIs, FMIs and DLT systems? and ii) What are the consequences of decentralized governance of DLT systems for supervisory authorities?

We chose the following four DLT systems because they each have a rather different setup, due to which we can cover more of the available design possibilities for DLT systems and compare their setup and governance with the traditional setup of governance in FIs and FMIs. We compare: (i) Ethereum, because it is a widely used public blockchain, ii) Corda, because it is widely used as private blockchain not only in the financial sector, iii) Diem, because this private blockchain has been developed and discussed extensively throughout the world, iv) Fnality, because this is a new private blockchain initiative by financial institutions only.

DLT systems themselves advocate the fact that they use (consensus) algorithms and cryptography to create a leaderless system (horizontal). How is it possible to ensure that decisions in these DLT systems are in the interest of all stakeholders and the public interest, including supervisory authorities? Given the popularity of the Bitcoin and Ethereum blockchains, for example, it is not inconceivable that a part of the FMI will be based on a public DLT system in the future. It is therefore important to gain a better understanding of the governance of such DLT systems, what the risks are for FIs when using DLT.

For our research we introduce the concept of *administrative or managerial governance* for the continued functioning and development of a system, infrastructure or institution and *operational governance* for the actual operation of the system, infrastructure or institution. Our research shows that there are similarities and differences between the governance of FIs, FMIs and DLT systems.

To answer research question 1, we introduce the concept of *vertical governance* in traditional FIs, which are governed centrally and *horizontal governance* in the traditional FMIs. Horizontal governance in the latter is made up of the good governance of all individual FIs together complemented with supervision based on relevant laws and regulations. Like an FMI, public permissionless DLT systems can exist without the presence of one single (legal) entity that is responsible for the whole of the infrastructure. In these DLT systems users, service providers/miners and the software developers stand side by side horizontally. We see that where traditional FIs can operationally take individual decisions, for example regarding the approval of transactions, DLT systems cannot. The operational governance structure therefore differs. Contrary to an FMI, data and software

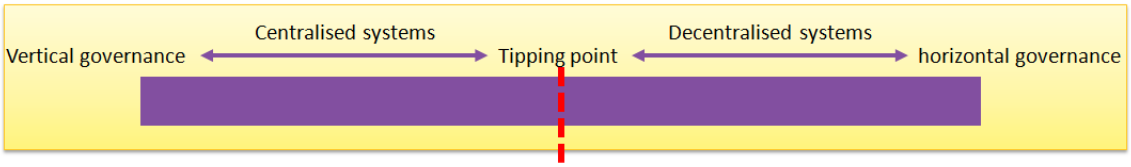
is shared within DLT systems. Given the fact that a public DLT has no legal structure or central authority, the governance model is set up to involve all those parties that are participating in the decision making, and that are needed to achieve common goals. The interesting aspect is that this community of participants, and thus decision makers, is fluid and can include literally all participants; e.g. end-users, node operators, developers, ideologists and experts. In reality however, we see forms of centralisation, likely to coalesce around experts. We therefore also conclude that the managerial governance of public DLT systems in particular is less horizontal than the decentralised name would suggest and hence entails risks of decision-making contrary to or not in line with the interests of the whole community. Governance models of private DLT systems resemble the vertical governance models of an FI more. Within a private DLT the governance model supports those involved in this private community.

Secondly, we researched the impact of such DLT governance models for financial sector supervisors. Private DLTs seem to have fit with current applications within the financial sector. Our research showed that public DLTs are more challenging from a governance perspective, because of their horizontal decentralised nature contrary to the traditional centralised financial sector. The objective of supervision is to ensure that FIs comply with the current regulation, ensure financial stability, promote the smooth operation of payment market infrastructures and protect consumers. An FI can use DLT to support its business if it can stay compliant with applicable laws and if risks related to the DLT can be mitigated. Within a DLT there may be conflicts of interest between the shared objectives of the DLT and the individual objective of a participant, like an FI. For a private DLTs this may be less complex since a private DLT has a legal structure where the FI(s) are responsible, accountable and liable. For public DLTs this is not a given, because anyone can join, also none financials next to the fact that a public DLT system exists without a legal structure or central authority. As a consequence, FIs in public DLT systems cannot mitigate risks using legal contracts and service level agreements. In general, for both public and private DLTs the FI has the responsibility to evaluate implemented operational and managerial governance models and to take appropriate action to stay compliant with regulation. We need to build experience and knowledge around the usage of DLT systems in a highly regulated financial sector. The DLT pilot regime may contribute to building this experience.

1. Introduction

A decade ago, many people were surprised by the emergence of the new peer-to-peer Bitcoin crypto phenomenon, because the design was so revolutionary. The introduction of Bitcoin (Nakamoto, 2008) brought the underlying blockchain technology to the attention of the public at large.[2] Bitcoin resulted from a desire in the market, which was based on a lack of trust regarding central authorities and institutions, to create a payment system and means of payment without involving a traditional central financial intermediary. The Bitcoin technology also solved the "double spending problem" of digital currencies, with financial transactions no longer requiring a central trusted third party. This distributed ledger technology (DLT) is now the transformational spearhead of a new method for storing and sharing in principle immutable transaction data, possibly by means of smart contracts in a decentralised, traceable and secure manner, and in many cases without intermediaries. The potential applications of this new technology are vast, including within financial market infrastructures (hereinafter FMIs) on which this study focuses.

The decentralised nature of DLT systems is of particular interest. DLT systems can function without a central responsible party. Whereas we can characterise current FIs as centralized, because the organization, including governance, has a hierarchical structure in which the board is ultimately responsible. For decentralized systems, like public DLT systems, we characterise the governance as horizontal because for these systems there is



no central responsible body (Schrepel, 2020)[i]. As stated by Schrepel (2020), with a pure form of horizontal governance no one controls any one. In the absence of any control, the existence of the system or entity is random and cannot be ensured or maximized. That being said, even with horizontal governance, we expect some form of control for the system to "survive", to ensure the continued existence of the system. In a perfectly decentralized system the governance lies with all the participants and serves the common goals of the system and its community. We do not foresee, nor have we found in our comparative analysis, any system with 100% horizontal governance, without at least some kind of centralised control. An apparent risk with horizontally governed decentralized systems however, is that the decision-making regarding the system does not serve its entire community. When a system claims to be completely decentralized and have a horizontal governance structure, we would assume that the goals and strategies of the system cannot change without full consensus amongst all the participants. Rules are not

[2] A blockchain is an electronic ledger that is shared over a network of operators. The ledger comprises a series of blocks. Each block contains a collection of transactions. New blocks are added by agents in the network (also referred to as operators). The decentralised nature of this network means that reaching consensus on the existing content of the ledger and new blocks is no trivial matter. A blockchain uses a consensus protocol to ensure consensus among operators. The consensus protocol is a set of rules whereby new blocks can be added to the ledger. The first public blockchain, Bitcoin, launched in 2009, uses a consensus protocol known as *Proof of Work (PoW).* Since then many alternatives have been developed, such as: *Proof of Stake (PoS), Hybrid PoW/PoS*, *Delegated Proof of Stake (DPoS)* etc. For more empirical background on these different consensus protocols, see for example (Hinzen, 2019).

expected to suddenly change (Schrepel & Buterin 2021). But when we see the governance structure shifting from horizontal towards vertical, thus passing the tipping point, goals and strategy changes can be reached with very limited consensus or by a smaller group. Against this background in this working paper we analyse and compare the governance mechanisms of different DLT systems also to understand the impact on the liability and accountability of the system as a whole.

The integrity, safety and stability of financial markets relies on trust in financial institutions (hereinafter FIs), and FMIs. When these rely on the decentralized characteristics of a DLT with a horizontal governance structure, the integrity safety and stability of the DLT becomes important to financial institutions and financial markets. We therefore analyse governance mechanisms of different DLT systems and compare these to the governance mechanisms of FIs and FMIs to gain a better understanding of possible risks. Because of its horizontal design, DLT systems lack the traditional structure in which governance of FIs has been developed. Governance concerns the management method, the code of conduct and supervision of organisations. It concerns decisions which determine expectations, grant power or verify performances. In a centrally controlled organisation the ultimate responsibility rests with the management board and standards are defined for good corporate governance, such as the Dutch Corporate Governance Code (Van Manen, 2016). The aim of this is to ensure that decisions taken by the management board are in the interest of all stakeholders, including the supervisory authorities. But how does governance operate within decentralised environments, where transactions are processed by a decentralised network of different independent parties? How centralised are the current traditional FMIs and will we see the emergence of more decentralised infrastructures due to the interconnectedness of institutions and longer financial and commercial chains? The governance structure of FMIs is amongst others directed at looking after the interest of the FMI as a whole. The supervisor is amongst others mandated to ensure financial stability and the smooth operation of the payments and securities market infrastructure. How can we promote that all decentralised parties that are part of a DLT system will act in the interest of the system as a whole and all stakeholders collectively, rather than in their own interest alone? How can the continuity and integrity of these decentralised networks be guaranteed? Who is liable in the event of operational problems or a difference of opinion among the member stakeholders? A better understanding of the governance of decentralised DLT systems is essential to enable regulatory and supervisory authorities to respond appropriately and determine whether these systems can be described as secure, reliable, efficient and sustainable systems for usage in the financial sector or whether modifications are required. In order to gain a better understanding of the governance of DLT systems we compare four examples of such systems with the governance of traditional FIs and FMIs. Hence, a comparative study in order to better understand what the differences in governance are. Future research may be directed at determining whether these differences entail risks that need to be addressed so that these DLT systems can potentially in the future also be used in the financial sector.

1.1 Central question & scope of study

From the above collection of questions, we have distilled one central question and a follow-up question:

i) What are the differences in governance between traditional financial market infrastructures and DLT/Blockchain infrastructures?

ii) What are the consequences of decentralized governance of DLT based infrastructures for supervisory authorities (supervision)?

In order to answer these questions, we begin with defining governance for the sake of this paper. We consider governance on a macro-level that is to say on the level of an institution, infrastructure or system as a whole, contrary to governance on a micro-level for individual contracts or smart contracts, the latter possibly a subject for further research. Also, algorithms or the governance of stable coins or other tokens using DLT are not part of this study. In section 2 we describe the governance in traditional FIs and FMIs based on a strong vertical top-down approach regarding the governance in FIs and a more horizontal approach regarding the governance in FMIs. Thereafter in section 3, we consider innovative DLT systems on the basis of four practical examples. We chose the following four DLT systems because they each have a rather different setup, due to which we can cover more of the available design possibilities for DLT systems and compare their setup and governance with the traditional setup of governance in FIs and FMIs. We compare: (i) Ethereum, because it is a widely used public blockchain, ii) Corda, because it is widely used as private blockchain not only in the financial sector, iii) Diem, because this private blockchain has been developed and discussed extensively throughout the world, iv) Fnality, because this is a new private blockchain initiative by financial institutions only. In section 4 we discuss the governance (both operational and managerial) of open source software projects, because many DLT systems use these projects. In section 5 we compare the governance of FIs, FMIs with the governance of DLT systems. Finally, in section 6 we conclude by answering our research questions. Annex I contains a schematic summary table with the key aspects of the comparative analysis.

1.2 A further definition of the research field

FMIs are essential for the proper, orderly operation of the financial system. Examples of organisations participating in FMIs are FIs, central counterparties, securities settlement systems, central securities depositories, transaction registers and payment systems. The institutions that pursue a particular common objective, such as securities trading, are referred to collectively as an ecosystem or FMI. FMIs arise in different parts of the financial sector due to the interconnectedness of institutions and infrastructure chains that collectively provide services for consumers and professionals. We can also describe an FMI as a decentralised system, because there is not one single party liable for the whole FMI. A comparison can be made here with a DLT system, which is a system based on distributed ledger technology, and which can also be seen as an FMI due to its design and structure. If such an infrastructure encounters operational difficulties, there can be major consequences for the operation of financial markets. A uniform set of standards for FMIs

(such as the Principles for Financial Market Infrastructures (PFMI) of CPMI-IOSCO) support the smooth operation of financial markets (BIS, 2012).

Traditional FIs have a hierarchical organisation with clear organisational boundaries. Governance in such organisations is vertical. However, FIs increasingly outsource services, partly to take advantage of new technological developments. Outsourcing does not mean that the FI is no longer responsible; the institution is and remains responsible for its contribution to the chain and is accountable for it through the partner in the chain under service level agreements (SLAs).[3] It is increasingly the case that no single party exerts control along the entire length of the chain. The complexity and interconnectedness of the chain, the intelligibility, intransparency, interdependence and hence also vulnerability of the chain will therefore increase further. In standard outsourcing however, there is still a customer/supplier relationship and responsibilities are assigned at organisational level, not at ecosystem or infrastructure level.

A public DLT system, which is different from a privately owned DLT system, comprises a network of businesses and private individuals (the nodes) who all participate out of their own free will and contribute to the operation of the blockchain.[4] However, in such a DLT system not one single node has any legal obligation towards the other nodes or users of the DLT system. This is what makes it different from an FI and FMI. For the sake of the continuance of the DLT system, the nodes must out of their own free will cooperate with each other (Schrepel, 2020) and reach consensus on matters, such as but not only regarding software modifications and transactions. In these situations, there is no longer a clear customer/supplier relationship based on contracts and there are no legal obligations. Due to the decentralised, horizontal organisational structure, the question is how important strategic decisions regarding the DLT system are taken and who is responsible.

[3] The parties agree on matters such as services, operational availability, fall-back options and compensation. See also section 2.1.6.
[4] This does not mean there is no corresponding remuneration.

2. Governance of the traditional FI and the FMI

In this section we consider the governance of an FI that forms part of an FMI and the governance of the FMI itself. The aim is to provide an understanding of the way in which governance is set up in FIs and FMIs first, so that we can ultimately compare it with the governance of DLT systems (both public and private). We start with the governance of the FI (in 2.1) after which we consider the governance of an FMI (in 2.2).

2.1 Governance of the FI

The aim of good governance in financial undertakings and pension funds is to ensure that risks are identified and managed in a proper and timely manner. Governance is important for supervisory authorities, because it provides the basis for controlled operational management. If the top tier of a company is not properly organised, there is a probability that the management of the risks in the operational processes will not be either. Good governance of the FI thus helps to protect the interests of all related parties, including the FI itself, customers and regulators. The use and meaning of the concept of governance is a key aspect of our study. The definition we use is as follows: **In the case of an FI, governance refers to the organisation of powers, responsibilities and liabilities with regard to the achievement of the FIs objectives. The aim of the governance structure of FIs is to create an efficient, secure, reliable, adaptable and sustainable FI.**

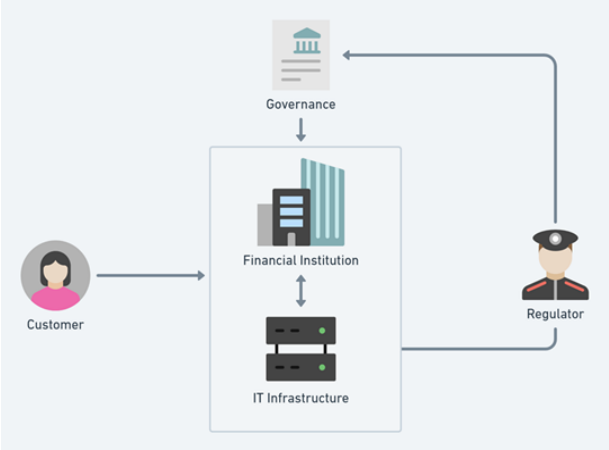


Figure 1 Governance of the FI. The governance of the FI entails the entire FI, but we can, as we will do later, make a distinction between the managerial and operational governance. The supervisor is not part of the FI governance, the supervisor has an interest in the proper functioning of the governance of the FI.

Although this definition is concise, we note that the concept of governance is susceptible to many nuances, additions and elaborations. In the following sections we first describe the concept of governance for the FI further, before we consider governance for the FMI in some greater detail. We will focus on the distinction between managerial and operational governance, the development from governance to good governance and the organisation of good governance.

2.1.1 Distinction between managerial and operational governance

The concept of governance is very broad in scope. It is used in a range of sectors (political, economic and social) and within sectors it is viewed from different perspectives (administrative, financial, operational, technical/IT). It is therefore very important to define the concept clearly in order to avoid miscommunication. Within an FI there is operational

governance, for the provision of services (including IT), and managerial governance for the development of services and the continued development of the FI itself. We apply this distinction because we also see these two forms in a DLT system.
Governance was originally focused on each of the individual institutions participating in the FMI on the assumption that if each component met the requirements of good governance, the ecosystem of the FMI as a whole would also fulfil the requirements of good governance (sum of the parts), with the supervisory authority being mandated by law and regulation to promote good governance and the interests of the FMI ecosystem as a whole (like a cherry on top).

2.1.2 Good governance

A consideration of governance, and particularly the requirements that governance must fulfil, leads naturally to a description of what is understood by "good governance". After researching the concept of governance, we have found that thinking on governance has evolved over time. In the past, it was focused on ensuring secure and reliable FIs. Subsequently other criteria were added: robustness, crisis management and efficiency, as well as the concept of availability, accessibility and inclusiveness. The objective of sustainability has also recently been added. At present we consider an efficient, secure and reliable FI to be an institution or system that processes transactions rapidly, transparently, in a cost-conscious manner and on the basis of inclusive participation. Such an FI provides valuable services for participants and enjoys the trust of participants, supervisory authorities and central banks. Good governance of FIs and FMIs is directed at both the continued smooth operation as well as the sustainability, the continued development of the FIs and FMIs. Therefore, good governance of FIs and FMIs entails both the operational and managerial governance.

2.1.3 Good corporate governance

The concept of corporate governance refers to the structure through which an institution is managed: its internal structures, the allocation of tasks and powers, the strategy, policy, processes and internal control functions. The Dutch Corporate Governance Code, often referred to as the Tabaksblat Code (Van Manen, 2016) is a code of conduct for listed companies which aims to improve the transparency of financial statements, improve accountability to the supervisory board and provide greater control and protection for shareholders. This Code contains guidelines for the relationships between: the management board, the supervisory board, the annual general meeting and shareholders of listed companies and is also used by many unlisted organisations that have an important social function. These guidelines can also be applied to institutions that are part of the FMI. The nature, size and complexity of the institution can be considered in fulfilling the requirements of the Tabaksblat Code. This means that although all institutions have to fulfil the requirements, some may have scope to take less far-reaching measures than others.

Best practices for the organisation of Good Corporate Governance are:

- Management Board – The management board (MB) is responsible for the day-to-day management of the organisation, achieving the organisation's objectives, preparing its policy, defining the strategy and objectives and defining the risk appetite.
- Supervisory Board (SB) – Supervising the management board and giving advice. They are also represented on important committees (see below).
- Shareholders – The shareholders can vote on important resolutions at the annual general meeting. Shareholders can dismiss members of the MB and SB and approve new members. The shareholders also approve the remuneration policy of the MB and the SB.
- Nomination Committee – New members of the MB and the SB are proposed by the nomination committee and approved by the shareholders.
- Remuneration Committee – The remuneration of the MB and the SB is proposed by the remuneration committee and approved by the shareholders. The remuneration must achieve the organisational objectives and promote integrity.
- Audit Committee – Responsible for supervising financial reporting, risk management and legal compliance. Internal audit provides independent assurance[5] that risks are properly managed and reports to the audit committee.

2.1.4 Internal control

Control measures are intended to ensure that risks fall within the risk appetite defined by the Management Board. This means an institution must assess the risks and then take adequate control measures. Control is the process designed to obtain reasonable assurance concerning the achievement of the organisation's objectives. Examples of control measures include segregation of duties, frameworks and guidelines, processes and procedures. A financial undertaking must have an adequate risk management system, in other words effective processes to identify, measure, determine, monitor, mitigate and report risks. It is important that a company has a clear and comprehensible risk control system. This could include processes for strategy, policy, individual risks, embedding in operational management, allocation of capacity and responsibilities. To ensure effective risk management, it is important that all risks/risk areas are controlled both individually and collectively. Institutions must have an internal control framework (second line of defence). The control function is important in assessing the efficiency of this internal control framework within the institution. The control functions must be organisationally separate from the units which they control and the management must be able to rely on the operation of the control functions.

A financial undertaking's control functions must include:

- Chief risk officer: responsible for the risk control function
- Compliance function
- Risk management function
- Internal audit function
- External audit function

[5] https://www.iia.org.uk/about-us/what-is-internal-audit/ – What is internal audit?

And in the case of insurance also:

- Actuarial function (internal control and risk management)

In more detail, the internal control measures must ensure among other things that the software used to process financial transactions is reliable and that transaction data are properly protected.
The operational management of financial institutions must not only be sound but also ethical in order to control integrity risks and safeguard the integrity of the financial sector as a whole. The compliance function is responsible for compliance with laws and regulations.

2.2 Governance of an FMI

A traditional FMI[6] comprises not one FI but a set of interdependent institutions that supply services collectively. The use and meaning of the concept of governance in an FMI is a key aspect of our study. The definition we use is as follows:
In the case of an FMI, governance refers to the organisation of powers, responsibilities and liabilities with regard to the infrastructure as a whole and its participants. The aim of the governance structure of FMIs is to create an efficient, secure, reliable, adaptable and sustainable infrastructure.

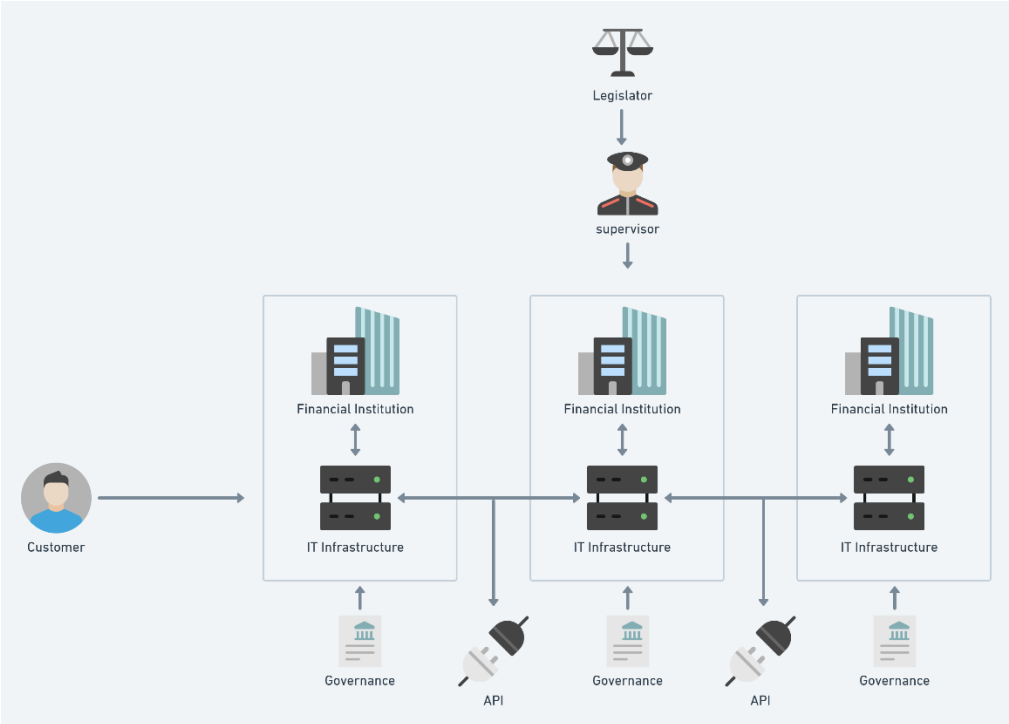


Figure 2 Governance of the FMI

An FMI is a collection of FIs. The governance of the FMI can be understood as the sum of the good governance of individual FIs together in combination with the regulatory

[6] Clearing, settlement and payment institutions are FIs, but are sometimes also described as FMI. In this paper an FMI is not one single FI, but a collection of FIs.

framework enforced by the legally mandated supervisor(s) on the individual FIs. The goal of the regulatory framework is to accommodate the proper functioning of the FMI, including the underlying FIs. As such the regulatory framework also supports the achievement of the FMI objectives and can be seen as a governance component.

An FMI consists of a number of different FIs. Which institutions belong to it depends on the purpose of the FMI. An FMI for payments differs from an FMI for insurers. An FI may belong to different FMIs; the boundaries of an FMI do not appear to be clear-cut. Individual FIs have their own customers and their own suppliers. Dependencies have arisen among these FIs over time, leading to chain dependencies within the traditional FMI. An FMI does not have a management or shareholders in the same way as an FI. None of the governance mechanisms referred to in section 2.1 therefore apply directly to the FMI, although they may operate indirectly. As we will also note in Section 3 with regard to DLT systems, in an FMI too there is not one single body or organisation that is responsible and that can be held accountable for the entire infrastructure, nor the possibility of bearing responsibility for maintaining the operation of the FMI as a whole. After all, there is no single hierarchical structure. So, what does governance look like in an FMI? It is made up of the good governance of all individual FIs together complemented with legally mandated supervision. For FMIs to function properly transactions are conducted and data are exchanged between the various parties in an FMI. This requires the use of standard protocols. Application programming interfaces are used in most cases (hereinafter: APIs). Maintenance of APIs is complex, because a change has consequences for all users. We understand the maintenance of APIs to be a part of the governance of FMIs. The governance of an FMI is very complex. See Figure 2. For example, issuers, the exchange, central counterparties, the settlement and custody company, banks and brokers all work together in the FMI to conduct securities transactions. The supervisory authorities oversee the FMI to ensure its proper and smooth operation and to protect consumers. Good corporate governance and supervision of an FI as part of the FMI contributes to the quality of the services provided by the FMI as a whole (sum of the parts). The supervisory authority is legally mandated to promote the interests of the FMI as a whole (like a cherry on top) through the supervision of FIs.

2.2.1 Risks within FMIs

It is essential that an FMI can improve and innovate to ensure that it continues to operate healthily, competitively, inclusively, sustainably and appropriately. This is also in the interest of all parties in the FMI. However, risks can arise in an FMI, such as:

- Concentration risk[7] – In an FMI there may be single points of failure, which in the event of continuity problems may jeopardise the quality of service of the FMI as a whole. Greater complexity and a lack of transparency may increase this risk. The lack of alternative service providers or high switching costs between service providers may also increase concentration risks.

[7] https://www.afm.nl/~/profmedia/files/doelgroepen/beleggingsondernemingen/2019/sectorbrief-uitbesteding-risicobeheering.pdf?la=nl-NL – Feedback on AFM study “Keten in Beeld” on outsourcing

- Control risks – Critical operational processes can be performed by different organisations in an FMI. This can lead to operational risks for the provision of services within the FMI as a whole, which cannot be addressed by hierarchy.
- Conflict of interests – The profitability of one party may be at the expense of the profitability of another party in an ecosystem.
- Change management – The modification of IT systems used for transaction processing and data exchange between parties in an FMI can be complex. All parties must modify their systems at the same time. Complex change management may impede innovation and increase the risk of software errors.
- Abuse of (market) power – Within an FMI there may be parties that have a strong power position or are even monopolists. Abuses of such power can impede innovation and lead to higher costs for consumers.

It is important to note that the risks in an FMI are actually risks caused by or characteristics of the individual FIs. The question is whether these risks can be sufficiently mitigated if we assume that the FMI itself is not an entity and cannot bear responsibility. This is why there is a legally mandated supervisor that looks after the good governance of the FMI as a whole, via the vessels of the FIs.

2.2.2 Supervision and FMI governance

Like the European Systemic Risk Board (ESRB) has been mandated by the European Commission to perform macroprudential oversight on the European financial system as a whole, in the Netherlands national supervisory authorities are entrusted with such supervision by the legislator to supervise the robustness of the Dutch FMI as part of the European FMI. A precondition for the proper operation of an FMI is good cooperation between various parties to implement improvements that can affect multiple parts of the FMI system, in particular with regard to the interoperability, like for a very practical example modifications to APIs. This is part of the managerial governance discussed earlier, concerning the development of the system. Consultative structures are an important prerequisite for this. Supervision and oversight can be seen as a form of managerial governance for an FMI.

Legislation is a means of reducing negative effects for customers due to market failure. Legislation, together with supervision of its implementation, therefore plays a role in the governance of an FMI. MiFID II, for example, aims to increase the efficiency and transparency of European financial markets and strengthen the protection of investors.[8] Legislation can increase competition, increase efficiency, reduce costs and lower concentration risks.

2.3 Contractual relationships between FIs and FMI governance

When services are outsourced, agreements are entered into between customers and suppliers regarding the quality of the services in an SLA. A more complex form of outsourcing is a network organisation. Organisational rules can be drawn up to ensure that

[8] https://www.afm.nl/nl-nl/professionals/on derwerpen/mifid-2/introductie-doel – Purpose of Mifid 2

all members of a network organisation act in the interest of the system as a whole. Participants in an FMI also record agreements between them in a rulebook. The legislator and regulator can also prescribe uniform rules such as the Single Rule Book.[9]

We will designate the mechanisms for the reliable processing of transactions in an FMI as operational governance. This responsibility often rests with an individual institution that is responsible for implementing internal control measures to guarantee the reliability of transactions. In certain cases, however, external parties can also be involved in approving transactions. These require agreements for a consensus mechanism. An example of this is reversing unsettled share transactions. If both parties to the transaction agree, these transactions can be reversed. We can view these interrelationships as a form of operational governance of an FMI.

[9] Single Rulebook, https://www.eba.europa.eu/regulation-and-policy/single-rulebook

3. DLT Case Studies

This section discusses the governance structure of four DLT systems: 1) Ethereum, 2) Corda, 3) Diem and 4) Fnality. A common feature of these four DLT systems is that the software is produced on an open source basis and supports a concept of smart contracts (programmable transactions). Part of the governance is also organised and actually automated by means of (consensus) algorithms and cryptography. The DLT systems are therefore operationally, so to speak, autonomised. The differences between these DLT systems concern the public or private nature.

In order to be able to analyse the governance of DLT systems better, we divide governance into two; **operational** governance and **managerial** governance. The operational part includes an examination of governance of the technical aspect of the network, i.e. the systems and operators that keep the network operational and how any disagreements (or accounting discrepancies) between participants are resolved[10]. The managerial governance includes examining how the infrastructure develops, i.e. how the software is developed and updates take place. Control measures in software, like algorithms and cryptography, have to ensure that the distributed ledger stays sound. When we discuss the governance of a DLT, we are referring to the governance (both operational and managerial) of the entire ecosystem making up the DLT. All nodes (miners) of a DLT form part of the governance, as do any individuals, participating foundations, associations or other companies involved.

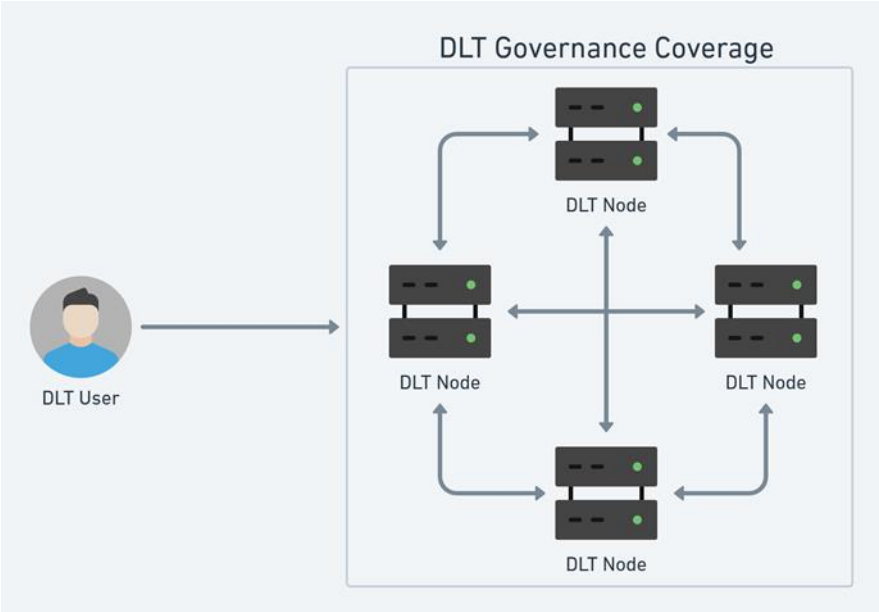


Figure 3 DLT governance. The operational governance of a DLT system is depicted. The managerial governance is separate from the operational governance and there is no overarching body as we can see with an FI, no central managing board.

[10] This is also known as "to maintain the integrity of the blockchain".

3.1 Ethereum

The Ethereum project dates from 2015 and is based on the vision of Vitalik Buterin. Buterin identified a deficiency in Bitcoin's scripting language[11] and decided to set up a new project with the aim of launching a fully programmable crypto (transaction token). In addition to the introduction of a transaction token, Ethereum is the first network built explicitly to process smart contracts. Buterin developed programming languages such as Solidity and Vyper in order to create smart contracts. Now, Ethereum has a team of core developers who maintain and update the code on behalf of the Ethereum community (the public), without the involvement of lawyers, policymakers or legal entities.

Ethereum[12] is a *public permissionless* infrastructure and uses a transaction token: the Ether. Ethereum is not managed by a company or group of companies. The Ethereum Foundation does not own the software and does not control the platform. The Ethereum Foundation is a non-profit organisation[13] whose sole purpose is to support the Ethereum platform (the distributed ledger) and the associated technologies in the interest of the continued and increased use of the Ethereum platform[14]. Founded by Vitalik Buterin, the Ethereum Foundation is a member of the larger ecosystem of organisations, individuals and companies that supports Ethereum. The Foundation allocates resources to critical projects and endeavours to be a valued voice within the Ethereum ecosystem.[15] The question is to what extent the existence of a foundation detracts from the decentralised, public character of a blockchain?
There is also a private Enterprise version of Ethereum. The Enterprise Ethereum Alliance (EEA) is an alliance of a wide range of companies committed to a blockchain based on Ethereum for business applications (Enterprise). The EEA has its own roadmap, which may differ from that of the public Ethereum DLT.[16] Above all, the EEA wants to create a stable, interoperable, decentralised infrastructure. The updates in the public Ethereum may nevertheless be adopted by the EEA, so they may affect the course of the EEA. We will briefly mention Ethereum Enterprise when discussing the governance of Fnality.

3.1.1 Operation of Ethereum

Ethereum is a decentralised platform (DLT) on which smart contracts can be implemented. It is based on an open infrastructure, which means anyone can access it and participate. Miners for example are computers, potentially owned by anyone, that participate in the DLT system to try to find a new block by solving a difficult mathematical problem. When a

[11] In the case of Bitcoin, scripting (a limited type of smart contracts) was not included in the initial design, but there was a means of inserting scripts. For example, to prove ownership, a script could be set to TRUE, but the functionality of the scripting language was very limited.
[12] There are actually two versions of Ethereum; this paper discusses the public version Ethereum Mainnet (hereinafter: Ethereum) and the private version Ethereum Enterprise. The differences between the public and private versions of Ethereum are explained briefly on the Ethereum website. https://ethereum.org/en/enterprise/#private-vs-public
[13] Members of the Ethereum Foundation can nevertheless own Ether and thus make a profit or loss as a result of rises or falls in the value of the Ether. Individual members may have a bias, but the Foundation is very limited and has no profit motive.
[14] The Ethereum infrastructure can continue to exist without the Ethereum Foundation, as the Foundation caters for sponsored development, the voluntary development continues to exist. https://ethereum.foundation/about/
[15] The Foundation itself determines which projects are critical and merit investment. https://ethereum.foundation/about/
[16] The option to use the Enterprise versions of Ethereum is also seen in other projects in the financial world, such as the JP Morgan coin project. The option of incorporating updates of the public Ethereum in the private blockchains remains available.

new block is found they receive a reward. Miners validate transactions and help to maintain the network secure and without any barriers. Developers, which can also be anyone, contribute to the development of the source code without any barriers, developers can launch smart contracts without any impediments and users can conduct transactions without any barriers. Whereas Ethereum was originally based on the consensus algorithm (part of operational governance) Proof of Work,[17] there are plans for Ethereum 2.0 to switch to a Proof of Stake model.[18]

3.1.2 Operational governance

Miners are the computers or nodes that maintain the operation of Ethereum. They make their computer system available for this purpose. The miners have no means of influencing the operation of the software. The software is autonomous from an operational perspective. Decisions on adding new blocks to the Ethereum blockchain are taken by the software on the basis of the consensus algorithm. Operational governance through the consensus algorithm gives rise to certain risks, such as the possibility of adding fraudulent transactions, the 51% attack, selfish mining[19] and nothing at stake attacks[20]. Miners could indeed commit fraud, but the more miners that participate in het operation of Ethereum, the less likely it is that miners can do so.[21] The 51% attack is based on the technical turning point at 51% of the total hash rate[22] (processing capacity). When a miner has more than 51% of the hash rate, it can determine the next block in the chain. Voting takes place through the consensus algorithm and the miner with 51% then has a majority (a 51% attack). This block will then be accepted by the other miners. However, inherent incentives are programmed into the code for miners to adhere to the rules. Miners have an interest in the continuity of the blockchain and in the appreciation of the Ether in order to continue mining profitably.[23] Still, the Bitcoin cash fork[24] shows, that different opinions in an open ecosystem cannot always be reconciled in a solution that all agree to. A fork is the creation of a new DLT by means of a split from the current DLT. Bitcoin and Ethereum have survived several hard forks. However, the risk of forks could be an issue for the use of Ethereum as an infrastructure for critical financial applications.

[17] Proof of Work is the original consensus algorithm on a Blockchain network. It is inextricably linked with the way in which the blockchain works, i.e. with mathematical hashing functions and digital signatures. Proof of Work is secure, immutable, uncrackable and delivers a decentralised blockchain. www.smartcontract.nl and www.cryptobieb.nl.

[18] With Proof of Stake there is no reward for creating a block. The advantage of Proof of Stake is a more efficient use of electricity. The person with the biggest stake is the person permitted to create the new block. This person receives remuneration for processing the transactions in the blockchain. https://cryptomaan.nl/blogs/news/wat-is-het-verschil-tussen-proof-of-work-en-proof-of-stake/

[19] Selfish mining is a strategy for mining bitcoin or other cryptocurrencies in which groups of miners collude to increase their revenue and exert power over a blockchain. ... With selfish mining, the cartel obscures newly created blocks from the main chain, revealing them at a later point in time. Investopedia.com

[20] The nothing-at-stake problem is a theoretical security hole in proof-of-stake systems. The problem can occur anytime there is a fork in the blockchain, either because of a malicious action or accidentally when two honest validators propose blocks simultaneously. https://golden.com/wiki/Nothing-at-stake_problem

[21] The more miners there are, the more control they have and the costlier it is to successfully carry out a 51% attack.

[22] "Hashrate" refers to the total combined computational power that is being used to mine and process transactions on a Proof-of-Work blockchain, such as Bitcoin and Ethereum (prior to the 2.0 upgrade). A "hash" is a fixed-length alphanumeric code that is used to represent words, messages and data of any length. Unblock.net

[23] Miners benefit from an appreciation of the Ether both if they own Ether and if they earn Ether as a mining reward. In the latter case they can sell the Ether immediately to avoid market risk. The value of Ether will only rise if users remain confident in the network.

[24] Powerful miners and manufacturers of mining hardware were mining here themselves before the modern hardware became available in the market. A fork is the creation of a new DLT by means of a split from the current DLT.

In addition to the consensus algorithm the operational governance of Ethereum also includes the Code is Law principle resulting in the immutability of the blockchain and the final execution of smart contracts by miners. Although Ethereum supports decentralised smart contracts, these smart contracts code can contain errors or security weaknesses that could be abused by hackers and thereby introduce risks to the network. This is because in contrast to the DLT software code, the smart contracts are not tested by the entire community. Following from the Code is Law principle, which is supported by the Ethereum community, these smart contracts must in principle always be executed, even if on closer inspection there are demonstrable errors in the code. The code takes priority over any events in the real world (e.g. force majeure) whereby (smart) contracts would potentially not have to be complied with. There are examples where this Code is Law principle is however not followed. Instead of seeking a solution or judgement in the courts, the DAO[25] shows that these participants take the law into their own hands and simply start a new system by forking (paragraph 3.1.5). We see this as a point where supervision could help increase reliability and ensure financial stability, for example by enforcing pre-vetted smart contracts. The group launching the smart contract should take this responsibility. The result of e.g. an audit can be added to the smart contract at launch. The user can then decide to avoid non-vetted contracts.

3.1.3 Managerial governance

The managerial governance of Ethereum, directed at the development of the DLT system, concerns the creation and development of the software for the Ethereum blockchain, which is used by the miners. There is no other DLT software apart from the smart contracts. Managerial governance of Ethereum comprises interaction between developers who are entirely free to propose modifications to the code and a team of core developers (including Vitalik Buterin) who vote on protocol changes in monthly meetings. A fixed process is followed for this purpose[26] (see figure 4) and this process has been adopted by the Ethereum community.[27] This kind of mechanism is not unusual in the open source development (see section 5).

Anyone can make a proposal to update the Ethereum software. The proposed update is then given a label; protocol-changing or non-protocol-changing. If the protocol has to be changed, the whole network will have to update. In case of a non-protocol-changing update, the code can be added by means of a simple review by the Ethereum team. Different from an FMI which is constituted by separate but more or less equal FIs, Ethereum's core development team has considerable power in this regard and can approve or reject changes. Once a month there is a core developers call on which proposed solutions are discussed. Vitalik Buterin, who has been called a benevolent dictator, has a crucial role here as he may have a casting vote (right of veto), which is a negative in terms

[25] DAO stands for decentralised autonomous organisation. Also see paragraph 3.1.5.
[26] https://eips.ethereum.org/EIPS/eip-1
[27] https://ethereum.org/en/community/

of good governance.[28] An average of 216 developers contribute to Ethereum updates each month.

Miners have no vote in the update, but are a means by which a proposed change can be accepted or refused, since they can refuse to install the new version that follows an update. In the event of a refusal, it is possible that half of the miners will still have the old version and the other half the new version, a fork takes place. There will then be two operational versions of Ethereum (see the section on the area of tension below).

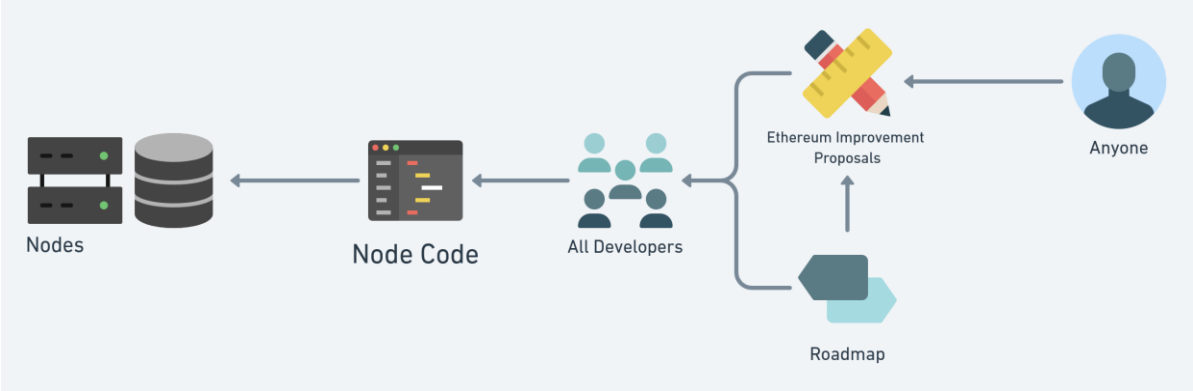


Figure 4 The governance processes of Ethereum. On the right the managerial governance process, on the left the operational. As shown everyone can contribute updates which can be accepted through the developers community proposals for change(if in line with the Ethereum Roadmap). The new version of the software results in code for the nodes. The miners are assumed to accept the new code.

Hence, although there is no governance in the traditional, vertical sense, with power and control being centralised and deployed to achieve a joint objective, Ethereum too has a form of vertical, hierarchical managerial governance, i.e. where the core development team and Vitalik Buterin ultimately have an important vote in the software development process (high priest model).[29] An alternative to this governance model could be to have updates accepted by means of a public vote. Whereas in theory this would lead to a more democratic, more horizontal form of governance, here too in practice there could be various objections that would make such a process less horizontal. After all, how do we ensure that everyone entitled to provide input and vote on (important) decisions actually does so? How is it possible to prevent votes being bought and the vote being unrepresentative of the full range of opinions in the ecosystem? Viewed from this perspective, having a board that represents the community (shift to vertical governance) can have advantages in terms of managerial governance. This is clearly demonstrated by the managerial governance of a public DLT system such as Ethereum. Whereas the operational governance (re. the operation of the DLT system) can also be conducted

[28] Benevolent dictator for life (BDFL) is a title given to a small number of open-source software development leaders, typically project founders who retain the final say in disputes or arguments within the community. https://en.wikipedia.org/wiki/Benevolent_dictator_for_life and https://www.vice.com/en/article/jpzd58/ethereums-boy-king-is-thinking-about-giving-up-the-mantle

[29] Also known as the cathedral model, see Section 4. https://medium.com/blockchainspace/ethereum-governed-by-a-benevolent-dictator-2a2be8aa331a

horizontally in a public DLT system by means of a well-organised consensus algorithm, the position with regard to managerial governance (re. the development of the DLT system) is different, because the interests of the members of the ecosystem do not always coincide.

3.1.4 Area of tension between operational and managerial governance of Ethereum

There is an area of tension between operational governance and managerial governance. The DAO of Ethereum makes this clear. The DAO was an initiative to set up a decentralised company structure. The DAO was intended as an investment vehicle and received money from participants which could then be invested in projects for the continued existence of Ethereum. An investment budget of around USD 10,000 was initially expected, but the ultimate figure was USD 150 million. The use of smart contracts was not appropriate for this level of interest. A hacker found a way to insert code into smart contracts to siphon off customers' money into his account. The DAO hack became so large (the hacker took 12.7 million Ethers with a value of USD 60 million) that the survival of the entire Ethereum ecosystem (managerial governance) was at stake. Miners on the Ethereum platform executed the transactions from and to the hacker, because according to the existing protocol (operational governance) they were legitimate operations. A fundamental division arose within the Ethereum ecosystem between supporters of the Code is Law[30] principle and those who believed that in the event of a hack no contract could be deemed to be legitimately coded (core developers and Vitalik). Ultimately it was decided to perform a rollback, cancelling all blocks and transactions during and after the attack (without regard for finality) and reverting to the position immediately before the hack. Such a decision made by the developers in consultation with the miners must then be accepted by the miners. Not all miners agreed with the decision, so the Ethereum Classic fork occurred. The DAO shows the difficult interplay between the operational part of the governance (the correct and continued execution of individual transactions) and the managerial governance (focused on the continued existence of the platform) in DLT systems. Ultimately 90% of the miners migrated to the hard fork and around 10% of the miners went to Ethereum Classic in accordance with the ultimate Code is Law principle. Although the interplay between the operational and managerial part of governance in DLT systems may be complex, it is still viable and public DLTs can survive hard forks. Because this concerns an innovative specialty with new norms and principles, the appropriate and adequate way to address any unacceptable risks in case potentially systemically relevant DLT systems are used in the financial sector, needs to be further analysed and developed.

3.2 Corda

The open source Corda software was launched for the financial sector especially in 2016 by the R3 consortium and is available on GitHub, a place on the internet where people collaborate to write software. R3 describes itself as an enterprise software firm that provides DLT solutions for an ecosystem of 350 companies. There is also a private

[30] Coded legitimate contracts must be executed with finality. According to the Code is Law principle, transactions must be executed in accordance with the precise rules of the smart contract (legitimacy).

commercial version, Corda Enterprise that combines the core attributes of Corda with the robustness and professional support expected from enterprise software.

3.2.1 Operation of Corda

Corda is a DLT environment that differs from Bitcoin or Ethereum, with regard to the form of the DLT (blockchain), see also the Corda white paper. Corda is a *pairwise distributed ledger.* In a pairwise distributed ledger the nodes that conduct transactions with each other validate their own transactions. This validation has two aspects: are the digital signatures correct and does the transaction comply with the smart contract? The transactions between two nodes are not visible for the other nodes. Each node has its own DLT that only shows the transactions in which the node has participated.
In addition to the nodes that validate a transaction, a notary node checks that there is no double spending (possible fraud) by one of the parties. A Corda DLT application can opt to have a single notary node or a cluster of notary nodes.[31] This cluster will use a consensus algorithm to obtain agreement on the proposed transactions. Notary nodes can also time-stamp a transaction. If a transaction is time-limited, the notary node can confirm that the transaction has been checked within the time. Finality can be derived from this. In addition to the task of checking double spending, the notary node can also validate[32] the transaction instead of the other nodes. This is optional.

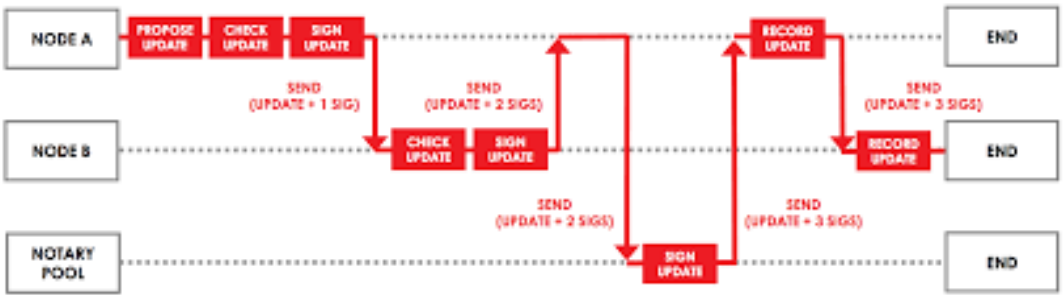


Figure 5 Corda transaction flow. If two nodes are performing a transaction, one node (A) will propose a transaction and sign it himself, the counterparty node (B) will check and sign for confirmation. A notary node will do the check on double spending and sign as well. All involved (A, B and C) can subsequently store the transaction.

Corda uses Corda Contracts (a type of smart contract). Every transaction on Corda is actually a Corda Contract, a simple or complex contract. Corda contracts can include an annex setting out rights and obligations in legal terms, for example in the case of dispute resolution. In addition to notary nodes, Corda has observer nodes and an emergency access facility. The observer nodes are specially designed for supervisory authorities, for example, to enable them to observe a transaction without being party to it.

[31] https://docs.corda.net/docs/corda-os/4.7/key-concepts-notaries.html
[32] Correctness of signatures and conformity with contract.

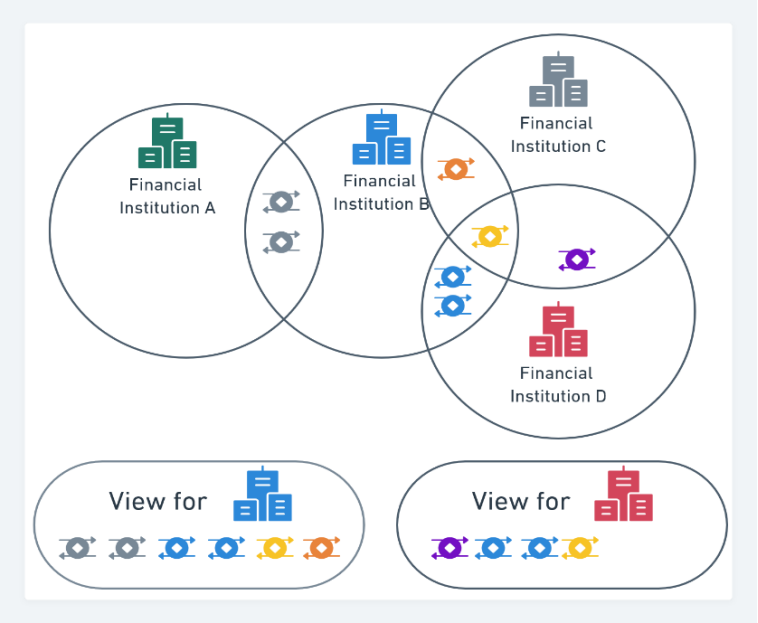


Figure 6 Corda ledger. The different nodes (FI A, B, C and D) each have their own ledger with shared transactions, not one ledger has all the transactions.

3.2.2 Corda governance

We examine the governance of Corda on two levels. The managerial governance looks at the process of developing the DLT/software. The operational governance of Corda is viewed from the perspective of the way in which Corda is used, for the processing of individual transactions.

There are three ways in which Corda can be used operationally (operational governance):

1. Enterprise use, private Corda network for one institution resulting in a specific business network (own/private enterprise network manager).
2. Consortium use. The use of Corda by a consortium of institutions is also referred to as a business network (Figure 7).
3. Public use. Anyone can download the software and start running a Corda blockchain. Unless enforced, if different individuals start a Corda blockchain these are not automatically connected.

A common feature of the different types of operational governance is that they involve different parties. For this report we consider the second type, because this has a specified governance structure, whereas the first is determined by one enterprise that plans to use Corda and the third is not specified anywhere. For consortium use there is an open consortium that anyone can join. The consortium governance model discussed here (model 2) is a governance model proposed by R3.

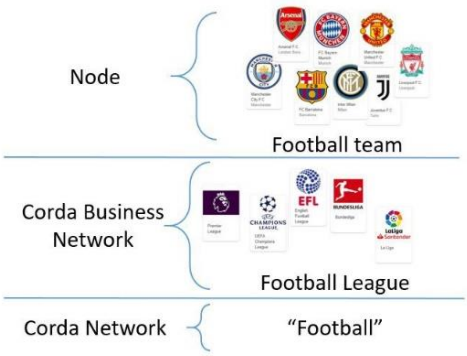


Figure 7 Operational view of Corda. A Corda Network, represented by the football, can be used by different business groups, in this example football competitions. And each competition can have their own team, this does not exclude a team to play in different competitions.

3.2.3 Operational governance

For consortium use the management of the Corda Network has been transferred from R3 to the Corda Network Foundation. The governance of the Corda Network Foundation has been designed on the basis of guidelines.[33] The guidelines are not legally binding obligations. The Corda Network Foundation is a Dutch 'Stichting'. Its mission is in line with the Corda white paper.[34]

Mission of the Corda Network Foundation is to achieve the vision of Corda – whereby the state of transactions and agreements of business partners can be recorded in a single global database, ending the need for costly reconciliation and error correction, while maintaining privacy. Further details of the vision are laid out in the *Corda Introductory White Paper*.

The Corda Network Foundation serves its members, the Corda users and provides operational services like an operational Corda DLT and joint services. The joint services include amongst others the onboarding of nodes (new users), identity services (who's who), notary services and emergency access The Foundation is accessible for any legal entity participating in the Corda Network. The membership of the Foundation is separate from R3 consortium membership. Membership of the Corda Network Foundation is a precondition for the use of the services maintained by the Foundation. Membership entails costs.

The Foundation is structured as follows:

- A Governing Board (the Board) consisting of 11 members
- A Technical Advisory Committee (TAC) consisting of representatives of the affiliated organisations.
- A Governance Advisory Committee (GAC) consisting of representatives of the affiliated organisations.

[33] https://corda.network/governance/governance-guidelines.
[34] Corda: an introduction, Richard Gendal Brown, May 2018

- A Network Operator (the Operator). The Operator passes on its costs to the Foundation. These are the costs incurred for supplying the Corda network and the administrative services (customer onboarding etc.). The Foundation pays these costs by means of membership fees. The operator is accountable to the Board.

By means of *advisory governance events* it is possible to exert influence on the Corda software (technical and consensus standards and hence also the way in which Corda smart contracts can be made). The Corda contracts themselves are made by the users. The Board votes on the proposals submitted through these advisory governance events. This vote can take place through a Corda contract (on chain governance).

3.2.4 Managerial governance

The managerial governance for the Corda software development process is being driven by R3 with an open source contribution model, but this part of Corda is also being transferred to the Corda Network Foundation. Through the Foundation various business networks and their nodes (users) can have a say on the further development of Corda and its network. Voting takes place in the Foundation on the standards for Corda (not the Corda contracts). The project described below concerns the implementation of these standards. At R3 the ongoing development of Corda (managerial governance) is referred to as “a project”; it has no name. R3 supports and facilitates this project and has the following roles:

- Project leadership
- Corda maintainers
- Developers
- Contributors.[35]

The project leader is currently the same as the lead platform engineer of R3. The project leader appoints the project community maintainers and they are responsible for merging the community contributions into the code base and are the primary contact point for these communities. All R3 contributions are peer-reviewed, with the associated documentation being stored on GitHub, before it is included in the code base. All contributions must meet the same standards[36] and the community is encouraged to participate in this review process.

3.3 Diem

Diem (previously known as: Libra) and USC (Utility Settlement Coin, also known as Fnality) are comparable in the sense that they both emerged from consortia of multinationals, Fnality from the financial sector (15 large FIs) and Diem with a more varied membership. The description in this section is a snapshot taken at the time of writing, the actual position at present may differ.

3.3.1 Operation of Diem

Diem is currently not (yet) operational. A group of companies has committed to taking part in the Diem initiative for the return on the Diem shares and the income from Diem

[35] This process is run on GitHub https://github.com
[36] https://docs.corda.net/docs/corda-os/4.5/contributing.html

transactions. Diem is a closed, private, distributed ledger. Diem plans to support smart contracts based on a new “Move” programming language. The Diem token is a stablecoin and is 100% pegged to a basket of currencies and government bonds to stabilise its value. The final word has not yet been said on the Diem coin, as there are also proposals to link the Diem one-to-one to a country’s currency.

3.3.2 Diem governance

For Diem governance we once again draw a distinction between administrative and operational governance. The Diem DLT system has a more centralised governance structure than for example Ethereum. This makes it easier to scale up and the transaction processing time can be reduced. The central component of governance is the Diem Association. This is a non-profit organisation in which all 21 Diem members have an equal interest. They must all buy themselves in for USD 10 million and undergo an onboarding process in which they satisfy the guidelines. This acts as a barrier to new entrants. All members have voting rights in the Diem Association. Only the members manage copies of the distributed ledger and approve transactions. The governance structure has many similarities to that of Corda and the governance of a traditional FMI. Diem’s plans include setting up a compliance and audit function. Independent auditors will periodically audit Diem and report publicly on their audit. The Diem Association plans to implement an extensive compliance programme to comply with relevant laws and regulations. This will comprise:

- A Chief Compliance Officer
- A committee overseeing reporting responsibilities
- AML/CFT/sanctions compliance policy and procedures
- Due diligence on all members, designated dealers and regulated and certified VASPs following a risk-based approach.
- Creation of an FIU (Financial Intelligence Unit) function to monitor possible suspicious and sanctioned activities on the Diem network.
- An independent internal audit function to conduct independent audits of the compliance policy
- Providing relevant training for employees.

3.3.3 Operational governance

According to the Diem technical paper the Diem validators (nodes, run by members of the Diem Association) all run a copy of the Diem DLT. They approve transactions by means of a consensus mechanism. According to the Diem white paper the Diem Blockchain will use the Diem Byzantine Fault Tolerance consensus protocol. This protocol has three objectives:

- The network continues to operate correctly even if multiple Diem validators are unavailable (up to one-third of the validator nodes);
- The possibility of processing a large volume of transactions fast and efficiently;
- Finality of transactions. A user can be certain that a transaction has been fully processed if a quorum of Diem validators has confirmed the transaction.

The security of the Diem DLT depends on the quality of the validators. The Diem Association therefore carries out due diligence on new validators. The Diem DLT will be designed on the basis that the network must withstand advanced cyber-attacks. Diem Networks[37] will implement policy and procedures to reconfigure the Diem DLT in the event of critical incidents or a need for upgrades to guarantee safe recovery after such incidents.

3.3.4 Managerial governance

The Diem Association is responsible for developing the Diem software. The Diem Association Council (internal Council) supervises the Diem Association. Each participant in the Diem project has one representative in the Diem Association Council. Important decisions require a two-thirds majority of the Diem Association Council. The members of the Diem project thus have voting rights on important decisions. This is comparable to a traditional FMI structure, in which shareholders have voting rights on important decisions.

The Diem Association:[38]

- is responsible for the managerial and operational governance of the Diem network and the development of the Diem project.
- conducts due diligence on Association Members, Designated Dealers and validators.
- manages the process of issuing Diem coins.
- sets compliance standards for participants and implements control measures.
- manages a Financial Intelligence Unit (FIU) function to monitor the network and identify suspicious activities.

The software used to implement the Diem Blockchain is open source and based on software development methods usually found in the open source community.
The open source structure supports technical decisions on Diem Core and the Diem protocol. Important decisions require a two-thirds majority of the Diem Association Council and for the other decisions the Diem Association Council provides a framework for decision-making. The Diem Association Council must guarantee that the decisions taken by the open source community are in line with the interests of the entire Diem ecosystem. This way Diem aims to ensure that technological decisions are fair and transparent.[39]

On the basis of the Diem white paper, it is possible to conclude that all members of the (private, closed) Diem Association contribute on an equal basis to the Diem infrastructure. In addition, the open source community (everyone) can make voluntary technical contributions to improve the software that is used by Diem. The participants in the open source community, such as developers of smart contracts and users of the Diem infrastructure, have no formal role in the Diem governance. NB: Diem smart contracts can

[37] Diem Networks, a wholly owned subsidiary of the Diem Association, manages the operations of the licensed Diem payment system. https://www.linkedin.com/company/diem-networks

[38] https://Diem.org/en-US/white-paper/ – Diem white paper and https://www.diem.com/en-us/association/#features. Members participate in key decision-making for the Diem network and the Reserve. They oversee the operation of the payment system, facilitate the provision of services on top of the blockchain in a safe and compliant manner and establish social impact grant-making in support of financial inclusion.

[39] https://developers.Diem.org/docs/Diem-open-source-paper – Diem Open Source paper

only be placed on the Diem DLT after they have been approved by the Council. This structure has similarities to the governance structure (vertical and central) of a traditional FMI.

Initially the software will be developed by a small group of core developers with simple governance structures. The core developers will be drawn from the Novi team that is part of Facebook. However, Facebook has assigned its rights and software to the Diem Association. The development of Diem is consequently under the governance of the Diem Association. No individual organisation, not even Facebook or Novi, has exclusive rights with regard to the strategy of the Diem blockchain. The managerial governance of the technology behind the Diem blockchain will evolve over time.

3.4 Fnality – a dFMI[40] system in the making

Diem and Fnality are similar in the sense that they both emerged from large consortia of large multinationals. Fnality comes from the financial sector only, whereas Diem has a more varied membership. Like Diem, Fnality is not (yet) operational. Plans may develop over time and this paragraph best describes the plans at the time of writing. After it became clear that the objective (*on-chain payment with finality*) was technically feasible, 15 FIs[41] established Fnality International. The plan[42] is to set up five Local Fnality Payment Systems, including one for Europe, Fnality Europe. Aside from the debate in the Eurosystem on this subject, the ultimate design objectives of the Fnality initiative are: i) settlement in pseudo central bank money (pre-funded, and a safe settlement asset) with finality[43], ii) settlement of (both) cross-border payments (PvP – payment versus payment) and iii) exchange of value payments (DvP, delivery of value versus payment) without the need for the use of a settlement agent. Fnality International began as a study of the scope for using tokenised cash assets by means of DLT to settle securities transactions. The tokenised assets, originally named USC[44], was based on the principle that the equivalent value in for example euros, is held on a central bank account to ensure that banks can rely on the value of USC as if it were fiat money. Fnality plans to initially offer five currencies, with potentially more in the future. For each of the five currencies an independent Fnality Local organisation will be set up in the relevant jurisdiction. This entity will assume the role of system operator and be liable to the supervisory authorities for the safe and effective operation of the Fnality Payment System (based on DLT). The structure of the entity for each Fnality Local is designed in such a way that the interests of the owners (initially 15 FIs, but eventually to be expanded to allow for any other participant) can be aligned as closely as possible with those of the participants in the system and the operators of the validator

[40] Decentralised Financial Market Infrastructure

[41] Fnality has 15 large shareholders: Banco Santander, BNY Mellon, Barclays, CIBC, Commerzbank, Credit Suisse, ING, KBC Group, Lloyds Banking Group, Mizuho Financial Group, MUFG Bank, Nasdaq, Sumitomo Mitsui Banking Corporation, State Street Corporation and UBS.

[42] We should emphasise that work is only at the planning stage at present.

[43] The intention in each FnPS is – in line with PFMI principle 8 - to ensure that Participants settle payments in a settlement asset with a credit risk profile as similar as possible to that of central bank money.

[44] Fnality no longer uses "USC" or "Utility Settlement Coin" to refer to any part of the FnPS or the wider Fnality initiative, or refers to any "tokenised" settlement asset.

nodes of each Fnality Payment System in order to ensure robust governance (Chu & Heller, 2020).

Each Fnality Local's income will derive from (i) transaction fees and (ii) membership fees. Fnality International will not own shares in any Fnality Local and therefore will not benefit from dividends (if any) declared by any given Fnality Local. One can question how Fnality's governance structure will address the risk of conflicts of interest. The governance of Fnality must guarantee that decisions by any Fnality entity are in the interest of the users and the continued existence of the system. Whereas the precise organisation of Fnality's governance has not yet been publicly specified, it is foreseen that each Fnality Payment System will, independently, comply with all applicable governance requirements of the PFMI[45] (and the relevant national implementation thereof). On issues that impact the Fnality Global Payments ecosystem as a whole, it is anticipated that there will be a co-ordination and co-operation mechanism such that decisions are taken for the collective benefit of all Fnality Payment Systems that comprise Fnality Global Payments.

3.4.1 Operation of the Fnality Payment System ("FnPS")

Each FnPS is a private network based on the Hyperledger Besu code base. There will be one blockchain per FnPS, rather than one master-chain serving multiple payment systems. Hyperledger Besu is based on Ethereum and meets the specifications of the private Enterprise Ethereum Alliance (EEA) as mentioned before in section 3.1 when discussing Ethereum. Hyperledger Besu is separate from the public Ethereum and can chart its own course according to the EEA roadmap. The updates in the public Ethereum may nevertheless be adopted by the EEA, so they may affect the course of the EEA.

The intention is that the Fnality network functions in a similar fashion to other pre-funded payment systems such as RT1.[46] In this set-up, the settlement asset is backed by central bank money, but is not as robust or secure as central bank money since no transactions are conducted in central bank money itself. As a result, the managerial and operational governance of the network must be sound in order to mitigate risks. The participants are intended to be large FIs that can settle large transactions; governance must be appropriate to this usage.

Fnality International, which is positioned above the Fnality Local entities, will give recommendations for improvements to the Local entities, which have full decision-making authority within their jurisdictions. Each Fnality Local will be entirely independent from the Fnality corporate group. According to the current plan the Fnality Locals have full decision-making power concerning the protocol, to the extent that it is operational within their jurisdiction. Nodes are maintained and operated by the FnPS participants. They have direct contracts with the Fnality Locals and must also comply with the conditions of the Local rulebook. Since all participants are regulated FIs that are known to the supervisory

[45] CPMI-IOSCO, Principles for Financial Market Infrastructures.
[46] https://www.ebaclearing.eu/services/instant-payments/overview/

authority and since Fnality is initially focusing only on the wholesale segment, different consensus algorithms are possible here, compared to public DLT systems. Fnality opts for a PoA (proof of authority) consensus. In PoA every designated node can validate transactions. The other nodes adopt these transactions on the basis that they know the identity of the validator. Whereas in the case of PoS (proof of stake) validators deposit a stake and risk losing it if transactions are incorrectly validated, that does not apply to PoA. The nodes in the latter put their reputation on the line if validations are incorrect. If transactions are incorrectly validated, the other participants will penalise the validator and may, for example, exclude the fraudulent validator from the network and seek compensation through the courts. This is possible because the participants know each other and have entered into a contractual relationship with each other.

3.4.2 Operational governance

The Fnality consortium consists of established parties in the financial world (FIs). The intended governance for Fnality is expected to be in line with the traditional financial governance requirements. The structure of the network is comparable to that of Diem, where each participant maintains a node. The combined nodes constitute a decentralised network (a dFMI, decentralised financial market infrastructure). Money is deposited by participants in a central bank account held for the FnPS. Participants make and receive payments in accordance with the FnPS rulebook on a peer-to-peer basis, and the dFMI records the resulting changes in entitlement to the monies held in the central bank account. The Fnality Local entities serve as the contact point for the central banks. The operational governance of the Fnality network is in the hands of the Fnality Local entities as these are responsible for the continuation of the operation of the local Fnality network. The FnPS will be used in the first place for wholesale payments only. In that sense the system appears to be more of an overall rival to Target2 or EURO1 than the three previous use cases in this paper. The choice of the wholesale segment has an impact on the governance. All participants are reputable entities that are known to the supervisory authorities. This makes coordination and cooperation easier than in the case of Ethereum, where a large group of unknown, mutually mistrusting individuals and companies have to cooperate. The choice for the PoA consensus method is also understandable for this reason. People trust each other and the reputational damage in the event of fraudulent acts is high.

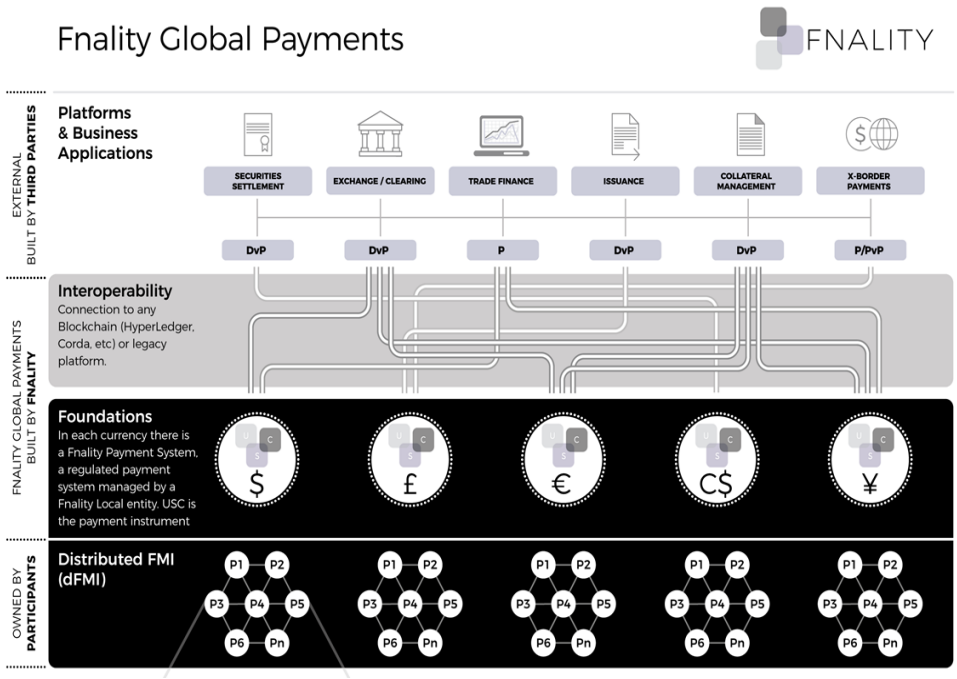


Figure 8 Overview of Fnality

3.4.3 Managerial governance

Fnality appears to be fully committed to traditional regulation by the financial supervisory authorities and to the associated governance requirements. To date the specific manner of supervision, possibly by way of direct access, has not been discussed. Depending on the relevant central bank's account policies, the central bank account for any given FnPS will be held by the Fnality Local, the system participants, or a subset of eligible system participants. In each case, the central bank account will be operated by the Fnality Local. The Fnality Locals will be structured as an FMI operator in accordance with applicable local rules (including licensing and/or recognition frameworks) governing entities that operate FMIs. The Fnality Locals will exist as entirely independent entities, not under the direct control of Fnality International. The principal entity of Fnality is a party with multiple owners, including 15 major shareholders that are traditional banks. The Fnality Locals will be responsible for the development and maintenance of the local Fnality network. The Locals maintain the codebase for the chain. Fnality International serves as an advisory medium for the Locals and will try to realise proposals for protocol updates centrally. There is no power of enforcement. Fnality International advises the Locals regarding updates.

4. Governance and open source

The world of open source software has grown enormously in recent years. Both the fintech community and traditional FMIs are heavy users of open source software. Many DLT environments use the label open source to show that anyone can contribute to the software and anyone can use the software. The open source process is part of the managerial governance of DLT systems, as it determines and concerns the continued development and existence of the system. In this section we describe the different options for implementing an open source software development process and show that despite its name this process too is not decentral by nature.

Software is open source when it fulfils 10 criteria drawn up by the OSI, the Open Source Initiative. An important precondition is that the source code is public and can be inspected by third parties. Open source is also frequently mentioned in relation to DLT systems. Bitcoin, Ethereum, Corda and Diem are all open source. Open source software has two key aspects: the development of the open source software (section 4.1) and its use (section 4.2).

4.1 Development of open source software

There are various models for the development of open source software. We divide the development process into two parts. The first involves the submission of contributions and the second concerns decision making on acceptance. For the first part there are models such as the cathedral model and the bazaar model. The cathedral model specifies in advance what is expected from the contribution. According to Wikipedia in the bazaar model anyone can contribute anything (like in a busy market place). Subsequently a decision is taken regarding the acceptance of the contributions. We distinguish two models for this: the horizontal model and the vertical model. In the horizontal model everyone can take part in the acceptance process of decisions, whereas in the vertical model there is a selected group that decides. Because in the horizontal governance model anyone can become part of the core dev (core developers) team, this is can be qualified as a democratic process. In the vertical governance model, the firm decides who joins the core dev team and the firm sets the agenda.

Besides the horizontal model and the vertical model there is another, a high priest model (a group, potentially led by one person, with some decision-making powers, between top-down and bottom-up). This includes DLTs such as Bitcoin and Ethereum, but also a software language such as Python. The group is not a formal group belonging to a corporate organisation and the composition method is as stated in (Jameson, 2020) an “emergent process decided primarily by contributions and reputation” or “contributors who have built up sufficient social capital within the project by making quality contributions over a period of time”. This process is not a formal process and is by invitation or request.

A feature common to all open software development models is that everyone can contribute to the development of the software product, the language or the operating

system. The difference lies at the point where the decisions are taken on the inclusion of contributions in the software product (the suite). In the corporate model it will come as no surprise that the corporation has the upper hand. In the bazaar model the developers and users have more say. In the high priest model, a person or a select group ultimately takes the decisions, although everybody can contribute.

Many open source projects use the GitHub development environment for both development and distribution (owned by Microsoft since 2018).[47] There are more than 56 million developers, more than 3 million organisations, more than 100 million projects (known as repositories) on GitHub and 72% of the Fortune 50 companies are involved. GitHub also includes non-open source products. GitHub provides various tools to control the open source software development, such as the GIT version management system. Economies of scale and network effects are important for commercial software development. The more users there are, the lower are the development costs. The more users that use the software, the higher is the commercial interest to improve the software, leading to a further increase in the number of users. For open source there is also a pull effect: the more widely certain software is used, the more programmers are interested in contributing to the continued development and improvement of the quality of the software.

There may be various reasons why software developers contribute to an open source project. Contributors to some projects receive a reward for their contribution. This may take the form of donations, a unique right to use the software for certain commercial applications (Firefox, WordPress) or financial support (sponsorship) from commercial companies. In the case of DLT systems, the reward may be a rise in the value of the cryptocurrency, provided the developers own it. In the case of Ethereum, the Ethereum Foundation pays 'bounties' in Ether for solving problems in the code. Diem is an example of a project whose participants are commercial operators that have a financial interest in the project. The governance of DLT systems must address such conflicts of interest in an appropriate way.

4.2 Use of open source software

Open source software can be used free of charge. This also has a downside in that no one is responsible nor accountable or liable for the code, there is no guarantee that it will operate and there is no service model or helpdesk. This may be an impediment to commercial applications, but the problem can be partly (not completely) solved if commercial IT companies provide support for the use of open source software, such as IBM in the case of Linux and Hyperledger (a DLT system). This solves the support aspect of open source software.

[47] https://github.com/

There is an open source licence model for the use of open source software. This means the software can be used free of charge, but that its use is subject to conditions.[48] The licence model is divided into three main categories:

- Free-software licences: the only obligation subsequent users have is to cite the original authors.[49]
- Keep-open licences: the requirement of these licences is that changes to the software must also be published as open software. Software that incorporates this software, on the other hand, does not have to be published entirely as open source.[50]
- Permissive software licence: these licences require both modifications and extensions to be published as open source.[51]

Some conditions of open source software state that the software must not be used for commercial (business) purposes. The licence model has no direct influence on managerial governance, only an indirect influence, since the DLT system itself determines how the updates will be developed and executed in its system.

[48] https://en.wikipedia.org/wiki/Free-software_license#OSI-approved_open-source_licenses
[49] https://en.wikipedia.org/wiki/Public_domain
[50] https://en.wikipedia.org/wiki/Permissive_software_license
[51] https://en.wikipedia.org/wiki/Copyleft

5. Answering our research questions

We conducted a factfinding exercise as presented in the previous sections to answer the following two research questions:

i) What are the differences in governance between traditional financial market infrastructures and DLT/Blockchain infrastructures?

ii) What are the consequences of decentralized governance of DLT based infrastructures for supervisory authorities (supervision)

In this section we will elaborate on the research questions using the results from the fact finding.

5.1 Comparing governance of traditional FIs, FMIs and DLT systems

Whereas we have established that governance has various definitions, the definition we use is set out in section 2.1; governance refers to the organisation of powers, responsibilities and liabilities with regard to the FI or FMI and its participants. The purpose of the governance structure of FI or FMIs is to create an efficient, secure, reliable, adaptable and sustainable institution or infrastructure. Governance is conducted in line with the objective pursued by the FI, FMI or DLT system. In a DLT system this objective is: to process transactions securely, irrefutably and soundly, whether through a public DLT such as Ethereum or Bitcoin or through a non-public one such as Corda, Diem and Fnality.

A challenging aspect of a DLT system is that it is leaderless. On the one hand it is just an IT infrastructure and on the other it is a (transaction) service offered, for which users need to pay. Just like an FI and FMI, the DLT offers services. A more precise characterisation of a DLT system is that of a decentralised autonomous organisation. From that perspective we can also characterize an FMI as a decentralised organisation and an FI as centralised organisation. However, a full comparison between the two is difficult, as they are so different. The purpose of our research was also partly based on the question whether DLT governance mechanisms are useful for an FI and FMI and if, and potentially under what conditions, a DLT, can have a role in the financial sector, a sector that is not autonomous nor leaderless, and very much based on trust. Trust needs to be earned and is based on positive experiences. The set-up of governance of an entity can help build this trustworthiness. Therefore, we started our research with looking at governance, both in the more traditional FIs and FMIs and the innovative DLT systems, to see how they compared.

In order to be able to better compare the governance of traditional FIs and FMIs with the governance of DLT systems, we use the concepts of vertical and horizontal governance.[52] By vertical governance we mean that the top tier ultimately determines what happens in the institution, and how it develops. This applies to an FI, a financial institution with a legal entity. If for example this institution contributes to an infrastructure, the top management tier of this institution determines the contribution and is also responsible for it. The FI has

[52] The concept of horizontal and vertical governance is also recognised by other academics, in some cases from a different perspective. Compare the description of horizontal trust in DLT systems and vertical trust in more traditional institutions, Rachel Botsman, via https://fd.nl/futures/1371645/technologie-is-niet-de-oplossing.

end-to-end control over its own service provisioning and related data. An FI may outsource parts of the services, but the responsibility remains with the FI.

Different from FIs which have a vertical form of governance, the FMI has a more horizontal form of governance. The FMI actually functions as a system without the presence of a single overarching institution due to its horizontal governance. The FIs operate alongside each other in an FMI. Within the FMI, services and data are owned and controlled by the FIs. The governance of an FMI is constituted by the good governance of all individual FIs together (horizontal base). Nevertheless, even in an FMI the participants are unwilling to leave its survival to chance. The governance of an FMI works because the roles of the various individual FIs are set down in a legal framework and one or more supervisory authorities are mandated to protect the interests of users and oversee the continued existence and proper functioning of the FMI as a whole. The governance of an FMI therefore also comprises a vertical element on top of the horizontal base and consists of: i) legislation; ii) cooperation and consultative structures; and iii) contracts and rulebooks.

This table compares characteristics of vertical and horizontal governance.

Characteristics of vertical governance	**Characteristics of horizontal governance**
Hierarchy	Autonomous participants
Decisions made by one person (natural/legal)	Decisions made by democratic voting
Individual accountability	The accountability issue is more uncertain and more unclear. On the one hand one could argue there is no accountability. On the other hand, one could argue there is some kind of decentralised, shared accountability and liability, comparable to group accountability (this may be food for further research)
Employment contracts	Incentives for contributions
Onboarding processes	Open to everybody

Although the governance of DLT systems might be considered horizontal, in section 3 we have shown that the governance of private DLT systems are more vertically structured with an overarching organisation controlling both the managerial and operational aspects. This overarching organisation often has the intention to transfer the control back to the member community, e.g. R3/Corda towards the Business Network Foundation.

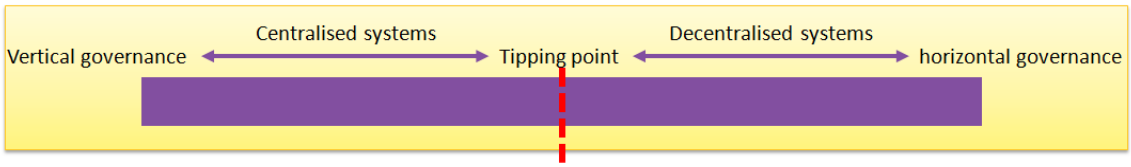
Private DLT systems strive to include all members and have a governance model where these members can have a say in the development as well as the operation of the DLT system. Most of the private DLT systems use a foundation as legal structure. The operational governance is often delegated towards a smaller group of members, for efficiency reasons. Regarding managerial governance an open model for contributions to

the software development is advocated, but the acceptance process is often controlled by a group of members.

With public DLT systems the DLT and corresponding governance models are open to the public (everyone and anyone). Where we noticed considerable overlap between the managerial and operational governance of the private and public DLT systems, the private DLT systems can be optimized for smaller groups of members that control the DLT. This is different for a public DLT. Here the governance should be properly decentralised in order to bear the notion of public DLT.

When comparing the governance of the various systems we can conclude that the FMI and the private DLT have a more horizontal governance model than an FI. However, for both it is true that one cannot simply join (need a license or become a member). Where the FMI has a supervisor and regulatory framework, the private DLT often has a foundation (non-profit organisation with a legal entity) as overarching mechanism. The scope of the managerial governance for both is different, because in an FMI the FIs can have very different roles and create their own infrastructure. The shared interest between participating FIs is related to the interfaces between FIs within an FMI. They need to have consensus on the interface used for the exchange of transactions and data. The FIs may have an indirect say in the governance of the FMI, by providing input on the content of rulebooks, laws and regulations.

Different from traditional FIs, FMIs and (indirectly) private DLT systems, at the moment public DLT systems are not at all supervised. The managerial governance is intended to be open to everybody. However, often a core development team acts as a gateway for driving the DLT development. Although a public DLT is open, joining a core development team is not straightforward, we have seen examples where developers can be invited by the core team to join the core team based on reputation.
Operationally the public DLT is open to everyone, anyone can start a node in the DLT network and contribute. Also, at the user level anyone can start using a public DLT and offer to settle transactions. Despite the inherent decentralised nature of a public DLT we see groups of users collude like mining networks and developers, such that the decentralised nature can be at risk. Even a public DLT cannot have a truly horizontal governance and leave its survival to chance. The goal of a DLT system should be to remain at the right side from the tipping point to ensure the reliability.



Operationally speaking the governance mechanism of a public DLT system is very much dependent on the type of consensus algorithm and cryptography used.

5.2 What are the consequences of decentralized governance of DLT based infrastructures for supervisory authorities (supervision)?

DLT systems can be characterised by their shared services and shared ledger (data). From a governance perspective the operational governance of both public and private DLT systems is based on algorithms. The managerial governance of a public DLT system can be seen as a social process with very different incentives for the participants. The managerial governance of a private DLT system, although promoted as open source, better reflects the governance of an IT departments that is owned jointly by several FIs.

An important aspect of supervision is risk management. Risk management is and should be part of the governance model and should ensure that risks are within accepted thresholds. As such there is not one single good governance model, not for traditional FIs, FMIs and neither for DLT systems. The type of services offered and its usage will determine whether the governance model is adequate to ensure financial stability, to support the smooth operation of financial market infrastructures and to safeguard consumers. Despite this inherent variation in what constitutes good governance we will discuss the general governance mechanisms and provide some first suggestions for supervisors when confronted with a DLT based infrastructure.

Public DLTs are from a supervisory view most challenging, because they lack a legal structure and a central accountable entity. This means that any FI using a public DLT must itself have sufficient mitigating measures to control the risks related to the use of a public DLT. The operational governance of the public DLT strives to achieve an immutable trustworthy ledger. But in case of a dispute about the execution of a transaction, the DLT offers no solution. Therefore, the FI should take care of proper dispute resolution mechanisms. A possible solution could be executing an additional rectifying transaction, because one cannot change transactions already included in the ledger. The supervisor should require the FI to implement controls that mitigate the risks that the FI is confronted with.
An even more complex question regarding public DLTs concerns ownership. Who owns the infrastructure services and data on a public ledger? The person or entity holding private keys can control the services and data, but is that the same as ownership? This may be food for further research.

As already mentioned in the previous section, the managerial governance of public DLT systems may not be as decentralised as is claimed or allured to. Instead of an open source process where all participants can contribute and steer the future development of the public DLT, the managerial governance can be seen as a social process with very different incentives for all the participants (a fluid group of users, merchants, exchanges, operators, developers, thought leaders). In this social process centralisation is likely to coalesce around experts (a fluid group of developers, system architects, other experts). Whereas in theory anyone can contribute to the code, the required engineering skills may very well

constitute a barrier to entry. This creates new challenges around understanding not only simple code (smart contracts), but also complex blockchain protocols. This type of centralisation next to the earlier discussed core development groups and high priest models may pose a risk on the continuity of the FI's services. Again, the FI's governance model should mitigate such risks.

Looking at the operational governance, the (decentral) consensus algorithms used for adding blocks with new transactions (data) to the blockchain is assumed to promote trustworthiness and support the immutability of the ledger. There are many different consensus algorithms and even different implementations of any one, e.g. the Proof of Work consensus algorithm of Ethereum is not the same as of Bitcoin. This creates challenge for both the FI and supervisor to arrange for sufficient adequate mitigating actions and governance mechanisms.

When using a public DLT the FI should consider mitigating actions to ensure reliability e.g. to guarantee business continuity. The FI could for example become a node in the public DLT. This would enable the FI to hard fork the public DLT when this would be necessary for the continuation of its operation. In addition, after safeguarding its services, data and transaction history the FI should have a plan for an alternative infrastructure.

Where public DLT systems are meant for settling pure person to person (P2P) transactions, we currently see an increase in the use of these public DLT systems, in particular the application of smart contracts that in a more traditional world would be regulated. This development is called decentralized finance (DeFi), but alike a DLT system itself, also a smart contract on the DLT has some form of governance and incentives are needed to develop this governance so that it is adequate to ensure financial stability, promote the smooth operation of financial market infrastructures and protect consumers. We need further research into the area of DeFi to answer the question if DeFi is a financial service offering and thereby should be regulated. We need to build experience and knowledge around the usage of DLT systems in a highly regulated financial sector. The DLT pilot regime may contribute to building this experience.

When utilizing a private DLT the FI is assumed to have a (legal) arrangement with an entity managing the DLT. This can be by means of an outsourcing arrangement or even by participating in a foundation and being part of the governance structure as discussed with Corda. The presence of a legal arrangement offers the opportunity to take care of the ownership issues, ownership of data and infrastructure services. From a regulation perspective the issue of shared services is known, the issue of shared data in an immutable shared ledger needs further research. The earlier remark related to the accountability of a group is an area that needs to be further researched.

6. Conclusions

To start our research into the potential future of DLT systems in the financial sector we defined two research questions: 1. What are the differences in governance between traditional FIs, FMIs and DLT systems? and 2. What are the consequences of decentralised governance of DLT systems for supervisory authorities?
To understand the differences in governance better we have based our research on a comparative study covering the governance of traditional FIs, FMIs and four DLT systems. DLT systems are inspired as a revolt against centralised power institutions and they function as decentralised systems. The governance of DLT systems is believed to be fully automated and based on IT code only. Because the financial sector centers around trust and the trustworthiness of its participants, we wondered whether the governance models of DLT systems could justify the level of trust and could qualify for usage in the financial sector. For this we asked ourselves what would be the impact of such DLT governance models for financial sector supervisors. For this study we selected private and public DLTs which use similar functionality and technology (DLT and support for smart contracts). Private DLTs seem to have fit with current applications within the financial sector. Our research showed that public DLTs are more challenging from a governance perspective, because of their horizontal decentralised nature contrary to the traditional centralised financial sector.

As an answer to the first question, we have identified differences in the governance structure of both FI, FMI and private and public DLT systems. Given that a public DLT has no legal structure or central authority, its governance model is set up to involve all those parties that are participating in the decision making, and that are needed to achieve common goals. The interesting aspect is that this community of participants, decision makers, is fluid and can include literally all participants; end-users, node operators, developers, ideologists and experts. In reality however, we see forms of centralisation, likely to coalesce around experts. Governance models of private DLT systems resemble the vertical governance models of an FI more. Within a private DLT the governance model supports those involved in this private community. An FI has a vertical model. The board has end-responsibility and the organization has a hierarchical structure.
We conclude that the governance of FMIs and DLT systems are more similar than the innovative nature of DLT systems seems to indicate. Like an FMI, a public permissionless DLT, such as Ethereum, can also exist without the presence of a responsible, accountable, liable legal entity. However, the accountability of FIs within an FMI are clearly defined, whereas in a DLT system they are not.

The second research question is focused on the consequence of decentralized governance of DLT based infrastructures for supervisory authorities (supervision). This question is inspired by the potential increasing use of DLT systems in the financial sector, which centres around trust. If DLT systems are to be used in the financial sector more, they need to be safe and sound, and trustworthy. The potential (increasing) use of DLT systems in the

financial sector may have consequences for the supervisor(s) as these DLT systems may have inherent risks that need to be addressed. The supervisors are legally mandated to ensure financial stability, promote the smooth operation of payment market infrastructures and protect consumers. We conclude that within a DLT system there may be conflicts of interest between the shared objectives of the DLT and the individual objective of a participant. For private DLT systems in the financial sector this is less of a problem, since a private DLT system is owned by a private group of regulated, authorised FIs, that have a vertical governance structure, and bear responsibility, accountability and liability. A private DLT system has a legal structure in which FIs participate and with which FIs can make legal arrangements, like setting up outsourcing arrangements.

For public DLTs this is not a given, because anyone can join, also none financials next to the fact that a public DLT system exists without a legal structure or central authority. As a consequence, risks are not mitigated by legal contracts and service level agreements. Having said that we are more or less used to the use of open source and free software and tools in the financial sector. The public DLT can be regarded as open source services. We need to build experience and knowledge around the usage of the public services in a highly regulated financial sector. The DLT pilot regime, discussed in the next paragraph, may contribute to building this experience.

Whereas the details of necessary regulatory revisions and potential new rules and requirements are food for further research as a first step we take note that the DLT pilot regime[53] currently discussed by the European Commission is to develop and promote the incorporation of transformative technologies in the financial sector, such as blockchain and DLT. The Union financial services legislation was not designed with DLT and crypto-assets in mind. The pilot regime should enable the competent authorities to gain experience on the opportunities and specific risks created by crypto-assets that qualify as financial instruments, and by their underlying technology. If necessary, existing laws, rules and guidelines could be revised to accommodate the possible use of such innovative systems in the financial sector.

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Annex I

A schematic comparison of the governance of more traditional FIs, Diem, Ethereum and Corda

Aspects	Financial institution	Financial market Infrastructure	Diem	Ethereum	Corda
Managerial governance					
Financial supervision	requires authorisation and is subject to financial supervision	Supervision of underlying financial institutions.	Not yet subject to financial supervision. Diem is awaiting approval by FINMA. This is a precondition for the start-up of Diem.	Not subject to financial supervision An FI that wishes to use Ethereum must mitigate all risks and is responsible for doing so.	Corda is not subject to direct supervision, but, through outsourcing, must indirectly comply with laws and regulations for companies that are subject to supervision.
Shareholder structure	Tradable on an exchange and shareholders have voting rights.	Not applicable, no one owns an FMI	All Diem members are represented in the Diem Association	Ethereum has no shareholders	Corda Association has control.
Board structure	Management Board and Supervisory Board	Not applicable	Diem Association and Diem Board	Group of core developers determines network updates. Miners decide on adoption.	Corda Association
Nomination committee	Members of MB and SB are approved by the shareholders	Not applicable	Not specified	None	Not specified
Remuneration committee	Remuneration of MB and SB proposed by the remuneration committee and approved by shareholders	Not applicable	Not specified	None Currency owners benefit from price rises. Miners benefit from transaction fees	Not specified
Risk/Audit committee	A risk and audit committee forms part of the corporate governance	Not applicable	An audit function is present. No independent audit committee is specified.	None	Not specified

Control framework	Various frameworks such as COSO, COBIT, NIST or guidelines of EBA and ESMA.	Not applicable	Control measures built into protocols.	Control measures built into protocols.	Control measures built into protocols.
Outsourcing	Service level agreements and monitoring	Not applicable	Onboarding process for new Diem members with contracts. Initial investment is 10 million.	There are no contracts or service level agreements.	Onboarding process for new users of the Corda network
Shareholder rights	Shareholders' rights enshrined in law, including voting rights at shareholder meetings and right to part of future cash flows.	Not applicable	The rights and obligations of the members of the Diem Association are contractually specified	No shareholders	The rights and obligations of members of the Corda Association are contractually specified
Open source	No	Not applicable	Yes, corporate model	Yes, bazaar model and benevolent dictator	Yes, corporate model
Change management process	Formal change management process including responsibility for approving new software versions	Concensus required between FI's for protocol changes used for data exchange	New versions of Diem software are approved by the Diem Association	The community proposes software improvements. These are approved by the core developers. The miners decide whether to use the software.	New software is approved by R3. The Corda Association determines which software version is used.
Business model	All costs are covered by fee income	Not applicable	All costs of members' transaction processing are covered by fee income. It is unclear whether part of the fee income also goes to the Diem organisation.	The costs of mining/staking are reimbursed by means of transaction fees and the issuance of new Ethers. There is a bounty programme for developers.	Part of the fee income is used to reimburse the notary's transaction approval costs and part goes to the Corda Association to defray its costs.
AML, KYC, WWFT Anti-Money Laundering and Anti-Terrorist Financing Act.	Internal compliance function	Not applicable	Internal compliance function in the Diem Association	Compliance on the network periphery in the exchange offices.	Compliance function in members of the Corda network
Operational governance					

Finality of transactions	Use of TP monitors and relational database. A transaction is technically final once it has been committed. Transactions may be rolled back. Transactions are approved by a central system.	Not applicable	A transaction is final if it has been approved by two-thirds of the Diem members	Finality is determined by the consensus algorithm	Finality of a transaction after it has been approved by the notary function.
Reliability of transaction data	Data replications between servers and computing centres. Transactions are approved by a central system. The transactions are only visible to the two parties conducting the transaction.	Not applicable	All members run a copy of the database.	Anyone can run a copy of the database/blockchain and all transactions are visible to everyone.	Corda members can run a copy of the database. The data is secure. The data cannot be read by everyone.
Access security	User IDs and passwords, possibly with 2FA	Not applicable	Public-key cryptography, or asymmetric cryptography	Public-key cryptography, or asymmetric cryptography	Public-key cryptography, or asymmetric cryptography
Data structure	A single data structure (relational database)	Not applicable	A single data structure with Merkle trees to guarantee integrity.	Blockchain (Merkle trees are used in a block to guarantee data integrity).	A single data structure

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