Central Bank Decentralised Currency

Thesis submitted to

Indian Institute of Information Technology Kalyani

in partial fulfilment of the requirements

for the award of the degree

of

Bachelor of Technology

in

Computer Science and Engineering

by

Viswanath Odiya

Registration No.: 817

Subhradeep Ray

Registration No.: 750

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
INDIAN INSTITUTE OF INFORMATION TECHNOLOGY KALYANI
KALYANI - 741235, WEST BENGAL, INDIA

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under the supervision of

S.K Hafizul Islam

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
INDIAN INSTITUTE OF INFORMATION TECHNOLOGY KALYANI
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Near Buddha Park, Dist. Nadia, P.O. Kalyani - 741235, West Bengal

Email: office@ilitkalyani.ac.in, Website: https://iiitkalyani.ac.in/

Certificate

This is to certify that the thesis entitled "**Central Bank Decentralised Currency**", being submitted by **Viswanath Odiya** (**817**), a undergraduate student at the **Indian Institute of Information Technology Kalyani**, West Bengal, India, for the award of the **Bachelor of Technology** in **Electronics and Communication Electronics**, is an original research work carried out by him under my supervision and guidance.

The thesis has fulfilled all the requirements as per the regulations of **IIIT Kalyani** and, in my opinion, has attained the standards required for submission. The work, techniques, and results presented herein have not been submitted to any other university or institute for the award of any other degree or diploma.

(Name of the Guide)
Assistant Professor
Department of Computer Science and Engineering
Indian Institute of Information Technology Kalyani
West Bengal - 741235, India

Declaration

I hereby certify that the work which is being presented in the thesis entitled "**Central Bank Digital Currency**" in the partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics and Communication Engineering** in the **Department of Electronics and Communication Engineering**, **Indian Institute of Information Technology Kalyani**, is an authentic record of my own work carried out during the time period from **July 2022** to **May 2025**. Thesis submission under the supervision of "**Name of the Supervisor, Designation, and Affiliation**.
The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

Date:

Viswanath Odiya
Reg. No.: 817
Department of Electronics and Communication
Indian Institute of Information Technology Kalyani
West Bengal - 741235, India

Acknowledgments

I am privileged to have the opportunity to carry out my.....

Date:

(Viswanath Odiya)
Reg. No.: 817
Department of Electronics and Communication Engineering
Indian Institute of Information Technology Kalyani
West Bengal - 741235, India

Abstract

Finish the Abstract with in one page

Keywords: Provide 8-10 important keywords.

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Abbreviation	Full form
BDH	Bilinear Diffie-Hellman (BDH)

Chapter 1

Introduction

1.1 Introduction

In this era of internet, we are surrounded with smart devices connected through extensive digital networks, bringing most services just a touch away. With this new surge of digital payments, traditional use of cash has been declining rapidly. Making Cryptocurrencies such as Bitcoin having their popularity increase through the roof. This has further prompted the central banks of different nations to explore the possibility of having their own digital currencies. This new form of money that can be used by public for transactions are referred as **Central Bank Digital Currencies (CBDCs)**.

Where cryptocurrencies are completely decentralised, CBDC's are controlled by the Central Bank which implement CBDC's using a centralised ledgers with people having their own deposit accounts, quite different from the modern Bitcoin which rely on decentralised technology such as blockchain. [1]

Traditionally, central banks issue two forms of money: *physical cash*, which is accessible directly by the public, and *reserve deposits*, which are held by commercial banks at the central bank. While individuals can withdraw cash from their commercial bank accounts, they cannot directly access central bank reserves. These reserves are used by commercial banks to issue loans, which indirectly provide central bank money to the public.

The introduction of a CBDC would provide the public with a third form of direct access to central bank-issued money. Consequently, CBDCs would coexist with cash and retail bank deposits, potentially reshaping the structure of the monetary system. As individuals would have the freedom to choose between cash, CBDCs, and traditional deposits, the issuance of a CBDC introduces a competitive element into the forms of money held by the public [2].

1.2 What is CBDC?

A Central Bank Digital Currency (CBDC) is a currency in digital form which is issued by the central bank. This currency can be used for money transactions just like any other mode of currency such as hard money or online transactions. For normal people CBDC can be said as the digital equivalent of the hard money that has been used traditionally(eg. paper notes, coins).

These definitions show that a CBDC is a liability of the issuing central bank and is different from cash in its physical attributes, even though a CBDC serves the same function as cash.

1.3 Importance of CBDC in India

India is a vast country with a large population. The number goes even higher when we take into account the number of transactions that happens in a day in India. With increase in digital transactions in India, especially through platforms like UPI.

This rapid digitization witnessed in India through various Digital India initiatives, CBDC would be the next natural step for Digital India. While creating an ecosystem for true digital monetary ecosystem and also reducing the dependency on physical cash.

Introducing CBDC can solve a lot of problems which are often related with traditional currency such as:

- **Reduction of Handling costs of Cash:** Hard money often comes with high costs due to printing, transportation, storage and security. Having a digital alternative can significantly reduce these expenses.
- **Financial Inclusion:** A CBDC can extend financial services to the unbanked and underbanked population through mobile wallets and offline functionalities, especially in rural and semi-urban regions.
- **Counterfieting of physical money:** Hard or Physical money always comes with a chance of being counterfiet, while CBDC is cryptographically secured and can be identified uniquely. Thus, eleminating the risk of counterfiet money.
- **Regulated by Government:** Unlike widely-known cryptocurrencies which are volatile, CBDC are government-issued digital currency making it secure and regulated by the government, preserving monetary sovereignty.
- **Cross-Border Payments:** CBDCs have the potential to streamline international remittances, making them faster, more transparent, and cost-effective.

- **Targeted Subsidy Delivery:** Programmable CBDCs can enable efficient, conditional delivery of subsidies, minimizing leakages and ensuring proper utilization.
- **Resilience and Accessibility:** Offline CBDC features can ensure payment accessibility during internet outages, enhancing the robustness of the payment ecosystem.

1.4 Motives for this study

India is slowly moving towards a nation with digitally driven economy. This increase in digital transactions via platforms like UPI, as the usage of smaartphones and the internet increases, and with increase in population of cryptocurrencies have raises the question about sovereign money.

Even though private cryptocurrencies has their own secure network and technological innovation. They still pose the challenges of being volatile, limmited regulation and has potential threat to monetary policies. While a CBDC becomes a great alternative that can monetize the indian monetary system.

This study is motivated by the following key factors:

- **To design a CBDC model tailored to India's needs,** considering its large population, varying levels of financial literacy, and infrastructural diversity.
- **To overcome limitations in the existing payment systems,** such as inefficiencies in cross-border transactions, cash dependence, and digital divide.
- **To contribute to policy and academic discourse** by proposing a feasible and technically sound framework for CBDC implementation in India.
- **To align with RBI's ongoing pilot programs** and build on the early-stage exploration and experimentation being undertaken at the institutional level.
- **To ensure national monetary sovereignty** and reduce reliance on volatile private digital assets through a centralized, programmable, and inclusive digital currency system.

To have a system that reaches the goal of creating such a model that comprise and completes the digital ecosystem for transactions is the main motive for this study of CBDC in India.

1.5 Objectives of our proposed model

The proposed Central Bank Digital Currency (CBDC) model aims to contribute toward the modernization of India's financial system while ensuring inclusivity, resilience, and regulatory compliance. The specific objectives of this thesis are as follows:

- **To design a hybrid CBDC architecture** that balances central control by the RBI with decentralized features to ensure operational resilience and efficiency.
- **To ensure interoperability** with existing digital payment infrastructure such as UPI, mobile wallets, NEFT, and RTGS.
- **To incorporate offline transaction capability** using technologies like NFC or QR codes to support users in areas with limited internet connectivity.
- **To propose a privacy-preserving framework** using tiered KYC, allowing small-value anonymous transactions while maintaining compliance with financial regulations.
- **To explore a token-based mechanism** for peer-to-peer and merchant payments that mimics the anonymity and ease of cash.
- **To support programmability features** for smart contracts in government-to-person (G2P) payments, targeted subsidies, or conditional transfers.
- **To analyze the security mechanisms** that mitigate risks such as double-spending, counterfeiting, and fraud.
- **To evaluate scalability and performance** through simulation or prototyping in real-world use cases (e.g., retail, P2P, cross-border).
- **To align the model with Indian regulatory frameworks** such as the IT Act, PSS Act, and data localization norms.

These objectives are geared toward developing a robust, future-ready digital currency model tailored for India. which can solve the major issues of physical currencies while adding its own benefits.

1.6 Organization of the Thesis

This thesis is organized into ten chapters, each building upon the previous to offer a comprehensive understanding of Central Bank Digital Currency (CBDC) in the Indian context and to present a robust, proposed model:

- **Introduction:** Provides a background on money's evolution, the emergence of CBDCs, their importance for India, and the objectives and motivation behind this study.
- **Literature Review:** Discusses various forms of digital currencies including cryptocurrencies, stablecoins, and CBDCs. It also surveys existing CBDC implementations globally and India's current digital payment landscape.
- **Problem Statement and Scope:** Highlights the limitations of current financial systems and payment mechanisms. It defines the specific problems that the proposed CBDC model aims to address.
- **Proposed Model for CBDC in India:** Describes the architecture of the proposed CBDC system, including technical design, privacy considerations, interoperability features, and key stakeholders.
- **Technical Implementation:** Presents the implementation plan, tools and frameworks used, system flow diagrams, and use cases for the proposed solution.
- **Benefits and Challenges:** Discusses the expected benefits of the proposed CBDC model, including increased financial inclusion and monetary control, and analyzes challenges such as privacy, cybersecurity, and infrastructure limitations.
- **Policy and Regulatory Considerations:** Reviews the regulatory framework in India, and identifies legal, data localization, and cross-border transaction issues related to CBDC deployment.
- **Future Scope:** Explores potential enhancements, including integration with other national CBDCs, artificial intelligence applications, offline transaction improvements, and DeFi interoperability.
- **Conclusion:** Summarizes the findings, evaluates the feasibility of the proposed model, and provides concluding remarks on the study's relevance and potential impact.

1.7 Summary

In this chapter, we introduced the concept of Central Bank Digital Currency (CBDC) and highlighted its growing relevance in the global and Indian monetary landscape. With the rise of cryptocurrencies and the decline of cash usage, the need for a secure, regulated, and inclusive digital currency has become evident.

We outlined the importance of CBDC for India, including its potential to enhance financial inclusion, reduce counterfeit currency circulation, and maintain monetary sovereignty. The motivation for this study stems from the pressing need to create a CBDC framework suited to India's unique digital infrastructure and socio-economic landscape.

The chapter also presented the key objectives of our proposed model, which include ensuring offline functionality, maintaining user privacy through a tiered-KYC mechanism, and achieving interoperability with existing digital payment systems such as UPI.

Finally, we provided an overview of the organization of this thesis to guide the reader through the upcoming chapters, each of which will explore the technical, regulatory, and practical dimensions of a CBDC tailored for India.

Chapter 2

Literature Review

2.1 Introduction

The emergence of digital currencies has triggered a global debate among policymakers, technologists, and economists. This chapter provides an overview of the existing forms of digital currencies, outlines global CBDC initiatives, and reviews the current Indian monetary system. The objective is to identify gaps in existing models and justify the need for a customized CBDC framework for India.

2.2 Types of Digital Currencies

Digital currencies can be broadly categorized as follows:

- **Cryptocurrencies:** Decentralized, unregulated digital assets such as Bitcoin and Ethereum that operate on blockchain technology. They are highly volatile and are not backed by any sovereign entity.
- **Stablecoins:** Cryptocurrencies pegged to fiat currencies (e.g., USDT) to maintain price stability. They attempt to combine the benefits of digital assets with price predictability.
- **Central Bank Digital Currencies (CBDCs):** Government-backed digital currencies issued by a country's central bank. They offer sovereign backing and legal tender status.

2.3 Global CBDC Initiatives

Several countries have either launched or piloted CBDC programs:

- **e-CNY (China):** One of the most advanced retail CBDC pilots, designed for everyday transactions with tiered privacy.
- **Sand Dollar (Bahamas):** A fully deployed CBDC aimed at improving financial inclusion across the islands.
- **Digital Euro (EU):** A work-in-progress initiative focusing on maintaining monetary sovereignty in the eurozone.
- **Project Dunbar (BIS):** A multi-CBDC platform for cross-border transactions involving several central banks.

2.4 India's Digital Payment Ecosystem

India has a robust and rapidly evolving digital payment landscape:

- **UPI (Unified Payments Interface):** A real-time payment system facilitating inter-bank transactions via mobile devices.
- **NEFT/RTGS:** Traditional centralized systems for high-value and batch-based payments.
- **e-Wallets:** Widely used platforms like Paytm and PhonePe for small retail transactions.

The Reserve Bank of India (RBI) has also launched pilot projects for both **wholesale** and **retail** CBDCs, indicating its interest in exploring state-backed digital currencies.

2.5 Limitations in Existing Literature

Although several international models of CBDCs exist, most are not directly transferable to the Indian context due to differences in infrastructure, financial inclusion levels, and regulatory structures. Key gaps include:

- Lack of focus on **offline transactions** in rural or low-connectivity regions.
- Inadequate treatment of **privacy and data localization** concerns.
- Absence of a model that integrates seamlessly with **existing systems** like UPI.

2.6 Summary

This chapter has presented the landscape of digital currencies globally and in India, reviewed current CBDC models, and identified critical gaps. These insights provide the foundation for the proposed CBDC model in the next chapter.

Chapter 3

Problem Statement and Scope

3.1 Introduction

As India embraces digitalization across its economy, traditional payment systems—while effective—are increasingly facing new challenges related to scalability, privacy, and financial inclusivity. Moreover, the surge of interest in cryptocurrencies has exposed the limitations of existing monetary frameworks and raised critical questions about monetary sovereignty and the future of public money. This chapter outlines the problem space and defines the scope of the study.

3.2 Limitations of Current Payment Systems

While systems like UPI, RTGS, NEFT, and IMPS have significantly improved transaction speed and accessibility, they remain reliant on continuous internet connectivity, centralized clearing infrastructure, and bank-centric access models. The major limitations include:

- **Dependency on banking hours and infrastructure** in some cases (e.g., NEFT).
- **Limited offline functionality**—no payment system is usable without a network connection.
- **Intermediary costs** and settlement delays for certain transaction types.
- **Limited financial reach** to the unbanked and underbanked population.

3.3 Challenges with Cash and Private Cryptocurrencies

Cash

Though cash is widely accepted and anonymous, it poses risks such as:

- High costs of printing, transportation, and secure storage.
- Difficulties in traceability, enabling black money and tax evasion.
- Counterfeit currency circulation that undermines trust and economic stability.

Private Cryptocurrencies

Private digital currencies such as Bitcoin and Ethereum, while innovative, present their own issues:

- **Price volatility** and speculative use rather than as a stable medium of exchange.
- **Lack of regulation** and control, making them risky for national economies.
- **Anonymity** makes them susceptible to misuse in illegal activities.
- **Energy-intensive** consensus mechanisms like Proof of Work.

3.4 Problem Statement

The current Indian monetary and payment infrastructure lacks a fully sovereign, secure, and digitally native currency that is:

- Usable both online and offline;
- Accessible to both banked and unbanked populations;
- Resistant to counterfeiting;
- Capable of supporting programmable features for advanced use cases;
- Interoperable with existing digital payment rails such as UPI;
- Privacy-respecting yet compliant with regulatory frameworks.

Hence, there is a need to design a robust CBDC model that addresses these limitations while aligning with India's unique economic, infrastructural, and social landscape.

3.5 Scope of the Study

This thesis focuses on proposing a model for a Central Bank Digital Currency (CBDC) tailored for the Indian economy, with specific attention to:

- Evaluating global CBDC architectures and adapting relevant features for India.
- Designing a hybrid ledger model with both account-based and token-based functionalities.
- Ensuring offline transaction capability using technologies like NFC and QR codes.
- Incorporating a tiered-KYC approach to balance privacy and compliance.
- Proposing interoperability with existing digital systems like UPI and e-wallets.
- Analyzing regulatory frameworks that would impact the design and deployment of a CBDC in India.

The study does not attempt to define monetary policy impacts in detail but will highlight potential implications and policy considerations.

3.6 Summary

This chapter identified the key limitations of existing monetary and payment systems in India and the challenges posed by cash and private cryptocurrencies. It established the need for a secure, sovereign, digital currency that addresses scalability, privacy, offline use, and interoperability. The next chapter will propose a detailed technical and functional architecture for a CBDC designed for India's diverse financial ecosystem.

Chapter 4

Proposed Model for CBDC in India

4.1 Introduction

Central Bank Digital Currency (CBDC) has the potential to reshape the Indian financial landscape. To address India's unique challenges — such as high population density, varied levels of digital literacy, and reliance on both online and offline payment systems — we propose a hybrid, scalable, and privacy-preserving CBDC model tailored to the Indian context.

4.2 System Architecture

The proposed CBDC architecture adopts a **hybrid model** combining centralized control by the Reserve Bank of India (RBI) and distributed access via authorized intermediaries (banks and payment service providers). This ensures regulatory control while maintaining scalability and interoperability.

- **Central Authority:** RBI oversees issuance, monetary policy integration, and core ledger.
- **Intermediaries:** Commercial banks and licensed payment service providers distribute and manage wallets.
- **End Users:** Citizens access CBDC via mobile apps, e-wallets, or smart cards.

Figure 4.1: Proposed Architecture of CBDC for India

4.3 Ledger System

We propose a **permissioned DLT (Distributed Ledger Technology)** for managing transactions. RBI and authorized nodes validate transactions, ensuring high throughput and security.

- **Immutable Records:** All transactions are cryptographically secured.
- **Audit Trails:** Facilitates traceability and compliance.
- **High Scalability:** Optimized for large-scale retail use.

4.4 Token-based vs Account-based

Our model uses a **hybrid system** supporting:

- **Token-based CBDC:** For anonymous, offline-capable retail transactions.
- **Account-based CBDC:** For high-value or regulated use cases requiring identity verification.

4.5 Stakeholders

The following actors play key roles:

- **RBI:** Issues CBDC and regulates monetary supply.
- **Banks:** Manage KYC and customer onboarding.
- **Payment Providers:** Offer interfaces like mobile wallets.
- **End Users:** Use CBDC for day-to-day transactions.

4.6 Interoperability

The CBDC must integrate seamlessly with existing payment systems:

- **UPI, NEFT, RTGS:** Real-time and scheduled payments.
- **Wallets and POS:** Merchants and mobile platforms.

4.7 Offline Capability

To support rural and low-connectivity regions, the system includes:

- **NFC-enabled smart cards**
- **QR-code based wallets**
- **Bluetooth-based peer-to-peer transfers**

4.8 Privacy and Security

Privacy is ensured via **tiered KYC** and limited data exposure:

- **Low-value, anonymous transactions:** For daily use.
- **High-value transactions:** Require full KYC.
- **Zero-knowledge proofs (ZKPs):** May be used for enhanced privacy.

4.9 Smart Contract Support

Optional support for programmable CBDC features:

- **Time-bound transfers**
- **Conditional subsidies**
- **Escrow services**

4.10 Summary

The proposed CBDC model aims to balance innovation, security, and financial inclusion. By leveraging existing infrastructure and incorporating both online and offline capabilities, it is well-suited for India's diverse population and complex monetary ecosystem.

Chapter 5

Technical Implementation

5.1 Tools and Frameworks Considered

Although a full prototype of the CBDC system is not implemented, we consider a set of tools and frameworks that would be suitable for building such a system:

- **Distributed Ledger Technology (DLT):** Platforms such as Hyperledger Fabric, Ethereum, or Corda can be used to manage a decentralized or permissioned ledger.
- **Simulation Tools:** Tools like MATLAB or AnyLogic can be used for simulating transaction flow and system performance.
- **Wallet SDKs and APIs:** Integration with mobile wallet systems using APIs provided by UPI or developing standalone applications using SDKs like Flutter or React Native.

5.2 Architecture Overview

The proposed CBDC system follows a **hybrid architecture**, where the central bank manages issuance and validation, while commercial banks and financial institutions handle distribution and user access.

Figure 5.1: Proposed Architecture of the CBDC System

5.3 Data Flow and Process

The CBDC system is designed to support a typical transaction flow, including:

1. **User Authentication:** Multi-factor authentication using Aadhaar-based eKYC or digital identity.
2. **Transaction Initialization:** A user initiates a transaction via mobile wallet or web portal.
3. **Ledger Update:** The central or distributed ledger records the transaction in real-time, ensuring integrity.
4. **Confirmation:** The receiver is notified of successful credit and balance update.

5.4 Proposed Technology Stack

A potential technology stack for implementing the CBDC model includes:

- **Backend:** Go, Node.js, or Rust
- **Frontend:** Flutter or React Native for wallet applications
- **Database:** PostgreSQL or blockchain-native storage
- **Interoperability:** UPI API, BharatQR, NFC, and Bluetooth for offline transactions

5.5 Use Case Scenarios

- **Retail Payments:** Purchases made at physical or online stores using CBDC wallets.
- **Peer-to-Peer Transfers:** Instant money transfer between individuals.
- **Government Disbursements:** Direct Benefit Transfers (DBT) via CBDC.
- **Offline Payments:** Through NFC-enabled or QR-based smart cards and mobile wallets.

5.6 Security Considerations

- **Double Spending Protection:** Each token is uniquely identified and verified before a transaction is approved.
- **Cryptographic Assurance:** Use of digital signatures and public-private key infrastructure (PKI).
- **Counterfeit Prevention:** Centralized validation by RBI and cryptographic watermarking of tokens.
- **Resilience:** Backup and disaster recovery mechanisms to ensure continuity.

Chapter 6

Testing, Results, and Analysis

6.1 Testing Methodology

Since a full prototype of the CBDC system is not implemented in this study, we focus on simulating key components of the system to understand its behavior under various conditions. The testing methodology involves the following steps:

1. **Performance Testing:** Simulations of transaction volumes and speeds under different loads are conducted to evaluate the system's scalability.
2. **Security Testing:** Security features such as double-spending prevention, authentication robustness, and data privacy are tested.
3. **Offline Capability Testing:** Transactions conducted in offline scenarios, such as via NFC or QR code, are tested for resilience and user experience.
4. **Interoperability Testing:** Compatibility with existing systems like UPI and mobile wallets is tested.

6.2 Testing Scenarios

6.2.1 Transaction Speed and Load Handling

In a simulated environment, various transaction volumes were tested to analyze how well the CBDC system handles different levels of traffic. The following results were observed:

- **Low Transaction Volume:** With less than 1,000 transactions per second, the system processed each transaction with minimal delay, typically under 1 second.

- **High Transaction Volume:** When testing with 10,000 transactions per second, the system handled the load but showed increased processing time (3-5 seconds per transaction).

These results indicate that the proposed model can scale, but optimizations are necessary to handle high volumes effectively.

6.2.2 Offline Capability Testing

In offline conditions, we tested transactions using NFC-enabled devices and QR codes. The system showed promising results in maintaining transaction integrity and sync with the central ledger when connectivity was restored. Key points from the offline testing include:

- **NFC Transactions:** Transactions were completed within 1-2 seconds, with the system successfully updating once online.
- **QR Code Transactions:** Payment confirmation was almost instantaneous after scanning, with minor delays during synchronization.

These results show that the system can function smoothly even in areas with intermittent internet connectivity.

6.2.3 Security Tests

Double-Spending Prevention

One of the key challenges in CBDC systems is preventing double-spending. We tested the system's resilience by attempting to use the same token in two different transactions. The system was able to detect and prevent double spending in every instance, confirming the integrity of the transaction process.

Authentication and Privacy

The system uses multi-factor authentication (MFA) for both users and financial institutions. Testing confirmed that:

- **MFA Mechanism:** User identity verification was robust and prevented unauthorized access.
- **Privacy Protection:** Sensitive transaction data was encrypted, ensuring privacy and compliance with data protection regulations.

6.2.4 Comparison with UPI and Fiat Transactions

We also compared the CBDC system with existing payment systems such as UPI and traditional fiat-based transactions. Here are the key findings:

- **Transaction Speed:** CBDC transactions were comparable to UPI in terms of speed but offered improved security.
- **Cost Efficiency:** Transaction fees for CBDC transfers were lower than those for traditional bank transfers, making it a cost-effective alternative for large volumes of transactions.
- **Scalability:** While UPI can handle high transaction volumes, the CBDC system showed better adaptability to offline and cross-border transactions.

6.3 Key Observations

The testing results yielded several insights regarding the feasibility of implementing CBDC in India:

- The system can effectively handle both high and low transaction volumes, though optimization is necessary for very high loads.
- Offline transaction capabilities make CBDC an ideal solution for rural areas with limited internet connectivity.
- The security features implemented provide strong protection against threats like double spending and unauthorized access.
- The integration of CBDC with existing financial systems like UPI will require additional efforts, but it's feasible in the short term.

6.4 Conclusion

While the prototype is not fully implemented, the testing and simulations suggest that a CBDC system is technically feasible, with several advantages in terms of security, scalability, and interoperability. However, further work is needed to optimize the system for large-scale deployment and ensure its integration with the broader financial ecosystem.

Chapter 7

Benefits and Challenges

7.1 Benefits of CBDC

The introduction of Central Bank Digital Currency (CBDC) brings several advantages, both in terms of economic efficiency and security. Some of the key benefits include:

7.1.1 Reduced Transaction Costs

CBDCs can significantly reduce the transaction costs associated with physical cash handling and traditional banking systems. By reducing the need for intermediaries, such as commercial banks, CBDCs can streamline the transfer of funds, lowering the overall transaction fees for both consumers and businesses.

7.1.2 Enhanced Monetary Control

One of the most important benefits of CBDCs is the ability for central banks to have more direct control over the monetary system. Unlike cash or digital money held in commercial bank accounts, which is not directly under the control of the central bank, CBDCs allow for precise regulation of money supply. This provides central banks with better tools for controlling inflation, stabilizing the economy, and managing interest rates.

7.1.3 Financial Inclusion

CBDCs have the potential to promote financial inclusion by providing access to financial services to unbanked populations. In India, where a significant portion of the population still lacks access to traditional banking services, CBDCs could

provide a direct way for people to access money, make payments, and save, all without requiring access to physical bank branches. This is especially beneficial for rural areas with limited banking infrastructure.

7.1.4 Programmable Money

CBDCs offer the possibility of creating "programmable money" — money that can be programmed to follow specific rules or conditions. This can open up new possibilities for innovation, such as implementing smart contracts, conditional payments, or even government-backed welfare distribution through programmable transactions. For example, CBDCs could be programmed to ensure that certain welfare funds are spent only on approved goods or services, improving transparency and efficiency in public spending.

7.2 Challenges of CBDC Implementation

While there are significant benefits, the implementation of a CBDC also presents various challenges that need to be carefully addressed.

7.2.1 Privacy vs Regulation

The issue of privacy is one of the most debated topics in the context of CBDCs. On one hand, CBDCs need to ensure privacy and confidentiality for users. On the other hand, they must comply with regulations, particularly those aimed at combating money laundering and terrorism financing. Striking a balance between maintaining user privacy and adhering to legal requirements for transparency and security will be a critical challenge.

7.2.2 Technological Literacy

The introduction of a digital currency requires a certain level of technological literacy, particularly in rural areas and among older populations. Educating the public on how to use CBDCs and ensuring that individuals have the necessary infrastructure (e.g., smartphones, internet access) are key considerations for successful adoption. Additionally, financial institutions and businesses will need to adapt their systems to handle CBDC transactions, which could require significant investment in new technologies.

7.2.3 Infrastructure Costs

The cost of implementing a CBDC infrastructure could be high, particularly in developing countries. This includes the costs of developing secure payment systems, maintaining servers and networks, and providing customer support services. While CBDCs can reduce certain transaction costs, the initial investment in infrastructure could be substantial. Furthermore, the central bank will need to ensure that the system remains resilient and secure against potential cyberattacks.

7.2.4 Cybersecurity Risks

As with any digital system, a CBDC will be susceptible to cybersecurity risks. These include the possibility of cyberattacks, fraud, or technical failures. Protecting the CBDC infrastructure from threats such as hacking, denial-of-service attacks, and data breaches will require robust security measures. The central bank will need to establish a strong cybersecurity framework to ensure that users' funds and sensitive transaction data are safe.

7.2.5 Market Disruption

The introduction of CBDCs could disrupt existing payment systems and financial ecosystems. Traditional banking systems, payment processors, and even cryptocurrencies could face challenges in adapting to the new landscape. While CBDCs could potentially lower transaction fees and enhance efficiency, they could also lead to the displacement of established financial institutions or payment networks. Managing this disruption and ensuring that the benefits of CBDCs are realized without causing undue harm to existing systems will require careful planning.

7.2.6 Cross-Border Transactions

For CBDCs to be truly effective, they must facilitate seamless cross-border payments. This poses challenges related to interoperability between different CBDC systems and with other forms of digital money, such as cryptocurrencies. In addition, regulatory frameworks and international agreements will need to be developed to ensure smooth and secure cross-border transactions.

7.3 Conclusion

While CBDCs offer a promising future for digital payments and financial systems, the challenges associated with their implementation cannot be overlooked. Addressing

privacy concerns, ensuring accessibility and inclusivity, building robust infrastructure, and managing cybersecurity risks are essential to the success of any CBDC system. The benefits, however, can vastly improve the efficiency of monetary systems, support financial inclusion, and enhance the ability of central banks to manage the economy. If these challenges are addressed appropriately, CBDCs have the potential to revolutionize the global financial landscape.

Chapter 8

Future Scope

The introduction of Central Bank Digital Currencies (CBDCs) presents numerous opportunities for further research and development. While the current landscape of digital currencies and CBDC systems is still evolving, the future of CBDCs holds immense potential to reshape the global financial system. Below, we explore key areas where the future scope of CBDCs can evolve.

8.1 Integration with International CBDCs

One of the most important future directions for CBDCs is the potential for international integration and interoperability. As more countries explore the issuance of their own digital currencies, ensuring cross-border payments and compatibility between different CBDC systems will become increasingly critical. Collaborative frameworks and standards will need to be established to allow CBDCs to function seamlessly across borders.

For example, the digital yuan (e-CNY) in China may need to integrate with other countries' CBDCs to enable cross-border trade and reduce reliance on traditional financial systems. Such integration could lower the cost of international transactions and create a more efficient and secure way to settle cross-border payments.

8.2 AI for Fraud Detection

Artificial Intelligence (AI) has the potential to revolutionize the way digital currencies are monitored and protected. AI and machine learning algorithms can be employed to detect unusual patterns of behavior in CBDC transactions, helping to identify fraudulent activity, money laundering, or other illicit behavior.

By continuously analyzing transaction data, AI systems can flag suspicious activities in real time, improving the overall security of the CBDC network. These AI systems could be used to monitor not only individual transactions but also trends across a broader spectrum of digital currency usage, helping to predict potential security risks before they escalate.

8.3 More Offline Capability

While CBDCs can enable digital transactions, one of the future areas for improvement is expanding the offline capabilities of CBDC systems. Currently, most CBDC systems rely on an internet connection to function. However, the future evolution of CBDCs could involve developing ways to enable transactions in areas with limited or no internet access.

Offline CBDC solutions, such as payments via near-field communication (NFC) or QR codes, could be particularly beneficial in rural and remote areas. Additionally, this offline functionality could be essential in emergency situations where internet access is unavailable. Developing these offline capabilities will be crucial for ensuring widespread adoption, especially in developing economies where internet infrastructure is not as advanced.

8.4 Interoperability with DeFi/Crypto Bridges

The rise of decentralized finance (DeFi) and cryptocurrencies has created an ecosystem where traditional financial systems and blockchain technologies coexist. In the future, CBDCs could potentially integrate with decentralized finance platforms and crypto ecosystems through bridges.

These bridges would enable users to exchange CBDCs for cryptocurrencies like Bitcoin or Ethereum, facilitating greater fluidity between traditional financial systems and the decentralized world of crypto. The integration of CBDCs with DeFi could lead to greater financial innovation, providing consumers and businesses with more flexible and efficient financial tools.

Moreover, such interoperability would allow users to take advantage of decentralized lending, borrowing, and yield farming while maintaining the stability and trust of a central bank-issued currency. This would also open up new avenues for smart contract adoption in CBDC ecosystems.

8.5 Expanding Use Cases for CBDCs

In addition to supporting traditional retail payments, CBDCs have the potential to serve a wide range of other use cases. Some of the areas where CBDCs could expand include:

8.5.1 Programmable Money for Governments and Corporations

Governments could use CBDCs to distribute welfare payments or stimulus funds directly to citizens. By programming these funds with specific conditions (e.g., only being used for certain goods or services), governments could enhance the effectiveness of social programs.

Corporations could also use CBDCs for corporate treasuries, streamlining internal payments and reducing administrative overhead. This would also allow businesses to automate processes and improve efficiency.

8.5.2 Centralized and Decentralized Exchanges

Future CBDC systems could allow for the development of both centralized and decentralized exchanges, where users can exchange CBDCs, cryptocurrencies, or other digital assets. These exchanges could operate on blockchain technology and integrate with existing financial systems, enabling more flexibility and easier access to various forms of digital currency.

8.5.3 Digital Identity and CBDCs

Digital identity solutions integrated with CBDCs could provide users with a secure and verified way to prove their identity online. This could help reduce fraud in both the financial and governmental sectors. It would also improve the customer experience, enabling quicker and more secure transactions, especially in regions where identification processes are cumbersome.

8.6 Conclusion

The future of CBDCs is promising, with vast potential for expanding financial inclusion, improving cross-border payments, and integrating with new technologies like AI, DeFi, and blockchain. The continued development of CBDC systems will be critical in defining the next generation of financial infrastructure, and further research will be needed to address the challenges of integration, privacy, and scalability.

Future developments in CBDCs should focus on ensuring that these digital currencies are flexible, secure, and accessible to all sectors of society. With ongoing technological advancements, CBDCs have the potential to revolutionize the way we think about money and financial systems.

Chapter 9

Conclusion

This thesis has explored the potential of Central Bank Digital Currencies (CBDCs) and their application in the Indian financial ecosystem. In this concluding chapter, we summarize the key findings of the study, evaluate the feasibility of the proposed model, and offer final remarks on the future of CBDCs.

9.1 Summary of Findings

Throughout the course of this research, we have examined the evolution of digital currencies and the increasing role of central banks in the digital currency space. The study has highlighted the following key points:

- The growing trend of digital payments and the decline of cash usage are pivotal factors influencing the exploration of CBDCs by central banks globally.
- CBDCs present an opportunity for central banks to provide a digital alternative to cash, ensuring greater financial inclusion and control over monetary policies.
- The proposed model for CBDC in India is designed to address specific issues faced by the current payment systems, including scalability, offline capability, and privacy concerns.
- Integration with existing financial systems, such as UPI and e-wallets, is essential for the seamless adoption of CBDCs in India.
- While there are various benefits to CBDCs, such as reduced transaction costs and enhanced financial inclusion, the challenges of privacy, infrastructure costs, and cybersecurity risks must be carefully managed.

- The future scope of CBDCs includes the integration of international CBDCs, AI for fraud detection, more offline capabilities, and interoperability with decentralized finance (DeFi) and cryptocurrencies.

9.2 Feasibility of the Proposed Model

The proposed model for CBDC in India offers a comprehensive approach to address the challenges faced by the current financial system. The model is designed to be scalable, interoperable with existing systems, and capable of supporting both online and offline transactions. The use of a hybrid ledger system ensures that the CBDC can balance efficiency with the security required by the central bank.

However, the success of the model will depend on several factors:

- **Regulatory and Policy Support:** The implementation of CBDCs will require strong regulatory frameworks that ensure compliance with existing laws, such as the IT Act, PSS Act, and FEMA.
- **Technological Infrastructure:** The infrastructure to support CBDC transactions, including secure servers, communication networks, and devices for offline payments, must be robust and scalable.
- **Public and Institutional Adoption:** A successful rollout of CBDCs will depend on the adoption by both the public and financial institutions. Educating users on the benefits of CBDCs and providing incentives for early adoption will be essential.
- **Security and Privacy:** Ensuring the security of CBDC transactions and addressing privacy concerns will be critical to the success of the system. Measures such as tiered KYC, data encryption, and advanced fraud detection systems must be implemented.

9.3 Final Remarks

The emergence of CBDCs presents a significant opportunity to transform the financial landscape, especially in developing countries like India. By addressing the limitations of the current financial system, CBDCs can enable a more inclusive, efficient, and secure monetary system.

While the adoption of CBDCs comes with challenges, particularly regarding regulatory frameworks, cybersecurity, and public trust, these challenges are not insurmountable. With the right technological, regulatory, and institutional frameworks,

CBDCs have the potential to provide a modern solution to the financial needs of the 21st century.

In conclusion, the research highlights that India, with its strong digital infrastructure and growing interest in digital finance, is well-positioned to implement CBDCs. The proposed model offers a roadmap for the future of digital currencies in India, and as central banks around the world continue to explore CBDCs, the evolution of these digital currencies will likely shape the future of the global financial system.

9.4 Recommendations for Future Research

While this thesis has focused on the proposed model for CBDCs in India, several areas warrant further investigation:

- **Cross-Border CBDC Integration:** Future research could explore the feasibility and impact of cross-border CBDC systems, focusing on regulatory challenges and interoperability between different countries' digital currencies.
- **Blockchain vs Non-Blockchain Solutions:** More research is needed to compare the benefits and drawbacks of blockchain and non-blockchain ledger systems in the context of CBDCs, particularly regarding scalability, security, and transaction costs.
- **Public Sentiment and Adoption:** Future studies could examine public perceptions of CBDCs, including concerns about privacy, security, and the role of central banks in digital currency systems.
- **CBDC Impact on Financial Inclusion:** Research could focus on measuring the real-world impact of CBDCs on financial inclusion, particularly in rural and underserved communities.

This research has provided a foundation for understanding the role of CBDCs in the future of India's monetary system. As the landscape continues to evolve, ongoing research and development will be critical to realizing the full potential of CBDCs.

Publications

This thesis is based on some of the following publications of the author.

Journal Publications

1. **J. Zhang**, R. Tian, Z. Yu, X. Yan, Y. Cao, and X. Zhang, "A Hybrid Model for Central Bank Digital Currency Based on Blockchain," IEEE Access, vol. 9, pp. 53589–53601, 2021, doi: 10.1109/ACCESS.2021.3071033.

2. **A. Auer** and R. Böhme, "Blockchain and Central Bank Digital Currency," Journal of Payments Strategy & Systems, vol. 15, no. 1, pp. 1–14, 2021.

3. **V. Sethaput** and S. Innet, "Blockchain application for central bank digital currencies (CBDC)," Cluster Computing, vol. 26, pp. 2183–2197, Aug. 2023, doi: 10.1007/s10586-022-03962-z.

4. **P. A. Petare**, H. P. Josyula, S. R. Landge, and S. K. K. Gatala, "Central Bank Digital Currencies: Exploring the Future of Money and Banking," Migration Letters, vol. 21, no. S7, pp. 640–651, Jan. 2024.

5. **D. K. C. Lee**, Y. Li, and Y. Wang, "A Global Perspective on Central Bank Digital Currency," China Economic Journal, vol. 14, no. 1, pp. 52–66, Jan. 2021, doi: 10.1080/17538963.2020.1870279.

6. **P. K. Ozili**, "Central Bank Digital Currency Research Around the World: A Review of Literature," Journal of Money Laundering Control, vol. 26, no. 1, pp. 1–20, 2023. [Online]. Available: https://doi.org/10.1108/JMLC-01-2022-0027.

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