Application Models for a Fiscal Blockchain: The Brazilian Tax System

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Abstract
Electronic tax documents represent an important advance in the process of digital transformation of tax administrations in Brazil. However, the current system still presents several challenges to be overcome. In the technological aspect, vulnerabilities and inconsistencies typical of a centralized model can be mentioned. In addition, from a functional perspective, the lack of control over taxes payments is a major concern. In this context, Blockchain technology emerges as a possibility to complement the current model, thanks to its characteristics, such as traceability, immutability, security and transparency, which are essential in the tax environment. This work proposes four application models based on Blockchain aimed at monitoring the payment of taxes, using different types of integration with existing systems. After the presentation and description of the models, they are discussed and compared, in order to reinforce their main characteristics, facilitating decision making in possible future applications.

Keywords: Blockchain; Fiscal Blockchain; Fiscal Blockchain for Brazilian Tax System; Taxation Brazilian; Smart Contracts for Fiscal Blockchain; CBDC

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1. Introduction

The issuance of *electronic tax documents* represented a major advance in the process of digital transformation of tax administrations in Brazil. Among some advantages, one can mention, for taxpayers, the reduction of printing and storage costs, since the document is issued electronically; for the government, the improvement in the fiscal control process, the increase in the reliability of the documents and the reduction of tax evasion stand out (Dias da Silva and Monteiro Carvalho, 2016).

However, the current system also presents several opportunities for improvement. The first one refers to the fact that the structure is predominantly centralized, always passing through the tax administration relative to the issuer of the document and, in the case of the Electronic Invoice (I-e), through the Federal Revenue Service, which is the national repository of this document. This aspect impairs real-time access to information, notably for the recipient of the transaction and the respective tax authorities, in addition to implying high development and maintenance costs (Viriyasitavat *et al.*, 2020).

The large amount of administrative burden imposed on companies to ensure compliance with legislation, in the form of ancillary obligations, is another aspect to be considered. Although the issuance of documents in electronic form may have facilitated the declaration process, considerable efforts are still being made to consolidate and record tax information, especially for medium and small companies (Søgaard, 2021).

Finally, there is also the difficulty of the current system in dealing with the payment of taxes, which occurs through an affiliated banking network. This configuration hinders the revenue stream for governments, as it adds a delay between the payment made by the taxpayer and the availability of the amounts in the public coffers (Saripalli, 2021). In addition, it results in high transaction and reconciliation operating costs.

Recent studies have focused on the use of Blockchain technology to solve the problems in the tax area listed above, notably in the scope of management and collection of the *Value Added Tax* (VAT) (Nguyen et al., 2019; Wijaya et al., 2017; Søgaard, 2021; Ainsworth and Shact, 2016; Ainsworth, Alwohaibi and Cheetham, 2016). Blockchain technology gained notoriety after the publication of the article that introduced Bitcoin in 2008 (Nakamoto, 2008). Therefore, the main use of this technology is the generation of cryptocurrencies. However, with the advent of *smart contracts*[1], other areas began to use Blockchain networks, such as health, education and supply chain.

In the tax area, the attributes of this technology, such as the ability to provide traceability, immutability, security and transparency to transactions, correspond to the priorities of a modern tax system (Marr, 2016; Nascimento et al., 2022). Blockchain technology also allows all network participants to have access to the same information in real time and to verify the authenticity of the data (Wang, 2020), in contrast to current systems, where there is a need for database synchronization, that do not always occur in a timely manner and satisfactorily.

In (Owens and de Jong, 2017), the authors point out that the transition to a new and potentially disruptive technology implies a large investment in terms of time and resources, which can be a factor of resistance to the adoption of Blockchain by governments. Therefore, it is important to identify whether it is in fact necessary to replace or complement what already exists with a solution based on Blockchain technology.

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[1]*Smart Contracts* are computer programs replicated and executed by all network nodes or by a predetermined set of nodes called *validators* (FORMIGONI FILHO, J. R.; BRAGA, A. M.; LEAL, 2017). Smart contract clauses are expressed in business logic, directly related to the application domain used, which can then be encoded in computer programs and automatically executed through computer systems.

As an intermediate solution, we propose the adoption of Blockchain technology in conjunction with existing systems. This is possible because, in addition to the aforementioned attributes, Blockchain can also work as a software layer that enables interaction between its users in a flexible, standardized and ready-to-use way (Grabatin, Hommel and Steinke, 2019). To this end, most applications that use Blockchain allow their integration with client modules to which the business logic is already integrated. In this way, it is not necessary to give up current systems, especially if they adequately meet the specific needs for which they were developed. Thus, Blockchain can be added to the existing environment without deconstructing it, reducing the degree of disruption of its adoption.

Thus, this work aims to develop an application of Blockchain technology for the tax area, focusing on improving the control of taxable transactions, by monitoring and recording the payment of amounts due to the tax authorities. In this context, Blockchain technology ensures the transparency and security of shared information, in addition to allowing the proposed functionalities to be developed, implemented and maintained at a potentially lower cost compared to conventional solutions.

According to (Nunamaker, Chen and Purdin, 1990), the first stage of a system development research process consists of defining a conceptual framework, which includes the investigation of the functionalities and requirements of the system, as well as the contextualization of the problem. In this sense, this work presents four conceptual models that describe how the current system of electronic tax documents could be extended to encompass the control of tax payments, using Blockchain technology.

In this work the problem to be addressed refers to the problems existing in the current Brazilian tax system, which in technological matters concern the vulnerabilities and inconsistencies typical of the centralized tax collection model, from a functional perspective, there is concern with control over the tax payment. Therefore, the novelty provided in this study is the application of Blockchain technology in the fiscal context, particularly in the Brazilian fiscal environment, which together with a CBDC (Central Bank Digital Currency) or through tokens allows the collection of taxes in a decentralized environment in that there is interaction between the various actors, i.e. government, tax administrations, social organizations, and the Central Bank, if CBDC is used as a means of payment. As a result, four possible Blockchain models are presented aimed at monitoring tax payments, using different types of integration with existing systems. Their main characteristics are discussed and compared, facilitating decision-making on possible applications.

The rest of this work is organized as follows: Section 2 presents a summary of related work. Section 3 discusses current fiscal management in Brazil. Section 4 presents the conceptual models proposed in this article. Section 5 discusses the presented models. Finally, Section 6 presents the conclusions and proposes future work.

2. Methodology

The inductive approach and structuralist procedure methods were adopted in this work following the classification of (Marconi & Lakatos, 2003). The inductive method starts from particular data, sufficiently verified, and infers a general or universal truth, not contained in the parts examined (Marconi & Lakatos, 2003). In this process, from the observation of facts, the relationship between them is discovered to, finally, generalize the relationship between similar facts and phenomena, many of which have not yet been observed. The observation of the facts was based on knowledge of the state of the art on the main topic, as well as an understanding of the current system used by tax administrations. Then, the relationship between the findings and the generalization to similar facts led to the identification of opportunities not yet explored in the literature, which led to the research's guiding hypothesis, which is:

H01: the integration between Blockchain and CBDCs allows the conception of a model capable of facing the managerial complexity inherent to the type of tax considered and, at the same time, offering a means of payment, an aspect that has not yet been explored in the literature dealing with the application of Blockchain in the tax area.

The structuralist procedure method starts from the investigation of a concrete phenomenon, reaches the abstract level, through the constitution of a model that represents the object of study, and finally returns to the concrete case (Marconi & Lakatos, 2003). In this work, five conceptual models are presented. Regarding the procedure, bibliographical research is carried out based on analyzed and published theoretical references and allows the researcher to know what has already been studied on the subject. A systematic literature review was carried out, the objectives of which were to understand the available studies related to the main theme of this work and obtain information necessary for the development of the research.

It should be added that this research used a qualitative approach, which is concerned with aspects of reality that cannot be quantified, focusing on understanding and explaining the dynamics of social relationships. Qualitative research works with a universe of meanings and reasons, which seeks to analyze and understand the complexity of relationships, processes and phenomena that cannot be reduced to the operationalization of variables.

3. Related work

There are several studies that address the use of Blockchain technology in the tax area. A literature review was carried out, the results of which can be seen in detail in (Nascimento et al., 2021) and (Nascimento et al., 2022). This article presents a summary of the literature review carried out.

The work of (Wijaya et al., 2017) proposes a protocol that reverses the process of managing tax documents in the context of VAT. In this solution, taxpayers initially need to acquire valid credits, in the form of *tokens*, so that they can create a tax document, which allows the

transfer of acquired credits to another taxpayer. The intention of the proposal was to inhibit the creation of false documents, related to fictitious transactions. However, this work recognizes that, for implementation purposes, a more flexible system and a model less dependent on the interference of the tax authority is needed. For that, it is suggested the use of *smart contracts* in future works.

In (Nguyen et al., 2019), two difficulties found in current VAT administration systems stand out: the costly and complex authentication process, and the fact that they work with centralized databases, which implies a high risk of attack by hackers. The work suggests a new model, based on Blockchain technology, associating independent nodes with a decentralized network of storage and smart contracts. Authentication of tax documents is done via a smart contract. Document information is stored encrypted on a decentralized network, through the *InterPlanetary File System* (IFPS)[2] protocol, and only the generated *hash*[3] code is inserted into the Blockchain network.

(Søgaard, 2021) presents a prototype and design principles of a platform for VAT settlement based on *Distributed Ledger Technology* (DLT). However, the authors point out that the tax payment layer was not implemented, as the purpose of the prototype was to demonstrate that administrative burdens can be reduced, eliminating the cost of compliance on commercial transactions, and not to discuss the most suitable payment channel.

In (Fatz, Hake and Fettke, 2019), a conceptual design and a prototype based on the *Ethereum* Blockchain are presented. This is the redesign of a compliance process linked to VAT, in which, in international sales within the European Union, the recipient is obliged to issue a receipt certificate for the goods, so that the seller can prove the exemption from the tax.

Finally, in an article that is also more focused on the aspect of tax compliance, (Hyvärinen, Risius and Friis, 2017) present an artifact based on Blockchain as a solution for managing dividend flows, in order to overcome the current problem of double expense of tax administrations when reimbursing illegitimate tax credits in situations of payment of multinational dividends.

It can be noted, based on the cited works, that the literature related to the use of Blockchain in the tax area primarily addresses the registration and monitoring of transactions related to VAT, notably through control of the issuance of documents. However, in the Brazilian context, the operating model for issuing and distributing electronic tax documents is already well established, which would not justify such a profound change in technological paradigm as the adoption of Blockchain technology.

Furthermore, current literature also does not propose solutions to enable the association between tax payments and Blockchain. Of the cited works, those that address the issue do so in a superficial and secondary way. Thus, the differential of this work is to present Blockchain technology as a layer that can integrate the current Brazilian VAT administration systems with payment layers, from conventional banking services to the imminent *Central Bank Digital Currencies* (CBDC)[4].

4. Current tax management in Brazil

Taxation on goods and services currently represents around 50% of the Brazilian tax matrix (*Especialistas debatem reforma tributária e recomendações da OCDE*, 2022). Among the taxes that belong to this category, there is the Tax on Circulation of Goods and Services (ICMS is the Portuguese acronym), which is the responsibility of the subnational states.

The first notable characteristic of ICMS is its non-cumulative nature, whose system, according to (Alexandre, 2017), works with a debit and credit mechanism. As a result, when acquiring a taxed good, the purchaser obtains a *credit*, the ICMS to be recovered, corresponding to the value of the tax levied on the transaction. Furthermore, for each taxable sale, the seller registers a *debit*, the ICMS payable, which constitutes an obligation of the taxpayer. This amount must be paid to the state public coffers or offset against credits related to previous operations.

This system directly interferes on how ICMS is calculated and managed. On the taxpayers' side, it is necessary to keep a record of all incoming (purchases) and outgoing (sales) operations, in order to be able to periodically determine the amount owed to the tax authorities, which consists of the difference between all debits and all credits for the period. Typically, this assessment takes place on a monthly basis. On the tax authorities' side, it is necessary to verify, among other aspects, whether all debts were considered and whether the indicated credits are valid.

The second relevant aspect of ICMS is a direct result of the first: it is the fact that this tax is charged on transactions carried out among organizations and their suppliers, as well as among organizations and their customers. This relationship implies an additional complexity, which is the large volume of operations, considering that each one of them must be formalized, to allow the subsequent calculation and collection of the tax.

At this point, it is necessary to present two essential tools in ICMS management for both sides – taxpayers and tax authorities: *tax documents* and *tax bookkeeping*. The former serves to prove the operations carried out by a taxpayer, recording, mainly, the value of the corresponding tax. Tax bookkeeping, on the other hand, is a rendering of accounts on the company's movements and revenues, as taxes to be paid and other information of interest to the tax authorities. Thus,

[2]IFPS is a protocol and network designed to create addressable associative storage for storing and sharing hypermedia content in a distributed file system. Unlike a centrally located server, IPFS is built around a decentralized system of operating users who own a piece of overall data, creating a resilient file storage and sharing system.
[3] The hash function generates a fixed-length random code from variable-length content information.
[4]Central Bank Digital Currencies refer to a digital currency issued by Central Banks denominated in the national unit of account representing a liability of the institution. They aim to be the digital equivalent of physical money and can be general purpose/retail or wholesale.

while the documents are associated with each operation, the tax bookkeeping consolidates the information and provides a view of the entire period considered.

In the Brazilian scenario, both obligations underwent a major revolution with the advent of the *Electronic Invoice* (I-e) and the *Public Digital Bookkeeping System* (SPED) (Federal, 2017). Thanks to these initiatives, the issuance of paper tax documents and tax bookkeeping in physical books were replaced by electronic versions.

In this vein, other electronic tax documents emerged later, intended to cover operations that are not part of the scope of the I-e. They all follow a very similar operating model, described in section 3.1.1.

More recently, in 2019, a *special regime*, called NFF, was instituted, with the aim of simplifying the process of issuing electronic tax documents for taxpayers (ENCAT, 2021). However, there are restrictions on the use of the NFF: its use is limited to just some of the tax documents provided for in the legislation and to a small group of operations.

4.1 The operational model of electronic tax documents

4.1.1 Standard model

According to the *Taxpayer Guidance Manual* (MOC) (Ministério da Fazenda, 2020), the I-e is an exclusively digital document, issued and stored electronically, used to document an operation that falls within the scope of ICMS. This definition can be extended to other electronic tax documents. The legal validity of such documents in electronic format is guaranteed by two conditions: the *digital signature* of the issuer and the *authorization for use* provided by the tax administration of the taxpayer's domicile.

Also according to the MOC, the process for authorizing the use of the I-e works as follows:

1)The company issuing the I-e generates an electronic file, prepared in the XML standard, containing the commercial operation information, which must be digitally signed;

2)The electronic file is transmitted via Internet to the tax administration of the jurisdiction of the issuing taxpayer;

3)The tax administration verifies the integrity of the document and, if the document is in fact valid, returns to the applicant a protocol called *authorization for use*;

4)After *authorization for use*, the tax administration must also transmit the file to the Federal Revenue of Brazil (RFB), which is the national repository of all issued I-e.

4.1.2 Special regime (NFF)

The NFF model was created with the aim of making the process of issuing electronic tax documents simpler for taxpayers. Thus, while the conventional systematic requires the acquisition or development of specialized software, or the download of a free issuer, the NFF model provides an application for generating the request for the issuance of electronic tax documents from mobile devices (App NFF)[5].

The NFF App collects all necessary and sufficient information for issuing the electronic tax document. On the other hand, the complexity brought by the tax legislation is in charge of a centralized system, the *National Portal* of the NFF, in which the tax intelligence for generating the document is embedded.

Operationally, the request for issuance made by the taxpayer from the NFF App generates a data structure in the *JavaScript Object Notation*[6] (JSON) standard. From the JSON information, coming from the fields filled in the application, the National Portal generates the XML file corresponding to the tax document in question, which is then transmitted to the states to follow the process of *authorization for use*.

5. Model proposals

In (Nascimento et al., 2022), it is highlighted that the Value Added Tax (VAT) is the most discussed tax in the literature that deals with the use of Blockchain in the tax area. In the current Brazilian tax matrix, one of the taxes that has characteristics closest to VAT is the *Tax on Circulation of Goods and Services* (ICMS), described in section 2.

The models described in this work aim to improve the control of tax payments. As described in the previous section, the model of electronic tax documents allows the tax authorities to monitor the commercial movement of companies in almost real time. However, the association between this information and the resulting revenue collection still needs to be improved, in view of two main factors. First, the time lag between the occurrence of the taxable event and its payment favors the existence of fraud, such as the issuance of false documents for the generation of credit by dishonest companies. Another relevant aspect is that the lack of integration between the *management* systems of both, companies and tax authorities, and the *payment* system prevents the automatic payment of taxes and demands the existence of a specific process to make the conciliation between what was declared and what was actually paid.

5.1 Coexistence with the current model

The commercial transactions that make up the ecosystem of electronic tax documents are predominantly characterized as interorganizational, in which the main organizations involved are *companies*, *tax authorities* and *payment service* providers. These entities do not

[5] https://dfe-portal.svrs.rs.gov.br/Nff/Sobre.

[6] JSON is a data representation format based on the Javascript programming language, hence the name JavaScript Object Notation. It is used to structure data in text format and allow the exchange of data between applications.

necessarily trust each other and information relating to operations is sensitive, protected by tax secrecy, and therefore cannot be freely shared. In this context, Blockchain technology is proposed to ensure that the recording of transactions is carried out in a secure, immutable and transparent way.

However, one cannot overlook the fact that current systems are quite robust in terms of operationalizing business rules related to the tax area. Thus, it is plausible to question whether it would be efficient or even feasible, to migrate this entire structure to a Blockchain. Alternatively, it would be prudent to use Blockchain technology with a specific goal, taking advantage of its resources to improve one or more specific requirements that are still not adequately met by existing systems, such as providing the same level of information to all interested parties, redundancy records in the decentralized network and the security and invulnerability of the network.

Indeed, in (Adams et al., 2020), the pertinence of using Blockchain technology in the context of Business Process Management (BPM) is discussed. According to this article, most of the proposed architectures turn business processes into smart contracts, which are then fully executed on a Blockchain platform. This approach, called *heavyweight*, or *heavy architecture*, overloads the Blockchain and requires a duplication of capabilities that already exist in current Business Process Management Systems (BPMSs).

Thus, the authors propose the so-called *federated architecture*, in which other components coexist in the system to perform the specific tasks or steps for which they are intended, instead of overloading the Blockchain with functionalities that would be better served by these other modules.

The proposals presented below have in common the fact that they follow the idea of *federated architecture*. As will be described, all of them keep current systems related to the process of *authorization for use* of electronic tax documents. Blockchain will then be an additional component in the already existing ecosystem.

5.2 Fiscal Blockchain

In the description of the models, the Blockchain added to the operational environment of electronic tax documents will be called *Fiscal Blockchain* (Fiscal BC), which, depending on the case, will be integrated into one or more of the following systems:

1. Authorizing systems: refer to the systems that receive authorization requests sent by taxpayers, process the document based on validation rules and return an *authorization for use* or rejection of the request.

2. NFF National Portal: receives the issuance requests made from the NFF App, generates the corresponding XML file and sends it to the authorizing system of the taxpayer's state.

3. Payment services: correspond to traditional means of payment, which include banking services and credit card, digital wallets and, more generally, payment service providers.

CBDC system: refers to the integration with the system that will manage the CBDCs. According to (Bech et al., 2020), CBDC projects can opt for a centrally controlled, conventional database infrastructure, or for a Distributed Ledger Technology (DLT), such as Blockchain. In any case, it is considered that the CBDC issuing system will provide integrations for users and external systems (Pandey & Katsikas, 2021), such as the Fiscal BC.

5.2.1 Configuration 1 - Prepaid system

This configuration proposes a prepaid system, in which the acquisition of Fiscal BC *tokens* is necessary prior to the request for authorization of an electronic fiscal document. To acquire tokens, it is possible to use both conventional means of payment and CBDCs. This proposal assumes that there will be integration between Fiscal BC, banking systems, systems of means of payment providers and the CBDC system.

The steps of this integrated process of authorizing the electronic tax document and paying the tax are described below and illustrated in Figure 1.

Token acquisition

1. The taxpayer accesses the NFF App and pays using a traditional payment methods or CBDCs. As a result, the Fiscal BC creates tokens, here called ICMS COIN, in the taxpayer's digital wallet.

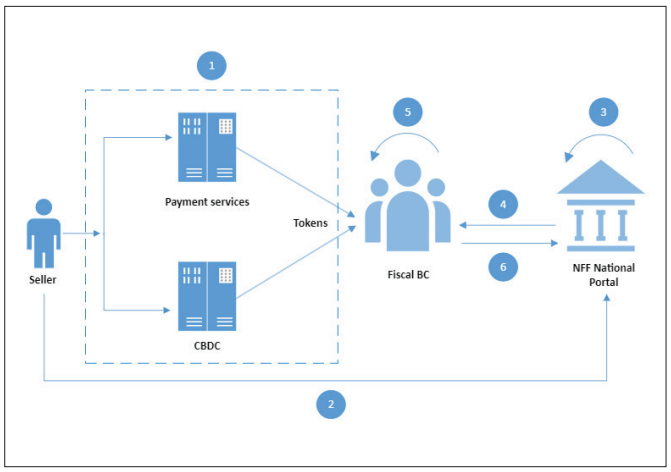
Document Authorization

2. The taxpayer requests NFF authorization, through the App, and chooses to make the payment with the ICMS COIN balance available at: his/her wallet.
3. The NFF National Portal executes the steps of the authorization process that currently exists.
4. If the document is validated, the NFF National Portal communicates it to Fiscal BC.
5. A Fiscal BC smart contract checks the taxpayer's wallet; if there is enough balance, the smart contract subtracts the tax amount from the taxpayer's portfolio balance and transfers it to the wallet of the State to which the tax is due.
6. The Fiscal BC communicates the completion of the transfer, and the National Portal finalizes the authorization of the NFF.

It is noteworthy that the money collected from the sale of ICMC COINs is centralized in a single account, belonging to all states; then, taxpayers can use the acquired tokens to pay taxes to any State. Therefore, periodically, the states need to reconcile the received ICMS COINs, in order to withdraw the corresponding amount in official currency from the single account.

Finally, it is important to clarify that the ICMS COIN is an internal currency of the Fiscal Blockchain, created by tax authorities, while CBDC is a digital currency managed by the Central Bank. In this configuration, taxpayers can use CBDCs to acquire Fiscal BC coins, which in turn are used for internal transfers between taxpayers and tax authorities.

Figure 1. Configuration 1 - Prepaid system



5.2.2 Configuration 2 - Tax payment with CBDC

In this configuration, the payment of the tax occurs directly in CBDCs, which requires an integration between the Fiscal BC and the CBDC system, different from the previous one. In Configuration 1, the result of the integration was the purchase of tokens, that were transferred, within the Fiscal BC, between tax authorities and taxpayers. This system requires a later stage of reconciliation between the ICMS COINs received in the accounts of the states and the common account to which the amounts paid by taxpayers when acquiring the tokens are destined.

In Configuration 2, CBDCs are transferred directly between the digital wallets of taxpayers and tax authorities. The operation of this model is described below and illustrated in Figure 2.

1. The taxpayer requests NFF authorization, through the App, and chooses to make the payment with the balance available in their CBDC wallet.

2. The NFF National Portal executes the steps of the authorization process that currently exists.

3. If the document is validated, the NFF National Portal communicates it to Fiscal BC.

4. A Fiscal BC smart contract communicates with the CBDC system, passing the following information: taxpayer responsible for payment, state to which the tax is due and tax amount.

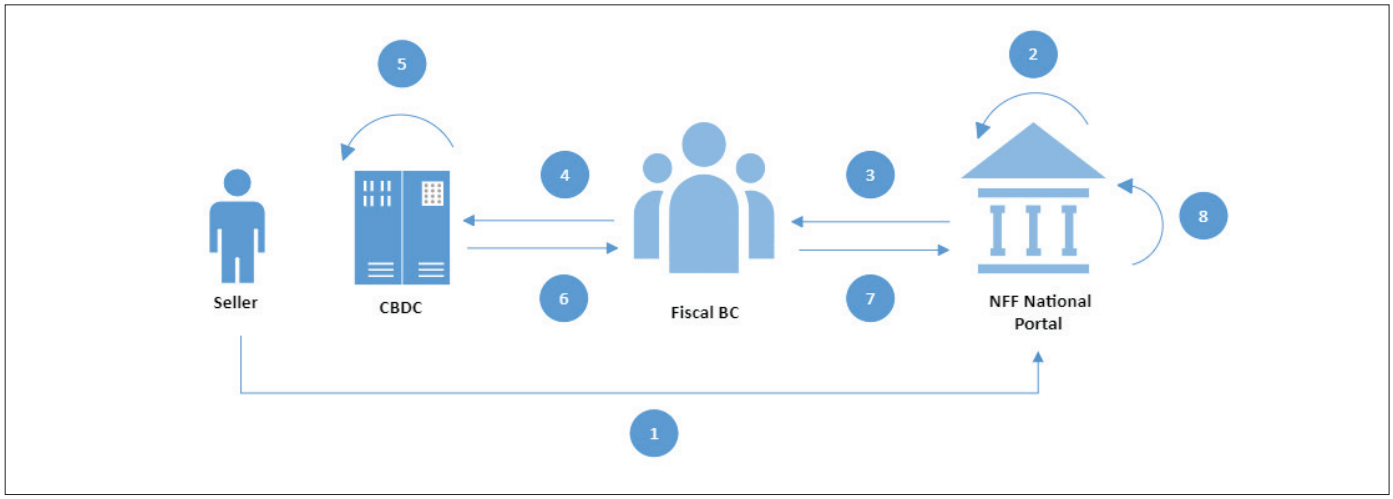
5. The CBDC system makes the payment, transferring the tax amount from the taxpayer's account to the account of the state to which the tax is due.

6.The CBDC system informs the Fiscal BC that the payment was successful.

7.The Fiscal BC communicates the completion of the transfer to the National Portal of the NFF.

8.The NFF National Portal finalizes the authorization of the NFF.

Figure 2. Configuration 2 - Tax payment with CBDC



It is possible to simplify this model by allocating the responsibility for paying the tax to the taxpayer himself, who, in this case, would transfer the amount due in CBDCs from his account to the account of the tax creditor. In this scenario, the taxpayer must send the payment receipt to the Fiscal Blockchain. This eliminates the need to develop a specific smart contract for the CBDC Blockchain and, consequently, its communication with the Fiscal BC smart contract.

5.2.3 Configuration 3 - Payment of tax with payment of the transaction

In the first two presented Configurations, the payment of the tax occurs at a different time from the payment of the operation, which is the situation we are used to. In a transport service operation, for example, the company providing the service makes the payment of the tax, and the customer who hired it makes the payment of the service itself.

In contrast, in Configuration 3, the payment of the tax occurs when the transaction is paid, as described below and illustrated in Figure 3.

1.The service provider/seller requests the issuance of a preview of the NFF, through the NFF App, and chooses to make the payment when the operation is settled.

2. A Fiscal BC smart contract defines the value of the payment portion that must be attributed to the tax authorities and that of the payment portion that is up to the service provider/seller.

3. The same smart contract sends to the recipient of the service/product a link to pay the operation, which contains: the identification number of the NFF preview, the total value of the operation and the amounts calculated for each of the creditor parties - tax authorities and service provider/vendor.

4. The recipient of the service/product receives a notification with the identification number of the NFF preview and the link to pay for the transaction in CBDCs. If the recipient agrees with all the information, he/she pays for the transaction under the terms indicated.

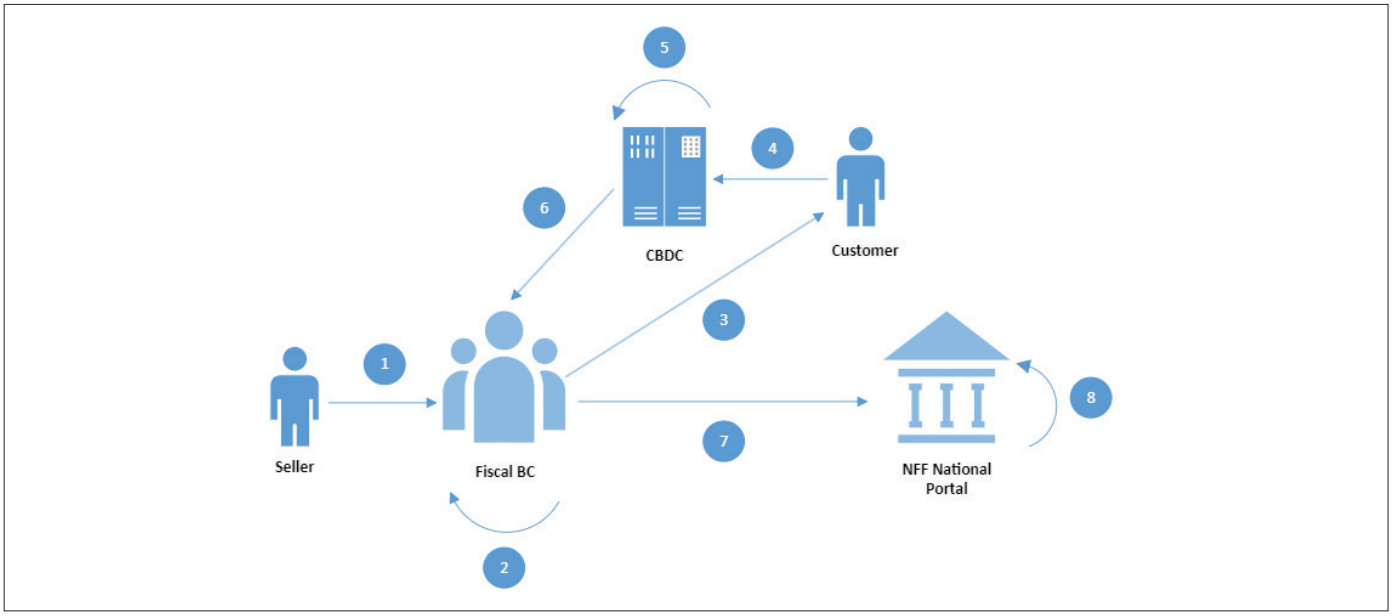
5. The CBDC system makes the payment, so that the tax part is transferred to the wallet of the state to which the tax is due, and the service provider/seller's portion is transferred to their respective wallet.

6. After finalizing, the CBDC system informs Fiscal BC that the payment was successful.

7. The Fiscal BC communicates the payment.

8. The National Portal finalizes the authorization of the NFF.

Figure 3. Configuration 3 - Payment of tax with payment of the transaction



It is important to highlight that, in this Configuration, the use of ICMS COIN is not applicable, since this currency will only exist internally, in the Fiscal Blockchain, and, therefore, will not be available for the payment of commercial transactions between taxpayers or final consumers.

5.2.4 Configuration 4 - Periodic tax payment with CBDC

In this configuration, the tax payment occurs periodically. However, in each transaction, the Fiscal BC calculates the due tax, consolidating all transactions of the period. At the time of payment, the Fiscal BC communicates with the CBDC system to inform the amount owed by each taxpayer.

The steps of the integrated process for authorizing the electronic tax document and paying the tax are described below and illustrated in Figure 4.

Synchronization between the authorization system and the Fiscal BC

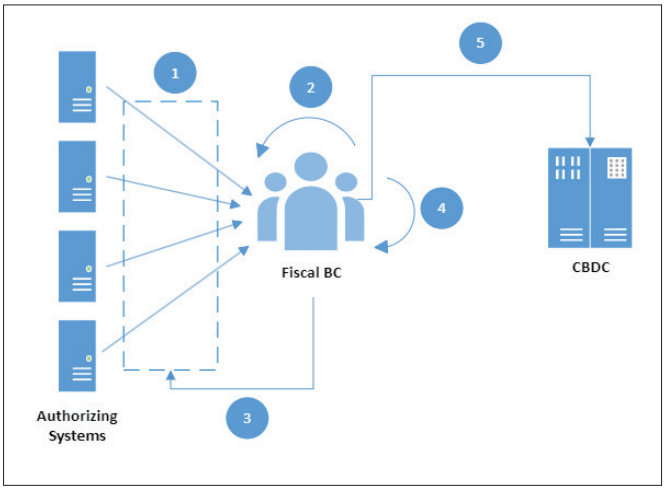
1.The authorization system of each state shares each authorized document with the Fiscal BC.
2.A Fiscal BC smart contract calculates the due tax, defining the corresponding debits and credits for the two parties of the operation (issuer and recipient).
3.After each new authorization, a smart contract verifies whether the recipient party is located in the state. If the operation is interstate, the Fiscal BC communicates with the other state to inform the operation, so that it considers the corresponding credits.

Payment

1.Periodically, a smart contract consolidates the information to calculate the tax owed by each taxpayer.

2.The same smart contract communicates with the CBDC system to pay the tax owed by taxpayers who authorized this type of collection.

Figure 4. Configuration 4 - Periodic tax payment with CBDC



6. Discussion on the proposed solutions

This section discusses and compares the proposed models, in order to highlight the situations to which each one is best suited.

Regarding the time of payment of the tax, Configurations 1, 2 and 3 contemplate situations in which, by legal provision, the taxpayer must pay the tax before the occurrence of the taxable event. In turn, Configuration 4 is suitable for cases in which the taxpayer calculates and pays the tax after the original commercial operation.

This temporal aspect connects to another relevant factor in the analysis of the presented solutions: the tax payment periodicity considered. In the cases of Configurations 1, 2 and 3, the payment occurs at each operation, while, in Configuration 4, the tax is paid periodically. In these cases, the smart contracts involved are more complex, as they consolidate the amounts related to various operations, comparing debits and credits.

Another pertinent comparison concerns the association between the payment of the tax and the payment of the operation that originated it. In Configurations 1, 2 and 4, the payment of the tax occurs independently of the payment of the operation. Therefore, it is possible to pay the transaction without paying the tax. It is important to point out that, in Configurations 1 and 2, the payment of the tax linked to the issuance of the tax document – and not to the payment of the operation – is a functionality that the taxpayer can opt for, that is, it will not necessarily be used.

In Configuration 3, the trigger for the payment of the tax is the settlement of the commercial transaction itself, like a withholding tax, as in the case of taxes levied on income. In this case, one comes closer to reaching a situation where the payment of taxes is inevitable (Khan and Syed, 2019).

However, the facts that the smart contract makes the calculation of the due tax and that the withholding is automatic make it imperative to analyze cases in which there is an error in the payment. This can happen, for example, if the seller informs an operation value higher than the correct one, and the customer thus pays the operation and, consequently, the tax. Later, upon realizing the error, the seller must be able to reimburse his customer. However, how to operate this refund?

To solve this situation, it would be necessary to provide a functionality in which a second smart contract controls adjustment requests, which, if approved by the tax authority, would give the right to generate complementary operations, to correct underpayments, or to get discounts on future operations, in cases of overpayments.

As for integrations with current systems, in the first three Configurations, the NFF National Portal is the reference system, which will execute all the business rules associated with issuing a tax document. The Fiscal BC will complement it, integrating with payment systems – conventional means or CBDCs –, recording both the amount to be paid and the payment status.

Configuration 4 deals with the situation in which the tax is paid after its periodic calculation, considering the acquired debits and credits. Its main feature is to allow a smart contract to control operations in real time and reflect, at the end of the period, the debit (or credit) balance.

In this case, the reference systems are the use authorization systems of each state, which must provide information to the Fiscal BC all the time, for each operation. Based on this information, the Fiscal BC calculates the credit or debit involved and accumulates them to find the balance at the end of the period.

Regarding the payment system, the Configuration 1 maintains the use of conventional means, such as bank transfers, through which it is possible to acquire Fiscal BC tokens. The other Configurations consider only the integration with the CBDC system, in order to take advantage of the possibility of using smart contracts to program transfers of values, associating them with the information provided by the Fiscal BC.

Table 1 summarizes the main characteristics, discussed above, of each of the proposed Configurations.

Finally, it is also important to note the potential impact of implementing the proposed models on taxpayers, regarding administrative burdens. Configurations 1, 2 and 3, which have a more simplified scope and deal with the payment of taxes for only one operation at a time, would not require any effort on the part of taxpayers, which is in line with the design of the NFF model.

Table 1. Comparative Summary of Proposed Configurations

Configuration	Time of tax payment in relation to the taxable event	Tax payment frequency	Is the tax deducted from the operation payment?	Current tax system to which BC will be integrated	Payment System
1	**Before**	**Each operation**	**No**	**App NFF**	**Conventional or CBDC[7]**
2	**Before**	**Each operation**	**No**	**App NFF**	**CBDC**
3	**Before**	**Each operation**	**Yes**	**App NFF**	**CBDC**
4	**After**	**Monthly**	**No**	**Authorizing System**	**CBDC**

Configuration 4 would require taxpayers to adjust their systems, to be able to interact with the Fiscal BC, either to obtain information, or to authorize and schedule the payment of taxes. However, this initial effort may reduce errors and improve efficiency, since the terms of smart contracts will be established in such a way as to automatically execute exactly what law recommends. In addition, the Blockchain-based solution ensures transparency, which enables a real-time audit by both the tax authorities and companies. This tends to reduce the demand for additional information and requests for additional clarification from both sides.

6. Conclusion and future work

The proposed solutions, using Blockchain technology, allow all participants to have access to the same information in real time. This avoids the asymmetry of information that exists in the current format, due to the need for synchronization between different centralized bases. Additionally, the automation of the tax payment stage increases operational efficiency, compared to current processes, which require a separate and often manual flow both to process payments, on the companies' side, and to reconcile them with the declarations, on the tax authority side.

It should also be noted that the current ICMS legislation is quite complex, so that it is very difficult to design a system capable of dealing with the full range of situations and possible variations. Therefore, the implementation of the proposed models in this work would require a preliminary stage of scoping, to select the most relevant operations, considering the expected volume of transactions, the required performance of the Blockchain network and the feasibility to implement the calculation of the due tax in a smart contract. Thus, to build a system based on objective rules, we understand that the abstraction of the subjectivity and complexity of the ICMS legislation is an essential requirement, although, on the other hand, it represents a limitation of this work.

From this work, it was shown the possibility of extending the current electronic tax document management system of the Brazilian tax system, covering tax calculation and payment functionalities, using Blockchain technology. The following contributions can be cited:

(i) Addressing a relevant gap in the current tax management system of state tax authorities – non-integration into the payment system – with the suggestion of using Blockchain technology for integration into the future CBDC system.

(ii) Mapping possibilities for integrating the current tax payment management system into the future CBDC system, with a description of the conceptual models.

(iii) Definition of the data structures necessary for identifying taxpayers and calculating taxes in the Fiscal Blockchain associated with one of the conceptual models.

(v) Identification of opportunities to use the future Brazilian CBDC in the scope of tax collection.

(vi) More broadly, the maturation of studies on the potential of using Blockchain technology in the public sector, to assist in the digital transformation of the Brazilian State.

Furthermore, it is expected to achieve the following benefits through the implementation of the proposed model:

(i) Facilitate the payment of taxes for taxpayers.

(ii) Increase the efficiency of the State, both directly, by increasing revenue, and indirectly, by improving its operation.

(iii) Increase transparency and expand the auditability of tax payment control.

A limitation of this study is related to the business context in which it is inserted, which is the taxation of goods and services. Particularly in Brazil, this context appears to be quite complex for several reasons. The first of them is that the competence to collect ICMS is statewide. Thus, there are 27 specific laws that deal with this tax, considering only internal operations. When operations occur between states, new rules are added and complexity increases. Another issue not considered in this work concerns tax secrecy and the general data protection law, whether at the national level (Brazil) or in relation to the laws of other countries, which should be addressed in future work.

[7] In this case, there is no interaction between Fiscal BC and the Blockchain of CBCBs, which is used only for the purchase of tokens, directly by the taxpayer.

As future work, we hope to implement a proof of concept for Configuration 4, which was chosen for two main reasons: first, because it is the only one that deals with the periodic calculation of the due tax, contemplating the debits and credits systematic. This is the applicable regime for large ICMS taxpayers and corresponds to a significant operational effort for companies. Thus, the validation of this model would consolidate its potential to cause a great impact in increasing the efficiency of the management of this tax. Second, because this model requires the most complex functions from smart contracts. Therefore, if the implementation validates this model, it is reasonable to consider that the other models would also be feasible from an implementation point of view.

It is worth mentioning that the option for Configuration 4 does not disregard the merits of the other Configurations, which also represent a great potential contribution to the Brazilian tax ecosystem, since they complement the NFF project, adding payment functionality. As already explained, the NFF was conceived with the laudable objective of simplifying ICMS management for small taxpayers, whose operations are generally less complex and for whom the cost of traditional bureaucracy is often prohibitive.

Thus, in our perception, the two factors explained show that Configuration 4 would result in a significant impact for a relevant portion of ICMS taxpayers. Other jobs may implement the remaining Configurations.

Other questions that need to be analyzed and addressed in future work are: how will the proposed configurations impact companies, especially small and medium-sized companies? What are the challenges and opportunities for the state to include cryptocurrencies in its monetary policies? How do global and internal crises potentially impact the tax system when assuming these configurations? What is the cost structure of each configuration in terms of technological and maintenance resources, and not just the efforts of taxpayers and the payment system? What are the risks associated with each of the proposed solutions? How would a system that incorporates multiple cryptocurrencies be set up and how could it face difficulties if one of them decreases in value or is more volatile? These issues need to be analyzed in depth before a decision to implement a Blockchain-based tax system is made.

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