

EXPLORING THE OPPORTUNITIES: BLOCKCHAIN INTEGRATION IN IoT AND ADDRESSING CHALLENGES IN NORTH MACEDONIA

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Abstract

In an era of rapid technological growth, the merging of Blockchain technology and the Internet of Things (IoT) offers new prospects for innovation. This article examines the advantages of using blockchain technology into IoT systems for North Macedonia, emphasizing the unique problems and solutions that this setting presents. The article first explains the principles of blockchain and the Internet of Things (IoT) before examining the current state of affairs and how adoption is being hampered by laws, technological constraints, and cybersecurity issues. Multiple strategies, specifically tailored to this context, are proposed, drawing from global best practices and local research studies conducted within North Macedonia. These include technological advancements and regulatory reforms like stakeholder collaboration drives aimed at raising awareness campaigns and other initiatives that could drive success in the coming years! What socioeconomic effects these developments might have is also discussed; this emphasizes the urgent need for government direction to ensure that everyone gains equally and that no one person has an unfair advantage over others through the creation of policy frameworks that are specifically designed to preserve all opportunities.

Keywords: IoT, North Macedonia, Blockchain, exploring.

1. Introduction

The previous years have observed a skyrocketing increase in the Internet of Things (IoT), which has disrupted many industries via billions of interconnected devices. But as it grows more and more connected, issues about scalability, privacy, and trustworthiness are also growing. This is especially critical in North Macedonia where innovative solutions need to be sought if IoT networks are to be integrated and operated without any hindrances. (Banafa 2018) In response to these challenges, Blockchain technology is emerging as the best option with a decentralized framework that can enhance efficiency, security, and privacy among others. As the IoT ecosystem develops in North Macedonia, this article discusses the possibility of incorporating blockchain into its niche market; this paper examines its benefits and how it can help overcome some of the challenges facing the sector. (S. Gillis n.d.)

2. Internet of Things (IoT)

The Internet of Things (IoT), on the other hand, is a network that connects numerous computing devices, machinery, objects, animals, or humans each having unique identifiers (UIDs) and capable of transferring data over a network without human-to-human or human-to-computer interaction. (Muthulakshmi and Chitra 2021)

Examples of these things include embedded medical devices in human bodies and sensor-equipped cars as well as smart home appliances. With this IoT technology spreading out to different sectors, it has become easier for organizations to know their customers better, improve customer service, make informed decisions, and create value for them. The potential impact of IoT on businesses and individuals is quite significant with some comparing it to the internet's influence on society. (Subramanian, Vellore Gopal and Muthusamy 2015)

For instance, Gartner predicts that by 2020 there could be anywhere from 26 billion to 50 billion connected devices leading to an unprecedented volume of data exchange among devices and systems. Consequently, innumerable volumes of data flow through information-processing systems as a result of this exponential growth in interconnectivity among devices. These streams are then subjected to extraction processes for producing actionable insights leading to decisions that drive further innovation. (S. Gillis n.d.)

3. Blockchain

A decentralized database, blockchain expands infinitely with each addition of new data records. In order to prevent any one master computer from controlling the entire chain, it is divided among all participating nodes. (Muthulakshmi and Chitra 2021) Participant-created activities, or transactions, are stored in blocks that preserve the accurate order and timestamps of the transactions. The public nature of blockchain, which enables everyone to examine blocks and transactions, is one of its main advantages. Private keys are still used to secure transaction content, nevertheless. Because of decentralization, transactions must be approved by consensus among network users rather than by a single authority. This guarantees security because it is very expensive to change earlier records. (Konstantinidis, et al. 2018)

Blockchain comes in three primary flavors: consortium, private, and public. Anybody can join a public (or permissionless) blockchain, such as Ethereum and Bitcoin, without needing authorization. A private, or permissioned, blockchain restricts access to approved users and sets participation guidelines. A consortium-controlled blockchain combines the wider inclusivity and efficiency of a private blockchain, making it appropriate for a variety of industries, including supply chain management and finance. Examples include Hyperledger and Ripple. (IsB)

4. Blockchain Internet of Things (BIoT) Architecture

The architecture of the blockchain internet of things (BIoT) is shown in Figure 1. The architecture contains a blockchain composite layer that works as a middleware between IoT and industrial applications. (Zafar, et al. 2021) There are two major advantages in this architecture:

- 1) It provides conceptualization from the lower layers of IoT.
- 2) Also provides blockchain-based services to the users. The heterogeneity of perception and communication is hidden. (Muthulakshmi and Chitra 2021)

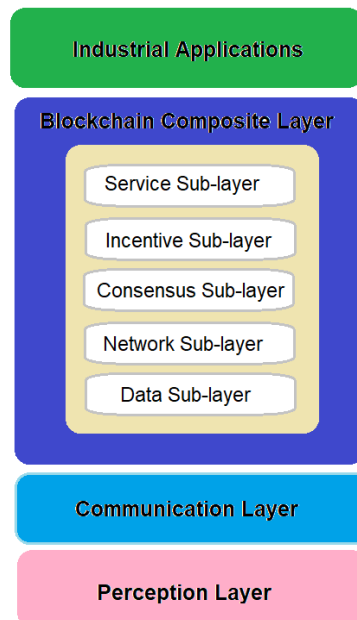


Figure 1. BIoT Architecture

Blockchain architecture consists of five sublayers:

1. Data sub-layer - is used to gather IoT data from the lower layers and covers the encrypted data with digital signatures through asymmetric cryptographic algorithms and hash functions.
2. Network sub-layer - only one node broadcasts the block of transactions to its connected peers. The peers will verify the transactions after receiving it. The block will be impregnate to other nodes via the network if it is failed.
3. Consensus sub-layer - is used to check the trustfulness of the block. There are many consensus algorithms used such as proof of work, proof of stack, etc.
4. Incentive sub-layer - involves in following activities.
 - a. Issuing digital currency
 - b. Distribution of digital currency
 - c. Reward mechanism design
 - d. Handling transaction cost
 - e. Designing the monetary policy of digital currency.
5. Service sub-layer - is used to provide blockchain-based services to the users. (Muthulakshmi and Chitra 2021)

5. Current Landscape of IoT in North Macedonia

5.1. Adoption Rate of IoT in North Macedonia: IoT technology have been gradually but steadily adopted by North Macedonia in a number of industries in recent years. Although not as quickly as in more developed countries, there is a discernible upward trend that reflects rising interest in and recognition of the advantages provided by IoT solutions. IoT is being used more and more by North Macedonian businesses, government agencies, and organizations to improve decision-making, increase productivity, and streamline operations. Despite experiencing significant difficulties, the adoption rate of IoT is on the rise, propelled by technological breakthroughs, rising awareness, and the urgency for digital transformation. (Aliti, et al. 2022)

5.2. Key Industries Utilizing IoT: IoT solutions have been implemented by numerous significant sectors in North Macedonia in order to spur innovation and increase output. Nonetheless, the manufacturing sector serves as an example of how IoT appliances and sensors are enhancing production processes, keeping an eye on the condition of machinery, and managing supply chain logistics. The nation's agriculture industry has also adopted Internet of Things (IoT) solutions for precision farming, allowing farmers to monitor changes in crop conditions, soil moisture, and weather online. Other industries that stand out as being among the main winners of IOT technologies in terms of improving operational efficiency through cost reduction and better service delivery include transportation and logistics, healthcare, energy, and smart cities. (Aliti, et al. 2022)

5.3. Challenges Faced: Despite the increasing popularity of IoT, North Macedonia confronts certain challenges that prevent its widespread implementation. One major barrier to the adoption of IoT solutions by organizations is the absence of a comprehensive legislative framework that addresses data privacy concerns. This leads to ambiguous rules and guidelines that can cause legal and compliance problems. Because IoT devices are susceptible to hacking and unauthorized access, concerns have also been raised regarding cybersecurity risks and data security. Inadequate network connectivity or inadequate infrastructure make it more difficult for these solutions to integrate seamlessly or scale. In order to overcome these obstacles, legislators, business leaders, and technology suppliers must work together to create strong legislative frameworks, improve cybersecurity protocols, and undertake critical infrastructure upgrades. (Aliti, et al. 2022)

6. Understanding Blockchain Integration in IoT

6.1. Advantages and Benefits of Blockchain Integration in IoT: The integration of blockchain technology with the Internet of Things (IoT) has a lot of advantages, which will change completely the way devices communicate, transact and secure data. (Muthulakshmi and Chitra 2021)

1. **Improved Security:** More secure for IoT devices and data, blockchain-enhanced security functions are based on the unchangeable, decentralized nature of this technology. Consequently, through cryptographic algorithms and distributed ledger technology blockchain assures tamper-proof transactions and hence secures data from unauthorized access or manipulation
2. **Data Integrity and Transparency:** It is through blockchain technology that verifiable transactions of data can be done openly and transparently maintaining the authenticity as well as integrity of the IoT-generated data. For each transaction recorded on the ledger, it is cryptographically linked to the previous one and timestamped which has resulted in a trustful audit trail that holds everyone accountable.
3. **Simplified Data Management:** Blockchain simplifies data management for IoT devices by eliminating intermediaries and central authorities thus ensuring they manage their affairs independently. When necessary conditions exist smart contracts will perform specific actions autonomously on behalf of IoT devices thereby allowing a seamless exchange of information between them leading to automation.
4. **Cost Reduction:** Integration of blockchain with IoT may reduce costs by removing intermediaries, cutting down transaction fees as well as simplifying processes. They do so through automating contractual agreements backed up with compliance enforcement measures such that manual processes related to administrative overheads and operational expenses are minimized as much as possible due to smart contracts' intervention.

5. **Inter-operability and Scalability:** IoT Ecosystems are made more inter-operable and scalable by the use of blockchain, this is through the provision of a secure and standardized platform for communication between devices and data exchanges. Additionally, with the establishment of the common protocol as well as the consensus mechanism, blockchain ensures smooth integration as well as interoperability among different devices found in IoT ecosystems. (Aliti, et al. 2022)

7. Potential Use Cases of Blockchain Integration in IoT

The integration of blockchain technology with the Internet of Things presents numerous possible applications in diverse sectors, such as:

1. **Supply Chain Management:** Through the tracking of goods movement, authentication verification of products, and recording of temperature and humidity conditions during transportation, blockchain-enabled IoT solutions may enhance transparency and traceability in supply chains.
2. **Smart Contracts and Automated Transactions:** IoT devices that are outfitted with blockchain-enabled smart contracts have the ability to autonomously carry out transactions, like asset transfers, payment settlements, and service agreements, in accordance with predetermined criteria and triggers.
3. **Identity and Access Management:** By offering a decentralized and secure framework for maintaining digital identities, access permissions, and authentication techniques, blockchain improves identity and access management (IAM) for Internet of Things devices.
4. **Asset Tracking & Management:** By storing asset ownership, location history, and maintenance data on a tamper-proof ledger, blockchain-based Internet of Things (IoT) systems allow real-time tracking and management of assets, including cars, equipment, and merchandise.
5. **Energy Trading and Management:** By enabling peer-to-peer energy trading and decentralized energy management systems, blockchain enables users to use Internet of Things (IoT)-enabled smart grids and meters to buy, sell, and trade excess energy produced from renewable sources. (Aliti, et al. 2022)

In general, the combination of blockchain technology and the Internet of Things has the potential to completely transform a number of sectors by improving the security, transparency, efficiency, and interoperability of IoT ecosystems. (Muthulakshmi and Chitra 2021)

8. Addressing Challenges in North Macedonia

North Macedonia like others has different challenges relating to the adoption and implementation. However, addressing these challenges is crucial if the country is to unlock the potential it has in these technologies and drive digital transformation. This article delves into three of North Macedonia's primary challenges and proposes ways of overcoming them. (Aliti, et al. 2022)

1. **Regulatory Challenges:** An important impediment to the widespread adoption of IoT and blockchain technologies in North Macedonia is the absence of an all-inclusive regulatory framework. Regulations relating to data privacy, security measures, standards as well as interoperability are necessary for guiding investors willing to put their money into these technological solutions. To solve this issue, policymakers must collaborate with business people from various industries so that they can come up with coherent regulatory guidelines that are responsive to North Macedonia's specific circumstances and needs. This encompasses the creation of data protection legislation,

a set of standards for IoT device interconnectivity as well as fostering better linkages between government departments, and private industrial organizations including universities.

2. *Security Issues: In North Macedonia, security remains a significant concern regarding the use of blockchain and IoT:* The continuous rise in connected devices as well as the growing amounts of valuable data generated and transmitted call for strong cyber security measures to prevent possible attacks and vulnerabilities in this regard. Measures such as encryption, authentication, and access control should be prioritized by organizations so that their IoT devices can be protected from unauthorized entry or use; while their Bitcoin networks are also shielded from hackers or any sort of data breach. Furthermore, investing in education on cyber-security issues as well as cultivating a culture of cyber-security within establishments may help increase awareness about emerging risks.
3. *Infrastructure constraints:* The paucity of infrastructure, along with poor network connectivity and bandwidth limitations, makes the integration and scalability of IoT and blockchain solutions a difficult task in North Macedonia. Therefore, for these infrastructural limitations to be addressed there is a need for both public and private sectors to invest in digital infrastructure such as broadband services, cloud computing systems, and edge computing capability among others. Also vital are measures aimed at reducing the digital divide and increasing accessibility to rural areas and low-income communities so that everyone has an equal footing in the new economy focused on digitization. (Aliti, et al. 2022)

9. Opportunities and Recommendations

North Macedonia is at a turning point in its blockchain technology adoption across multiple industries. To fully realize the potential of blockchain, deliberate investments, cooperative efforts, and strategic policies are needed. The following are some suggestions and chances to take advantage of blockchain technology's revolutionary potential:

1. *Policy Suggestions for Blockchain Integration:* To facilitate the seamless incorporation of blockchain technology into the economy, policymakers in North Macedonia should consider:
 - Developing a comprehensive regulatory framework: Establish clear and adaptable policies that give legal clarity and stimulate innovation while addressing concerns relating to data privacy, security and consumer protection.
 - Encouraging blockchain education and research: Invest in training programs and research projects to develop a workforce with the necessary skills and to encourage blockchain innovation..
 - Creating incentives for blockchain adoption: In order to encourage innovation and investment in the technology, provide grants, tax breaks, and other financial aid to companies and institutions that implement blockchain solutions.
2. *Collaboration Initiatives:* The realization of blockchain technology's full potential requires collaboration. North Macedonia ought to concentrate on encouraging cooperation among interested parties, such as:
 - Public-private partnerships: Foster collaboration between government agencies, industry players and academic institutions to develop and implement blockchain solutions that address societal challenges and drive economic growth.
 - International partnerships: Collaborate with international organizations, governments and industry consortia to share best practices, exchange knowledge and promote interoperability in blockchain ecosystems.

- Community engagement: Engage with local communities and grassroots organizations to raise awareness about blockchain technology, build trust and ensure inclusivity in the development and deployment of blockchain solutions.
3. *Investment Opportunities*: Investment in blockchain technology presents lucrative opportunities for both domestic and foreign investors. North Macedonia should focus on:
- Investing in blockchain infrastructure: Allocate resources to develop the necessary infrastructure, including blockchain platforms, digital identity systems and secure communication networks, to support the widespread adoption of blockchain technology.
 - Supporting blockchain startups and entrepreneurship: Provide funding, mentorship and incubation support to blockchain startups and entrepreneurs, thereby fostering innovation and entrepreneurship in the blockchain ecosystem.
 - Attracting foreign investment: Create a conducive regulatory environment and offer incentives to attract foreign investment in blockchain technology, positioning North Macedonia as a hub for blockchain innovation and investment in the region. (Aliti, et al. 2022)

10. Case Studies and Best Practices

Through the analysis of blockchain technology's successes in different places, we can gain vital knowledge and insights that could aid in the effective implementation and execution of similar solutions in North Macedonia. Case studies and the best practices that demonstrate successful implementations coupled with the lessons learned during those implementations are presented below: (Aliti, et al. 2022)

10.1. Successful Implementations in other Regions:

- e-Residency Program in Estonia: This program, which enables people to start and run enterprises from a distance, has integrated blockchain technology. Estonia has expedited bureaucratic procedures, decreased administrative costs, and drawn foreign investment by utilizing blockchain technology for secure digital identities and document authentication.
- Walmart's Food Traceability: Walmart has incorporated blockchain technology to improve food safety and freshness throughout its supply chain. Walmart was able to improve process transparency, severely reduce waste, and minimize any negative effects associated with illnesses brought on by food-borne illnesses by using blockchain technology to track edibles from farms to store shelves.
- Dubai's Blockchain Strategy: Dubai has unveiled a comprehensive plan to utilize blockchain technology with the goal of changing administrative services and fostering innovation across a range of businesses. The city is using blockchain technology to improve the operational efficacy of governing structures, raise the standard of public services provided, and promote overall economic progress by leveraging the Dubai Blockchain Platform and Dubai Future Accelerators program. (Aliti, et al. 2022)

11. Conclusions

Finally, the investigation into the integration of IoT and blockchain in North Macedonia and the resolution of associated challenges reveals a region rich in development and innovation prospects. Key conclusions that explore how to incorporate blockchain technology into IoT as well as its possible implications were thus made public. (Aliti, et al. 2022)

11.1 Summary of Key Findings:

- North Macedonia is implementing Internet of Things technology gradually but steadily, driven by the demand for increased productivity, lower expenses, higher accuracy, and better decision-making.
- Key sectors such as industry, agriculture, transport, health care, energy, and smart cities use IoT to promote innovation and improve performance.
- However, there are also issues, such as infrastructural limits, safety concerns, and regulatory impediments, which pose serious roadblocks to the widespread adoption and implementation of blockchain technology and IoT in North Macedonia.
- This implies that thorough laws on the appropriate use of these two technologies to improve data safety and promote quick access to data through digitization must be developed by legislators, industry participants, and technology suppliers. (Aliti, et al. 2022)

11.2. Future Outlook for Blockchain Integration in IoT in North Macedonia: Notwithstanding these obstacles, North Macedonia's prospects for blockchain integration with IoT are bright. It can unlock the revolutionary potential of blockchain technology and spur digital innovation across a range of sectors by addressing regulatory issues, bolstering cybersecurity safeguards, and investing in infrastructure development.

Going forward, North Macedonia may establish itself as a leader in the region for blockchain adoption and use by promoting cooperation, drawing capital, and giving practical blockchain applications top priority. IOT integration will spur economic growth through improved efficiency and people's quality of life through collaborations, investments, and favorable policies. (Aliti, et al. 2022)

To sum up, North Macedonia is only at the beginning of its blockchain integration adventure with the Internet of Things. Reaching its full potential in the digital age is possible with the application of strategic planning and a shared goal.

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