

# Vaxchain - Safe, Efficient, and Rewarding Vaccine Storage with IoT on Solana

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**Abstract**— “VAXCHAIN” is a novel solution for enhancing global vaccine distribution, integrating IoT, Solana blockchain technology, and cloud services. It leverages blockchain tokens to speed up transactions and improve supply chain flexibility. The system ensures real-time monitoring of vaccines, upholding data integrity and regulatory compliance. With tailored interfaces for various stakeholders and automated compliance processes, “VAXCHAIN” is poised to transform vaccine distribution efficiency and security on a global scale.

**Index Terms**— VAXCHAIN, Tokens, Data integrity, Supply chain optimization, Solana.

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## I. INTRODUCTION

Given that global health challenges remain a pressing reality, the desire to improve the allocation of vaccines has never been as urgent as it is today. Inefficiencies in traditional vaccine supply chains as well as insufficient transparency along with concerns about security are common. ‘VAXCHAIN’ is a state-of-the-art solution that this paper brings to address these hurdles with the collaboration of IoT technology, blockchain on the Solana blockchain, and alternative cloud services. Token integration is driving this innovation at the core level changing the paradigm of speed and flexibility associated with informational options for the vaccine distribution supply chain.

What makes “VAXCHAIN” an important concept is not just its technical potential but a whole package effectively targeting to change the current status of vaccine distribution. Such a system enables the monitoring of vaccine states in real-time, preserving data good quality and corresponding to strict regulatory requirements. Easy-to-use interfaces customized for healthcare providers, retailers, medical component producers, and consumers simplify relationships adoption of the user orientation. “VAXCHAIN” represents the capacity that new technologies have to reconfigure the whole world’s health infrastructure, emerging as a scalable, safe, and transparent digital infrastructure that ensures the equitable distribution of vaccines.

This paper delves into the architecture, functionalities, and the innovative integration of tokens within ‘VAXCHAIN,’ offering a comprehensive exploration into the transformative potential of this solution in the realm of vaccine distribution.

## II. LITERATURE SURVEY

The introduction of ‘VAXCHAIN’ can be regarded as one of the milestones in the evolution of vaccine distribution represented by resolutions of the past research limitations in a novel fashion.

The first bit of groundwork set by ‘A Comprehensive Blockchain Framework for COVID-19 Vaccine Program Registration, Supply Chain, and Side Effects’ was a rich starting point for the application of blockchain in vaccine programs. Nevertheless, this provoked abstract features in the direction of the replacement of older norms of blockchain and IoT technology practicing. The gap that is evident in such a setup is bridged by “VAXCHAIN” through the vital integration of the Solana blockchain – highly efficient in terms of throughput and cost of transactions – and IoT functionalities. The integration of the aforementioned features allows real-time monitoring and tracking of vaccines hence ensuring their integrity at all supply chain points, i.e., manufacture down to administration.

In addition, the blockchain technology discussed in the article “A Blockchain-based Solution for COVID-19 Vaccine Distribution”, has shown to revolutionize vaccine distribution process. Nevertheless, the study herein did not focus on the details of using the Solana blockchain or analyze the role of IoT in improving the distribution processes. ‘VAXCHAIN’ is an expansion on these concepts, as it not only uses the Solana blockchain but also incorporates IoT, improving to become a more elaborate and integrated solution for vaccine distribution. Such an approach guarantees a safer, less obscure, and more effective system of distribution, dealing with key problems of the vaccine supply in the world.

Moreover, the supply chain traceability prototype discussed in “A Prototype of Supply Chain You want should always fill your needs with a stable, stylish and much quicker service of this type. Traceability using Solana as blockchain and IoT” indicated that both Solana blockchain and also IoT have the ability to provide for supply chain traceability. This prototype was a notable advancement but it did not delve into the many possibilities of using these technologies in a comprehensive implementation of vaccine distribution or integration token functionality. “VAXCHAIN” extends the above discussed prototype by using Solana blockchain and IoT not only for traceability but also for operating all of these stages of the vaccine chain. Token functionality presents the additional innovation to the system that aids faster and more versatile transaction flows which is very much essential for the bustling vaccine distribution environment.

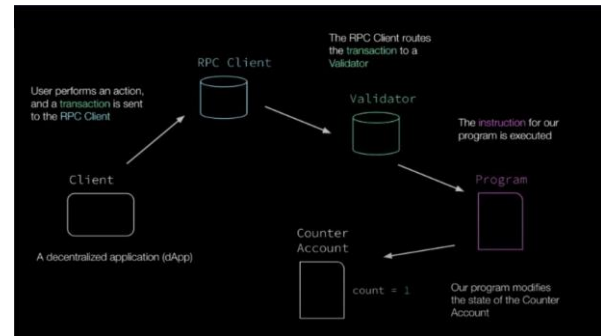
Additionally, the Solana guide for token development was also found to be a highly beneficial reference for “VAXCHAIN”. It helped towards the establishing blockchain tokens, a critical aspect of improving operations as far as the vaccine distribution network is concerned. With these tokens, that run on the Solana blockchain, the response of the supply chain to changing needs, can be enhanced enough to accommodate all demands. Remaining quick and versatile at same time is now very much possible with this decentralized architecture!

### III. PROPOSED METHODOLOGY

The proposed methodology for “VAXCHAIN” is a comprehensive approach that blends advanced technologies like blockchain, the Internet of Things (IoT), and cloud services to revolutionize vaccine distribution. This methodology is structured around several key components:

#### A. Integration of Solana Blockchain:

- **Blockchain Selection:** Due to its high throughput, low transaction costs, and fast block times, Effectively, it makes it ideal for real-time applications.
- **Token Implementation:** Utilizing Solana’s token capabilities, “VAXCHAIN” provides efficient and responsive Vaccine supply chain transactions. This encompasses custom token creation and management. To be a symbol of diverse assets or actions occurring within the system. For example, vaccination lots or distribution operations.
- **Smart Contracts:** To automate and enforce agreements In the supply chain smart contracts are implemented on the Solana blockchain. These contracts govern transactions and interactions; firstly, the various gateways will be added to comply with the predefined rules and standards.



**Fig. 1. Solana Transaction Lifecycle**

#### B. IoT Integration for Real-Time Monitoring:

- **Sensor Deployment:** IoT sensors are attached to vaccine containers to monitor conditions like temperature, humidity, and location in real-time.
- **Data Transmission:** Sensor data is continuously transmitted on-chain via the contracts to ensure tamper-proof and real-time tracking of vaccine condition.
- **Alerts and Notifications:** The system is constructed so that divergence from the pre-established conditions is observed and alerted immediately, thus allowing the reflex intervention for preserving the vaccine integrity.



**Fig. 2. IOT Setup having temperature sensors and RFID kit**

#### C. Cloud Services Utilization:

- **Data Storage and Management:** Cloud services are used for scalable and secured data storage. This also includes various other additional information such as history of transactions, data from sensors among others.
- **Data Analytics:** The cloud-based analytics tools perform data processing and analysis in which areas on the optimization of the supply chain operations and decision-making are reflected.

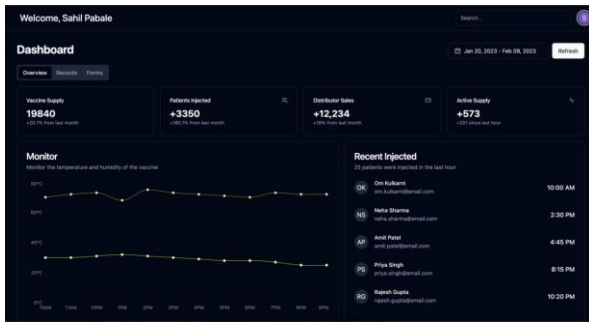


Fig. 3. Cloud Dashboard

#### D. User Interface Development:

- **Stakeholder-Centric Design:** Tailored interfaces are developed for different stakeholders, such as healthcare providers, manufacturers, distributors, and patients.
- **Accessibility and Usability:** The focus is on creating user-friendly, accessible interfaces that facilitate easy interaction with the system.



Fig. 4. Landing Page UI

#### E. Compliance and Security Measures:

- **Regulatory Adherence:** The system is designed to comply with relevant health and safety regulations, including data protection laws.
- **Security Protocols:** Robust security measures are implemented to protect against unauthorized access and data breaches.

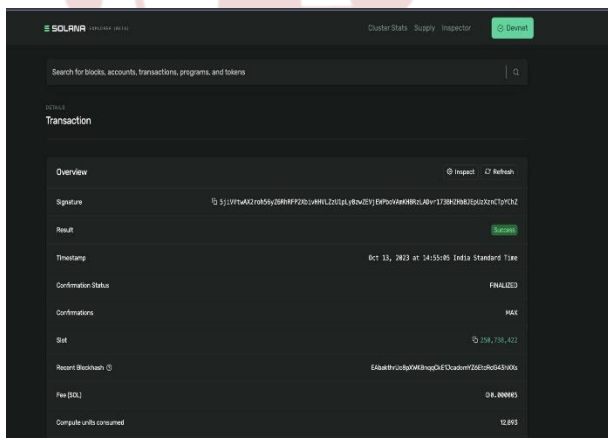


Fig. 5. Solana Blockchain Transaction Overview

#### F. Testing and Validation :

- **Prototype Testing:** We have made it possible to say, all systems with "VAXCHAIN", through their paces, testing the speed, security, and cost of its development. Think of it as something about guaranteeing its ability to endure a marathon and a sprint, and all this with data keeps intact.
- **Feedback Integration:** Feedback from initial testing phases is used to refine and enhance the system. It's a cycle of listening, improving, and fine-tuning.

#### G. Deployment and Monitoring:

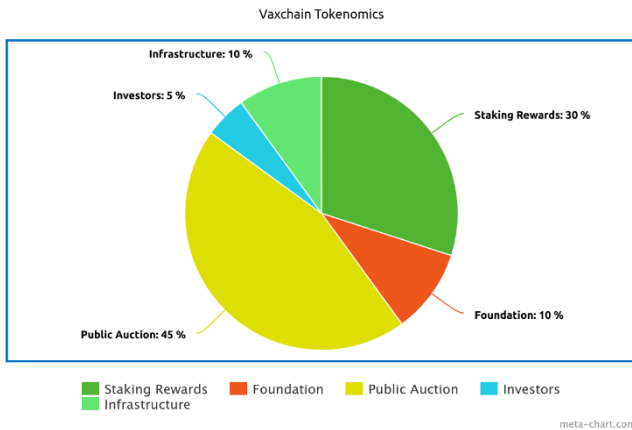
- **Rollout Strategy:** A phased rollout is planned, starting with pilot implementations in controlled environments.
- **Continuous Monitoring and Updates:** Post-deployment, the system is continuously monitored for performance and security, with updates and improvements made as needed.

### IV. TOKENOMICS

The VAXCHAIN ecosystem, fundamentally, is powered by its native VAX token functioning as the utility token for the provision and preservation of vaccines. Network efficiency is linked directly to the amount of VAX tokens staked by distributors who are forced to do so. Such staking is critical for vaccine supply chain, assuring an incentive interest in cold chain preservation.

The VAXCHAIN ecosystem has reward allocation as a vital aspect, and VAX tokens are distributed based on the conditions vigorously enforced to the storage of the vaccine platform. The provision of these incentives is however dependent on the period spent in storage and the sustainment of vital temperature conditions. Alternatively, the violation of these conditions – defective marking of vaccines causes the loss of proprietorship of the stake, maintaining the accountability paradigm of the network.

Additionally, the tokenomics of VAXCHAIN has a deflationary feature in that the tokens realized out of unstaking and subsequently slashes are burnt, reducing the overall supply which can result in increasing the value of the surviving tokens. These token offers are allocated about 45% for Public Auction, 10% for Foundation, 30% for Staking Rewards, and 10% for Infrastructure and rest 5% for the Investors accordingly helping the network to grow and function on demand.

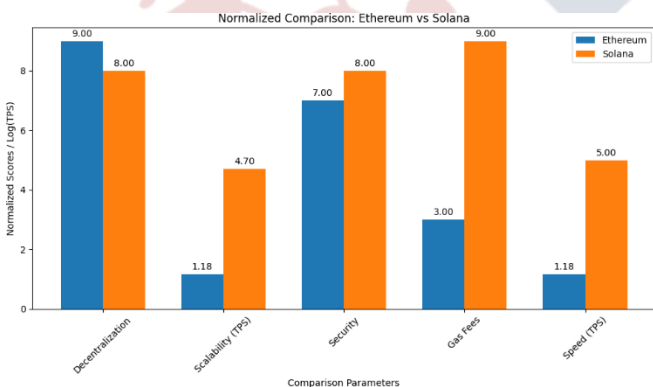


**Fig. 6.** \$VAX Tokenomics

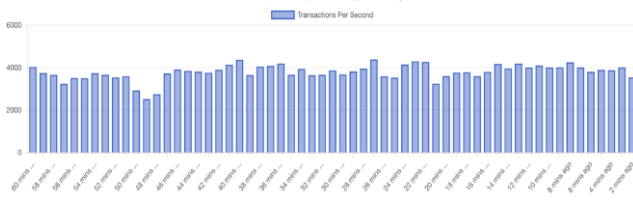
**V. RESULTS**

Ethereum is ahead in the decentralization game. That’s because it’s been around longer and has a larger network of users and computers confirming transactions. Solana isn’t too far behind though. It’s newer, but it’s quickly growing and showing it can keep up.

Now, when it comes to handling lots of transactions fast, Solana is the clear winner. It can manage 50,000 transactions every second, which is a lot more than Ethereum’s 15. This is a big deal if you need things done quickly and it’s why Solana gets a high score for scalability and speed. For security, they’re both doing well, but Ethereum has been tested more over time, so it’s got a slightly higher score. However, Solana’s right there too, proving it’s safe to use. Gas fees are another big point; Solana makes things cheaper with lower fees, which is great for when you’re doing a lot of transactions. Ethereum’s fees are higher, which can be a downside if you’re looking to save money.



**Fig. 7.** Why is Solana better than Ethereum



**Fig. 8.** Raw Transactions Per Second



**Fig. 9.** Historic Fees Data

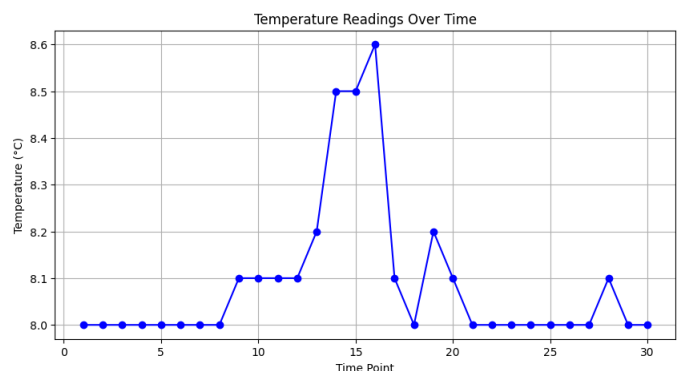
Solana’s impressive speed can be attributed to a combination of its unique consensus mechanism, Proof of History (PoH), and its innovative architecture. PoH allows Solana to process transactions more efficiently by creating a verifiable timestamp for each transaction. This enables the network to process transactions in parallel, significantly increasing its throughput. Additionally, Solana uses a variety of optimization techniques, such as:

- **TurboVote:** A feature that allows validators to vote on the state of the network more quickly, reducing confirmation times.
- **Gulf Stream:** A protocol that enables validators to receive transaction data ahead of time, reducing the time it takes to propagate transactions across the network.
- **Sealevel:** A parallel smart contracts runtime that allows multiple smart contract transactions to be executed simultaneously, further increasing the network’s processing capacity.



**Fig. 10.** Compute units Per Second (highest amongst all blockchains)

In our project Vaxchain, we’re leveraging the Solana blockchain to ensure the integrity of vaccine temperature data. Each vaccine batch’s temperature is meticulously monitored and recorded, and any deviations, like the brief spike observed when a fridge door is opened, are logged in real-time. This event, represented by the sharp increase in our temperature graph, is crucial for maintaining the efficacy of the vaccines, as it signals a potential risk to the cold chain process.



**Fig. 11.** Sensor Temperature Spike

Choosing Solana for this task brings several benefits. Its high throughput allows for thousands of temperature logs to be recorded each second, making it ideal for real-time monitoring. Additionally, Solana’s low transaction costs make it economically viable to log numerous data points without incurring significant fees. The combination of these factors — speed, cost-efficiency, and the added layer of security provided by blockchain technology — ensures that Vaxchain can operate reliably and transparently, maintaining the integrity of vaccine storage and transport.

Number of NFTs	Solana Today	Solana with Compression	Ethereum	Polygon
1,000	12 @ \$253.68	2.57 @ \$64.33	17.69 @ \$33,774.35	28.94 @ \$33
10,000	120 @ \$2,536.80	3.49 @ \$73.78	176.09 @ \$336,231.23	288.14 @ \$328.48
100,000	1200 @ \$25,368	4.22 @ \$99.21	1760.09 @ \$3,360,800.03	2880.14 @ \$3,283.36
1,000,000	12000 @ \$253,680	5.35 @ \$113.10	17600.09 @ \$33,606,488.03	28800.14 @ \$32,832.16
10,000,000	120000 @ \$2,536,800	10.76 @ \$227.47	176000.09 @ \$336,063,368.03	288000.14 @ \$328,320.16
100,000,000	1200000 @ \$25,368,000	58.45 @ \$1,193.35	1760000.09 @ \$33,606,320,168.03	2880000.14 @ \$3,283,200.16
1,000,000,000	12000000 @ \$253,680,000	507.13 @ \$10,720.73	17600000.09 @ \$33,606,320,168.03	28800000.14 @ \$32,832,000.16

**Fig. 12.** How Solana stores data efficiently on-chain

In terms of technical challenges, one of the issues for blockchains is how to store data efficiently on-chain, especially for NFTs which may necessitate the storage of complex and large metadata. Compressed NFTs is a mechanism developed by Solana to mitigate this problem by reducing the necessary space for NFT storage on the blockchain.

In the case of Solana which is already high throughput low transaction cost Solana, the compression NTTs further compressed efficiency. The compression method includes encoding the metadata and possibly the asset itself, such as images or files that are associated with the NFT, in such a way that takes less space. The typical means of achieving this is by using algorithms that compress the data without losing the necessary

information needed to reconstruct it later on referred to as lossless compression.

Compressed data, with Solana, is stored, which allows on-chain placement of a greater number of NFTs with a low cost. The stored compressed data is decompressed upon accessing or transferring an NFT such that end-users can interact with NFTs as intended, without losing any detail or functionality.

However, this method is especially beneficial for those applications which require minting and managing large amounts of NFTs. This ensures the scalability and responsiveness of the blockchain and that the costs of deploying and interacting with NFTs do not become unreasonably high with a surge in volume of transfers. This provides access, respectively, to developers and users of a more rewarding and viable NFT environment for the growing

market.

**VI. CONCLUSION AND FUTURE WORK**

“VAXCHAIN” is a breakthrough in vaccine distribution. It successfully merges IoT, Solana blockchain tech, and unique cloud services. Using tokens on the Solana blockchain brings fast, flexible transactions. It changes how efficient and safe vaccine supply chains are. Real-time tracking, strong data protection, and automated compliance make it a strong, transparent system. It solves deep-rooted vaccine distribution issues. The design puts users first: healthcare providers, distributors, manufacturers, and patients. It shows the project’s focus on being inclusive and easy to use. “VAXCHAIN” is more than a tech upgrade; it’s a game-changer in global health.

Looking ahead, “VAXCHAIN” sets the stage for continued advancements in vaccine distribution. Future work could explore scalability for large-scale vaccination campaigns, integration with emerging technologies, and adaptation to diverse global healthcare ecosystems. Collaborations with international health organizations and governments present opportunities for “VAXCHAIN” to become a global standard. Ongoing advancements in blockchain, IoT, and cloud services offer the potential for continuous optimization. Collaborative efforts with stakeholders and regulatory bodies can enrich capabilities, ensuring alignment with evolving global health standards.

In conclusion, “VAXCHAIN” not only serves as a groundbreaking solution for contemporary challenges but also as a catalyst for ongoing exploration and refinement, laying the groundwork for a future where vaccine distribution is efficient, secure, and accessible to all.

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