Blockchain Applicability for Securities Settlement

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Abstract. Blockchain technology has been recognized as one of the potential technologies to be utilized in capital markets. The goal of this paper is to evaluate the applicability of using the blockchain technology in securities settlement process. First, current financial market infrastructure is examined. Then Central Securities Depositories Regulation is studied. Blockchain applicability framework is applied to assess the blockchain technology's applicability to securities settlement. A blockchain architecture model and potential node structure for securities settlement are developed. The proposed blockchain architecture model and node structure is then evaluated against scholar expected benefits and drawbacks of using blockchain for securities settlement and cross-border settlement efficiency.

Keywords: Blockchain, Securities Settlement, Financial Markets.

1 Introduction

Blockchain technology has a potential to be the technological driving force of the next advancement leap in the financial market industry. Current financial market participants, while focusing on serving their local markets, are standardizing processes, and accommodating cross-border relationships. Many industry professionals have recognized the potential of the blockchain technology that could significantly improve the currently existing processes and solve many of the existing inefficiencies [1].

One of the identified processes that could significantly benefit from the blockchain technology is securities settlement process. Also as referred as securities post-trade (since it happens after securities are traded), the process involves a lot of intermediaries, especially when there are long chains of custody and cross-border settlements. The nature of the financial market ecosystem, where there are centralized entities that execute securities settlement processes and contain large number of intermediaries that share information between each other, indicates potential to use blockchain technology. Scholars support it and claim that this kind of environment with multiple intermediaries can benefit from blockchain technology, for example, from data reconciliation process efficiencies, reduced risks, increased transparency, and other benefits [2].

Because the securities settlement practices and legislative requirements vary from country to country, it is hard to generalize blockchain's potential in securities settlement on a global scale. Since financial markets in the European Union (EU) are operating under the same or similar legislations, they have harmonized the financial market

practices and structures in the EU countries. Therefore, the scope of this paper is to examine the applicability and usability of blockchain technology within the EU, considering the current EU-level rules and regulations.

Considering the nature of the current securities settlement process and the financial market ecosystem, the aim of this study is to assess applicability of using blockchain technology in securities settlement process in the current regulatory environment in the EU. Namely, the authors of this paper evaluate if blockchain technology can be used to ensure securities settlement, and, if it can, then what would be the possible blockchain architecture and node structure. To make this assessment, the following research question is asked: Can blockchain technology be used to process securities settlement in the EU?

To answer the research question, the following tasks are defined:

- Examine the applicable regulations for securities settlement in the EU,
- Evaluate blockchain technology's applicability for securities settlement,
- Develop a blockchain architecture model and node structure that describes potential blockchain usage for securities settlement,
- Assess the benefits and drawbacks of the proposed blockchain architecture model and node structure.

2 Financial Market Infrastructure Components

The current financial market infrastructure in the EU consists of multiple components that are interconnected with each other and allow securities (also called financial instruments) transactions between the parties. Financial market infrastructure is the core of safe, efficient, and robust financial markets [3]. Financial market landscape in different regions and countries can vary and have different components and business practices. However, for this paper the main focus is on EU region where the financial market landscape is standardized by similar regulatory standards and requirements. The countries within the EU are regulated by the same laws and regulations that are dictating how the financial markets are operating. To define the current financial market infrastructure, the following information sources are used – CSDR [4], T2S Framework Agreement [5], T2S User Detailed Functional Specifications [6], standards published by Securities Market Practice Group (SMPG) [7], and literature provided by Benos, Garratt and Gurrola-Perez [8]. Using the information provided by the listed sources, Fig. 1. is created to describe the main components of the financial market. Each component is either directly involved in securities settlement process or is providing services that lead to securities transfer.

Central securities depositories (CSDs) have a crucial role in the financial market infrastructure. By some authors, the CSDs themselves are defined as financial market infrastructures because of their position in the securities settlement chain [3]. All securities transactions that are conducted on stock exchanges or otherwise are processed by the CSDs during post-trade period. According to Regulation (EU) No 909/2014 of the European Parliament and of the Council (CSDR), "securities settlement systems operated by CSDs are of a systemic importance for the functioning of securities markets"

[4]. Because of their importance in the financial market infrastructure, the CSDs are highly regulated, usually by the local competent authorities of the country where CSD operates, such as financial services authorities. CSD importance in the financial market infrastructure is crucial since the ultimate ownership change of securities is registered in CSDs [9]. CSDs operating in the European Union (EU) must comply with EU level regulations, from which the main is CSDR.

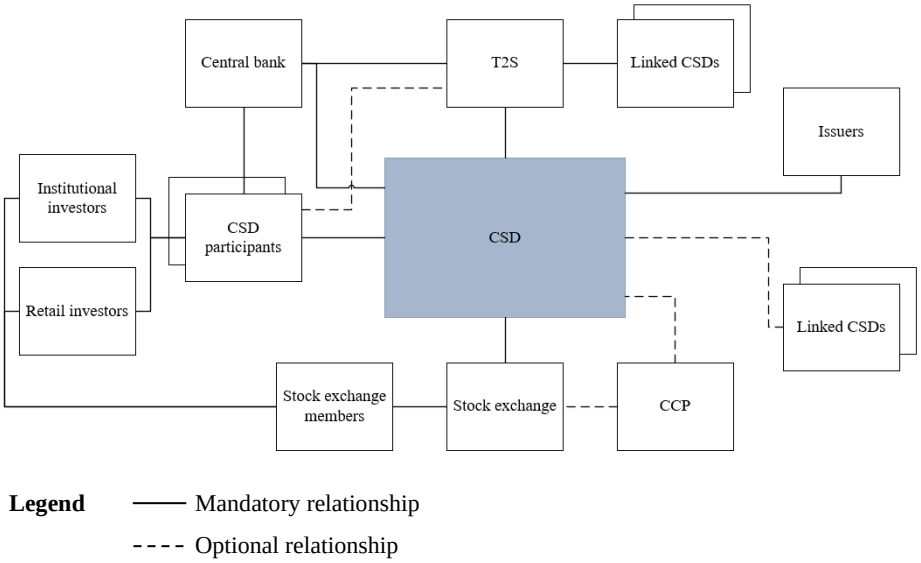

Fig. 1. Financial market components and relations.

CSDs are entities that operate securities settlement systems (SSS), provide notary service (initial recoding of securities in a book-entry form), and provide central maintenance service (registration of securities accounts at the top tier level) for CSD participants – banks or brokerage companies. CSDR defines these functions as core CSD services. Different CSDs operating in different countries may have varied service scope that they provide, but they usually provide the same set of core services.

SSS ensure technically and legally safe securities transfer between the involved parties at CSD participant level. Securities settlement can be either free of payment (FOP) or delivery versus payment (DVP). FOP transfers involve only securities transfer, and DVP involve simultaneous exchange of securities and money. Depending on the regulation and market practices, the securities settlement can happen in real-time, or it can be aggregated and netted at pre-defined times.

3 CSD Regulation

Legal requirements towards how financial markets, in particular securities settlement, must operate are dependent on the locally adopted laws and regulations. Since the scope

of this paper covers securities settlement in the EU, the relevant legal acts are inspected to identify the legal requirements that any current or future solution must comply with, including one built on blockchain. European Commission has published many EU regulations that describe how financial markets should operate and define requirements for the financial market components. According to European Commission, various legal acts have been published to ensure that settlement systems operate as expected, especially after the financial crisis in 2008.

Central securities depositories Regulation (CSDR) is the main regulation that defines how various aspects of securities settlement must operate. The date of entry into force of this regulation was 17 September 2014, and since then multiple CSDs in the EU have licensed their operations under the regulation. The aim of this regulation is to synchronize how CSDs function and how securities settlement is organized within the EU. According to the regulation's subject and scope, it "lays down uniform requirements for the settlement of financial instruments in the Union and rules on the organization and conduct of CSDs to promote safe, efficient and smooth settlement." Similar operational and legal requirements set by the CSDR also improve the environment for more streamlined cross-border settlement across the EU [4]. CSDR considers the existing global standards issued for the financial market infrastructures by the Committee on Payments and Settlement Systems and the International Organization of Securities Commissions.

CSDR stresses the systematic importance of CSDs and the SSSs they operate for the securities markets. It recognizes the multi-level relationships between the parties involved in the financial markets, and the importance of CSDs to ensure that the information and assets shared in the financial markets are secure, processes are trustworthy, and there is no unjustified creation or deletion of securities. CSDR provides common definitions to all the relevant items – physical, legal, and theoretical – related with financial markets, CSDs, and their operations. It defines the requirements on securities settlement, CSD supervision mechanisms, requirements for CSDs, and other items. The CSDs are required to record all securities traded on the stock exchanges in book-entry form so they can be properly settled in an SSS. In other words, all the securities should be issued digitally and recorded in an SSS in a way that the ownership of the securities can be traceable. An important aspect is settlement finality – the moment when the change of ownership can be considered final and irrevocable. The CSDs must comply with the Settlement Finality Directive (Directive 98/26/EC) and define exact moments of entry and irrevocability when the settlement instructions are accepted, matched, and executed. Besides, CSDR states that for all cash settlement originating from securities settlement (for example, for simultaneous securities exchange for cash) the CSD should settle cash using the CSD participant cash accounts opened in the relevant central banks (cash settlement in central bank money), where it is practical and possible.

In addition to the CSDR, the European Commission has published Level 2 measures that complement CSDR with more detailed descriptions and requirements towards CSDs. These Level 2 measures include regulatory and implementation technical standards on CSD requirements, regulatory technical standards on settlement discipline, and others. For CSDs to be compliant with the CSDR and be allowed to operate in the EU, they must comply with the CSDR and the Level 2 measures and certify with the local

competent authorities that they have completed all the requirements defined by the CSDR and Level 2 measures.

For this paper it is important to understand the legal requirements and implications towards securities settlement. The current laws and regulations are technology-agnostic and do not specifically define what technological solutions are allowed or not allowed to be used for the securities settlement. Therefore, any solutions that are used should still be compliant with the legal and regulatory environment. Since blockchain technology as such is considered as disruptive and could potentially replace or drastically change the operations of some financial market infrastructure components, it is important that the imposed changes are still compliant with the relevant legal and practical requirements defined by the law. When modeling the potential blockchain architecture that could be used for securities settlement, the general principles and operational requirements defined by CSDR must be respected. In particular, the following general aspects must be considered:

- Requirements on securities records in a book-entry form,
- CSD participant and account structure,
- CSD link requirements,
- Settlement finality aspects,
- Cash settlement in central bank money.

Other requirements defined by the CSDR that are not directly related to the operational aspects are disregarded in this paper, as they do not impact the underlying system ensuring the securities settlement. These requirements include cooperation between the competent authorities, CSD authorization, CSD's capital and organizational requirements, and other non-operational requirements.

4 Using Blockchain Applicability Framework

While some scholars recognize the potential usage of blockchain technology in the financial markets, others argue that for some applications it is hard to pinpoint whether blockchain based solution would be suitable, or the centralized technology is more appropriate [10]. In order to assess the applicability of blockchain technology in securities settlement, a blockchain applicability framework designed by Gourisetti, Mylrea and Patangia [10] is used.

The blockchain applicability framework asks 92 control questions to determine the blockchain technology's applicability. The authors of the framework claim that the control questions have been designed by evaluating numerous operating blockchain solutions, their core concepts, similarities, and differences, as well as by analysis of consensus mechanisms, and other aspects [10]. Within the framework, the controls are being categorized in five distinct groups or domains:

1. Data and participation (DP),
2. Technical attributes (TA),
3. Security (SC),
4. Trust parameters (TP),
5. Performance and efficiency (PE).

Each domain is further divided in smaller sub-domains that contain a group of controls in question formats. The framework states that answering the control questions gives a mathematical result for applicability of blockchain solution for securities settlement. In particular, the framework allows to answer the following decisions:

1. Does the application need a blockchain?
2. If the application needs a blockchain, does it need a private blockchain or permissionless/public blockchain?
3. What consensus is most suitable for the application? Proof-of-work (PoW), proof-of-stake (PoS), proof-of-burn (PoB), and proof-of-authority (PoA)?

We applied the framework to securities settlement context. The results of the application are available in full scope in [11]. The answers to the control questions were derived from the previously reviewed literature on the blockchain technology, performed analysis of the current financial market infrastructure, components, and their roles, as well as regulatory framework. Each answer carried a weight (not applicable – 2, partially applicable – 1, largely applicable – 1, fully applicable – 2), and each control question indicated which decision it impacts.

Domain 1: Data and participation. This domain summarizes the control questions on data attributes, authority nodes, readers and writers and their characteristics. The assessment of the answers was made based on the previous literature on blockchain's applicability in securities settlement, where it was indicated that CSDs could retain the role of governing who could access the network, and what would be the participant rights [9]. Additionally, control questions that required to determine the environment of the application were answered based on the current definitions set by the CSDR. The control question answers indicated that the participants of the potential network would be known, and their access would be regulated. Namely, the nodes of the network would be CSD participants and their ability to operate would be assessed by the CSD, as the current regulation requires.

Domain 2: Technical attributes. This domain includes sections of codebase and networks, smart contracts, transaction constraints, transaction processes, and miners and consensus sub-domains. The answers to these control questions were based on the current financial market infrastructure and the specifics of the securities settlement process defined by the CSDR, and the evaluation of the blockchain applicability by other scholars. As previously identified by Mori, if blockchain is used in securities settlement, the blockchain network should ensure close to real-time settlement, it should be cryptographically safe and accurate, as well as the transactions and securities ownership should be traceable [12]. This view was reflected in the control question answers, where the transactions should be private, there is no need for public access to the network, as well as there is no need to have voting-based consensus mechanism.

Domain 3: Security. This domain includes governance, security activities, and access control sub-domains. Answers to these control questions were based on the technical requirements originating from CSDR. CSDR is clear on the responsibilities of the CSDs and what are the necessary security measures that the CSDs and their SSSs must ensure. Should a blockchain solution either partially or fully replace the CSDs and their SSSs, it would still be required to be compliant with the applicable regulations, including the ones regarding security and proper governance of the securities settlement. It

means that the CSD participants would need to be vetted, counterparties should be able to access only the data that is relevant to them, and the integrity of securities issuances, transactions and balances would need to be compliant with the applicable standards and regulatory requirements.

Domain 4: Trust parameters. This domain includes visibility, integrity, and validation sub-domains. The answers to these control questions were based on both CSDR requirements and Mayer's view on the future tasks of the CSDs. The involved parties in the securities transactions should be known, but the data scope they access should be limited to themselves. For example, a CSD participant should be aware of the transactions and balances of its own clients, and not the clients of another CSD participant. There should be a party that governs the access rights and defines the rules on what information can be accessed by what party [9].

Domain 5: Performance and Efficiency. This domain includes system performance, expandability, and market design sub-domains. According to CSDR, the system that operates securities settlement should be capable to ensure the volumes of the peak amounts of securities transactions. Therefore, the answers to the control questions considered no compromises on the latency, throughput, and performance of the system. Additionally, the blockchain solution should be capable to scale up to ensure cross-border securities settlement and function as the current CSD links.

The answers were grouped according to the decision they impact, and their weights were summed up and compared per each decision. The results of the comparisons are summarized in Fig. 2.

The blockchain applicability framework indicates that blockchain is indeed suitable to be used for securities settlement (61% vs 39%). This is consistent with the previously reviewed literature that indicates blockchain's potential usage in the financial markets [13]. Identified potential to use blockchain technology allowed to proceed further to analyze the appropriate type of the technology.

By a large margin (90% vs 10%) the framework suggests that for securities settlement the most appropriate type of the technology is private permissioned blockchain. Again, this finding is consistent with the reviewed literature and can be explained by the regulatory and practical need to have a governed control over the blockchain network [14], [15]. Furthermore, it also complies with a possibility for the CSD to maintain its governance role in the financial market ecosystem and become the gatekeeper of the network [8].

Regarding the most suitable consensus mechanism, there are two distinct consensus mechanisms that are considered more suitable than two others. In particular, PoS and PoA consensus mechanisms are considered as the most suitable ones for securities settlement (36% and 35% vs 12% and 17%). Not considering PoW consensus mechanism as applicable is in line with the need to have fast and high-volume based transaction and information exchange between the blockchain participants. PoW consensus mechanism is computationally expensive and can result in limed performance capabilities of the network [15]. Also, it is understandable why PoB consensus mechanism was not indicated as suitable one since CSDR and the business logic suggests that the investor holdings should not be affected by non-relevant activities, and therefore, they should not be decreased to ensure the operations of the underlying blockchain. Additionally,

PoB consensus mechanism is more suitable to cryptocurrencies, not for cases where the underlying asset is a security [10]. Regarding the suitable consensus mechanisms, there is no distinct indication from the framework which would be more suitable for securities settlement. However, considering the assessment of Meijer on the potential role of the CSD as the governing party, the PoA consensus mechanism could be more suitable consensus mechanism [9]. If PoS consensus mechanism is chosen, then it becomes unclear which entity would fulfill the governing responsibilities of the network [15].

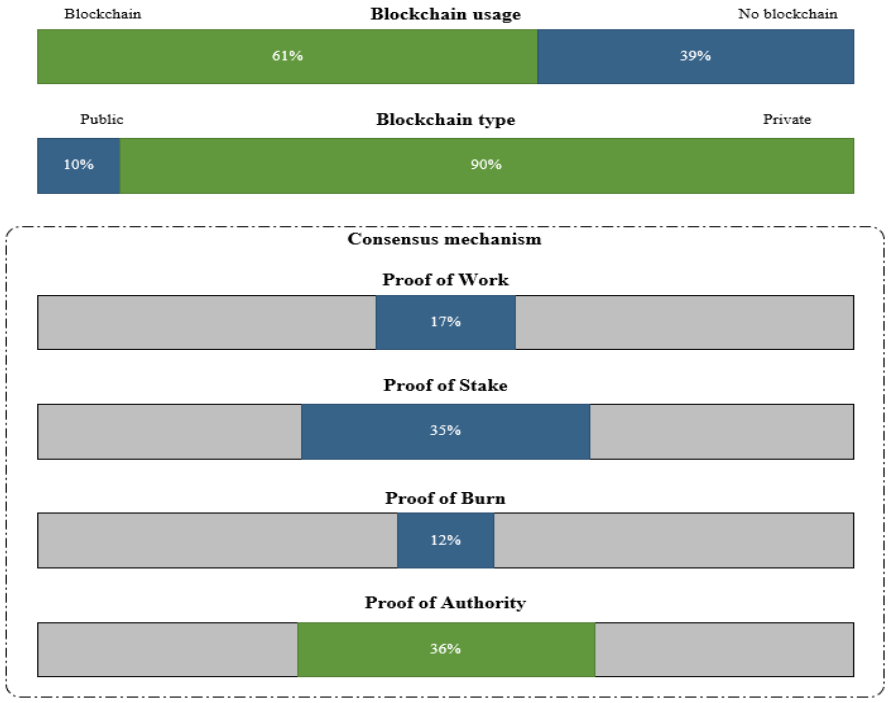

Fig. 2. Results of blockchain applicability analysis.

This section analyzed the results originating from the blockchain applicability framework. The results show that it is worth to further develop the model of the blockchain architecture and the model for node structure for securities settlement.

5 Blockchain Architecture Model

To define and represent the overlay of the blockchain architecture, a modeling approach used by Zhuang, Chen, Shae and Shyu [16] is adapted for securities settlement on blockchain. These scholars have defined a generalized blockchain architecture for healthcare applications [16]. This architecture was chosen among others because the developed model represents the main components of a blockchain architecture, as well

as indicates the information exchange principles, which are consistent with the goals of defining the blockchain architecture in this paper. Additionally, the model is using a private blockchain environment, which is suitable for securities settlement as outlined in the results of the blockchain applicability framework. Lastly, the model is agnostic of the underlying blockchain solution and consensus mechanism, as it uses blockchain as one of the layers of the architecture. The described current environment of healthcare system is also relatable to financial market ecosystem. In healthcare, similarly to securities holding information, the personal client information, health records and other information is highly sensitive, and are stored in encrypted form in the local healthcare facilities in protected IT networks [16].

The blockchain architecture model proposed by Zhuang, Chen, Shae and Shyu [16] assumes three layers – application layer, interfacing layer, and transaction layer. Each of the layers allows different functions to be performed. For modeling the blockchain architecture, in this paper, each layer is examined and adapted for applicability for securities settlement. Fig. 3 displays proposed layered blockchain architecture for securities settlement.

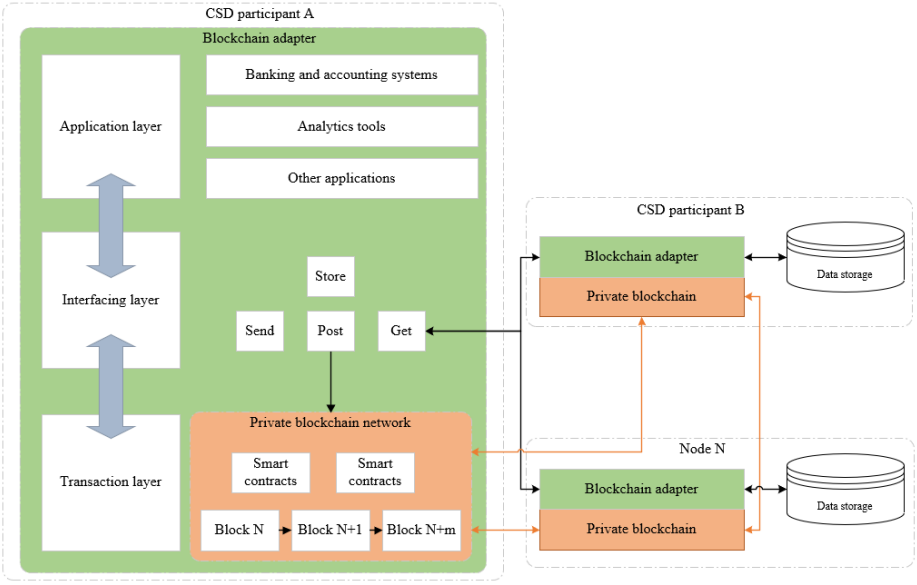

Fig. 3. Proposed layered blockchain architecture model for securities settlement.

Transaction layer. At the core of the transaction layer is the blockchain network itself and the used smart contracts for automated processes. At this layer, the nodes would maintain the distributed databases at their premises and ensure operation of the underlying blockchain solution. Transaction layer also ensures data encryption and safe transfer between the blockchain network's participants. In the context of securities settlement, the information being transmitted on the transaction layer would be close to

the currently exchanged information between the CSD and CSD participants in ISO 20022 messaging standards. The data scope would be close to the ISO 20022 messaging standard because it contains the mandatory information fields required by CSDR. In their model Zhuang, Chen, Shae and Shyu [16] use defined smart contracts in the transaction layer to exchange information between the blockchain network members and manage the information access. However, when securities settlement is considered, the intended functions of the smart contracts can be different from the ones defined in [16] because the processes that a blockchain would perform for securities settlement are different from the ones ensuring healthcare information exchange. Additionally, usage, scope definition, and functions of smart contracts are dependent on the specific underlying blockchain solution that is used for building the network [15]. Therefore, in the developed model for securities settlement, the specific smart contracts are not listed so the model would be agnostic to any specific blockchain solution.

Interfacing layer. This layer allows any blockchain adapters and graphical user interfaces to interact with the blockchain network. The proposed model by Zhuang, Chen, Shae and Shyu [16] includes 4 methods for interacting with the blockchain network:

- Get: to receive a certain data from the network participants,
- Store: to save certain data in the network,
- Post: to enter metadata or requests in the blockchain,
- Send: to deliver data to an authorized recipient.

For securities settlement process defined by CSDR, settlement should be initiated by submitting settlement instructions – a set of mandatory information of the transaction. This requirement can be fulfilled by Post method. The CSD participants or other entities, such as supervisory authorities, may need to reconcile their systems with the blockchain network. Therefore, Get method could be used for such purpose. The same method can be used by the CSD participants to receive updated on the settlement instructions they have submitted, as well as perform internal data reconciliation. When securities are registered and issued, their information must be stored and shared on the blockchain network. For this purpose, Store method could be used. The CSD can use Send method to deliver settlement related information to the network participants, such as information about securities issuance, corporate actions, and other. Therefore, all four methods – Send, Get, Store, Post, can potentially fulfill all the necessary actions for the securities settlement on blockchain.

Application layer. The application layer allows for blockchain participants to build and integrate applications with the blockchain network, such as ERP systems, business-specific systems, analytics tools, and others. It uses interface layer to collect the data or instruct data to be transmitted to the blockchain. The applications themselves do not have direct interaction with the blockchain network, and they cannot change or impact the settings of the network [16]. In context of securities settlement, the main applications in this layer would be the relevant banking systems or other systems used by the CSD participants for recordkeeping the CSD participants' client information. Most blockchain solutions are not suitable to keep large sets of information on the blockchain and require such information to be stored off-blockchain [16]. Therefore, the CSD participants should not keep all the information about their clients on blockchain. The blockchain network should ensure information exchange related primarily with

securities settlement. The CSD participants would need to integrate their own internal banking or other systems where the client information is kept in the application layer of the blockchain architecture. At the same time, other relevant applications, such as analytical tools, reporting applications, reconciliation applications also would be able to process data gathered on blockchain in application layer.

The proposed layered blockchain architecture model would allow securities settlement to occur as follow (see Fig. 3):

1. CSD participant A initiates securities transfer in its banking or accounting system,
2. The securities transfer is communicated to the blockchain network using Post method (equivalent to settlement instruction),
3. The counterparty CSD participant receives the relevant information about the initiated securities transfer using Get method,
4. Depending on the underlying blockchain solution, the counterparty CSD participant either approves (signs) the proposed transaction, or also communicates transfer information to the blockchain network (equivalent to settlement instruction),
5. Depending on the underlying blockchain solution, the securities are settled either by the smart contract configuration or other pre-defined process,
6. The CSD validates the securities settlement and the state of the network,
7. The CSD participants update their banking or accounting systems according to the information received from the blockchain network using Get method.

6 Node Structure

When the blockchain architecture is defined at each node's level, it is important to also define the node structure itself to describe the financial market infrastructure if blockchain is used for securities settlement. According to the proposed blockchain architecture model, each of the network participants that hold and exchange information on blockchain should be a node – holder of the copy or part of the copy of the shared database. This approach is also consistent with the literature on blockchain fundamentals where nodes are the individual parties that interact with the distributed system, can send and receive information to the network, and work in an organized manner according to the network's rules [15]. In context of the current securities settlement process, all parties that are directly involved in sending securities settlement instructions to the CSD should become nodes of the blockchain network. Therefore, for securities settlement on blockchain, the nodes should be banks and brokerage companies that are currently being CSD participants.

Currently, to ensure cross-border securities settlement, the CSDs have to establish technical and legal links with each other to allow securities issued in one CSD to be settled in another CSD. It is being done either in T2S (if both CSDs are members in T2S) or outside T2S (if at least 1 CSD is not a member in T2S). If a blockchain solution is used for securities settlement, the usage of CSD links is dependent on the geographical and legal participation of the linked CSD's participants in the blockchain network.

If they are capable technically and legally to be a part of the blockchain network, then there is no need for having links between the CSDs, and the linked CSD's participants can become nodes or participants of the blockchain network themselves. However, if they are not capable or willing to become members of the blockchain network, only the linked CSD can become a node of the network and ensure cross-border interoperability between the CSD participants on the blockchain network and off the blockchain network. Taking into account that there can be multiple scenarios with various kinds of combinations of how links between blockchain network and off-blockchain CSDs are created, controlled, and practically operated, this paper does not consider all the possibilities and details of such relationships as they are not in the main focus of this research. Only generalized possibility of a potential links with an off-blockchain CSD, and consequently with its participants, is recognized. Similarly, T2S as the central hub between the CSDs within the EU is considered as a potential, but not necessary part of the blockchain network.

Central banks are also components that are part of the securities settlement process. They can have a dual role – the central banks are involved in cash transfer part of securities settlement, and they can be CSD participants themselves. Since they must directly interact with the network (settle cash leg of the securities transfers), they should be part of the blockchain network as nodes as well.

According to other scholars, CSDs can be part of the blockchain network and provide supervisory, validator, or gate-keeper functions of the network [9]. Therefore, in the blockchain architecture the CSDs are considered as nodes of the blockchain network.

Additionally, there can be other interested parties that could become members of the blockchain network. For example, supervisory authorities or regulators could access the network to directly receive information that is traditionally delivered to them by the CSDs.

Fig. 4 summarizes the components of the current financial market ecosystem members that would become nodes of the blockchain network for the securities settlement.

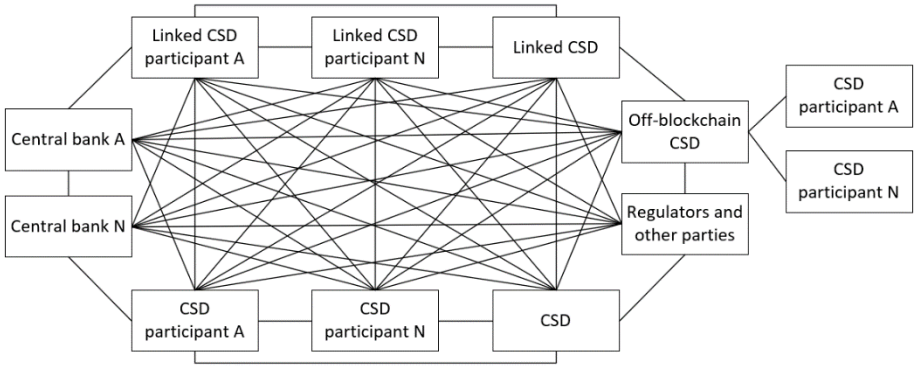

Fig. 4. Proposed node structure for securities settlement on blockchain.

7 Evaluation of Securities Settlement on Blockchain

The proposed blockchain architecture model and node structure for securities settlement on blockchain was evaluated against the potential benefits and drawbacks identified by Benos, Garratt and Gurrola-Perez [8]. The evaluation details are available in [11]. The analysis outlines that the proposed blockchain architecture model and node structure for securities settlement on blockchain would provide most of the benefits listed by the authors, for example, reduce the reconciliation costs and improve the transparency. At the same time, it would mostly not raise the identified potential issues, such as legal ownership issues and inability to handle errors.

The proposed blockchain architecture model and node structure was also evaluated in context of cross-border settlement efficiencies. The blockchain architecture model and node structure was assessed against the criteria defined by Schaper [17] and compared with other securities settlement models. The details of this evaluation are available in [11]. The assessment highlights that the proposed model would be efficient for the cross-border securities settlement by reducing settlement risk and ensuring cross-border settlement integration. The analysis also indicates that implementation of such a solution would require market-wide commitment and long implementation time.

The performed evaluation of the proposed blockchain architecture model and node structure indicated the model's and node structure's usefulness for the application. It also highlighted the benefits and drawbacks that the proposed blockchain architecture model and node structure would have in comparison with the traditional settlement systems.

8 Conclusion

The evaluation of blockchain technology's applicability for securities settlement was done by applying a blockchain applicability framework developed by Gourisetti, Mylrea and Patangia [10]. 92 control questions in 5 domains were answered to evaluate the blockchain's applicability for securities settlement. The results of the applied framework indicated that blockchain technology can be used for securities settlement. Additionally, it indicated that the most appropriate type of blockchain for securities settlement would be private permissioned blockchain with PoA consensus mechanism.

For further evaluation, the blockchain architecture model for securities settlement was created. To define the possible blockchain architecture a blockchain architecture modeling approach used by Zhuang, Chen, Shae and Shyu [16] was applied. The proposed blockchain architecture model consists of 3 layers – transaction layer, interfacing layer, and application layer. Further on, the potential node structure of the blockchain network for securities settlement was proposed. The proposed node structure contains the members of the financial market ecosystem if blockchain technology is used – CSDs, CSD participants, central banks, and others.

The proposed blockchain architecture model and node structure were evaluated using Benos, Garratt and Gurrola-Perez's [8] method for estimating impact of using blockchain technology for securities settlement. The analysis indicated that the

proposed blockchain architecture model and node structure could solve the existing issues in the securities settlement process. Schaper's [17] evaluation of cross-border efficiencies was also applied. It suggested that the proposed blockchain architecture model and node structure would be beneficial for cross-border settlement, but it would require long implementation time and market-wide commitment.

The findings of the paper as well as the developed artefacts can be considered as the contribution to the scientific body of knowledge and can be used by anyone who is interested in further elaboration of more specific applications of blockchain technology in securities settlement or in expanding blockchain's usage to other financial market processes than securities settlement. The results of this research also can be used by the current financial market infrastructure components to design and implement blockchain-based securities settlement systems. Additionally, the graphical representation of financial market components and relations (Fig. 1) that was produced during the current financial market infrastructure examination can be considered as an additional artefact that can be used by other scholars to navigate the financial market ecosystem and understand the relationships between the components.

Even though it has been indicated that blockchain technology can be used for securities settlement in the EU, it was also noted that a practical application of a blockchain solution for securities settlement would be a complex implementation project that would require commitment from many financial market participants [18], [19]. Additionally, it would require more thorough analysis of how a specific blockchain solution can be used to fulfill all the technical and legal requirements stipulated by CSDR. Further research in this area could review specific blockchain solutions that could be used in the proposed blockchain architecture model (transaction layer). Additionally, analysis of blockchain's applicability in other settlement related services could be explored further, for example, voting services for elective corporate actions or securities collateralization services. Moreover, evaluation of applicability of blockchain technology for securities settlement outside the EU regulatory framework could be considered.

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