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Cryptographically Secured Communication With Extraterrestrial Intelligence Using Blockchain Technology

Shriram Srinivasan

Modern International School Bangkok, Thailand

Abstract – *As the size of the universe expands every day, so does the intriguing prospect of the possibility of encountering extraterrestrial intelligence. Establishing communication with such entities requires innovative approaches to ensure the security and integrity of the exchanged information. This paper explores the concept of utilizing blockchain technology to facilitate cryptographically secured communication with extraterrestrial intelligence.*

Blockchain, known for its data security and integrity, could be adapted to serve as a foundation for space communication. Combining advanced encryption techniques with blockchain's decentralized consensus mechanism. This protocol addresses challenges associated with speed of light, real time communication, network infrastructure, data size and efficiency, and complexity and compatibility, while ensuring the confidentiality, authenticity, finding way back to earth, message history, and tamper-resistance of messages.

1.INTRODUCTION

The aim of this research is to provide a comprehensive overview of the various implementations of blockchain technology, examining its adoption beyond its original purpose in digital currencies and into diverse domains. Over the last decade, blockchain technology has swiftly gained prominence and extended its impact across numerous sectors, including cryptocurrencies, healthcare, and the Internet of Things (IoT). [1] Projections suggest that by 2027, the IoT market will reach an estimated value of $1,463.2 billion, and with a projected compound annual growth rate of 56.3%, the blockchain industry is anticipated to reach a value of $163.83 billion by 2029. All these data acknowledge the tendency of blockchains presence in all the fields in the near future.

Every time a reference is made to the blockchain technology, all that comes to mind is bitcoin. And now it has extensively leveled up and now is not only about digital money, it's more like a Swiss Army knife of technology. [2] Even though blockchain was designed to serve as the public distributed ledger for bitcoin cryptocurrency transactions, it's now a major player in all kinds of fields. What I am referring to is way more than transacting money. The fusion of blockchain's distributed and tamper-resistant ledger with advanced cryptographic methodologies could create a powerful framework. This deals with the various difficulties of talking over really long distances in space, lessening the effect of delays caused by traveling between stars, and solving the linguistic disparities that might impede communication and understanding.

2. THE FUNDAMENTALS

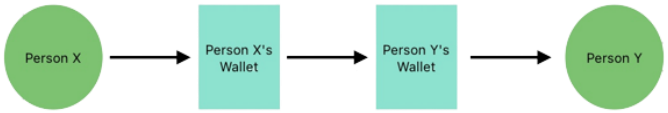

Fig -1: Cryptocurrency and decentralization

Cryptocurrency is a form of digital payment platform, that does not require the users to use fiat money. [3] There are several cryptocurrencies that are being traded the most common ones are Bitcoin, Ethereum, Dogecoin, Tether, USD Coin, Uniswap. The cryptocurrency system operates within a blockchain network, enhancing its security significantly. Blocks of cryptocurrencies are made by the process called mining. This process uses the computer's power to solve complex mathematical problems and then generates the coins.

Understanding the blockchain system in the case of cryptocurrency. The block typically consists of 3 main components the header, hash value, previous hash value. [4] The header is contained with metadata and control information, such as recipients and sender details, transaction details, etc. The header is crucial for maintaining the chronological series of each block and ensuring the security and integrity of the blockchain.

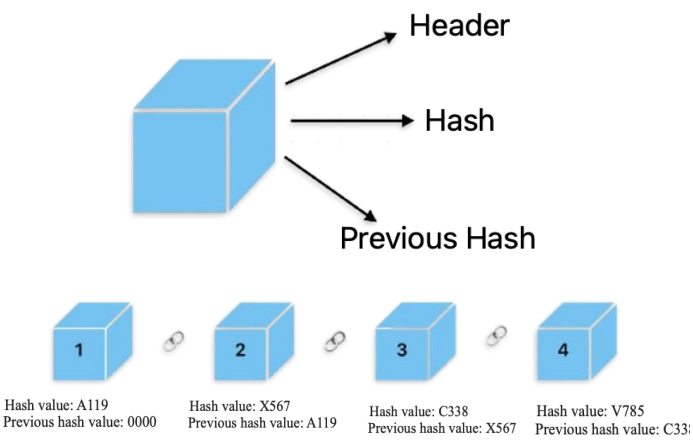

Fig -2: Block description and a part of blockchain showing 4 blocks

[5] The hash value is a fixed length alpha numeric string is formed. Hash value's role is to protect data integrity, security, and ensure verification processes. [2] Within a blockchain, every block contains a previous hash value that refers to the preceding block, creating a sequential chain of interconnected blocks. This connection guarantees the specific order of blocks, resulting in an unbroken chain. If an attempt to modify a block is made, it forces altering the block's data and rehashing all subsequent blocks. This process makes it difficult to tamper with the data stored in the blockchain.

3. CHALLENGES

- Consensus: Various consensus algorithms like Proof-of-Work (PoW), Proof-of-Stake (PoS), Delegated Proof of Stake (DPoS), and Practical Byzantine Fault Tolerance (PBFT) are used in distributed ledger technologies (DLTs) to determine which nodes can create and add new blocks to the blockchain. PoW demands a lot of energy as miners must solve complex problems. PoS and DPoS are more energy-efficient as they require validators to stake tokens. PBFT can handle some faulty nodes. For space networks, it's crucial to balance security and energy efficiency. PoW is too energy-intensive. PoS and DPoS are efficient but vulnerable to attacks with concentrated control. PBFT is secure and can tolerate faults, making it suitable for space networks. The choice depends on the network's specific needs: PBFT for high-security critical networks, PoS or DPoS for non-critical networks prioritizing energy efficiency. [12].

- Storage: In technical terms, every space node must store the blockchain, but many space components have limited storage. Researchers are working on finding a balance between efficient storage and performance for advanced satellite equipment. [14] Some methods involve algorithms that analyze the space information network's structure from ground stations to orbital setups.[13]

- Transmission delay: In a traditional land-based network, block addition speed is limited by network speed. In satellite networks, it's limited by transmission delay, varying based on satellite type and distance. GEO satellites have the highest delay, followed by MEO, and then LEO satellites. The blockchain takes 10 minutes for a new block, longer than LEO satellite delay. If two LEO satellites create blocks simultaneously, one might be added before the other, disrupting the ledger. Researchers are working on solutions like tailored consensus algorithms and blockchain compression techniques for faster satellite transmission. [14]

- Language: Deciphering an alien language is incredibly challenging due to the language barrier. Even if we detect a message, understanding it requires understanding their language and culture. We can try finding patterns or using machine learning on alien language data, but grasping their message might still be difficult. Their communication is likely tied to their unique cultural and historical background, making it crucial for us to understand their culture and history to fully comprehend their message.[15]

4. HOW BLOCKCHAIN WORKS

- The chosen node initiates a specific transaction, to another node using the blockchain network.

- A node creates a transaction and the transaction is sent to the network. Miners verify the transaction and add it to a block. The block is added to the blockchain. The transaction is confirmed, if not then it remains unconfirmed.

- Miners are responsible for putting transactions into blocks and adding them to the blockchain. However, before they do this, they need to check that the transactions are valid. For example, they need to make sure that the sender has enough currency to send. Different miners might choose to include different transactions in their blocks. This is because they are all competing to be the first to add a new block to the blockchain. The first miner to do this receives a reward. If a transaction owner wants their transaction to be processed faster, they can offer a reward to miners. This will make miners more likely to choose their transaction to include in their block.

- The blockchain smart contract needs to clearly state the rules for valid and unique blocks, identified by a hash code. For example, Proof of Work (PoW) [11] The smart contract outlines that a valid block's hash code is calculated following Equation and must begin with a specific number of continuous zeros.

  BHC = Hash (TD + P + Nonce)

- Where BCH is the Block Hash Code, TD keeps hold of Transaction Data, and P carries the previous block inside the chain 'Nonce' (Number only once) is a random number that can only be used once and outputting the consecutive BHC.

5. WHAT'S TOKENIZATION? AND TOKENIZING SPACE ATTRIBUTES.

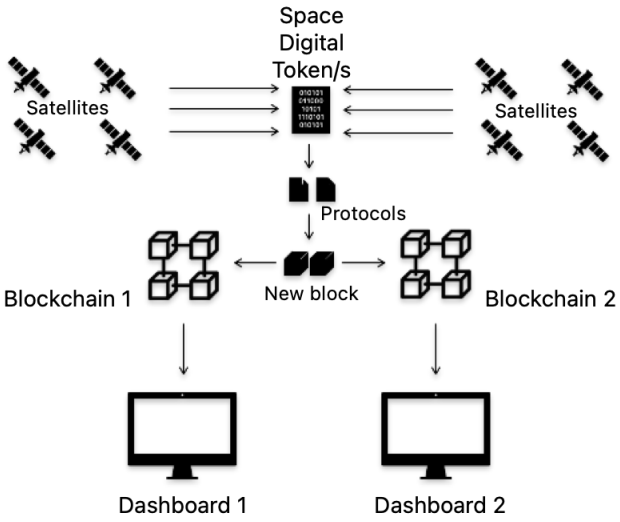

Fig -3: Blockchain concept for space vehicles: Space digital tokenization [18]

[8] Tokenization involves replacing sensitive data with unique symbols that contain necessary information without compromising security. This widely was used in protecting credit card data and several bank information of the customer. [9] How tokenization works in 3 simple steps; Identify tokens, normalize tokens, return tokens. [16] The space industry is increasingly exploring the potential abilities of blockchain technology and its contributions. [6] In 2017, NASA provided an award of $330,00 grant to Dr. Jin Wei Kocsis for her project named Resilient Networking and computing paradigm (RNCP). [7] For NASA missions to be successful, good communication and smart computing are vital. Space communication is tricky because it's often disrupted and wireless. To solve this, a project is working on a smart system called RNCP. It has two main parts: a secure and decentralized computing setup and a smart network management system.

These parts help improve communication in space. The project will test how well RNCP works in different space communication situations. The space reserves like the spacecrafts, space debris, satellites orbits, asteroids, and etc. Tokenizing space objects is challenging due to their complexity and multiple components. For instance, describing a star involves details like its name, type, mass, and distance from Earth. [10] To tokenize this information accurately, it's crucial to identify each part of the object and treat them as individual tokens. And all their features must be universally recognized and accepted. [10] Another challenge is that space objects can have abbreviations and acronyms. For example, the International Space Station is often abbreviated as ISS. To accurately tokenize such abbreviations, it is important to have a dictionary of common space object abbreviations and acronyms.

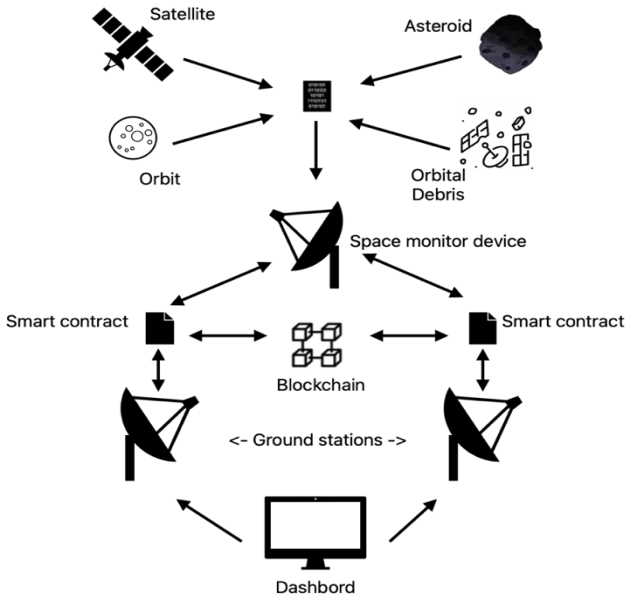

Fig -4: Orbital assets tokenization using blockchain process [18]

The primary roles of a satellite system based on blockchain technology can be classified as follows:

- Transmitting data to and receiving TT&C (Telemetry, Tracking, and Command) data from an earth station.
- Enabling bidirectional communication with user terminals.
- Receiving data from a satellite constellation and forwarding it to cloud services.
- Facilitating real-time communication among satellites within the system.
- Performing Telemetry, Tracking, and Command (TT&C) functions.
- Managing smart contracts at the earth station.
- Distributing operating system updates and application codes to satellites.

- Executing regular applications and blockchain operations.

Specific Technical Contributions

- Tokenization of Space Assets: Blockchain technology enables the tokenization of space assets like satellites, launch vehicles, and ground stations. This facilitates easier trading and investment in space assets and supports financing for new space missions.

- Management of Satellite Mission Data: Blockchain technology is applied to manage satellite mission data across the Satellite Life Cycle, enhancing mission efficiency, transparency, and cost-effectiveness.

- Securing Satellite Swarms Communications: Blockchain technology establishes secure virtual zones in space to safeguard satellite swarms from cyberattacks and other threats, ensuring the integrity of communications. [17]

- Space Chain: The Space Chain case study demonstrates the successful use of blockchain technology in building satellite systems, providing secure data transmission and satellite communication services.

Future Research Directions

I. Experimental Studies: Conducting more experimental studies is vital to validate proposed blockchain models and assess their real-world performance.

II. Simulation Studies: Simulation studies help model and simulate the behavior of blockchain-based space systems. They are instrumental in identifying potential issues and developing strategies to mitigate them.

III. Addressing Other Challenges: Addressing challenges such as scalability, security, and regulatory concerns is crucial for the continued advancement of blockchain technology in space applications.

6. CONCLUSION

A conceptual framework has been developed to explore the substantial contributions of blockchain technology in space missions. The qualitative findings from this study indicate that leveraging digital tokens and blockchain platforms can effectively address major challenges in the space industry. The research also introduced innovative blockchain process models to tackle significant issues in the field.

The study concluded by analyzing Space Chain, the world's first open-source blockchain-based satellite network, as a case study for integrating blockchain into satellite systems. While this research marks one of the initial efforts to investigate tokenizing space assets and utilizing blockchain technology in the space industry, several questions remain unanswered. Further research is necessary to conduct experimental studies and simulate the functionality of the proposed blockchain models discussed in this study. In summary, blockchain technology holds substantial promise for revolutionizing the space industry and satellite communication. It offers solutions to critical challenges, including the demand for more efficient and transparent transactions, as well as the need for enhanced cybersecurity measures.

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