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Conceptual Design e-Wallet for Rupiah Digital

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Abstract

This research study the advancement of Central Bank Digital Currencies (CBDCs) spurred by fi-nancial technology progress. It focuses on Rupiah Digital, Indonesia's CBDC initiative led by the Bank of Indonesia (BI). The study explores the technical aspects of Wholesale and Retail Digital Rupiah, proposes an e-wallet system for seamless digital transactions in related to blockchain technology, specifically Permissioned Distributed Ledger Technology (DLT). The objective of this research to provide recommendations to BI regarding appropriate e-wallet conceptual design based on study literature review (LR) methods and qualitative research method by conducting interviews throughs forum group discussion (FGD) and e-mail with leading economic (banks), legal (BI and Government), and technical experts (banks, academic expert on this field, BI and Government) to get reviews and input regarding the e-wallet conceptual design that was proposed. As result, we recommended the architecture for Rupiah Digital using Hyperledger Fabric blockchain with two-tiered distribution and user layer backed by digital token using ID on mobile apps to enhance the security of the system. The FGD with experts and executor result in approval on those conceptual design to be part of the option on development of CBDC in Indonesia.

Keywords: *CBDC; rupiah digital; e-wallet; blockchain; private blockchain*

1. Introduction

The COVID-19 pandemic has accelerated the digitalization of the economy and finance, driving a shift towards online transactions as social distancing measures restricted physical mobility [1],[2]. To facilitate seamless, secure, and cost-effective digital transactions, a novel solution is required to ensure the efficacy of central bank mandates in the current and future digital landscape. Additionally, the pandemic has witnessed a surge in cryptocurrency adoption, including its derivatives DeFi and Metaverse, giving rise to the phenomenon of 'cryptoization'. Digital disruption has transcended the realm of shadow banking, encompassing shadow currencies and even shadow central banking.

This evolving landscape has compelled central bank communities worldwide, including Bank Indonesia, to recalibrate their policy approaches [3]. Digital transformation confined to payment system digitalization is no longer deemed adequate. As a public policy objective, the scope of digital transformation must encompass efforts to democratize access to trusted money in digital form. Beyond addressing the societal demand for fast, convenient, affordable, secure, and reliable digital transactions, a novel solution is imperative to safeguard the effectiveness of central bank mandates now and in the future. Central bank digital currencies (CBDCs) emerge as a sustainable (future-proof) solution.

CBDCs offer several advantages. They can streamline payment operations for traditional fiat currencies [4]. This reduces reliance on private payment service providers and potentially lowers regulatory burdens and pressures on central banks [4]. Additionally, CBDCs can strengthen the authority of fiat currencies [4]. They also function as an electronic form of central bank-issued money that can be used for payments [5].

The Bank for International Settlements (BIS) highlights the potential of Distributed Ledger Technology (DLT) to revolutionize banking operations [6]. DLT could fundamentally transform how assets are managed, obligations are met, contracts are enforced, and risks are mitigated [6].

The launch of the Digital Rupiah White Paper signifies Bank Indonesia's (BI) commitment to developing a digital form of the Indonesian Rupiah [3]. This digital currency will be encrypted and recorded on a platform utilizing blockchain

technology or DLT [3]. BI plans to implement the Digital Rupiah in three stages:

1. Wholesale Digital Rupiah: Initially, the digital currency will be distributed through a limited number of large financial institutions designated by BI [4]. These institutions will primarily be large traders.
2. Expansion of Wholesale Digital Rupiah: In the second stage, the use of the wholesale digital rupiah will be expanded to support monetary operations and financial market development.
3. Retail Digital Rupiah (r-Digital Rupiah): The final stage will involve enabling interaction between the wholesale digital rupiah and the r-Digital Rupiah, which will be accessible to the general public similar to banknotes and coins. Individuals will be able to obtain r-Digital Rupiah by exchanging cash, transferring funds from checking or savings accounts, or converting existing electronic money balances through intermediaries appointed by BI.

W-Rupiah Digital will use the DLT platform [7]. BI views DLT as a solution that has the potential to overcome the risk of single point of failure, improve transaction integrity and encourage efficiency. The w-Rupiah Digital DLT platform will be permission-based. This option is considered safer and is in accordance with the character of large-value-small-volume transactions as is common in financial market transactions.

Research on CBDCs in Indonesia remains scarce. While Zams et al. (2019) explored a conceptual CBDC model suitable for the Indonesian context [8], and Purnawan & Riyanti investigated the impact of CBDCs on monetary policy [5], most existing research focuses on operational and technical challenges associated with CBDCs [9]. Given the limited research base, there is a pressing need for more comprehensive studies in Indonesia, particularly regarding:

1. E-wallet Design: Exploring optimal e-wallet design principles for seamless integration with the Digital Rupiah.
2. Technology Acceptance: Investigating factors influencing the public's adoption of the Digital Rupiah.
3. Factors Influencing Adoption: Identifying key drivers and potential barriers to widespread acceptance of the Digital Rupiah.

These research efforts are crucial to accelerate the successful implementation of the Digital Rupiah in Indonesia.

Based on problem analysis, there are 4 factors which taken from Consultative Paper from BI [7] as shown in Figure 1. Our research mainly focused on Distribution and User Layer design to enhance the conceptual design e-wallet for Rupiah digital by giving specific explanation on that part. The research that was conducted in Indonesia for CBDC focused mainly on CBDC design that explained the benefit and weakness, and principal technology inside the blockchain for transaction, with no research about the design for e-wallet. Our research objective is to give recommendation for BI about the conceptual design of e-wallet, specially for digital Rupiah distribution and user layer. Based on those problem, we design a research question (RQ) namely, **"What e-wallet design could be suggested to support the progress of digital Rupiah development in part of distribution and user layer?"**.

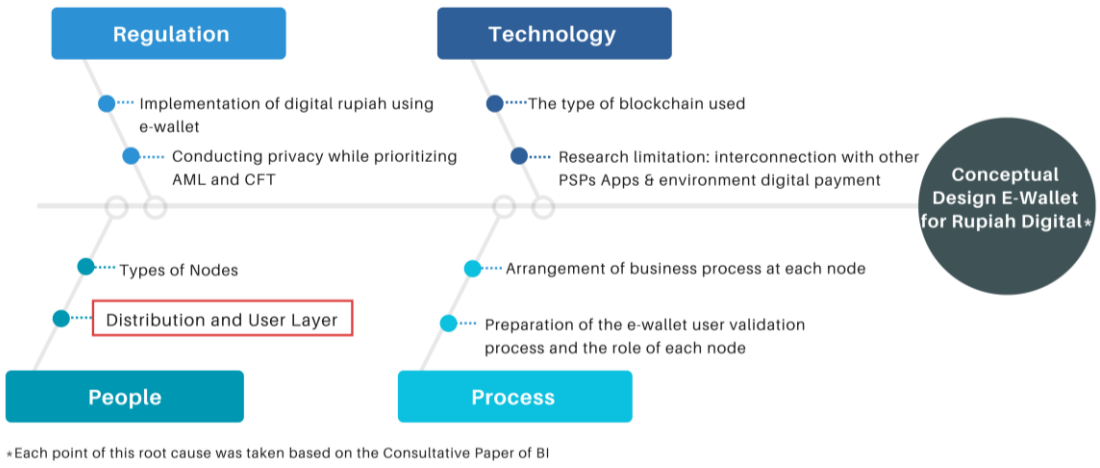

Figure 1. Ishikawa Diagram for conceptual design e-wallet for Rupiah digital

Overall, this study explores critical aspects influencing the conceptual design of the Rupiah e-wallet. The key facets encompass regulation, focusing on the rules governing digital Rupiah implementation through e-wallets [3]. Additionally, it emphasizes the importance for BI to identify stakeholders and target users. The technological dimension delves into blockchain type selection and integration challenges with legacy systems. Lastly, the study addresses process aspects, including e-wallet user validation preparation and necessary business process reengineering before fund transfers reach the beneficiary.

Designing conceptual e-wallet for digital Rupiah involving the technology inside including blockchain types and layer behind distribution for user [10]. Permissioned blockchain used must available real-time for end user with high transaction and low nominal because it will be used for every citizen in Indonesia. To create an e-wallet system that guarantees each user possesses just one account, thereby ensuring the effectiveness of turnover and balance limits, our approach hinges on having a distinct digital identity for each end-user. To achieve this, we propose the utilization of government-issued, certificate-based digital IDs or company certification with tax ID (NPWP), a concept being explored in different countries presently. Alternatively, payment service providers (PSPs) like banks could also issue these digital identities. However, this approach would necessitate coordination among these intermediaries to prevent multiple registrations.

A recipient account in the form of an e-wallet is required to receive digital money [10]. This account is not a bank account so it does not duplicate and disrupt existing accounts, users can also transfer money from a bank account to a Digital Rupiah account. In preparing this research, we limited the use of e-wallet to only available to end users (recipient accounts) so that it is not used in W-Rupah Digital.

From a user's perspective, a transfer in the system involves invalidating their existing bank account and creating a new account state [10]. In this new state, the difference between their previous account balance and the new balance equals the amount of the transfer. In this digital Rupiah system, which employs comprehensive user-side accounting, also allows for integrating rewards or remuneration into private CBDC accounts, directly impacting the balance difference between the previous and new account.

To ensure security and prevent third parties from tracing transaction histories back to specific users, as well as making transfers by the same user untraceable, certain measures are in place [2], [11]. Only the users themselves and authorities based on regulation have access to their account details, including their identification information, balance, and transaction history. Users store their CBDC in a digital wallet, typically within a dedicated mobile app. This digital wallet contains the user's digital identification, cryptographic keys, and account information for their private CBDC account, along with the necessary credentials for their transparent CBDC account. The wallet also assists the user in managing both their private and transparent accounts

The perspectives of this research is divided into three perspectives to allign with BI research paper [3] in the form of:

a. Regulator: BI as the policy maker in determining the Digital Rupiah e-wallet, manages and monitors the network, including real-time data collection and analysis. BI collaborates with the Government based on regulation in the fields of anti-money laundering (AML) and eradicating the financing of terrorism (CFT).
b. Executor: BI acts as a proxy in providing ledger access to participants who do not have their own node (no node) whie banks act an intermediary for transferring the Rupah Digital for end-user. Banks act as a node either validating node or non validating node.
c. Academics: act as an expert in the field of technology in blockchain applications. They are also tasked with reviewing e-wallet design concepts that are designed to be applicable.

The e-wallet conceptual design will not eliminate the purpose of CBDC for AML and combating the CFT regulation while allowing for fully private payments. We conducted research to provide recommendations to BI regarding appropriate e-wallet conceptual design based on study literature review (LR) methods and qualitative research method by conducting interviews throughs forum group discussion (FGD) and e-mail with leading economic (banks), legal (BI and Government), and technical experts (banks, academic expert on this field, BI and Government) to get reviews and input regarding the e-wallet conceptual design that we proposed.

2. Methods

a. Literature Reviews (LR)

The stages in writing a Literature Review [12],[13]:

1. Defining the Scope of the Topic: Clearly articulate the scope of the topic to be reviewed.

Establish specific boundaries to maintain focus and direction in the literature review.
2. Identifying Relevant Sources: Conduct a search for sources relevant to the predeter-mined topic. Utilize various sources, including articles, books, and scholarly journals.
3. Reviewing the Literature: Gather and thoroughly read the identified sources. Analyze and evaluate each source to understand key concepts, findings, and existing thoughts.
4. Writing the Review: Systematically compose the literature review by presenting findings from the reviewed literature. Discuss the relationships between sources, supporting or conflicting findings, and the conceptual framework that emerges.
5. Applying Literature to the Planned Study: Apply the knowledge gained from the liter-ature review to the upcoming study or research. Explain how the literature supports or influences the research approach and methodology.
6. Choosing the Topic for Review: Select a review topic based on the needs or focus of your research.
7. Tracking and Selecting Relevant Articles: Search for articles relevant to the topic and choose sources with high credibility and relevance.
8. Conducting Analysis and Synthesis of Literature: Critically analyze each source, identify patterns or common findings, and synthesize information to build a strong conceptual foundation.
9. Organizing the Review Writing: Structure the review logically and systematically. Arrange information according to themes or emerging concepts identified during the literature review.

By following these stages, we can produce a robust and comprehensive literature review to support this research. Research using this method aims to select a suitable blockchain platform to develop the most appropriate blockchain system for use in the Digital Rupiah e-wallet with the characteristics of high scale, low nominal rate and high number of transactions so that it becomes a blockchain that is capable of processing. required. The ideal platform must possess specific characteristics: high scalability, low transaction costs, high transaction throughput. This characteristic assumption is based on the use of digital rupiah in daily transactions by all Indonesian people.

The first step the author takes is to determine the sources used in a literature search with year limitation from 2019 with the objectives to find the insight and theory to enrch this research. There are several sources used, including:

- ScienceDirect (sciencedirect.com)
- Scopus (scopus.com)
- IEEE Xplore (ieeexplore.ieee.org)
- Emerald Insight (emerald.com)
- ACM Digital Library (dl.acm.org)
- Google Scholar (https://scholar.google.com)
- Google (official website for blockchain)

The next step is determining keywords. Use of appropriate keywords and well formulated will produce accurate findings. The author formulates search keywords to obtain research previously related to data integration. In the second part, The author takes a government perspective so he uses the keyword e-governance. Then, the final part The author uses the keyword CBDC. Therefore, the search string formulation used is:
("CBDC" OR "DIGITAL" AND "CURRENCY") OR ("PRIVATE" AND "BLOCKCHAIN" OR "DLT") OR "BLOCKCHAIN".

b. Previous Study

A CBDC is a form of digital currency issued and controlled by a central bank, serving as legal tender similar to traditional currency. CBDC functions as a digital representation of a nation's official currency and serves the fundamental purposes of money: a store of value, a medium of exchange/payment, and a unit of account [7].

Despite both CBDCs and cryptocurrencies utilizing blockchain technology, they exhibit significant distinctions. CBDC operates on a private blockchain where the user's identity is linked to their bank account. It primarily serves as a method of payment, and the central bank has authority over supply, transaction recording, ownership records, and network regulation. In contrast, cryptocurrencies operate on public blockchains, allowing users to maintain anonymous identities. Their usage for speculative purposes and as payment systems is contingent on each country's regulations, with the crypto network market being the regulating authority.

The Digital Rupiah, issued by the Bank of Indonesia (BI), is a digital currency in Indonesia that serves as an addition to the existing money supply. It represents a diversification of the base money component (M0) and is not intended to eliminate or substitute paper currency or other forms of M0 [3]. Rupiah Digital is using two-tier method of distributing money where the bank appointed by BI acts as an intermediary before the digital Rupiah is received by the end user [7].

According to the BI, distribution layer for digital Rupiah will be conducted through two-tier system where BI as creator for digital Rupiah

distributed for wholesaler through validator nodes that appointed by BI before the digital Rupiah accepted by end-user.

- **Blockchain Type**

The Digital Rupiah will leverage permissioned DLT to execute and settle peer-to-peer transactions securely. Permissioned DLT utilizes blockchain technology to establish an immutable ledger, essentially a tamper-proof record, for tracking orders, payments, accounts, and other financial activities. This system incorporates robust mechanisms that prevent unauthorized data entries and ensures consistency in the shared view of all transactions on the ledger. DLT type of blockchain is selected because it reduces the risk of single point of failure [7]. Apart from that, DLT opens up the option for users to utilize the smart contract feature, making it easier to develop transactions by interconnecting other applications. Permissioned DLT has closed access where only Bank of Indonesia and appointed parties can validate transactions between nodes to ensure a better level of security.

Financial transactions necessitate strict access controls, ensuring only authorized participants can view transaction details. This requirement has driven the adoption of permissioned DLT platforms as a robust solution. Many central banks, recognizing this advantage, choose permissioned DLT platforms for implementing their CBDCs. One prominent example of a permissioned DLT platform is Corda. This open-source platform is specifically designed to prioritize privacy during contract recording and management amongst parties with potentially conflicting interests.

Ensuring confidentiality in financial transactions is paramount. Only authorized participants should be able to access transaction details. To address this critical requirement, permissioned DLT platforms have emerged as a powerful solution. Permissioned DLT systems require explicit permission for nodes to join the network, effectively restricting access. This secure access control makes permissioned DLT a compelling choice for many central banks as they implement CBDCs [14]:

1) Corda [15] distinguishes itself by introducing a "Notary" mechanism for transaction verification and validation, preventing double-spending.
2) Another "permissioned" DLT platform is Hyperledger Fabric [16], which provides a robust foundation for application development, featuring a modular architecture.
3) Quorum [17], leverages the Ethereum blockchain as its base, incorporating enhancements tailored for enterprise needs. It bridges the gap between public and private blockchain applications.
4) Hyperledger Iroha [18] prioritizes ease of use and integration, featuring a novel consensus algorithm (YAC) for fault tolerance.
5) Hyperledger Besu [19] caters to enterprise environments, supporting both public and private permissioned networks. It offers a variety of consensus algorithms and permissioning schemes for consortium deployments.
6) Elements [20] is an open-source platform that facilitates the use of sidechains and grants access to advanced features like Confidential Transactions and Issued Assets.
7) Interledger [21] promotes interoperability between different ledger systems by enabling secure payments across them.
8) Bitt [22] offers specialized expertise in digital currency solutions, assisting central banks in developing and implementing CBDCs using blockchain or DLT technologies.

- **Digital Token**

The model employed by bitcoins, a widely-used cryptocurrency, serves as an illustration of token-based systems [23]. In token-based systems, there is no need for a third party for authentications, allowing direct transfers between parties [24]. However, account-based systems introduce an authentication layer to digital currency, requiring validation of the involved parties for any transaction [24]. Confirmation messages are exchanged between the parties, resembling an extension of the existing banking framework. In account-based systems, both the sender and receiver witness their balances being updated, whereas, in token-based systems, the token is directly transferred to the recipient. Both systems leverage digital ledger technology for transaction storage and processing [24].

The rise of token-based CBDC usage raises concerns about the potential circulation of counterfeit tokens, similar to the challenges faced with physical cash. Therefore, a mechanism for validating tokens becomes essential. Account-based tokens address this need for authenticity but sacrifice the anonymity or privacy inherent in token-based systems [24]. Consequently, a comprehensive exploration of both systems is necessary before determining which is more suitable for the future of CBDC.

- **Distribution Layer and User Layer**

Distribution layer for digital Rupiah will use a one-tier money transfer method for wholesale and two-tier for retail two-tier system. This method makes it easier for BI to control the money market

by dividing tasks with banks. It also sharing the burden for the infrastructure supporting blockchain on digital Rupiah. Digital Rupiah will be distributed to end users through wholesalers appointed by BI. Our research will focus on end users (digital Rupiah retailers) where the use of two-tier money distribution will be implemented.

In the blockchain mechanism, multiple node roles are required to separate tasks. In regulating the Digital Rupiah, BI collaborates with the Government and law enforcement to be able to carry out AML and eradicating the CFT functions. BI will carry out a number of roles [7]:

1) Genesis developer, who builds and modifies the source code of the w-Rupiah Digital platform;
2) Validating node, who validates transactions;
3) Regulatory node, who regulates and supervises the network, including collecting and analyzing data in real-time, collaborates with the Government and law enforcement;
4) Node operator, who acts as a proxy in providing ledger access to participants who do not have their own node (no node);
5) Administrative node, who manages membership in the network.

Commercial banks and non-bank institutions or Government, whether they have the status of wholesaler or non-wholesaler, can act as validating nodes, non-validating nodes, or no nodes with the approval of BI. Validating nodes on blockchain have the task of validating transactions to be recorded in the ledger and obtain remuneration from the blockchain publisher.

- **Mobile Application for e-Wallet**

Mobile Application is selected because it is convenience for user and offers several security advantages over traditional payment methods. To begin with, it eliminates the necessity of carrying physical cash or credit cards, which always entails the risk of being stolen or misplaced. It also eliminates the risk for money stolen, without having access to login into the apps, the phone carrier cannot transfer the money from user account.

- **Research Limitation**

In the case of digital payments, the key to success lies in providing consumers with more convenient, dependable, and secure transaction options. This success is closely tied to businesses' ability to readily access data, applications, networking controls, and the associated technologies required for these transactions. Moreover, the proximity of these services to end-users plays a critical role in delivering a positive digital payment experience. The closer these services are to the end-users; the more successful and seamless their digital payment experiences will be.

There are more than 48 licensed e-wallet systems operated by domestic companies [25], and the use of mobile wallets is on the rise so that the interconnection between Rupiah Digital e-wallet and others PSPs e-wallet systems is essential.

The adoption of Digital Rupiah in Indonesia faces a limitation due to uneven internet access across the country. The Digital Rupiah operates on a blockchain, requiring internet connectivity for transactions to record data at Bank Indonesia. This recording ensures that information about fund owners and money flow is available in real-time.

According to Statista data [25], Indonesia's digital payments industry generated $63.6 billion in revenue in 2021, and it is projected to reach $124.42 billion by 2027. The number of digital payment users in Indonesia is also expected to grow from 196.49 million users in 2023 to 247.26 million users in 2027. E-wallets and electronic money represent the most popular digital payment methods in the country. There are more than 48 licensed e-wallet systems operated by domestic companies, and the use of mobile wallets is on the rise. In 2020, approximately 26 percent of Indonesia's population had a mobile wallet, and this figure is expected to increase to 77 percent by 2025.

c. Qualitative Research Method (QRM)

Qualitative research is a research approach designed to collect and analyze non-numerical descriptive data with the aim of understanding an individual's social reality. This includes gaining insight into their attitudes, beliefs and motivations. Qualitative research delves into participants' perspectives through interactive and flexible methodologies. It aims to gain a deeper understanding of social phenomena from the participants' point of view. In essence, qualitative research explores the "why" behind human behavior and social interactions, using the researcher as a key instrument for data collection and analysis [26].

In this research, the author using narrative research to gain insight and propose conceptual design. Data was collected through interview and asking response methods both online and offline to capture information that is rich in detail and context. This research method is used to understand the experience and perspective of experts regarding the type of blockchain, digital token, distribution and user layer, digital rupiah

workflow between e-wallets and also limitation for interoperability with PSPs wallets and environment of digital payment in Indonesia.

Using the results from literature review, we recommend blockchain type that will be used for Rupiah Digital. Then, we will design a conceptual for e-wallet Rupiah Digital with selecting the right platform for the apps, the type of security (token-based/account-based), the scope of validating node, regulatory consent, and future research for this field. Starting from the architectural design, we will provide an overview to experts in the fields of economics, law and technology to obtain reviews and input regarding stakeholder needs to be able to perfect the e-wallet conceptual design that can be implemented. This conceptual design architecture will be a prototype recommendation for BI as a genesys developer so that the e-wallet conceptual design created has the right founda-tion according to stakeholder needs.

The e-wallet conceptual design will not eliminate the purpose of CBDC for AML and CFT regulation while allowing for fully private payments. The interview for this research is divided into three perspectives in the form of:

a. Regulator: BI as the policy maker in determining the Digital Rupiah e-wallet, manages and monitors the network, including real-time data collection and analysis. BI collaborates with the Government in the fields of AML and eradicating the CFT.
b. Executor: BI acts as a proxy in providing ledger access to participants who do not have their own node (no node) whie banks act an intermediary for transferring the Rupah Digital for end-user. Banks act as a node either validating node or non validating node.
c. Academics: act as an expert in the field of technology in blockchain applications. They are also tasked with reviewing e-wallet design concepts that are designed to be applicable.

Based on those methodologies, our research conducted using the scheme Figure 2 as follow:

a. The first step on this research is conducted with problem identification and motivation by collecting initial data from BI white paper and previous study literature then analzed it to select the suitable blockchain type, digital token, distribution layer, design apps and constraint.
b. The second step is defining solutions based on analysis fro previous step concerning the AML and CFT regulation.
c. The third step is designing and developing the propose technology depicted in first step to be presented at the next step.
d. The fourth step is demonstrating the conceptual design in FGD with BI as an executor and expert on this matter.
e. The last step is conducting evaluation and communication to answer the RQ and get conclusion as an alternative solution of conceptual design for BI.

Our QRM is conducted by Forum Group Discussion (FGD) with Ministry of Finance, BI, and academics with detailed expert/professional as showed in Table 1.

To ensure the validation and realibility of this research, the FGD conducted using those materials above with discussion for each materials then the participant commented for each and validation from experts and executors will be obtained. The draft of this paper was send through email to BI so that the participant could study the paper before the FGD started.

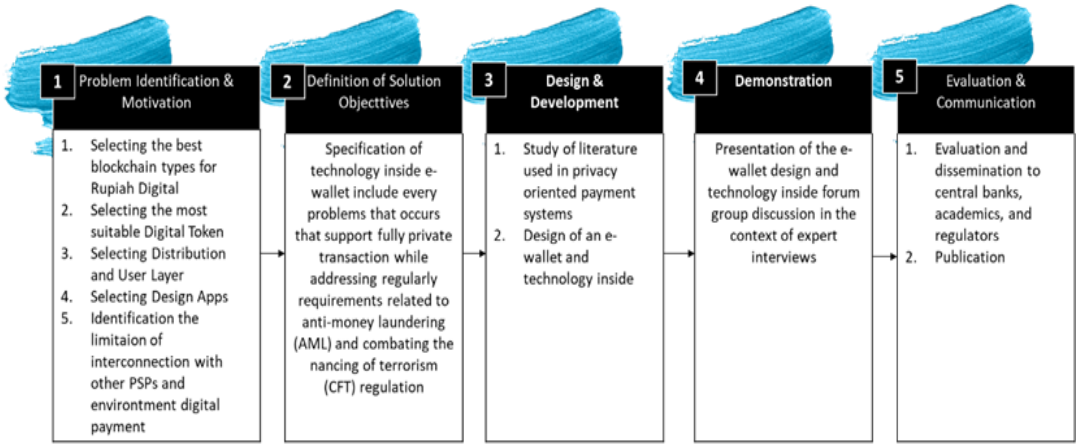

Figure 2. Methodology for LR and QRM

Table 1. Overview of interviewed experts

No	Field of Expertise	Role	Organization
1	CBDC and Economy	Senior Economist	Bank of Indonesia
2	IT	Blockchain Developer	Bank of Indonesia
3	Economics	Assistant Manager	Bank of Indonesia
4	Economics	Task force team for Rupiah digital	Bank of Indonesia
5	CBDC	Research Assistant	Bank of Indonesia
6	IT	Assistant Manager	Bank of Indonesia
7	Law	Task force team for Rupiah digital	Bank of Indonesia
8	Blockchain	Lecturer	University of Indonesia
9	Law	Head of the Financial and Agreements Sector Legal Department	Legal Bureau of the Secretariat General, MoF
10	Economics	Young Expert Policy Analyst	Department of Economic and Monetary Policy, MoF
11	Economics	Head of Subdirectorate Cash Optimalization	Department of State Cash Management, MoF

3. Results

Our research conducted by using literature review by using these stages Defining the Scope of the Topic: Clearly articulate the scope of the topic to be reviewed. Establish specific boundaries to maintain focus and direction in the literature review.

a. Identifying Relevant Sources
b. Reviewing the Literature
c. Writing the Review
d. Applying Literature to the Planned Study
e. Choosing the Topic for Review
f. Tracking and Selecting Relevant Articles
g. Conducting Analysis and Synthesis of Literature

The result of the review shown in Table 2.

The first study, by Samudaya Nanayakkara et al., proposes a methodology for selecting an appropriate blockchain platform for developing complex enterprise solutions [27]. The proliferation of blockchain platforms has created challenges for developers in choosing the most suitable option. This study addresses this gap by providing a step-by-step process to guide developers in platform selection, ensuring scalability for even demanding enterprise applications. The key contributions of this study are the process protocol for blockchain platform selection, methodology for selecting a platform to develop blockchain systems, including complex enterprise solutions, and detailed evaluation of Hyperledger Fabric, the chosen platform in the provided case study.

The initial step involved identifying and cataloging available blockchain platforms. Next, these platforms were evaluated using the SMART criteria, tailored with specific criteria and weightages relevant to this study. (Note: You may need to define SMART criteria in your actual research). Based on this evaluation, Hyperledger Fabric emerged as the most appropriate platform for developing a complex enterprise blockchain system. To validate this selection, Hyperledger Fabric's architecture, libraries, tools, and its capacity to support business logic, APIs, and GUIs were thoroughly investigated. This confirmed Hyperledger Fabric's suitability for the chosen enterprise project. Finally, the entire methodology was validated by developing a prototype enterprise blockchain system. This process can be applied by developers to select platforms for building blockchain solutions, ranging from basic applications to complex enterprise systems.

Second study conducted by Bhawana and Sushil Kumar that introduced a two-layered architecture for Central Bank Digital Currency (CBDC) within the current financial infrastructure. The first layer is distribution layer which utilizes a permissioned blockchain network (PBN) to manage wholesale CBDCs. Smart contracts within the PBN govern various functionalities. Commercial banks, similar to the central bank, maintain nodes within the PBN for legitimacy. The second layer is user layer where the central bank authorizes commercial banks to manage token-based accounts for end-users.

To ensure compliance with Anti-Money Laundering (AML) and Countering the Financing of Terrorism (CFT) regulations, commercial banks conduct Know Your Customer (KYC) checks. A Certificate Authority (CA) plays a vital role in distributing digital certificates to participating banks, validating transactions, and securing communication within the PBN. Importantly, the central bank does not directly interact with end-users in this model.

This proposed architecture offers several advantages over contemporary Real-Time Gross Settlement (RTGS), Immediate Payment Service (IMPS), etc., currently utilized by central banks. Notably, it eliminates the single point of failure by introducing the PBN for wholesale CBDC, enabling direct interaction between commercial banks without relying on existing interbank

Table 2. Literature review result

Classification	Highlight	Author	Year	Pivotal contribution
Empirical analysis	Systemic review of CBDC	Bofinger, P. and Haas, T.	2021	Delves into the purpose and rationale behind CBDC development, examines various CBDC proposals for integration into existing payment systems, analyzes the potential risks and impacts associated with CBDCs, proposes a specific CBDC banking model for further consideration.
Empirical analysis	Technical review of CBDC	Auer, R.A., Cornelli, G. and Frost, J.	2020	Employed an empirical analysis to investigate the motivations, drivers, and approaches for central bank to issue CBDCs, introduced technical challenges and solutions of CBDC, discussed taxonomy of CBDC.
Empirical analysis	Systemic review of CBDC	Giancarlo, C. H., et al.	2020	Conducted empirical analysis on the motivations for US dollar to be tokenized, designed a model of tokenized digital dollar. use case analysis delves into CBDC , including a detailed discussion of CBDC taxonomies
Empirical analysis	Systemic review of CBDC	Demmou, L. and Sagot, Q.	2021	Conducted empirical analysis on the challenges of existing cross-border payment systems. as well as the oppor1tmities. risks. and benefits of CBDCs for international and domestic payment.
Empirical analysis	Survey on CBDC	Boar, C., Holden, H. and Wadsworth, A.	2020	This exploration examines Central Bank Digital Currency (CBDC) proposals, analyzing the motivations behind their development and exploring the arguments of both proponents and opponents including a detailed discussion of CBDC taxonomies
Empirical analysis	Guidance for blockchain of CBDC design	Samudaya Nanayakkara , et al.	2021	Provided A Methodology for Selection of a Blockchain Platform to Develop an Enterprise System
Guidance and best practice	Guidance for CBDC design	Han, X., Yuan, Y. and Wang, F.Y.	2019	Proposed a blockchain-based framework for CBDC, introduced key business processes the lifecycle of CBDCs, including a detailed explanation of the transaction process for cross-border payments
Guidance and best practice	Guidance and best practice for CBDC design	Lee, D.K.C., Yan, L. and Wang, Y.	2021	Introduced multi-tier ledger design, proposes ten enablers for CBDC mass adoption and implementation.
Guidance and best practice	Guidance for CBDC design	*ThebBank for International Settlements*	2021	Explored CBDCs, examining both their design principles and the technical considerations involved. It further reviews the motivations for CBDC development, along with the challenges and potential risks associated with their implementation for international and domestic payments
Guidance and best practice	Technical design choice of CBDC	Auer, R. and Böhme, R.	2020	Examined the design principles of CBDCs and explores the associated technical considerations (trade-offs)
Guidance and best practice	Design choice of CBDC	Kiff, J., et al.	2020	Investigated key design considerations for retail CBDCs. It further explores CBDC insurance and policy options, ultimately proposing a structured framework to guide central banks in their decision-making regarding CBDC issuance
Guidance and best practice	Guidance and best practice for CBDC design	Bhawana and Sushil Kumar	2021	Permission Blockchain Network based Central Bank Digital Currency

settlement systems (e.g., RTGS) and achieving zero downtime. Scalability and cost considerations are addressed by leveraging smart contract logic and a permissioned blockchain environment, aiming to reduce overall system costs and facilitate increased transaction volume as the number of commercial banks grows. The use of blockchain technology in the distribution layer is highlighted for its ability to introduce transparency and trust of all banks through securing a distributed immutable ledger. Looking ahead, the proposed CBDC system architecture could benefit from enhancements, such as implementing hybrid encryption cryptography for PBN to safeguard against potential quantum computing attacks.

Based on the results of the literature review and research analysis, there are two FGD that was conducted to get review from this research. The first FGD on the Rupiah Currency Forum was conducted on 13-15th November 2023 at the Novotel Gajah Mada Hotel with participants from the Ministry of Finance with representatives from Fiscal Policy Agency, Legal Bureau of the Secretariat General, and Directorate General of Treasury and Bank Indonesia with representatives from the Department of Money Management and the Department of Economic and Monetary Policy.

The second was conducted via Zoom on December 7th 2023 with participant from task force team for digital Rupiah, Bank of Indonesia and academics from University of Indonesia.

This FGD conducted to gain validation and reliability of the research. We presented the research in question to obtain feedback and insight into all materials and limitations in the conceptual design of the digital rupiah e-wallet. Based on those forum, we obtained some validation as follow:

a. Blockchain Type

Hyperledger Fabric was selected as the most suitable platform to develop a blockchain-based complex enterprise system by selecting a suitable blockchain platform using a multi-criteria decision-making method such as Simple Multi Attribute Rating Technique (SMART) [27]. Consequently, Hyperledger Fabric was explored in detail considering its system architecture, libraries, tools and domain-specific applications, support to develop business logic, APIs and GUIs.

The research introduces a methodology to guide system developers in selecting a suitable blockchain platform for developing complex enterprise systems. The proliferation of blockchain platforms has created challenges in choosing the most appropriate option. This methodology addresses this gap by providing a structured approach. The research analysed the following blockchains:

- BigChainDB
- NEM
- Hyperledger Fabric
- IOTA
- Eris
- Symbiont Assembly
- MultiChain
- Corda R3
- Openchain
- Hyperledger Sawtooth
- Elements
- Stellar
- HydraChain
- Chain Core
- NEO
- Stratis
- Lisk
- Ethereum
- Waves
- Hyperledger Iroha
- Credits
- Quorum
- IBM Blockchain
- EOSIO

This research addresses the challenge of selecting a suitable blockchain platform for developing complex enterprise systems. It introduces a novel methodology that can be effectively utilized by system developers. The methodology streamlines the platform selection process, ensuring scalability for even demanding enterprise applications.

Through FGD, BI stated that this blockchain type that was recommended in this paper will become one of the option that was considered to be used in digital Rupiah. Based on the characteristic for complexity, it can provide the necessity and environment for end-user. This type also aligned with the permissioned-based blockchain that was needed to secure the environement of the system.

b. Digital Token

Digital token for end-user could be differed with account-based and token-based. account-based systems introduce an authentication layer, requiring validation of the involved parties for every transaction [24],[28]. By using account-based CBDC, the end-user obligated to open an account with the third-party provider authorized by the central bank in this case commercial banks [29]. Hence, the commercial banks will responsible for identity verification, know-your-customer (KYC) process, digital tokens distribution from one account to another, and transaction's approval.

Token-based systems, as demonstrated by Bitcoin, operate without the need for third-party authentication, enabling direct transfers between parties [24]. Unlike account-based CBDCs, token-based systems require end-users to possess digital wallets. These wallets are opened by the central bank through authorized Payment Service Providers (PSPs). End-user transactions are validated using a public-key cryptography system, where a public/private key pair or digital signature is employed for access and verification. Commercial banks authorize transactions based on the validity of the user's public key. Token-based CBDCs can be designed with varying degrees of anonymity. Unlike cash or some cryptocurrencies (e.g., Bitcoin, Ether), some token-based CBDCs may incorporate user identities, reducing anonymity within the network.

In account-based systems, transactions involve updates to the sender's and receiver's account balances reflected directly in the digital ledger. Both parties can witness these changes, whereas token-based systems involve the transactions directly to transfer tokens from the sender to the recipient, with the digital ledger recording the transfer [24]. The growing popularity of token-based CBDCs raises concerns about counterfeit tokens entering circulation, similar to the challenges encountered with physical cash. To mitigate this risk, robust token authentication mechanisms are essential.

However, account-based tokens, while addressing the need for authenticity, may compromise the anonymity or privacy that are inherent advantages of token-based systems. [24].

Consequently, the author recommended a comprehensive combination of both systems for better suited for the future of CBDC. In accordance with implementation of Rupiah Digital, to achieve the of AML and eradicating CFT, we recommend

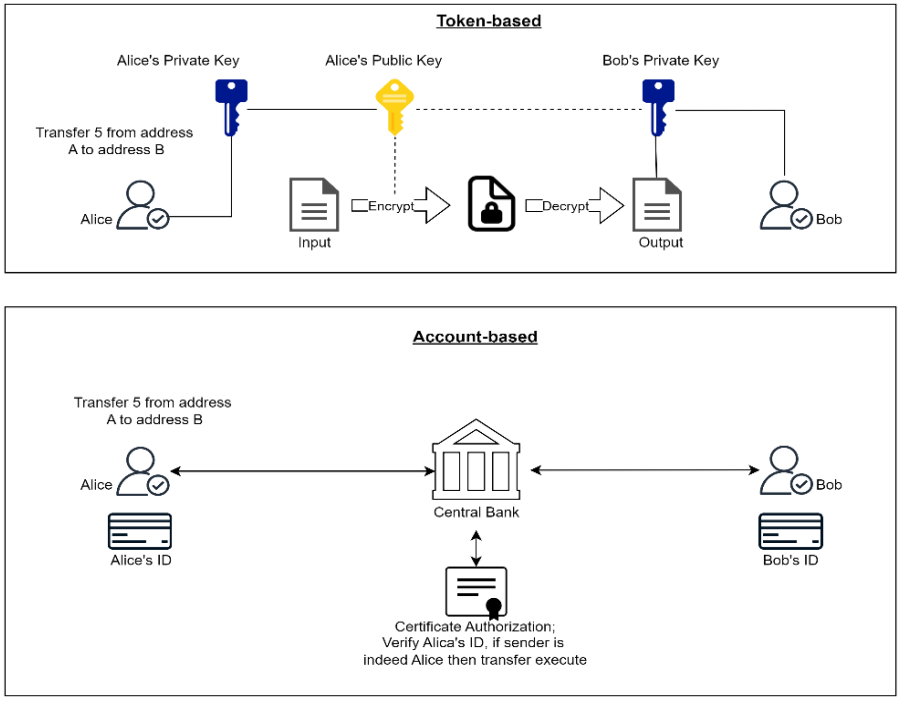

Figure 3. Digital Token: Token-based and Account-based [28]

that BI using token-based CBDC to remove anonymity of end-user. The end-user requires to open a digital wallet with central bank to hold digital tokens accessed by a public/private key pair or digital signature as described in Figure 3.

Digital token that was recommended was part of option which is being researched by BI through FGD to obtain a final design that is sufficient for the entire Rupiah digital payment ecosystem. This token could ensure the security because user to register the account using ID.

c. Distribution Layer

The distribution layer outlines the structure of a two-layer CBDC framework, where the central bank creates the Digital Rupiah [10]. This currency is then distributed by commercial banks to end-users. The upper layer deals with wholesale CBDC and is described within the distribution layer. The lower layer pertains to retail CBDC and is specified in the user layer.

In this framework, the key actors are the Bank of Indonesia, denoted as (RBI), and the commercial banks, indicated as (CB) as shown in figure below. The scenario involves the central bank establishing a permissioned blockchain network (PBN) while blockchain denoted as (BC), which includes the BI, commercial banks, and a certificate authority (CA). The PBN can be established using well-established blockchain frameworks like Hyperledger Fabric. This approach offers the benefit of utilizing proven technology or the central bank could develop its own customized PBN platform. This option allows for greater control and flexibility but may require significant investment in resources and expertise. A pair of public and private keys (asymmetric keys) will be used inside blockchain for security reason. Privat key will be used for signing the transaction, while public keys will be used for verification of the user sign.

In this setup, the central bank takes responsibility for publishing various smart contracts. These contracts cover tasks such as central bank registration, digital certificate generation, token issuance, commercial bank registration, token request handling, and interbank settlements within the PBN at the distribution layer, as indicated in figure below. The CA serves as a legitimate blockchain node, responsible for issuing digital certificates to both the central bank and commercial banks within the PBN. These digital certificates serve to link the original identity of the banks (whether central or commercial) and authenticate their transactions within the PBN when they sign transactions as shown in Figure 4.

Initially, the central bank initiates the registration of the smart contract by inputting essential data, resulting in the creation of a token-based account for the central bank within the PBN.

Smart contracts are self-executing programs that automate the fulfillment of agreements upon meeting predetermined conditions. These contracts can be programmed to enable automatic execution of specific functionalities within a transaction [30].

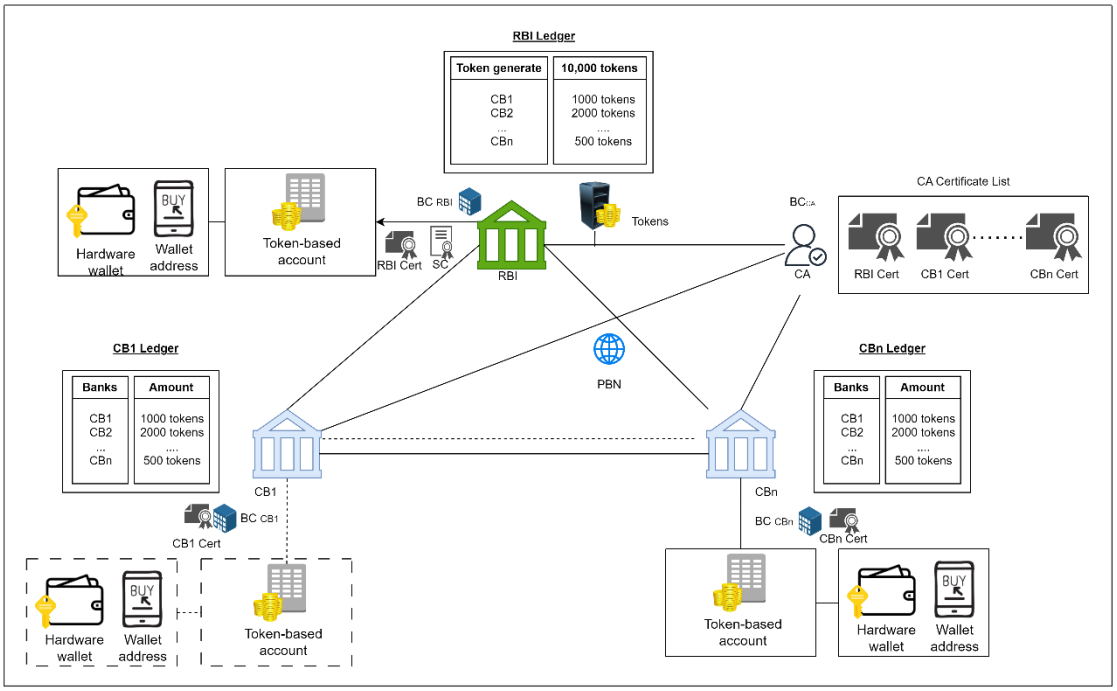

Figure 4. Distribution Layer [10]

This process also yields a pair of public and private keys denoted by [PKRBI, SKRBI], employing public-key cryptography

The central bank collaborates with the Certificate Authority (CA) via a smart contract to generate a digital certificate. This process involves submitting a certificate signing request containing the central bank's information. Upon verifying the information's accuracy, the CA issues a digital certificate, denoted as [CertRBI], to the central bank. The CA signs the certificate using its private key for security. Then, the central bank securely stores its information in a hardware wallet for future PBN interactions. The central bank's public key is used to generate its wallet address through a hashing algorithm, denoted as [WARBI]. A blockchain node, denoted as [BCRBI], is created specifically for the central bank within the PBN.

Additionally, the central bank initiates a smart contract to generate digital tokens within its wallet address. These tokens represent the digital form of the central bank's fiat currency and can be backed by assets like gold or foreign currency. The central bank may introduce new policies to support these tokens with other commodities.. The central bank can also introduce new monetary policies to support these digital tokens with other commodities.

For commercial banks, the process involves initiating a smart contract for registration, providing relevant information to request a token-based account. Commercial banks initiate a smart contract for registration. They provide necessary information to request a token-based account. The central bank verifies this information against its existing database (e.g., RTGS server) to ensure legitimacy and returns a public/private key pair denoted by [PKCB, SKCB]. Upon successful verification, the central bank issues a public/private key pair to the commercial bank. The public key serves as the commercial bank's wallet address within the PBN, while the private key is securely stored in a hardware wallet for transaction authorization, denoted by [WACB]. Commercial banks then leverage a smart contract to request a digital certificate from the Certificate Authority (CA). Once the CA verifies the request, the commercial bank receives a digital certificate (denoted as [CertCB]) and a corresponding blockchain node is created within the PBN (denoted as [BCCB]).

The commercial bank triggers a smart contract within the PBN to request digital tokens. To cryptographically sign the transaction for security, the commercial bank utilizes its private key. This transaction includes the commercial bank's digital certificate (proof of identity), the public key of the central bank (destination for the tokens), the central bank's wallet address (where the tokens will be deposited). Then, the central bank receives the transaction and decrypts it. It verifies the authenticity of the commercial bank's digital certificate with the CA. Upon successful verification, the central bank credits the requested

digital tokens to the commercial bank's wallet address within the PBN. The central bank broadcasts a signed transaction on the PBN, confirming the successful completion of the token request. Then, the commercial bank retrieves the central bank's digital certificate from the signed transaction. To ensure the tokens' legitimacy and prevent double-spending, the commercial bank forwards the central bank's certificate to the CA for verificationThis transaction is stored by various blockchain nodes in their corresponding distributed ledgers within the PBN, ensuring consistency and transparency.

The recommended distribution layers are aligned with the concepts developed by BI. Furthermore, the explanation in this paper is quite complete so that it can provide new insights. BI stated that this architecture was accepted through FGD.

d. User Layer

The primary goal of the user layer is to distribute digital tokens received from the central bank to end-users through commercial banks via the PBN. These tokens are intended for daily-usage by end-users, as illustrated in Figure 5. The user layer comprises commercial banks and end-users, denoted by [EU1,EU2,…EUm]. Notably, the central bank does not directly interact with end-users. Instead, it authorizes com-mercial banks to handle the Know Your Customer (KYC) process for end-users.

Commercial banks maintain records of spent digital tokens by end-users in their local ledgers. They offer token-based accounts to end-users, either through their own applications or by leveraging third-party software like GoPay. End-users visit their commercial banks for KYC processes if not done previously and request a token-based account.

Commercial banks play a crucial role in onboarding end-users into the token-based CBDC system. This process entails the following steps:

1. Mobile App Download: Commercial banks guide end-users to download the designated mobile application onto their devices.
2. Token-Based Account Creation: End-users establish token-based accounts within the application. This requires them to provide mandatory information as stipulated by the commercial bank.
3. Public/Private Key Generation: Upon successful account creation, the commercial bank generates a unique public/private key pair for each end-user.

In return, the commercial bank generates a pair of public/private keys for the end-user, represented by [PKEU, SKEU]. The end-user's public key is utilized to create a wallet address for external interactions, represented by [WAEU]. Upon verification, the commercial bank retrieves the end-user's wallet address associated with their token-based account. The commercial bank establishes a link between the end-user's wallet address and their existing domestic bank account held with the commercial bank [31].

The end-user keeps their private key confidential, using it to manage their token-based

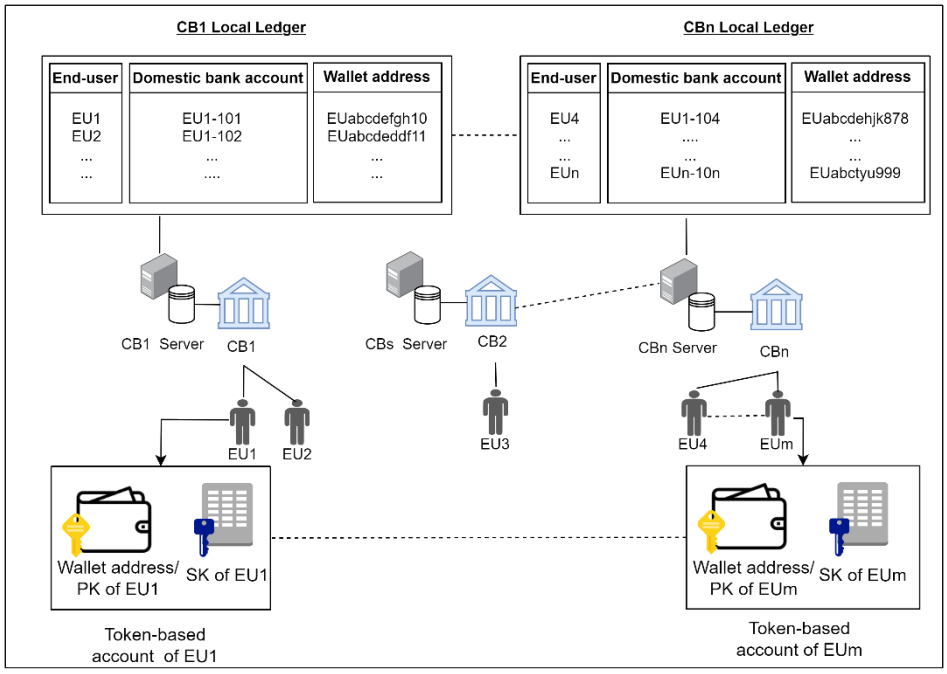

Figure 5. User Layer [10]

account for sending and receiving digital tokens. The same [PKEU, SKEU] is employed for logging in on other devices to access the token-based account as depicted in Figure 5.

The recommended user layers are aligned with the concepts developed by BI. Furthermore, the explanation in this paper is quite complete so that it can provide new insights. BI stated that this architecture was accepted through FGD.

e. Wallet Conceptual Design Apps

Mobile wallets offer a speedy, convenient, and time-saving method for in-store payments, contrasting with traditional cash or physical credit card transactions [11], [32]. This technology relies on near-field communication (NFC), facilitating device-to-device communication via radio waves [33],[31]. Utilizing a personal identity format developed for the user, NFC transmits payment data to the dealer's point-of-service (POS) terminal [31]. Users can activate the NFC feature on their smartphones and transmit information by passing it over the store's NFC scanner.

Mobile wallets support a variety of transactions, including online purchases, utility payments, money transfers, automated payments, and expense management [34]. They are gaining popularity, with a projected user base of 4 billion and a market size of $7,580.1 billion by 2024 and 2027, respectively [1] Due to their convenience, ease of use, security features, and prompt service delivery, mobile wallets are among the rapidly advancing areas in future mobile technology payment methods.

Mobile wallet adoption has substantial implications for technology-enabled financial inclusion, particularly in developing nations [2]. The innovation of mobile wallets is beneficial for businesses, as it facilitates cashless payment transactions, providing financial institutions with an additional source of income [11]. Further-more, mobile payment apps incorporate additional security layers to safeguard user data. These measures include encrypting all personal information and leveraging biometric authentication features like fingerprint scans and facial recognition, significantly enhancing overall security.

Lastly, each transaction conducted through a mobile payment app undergoes a process known as tokenization. This involves the generation of a unique, one-time code by the payment terminal, commonly referred to as a "token." This token is employed to complete the transaction in place of the buyer's actual payment details. Importantly, the token cannot be repurposed for any other transaction and holds no value if it were to be compromised. Consequently, buyers are effectively shielded from fraud activities.

The security for mobile wallet will be conducted using account-based where the user needs to register their account using civil ID or company certification wheter they has NPWP or not. This verification of new account will be conducted by BI because BI is the administrator for digital Rupiah. After an acoount is created, the user get password/PIN for login. The transaction of digital Rupiah will be using token-based for security because every flow of digital Rupiah will be recorded in blockchain.

From table 3 above, we propose the Bussiness Data Application Technology (BDAT) Architecture Diagram as illustrated in Figure 6.

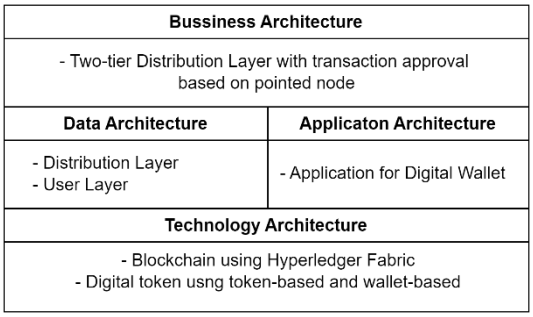

Figure 6. BDAT Architecture Diagram

This architecure was followed by discussion through FGD with executor and experts in this topic.

Through FGD, BI stated that mobile apps for e-wallet that was recommended was part of option which is being researched by BI to obtain a final design that is sufficient for the entire Rupiah digital payment ecosystem.

Based on literature review and FGD, the propose architecture result of this research as listed in Table 3.

Materials shown in Table 3 were discussed as an option of solution for BI to gain insight and recommendation for developing e-wallet for digital

Table 3. Result of the proposed architecture

No	Materials	Recommendation	Validation
1	Blockchain Type	Hyperledger Fabric	Approved for option
2	Digital Token	Combination of Token-based and Account-based	Approved for option
3	Distribution Layer and User Layer	Two-tiered	Approved for option
4	Application for e-Wallet	Mobile Application	Approved for option

Rupiah in Indonesia. The conclusion from FGD are as follow:

1. Blockchain type that needed is using private DLT with trusted nodes to secure the transactions. As Hyperledger Fabric proposed, this blockchain type is the needed type and meets the requirements. BI will considered Hyperledger Fabric as one of the option to develop in its system.
2. Digital token offered security system with two-tiered as proposed (token-based and account-based) so it will enhanced the transaction security. It meets the requirements and will be considered to be applied in the system.
3. Distribution layer that was proposed was alligned with BI White Paper so its dont needed to be discussed as the whole architecture is suited with BI research.
4. Application for e-wallet was also alligned with security issues of BI policy so it was approved to be part of option to be developed in BI system.

The whole proposed architecture was alligned with BI policy as security is the most concerning topic for developing digital Rupiah. BI accepted the materials and research carried by authors as an option to be implemented for future digital Rupiah system. This research gave BI an insight to carry on a new research for digital Rupiah by conducting more discussion with banks and regulator because not only the technology, but also the resources is needed to be discuss more.

4. Discussion

A methodology designed to assist system developers and programmers in selecting a suitable blockchain platform for developing blockchain systems, particularly complex en-terprise solutions [10]. The proliferation of various blockchain platforms has posed a chal-lenge for developers in making informed choices. The methodology outlined in this study encompasses a process protocol for the selection of a blockchain platform, considering the specific needs of each project. The evaluation process involves identifying and listing available blockchain platforms, followed by a SMART evaluation based on predefined criteria and weightages. In this study, Hyperledger Fabric emerged as the most suitable platform for developing a blockchain-based complex enterprise system. The evaluation further delves into the detailed analysis of Hyperledger Fabric, covering aspects such as system architecture, libraries, tools, domain-specific applications, support for business logic development, APIs, and GUIs. The validation of the methodology was carried out through the development of a prototype enterprise blockchain system using Hyperledger Fabric.

. A two-tiered architecture for Central Bank Digital Currency (CBDC) is proposed within the existing financial infrastructure, designed specifically for a permissioned blockchain network-based CBDC [10]. The use of two layers is also in line with the conceptual design designed by BI [3], [7]. The initial layer, referred to as the distributional layer, encompasses wholesale CBDC and defines various smart contracts within the Permissioned Blockchain Network (PBN). Commercial banks, mirroring the central bank, uphold a blockchain node in the PBN to establish legitimacy. The Certificate Authority (CA) assumes a vital role in distributing digital certificates to all participating banks in the PBN, validating transactions related to tokens, and ensuring secure communication. Significantly, the central bank maintains no direct interaction with end-users but instead authorizes commercial banks to allocate token-based accounts to end-users.

This proposed architecture offers several advantages over existing systems like Real-Time Gross Settlement (RTGS) and Immediate Payment Service (IMPS) commonly employed by central banks. Notably, it eliminates a single point of failure by introducing the PBN for wholesale CBDC, enabling direct interaction between commercial banks without reliance on existing interbank settlement systems (e.g., RTGS), thereby achieving zero downtime. Scalability and cost considerations are addressed through the utilization of smart contract logic and a permissioned blockchain environment, aiming to reduce overall system costs and facilitate increased transaction volume as the increasing of commercial banks. The use of blockchain technology in the distribution layer is empha-sized for its capacity to introduce transparency and trust of all banks by securing a distributed immutable ledger. Looking forward, potential enhancements for the proposed CBDC system architecture include implementing hybrid encryption cryptography for the PBN to safeguard against potential quantum computing attacks.

Regulation consent regarding consumer data protection is very high because Rupiah digital uses blockchain technology so it is necessary to ensure that transactions in it can only be known by the authorities. In discussions related to regulations, the views of all participants felt that the P2SK Law was not enough to give privacy because the validating node could know the costumer. BI still conducting a research to obtain the best ways of transaction which can’t be seen by banks in order to gain privacy for end-user.

5. Conclusions

The Rupiah digital e-Wallet conceptual design recommend the use of a mobile wallet for user security and convenience as it eliminates the need to carry physical cash or credit cards and minimizes the risk of it being stolen or misplaced. Meanwhile, private blockchains choose Hyperledger Fabric as the most suitable platform for developing complex blockchain-based enterprise systems. And the distribution scheme uses a two-level system involving commercial banks as validation nodes.

As depicted above, the distribution and user layer we recommend, based on study literature and demonstration with BI, is using two layer system which involve commercial bank as validating node that is strictly selected by BI in order to enhance the privacy and security. Private blockchain required known validating nodes that is regulated in BI regulation. As regulatory consent for the implementation of digital Rupiah remains focused on end user privacy while prioritizing transaction objectives to prevent AML and CFT, BI is obliged to prepare derivative regulations from the P2SK Law to regulate the administration and distribution of digital Rupiah.

Future research is needed to focus on interconnection with other PSP applications to attract and make it easier for users to carry out daily transactions. Digital payment infrastructure in Indonesia must be provided by the government and private sector to increase digital payment transactions throughout Indonesia.

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