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Original Paper

# INTEROPERABILITY BETWEEN BLOCKCHAIN NETWORKS TO SUPPORT DECENTRALIZED APPLICATIONS

Aniket S. Inamdar[a*], Sheetal Girase[b]

[a] Computer Science and Engineering, MIT World Peace University, Pune, India,
aniketinamdar02@gmail.com
[b] Computer Science and Engineering, MIT World Peace University, Pune, India,
sheetal.girase@mitwpu.edu.in

## *ABSTRACT*

Interest has been generated by the possibility of using decentralized, transparent, and secure systems enabled by blockchain technology to transform various industries. Blockchain networks have nonetheless become increasingly fragmented, which has made it more difficult to transmit and communicate data effectively. Interoperability between various networks is necessary if blockchain technology is to completely pay off. This paper discusses various issues related to the interoperability between blockchain networks along with a solution in the form of appXchain, an application layer-based strategy. DApps, or decentralized applications, are used to facilitate seamless integration and communication among various blockchain platforms. AppXchain intends to enable the exchange of assets, smart contracts, and data across dissimilar systems while assuring security, scalability, and reliability by bridging the gap between various blockchain networks.

## *KEYWORDS*

*Blockchain Technology, Interoperability, appXchain, Decentralized systems, Smart contracts, Scalability.*

## 1. INTRODUCTION

Now days blockchain technology is becoming popular in industry as well as in academia. It has its applications in the domains like finance, healthcare, public sector, administration to name a few. The concept of blockchain interoperability is to make it possible for various blockchain networks to collaborate and interconnect, allowing for smooth communication and the sharing of data between chains. interoperability is defined as the ability of blockchains to flexibly transfer assets, share data, and invoke smart contracts across a mix of public, private, and consortium blockchains without any changes to the underlying blockchain systems [7].

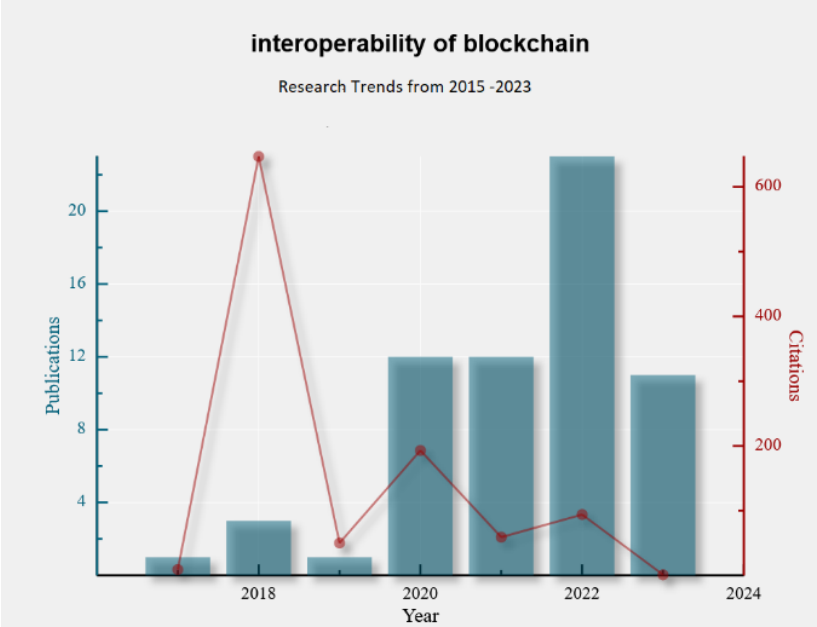


Figure 1. Research trends on google scholar for in Blockchain

Figure 1 shows, research trends for the term ‘interoperability of blockchain’ from year 2015 to 2023. As shown in the graph the number of publications is increasing every year. In 2015, there were only two documents related to the topic. In 2022, there were more than 25 publications related to the topic and still growing in 2023. In case of blockchain technology if for every new use case new blockchain is implemented with all scenarios, security will be at risk. The need for flexible and stable blockchains is still motivating factor along with need for interoperability resolving challenges pertaining to data and value silos [8]. what if the blockchain in which a particular service is running becomes obsolete, vulnerable, or is shut down? [9]. The question remains how to increase portability if we want to reproduce one use case to another blockchain? As the biggest hurdle in adopting blockchain technology is the lack of interoperability among different blockchains.

The key motivation behind development of techniques for interoperability of blockchains is scalability and integration. Homogeneous blockchain solutions can benefit from interoperability to scale-out to new stakeholders whereas heterogeneous blockchain solutions can benefit from interoperability through integration [1]. The basic interoperability solution aims for interacting and sharing data in a heterogeneous blockchain systems.

The AppXchain is a solution that provides application-level interoperability for blockchain networks that enables adaptability and upgradability of Decentralized Applications (DApp) to develop a practical and standardized solution for cross-chain communication. The enabling technology for reading and writing data between blockchains is cross-chain messaging protocols. Decentralised applications (DApps) can interface with smart contracts on various blockchains via these protocols. Cross-chain decentralised applications (DApps) stand out from multi-chain decentralised applications (DApps) in that the former allow for communication and cooperation between various blockchains, whereas the latter typically deploy independent instances of the same application on various blockchains with no connection.

The study makes use of appXchain, a solution based on application layers, to successfully address the problem of blockchain interoperability. AppXchain substantially boosts efficiency and encourages creativity within the blockchain ecosystem by using a Decentralised application

(DApp) strategy. This ground-breaking method makes it possible for seamless data sharing and trade across various blockchain networks, encouraging peaceful cooperation and opening up limitless prospects for creativity.

## 2. LITERATURE REVIEW

To understand how to develop new mechanisms/ approaches that are way better than the existing solutions, we need to understand the entire timeline of this area of study.

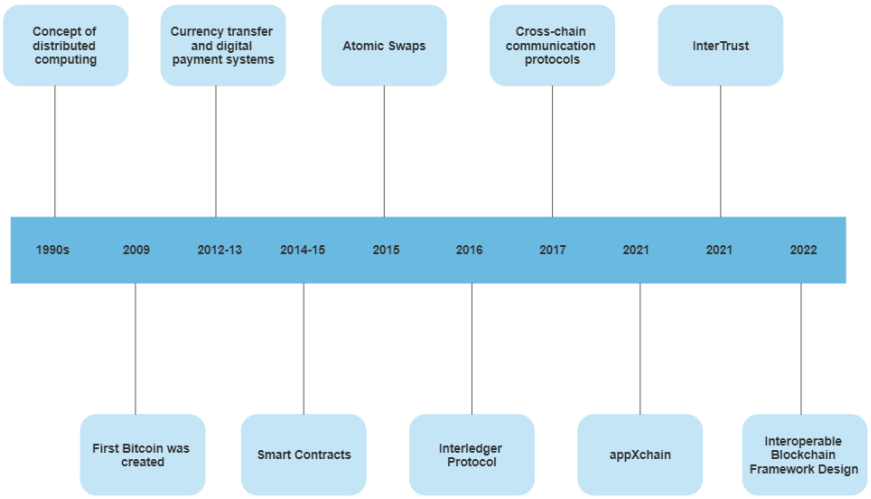


Figure 2. History of Blockchain and Blockchain Interoperability

Figure 2 depicts the timeline, in 1990's the concept of distributed computed was introduced. This paved the way for Blockchain Technologies. In 2009, the first bitcoin was created known as Satoshi Nakamoto. In order to represent a decentralized ledger maintained by anonymous parties, Satoshi Nakamoto proposed the concept of Blockchain. Currency transfer and digital payment systems were first launched in 2012–2013, and smart contracts were first conceptualized in 2014–2015. In 2015, Atomic swaps were introduced. Atomic swaps are peer-to-peer cryptocurrency exchange contracts that are automated and self-enforcing, enabling peer-to-peer trading without the need for a reliable third party. The Inter Ledger Protocol (ILP)[11] idea first appeared in 2016. The ILP is a protocol designed to facilitate seamless transactions across different ledgers, such as blockchain and traditional financial systems. It provides a common framework for cross-ledger payments and asset transfers. In 2017, cross-chain communication protocols were released. Cross-chain communication is the capacity of several blockchain networks to communicate and share data with one another, allowing for seamless interoperability and cooperation between dissimilar chains. In 2021, studies on appXchain were published. It is based on the 2017 release of the cross-chain communication. Decentralized apps (DApps) can be used for cross-chain communication with the help of the application layered technique known as appXchain. InterTrust was released in 2021 which is based on Atomic Swaps. It makes use of threshold signature technology and trustworthy hardware. Atomic swaps communication can be acquired, resulting in Blockchain interoperability. In a research published in 2021 [1], Mohammad Madine et al. developed the appXchain method, which makes use of decentralised applications to promote cross-chain interoperability between various blockchain networks. Along with it, Gang Wang and Mark Nixon[2] in 2021 proposed InterTrust an architecture which focuses on effective blockchain

interoperability via trusted services, threshold signature systems, and trusted hardware. They were able to communicate atomic swaps for interoperability.

Recent research has looked into several strategies for interoperability between blockchain networks. The pioneer work was done by Vitalik Buterin in this field, providing blockchain Ethereum framework and proposed three strategies for providing interoperability as 1. Notary scheme 2.relay also referred to as side-chain and 3.hash-locking. In a notary scheme, a trustworthy set of entities allow atomic interaction and information sharing across multiple blockchains, acting as intermediaries. The second strategy i.e. relay, requests one of the blockchains to be responsible for verifying the claims and information of another blockchain, and the third strategy is hash-locking, which inter-locks multiple operations on different blockchains using the original message of a hash. Although the suggested strategies can provide interoperability in certain use cases, practically they fall short of being a standard that stimulates scalability and maintains security of the network [10].

Maha Helal et al. [12] suggested Inter-operable Blockchain Framework Design (IBFD), which is an architecture that facilitates cross-chain interoperability by verifying smart contracts across several blockchain networks, was suggested by in 2022 [6]. One of the biggest challenges in the integration of the data is the integrity of the shared data for the same Babu Pillai et.al. [12] reviewed advancement in blockchain integration systems, analyzed them and have designed Interoperable Blockchain Framework Design (IBFD) that provides a decision framework which identifies key assumptions and critical characteristics of the cross-blockchain technology. Thus developing a standardized framework that facilitates smooth interoperability and communication between various blockchain networks, encouraging cross-chain cooperation and data sharing. The cross-chain interoperability approach makes use of transactions to facilitate communication between blockchain systems was introduced by Babu Pillai et al. in 2020 [3]. The model's primary components are state changes and information querying. Pascal Lafourcade and Marius Lombard-Platet [4] in their work discussed a formal challenge pertaining to the theoretical constraints of attaining blockchain interoperability. The topic of blockchain interoperability was covered by Seth Djanie Kotey et al. [5] in their discussion of notary schemes, Hashed Time-Lock Contracts (HTLC), relays, and relay chains. They organised several procedures and emphasised data- and cryptocurrency-based interoperability solutions. The efforts are focused on enhancing the scalability and cost effectiveness of interoperability methods between blockchain networks. When considering the history of various approaches, these studies have also highlighted the necessity of ongoing evolution in this field to provide easy for integration, better security at low cost.

The next section describes AppXchain in detail along with its comparison with the existing solutions.

## 3. APPXCHAIN

The appXchain solution design was developed to make it simpler for various apps and use cases to interact across chains. It is a method to blockchain interoperability that is focused on the application level. It allows for seamless data sharing and exchange between different blockchain networks and provides support for new systems. The proposed approach concentrates on application-level interoperability while developing a standardized manner for cross-chain communication by utilizing the adaptability and scalability of decentralized apps (dApp). By providing a practical and adaptable solution, AppXchain aims to address the interoperability

problems experienced by blockchain networks, paving the way for increased efficiency and innovation in the sector.

## 3.1. Comparative study with existing solutions

Cosmos: Cosmos is recognized as being reliable, scalable, domain-neutral, and preserving integrity despite lacking decentralization, efficiency, and framework independence. AppXchain offers improved decentralization efficiency and framework independence while retaining the necessary characteristics of dependability, scalability, and integrity.
Polkadot: Polkadot lacks decentralization, efficiency, and framework independence but is reliable, scalable, domain-neutral, and has strong integrity. AppXchain, in contrast, is a decentralized, powerful, and framework-free platform that is trustworthy, scalable, neutral in terms of domain, and has high integrity.
HTLC: Although HTLC is decentralized, reliable, effective, efficient, and has strong integrity, it depends on a framework and is not domain-specific. However, appXchain still possesses the benefits of HTLC and has a higher level of scalability.
On the basis of above comparative study, we can conclude the following comparison.

| Study | Decentralized | Trustworthy | Integrity | Efficient | Scalable | Framework-dependent | Domain-neutral |
|---|---|---|---|---|---|---|---|
| Cosmos | | ✓ | ✓ | | ✓ | | ✓ |
| Polkadot | | ✓ | ✓ | | ✓ | | ✓ |
| HTLC | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| appXchain | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Table 1. Contrasting appXchain with already existing options

## 3.2. Problems with existing solutions

Existing solutions have some drawbacks- Most solutions rely on a central authority to confirm transactions and ensure equitable transfer of data and assets, with the exception of those that use hash-locking. Because of the complicated integrity checking procedures used by notary-based systems, they are unsuccessful. With the exception of Cosmos and Polkadot, all other solutions rely wholly on another entity and have limited scalability. Furthermore, because certain solutions are not framework-independent, they cannot support cross-chain communication for networks built using different frameworks. Some systems also can't offer domain neutrality because they can only support token-based assets. It is therefore necessary to find a superior cross-chain interoperability solution that is decentralized, efficient, scalable, framework independent, and domain independent.

## 3.3. Architecture of appXchain

Blockchain: Blockchain networks like Ethereum and Hyperledger Fabric are part of it. Running on the cryptocurrency Ether, Ethereum is a decentralized network that uses smart contracts to move assets. Without using bitcoins or Proof of Work, Hyperledger Fabric, a permissioned blockchain platform, establishes consensus. Its three components are the orderer, the peer, and the certificate authority.

Verifier Node: Verifier nodes can host a web service for off-chain communication and data access, and the blockchain network registers them as thin clients with access to ledger data and events.

Reputation System: Even if the verifiers are unreliable computing equipment, the reputation system's internal and external components are there to control and encourage behaviour. Based on response validity and delay, verifiers are assessed, with their average scores being updated dynamically. The most trustworthy external validator is chosen using an Ethereum-based smart contract that keeps track of their information and evaluations across several blockchain networks.

EMR storage: The appXchain design uses off-chain storage, more notably EMR storage, to handle the storing of huge documents on the blockchain. To ensure security, this system encrypts data before uploading it. While EMR data can be stored in private cloud-based databases or decentralized systems like IPFS, blockchain networks should use recognized file format standards like HL7-FHIR to improve cross-chain interoperability.

Cross-chain hub DApp: In the appXchain design, the primary interoperability hub is in charge of allowing communication and transaction exchange between several blockchain networks. In addition to supporting communication between DApps and numerous blockchain networks, it makes use of the default APIs of different networks and a Fusion Interface (FI) layer as a translation mechanism for cross-chain transactions.

### 3.4. Evaluation of appXchain

The cost of executing smart contract operations independently on both networks was evaluated as part of the evaluation of appXchain, and it was discovered that the functions of the verifier nodes were the most expensive. Considering the tenfold increase in Ethereum transaction fees over the previous year, and the reasonable fees of $3 to $7 found for request answers and entity registrations, appXchain emerged as an overall cost-effective alternative.

### 3.5. Challenges faced by appXchain

Cost analysis results for the suggested method are encouraging, but more testing is required to mimic real-world circumstances and handle the possible complexity and higher costs linked to reputation systems. In addition, there are difficulties in attaining cross-industry interoperability in other industries, such as insurance and supply chain, due to the limited upgradeability of Ethereum-based smart contracts and the requirement for industry-specific considerations.

Now let us look at the case study of patients' dApp in the following section.

## 4. CASE STUDY OF APPXCHAIN SYSTEM-PATIENT'S DAPP

The interoperability approach we used for our study, appXchain, was covered in the section before. Let's take a closer look at the case study's entities now.

### 4.1. Evaluation of appXchain

The hospital, the patient, and the doctor are the four entities in the case study. Let us take a quick look at each entity.

Hospital: A governing body that makes use of smart contracts to gather and maintain patient electronic medical records (EMR), facilitate information requests from physicians, and assess and transmit reputation ratings of verification nodes to the Ethereum reputation system.

Patient: A hospital blockchain network's client entity can control access for doctors, request data, manage IPFS hash delivery to the blockchain, upload data, and hold an IPFS token key.

Doctor: The hospital blockchain network client entity oversees requesting EMR data from users within the network and may also give its public key to a PRE-verifier, often in emergency scenarios where a third party decides access authorization.

An overview/architecture of the case study, or patient's dApp, based on the entities, is provided below in figure 3.

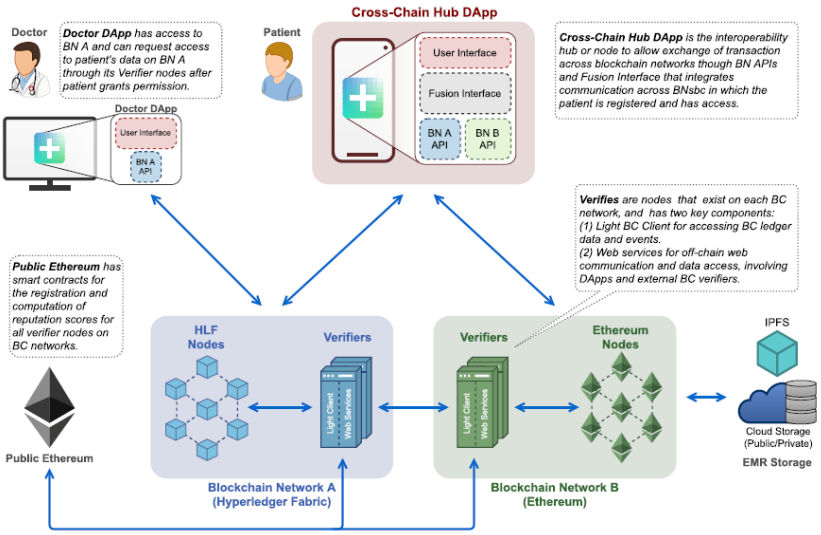


Figure 3. Illustrates how the patient's dApp allows many blockchain networks to communicate with one another [1].

## 4.2. Sequence diagram of Patient's dApp

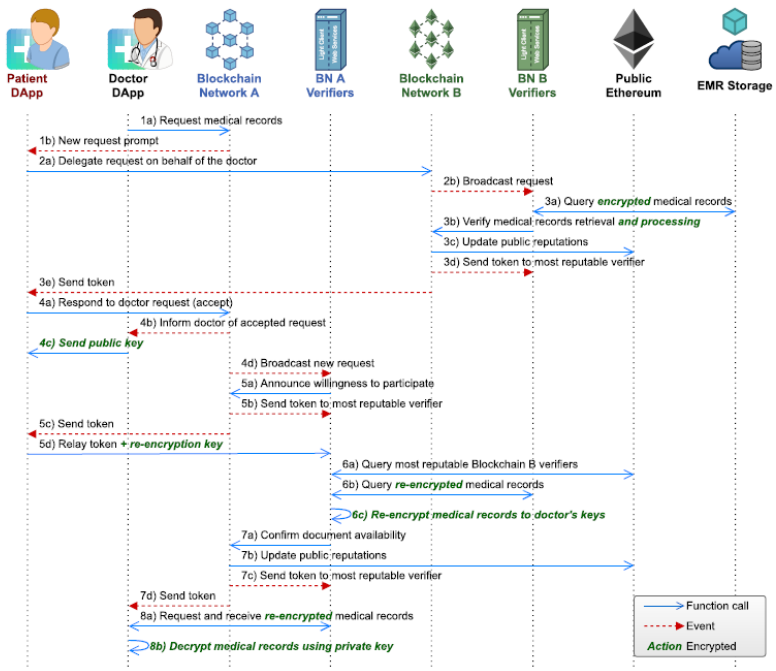

Figure 4. Sequence diagram of case study of appXchain [2]

A sequence diagram for the patient's dApp from the appXchain case study is shown in the figure 4 above. Here for hospital case study let's discuss each stage.

Step 1: The doctor creates a token, asks BNA for an EMR record, and gives the patient the request identification.

Step 2: The patient calls BNB, makes a self-request for an EMR document, and is given identity for the request.

Step 3: BNB verifiers get the patient's EMR document, present their receipt as proof of purchase, and receive small rewards.

Step 4: The patient gives permission, the doctor notifies BNA, broadcasts the request identity, and gives the patient access to the public key.

Step 5: BNA verifiers declare their interest in taking part, tokens are given to a patient and a trustworthy verifier, and tokens are transferred off-chain from the patient to the verifier.

Step 6: Reliable verifiers pass the EMR document from BNB to BNA once BNA verifier checks BNB verifier's credibility.

Step 7: The BNA verifier gives tokens to the doctor and the verifier after verifying document availability, providing proof, and updating their reputation.

Step 8: Using tokens to connect, the doctor decrypts the EMR document using his or her private key.

## 5. DISCUSSION

There are various techniques that can be employed if one wants to use an interoperability strategy that does not require any parameters. For instance, HTLC can be used if scalability can be compromised, however appXchain is the best suitable method if all the parameters are needed. By utilizing Decentralized applications (DApp), appXchain addresses scalability issues and offers a workable solution for higher transaction throughput and network expansion. The design of appXchain makes it possible to support cross-chain communication for networks created using diverse frameworks, increasing its adaptability to different blockchain ecosystems. appXchain evaluates and promotes the behaviour of verifiers using a reputation system, assuring the dependability and integrity of the system. Participants in the network develop trust through reputation-based procedures. appXchain reputation system implementation can be difficult and expensive, necessitating field testing and improvement to assure effectiveness and efficiency. appXchain’ s success depends on the reliability and conduct of verifiers. Verifiers must be carefully chosen and evaluated since, if compromised or unreliable, they could endanger the security and integrity of the network.

Most importantly, appXchain must constantly adapt and upgrade to stay up with innovations and compatibility needs in the blockchain technology landscape in order to sustain seamless communication between growing blockchain networks as it has future in many domains like finance, healthcare, public sector, precision agriculture where secure transaction is the need.

## 6. CONCLUSION

In conclusion, blockchain interoperability has the power to fundamentally alter the way that decentralized technologies are developed. Blockchain platforms' limited interoperability has prevented them from being widely adopted and used. However, the development of interoperability solutions, such as cross-chain communication protocols and specialized networks focused on interoperability, has opened the door for smooth data transmission and communication between various blockchain ecosystems. This invention has made it possible to collaborate, innovate, and improve functionality, which will ultimately lead to the widespread adoption of blockchain technology.

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**Authors**

Short Biography