# A FRAMEWORK FOR ENTERPRISE BLOCKCHAIN FAULT TOLERANCE WITH STATE MACHINE REPLICATION

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**A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE (M.SC) DEGREE IN COMPUTER SCIENCE DEPARTMENT, DEPARTMENT OF COMPUTER AND INFORMATION SCIENCES, COLLEGE OF SCIENCE AND TECHNOLOGY, COVENANT UNIVERSITY, OTA, OGUN STATE, NIGERIA**

**DECEMBER, 2022**

# ACCEPTANCE

This is to attest that this dissertation is accepted in partial fulfilment of the requirements for the award of the degree of Master of Science in Computer Science in the Department of Computer and Information Systems, College of Science and Technology, Covenant University, Ota, Nigeria.

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# DECLARATION

I, **IKOH, OBARO BENEDICT (20PCG02180)** declare that this research was carried out by me under the supervision of Dr. Iheanetu U. Olamma of the Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria. I attest that this dissertation has not been presented either wholly or partially for the award of any degree elsewhere. All sources of data, scholarly information used in this dissertation are duly acknowledged.

**IKOH, OBARO BENEDICT**

**Signature and Date**

# CERTIFICATION

We certify that this dissertation titled "**A FRAMEWORK FOR ENTERPRISE BLOCKCHAIN FAULT TOLERANCE WITH STATE MACHINE REPLICATION**" is an original research carried out by **IKOH, OBARO BENEDICT (20PCG02180)** in the Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria under the supervision of Dr. Iheanetu U. Olamma. We have examined and found this work acceptable as part of the requirements for the award of Master of Science (M.Sc.) in Computer Science.

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**(External Examiner)** **Signature and Date**

**Prof. Akan B. Williams**
**(Dean, School of Postgraduate Studies)** **Signature and Date**

# DEDICATION

I dedicate this dissertation to the Almighty God unreservedly.

# ACKNOWLEDGEMENTS

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AI | Artificial Intelligence |
| BFT | Byzantine Fault Tolerance |
| CFT | Crash Fault-Tolerant |
| CPU | Central Processing Unit |
| DAC | Decentralized Autonomous Corporation |
| DAG | Directed Acyclic Graph |
| DAO | Decentralized Autonomous Organization |
| DApp | Decentralized Application |
| DBFT | Delegated Byzantine Fault Tolerance |
| DDoS | Distributed Denial of Service |
| DLT | Distributed Ledger Technology |
| DoS | Denial-of-Service |
| DR | Disaster Recovery |
| EBDF | Enterprise Blockchain Design Framework |
| FBA | Federated Byzantine Agreement |
| FBFT | Federated Byzantine Fault Tolerance |
| FSM | Finite State Machine |
| GPU | Graphics Processing Unit |
| HPE | Hewlett Packard Enterprise |
| hOCBS | hybrid Off-Chain Blockchain Systems |
| IBM | International Business Machines |
| IT | Information Technology |
| IoT | Internet of Things |
| NEM | New Economic Movement |
| NONCE | Number used ONCE |
| O & M | Operation and Maintenance |
| P2P | Peer-to-Peer |
| PBFT | Practical Byzantine Fault Tolerance |
| PoET | Proof-of-Elapsed-Time |

| | |
|---|---|
| PPCA | Point-to-Point Channel Authentication |
| PoI | Proof-of-Importance |
| PoL | Proof-of-Location |
| PoS | Proof-of-Stake |
| PoW | Proof-of-Work |
| PPCA | Point-to-Point Channel Authentication |
| RAM | Random Access Memory |
| RDMA | Remote Direct Memory Access |
| RSM | Replicated State Machine |
| SAP | Systems Applications and Products |
| SC | Smart Contract |
| SCADA | Supervisory Control and Data Acquisition |
| SMR | State Machine Replication |
| SSD | Solid State Drive |
| TPS | Transactions Per Second |
| UCLA | University of California, Los Angeles |
| VM | Virtual Machine |

# ABSTRACT

Enterprise blockchain is a decentralized system which has become critical to maintaining continuous operation and maximising value for private blockchain networks across industries. This study aims to design a distributed state replicated machine with multiple replicas for fault tolerance in enterprise blockchain. The proposed framework will be based on a threat and node model, with various replicas and an authenticated point-to-point channel that ensures the network's resilience if some of its nodes crash or fail and the ability to recover from this failure. It also presents fundamental concepts of blockchain and fault tolerance algorithms and a critical review of existing approaches to implementing and evaluating fault tolerance for enterprise blockchain technology. The study provides validation of the implemented framework by testing the network's ability and reliability to detect faults, restore crash nodes and re-adding them to the network.

The findings show that it takes around 0.114 seconds for the first node to join the network, while the worst-case scenario for any node to join the network is around 0.119 seconds. The result of the implemented framework also shows that it requires 2 seconds to detect an attempted crash, and after crashing or wiping out all the Nodes in the network, it takes an additional 13 seconds to reestablish a new node. After that, the restored Nodes are ready in 50 seconds. Based on these findings, it can be concluded that no matter how many crash nodes there are, the network cannot go down for longer than 50 seconds and all network defects can be detected in 2 seconds or less.

***Keywords: Consensus Algorithm, Enterprise Blockchain, Fault Tolerance, Hyperledger, Replica Algorithm, State Machine Replication***