# Depin for Internet of Things Scalability in Smart Societies Using Blockchain Technology

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## Abstract

A new narrative that has emerged refers to the new generation of Internet of Things technology: the consolidation of the Internet of Things with artificial intelligence and blockchain (BSEIOT). This concept is known as the Decentralized Physical Infrastructure Networks (DEPIN) narrative on the blockchain. This narrative includes successful projects such as render, IOTeX, and OpSec. Indeed, an intelligent society interacts with digital devices connected to the Internet to make transportation/logistics, energy use, and services fields more efficient. In this case, the challenge facing the scalability of the Internet of Things is addressed: the connection incompatibility of a great diversity of devices that contain different communication parameters and the loss of latency as the network grows. A Decentralized Autonomous Organization (DAO) scheme is proposed and validated.

**Keywords:** Decentralized Physical Infrastructure Networks (DEPIN), Decentralized Autonomous Organization (DAO), Smart Societies.

## 1. Introduction

Decentralized IoT (DEPIN) and Federated Learning [1-3], a collaborative training approach where individual device clients operate as independent AI models, harnesses the collective computing resources of client devices to reduce latency and enhance privacy. In this framework, personal data remains on the client's device, bolstering privacy. This approach is exemplified in a Decentralized Application (DAPP) that leverages local machine learning tasks, forming an Internet of Federated Learning Things (IoFLT) paradigm. Here, electronic devices gather data and process it locally before transmitting pre-processed information to a central ledger. This ledger, backed by shared computing resources typically hosted on a server with GPU capability, completes the machine learning process. IoFLT holds promise for decentralized trading bots utilizing blockchain technology [4-7], particularly when enhanced with generative adversarial networks (GAN) [8-9] for training assistance. This paper draws from several disciplines, including data science, machine learning, API bot integration, and GANs. Data science is pivotal for collecting, cleaning, analyzing, and visualizing trading data, with machine learning handling predictive and classification tasks based on trading volume and price orders. A GAN neural network augments this process, training the expert system [10-15]. Moreover, the GAN contributes to blockchain security by auditing API blockchain data, thereby fortifying automated Python bot [16] driven by predictive machine learning models with fuzzy logic control [17]. While Federated Learning hinges on the mass adoption of the Internet of Things (IoT), projections suggest this may be a manageable hurdle shortly. The exponential growth of IoT adoption, forecasted to double cellular IoT connections within four years and reach nearly 6 billion connections by 2026 [18], underscores the potential for widespread integration. In the broader technological landscape, the convergence of IoT with artificial intelligence and blockchain, termed BSEIOT, is shaping the narrative of Decentralized Physical Infrastructure Networks (DEPIN) on the blockchain. Notable projects like render, IOTeX, and OpSec epitomize this evolution, envisioning an intelligent society where digital connectivity optimizes various sectors such as transportation, energy usage, and services. However, challenges persist, notably interoperability issues stemming from the diverse communication parameters of IoT devices and the looming threat of latency issues as networks expand. Proposals for innovative Decentralized Autonomous Organization (DAO) schemes aim to tackle these challenges, potentially revolutionizing interconnected physical infrastructures and paving the way for smarter societies [19].

## 2. GLOBALPIN DAO

Integrating decentralized nodes (DEPIN) in the Internet of Things has given birth to IoTX in two types: IoTeX and IoTcX. This paper works with IoTcX for smart societies; sensor/device data collected by nodes connected to the internet are systematically analyzed through artificial intelligence technology to assist the system in choosing the protocol and changing with a decentralized autonomous organization (DAo). However, traditional artificial intelligence technology may leak users' privacy. However, a DEPIN technology can realize multisignature collaboration to generate a global IoT system with machine learning and privacy protection capabilities. Moreover, IoTcX cannot resist inference attacks. Therefore, a privacy-enhanced system mechanism uses a DAO scheme (Figure 1). With this application, the original data generates forged data through the Variational autoencoder (VAE) [20]. These forged data train a local trading model to protect data privacy. The validation experiment is conducted on an automated trader BOT system to access the IoTeX network. The name given for this DAPP is GLOBALPIN.

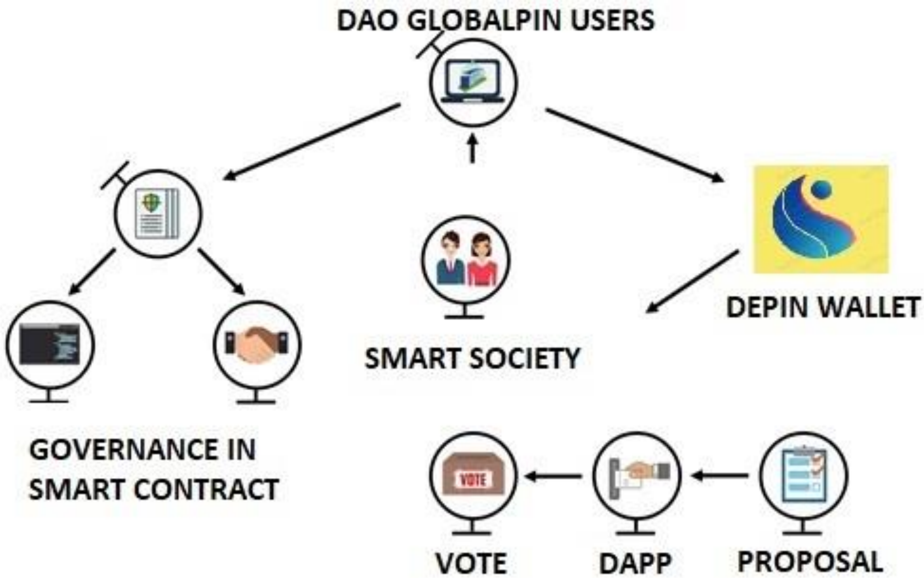


FIG. 1. GLOBALPIN DAO.

In Figure 1, GLOBALPIN users are smart society members using any kind of Internet of Things device, either a mobile phone or a domotic/industrial sensor. The user must pick a sensor type, and he can propose a protocol change to improve IoT performance. Any change proposal must be submitted via the DAO system to vote and released by a smart contract. This DAO focuses on an autonomous system that addresses interoperability and scalability challenges in IoT networks.

The focus of this paper is identifying specific interoperability and scalability problems and establishing the limits and scope of the DAO in terms of its participation in IoT networks and the design of the Governance Protocol that allows its members to participate in decision-making. DAO-weighted voting mechanisms, improvement proposals, and transparent review processes. Development of Smart Contracts to automate DAO processes, such as executing governance decisions and verifying compliance with the IoTcX performance. Integration with IoTX Networks: The DAO must integrate with existing IoTX networks to facilitate interoperability. It is essential to include the development of specific interfaces and communication protocols to enable interaction between the DAO and IoT sensors/devices. Implementation of Incentives: To encourage participation and fulfillment of the DAO's objectives with incentive mechanisms, such as GLOBALPIN tokens rewards or additional voting rights, for those who contribute significantly to the organization's success.

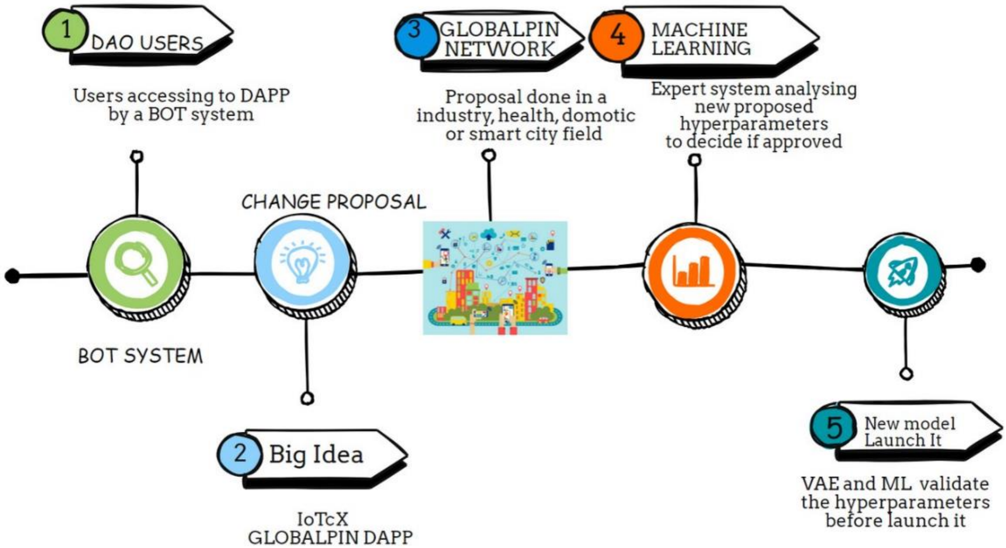


FIG. 2. SMART GLOBALPIN ARCHITECTURE.

Any change proposal in Figure 2 must go thru DAPP (decentralized application) accessing by the BOT system and, a machine leaning module will decide to do or not the change using a smart contract.

Robustness and resistance validations were performed against attacks or failures. Deployment and Iteration: Once the DAO was developed, it was tested continuously to adapt to changes in the technological landscape and address new challenges as they arise.

In summary, as a DAO developer in the context of Decentralized Physical Infrastructure Networks (DEPIN), the focus is on creating an autonomous system that addresses the specific challenges of interoperability and scalability in IoTX networks, thus promoting progress toward smarter societies.

GLOBALPIN TOKEN is led by a governance system that empowers token holders to contribute to the decisions of changes to the parameters corresponding to each type of node according to the device/sensor to be connected. Governance is to guarantee the sustainability and evolution of the hyperparameters and the decentralization of the DAO system, which is structured in such a way that it minimizes the complexity of decision-making. Like natural law, blockchain networks best adapt to their environment, in this case, to the intelligent society. This DAO considers the following characteristics for efficiency in changes: an incentive to make change proposals by users according to their interests and the interests of each group of users not having to be alienated, thus competing among themselves to prevail. The changes proposed by user groups will have more preponderance depending on the number of tokens they have staked.

## 3. SCALABILITY

Decentralized Internet of Things (IoTX) in local or specific use networks is already a reality; applications offer solutions at the home automation, smart cities, or industrial level; however, connecting these solutions between them, that is, at the societal level, contributing to the formation of intelligent societies is a challenge due to the incompatibility between the great diversity of sensors or devices that generate data. Using global networks connecting device nodes with artificial intelligence is what the concept of DEPIN proposes, with application cases proposed by Smart world global token (SWG) [21], among others, such as the Internet of Decentralized Things IoTcX [22].

The scalability problem is solved mainly using machine learning to automatically choose the type of consensus and the block size [23] and optimize the algorithm with the SGD [24] technique in such a way that any type of sensor or device can be compatible with this network called GLOBALPIN. In the deep training process, correctly assigning the values of the hyperparameters is crucial for the correct functioning of an artificial intelligence system. However, finding the optimal hyperparameter values requires comparing a range of options. Therefore, this study proposes to automate the hyperparameter comparison process in a distributed manner using an algorithm based on a systematic methodology with tools such as a causal map and process diagram based on states and state variables; a way to improve similar existing systems is presented. Functional tests based on dynamic simulations were developed to verify that the proposed system meets the expectations of being a viable and functional option to find the optimal values of the hyperparameters in a distributed and automated way. This system represents a competitive proposal compared to similar works since it focuses on distributed control use cases [25].

A blockchain can be perceived as a four-dimensional continuum with three horizontal layers, including transaction and blocks, consensus, compute interface, and governance, and one vertical layer.

This is the foundation of blockchain where transferring of digital assets (thus the inherent values) and account security are achieved via crypto primitives like elliptic curve signature, hash function and Merkle tree.

The consensus layer, where all nodes within the network reach consensus on all internal states on the chain via techniques like Proof of Work (PoW), Proof of Stake (POS) and their variants, and Byzantine-fault tolerance (BFT) and its variants, affects scalability the most. PoW is usually considered less scalable than PoS.

Ethereum has implemented smart contracts to enable programmability where one can count on the distributed "world computer" to execute the terms of a contract. Sidechain and merged mining have also been developed intensively to support programmability. Second-layer protocols like the Raiden network [26] and state channel have been developed to extend the scalability of a blockchain at this layer. In addition, tools, SDKs, frameworks, and GUIS are also essential to usability. The Compute Interface layer allows developers to develop decentralized apps (DApps), an essential part of making the blockchain useful and valuable.

## 4. MODELING

Blockchains can be of two types: permissionless or permissions, depending on their operation. Bitcoin permissionless means anybody can create an address and begin interacting with the network, which builds trust from trust. In contrast, the permissioned blockchain is a closed and monitored ecosystem where the access of each participant is defined and differentiated based on role, which builds trust from less trusted.

Bitcoin and Ethereum are blockchains built on top of trustless nodes because scalability is strongly desired. Hence, either lots of computation is needed (in the case of PoW), or a more sophisticated consensus mechanism is needed. In contrast, Fabric [27] is a permissioned blockchain where all nodes are trusted and have cryptographic identities issued by member services like Public Key Infrastructure (PKI). This makes them highly scalable with low computation and a relatively straightforward consensus mechanism.

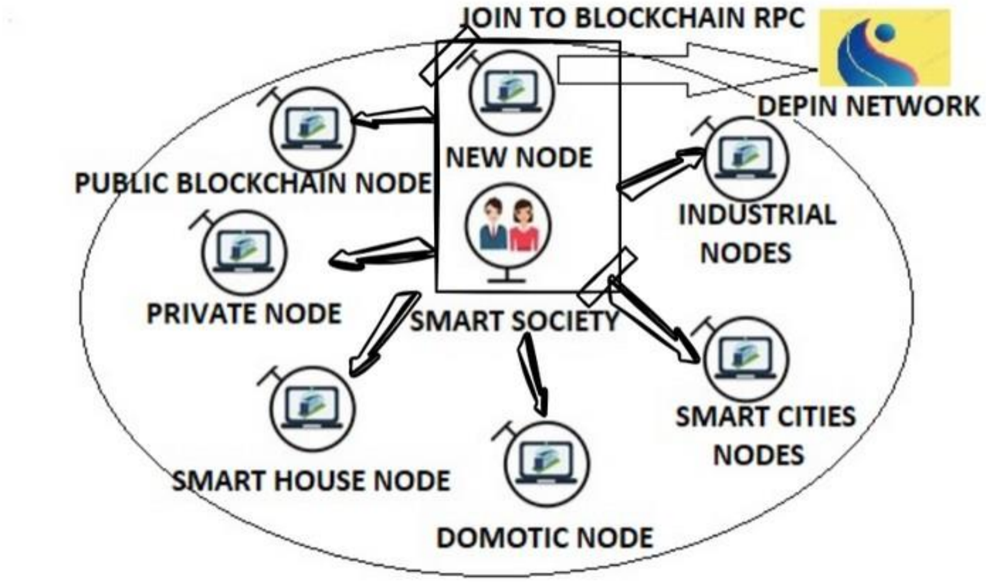


FIG. 3 GLOBALPIN PROTOCOLS INTEGRATION

There are a bunch of protocol variants in the Internet of Things sensors/devices/nodes: public blockchain, private, smart house, domotic, smart cities, and industrial, among others. However, sensible information is in the blockchain ledger. The smart society accesses the blockchain via the RPC interface (figure 3).

## 5. GLOBALPIN DAPP CHALLENGES

Benefiting from common properties provided by blockchains does not mean every blockchain is suitable for IoT use.It does not seem like any existing public blockchain can be applied to IoT since there are many challenging problems. Since there are a bunch of IoT variants: public blockchain, private, Smart house, domotic, smart cities, industrial, among others, and each variant has its own protocol, there is a big challenge in the connectivity. The most impacting hyperparameter is the consensus algorithm. That is why this paper contributes to the smart/automated protocol adjustment to optimize the protocol tps.

GLOBALPIN IoTcX blockchain has layers for sensing, perception, transformation, transmission, and processing. These layers are needed for most scalability, privacy, and extensibility problems. Native privacy guarantees from blockchain can only help address the privacy pain point in IoT. All blockchain ledgers are published on the internet, meaning they are public, but information is encrypted, and it is impossible to know the private names of the peers. However, if blockchain nodes are linked to private data, then sensible information can be known according to this private data. In other words, the blockchain ledger is not 100% private, which is another challenge.

IoT is a universe of heterogeneous systems and devices with different purposes and capabilities. For instance, a blockchain for coordinating millions of industrial IoT nodes should focus on high scalability and transaction throughput. In contrast, a blockchain for coordinating smart devices at home should focus on privacy and extensibility. At a macro level, IoT devices as one species are evolving quickly; new technologies are integrated, new standards are developed, and new devices are manufactured with new capabilities, and at a micro level as well.

Another challenge in the IoT blockchain is that chain operation is heavy. PoW algorithm is especially heavy for mining but is the most secure consensus algorithm. In the IoT world, many devices are considered weak nodes because; they are not able to store a large amount of data, they are not able to verify all transactions, and they are not able to connect to peers all the time. Therefore, most existing blockchains are too heavy for IoT.

GLOBALPIN is a network of many hierarchical blockchains where many blockchains can run concurrently with one another while retaining interoperability. In the GLOBALPIN, the root blockchain manages many independent blockchains or subchains. A subchain connects to and interacts with IoT devices that share something in common. They have a similar functional purpose, operate in similar environments, or share a similar level of trust. The root chain is completely unaffected if a subchain does not function well in case of being attacked. In addition, cross-blockchain transactions are supported to transfer value and data from subchains to the root chain or from one subchain to another via the root chain.

TABLE I. PROTOCOLS HYPERPARAMETERS

| | CONSENSUS | CONNECTIVITY Tx (transaction) | PRIVACY | TPS |
|---|---|---|---|---|
| 1 | PoW | (Basic Tx P2PKH) | ZK-SNARKS | 19 |
| 2 | PoW | (Basic Tx P2SH) | ZK-SNARKS | 14 |
| 3 | PoW | (Basic Tx Multisig) | ZK-SNARKS | 13 |
| 4 | PoW | (Advance Tx Bonded registration) | ZK-SNARKS | 23 |
| 5 | PoW | (Advance Tx relock) | ZK-SNARKS | 29 |
| 6 | PoW | (Advance Tx Reorg) | ZK-SNARKS | 21 |
| 7 | PoS | (Basic Tx P2PKH) | ZK-SNARKS | 859 |
| 8 | PoS | (Basic Tx P2SH) | ZK-SNARKS | 758 |
| 9 | PoS | (Basic Tx Multisig) | ZK-SNARKS | 815 |
| 10 | PoS | (Advance Tx Bonded registration) | ZK-SNARKS | 1200 |
| 11 | PoS | (Advance Tx relock) | ZK-SNARKS | 1515 |
| 12 | PoS | (Advance Tx Reorg) | ZK-SNARKS | 1400 |
| 13 | PoM | (Basic Tx P2PKH) | ZK-SNARKS | 1700 |
| 14 | PoM | (Basic Tx P2SH) | ZK-SNARKS | 1989 |
| 15 | PoM | (Basic Tx Multisig) | ZK-SNARKS | 1815 |
| 16 | PoM | (Advance Tx Bonded registration) | ZK-SNARKS | 2100 |
| 17 | PoM | (Advance Tx relock) | ZK-SNARKS | 2600 |
| 18 | PoM | (Advance Tx Reorg) | ZK-SNARKS | 2300 |

The item 17 combination (table I) resulted in the best TPS; however, it depends on the node/sensor/device to support this configuration. Therefore, the item 17 combination is not always the best choice and an automated reconfiguration assisted by machine learning is required for IoT scalability. The protocol reconfiguration is the main contribution; however, the blockchain scheme with sidechains and a root chain also helps.

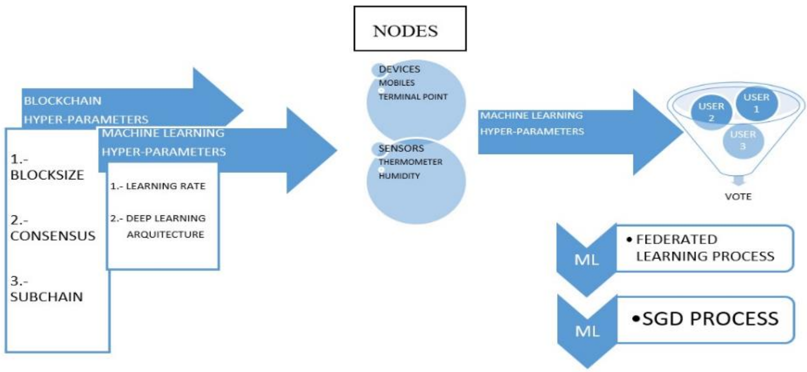


FIG. 4: IoTeX: BLOCKCHAINS IN BLOCKCHAIN (ROOT CHAIN AND SUBCHAINS ARCHITECTURE).

GLOBALPIN scheme consider any node, sensor or device connected to the network as an Internet of Things access point (see figure 4). GLOBALPIN system is considered an expert system with a machine learning module with federated learning (cooperative users processing) and SGD optimizer algorithm.

The root blockchain uses an unspent transaction output (UXTO) based model as Bitcoin and Monero [28], either due to transaction ordering becomes trivial without the need for nonce or sequence numbers and due to applying privacy-preserving techniques such as ring signature and ZK-SNARKS [29] to hide the sender, receiver, and transaction amount becomes possible. The root blockchain comprises hash-linked blocks, and a block comprises a header with hash-links to the previous block and a list of transactions. The root chain allows primarily two types of transaction: basic transactions, including P2PKH, P2SH, and Multisig [30], and advanced transactions that enable cross-blockchain operations like Bonded Registration, Lock, ReLock, and Reorg [31]. Validated transactions are added into a block that has a dynamic size, upper-bounded by 8MB. As detailed in the next section, our consensus scheme produces a block every three seconds.

IoTeX comes with a framework for developing and provisioning a tailored subchain for decentralized IoT applications. The subchain encapsulates low-layer primitives like gossip protocol and consensus mechanism. The permission model, specification, parameters, and transaction types can be customized to fit the application.

IoTcX subchains use an account-based model, which is better for tracking state transitions. Two types of accounts, similar to Ethereum, are regular accounts and contracts. Valid transactions are added into the block, which is produced by the same consensus scheme as the root chain to achieve the same degree of finality and make cross-blockchain communication more efficient. Subchains use the root chain's token, IoTX token, or define their token. The tokens defined by developers on subchains can be distributed publicly through token sales or exchanges on publicly traded exchanges.

Subchains support a smart contract and run on a lightweight and efficient virtual machine. We are evaluating Web Assembly (WASM) [32], an emerging web standard for building high-performance web applications. WASM is efficient and fast and can be made deterministic and sandboxed with some modifications as attempted by the EOS project [33]. Other options are also being explored. With smart contracts, IoT devices connected to the same subchain utilize the shared state, it means that devices can mutate the state on subchains when the physical environment changes. For example, a thermostat updates its temperature via a smart contract based on its sensor data.

Cross-blockchain communication is expected to be used with high frequency in IoT applications. There is always the need for an IoT device in a subchain to coordinate with another device in a different subchain. Again, limited by IoT devices' low computation and storage footprint, we are motivated to design cross-blockchain communication in a fast and cost-effective way.

The pegging mechanism is used for scaling the GLOBALPIN network via sidechains, initially proposed in [34]. It heavily relies on Simplified Payment Verification (SPV) [35] and allows

GLOBALPIN to effectively move from the IoTcX blockchain to the sidechain and back. GLOBALPIN tokens are sent to a unique address to be locked up on the GLOBALPIN blockchain; once this Lock transaction has been confirmed, one sends a Reorg transaction to the side chain, including the Lock transaction and a proof of inclusion in the form of a Merkle branch. The sidechain uses SPV to verify Reorg transactions and, if validated, creates the same number of tokens and sends them to the desired address on the sidechain. Pegging is a primitive for almost all cross-blockchain communication protocols (Cosmos et al.). Two separate pegging flows can be easily coupled together to make the Two-Way Pegging (2WP) to transfer tokens back and forth.

Block finality guarantees that the new block generated is final and cannot be changed. Block finality impacts the concrete implementation of pegging substantially as one has to wait until block finality is achieved on the sending blockchain before requesting Reorg. The more PoW miners confirm a transaction, it is more probable the transaction has been accepted. Utilizing a finalizing consensus addresses this problem because the receiving chain has assurance with one block confirmation on the sending blockchain. For IoT applications, cross-blockchain transferring value and data is expected to be fast and cost-effective, which requires a finalizing consensus mechanism, but GLOBLAPIN consensus achieves instant block finality.

Applying pegging naively, four transactions are needed to make a "remote call" between subchains via the root chain. One possible concern regarding cross-blockchain communication is that a malicious subchain spams the root chain or another subchain by sending over a huge number of cross-blockchain transactions that exhaust other blockchains' capacity. One way to mitigate this is to let each subchain bid for its quota and "rate-limit" transactions from a subchain if its quota is exhausted.

## 6. FUNDING HYPERLEDGER BLOCKCHAIN GLOBALPIN DAPP

The system is seen as a Kermack-McKendrick process [36-39] with reinforcements (retraining in each reconfiguration). In this way, parameter estimation can be found to identify the system for each period, where every reinforcement period (outbreak) is based on a Hyperbolic secant distribution as follows (equation 1).

$$\dot{T} = P_1 \operatorname{sech}^2 (P_2 * t - P_3) \quad (1)$$

Where T is the transactions per second (tps) of the GLOBLAPIN blockchain. $P_1$, P, and $P_3$ are the hyperparameters of the model, and t is the time. The critical value governing the time evolution of these equations is the deep learning training time; every learning reinforcement is a cycle;

$$R_n = \beta S/\gamma \quad (2)$$

Where R is defined as the reinforcements item, in total, the reinforcement was ended up to 19, therefore R = 19. Since R>1, the tps tended to increase since the system is optimizing each reinforcement.

Once the system is identified, we can see the system as a homeostasis system reconfiguring the hyperparameters to make the tps better. In essence, improvement in tps is a result from improvement of the protocols adaptability to the device/node/sensor to the specific application in the specific usage time. It can be seen as a binomial probability (see eq. 3) issue with two cases: the possibility that the new GLOBALPIN reconfiguration be prosperous or not successful.

$$nC_x \, p^x \, (1-p)^{n-x} \quad (3)$$

Where p is the probability that GLOBALPIN reconfiguration be successful, x is the improvement factor, n is the total number of protocol categories; industry, health, domotic and smart city (4); proof of work (PoW), proof of stake (PoS) and proof of movement (PoM), and C which is the combination for n and x. Thus, the more times protocols tested, the better blockchain tps.

## 7. MACHINE LEARNING PROCESS

The sensor adaptation scheme to the network is a hybrid scheme (hyper ledger) with modular distributed control. In the deep training process, the transactions per second (tps) is optimized to reconfigure the hyperparameters (mainly the consensus algorithm). Therefore, the values of the hyperparameters are crucial for the correct functioning and improvement of the tps based on an improvement in the connectivity by the hyperparameter reconfiguration in the training model. However, finding optimal hyperparameters requires comparing a range of options. Therefore, this study proposes to automate the hyperparameter comparison process in a distributed control manner using an algorithm based on a systematic methodology based on tools such as a causal map and process diagram with states and state variables to improve similar existing systems. Functional tests based on dynamic simulations were developed to verify that the proposed system meets the expectations of being a viable and functional option to find the optimal values of the hyperparameters in a distributed and automated way. This system represents a competitive proposal compared to similar works since it focuses on distributed control use cases.

## 8. BLOCKCHAIN

A hybrid hyperledger blockchain accommodates this application since any public or private network could be integrated into the GLOBALPIN network.

GLOBALPIN DAPP expert system includes an autoencoder (filter) for preparing data to find a model using stepwise linear regression [40] and KNN classification [41] to find classes: industry, health, domotic and Smart city. The sensors/devices/nodes maps are identified easily with a convolutional network (ResNet-coco: 101) [42-44]. Regression, stepwise, and machine learning performance are compared. Analyzing tps improvement in the time as a fractal [45] with 19-year cycles (retraining) is helpful.

Table number II shows the chart's critical values of the fuzzy decision tree. The fuzzy module works as a distributed control to make the final decision using a deep learning network. The fuzzy table is as follows:

TABLE II. FUZZY TRUE LOGIC TABLE FOR THE DECISION TREE.

| | CONNECTIVITY | LATENCY | NODES MAP | USER TYPE | SATURATION | TAKE DECISION |
|---|---|---|---|---|---|---|
| INDUSTRY | 1 | 0 | 1 | 1 | 0 | CHANGE |
| HEALTH | 1 | 1 | 1 | 1 | 1 | CHANGE |
| DOMOTIC | 0 | 0 | 1 | 1 | 1 | CHANGE |
| SMART CITY | 0 | 0 | | | | CHANGE |

The five headers in Table II are the basic features when deciding to change the consensus algorithm combination 1-18 (see Table I) to improve tps. The configuration of the last header CHANGE/NO CHANGE, is the label TAKE DECISION with two targets: CHANGE or no CHANGE. The first column has four categories: industry, health, domotic, and smart city, which form the smart society. Table II only shows take decision change because it is the only matters.

## 9. BLOCKCHAIN LEDGER

The logic in Table II is performed in a smart contract that is kept in an IoTeX smart contract. All other data is not protected with blockchain since it already has an encoder (VAE) and GAN protection; therefore, a blockchain stability study is unnecessary.

The smart contract is built using solidity in IoTX and an API es created in python. Some companies have pioneered DEPIN applications with machine learning models on distributed datasets without compromising privacy but with scalability challenges.

In recent years, systems with applications of smart contracts [46-49] for data protection have grown exponentially. The difficulty of hacking a database in a smart contract means offering potential donors, investors, and initial developers the confidence to donate, invest, and work with this expert system.

The BOT expert system has an ad-hoc design for accessing GLOBALPIN DAPP. Using the DEPIN concept, data connects to the internet cloud to form an extensive data repository using a semantic browser [50-52] to avoid saturation in the blockchain ecosystem. This system has a smart contract that meets the characteristics of being reliable, versatile, accessible, and sustainable and, at the same time, contributes to a documented study that serves as a reference for similar future works, given that the use of DEPIN IoTX is not yet in everyday use due compatibility and scalability issues.

## 10. DISCUSSION

IoTcX can be considered the next level of the Internet of Things. Initially, IOTA used tangle [53]. IOTA attempts to decouple the state transition mechanism with the consensus canonicalization mechanism by throwing away concepts like blocks and chains. However, IoTx focuses on root chains and subchains, which is more promising than Ethereum version 2's structure.

IOTA transaction issuers are transaction approvers, and transaction verification is constructed using a Directed Acyclic Graph (DAG) to make transactions fast and at zero cost. The efficiency is by losing globally definite states, which makes desired features like Simple Payment Verification (SPV). However, IoTcX promises more secure transactions and scalability; fast transactions and low cost have already improved with other blockchains such as Solana and Ethereum version 2.

Smart contracts are challenging. IoT Chain (ITC) [53], another IoT blockchain project based in China, inherits the same tangle structure from IOTA but uses traditional blockchain, with root chains and subchains prevailing.

## 11. CONCLUSIONS

The smart contract implements the creation of the GLOBLAPIN token using a friendly bot interface. Tokens can be generated, only by the initial ICO investors with 10,000 tokens airdrop reward. Moreover, anyone can buy, use and send coins to other holders without registering with a username and password.

The stability model was not considered since DEPIN is based on models in each client device then it is not supposed that learning to be saturated. Therefore, IoTcX GLOBALPIN model challenge is not saturation nor scalability but client adoption does since GLOBALPIN DAPP needs to be more known by the clients/users.

On table I item 17 is clear that consensus algorithm PoM proof of movement has the best performance with 2,600 tps with connectivity of advance transactions relock. Change in the consensus algorithm makes the biggest difference in the tps, then advance/basic transaction and the types of the transactions make la less difference (relock in this case prevail).

Proof of movement gives the best results in tps. However, consensus algorithm, normally is more used since it is in the equilibrium between speed and security to hack attacks.

## WORKS CITED

Tian Liu et.al, Towards Fast and Accurate Federated Learning with Non-IID Data for Cloud-Based IoT Applications, Journal of Circuits, Systems and Computers, (2022), 1-10.

Bimal Ghimire et al, Recent Advances on Federated Learning for Cybersecurity and Cybersecurity for Federated Learning for Internet of Things, IEEE Internet of Things Journal, 5-8.

Khandaker Mamun Ahmed, Federated Deep Learning for Heterogeneous Edge Computing, International Conference on Machine Learning and Applications (ICMLA), (2021), 2-4.
S. Pradip, C. Mu-Yen and P. Jong, A software-defined fog node based distributed blockchain cloud architecture for IoT, IEEE Access 6 (2017), 115-124.
J. Sun et al., Blockchain-based sharing services: What blockchain technology can contribute to smart cities, Financial Innovation 2(26) (2016), 1-9.
J. L. Zhao, Overview of business innovation and research opportunities in blockchain and introduction to the special issue, Financial Innovation 3(9) (2017), 1-7.
T. Aste, P. Tasca and T. D. Matteo, Blockchain technologies: The foreseeable impact on society and industry, Computer 50(9) (2017), 18–28.
Christine Dewi, Rung-Ching Chen and Yan-Ting Liu, Synthetic Traffic Sign Image Generation Applying Generative Adversarial Networks, Vietnam Journal of Computer Science, (2022), 2-12.
HoBae et al, AnomiGAN:Generative Adversarial Networks for Anonymizing Private Medical Data, Pacific Symposium on Biocomputing 2020, (2020), 564-570.
R. Carreño et al, An IoT Expert System Shell in Block-Chain Technology with ELM as Inference Engine, IJITDM, , 18 (1) (2019), 87-104.
W. Gu t al., Expert system for ice hockey game prediction: Data mining with humanjudgment, IJITDM, 15(4) (2016), 763–789.
N. J. Pizzi et al., Expert system approach to assessments of bleeding predispositions in tonsillectomy/adenoidectomy patients, Advances in Artificial Intelligence 27 (1990) 67–83.
Agrawal, Prateek & Madaan, Vishu & Kumar, Vikas, Fuzzy rule-based medical expert system to identify the disorders of eyes, ENT and liver. International Journal of Advanced Intelligence Paradigms. 7(3) (2015), 352-367.
H. Dong, A & Shan, D & Ruan, Z & Y. Zhou, L & Zuo, F. The Design and Implementation of an Intelligent Apparel Recommend Expert System. Mathematical Problems in Engineering. (2013).
Som, Pradip & Chitturi, Ramesh & G. Babu, A.J. Expert Systems Application in Manufacturing. Proceedings of SPIE - The International Society for Optical Engineering. 786 (1987). 474-479.
R. Carreño, A NON-LINEAR MODEL FOR A SMART SEMANTIC BROWSER BOT FOR A TEXT ATTRIBUTE RECOGNITION, fractals, (2020), 1-10
Raheleh Jafari, Wen Yu, Fuzzy Control for Uncertainty Nonlinear Systems with Dual Fuzzy Equations, Journal of Intelligent and Fuzzy Systems, Vol. 29 No.3, 1229-1240, 2015
https://www.ericsson.com/assets/local/reports-papers/mobility-report/documents/2020/november-2020-ericsson-mobility-report.pdf
files/publications/IoTeX_Whitepaper_1.5_EN.pdf at main · iotexproject/files · GitHub
Erick De la Rosa, Wen Yu, Xiaoou Li , Nonlinear system modeling with deep neural networks and autoencoders algorithm, 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC16), Budapest, Hungary, (2016), 2157-2162.
https://swg.io
IoTeX - DePIN's Modular Platform
Samit Shivadekar et al., Edge AI cosmos blockchain distributed network for precise ablh detection, Multimedia tools and applications, (2024), 7.
Feipeng Li et al., A LPSO-SGD algorithm for the Optimization of Convolutional Neural Network, 2019 IEEE Congress on Evolutionary Computation (CEC), (2019), 1-5.
Riya Tapwal et al., PerBlocks: A Reconfigurable Blockchain for Service Provisioning in Industrial Environment, IEEE Transactions on Industrial Informatics, (20) (2023), 1-3.
S. N. Aurpita, A. T. Momo and M. A. Rahman, "RaiDen: An IOT-based automated and integrated system for improvement of plant growth," 2024 International Conference on Advances in Computing, Communication, Electrical, and Smart Systems (iCACCESS), Dhaka, Bangladesh, (2024), 01-06.
Introduction — Hyperledger Fabric Docs main documentation (hyperledger-fabric.readthedocs.io)
Cryptocurrency Prices, Charts And Market Capitalizations | CoinMarketCap
J. H. Khor, M. Sidorov, N. T. M. Ho and T. H. Chia, "Public Blockchain-based Lightweight Anonymous Authentication Platform Using Zk-SNARKs for Low-power IoT Devices," 2022 IEEE International Conference on Blockchain (Blockchain), Espoo, Finland, 2022, pp. 370-375.

D. Melo, S. P. Hernandez, L. Rodríguez and J. C. Pérez-Sansalvador, "Bitcoin Transactions Types and Their Impact on Storage Scalability," 2023 IEEE International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), Paris, France, 2023, pp. 1-6

Alexander Lipton et al., Chapter 5- A deep dive, Blockchain and distributed ledgers, Worldscientific, (2021), 145-203.

W. Chen, Z. Sun, H. Wang, X. Luo, H. Cai and L. Wu, "Poster: Uncovering Vulnerabilities in Wasm Smart Contracts," 2023 IEEE 43rd International Conference on Distributed Computing Systems (ICDCS), Hong Kong, Hong Kong, (2023), 1073-1074

Blue Paper Archives - EOS Network

L. Yin, J. Xu and Q. Tang, "Sidechains With Fast Cross-Chain Transfers, IEEE Transactions on Dependable and Secure Computing, (2022), (19) (6), 3925-3940.

X. Feng, J. Ma, H. Wang, S. Wen, Y. Xiang and Y. Miao, Space-Efficient Storage Structure of Blockchain Transactions Supporting Secure Verification, IEEE Transactions on Cloud Computing, (2023), (11) (3), 2631-2645.

Sourav Chowdhury et al., Universality and herd immunity threshold: Revisiting the SIR model for COVID-19, International Journal of Modern Physics C, 32 (10), (2021), 1-9.

https://mathworld.wolfram.com/Kermack-McKendrickModel.html

https://www.kaggle.com/lisphilar/covid-19-data-with-sir-model

https://towardsdatascience.com/extending-the-basic-sir-model-b6b32b833d76

Yiqian Zhou, Jacqueline Gerhart, Ahmet Sacan, Reconstruction of gene regulatory networks by stepwise multiple linear regression from time-series microarray data, 2011 IEEE International Conference on Bioinformatics and Biomedicine Workshops (BIBMW), (2011), 1017-19.

Poonam Kumari et al, Comprehensive investigation of structural, dielectric and local piezoelectric properties of KNN ceramics, JOURNAL OF ADVANCED DIELECTRICS, 9(2), (2019), 1-12.

https://docs.openvino.ai/latest/omz_models_model_rfcn_resnet101_coco_tf.html

Jifeng Dai et al, R-FCN: object detection via region-based fully convolutional networks, ACM, (2016), 1-9.

Benny Avelin et al, Neural ODEs as the deep limit of ResNets with constant weights, Analysis and Applications, 19(03), (2021), 397-437.

J. PATIÑO ORTIZ et al, Seismic activity seen through evolution of the hurst exponent model in 3D, Fractals, 24(04),(2016), 1-10.

Ernie Teo, Chapter 7: Introduction to Blockchain Smart Contracts and Programming with Solidity for Ethereum, Blockchain and Smart Contracts, 4 (2021), 189-216.

S. Kumar, An Investigation into Smart Contract Deployment on Ethereum Platform Using Web3.js and Solidity Using Blockchain, Data Engineering and Intelligent Computing, (2021), 549-561

H. Kim and M. Laskowski, A perspective on blockchain smart contracts: Reducing uncertainty and complexity in value exchange, 26th International Conference on Computer Communication and Networks (ICCCN), (2019), 265-278.

V. Youdom K. et al., Recent Advances in Smart Contracts: A Technical Overview and State of the Art, IEEE Access, 8 (2020), 1-5.

S. X. Fang et al., WEB CONTENT VISUALIZER: A VISUALIZATION SYSTEM FOR SEARCH ENGINES IN SEMANTIC WEB, IJITDM, 10 (5), (2011), 913-931.

S. Shirgave et al., Semantically Enriched Variable Length Markov Chain Model for Analysis of User Web Navigation, IJITDM, 13 (4) (2014), 721-753.

Phillip C.-Y. Sheu, Semantic Computing, Cloud Computing, and Semantic Search Engine, 2009 IEEE International Conference on Semantic Computing, (2020), 1-3.

https://www.iota.org