Demonstrating a Hyperledger Fabric-based Blockchain with Knowledge Graphs for a Supply Chain Ecosystem

***Abstract*—Supply chain management is one of the leading applications of chain-based Distributed ledger technology, such as blockchain, due to its features of traceability, automation through smart contracts, tamper-resistance and immutability. One of the most common types of blockchain implementation for a supply chain ecosystem is Hyperledger Fabric, which follows a modular architecture. Within the supply chain, the innovators have been emphasising scenario generation to let them plan via predictive algorithms using the content over the blockchain. Such requirements can be connected to a feedback method that can be considered equivalent to a digital twin. However, to support enabling technologies such as digital twins and better organise the digital assets, a pipeline with data accessibility is required, which is the motivation behind this demo. Chaincode, IPFS and off-chain execution enable the pipeline to provide knowledge graphs that can facilitate further insights into the type of data in the blockchain with better control and privacy-aware filtration.**

I. Introduction

Blockchain is a chain-based distributed Ledger Technology (DLT) which operates as a peer-to-peer system. Each peer has its copy of the ledger that consists of blocks and transactions, executed by running an agreement protocol, termed consensus, to ensure that the order of blocks and transactions is agreed upon among peers [1], [2]. In recent years, the direction of research has moved towards expanding blockchain applications beyond cryptocurrencies. With the introduction of Industry 4.0, blockchain has seen wider applicability because of its inherent features like tamper-resistant, transparency, data provenance and immutability of data [3]. With the globalisation of industries and lack of trust in global economies, Supply Chain Management has become one of the largest industries to consider the implementation of blockchain [3], [4]. An inherent nature of blockchain is transparency, which supply chain organisations do not desire as competitors can view the information. As a result, using permissionless blockchains is not applicable. Instead, a permissioned blockchain approach can be utilised as transparency is maintained within an agreed number of participants [2]. This demo implements a web interface that is driven by Hyperledger Fabric. It helps to understand the modularity and flexibility to set up a blockchain efficiently. Furthermore, it emphasises a new pipeline that provides data accessibility and control over the features visible to owners involved with an ideology of ensuring accessibility and privacy.

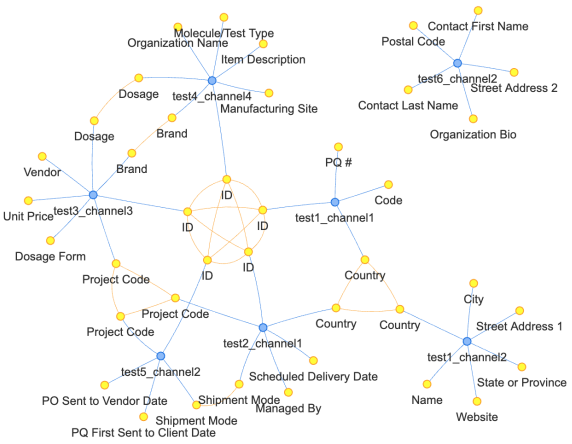

Fig. 1. An exemplary graph representation showing data values amongst four channels.

II. Preliminaries: Hyperledger Fabric

Among enterprise blockchain networks, Hyperledger Fabric is one of the most used platforms [5]. The advantage of its modularity allows organisations to customise parameters to suit their preferences [6]. Hyperlegder is a project that is sponsored by IBM and the Apache Foundation and has several implementations – Hyperledger Fabric is one of them [6], [7]. Hyperledger Fabric consists of several components that include gossip protocol to ensure that blocks are relayed across peers, an endorsor to validate transactions, a membership service which provides authorities with access to participate in the blockchain and an orderer service to ensure all peers follow the same order of transactions within a block [6]. Furthermore, unlike the existing blockchain solutions that follow the *order-execute* structure, Hyperledger Fabric follows *execute-order-validate* architecture, which helps improve its overall performance [6]. It follows a pluggable consensus mechanism which allows any consensus to be utilised. Solo is the default consensus within the development of the protocol [6], which can be switched towards a customised implementation.

III. Pipeline based on Hyperledger Fabric

Hyperledger Labs [8] provides documentation to set up a fabric-samples network, which helps understand the workings of the blockchain. To further expand on that, several Software

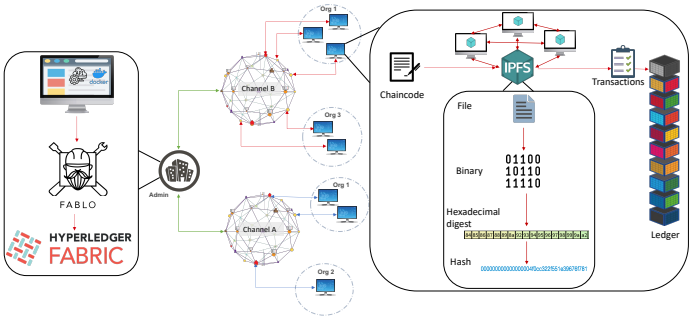

Fig. 2. An exemplary rundown of the system's architecture using two channels.

Development Kits (SDK) can be utilised to run the network. These are implemented in GO, Node, Java and Python [9] and can be run using a docker container. It is understandable that supply chain data can be complex and have diverse relationships and headers in varying file formats. To achieve an effective system, administrators of the permissioned blockchain can benefit from gaining insights from these data sets [10], such as aspects of community identification, clustering, data point accessibility and dependencies without compromising privacy. Using graph theory and off-chain computation, this demo presents a pipeline that serves these benefits to fit real-world applications. Fig 1 represents a knowledge graph based on multiple sample data uploaded to the platform. With this feature, the proposed pipeline can be scaled to allow digital asset management [11] and also help to form an enhanced digital twin with control over data visibility.

IV. Demonstration, Conclusion and Future Steps

Setting up a network topology is complex with Hyperledger Fabric when the number of parameters increase [12], [13]. To help facilitate this, FABLO [14] is a tool that helps generate configuration files to start up the network. Fig 2 shows the pipeline of the interface. The admin will have control over the private blockchain. This could be the manufacturer in a supply chain, who will configure the network based on the participants, such as suppliers and vendors. To ensure competitors are not exploited, they can be isolated through channels. There are two channels, A and B, each representing a different group of organisations. It is important to note one organisation may have multiple instances that would allow each instance to be a part of different channels. Once an organisation sends a transaction to the network, it follows the *execute-order-validate* architecture, where chaincode is also executed [6]. The information uploaded through the interface can be of any file type as chaincode interacts with the InterPlanetary File System (IPFS). IPFS is a distributed file system that operates as a peer-to-peer network and relies on the underlying network for content distribution where nodes collaborate to share and retrieve information [15] (See Fig 2 for a simplified workflow of IPFS). Based on the pipeline, the IPFS hash is then stored in cache memory, which is then accessed off-chain to produce the knowledge graph with the relationship of headers within channels. This can be scaled for future research, and further insights can be obtained based on this pipeline. As a part of the demo, we are aiming to showcase a live, interactive supply-chain ecosystem along with dynamically generated knowledge graph formulations. This work will get scaled towards handling finality within asynchronous blockchain via Hyperledger Fabric to reduce latency impact on digital twins.

References

[1] J. Xu, C. Wang, and X. Jia, "A survey of blockchain consensus protocols," *ACM Comput. Surv.*, vol. 55, jul 2023.

[2] Y. Xiao, N. Zhang, W. Lou, and Y. T. Hou, "A survey of distributed consensus protocols for blockchain networks," *IEEE Communications Surveys Tutorials*, vol. 22, no. 2, pp. 1432–1465, 2020.

[3] M. Asante, G. Epiphaniou, C. Maple, H. Al-Khateeb, M. Bottarelli, and K. Z. Ghafoor, "Distributed ledger technologies in supply chain security management: A comprehensive survey," *IEEE Transactions on Engineering Management*, vol. 70, no. 2, pp. 713–739, 2023.

[4] B. Müßigmann, H. von der Gracht, and E. Hartmann, "Blockchain technology in logistics and supply chain management—a bibliometric literature review from 2016 to january 2020," *IEEE Transactions on Engineering Management*, vol. 67, no. 4, pp. 988–1007, 2020.

[5] A. I. Sanka, M. Irfan, I. Huang, and R. C. Cheung, "A survey of breakthrough in blockchain technology: Adoptions, applications, challenges and future research," *Computer Communications*, vol. 169, pp. 179–201, 2021.

[6] E. Androulaki, A. Barger, V. Bortnikov, C. Cachin, K. Christidis, A. De Caro, D. Enyeart, C. Ferris, G. Laventman, Y. Manevich, S. Muralidharan, C. Murthy, B. Nguyen, M. Sethi, G. Singh, K. Smith, A. Sorniotti, C. Stathakopoulou, M. Vukolić, S. W. Cocco, and J. Yellick, "Hyperledger fabric: a distributed operating system for permissioned blockchains," in *Proceedings of the Thirteenth EuroSys Conference*, EuroSys '18, (New York, NY, USA), Association for Computing Machinery, 2018.

[7] R. Zhang, R. Xue, and L. Liu, "Security and privacy on blockchain," *ACM Comput. Surv.*, vol. 52, jul 2019.

[8] "Hyperledger labs." https://labs.hyperledger.org. Accessed: January 31, 2024.

[9] T. L. Foundation, "Hyperledger fabric sdks," 2022. Accessed: January 31, 2024.

[10] Q. Lu, A. Binh Tran, I. Weber, H. O'Connor, P. Rimba, X. Xu, M. Staples, L. Zhu, and R. Jeffery, "Integrated model-driven engineering of blockchain applications for business processes and asset management," *Software: Practice and Experience*, vol. 51, no. 5, pp. 1059–1079, 2021.

[11] C. Ramonell, R. Chacón, and H. Posada, "Knowledge graph-based data integration system for digital twins of built assets," *Automation in Construction*, vol. 156, p. 105109, 2023.

[12] I. Zikos, A. Sendros, G. Drosatos, and P. S. Efraimidis, "Hfabd+m: A web-based platform for automated hyperledger fabric deployment and management," in *2022 IEEE 1st Global Emerging Technology Blockchain Forum: Blockchain Beyond (iGETblockchain)*, pp. 1–6, 2022.

[13] R. Mathwale, "Ahfd: A framework for deployment and management of hyperledger fabric enterprise blockchain," in *2023 International Conference on Data Science and Network Security (ICDSNS)*, pp. 1–4, 2023.

[14] H. Labs, "Fablo: A toolset for blockchain fabric operators." https://labs.hyperledger.org/labs/fablo.html. Accessed: January 30, 2024.

[15] J. Benet, "IPFS - content addressed, versioned, P2P file system," *CoRR*, vol. abs/1407.3561, 2014.