ISSN: 3007-3391

Journal of Computers and Intelligent Systems
Vol. 3, No. 3, 2025, pages 234 - 243
Journal Homepage:
https://journals.iub.edu.pk/index.php/JCIS/

Optimizing Blockchain Scalability: Enhancing Consensus Mechanisms with Nodetovector Algorithms

Muhammad Ameen[1], Engr. Muhammad Akram Khan[2], Dr. Bakhtiar Khan Kasi[3], Dr. Jan Muhammad[4]

[1]Student, Balochistan University of Information Technology, Engineering and Management Sciences
[2]Lecturer, Dept of Computer Engg., Balochistan University of Information Technology, Engineering and Management Sciences
[3]Professor, Dept of Computer Engg., Balochistan University of Information Technology, Engineering and Management Sciences
[4]Professor, Dept of Computer Engg., Balochistan University of Information Technology, Engineering and Management Sciences

ARTICLE INFO

Article History:

Received:	May	05, 2025
Revised:	August	10, 2025
Accepted:	August	30, 2025
Available Online:	Month	30, 2025

Keywords:

Blockchain
Scalability
TensorFlow
Node2Vec embeddings

Classification Codes:

Funding:

This research received no specific grant from any funding agency in the public or not-for-profit sector.

ABSTRACT

Blockchain technology has transformed multiple industries through decentralized and secure data management. Despite these advantages, scalability remains a major challenge as networks grow in size and complexity. This study explores the integration of TensorFlow with Node2Vec embeddings to optimize consensus mechanisms and improve blockchain scalability. Using the Hyperledger Fabric framework, experiments were conducted to evaluate system performance across key metrics, including block size, timeout, arrival rate, and probability of timeout. The analysis identified significant variability and patterns relevant for machine learning–based modeling. Results demonstrate that the proposed model, incorporating embeddings and Principal Component Analysis (PCA) for feature reduction and visualization, outperforms traditional Linear Regression, achieving a lower Mean Squared Error (MSE) of 0.0341 compared to 0.0658. These findings highlight the potential of AI-driven techniques to address scalability limitations in blockchain networks. The study contributes to advancing blockchain analytics by demonstrating how the integration of machine learning models with graph embeddings can enhance network efficiency and scalability, thereby bridging the gap between theoretical approaches and practical innovation in decentralized systems.

1. Introduction

As a part of the digital ecosystem, blockchain technologies have rapidly evolved to incorporate various principles of decentralization, data security, and data integrity. Blockchain's capability to conduct trustless transactions using distributed ledgers has applications that impact virtually all aspects of society with the most potential in finance, healthcare, supply chain, and identity verification. Overall, blockchain technologies are promising regarding trustless transparency, immutability, and lack of centralized authority. At the same time, and as an extension of this promise, as a blockchain develops in terms of users, transactions, and applications, it is going to encounter an unprecedented and ongoing issue, namely, scalability. The ability for a blockchain ecosystem to process significant transactions and reproducibility (often referred to as finality) with more significant loads is the choke point for widespread adoption of blockchains with enterprise solutions. The issue is particularly relevant to permissioned blockchains where consensus protocols, such as practical Byzantine fault tolerance (PBFT), for example, are designed to work efficiently under known trusted conditions but do not offer the same or improved performance as the number of nodes scales beyond those parameters. [1]

Consensus mechanisms are an essential part of blockchain systems, allowing distributed nodes to come to agreement on the state of the ledger. Standard algorithms, such as Proof of Work (PoW) and Proof of Stake (PoS), have been effective in the public blockchain domain, but lack the energy efficiency or scalability in a permissioned environment. The PBFT algorithm that Hyperledger Fabric provides, while having some fault tolerance and a faster time to finality, also has exponential communication overhead as the network size increases [1], [2]. As we see blockchain-based systems integrated within more complex infrastructures, the limitations of these consensus mechanisms are bringing forward critical issues. Increasing the scalability and efficiency of these systems will no longer be an option, it will be a requirement to unlock blockchain's full potential across industry domains.

Addressing these challenges will necessitate innovative solutions that go beyond traditional rule-based algorithms, and in fact leverage the adaptive features of AI. We saw, particularly over the last couple of years, a trend by the academic community to study machine learning and graph-based representation learning as a means to enhance the capabilities of blockchain. An example of a recent method described in the literature is Node2Vec, which is a graph embedding algorithm that generates continuous feature representations of the nodes in the network, and has the potential to be a disruptive technology [3]. Node2Vec was designed to be used for tasks such as link prediction and community detection. It allows you to diverge complicated network topologies into structured datasets that can be used by machine learning algorithms. This paper investigates how Node2Vec can be used in the consensus mechanisms of Hyperledger Fabric and is the beginning of applying data-driven decision making in blockchain systems.

This study is motivated by the need for solutions to the current limitations of scalability in blockchain while taking advantage of the anticipatory abilities of artificial intelligence. This study suggests the combination of Node2vec embeddings with TensoFlow one of the most widely used ML frameworks- in order to enhance Consensus Algorithms by improving efficiency, reducing latency, and increasing throughput in Blockchains. The integration would allow the implemented system to model node relationships more accurately and provide predictive inference of the performance characteristics of the Network under changing contextual variables. This study seeks to do more than simply increase capacity for transactions, but to develop a smarter more adaptive consensus mechanism capable of dynamically responding to changes in state, resources, and load of transactions.

The presented research adds to the interdisciplinary progression of the blockchain ecosystem, uniquely implementing AI and network representation learning in a highly scalable and efficient solution to a cognizable existing problem. Previous attempts to improve consensus have typically contingent on either modification to the underlying protocols on which consensus is based or tuning the corresponding parameters of the network, while this study proposes a optimization layer leveraging machine learning to inform data streams from both historical and real-time sources. Within the presented research, the TensorFlow-based model vastly outperforms a linear regression-based model and also has a lower Mean Squared Error (MSE). The training of the TensorFlow-based model incorporates key performance indicators pertaining to block size, transaction arrival illumination, and timeout probability, which can emphasize representation of complicated nonlinear relationships that are not traditionally established by regression. Improvements are particularly salient in the real world application of blockchain given that as the performance predictor has improved, the stability of the blockchain network along with the improved user experience from faster transaction processing and block confirmations should each be better.

In Conclusion, this study introduces a transformative approach for improving scalability in blockchain networks through optimizing consensus methods based on artificial intelligence and graph embeddings. The approach leverages Node2Vec and TensorFlow for the Hyperledger Fabric framework and demonstrates a theoretical grounding and an applied applicability to the approach. The study proposes a pathway that advances the ability to build more intelligent, scalable and adaptive blockchain systems to deal with the dynamic challenges and demands in complex digital ecosystems.

2. Related Work

The research presented by Sukhwani et al in [1], concerns the study of performance of the Practical Byzantine Fault Tolerance (PBFT) consensus scheme in networking contexts concerning frameworks like Hyperledger Fabric. The significance of this source lies in the contribution to the depiction of PBFT as a consensus scheme for networks. Given that the present research describes the enhancement of consensus schemes for Hyperledger Fabric, a used permissioned framework in business contexts, Sukhwani's research provides an important grounding view. The most interesting relevant providing an important grounding viewpoint. The most interesting relevant point to this paper is the performance model of PBFT consensus scheme. The performance model works as an internal benchmark to help measure consensus schemes that closely related to performance, efficiency, and scalability per the scope of the project. The conclusions from Sukhwani et al, [1], will help guide research objectives for this research, to address issues and enhancements for consensus schemes in authorized blockchains. Overall, these contexts enrich the study, expand knowledge of PBFT, and use of PBFT consensus schemes in permissioned networks. It is also worth commenting that the element of the research, that I would not be a foundational theory, they do offer a practical performance model for assessing consensus schemes, which is key to achieving the research objectives. The significance of this reference lies in its alignment with the project’s scope and its potential to inform and enhance the application of Node2Vec algorithms as proposed in this study.

Mingxiao et al [2] presented a comprehensive analysis of consensus algorithms in the technology space, providing an important contribution to our understanding of this developing area. This is important for the project as it investigates the optimization of consensus mechanisms and scalability as objectives of this project. This paper aims to provide an overview of several consensus mechanisms used within the blockchain technology space to optimize consensus mechanisms in permissioned blockchain systems such as Hyperledger Fabric. This literature review serves as a reference to help understand optimization approaches for blockchain systems. By exploring consensus algorithms as well as articulating their merits, demerits, and potential applications, Mingxiao's work contributes to enriching the knowledge in the area of consensus algorithms in the blockchain domain. This literature does not synthesize existing literature to add to the base of knowledge in the area. This literature expands upon our views on consensus mechanisms in blockchain technology while influencing the construction and evaluation of node-to-vector algorithms proposed as part of the project. Additionally, the aspect of the paper promotes cross review of the literature and assists in meeting this project's goal of improving consensus mechanisms and scalability within blockchain frameworks through the duality of existing knowledge of algorithms.

The research by A. Grover and J. Leskovecs [3] emphasizes the importance of the Node2vec paradigm on network feature learning representation. Although it is not focused on blockchain or Hyperledger Fabric per se, Node2vec does propose an approach to representation learning of networks which can be applied to enhance consensus and scalability challenges, specifically for permissioned blockchains. The research does address investigating and applying the concepts proposed to network feature learning. The research primarily focused on consensus, however, Node2vec does provide an avenue to leverage network representation learning to potentially improve Hyperledger Fabric's consensus process. The research introduces Node2vec as a meaningful contribution that learns features representations of nodes in a network. It accomplishes this by observing the neighborhood of the network and permitting researchers to construct node embeddings. This method is very flexible across a range of methodologies. Therefore, this approach, and the multiple objectives in which Node2vec can be compiled in, provides another useful avenue to develop consensus through learning embeddings of networks features. This analysis enhances the current project significantly as the study develops and examines Node2vec and its role and responsibility to act as one approach to network feature learning. Again, while its influence accurately improves technology, resilience, and achieving processes in networks, its contribution to blockchain technology is a far reaching idea when examining scalability and consensus.

Tanwar et. al [4] examined the challenges and solutions surrounding the integration of machine learning into applications based on technology. This source is particularly useful for the present study because it analyzes how machine learning can be applied in blockchain while adhering to the focus of the proposal to integrate AI algorithm's into developing consensus mechanisms. The purpose of this publication is to present the challenges of integrating machine learning into applications based on technology and recommend ways in which to more holistically address these challenges. By utilizing AI algorithms to enhance consensus mechanisms, this study informs the reader of challenges while providing recommendations through the information in this journal article. All in all, one unique and informative feature of this article is its report on the challenges of integrating machine learning into blockchain based applications, sharing informative information to support the studies focus on optimizing consensus mechanisms in Hyperledger Fabric with AI algorithm's in identifying obstacles and making recommendations. This source greatly enhances the project by offering perspectives on the obstacles and possible remedies linked to incorporating machine learning, in applications based on blockchain technology. The information obtained from this paper contributes to the projects objective of enhancing consensus mechanisms by utilizing AI algorithms.

In their work on resource management in networks, Yang et. al [5], have significantly progressed our project and examined the use of resources in Hyperledger Fabric as a variable to meet project outcomes. Yang et al examined resource considerations regarding consensus algorithms focused on scalability, and performance, in the Hyperledger Fabric framework. The value of this research rests in examining the resource performance implications of consensus algorithms as it adds value to understanding the trade-offs, and trade-offs considerations that are needed to improve core consensus mechanisms within Hyperledger Fabric. A commendable aspect of the research is their examination of resource use in which, they also identify considerations regarding eventual impacts of the consensus algorithms such as power use, network bandwidth requirements, and storage considerations across consensus algorithms. This was applied research that informed the direction of our project research to consensus mechanisms. The approaches and findings of Yang et. al, provided significant input into the objectives of our project, by carefully considering how consensus algorithms usage will affect the use of resources in the Hyperledger Fabric environment, as well as the inputs providing a real-world lens into resources use in blockchain consensus algorithms in Hyperledger Fabric. The paper clarifies specific aspects of resource usage that are useful in guiding our projects objectives around consensus mechanisms, as well as contributing to the optimization of consensus mechanisms in permissioned blockchain networks.

Thakkar et al. [6]'s study offers valuable capabilities to the project through its aim to investigate and improve the performance of Hyperledger Fabric blockchain platform, which complement the research objectives of improving the consensus mechanisms and scalability. This work is significant in nature, because it studies some performance metrics and characteristics (e.g., transaction speeds for different transaction scenarios) related to the widely accepted permissioned blockchain framework, Hyperledger Fabric. Additionally, and in the spirit, of studying consensus optimization mechanisms from within the context of the paper that studies Hyperledger Fabric, builds a comprehensive overview of practical challenges for achieving performance improvement around a Hyperledger Fabric blockchain system's consensus approaches. An additional consideration, that is particularly valuable, to the study is the performance measurements the paper studied, that examine many performance scenarios (transaction speed, latency, and, resource use, etc.) across Hyperledger Fabric. This empirical research is particularly valuable to the project, because the authors provide specific benchmarks and performance improvement mechanisms, that could directly influence the proposed node to vector algorithm improvement that is added to the original performance benchmarks study for Hyperledger Fabric blockchain technology. Overall, the paper describes current best practices for overcoming real world challenges and possible solutions for the improvement of consensus mechanisms and scalability in Hyperledger Fabric.

Wang et al [7] enhances the project by exploring the topic of data collection in the context of the Hyperledger Fabric framework, relating to the project objectives of improving consensus mechanisms and scalability. This work is important because it discusses aspects of managing data, a component of permissioned blockchain networks. As the project has focused on improving consensus mechanisms and scalability of these processes, the original research adds valuable insights into improving the challenges involved in dealing with data in Hyperledger Fabric. The original research offers original research contributions by looking at the techniques and factors involved in data management in Hyperledger Fabric environments. Data security, privacy and confidentiality are the factors considered significant for businesses using permissioned blockchains, and discusses, within the research. The project can use this research analysis to better understand how private data management can affect consensus, to help inform the development of private and robust algorithms for node to vector exchanges. This resource adds to the projects understanding related to barriers of data collection in Hyperledger Fabric. This research provides an overview to facilitate the managing of information, directly aligned with the objectives of the project, again improving consensus mechanisms, and providing scalability for the process.

Androulaki, et. al [8] offers an overview of Hyperledger Fabric, a prominent permissioned blockchain framework. It discusses the architecture, features, and design principles of Hyperledger Fabric in order to improve upon the consensus mechanisms, and scalability of Hyperledger Fabric. The focus of the corpus is to understanding Hyperledger Fabric as a whole in reference to permissioned blockchains. The aim of the research project is to use the discovery from this research project to make improvements to the consensus mechanisms baked into Hyperledger Fabric. It discusses various aspects of Hyperledger Fabric, such as membership services, ordering services, and smart contracts to provide clarity on the structures and mechanisms in which the node to vector algorithms will operate when applied in reality. Moreover, this resource provides clarity to the project scope by offering an exploration of Hyperledger Fabric as a resource for better understanding the various workings of a permissioned blockchain structure. The enlightenment offered by this resource will allow for the developing, implementation, and evaluation of the proposed node to vector algorithms in a very efficient manner.

C. Gorenflo, et. al [9] present the FastFabric framework, focusing on its potential to dramatically improve transaction processing speeds of Hyperledger Fabric. This work matters because it suggests scalability solutions for Hyperledger Fabric in line with enhancing consensus mechanisms and scalability, the essential facets of this whole effort. This reference explores how FastFabric improves Hyperledger Fabric's transaction processing efficiency, offering potential improvements to transaction throughput in any permissioned network. Development of FastFabric as a scalability solution for Hyperledger Fabric is one part of this research project. Gorenflo's research discusses the detail and optimizations that allows for the described throughput of 20,000 transactions per second. The project will benefit from this research because it will help guide the optimization of consensus methods to achieve better scalability. The efficiencies FastFabric introduces, and its overall impact on scaling Hyperledger Fabric, will add considerably to this project. This research adds considerably to the resources already referenced to improve throughput.

Barger et al [10] discusses the design of a Byzantine Fault Tolerant (BFT) consensus library for Hyperledger Fabric and its relevance in enhancing the project and its consensus mechanisms. The primary focus of this study is the assessment of whether a customized Byzantine Fault Tolerant consensus library can strengthen fault tolerance in Hyperledger Fabric, while aligning closely with the project goal of refining consensus protocols for permissioned blockchains. Contributions include the successful design and assessment of this consensus library for strengthening fault tolerance of Hyperledger Fabric and implications to mitigate faults and improve consensus methods for increasing scalability, a primary goal of the project. The results presented in this study provide implications for improving consensus mechanisms relative to the project objective.

Hao et al [11] presents a helpful research performance evaluation of consensus methods in an environment. The relevance of this paper to the project is its evaluation of the efficiency of consensus algorithms overall blockchains in a way that provides relevant detail to the projects research aim which is to evaluate consensus algorithms to improve consensus performance, specifically node scalability and overall blockchain design. This research serves as a reference for performance evaluating the algorithms specific to a blockchain. The research chapter provides insight into the performance results presented as critical information to help understand the performance consideration and potential optimizations to permissioned blockchain networks, which is important given the project includes research aimed at developing the functionality of consensus mechanism. The research provides useful contribution to the project through considerations for variability of consensus algorithms to help to the evaluate their utility and effectiveness specifically within the private blockchain domain. This the authors call their evaluation of exploration efficacy and efficiency in consensus algorithms which present the analysis of performance support the grants aim to improve consensus process provide better node scalability in Hyperledger Fabric Application. The paper is critical to both aims of performance evaluating the methods of consensus and performance in blockchain to find critical details for better use cases for consensus methods in permissioned blockchain.

Chen et al [12], examines the intersection of machine learning and blockchain technology providing an insight into the benefits and drawbacks of their convergence. The significance of the citation to the project is in its exposition into the application of AI algorithms to enhance consensus mechanisms in the blockchain space. As an examination of benefits and drawbacks of leveraging machine learning into technology, the reference seeks to develop consensus processes with AI algorithms. The results of this journal article provide insight into barriers and futures in this field of study. This journal article adds a significant value to the project as it will examine benefits and drawbacks of utilizing machine learning in technology. The authors discusses applications where machine learning may enhance both security and efficiency whilst also discussing the barriers to entry for industry practitioners and scholars. In summary, this citation adds additional value to our project as it offer insights concerning the benefits and barriers of merging machine learning with blockchain technology. The insights gleaned from this journal article further supports the project goals of using AI algorithms to enhance consensus mechanisms in Hyperledger Fabric.

Y. Liu et al. [13] examine the relationships among blockchain technology, machine learning, and systems within communications and networks. This source contributes to the project because it surveys how blockchain and machine learning can be integrated into networking and communications systems to enhance consensus mechanisms using AI algorithms. The main point of this document is to present a survey of the extent that AI algorithms can be integrated into consensus mechanisms to improve them. In addition, the journal article elaborates on the opportunities and future challenges that can result from the convergence of these technologies and analyze how the convergence can respond to challenges in networking and communications systems. After surveying the convergence of using blockchain technology and machine learning to address challenges in networking systems, the authors examine use case opportunities in terms of security, privacy, and performance optimization. This adds to the capacity of the project to use AI algorithms in achieving aims associated with improving consensus mechanisms for Hyperledger Fabric. Overall, this source greatly supports the project by showcasing the potential to use blockchain and machine learning in communications and networking systems.

3. Methodology

The methodology used for this study addresses the concerning aesthetic aspect of scaling permissions blockchain systems through some newly introduced machine learning methods, especially in the areas of representation learning through networks that utilized Node2Vec and forecasting analysis using TensorFlow (14). The tacit goal is to improve the consensus methods in Hyperledger Fabric, through the modeling and forecasting of significant behaviors of critical operating systems that lead to performance deterioration. This approach supplements the consensus evaluation with an intelligent adaptive layer that encompassed data driven learning in an accountability which moved away from prior, static universal designs.

The experimentation context is defined by a representative, experimental dataset from the analysis provided in [1], the aforementioned analysis series which presented a systemic performance and load analysis for the PBFT (Practical Byzantine Fault Tolerance) consensus mechanism in Hyperledger Fabric. The authors observed the performance and reliability of a blockchain in load regarding block size, timeout time, transaction arrival rate, and timeout probabilities. Thus, the use of the authentic ordering dissertation data, examined and harvested from their simulation, adds to the postulation of efficacy, appropriateness, and provides external validity in responsiveness to network dynamics with regard to the experiments in this inquiry.

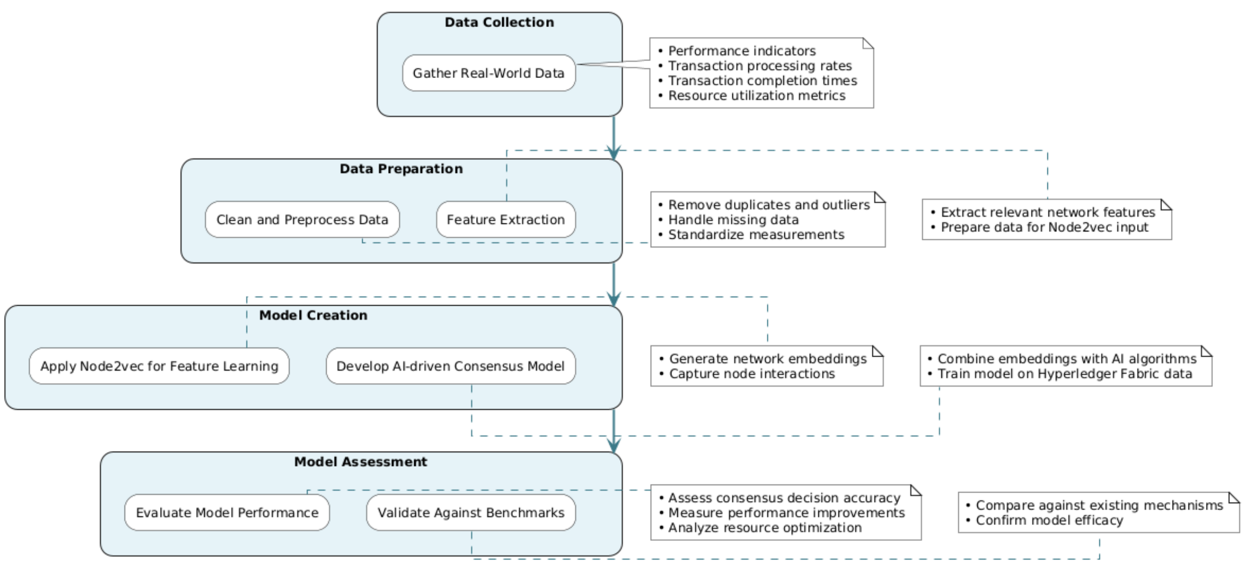

Figure 1 Research Workflow

The procedure commences with the data preprocessing phase, wherein the ingested data undergoes conventional treatments: deduplication, handling of missing or null values, and normalization. Each of these steps are considered important for enabling subsequent robust feature learning and normalizing the numerical features. In addition, descriptive statistical analysis and corresponding visualizations, such as pairplots and histograms, are used to review the distributions of the values and identify either visible patterns or anomalies that could represent a majority or minority population in the data set. The visualizations also contribute to understanding correlations between features, such as how the probability of a timeout increases with increases in the block size parameter or the arrival rate parameter. These findings would then inform or help develop the predictive model.

To formally represent and leverage dependencies at the network level, a technique called Node2Vec is used toward the feature development. Node2Vec is defined as a graph embedding algorithm, which uses the concept of simulating biased random walks to translate nodes in a network representation into continuous vector representations [3]. In this work, a directed, temporal graph is constructed in which nodes represent operational states (or components) in the ordering service and edges are formed to express relationships between specific states, in this case, the co-occurrence of values of particular parameters during the block formation process. In this manner, we endeavor to capture the latent structural dependencies within the system, for example, whether or not specific ranges of block sizes have a higher rate of co-occurrence with a higher rate of timeouts.

The generated embeddings are then combined with the original dataset to create an improved feature matrix. Given that the embeddings have created high-dimensional feature space, Principal Component Analysis (PCA) is applied for dimensionality reduction while attempting to keep most of the variance intact. PCA helps in two main ways; it aids in improving efficiency of the model, as well as gives opportunities to visualize high-dimensional trends for researchers to potentially use in order to understand which features or combinations of features are resulting in the most variance of the output.

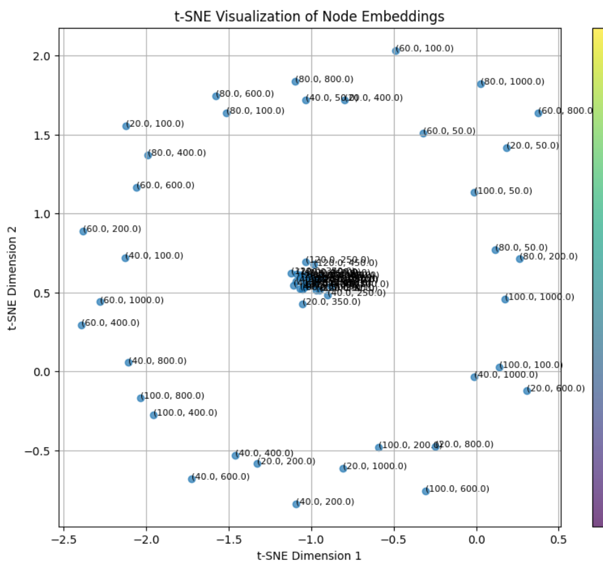

Figure 2 Node2Vec Embeddings Visualization

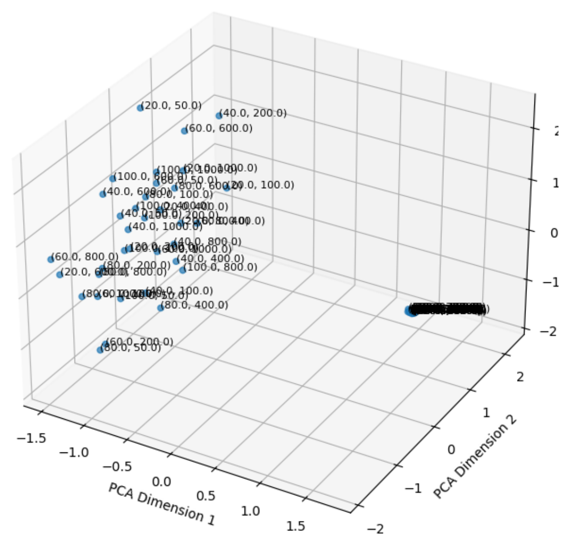

Figure 3 PCA Explained Variance Ratio

After this, a deep learning model is made from TensorFlow, using a sequential neural model architecture with multiple dense layers that utilize ReLU activation functions and dropout to regularize, in order to minimize overfitting, and to support generalization of the model. The model is trained to predict prob_timeout, the probability of transaction timeout events, using the expanded input feature set. In general, this is an important measure of network performance and directly relates to the efficiency and dependability of the consensus protocol, given the operational load applied to it.

The training occurs using the Mean Squared Error (MSE) as the loss function. In practice, it is shown the proposed AI-enhanced model yields an MSE of 0.0341 that is approximately half of that of the baseline linear regression model with an MSE of 0.0658, which demonstrates the AI-enhanced model's superior ability to learn the nonlinear relationship between operational parameters and consensus outcomes. This demonstrates the efficacy of adding in network embeddings and deep learning to model and develop consensus dynamics.

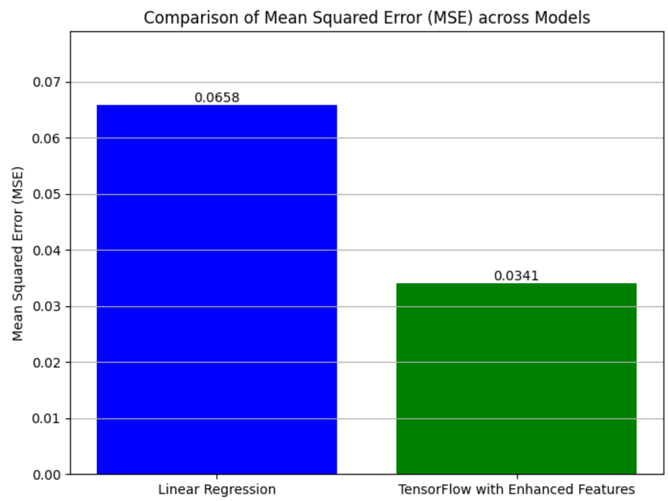

Figure 4 Comparison of MSE across Models

The experimental setup was created to closely resemble actual deployment conditions. All components were included in Docker containers to ensure reproducibility and uniformity throughout development, testing, and deployment competencies. The simulated blockchain network was created using Hyperledger Fabric, and experiments were executed in a controlled testbed with AWS support to facilitate scalable computing resources. The system was built primarily in Python, taking advantage of several available libraries, including Scikit-learn, NetworkX, Pandas, and Matplotlib, as well as TensorFlow and Keras.

This type of approach provides several benefits over traditional performance optimization techniques used in blockchains. First, it provides a predictive understanding of performance; instead of making adjustments after concerning performance degradation is observed. We rely on intelligent models to predict and avoid performance degradation. Second, both types of features collected or engineered for use in our model, i.e., structural (graph-based features) and numerical (parameter-based features incorporated into the model) are contained in a single model improving the understanding of all aspects of system behavior. Third, the entire framework was designed and built to be modular, extensible, and deployable into operational environments, which is highly valuable to real-world blockchain network operators.

4. Conclusion

This work presents a new approach for enhancing scalability and performance in permissioned blockchain systems, particularly Hyperledger Fabric. The proposed solution incorporates network representation learning with Node2Vec and deep learning models developed with TensorFlow to establish an intelligent layer for assessing the consensus mechanism under the dynamic aspects of the system with its complex non-linear dependencies. This methodology is based on a solid experimental basis utilizing non-trivial empirical performance data derived from pre-existing experimental studies [1], establishing internal relevance and external validity. After systematic data preparation and exploratory analysis, and the features extracted in the context of graphs, a data space is created containing measurements of both statistical and structural properties of empirical blockchain operations. The analysis is contextualized from Node2Vec embeddings that rely on PCA to dimensionally reduce to visualize and illustrate the multifaceted relationships in performance features, utilizing transaction arrival rates, block sizes, and timeout probabilities, while using the last embedding that leverages higher level features to improve the predictive performance of the model.

The proposed deep learning model showed better performance in predicting the transaction timeout probability, as exhibited by notable improvements in the Mean Squared Error metric, when compared to the traditional linear regression model. This enhancement in performance demonstrates the capabilities that artificial intelligence provides to historical challenges relative to designing a blockchain consensus. The overall framework designed in this study contributes to the construction of blockchains that are more scalable, adaptive and intelligent, and allows for adopting techniques for consensus that maintain performance in distressed network conditions, while realizing improved momentum for speed, and smart adoption and consensus technique efficiency. This study also provides a basis for a platform for defining future research activities that relate to blockchain and artificial intelligence, and illustrates the good interdisciplinary activities to solve problems in relation to complex distributed systems.

5. Acknowledgements

The authors would like to sincerely thank Harish Sukhwani for generously providing the data needed for this research. The data has provided a valuable catalyst for exploration and analysis connected to this study. We are grateful for his support and interest in working collaboratively with us, which enhanced the richness and depth of this research.

6. References

[1] H. Sukhwani, J. M. Mart\'\inez, X. Chang, K. S. Trivedi, and A. Rindos, "Performance modeling of PBFT consensus process for permissioned blockchain network (hyperledger fabric)," in *2017 IEEE 36th symposium on reliable distributed systems (SRDS)*, 2017, pp. 253–255.

[2] D. Mingxiao, M. Xiaofeng, Z. Zhe, W. Xiangwei, and C. Qijun, "A review on consensus algorithm of blockchain," in *2017 IEEE international conference on systems, man, and cybernetics (SMC)*, 2017, pp. 2567–2572.

[3] A. Grover and J. Leskovec, "node2vec: Scalable feature learning for networks," in *Proceedings of the 22nd ACM SIGKDD international conference on Knowledge discovery and data mining*, 2016, pp. 855–864.

[4] S. Tanwar, Q. Bhatia, P. Patel, A. Kumari, P. K. Singh, and W.-C. Hong, "Machine learning adoption in blockchain-based smart applications: The challenges, and a way forward," *IEEE Access*, vol. 8, pp. 474–488, 2019.

[5] G. Yang, K. Lee, K. Lee, Y. Yoo, H. Lee, and C. Yoo, "Resource analysis of blockchain consensus algorithms in hyperledger fabric," *IEEE Access*, vol. 10, pp. 74902–74920, 2022.

[6] P. Thakkar, S. Nathan, and B. Viswanathan, "Performance benchmarking and optimizing hyperledger fabric blockchain platform," in *2018 IEEE 26th international symposium on modeling, analysis, and simulation of computer and telecommunication systems (MASCOTS)*, 2018, pp. 264–276.

[7] S. Wang *et al.*, "On private data collection of hyperledger fabric," in *2021 IEEE 41st International Conference on Distributed Computing Systems (ICDCS)*, 2021, pp. 819–829.

[8] E. Androulaki *et al.*, "Hyperledger fabric: a distributed operating system for permissioned blockchains," in *Proceedings of the thirteenth EuroSys conference*, 2018, pp. 1–15.

[9] C. Gorenflo, S. Lee, L. Golab, and S. Keshav, "FastFabric: Scaling hyperledger fabric to 20 000 transactions per second," *International Journal of Network Management*, vol. 30, no. 5, p. e2099, 2020.

[10] A. Barger, Y. Manevich, H. Meir, and Y. Tock, "A byzantine fault-tolerant consensus library for hyperledger fabric," in *2021 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*, 2021, pp. 1–9.

[11] Y. Hao, Y. Li, X. Dong, L. Fang, and P. Chen, "Performance analysis of consensus algorithm in private blockchain," in *2018 IEEE Intelligent Vehicles Symposium (IV)*, 2018, pp. 280–285.

[12] F. Chen, H. Wan, H. Cai, and G. Cheng, "Machine learning in/for blockchain: Future and challenges," *Canadian Journal of Statistics*, vol. 49, no. 4, pp. 1364–1382, 2021.

[13] Y. Liu, F. R. Yu, X. Li, H. Ji, and V. C. M. Leung, "Blockchain and machine learning for communications and networking systems," *IEEE communications surveys & tutorials*, vol. 22, no. 2, pp. 1392–1431, 2020.

[14] A. Zollanvari, "Deep Learning with Keras-TensorFlow," *Machine Learning with Python*, pp. 351–391, 2023.

[15] M. Alser *et al.*, "Packaging and containerization of computational methods," *Nature Protocols 2024*, pp. 1–11, 2024.

[16] G. James, D. Witten, T. Hastie, R. Tibshirani, and J. Taylor, "Linear Regression," *Springer Texts in Statistics*, 2023.

[17] E. U. Castaneda and E. J. Baker, "KNeXT: a NetworkX-based topologically relevant KEGG parser," *Front Genet*, vol. 15, 2024, doi: 10.3389/fgene.2024.1292394.