

Pure Chain Ecosystem

NSLab. Co. Ltd
June 13, 2023

1 INTRODUCTION

Pure Chain is a blockchain ecosystem that proposes a stable structure to manage the prevalent blockchain quad-lemma issues of Decentralization, Security, Scalability and Gas cost [1, 2]. It is made up of five integral components working in conjunction with each other to provide sustainable and reliable solutions to the blockchain. The ecosystem consists of two enhancement algorithms and three blockchain networks. The enhancement algorithms are Smart Auto Mining Plus (SAM^+) and Proof of Authority and Association (PoA^2), and the blockchain networks are NSL Layer 2 (NSL-L2), NSL Layer 1 (NSL-CL1), and Augmented Layer 1 blockchain. Figure 1 shows the network and technology components of the Pure Chain Ecosystem.

SAM^+ is an upgrade of the already existing SAM technology developed by NSLab[3, 4]. It optimizes transaction mining time and significantly reduces the energy required to power the network. The upgrade to SAM^+ was implemented by considering node capacity, block size and mining speed within a time frame to measure and address mining delay.

The PoA^2 is an enhanced version of the already existing PoA. It ensures uninterrupted network operation, even in the event of miner downtime. This enables Pure Chain to provide a more seamless and reliable blockchain network. NSL layer 2 (NSL-L2) makes use of zero-knowledge (Zk)-Rollups technology together with SAM^+ and PoA^2 to enhance blockchain scalability and also to significantly reduce the gas cost for blockchain operations. The Zk-Rollups architecture used by NSL-L2 involves grouping transactions into a compact representation called a "rollup" which is then sent to the blockchain network for validation. Centralized Layer 2: This is a customized target purpose layer 2 which is suitable for specific application areas. This is developed with industrial applications as its main focus. Layer 1 : This is an upgrade of the existing blockchain layer 1 architecture. SAM^+ and PoA^2 are integrated into blockchain layer 1 to improve efficiency and reliability.

Some applications for the Pure Chain networks have been built while others are ongoing. These applications include Pure Wallet, Pure Voting, Pure Media, Pure Trace, Pure World, Pure Medical, Pure Drone, Pure ATS, Pure Crowdsourcing, and Pure PIN.

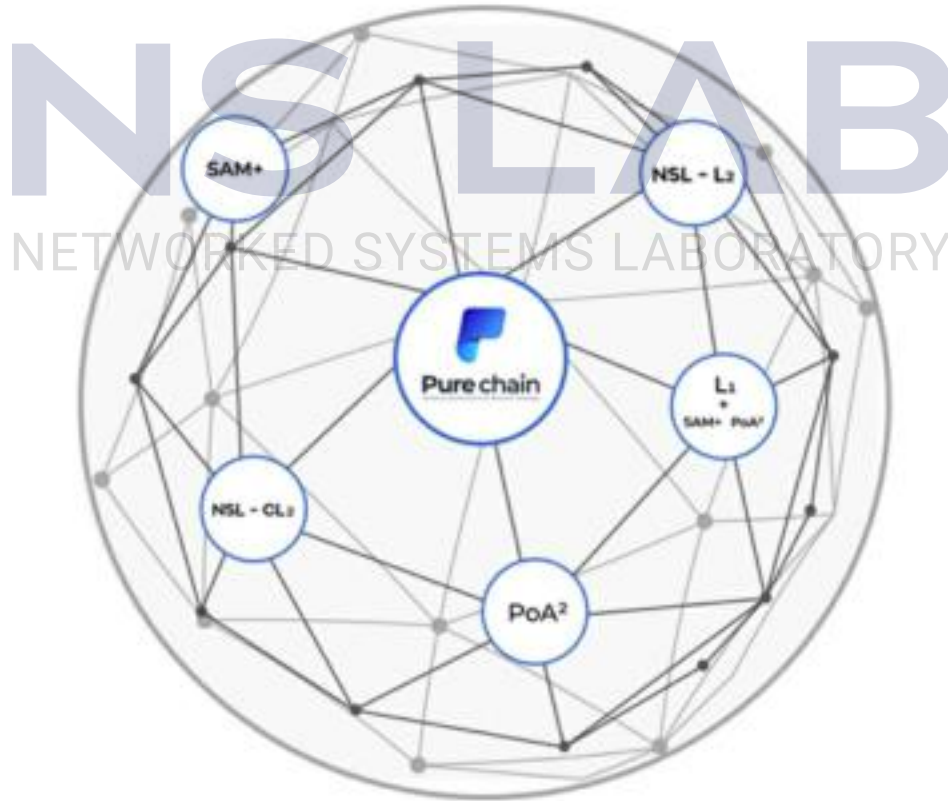


Figure 1: Pure Chain Ecosystem

2 PROOF OF AUTHORITY AND ASSOCIATION (PoA^2)

The purpose of PoA^2 is to investigate and improve the security, performance, and trustworthiness of a PoA blockchain network. It proposes the introduction of a standby validator in the network, which monitors and follows up other activities of validators on the network. The network signers automatically vote for the transfer of authority. The PoA^2 is proposed by introducing an idle redundant signer associated with the network, which monitors and follows up the signers' activities on the network, and in-turn identifies, removes and replaces inactive validators [5]. Signers on the network automatically vote for the transfer of authority to a new signer to replace the inactive one. The PoA consensus method that will be implemented in this research is Clique. Clique can accept even a single validator, and hence is suitable for even smaller private networks. Figure 2 shows the PoA^2 architecture.

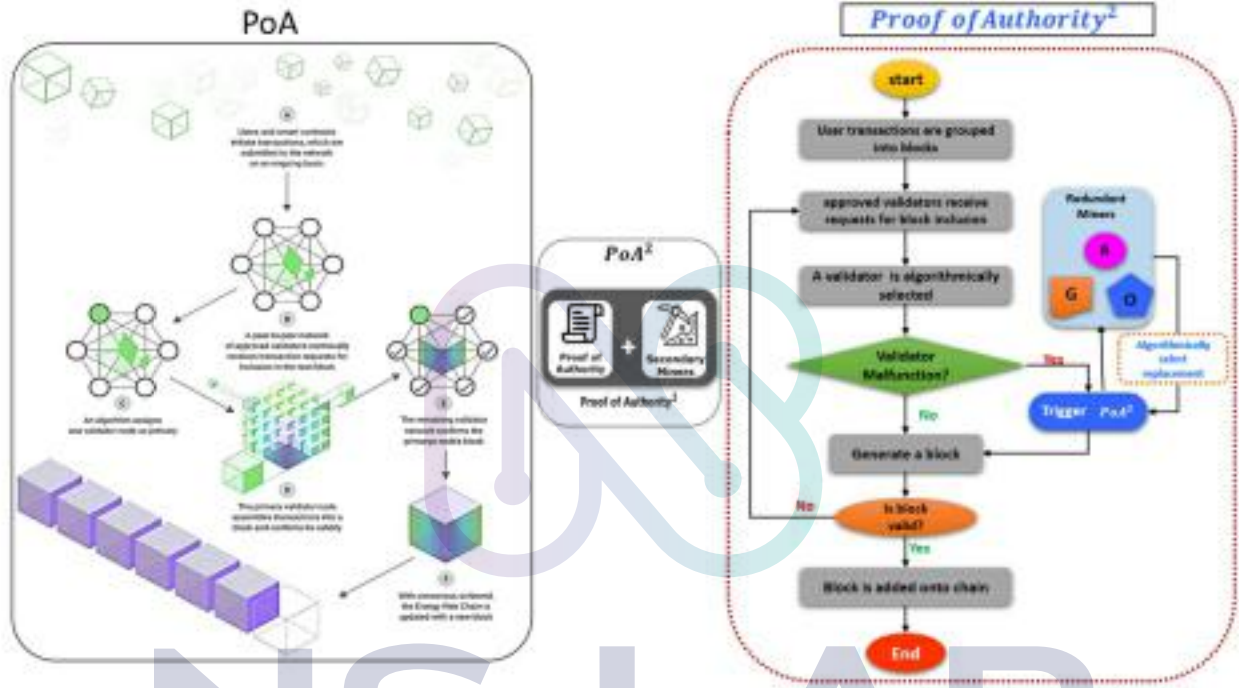


Figure 2: Proof of Authority and Association (PoA^2) Architecture

To dynamically add new signers and remove old ones, the protocol specifies a voting mechanism using the Geth method to authorize and reauthorize signers. The storage capacity, computing power, bandwidth and elapsed block sealing time are the conditions taken into account to select secondary sealers. Authorization is immediately taken into action if requested by more than half of the signers, and the new account can begin signing blocks. Similarly, current signers can also propose to deauthorize an invalid/dysfunctional node. Once again, if half + 1 signers deauthorize a signer, that signer is immediately removed from the list, and all future blocks created are rejected. In Clique PoA, the signers list is arranged sequentially. The following assumptions are made to implement PoA^2 on the blockchain network:

- The identity of signer is verified to maintain the integrity of the blockchain.
- Eligible node must have their public key registered into the chain by a digital signature.
- Eligible nodes are considered active on a long-term commitment.

3 SMART AUTO MINING PLUS(SAM^+) [3]

Smart auto mining (SAM) is used for resource-efficient mining in a blockchain network. The SAM algorithm stops the miners when there are no pending transactions and starts the miner when there is at least one transaction sent into the network. The miner listens to the network to identify when a transaction has been made by a node. The model does not need any instruction to start mining when there is a pending transaction. The implementation of SAM decreases mining overhead by reducing the production of empty blocks in the network which saves energy, storage space, network bandwidth, and computational complexity. Figure 3 represents the block diagram of the SAM^+ architecture.

SAM^+ is an upgrade of the existing SAM technology that optimizes the transaction processing time, thus significantly reducing the energy required to power the network. The upgrade to SAM^+ was implemented by considering the

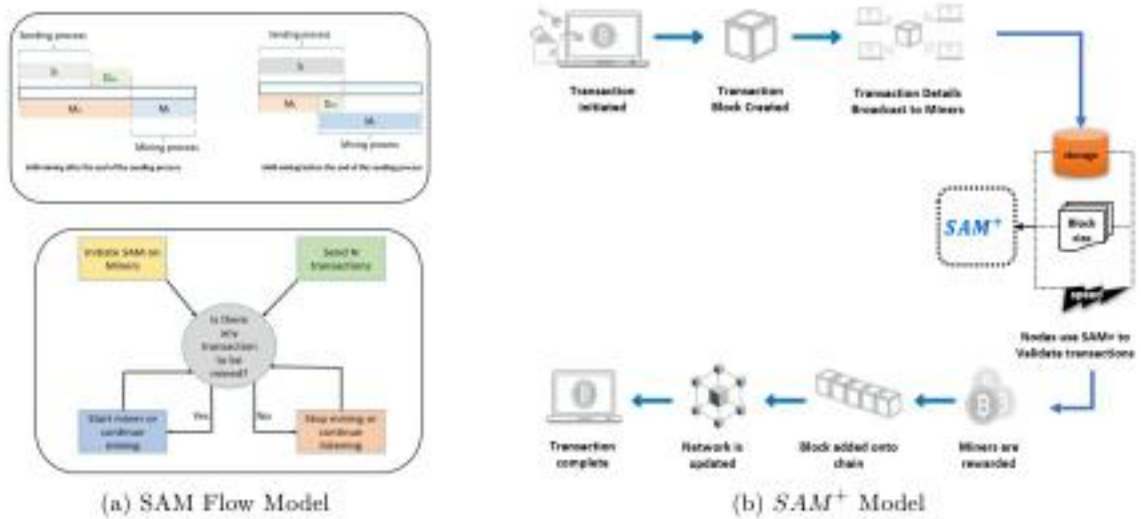


Figure 3: Architecture of the SAM^+ Model

storage requirements before mining (i.e. node capacity to run SAM), sorting transactions according to the size of each transaction, and computing the percentage or speed for each miner within a time-frame to measure and address mining delay.

4 NSL LAYER 2 (NSL-L2)

NSL-L2 makes use of Zk-Rollups technology [6, 7, 8] together with two core technologies developed by NSL: Smart Auto Mining (SAM^+) and Proof of Authority Square, PoA^2 . SAM^+ technology optimizes transaction mining via an on-and-off algorithm which significantly reduces the energy required to power the network. PoA^2 is a novel consensus algorithm that ensures uninterrupted network operation even in the event of miner downtime. Thus NSL-L2 does not only enhance blockchain scalability but also significantly reduces the gas cost for blockchain operations [9].

NSL-L2 is broken up into four major components: the Server/Sequencer, Aggregator and prover, consensus contract and the bridge. The zkNode (zero-knowledge) is the software needed to run any zkEVM node. It is made up of the server, aggregator and consensus algorithm. The zkNode architecture is modular in nature. It is a client that the network requires to implement Synchronization and govern the roles of the participants (Server/Sequencers or Aggregators) in NSL-L2 zkEVM [10, 11]. Participants decide to participate in the network either as a node to manage the state of the network or to process and batch transactions in any of the two roles: Server(Sequencer) or Aggregator and Prover.

1. **Server/Sequencer:** The server manages smart contracts and on-chain operations, accepts transactions, rolls them into batches to generate blocks and creates a witness used by the aggregator to generate proofs. Its operations are managed by four core components:
 - Core bin: Commits new blocks and manages transactions.
 - API-Service: Provides a front end for the server for RPC HTTPS and JSON implementations
 - Sender Service: Finalizes blocks and forwards corresponding transactions to the layer 1 smart contract.
 - Witness Generator Service: Generates an input data called "witness", which is used to generate proofs.
2. **Aggregator and Prover:** The aggregator aggregates and coordinates proofs and the prover employs advanced zero-knowledge technology to perform complex mathematical computations using SNARKS (Succinct Non-Iterative ARGument of Knowledge) in order to generate proofs and validate batches [7, 12].
3. **Consensus smart contract:** NSL-L2 leverages a novel consensus algorithm proof of authority square (PoA^2) to select validators and provide permission to produce batches in a specific timeframe. In this mechanism, there are no economic incentives, so the validators are selected based on strictly efficiency and privacy.
4. **zkEVM Bridge:** This is a Smart Contract that lets users transfer their assets between layers one, L1 and two, L2. The L1-L2 in zkEVM is a decentralized bridge for secure deposits and withdrawal of assets. It is a combination of two smart contracts, one deployed on one chain and the second on the other.

Table 1: Comparison of Layer 2 Technologies

L2 Technology	Withdrawal Time	Required Trust	Privacy	Throughput	Gas Fees	Cross-chain Interoperability
Validium	Instant withdrawal	High	High	Very High	Very Low	No
Plasma	7 Days	Medium	Medium	High	Medium	Yes
Optimistic Rollup	7 Days	Medium	Medium	Medium	Low	Yes
ZK Rollup	Instant withdrawal	Low	High	High	Low	Yes

The technology used for NSL-L2 is Zk-Rollups as shown in Figures 4 and 5. It is a prominent technology that provides clear-cut advantages over its competitors (validium, plasma and optimistic rollups). It involves processing transactions into batches and grouping them into a compact representation called a "rollup". This rollup is then sent to the blockchain network for validation. The zero-knowledge proof is used to prove the validity of the transactions included in the rollup without revealing any of the transaction details. Thus, the blockchain network can validate the rollup without the need to process each transaction individually, reducing the load on the network and increasing its scalability.

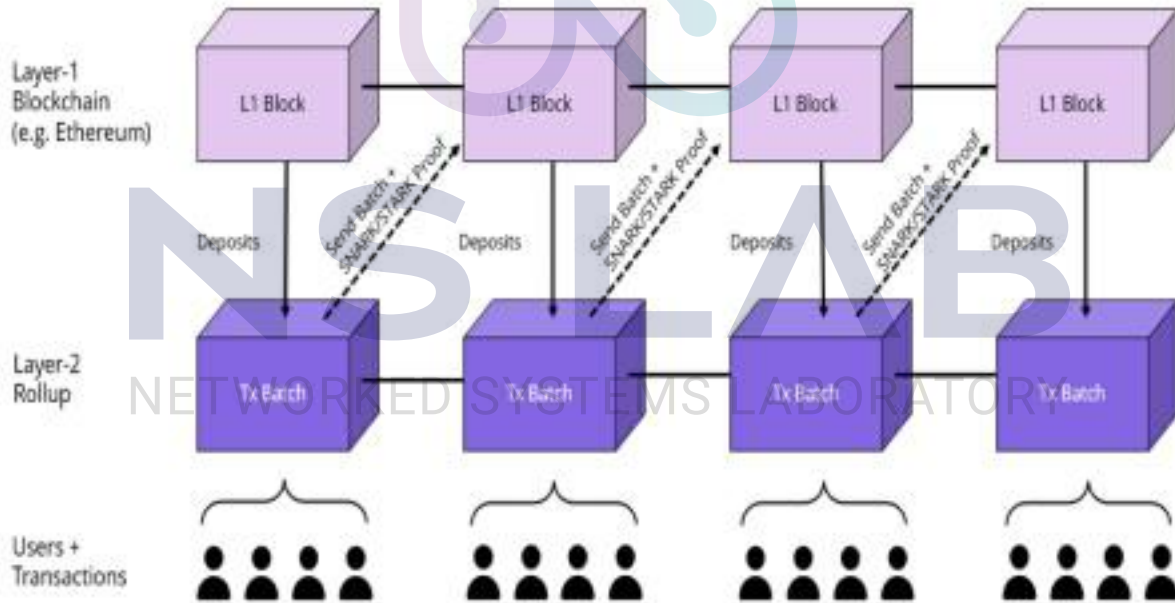


Figure 4: ZK Rollup transaction process in brief.

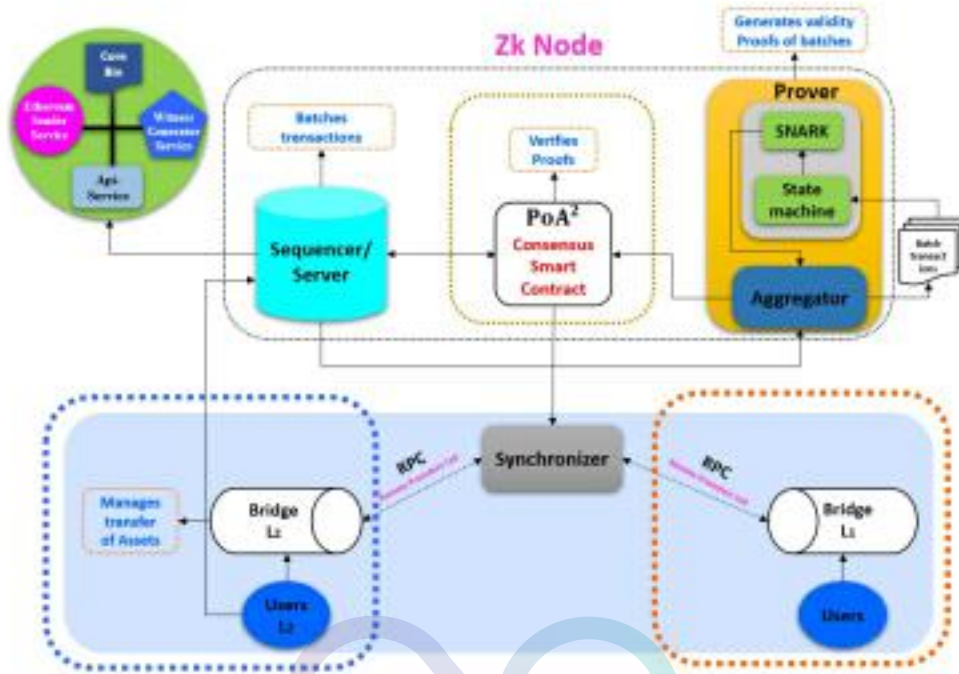


Figure 5: NSL-Layer 2

5 CENTRALIZED LAYER 2

The semi-centralized layer 2 consists of three active levels: The Mainnet, the Smart Contract, the JavaScript and the IPFS. The system is made up of 'participants' who can join by sending Ether to the smart contract written in solidity.



Figure 6: Centralized Layer 2

The smart contract acts as a bridge to the Mainnet which offers a level of security to the entire architecture. Once in the system, participants can perform transactions amongst each other at a much faster and cheaper rate, using the interface created at the JavaScript level. In order to provide an extra level of security and a feel for decentralization, user data at the JavaScript level are deployed on the IPFS peer-to-peer protocol. In addition to the faster and cheaper transfer of coins and data amongst participants, our centralized layer 2 also provides an interface for participants to add new functionalities and build upon them. This allows for a unique and customized experience of the platform for various participants. Figure 7 illustrates the flow model of the Centralized Layer 2 expanded from Figure 6.

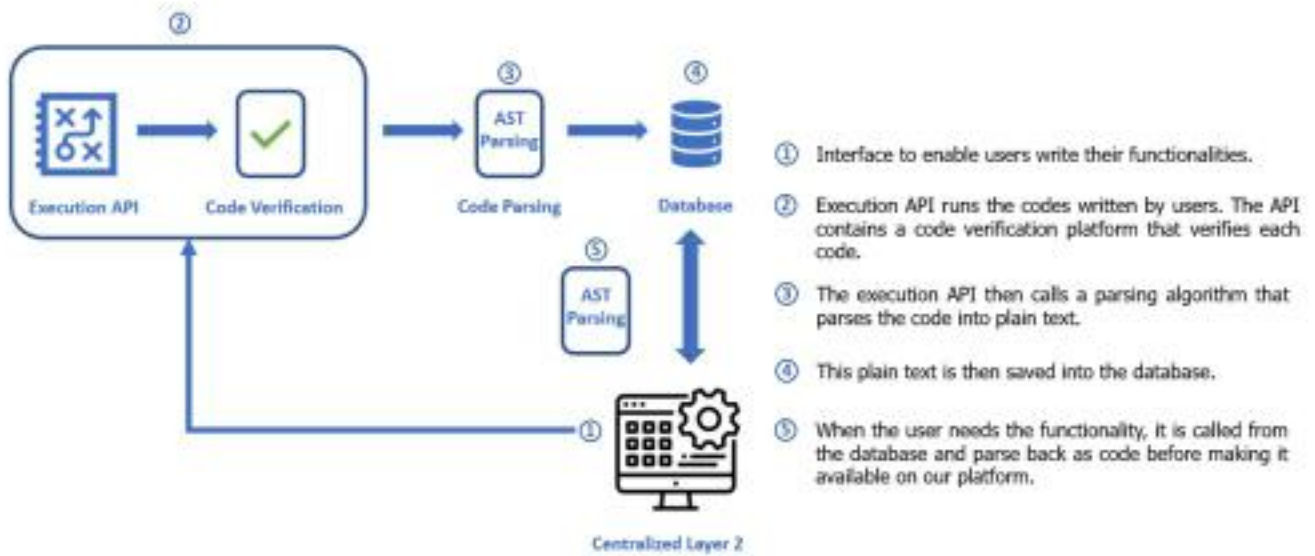


Figure 7: Centralized Layer 2 Architecture

6 BLOCKCHAIN LAYER 1 UPGRADE

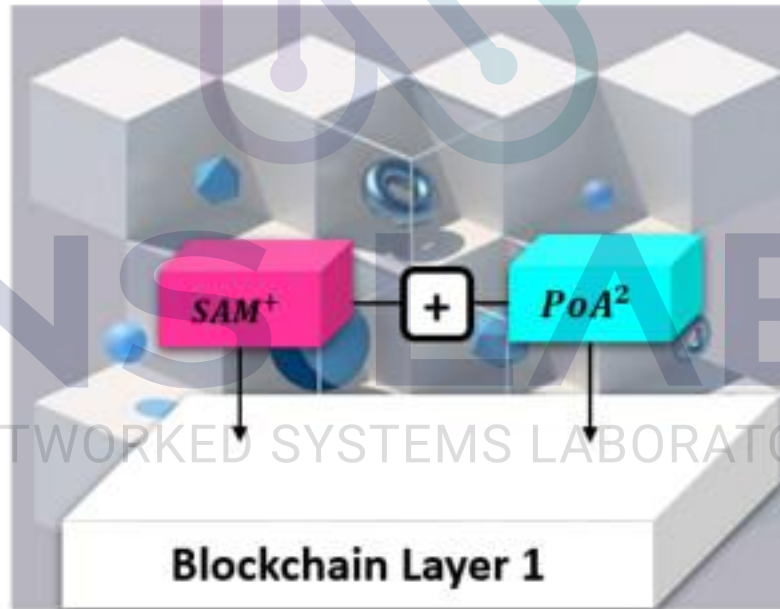


Figure 8: Blockchain Layer 1 Upgrade

This blockchain network is compatible with the Ethereum Virtual Machine (EVM). It is a layer 1 solution, but includes SAM^+ and PoA^2 models to enhance efficiency and reliability. The consensus protocol implemented is the Clique protocol, a proof of authority consensus mechanism implemented in Geth. It is a permissioned consensus protocol which means only a set of re-approved validators can participate in block production. To participate in block production, a validator must be verified by having their public key registered in the chain with a digital signature. The PoA^2 model is a useful way to improve the scalability and efficiency of the conventional PoA network. Figure 8 illustrated the Blockchain layer1 with the SAM^+ and PoA^2 associated with it. A staking smart contract will also be implemented to manage the distribution of cryptocurrency on the network. By including the staking smart contract, users can receive the reward of cryptocurrency based on how much and for how long. This network separates the governance of the network by authorized miners and the economics of investing in the network. The mining of blocks is not incentivized by block reward. The mining operation is in the hands of committed entities whose integrity and reputation have been verified.

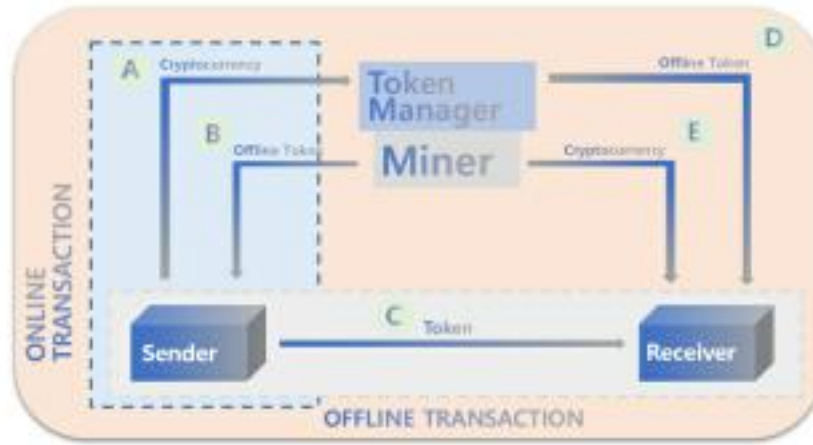


Figure 9: Pure Wallet System Model

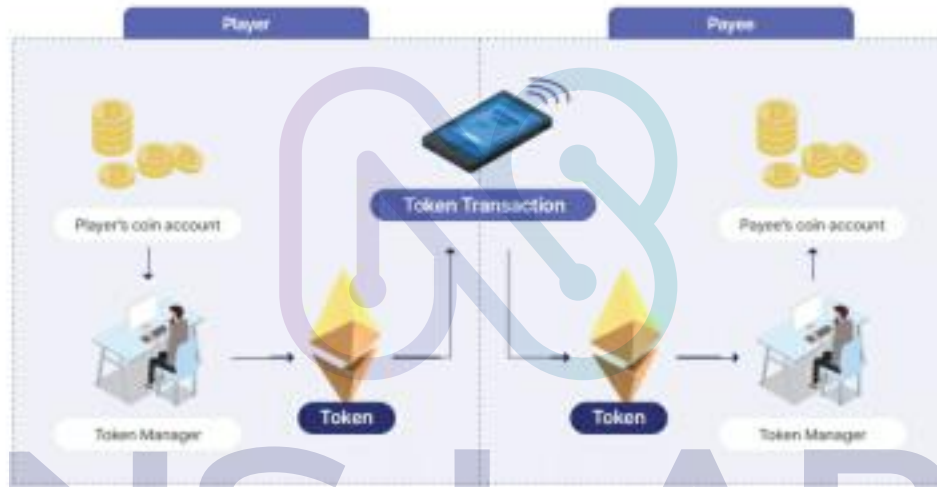


Figure 10: Pure Wallet Overview

7 PURE CHAIN ECOSYSTEM APPLICATIONS

The Pure Chain Ecosystem in addition to providing sustainable and reliable solutions to the prevalent blockchain challenges, also provides a robust platform to run customized blockchain applications. Some of the target-specific applications developed by the NSL team and integrated into the Pure Chain Ecosystem include Pure Wallet, Pure Voting, Pure Media, Pure Traces, Pure World, Pure Medical, Pure Drone, Pure ATS, Pure Crowd-sourcing, and Pure PIN.

7.1 PURE WALLET [4]

This work proposes an electronic payment architecture named Pure Wallet (PW), which extends the concept of Blockchain cryptocurrency for offline transactions. The process is divided into three steps. The first step requires the use of an Internet connection, to convert cryptocurrency into a token at the token manager. The token manager initiates a transaction that requires the information in the token to be complete. Then the offline transactions step is performed between electronic devices like mobile phones through a secure Near Field Communication (NFC) or similar technology using the token in the sender's device. The financial value in the form of a token is encrypted by the sender and sent to the receiver's device. In the third step, the receiver converts the received token into cryptocurrency in the presence of an Internet connection by sending the information required to complete the transaction to the token manager. The goal is to propose an electronic payment architecture utilizing Blockchain, which will enable financial transactions without instant connection to the Internet. The Blockchain implementation in this work utilized an EVM-compatible smart contract. The result shows a successful transfer of value without an instant Internet connection [4]. Figure 9 and 10 represent the Pure Wallet system model and overview respectively.

7.2 PURE VOTING [13]



Figure 11: Pure Voting logo

Pure Voting is a blockchain-based e-voting system that securely lets voters cast their votes without an Internet connection. Figure 11 shows the logo for the intended commercial version. This work proposes the use of blockchain for offline voting by using the smart contract feature of the blockchain network. The process involves voter registration and the generation of offline tokens, which can be used to cast a vote in offline situations. The generated offline token and voting information are transmitted to a smart contract, where the votes are tallied, and results are obtained. Pure Voting also allows for the sharing of cast votes with other voters, who can then send the new token to the vote counters. In cases where multiple voters submit the same vote, the system can identify and count such votes only once [13].

The way the voting system is achieved is shown in Figure 12 below. The voter logs in using their private key to access the public key to get the offline token. Through this information, in step 4, the hash generator in the smart contract returns the offline token used for the voting. This token is made to be anonymous and traceable. Through this token, in step 5b, the token can be sent to another voter who will send their vote, as briefly mentioned before. A pure voting system is able to give anonymity and traceability in the voting system while also enabling the offline scenario. This makes the model suitable for both developed and developing societies.

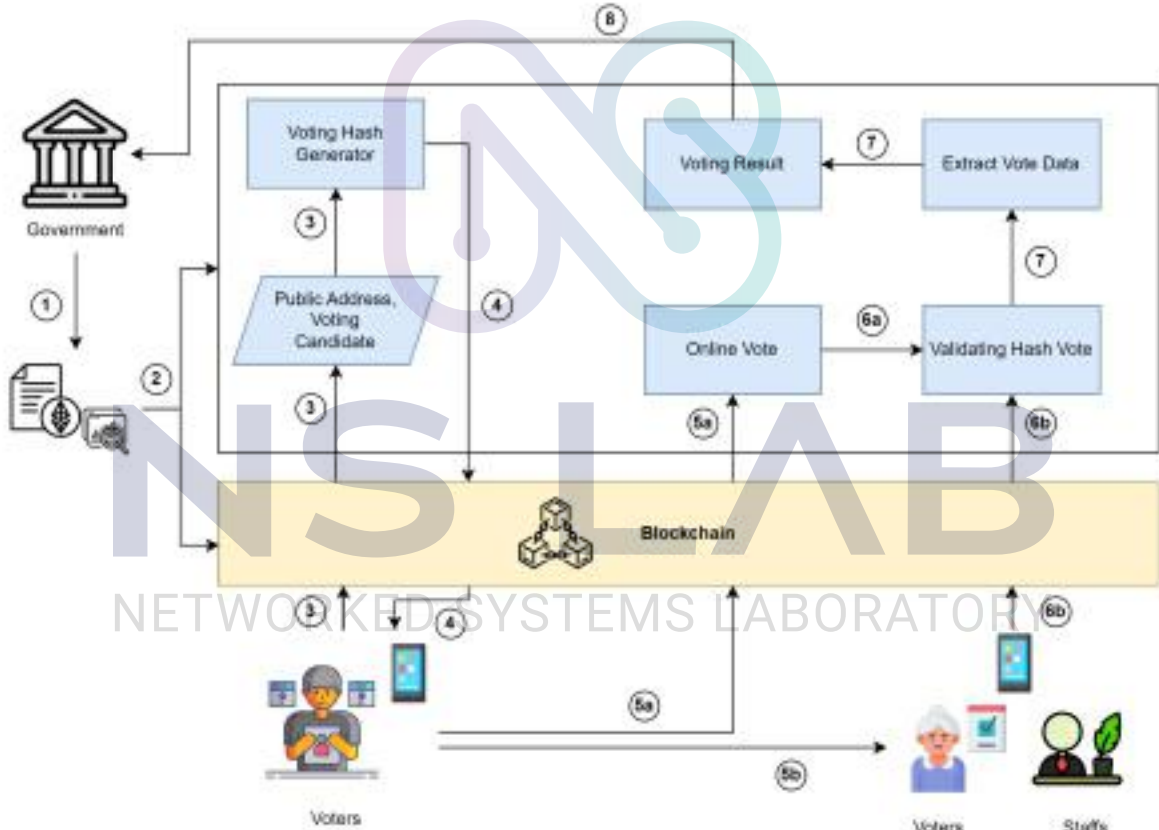


Figure 12: Pure Voting System Architecture

7.3 PURE MEDIA [14]

Blockchain technology has been revolutionizing the music industry by enabling musicians to have greater control over their work and profits. By eliminating intermediaries, artists can directly monetize their creations and maintain more ownership over their intellectual property. However, the rise of decentralized music-sharing platforms has brought new challenges, such as increased pirated audio file distribution. These platforms have become hubs for unauthorized sharing, with many users uploading copyrighted content without permission due to the absence of audio copy detection mechanisms. This issue has led to a need for effective measures to prevent copyright infringement and protect the rights of musicians.

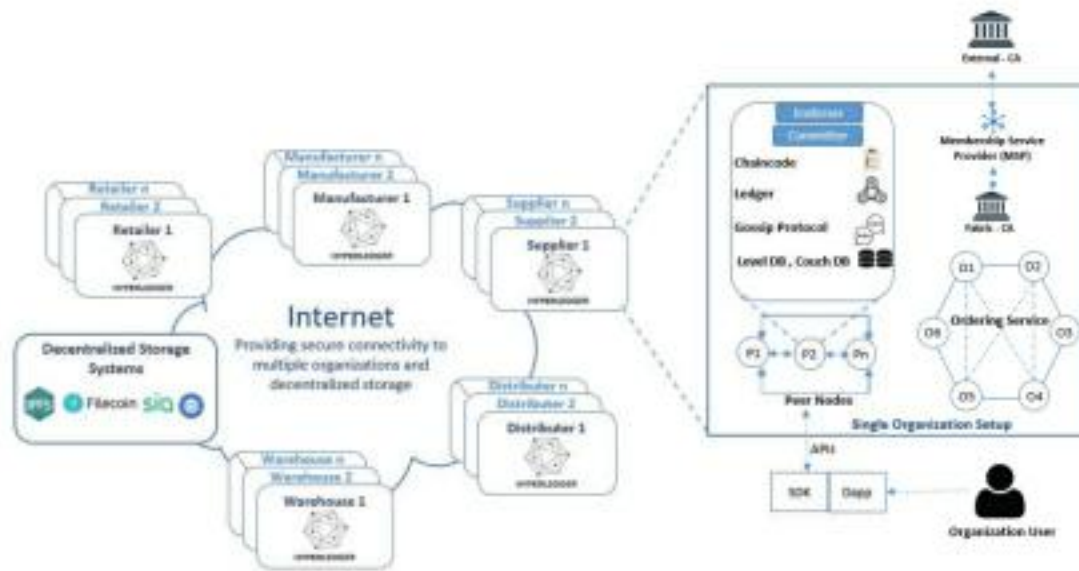


Figure 22: Pure PIN Architecture

the retailers, manufacturers, suppliers, distributors, and warehouses are all connected together in the permissioned network. Channels can be created between participating entities based on their geographical locations to maintain confidentiality. Any documents related to the transportation freight can be stored in the decentralized storage systems. Each supplier and manufacturer can have their external CAs in addition to the Fabric CAs to internally identify their team members.

8 CONCLUSION

The Pure Chain Ecosystem encompasses the two efficiency models Proof of Authority and Association (PoA^2) and Smart Auto Mining Plus (SAM^+), and three Blockchain network models: NSL Layer 2 (NSL-L2), NSL Centralized Layer 2 (NSL-CL1), and Blockchain Layer 1 (Augmented Layer 1 blockchain). The Ecosystem provides specialized solutions for blockchain applications, and the priority of the application will determine the suitable network in the ecosystem to be used.

The roadmap to enhance these blockchain technologies is already ongoing. Properties of the networks like the transaction speed are expected to improve. Two consensus algorithms: Proof of Useful Work consensus and Dragonfly consensus are in the design stage. Fork delay, block size and block time adjustments will be considered in future upgrades of the network. The ecosystem applications will also continue to improve to extend their functionalities. Pure Wallet will extend to an all-in-one payment solution and Pure Media will extend to videos and other media copyright protection. Other applications in the ecosystem will be constantly evaluated for upgrade and new applications will be built as well.

REFERENCES

- [1] I. S. Igboanusi, R. N. Alief, M. R. R. Ansori, J.-M. Lee, D.-S. Kim *et al.*, "Ethereum based storage aware mining for permissioned blockchain network," in *2022 Thirteenth International Conference on Ubiquitous and Future Networks (ICUFN)*. IEEE, 2022, pp. 161–166.
- [2] R. Akter, M. Golam, V.-S. Doan, J.-M. Lee, and D.-S. Kim, "Iomt-net: Blockchain-integrated unauthorized uav localization using lightweight convolution neural network for internet of military things," *IEEE Internet of Things Journal*, vol. 10, no. 8, pp. 6634–6651, 2023.
- [3] I. S. Igboanusi, A. Allwinna, R. N. Alief, M. R. R. Ansori, J.-M. Lee, and D.-S. Kim, "Smart auto mining (sam) for industrial iot blockchain network," *IET Communications*, vol. 16, no. 18, pp. 2123–2132, 2022.
- [4] I. S. Igboanusi, K. P. Dirgantoro, J.-M. Lee, and D.-S. Kim, "Blockchain side implementation of pure wallet (pw): An offline transaction architecture," *ICT Express*, vol. 7, no. 3, pp. 327–334, 2021.

- [5] X. Li, Q. Zhu, N. Qi, J. Huang, Y. Yuan, and F.-Y. Wang, "Blockchain consensus algorithms: A survey," in *2021 China Automation Congress (CAC)*, 2021, pp. 4053–4058.
- [6] C. Sguanci, R. Spatafora, and A. M. Vergani, "Layer 2 blockchain scaling: A survey," *arXiv preprint arXiv:2107.10881*, 2021.
- [7] P. Robinson and R. Ramesh, "Layer 2 atomic cross-blockchain function calls," *arXiv preprint arXiv:2005.09790*, 2020.
- [8] M. Jourenko, K. Kurazumi, M. Larangeira, and K. Tanaka, "Sok: A taxonomy for layer-2 scalability related protocols for cryptocurrencies," *Cryptology ePrint Archive*, 2019.
- [9] R. N. Alief, M. A. P. Putra, A. Gohil, J.-M. Lee, and D.-S. Kim, "Flb2: Layer 2 blockchain implementation scheme on federated learning technique," in *2023 International Conference on Artificial Intelligence in Information and Communication (ICAIIIC)*. IEEE, 2023, pp. 846–850.
- [10] "<https://github.com/matter-labs/zksync-era>."
- [11] "<https://era.zksync.io/docs/dev/building-on-zksync/hello-world.html#retrieving-token-balance-and-transaction-fee>."
- [12] "<https://github.com/l2labs/zk-space-whitepaper>."
- [13] I. S. Igboanusi, R. N. Alief, M. R. R. Ansori, A. Allwinnaldo, J.-M. Lee, and D.-S. Kim, "Pure voting (pv): An offline voting algorithm," in *2022 27th Asia Pacific Conference on Communications (APCC)*, 2022, pp. 586–587.
- [14] M. R. R. Ansori, Allwinnaldo, R. N. Alief, I. S. Igboanusi, J. M. Lee, and D.-S. Kim, "Hades: Hash-based audio copy detection system for copyright protection in decentralized music sharing," *IEEE Transactions on Network and Service Management*, pp. 1–1, 2023.
- [15] Allwinnaldo, R. N. Alief, M. R. R. Ansori, I. S. Igboanusi, J. M. Lee, and D.-S. Kim, "Blockchain-based lightweight fish auction marketplace platform for traceability seafood supply chain," in *Proceedings of Symposium of the Korean Institute of communications and Information Sciences*, 2023, pp. 718–720.
- [16] C. I. Nwakanma, J. N. Njoku, J. Jo, C. Lim, and D. Kim, "'creativia' metaverse platform for exhibition experience," in *2022 13th International Conference on Information and Communication Technology Convergence (ICTC)*, 2022, pp. 1789–1793.
- [17] J. N. Njoku, C. I. Nwakanma, G. C. Amaizu, and D.-S. Kim, "Prospects and challenges of metaverse application in data-driven intelligent transportation systems," *IET Intelligent Transport Systems*, vol. 17, no. 1, pp. 1–21, 2023. [Online]. Available: <https://ietresearch.onlinelibrary.wiley.com/doi/abs/10.1049/itr2.12252>
- [18] S. O. Ajakwe, V. U. Ihekoronye, G. Mohtasin, R. Akter, A. Aouto, D. S. Kim, and J. M. Lee, "Visiodect dataset: An aerial dataset for scenario-based multi-drone detection and identification," 2022. [Online]. Available: <https://dx.doi.org/10.21227/n27q-7c06>
- [19] S. O. Ajakwe, V. U. Ihekoronye, D.-S. Kim, and J. M. Lee, "Dronet: Multi-tasking framework for real-time industrial facility aerial surveillance and safety," *Drones*, vol. 6, no. 2, 2022.
- [20] S. O. Ajakwe, V. U. Ihekoronye, D.-S. Kim, and J.-M. Lee, "Alien: Assisted learning invasive encroachment neutralization for secured drone transportation system," *Sensors*, vol. 23, no. 3, 2023.
- [21] Q. Nasir, I. A. Qasse, M. A. Talib, and A. B. Nassif, "Performance analysis of hyperledger fabric platforms," *Security and Communication Networks*, vol. 2018, no. 14, 2018.
- [22] D. Tith, J.-S. Lee, H. Suzuki, M. A. B. W. W., N. Taira, T. Obi, and N. Ohyama, "Application of blockchain to maintaining patient records in electronic health record for enhanced privacy, scalability, and availability," *Healthcare Informatics Research*, no. 3-12, 2020.

To address this issue, we have developed an innovative audio detection module using perceptual hash-based technology to generate a unique value for each audio file. Our system, represented as HADES in [14] and has a logo as shown in Figure 13 detects potential infringements by matching their perceptual hash to those already recorded in the database. If the system identifies a copy, it rejects it, preventing copyright infringement. This approach ensures that only original audio files are shared on decentralized music platforms, safeguarding musicians' rights and reducing the distribution of unauthorized content. The proposed model is illustrated in Figure 14.

Our system has been rigorously tested and effectively detects potential audio copies in decentralized music-sharing platforms. Pure Media is highly practical and efficient, making it a highly effective solution for combating copyright infringement in the decentralized music platform. This approach not only protects the intellectual property rights of musicians but also provides availability for musicians to store their original music.

In conclusion, blockchain technology has been transformative for the music industry but has also presented new challenges related to copyright infringement. Our innovative approach using perceptual hash-based technology provides a unique solution that ensures that only original audio files are shared on decentralized music platforms. With its proven effectiveness, Pure Media offers a practical and efficient way to combat copyright infringement and protect musicians' rights in the music industry.



Figure 13: Pure Media logo

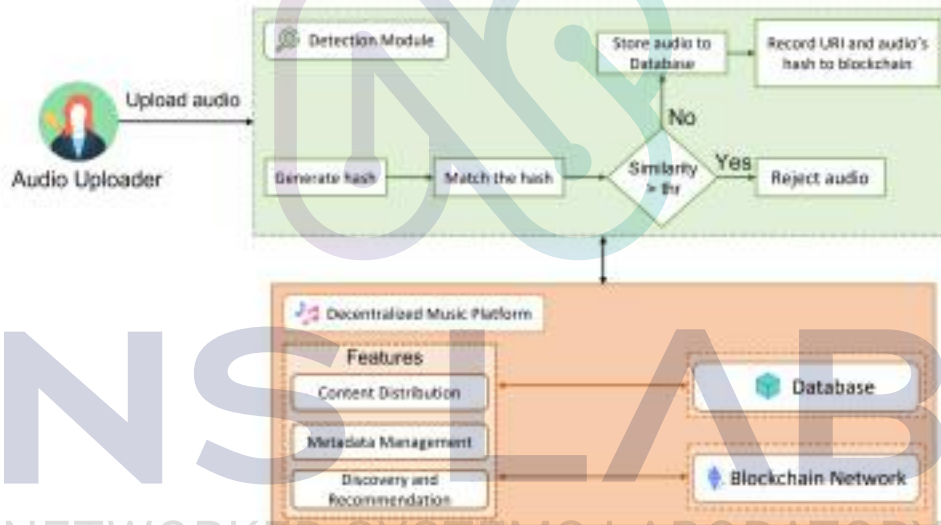


Figure 14: Pure Media System Architecture

7.4 PURE TRACES [15]



Figure 15: Pure Traces logo

The seafood supply chain has an immersive affection for certain nations with a high demand of food and economic needs from the sea or a country with a big sea area to be explored. The proposed lightweight fish auction marketplace smart contract provides the solution for the transparency and consistent issues associated with auction platforms. Also, traceability from the blockchain network follows the benefits of smart contract usage that solved the issue from the seafood supply chain in general. The cost to fully function the smart contract was relatively low on gas cost; therefore, from every user's view, they all received the benefits from the blockchain

without being burdened by the gas cost required to do the transaction. Figure 15 shows the logo for our published model in [15].

The comprehensive system encompasses all stages of the fishery and aquaculture supply chain, which consists of registration, authenticity verification, marketplace, and delivery phases. Within the marketplace, an auction mechanism serves as the primary method for conducting transactions. The entities involved in Coral's ecosystem include fishermen

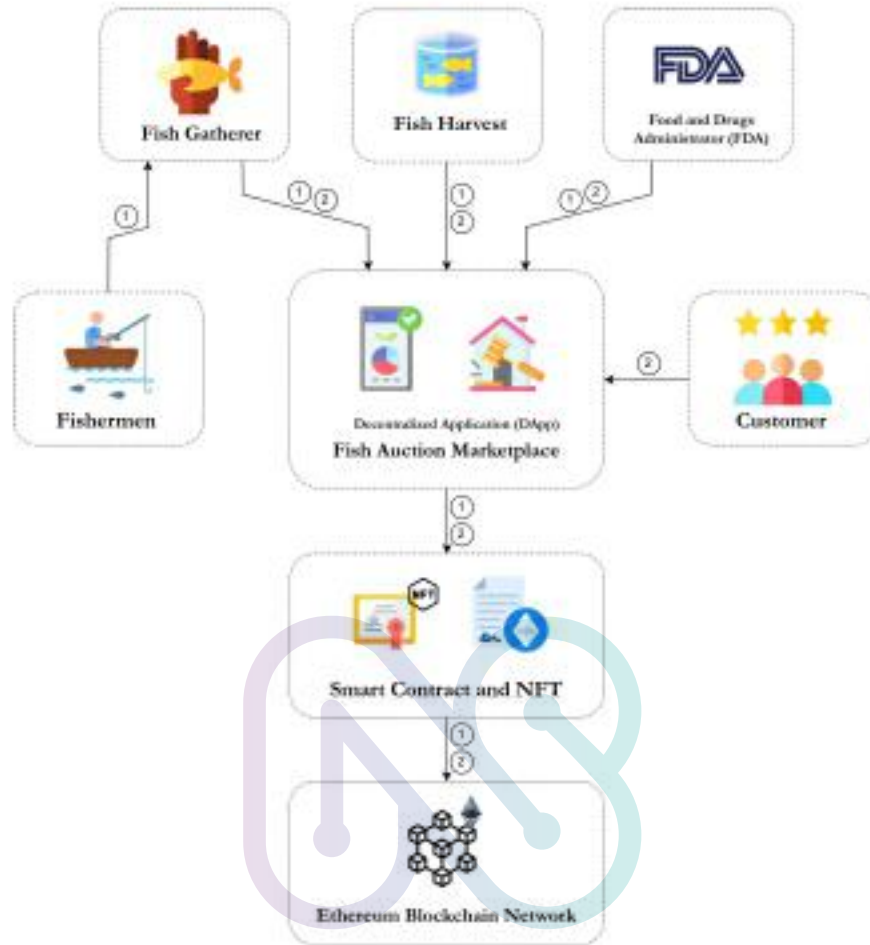


Figure 16: Pure Trace System Architecture

and harvesters, who act as the sources of the stock. Their authenticity is verified by the Food and Drug Administration (FDA). The marketplace, known as Pure Trace, serves as the platform for selling these products, and every transaction that takes place is recorded on the blockchain network. Illustrated in Figure 16, Pure Trace facilitates user registration, enables sellers to list their fishery products, involves FDA authentication, and manages the delivery process. All of these interactions are meticulously recorded and can be traced on the blockchain network. Pure Trace is the primary manager of all transactions within the supply chain, including the auction marketplace, where high transaction speed is essential. To enhance the transaction speed of Pure Trace, it will undergo improvements in terms of consensus and network configurations within the blockchain network. One configuration option is to utilize the Proof of Useful Works (PoUW) consensus. This technology integrates Artificial Intelligence (AI) to analyze transaction conditions and prioritize the most crucial ones, accelerating transaction processing time. Moreover, implementing Pure Trace on the Pure Chain network can be integrated with other functionalities, further expanding its capabilities.

7.5 PURE WORLD [16]

Metaverse refers to a virtual world that is created by the convergence of virtual and physical realities. It provides an immersive digital space that enables users to interact with each other and with digital objects in a three-dimensional space [17]. These digital objects are replicas of physical objects. Pure World, formerly known as Creativia [16], is a cutting-edge metaverse platform that is designed to integrate a variety of solutions. Assets in the Pure World include digital art and cryptocurrency. Ownership of these assets can be facilitated using Blockchain technology. This will enable users to have full control over their digital assets. Thus, they can transfer ownership of their assets, sell them, or use them in diverse applications. Ownership of assets in the Pure World is enforced by the use of NFTs.

Metaverse-assisted Battery Management System (BMS): One of the primary use cases of Pure World is the development of a Metaverse-assisted Battery Management System (BMS). This system utilizes the power of the Pure World platform to provide real-time monitoring and management of battery systems. By leveraging the Metaverse's

ability to integrate data from multiple sources, the system can offer a comprehensive view of battery performance including the battery's state of charge, state of health, and temperature. By leveraging the Metaverse's spatial computing capabilities, users can interact with the BMS, simulate different scenarios, and visualize the results. Figure 17 illustrates the system architecture of the Metaverse-assisted BMS. So far, we have achieved the following for the Metaverse-assisted Battery Management System:

1. **Digitizing Battery:** We have been able to develop a digital battery that can represent the true behavior of Lithium-NMC batteries. This digital battery has been verified with real-world battery data.
2. **AI-based Battery State estimation:** We have been able to develop an AI solution for battery state estimation and integrate it into the digital ecosystem.
3. **Visualizing Battery States:** We have been able to achieve visualization of the battery conditions in the *Pure World* platform.

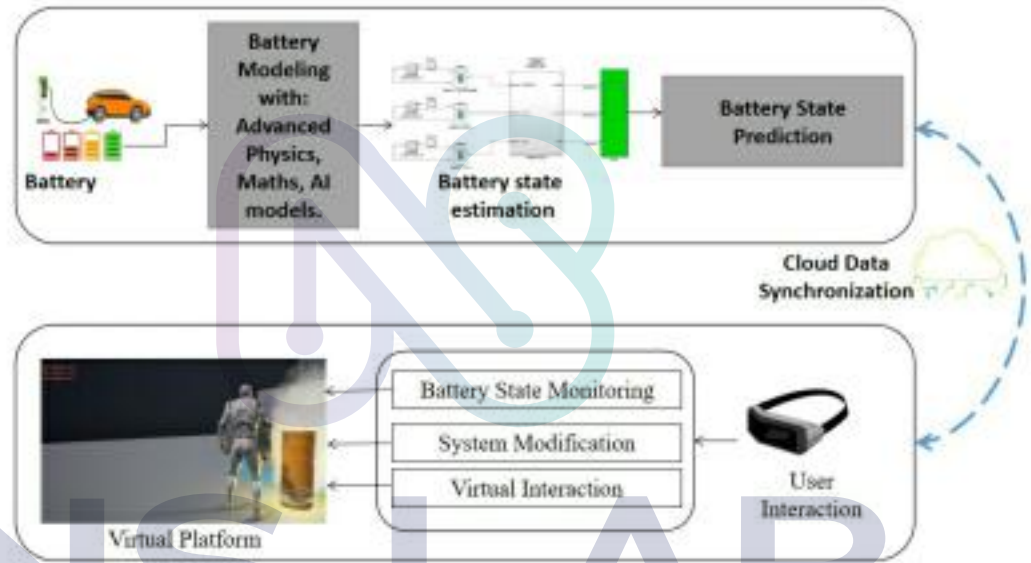


Figure 17. System Architecture for Metaverse-assisted BMS

7.6 PURE MEDICAL

This research proposes a blockchain-based system to address the issues of centralized medical data management and provide patients with greater control over their health information. The proposed system uses a smart contract to implement access control and ensure that only authorized hospitals can add medical information to the blockchain, thus ensuring the integrity and security of the medical data. This approach allows patients to have direct access to their medical information and share it securely with healthcare providers. The proposed approach has the potential to improve the efficiency and transparency of the healthcare system while maintaining the privacy and security of patient data.

Medical Data Storage: We have been able to achieve medical data storage in a blockchain test network powered by Ethereum using the smart contract. For now, we can store medical information in the form of strings and integers in a decentralized manner.

Patient-Centric Access Control: As medical data is very sensitive, it is paramount to design the smart contract in such a way that the patients give access to whomever they wish. This means that the health service provider that received the access approval from the patient can make use of such data. This access can also be withdrawn by the patient if the need be.

Figure 18 below depicts the system architecture of Pure Medical. From the figure, the health stakeholders (patient, hospital and health services) are all connected to the blockchain (decentralized) network using mesh topology. Hence, they can communicate with one another and share medical information.

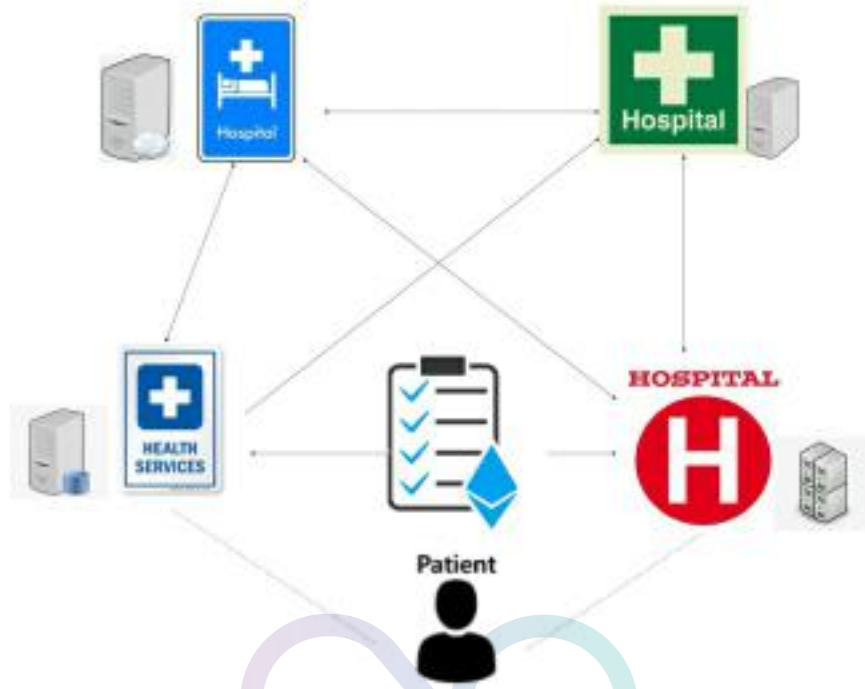


Figure 18: Pure Medical System Architecture

7.7 PURE DRONE

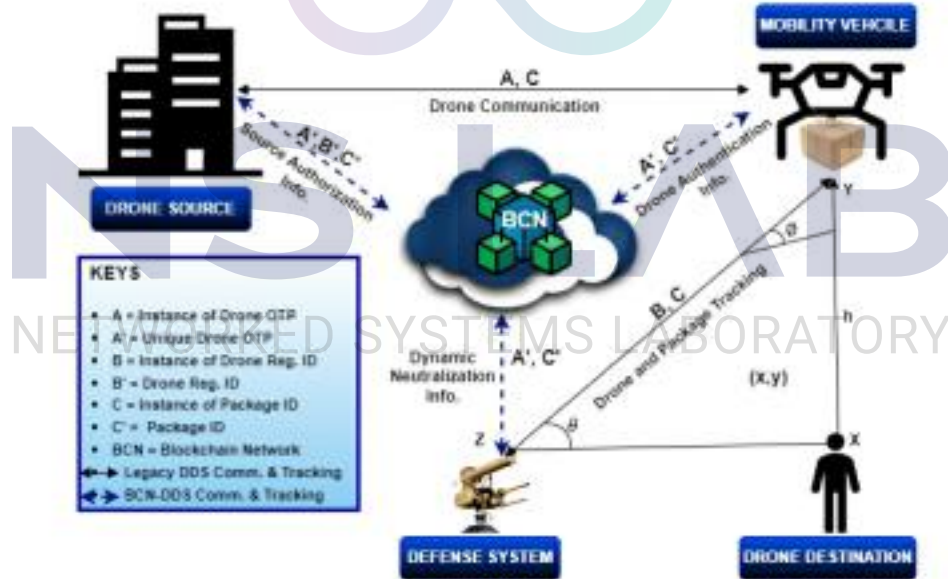


Figure 19: Schematics of Pure Drone

Pure Drone is an AI-driven and Blockchain-assisted drone defense system framework that is designed to accelerate secured drone operations and logistics by ensuring that the legitimacy of any drone in the airspace is validated through authentication, authorization, and accountability before a scenario-specific incapacitation response is triggered. The pure drone is a convergence-based design that utilizes a hybridization approach to developing a mobile time-sensitive mission-critical cyber-physical system (CPS) that compliments the operational capacity of the existing legacy drone defense system. The objective function of the pure drone framework is an optimal solution to maximize secured drone deployment through efficient resource utilization and reliable data that is subject to time, transparency, and trustworthiness provided by blockchain technology. Thus, the pure drone performs five (5) operations namely; (i.) Real-time detection and tracking of drones and attached packages; (ii.) Real-time legitimacy and harmful status

determination of the drone and the attached package; (iii.) Real-time proximity and boundary legality determination of drones; (iv.) Real-time drone authentication and package verification; (v.) Real-time scenario-specific neutralization response. Figure 19 highlights the schematic diagram of Pure Drone.

All the components that perform these operations are fully functional and operational; **VisioDect** [18]; **DRONET** [19]; **ALIEN** [20]; and **iBANDA**. With Pure Drone, secure drone usage for recreational, logistics, and other purposes is guaranteed and incessant reprisal attacks via drone are curtailed if not completely annihilated thereby fostering territorial integrity against invasion from non-state actors.

7.8 PURE ATS (AIR TRAFFIC SAFETY)

Pure ATS is a blockchain and machine learning-based drone technology that offers a potential solution to driving drones in a secure manner. This is aimed to develop a commercial application platform to drive drones in a safe manner. On this platform, as shown in Figure 20, drones will be registered in a blockchain network, where the drone's legal information (according to the Federal Aviation Administration (FAA)), such as the operator license, aim of the operation, threshold, start longitude, end longitude, start latitude, end latitude, operation time, highest altitude range, etc., needs to be provided. During the operation, the drone activities will be monitored through the Pure ATS platform. If any violation, such as driving over crowds of people, between other vehicles, over a public roadway, or flying at high altitudes is observed, the algorithm in Pure ATS can stop the violation and penalize the drone operator. With the aid of predictive AI technology, Pure ATS safely manages an expanding drone fleet and identifies and resolves issues before there is a problem in operation. Moreover, Pure ATS will also offer more advanced features, such as the estimated time to reach the destination, an optimal roadmap of the pathway, battery status, fleet level, etc.

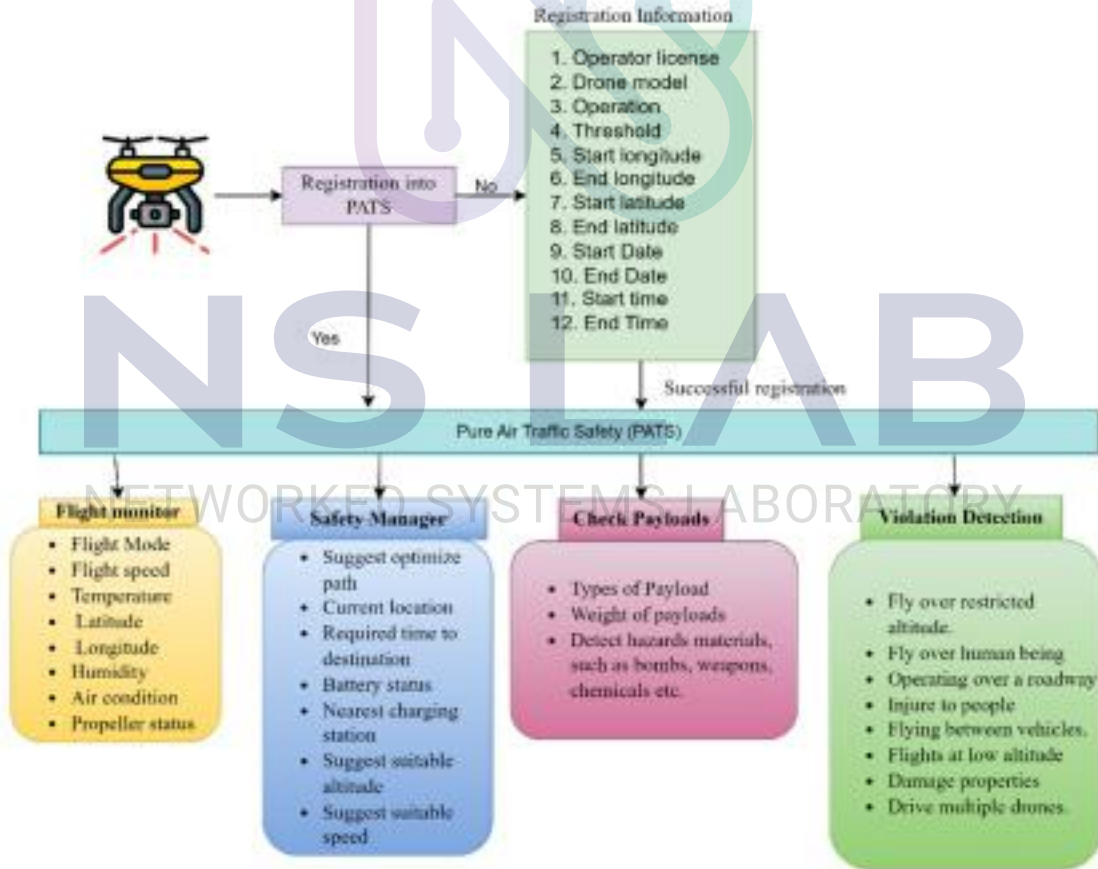


Figure 20: Concept of Pure ATS

7.9 PURE CROWD-SOURCING

Pure Crowd-sourcing refers to the use of Pure Chain to facilitate a decentralized and transparent process of obtaining contributions or services from a large group of dispersed participants, known as a crowd. For example, in smart traffic

management, crowdsourcing can be used to collect traffic data in real-time from users' smartphones, vehicles, or GPS devices. See Figure 21. The pure crowd-sourcing system model consists of four main functional roles or entities.

1. **Publishers (a.k.a., requesters):** These are the system users who initiate crowd-sourcing tasks (e.g., data collection, image processing, content moderation, and so on) and deposit funds into the smart contract on the Pure Chain as a reward for completing tasks.
2. **Workers:** These are those who process the crowd-sourcing tasks, submit the solutions to the crowd-sourcing system and get the corresponding reward if the solutions are valid.
3. **Evaluators:** They engage in the solution assessment, which can be other workers or the smart contract depending on the type of task.
4. **Pure crowd-sourcing Platform (PCP):** PCP provides a stage for efficient, secure and seamless interaction between publishers, workers, and evaluators. All operations at various levels of the crowd-sourcing process are executed using Pure Chain in a secure and efficient manner.

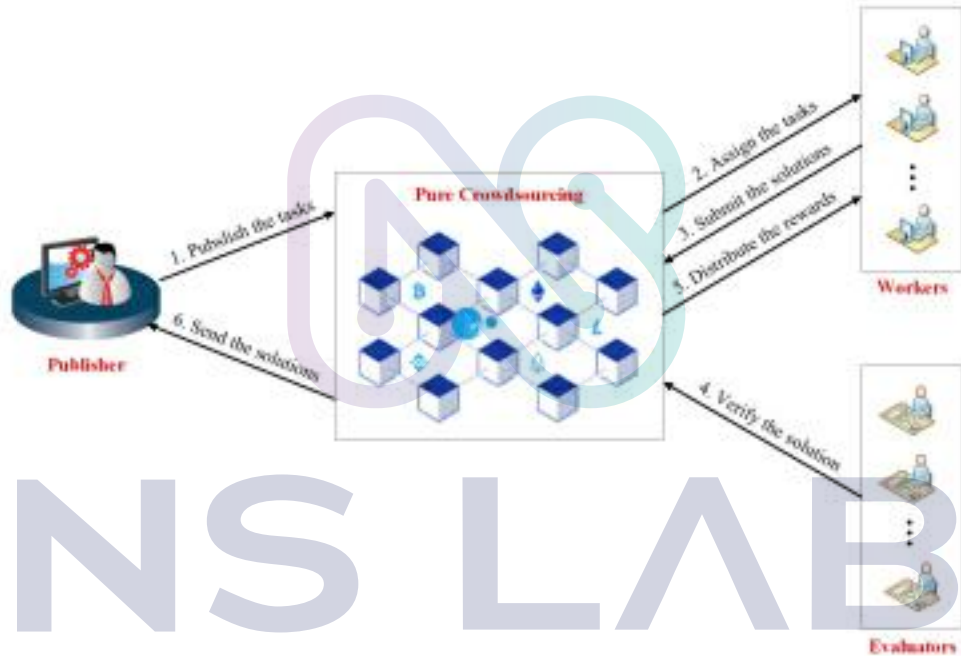


Figure 21: Pure Crowdsourcing System Model.

7.10 PURE PIN (PURE-PHYSICAL INTERNET NETWORK)

This work is a Hyperledger fabric-based architecture. It has a versatile plug-and-play design that provides privacy, consensus, and membership services that make it ideal for business use cases. Since it is a permissioned network, all members maintain an identity that is authenticated and authorized before using the network [21].

Figure 22 shows the Hyperledger Fabric architecture. It shows the different PI participants connected to the network along with the decentralized storage systems, such as IPFS, Filecoin, Sia, and Storj. Each entity in the network is considered as an organization. An organization in Fabric is made up of several peer nodes and an ordering service. Peer nodes could be committers or endorsers. Moreover, to ensure privacy and confidentiality in Fabric, the Membership Service Provider (MSP) is available per organization (manufacturer, retailer, supplier, distributor, and warehouse) that communicates with a local Fabric Certificate Authority (CA) and an external CA. A peer node has the chaincode, a copy of the ledger, and uses gossip to disseminate messages. Level DB and Couch DB are used for storage purposes. Hyperledger Fabric follows the execute-order-validate paradigm for its transactions. A transaction is sent to the endorsers to get enough signatures. Subsequently, it is sent to the orderer which creates blocks in which the transaction sequence is maintained. Later on, the validator helps to validate whether or not the transaction meets the predefined endorsement policy. The core components of the Hyperledger Fabric include Ledger, Chaincode, Peer Node, Channel, Endorser, Committer, Endorsement Policy, Ordering Service, Gossip Protocol, and MSP [22]. Figure 22 shows how