# Analyzing Collaborative Networks in Block-chain Research (2016-2022): A Scopus-based Study of Research Publications

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## ABSTRACT

Block-chain technology has swiftly emerged as a transformative force across varied sectors, revolutionizing data storage, security, and sharing. Originally introduced as the spine of cryptocurrencies like Bitcoin, Block-chain has evolved into a multifaceted innovation with applications surpassing finance. As its potential gains recognition, research volume dedicated to understanding and enhancing its applications intensifies. Block-chain, a secure and decentralized data management system, offers anonymity, security, privacy, transparency, and authenticity. The rapid evolution of this technology, extending beyond its cryptocurrency origins, has spurred prolific research across industries, driving collaborative efforts among authors, institutions, and regions. Analysis of 3419 research publications from 2016 to 2022 reveals a steep growth rate of 149.99%, emphasizing the field's exponential expansion. The scholarly impact is evident, with an average of 11.73 citations per document and 118,957 references. Collaboration metrics, including the Collaboration Index, Degree of Collaboration, and Collaboration Coefficient, demonstrate a growing trend of cooperation, reflecting a collective endeavor to unravel the complexities of Block-chain. The Modified Collaboration Coefficient further highlights inclusivity, displaying diverse voices contributing to Block-chain research. This collaborative ethos underscores the promise of Block-chain technology, propelling us toward a future enriched by collective intellect and innovative advancements.

**KEYWORDS**: Block-chain technology; Collaborative Networks; Scientific Collaboration; Bibliometric Study; Research publications; Collaborative dynamics

## INTRODUCTION

The Block-chain has swiftly developed as a transformative force across diverse industries, revolutionizing how data is stored, secured, and shared [1]. Introduced initially [2] as the foundational technology, Block-chain has evolved into a multifaceted innovation with applications extending beyond the financial sector. As the technology's potential becomes increasingly recognized, so does the research volume dedicated to understanding, improving, and expanding its applications. "Block-chain is a [3] secure, decentralized, and incorruptible networked data management system. It provides anonymity, security, privacy, transparency, and data authenticity." [4] The rapid evolution of this revolutionary technology, extending far beyond its initial association with cryptocurrencies, has spurred a prolific body of research. As Block-chain applications diversify across various [1] industries, academic interest in this domain has intensified, significantly increasing research output.

Block-chain technology, initially devised for facilitating [5] cryptocurrency transactions, has transcended its initial purpose to revolutionize various industries, including finance, healthcare, supply chain management, and beyond. Its decentralized nature, immutability, and transparency have garnered significant [6]

attention from researchers, practitioners, and policymakers. However, the rapid pace of innovation within the Block-chain space necessitates a nuanced understanding of the [7] collaborative dynamics driving research and development. The collaboration lies at the core of scientific advancement, enabling the exchange of concepts, expertise, and resources. Within Block-chain research, collaboration assumes diverse forms, from partnerships between academic institutions to interdisciplinary collaborations bridging the gap between technology and domain-specific knowledge [7]. By analyzing the collaborative networks that underpin Block-chain research, we gain insights into the distribution of knowledge, the flow of information, and the formation of research communities.

In navigating the complex terrain of collaborative networks in Block-chain research, we encounter a [8] myriad of challenges and opportunities. From fostering inclusive collaboration across diverse stakeholders to addressing issues of trust, governance, and intellectual property [9], the journey towards harnessing the full potential of Block-chain technology is replete with obstacles. Nevertheless, we can collectively advance our understanding of Block-chain technology and its transformative potential by fostering open [10] dialogue, fostering cross-disciplinary collaboration, and embracing emerging methodologies.

## 1 Procedure:

The methodology employed in this study probes into the burgeoning field of Block-chain research, focusing on articles published between 2016 and 2022. The objective is to comprehend the collaborative networks that have emerged within this domain during this timeframe. By examining authorship patterns, collaboration indices, and collaboration coefficients, this research endeavors to elucidate the collaborative landscape driving the evolution of Block-chain research. Utilizing a comprehensive dataset of 3419 research publications from Scopus, encompassing diverse scholarly sources, this study aims to unveil critical facets of collaborative dynamics within the Block-chain research community. This research provides insights into the extent and nature of collaborative efforts shaping scholarly endeavors in the Block-chain domain by analyzing metrics such as mean citations per article, degree of collaboration, and modified collaboration coefficient. The results pay to a nuanced understanding of collaborative trends and their implications for advancing Block-chain technology and its diverse applications across industries.

## 2 Data Analysis and Interpretation

This study considered a comprehensive dataset of 3419 research publications related to Block-chain sourced from Scopus, encompassing journals, books, and other scholarly sources. Analyzing this extensive corpus was intended to unveil critical facets of the collaborative landscape within the Block-chain research community, examining the dynamics that have shaped the trajectory of research and innovation in this domain. The annual growth rate of 149.99% over the years underscores the exponential expansion of Block-chain -related research during this period. The average document age of 1.54 indicates the timeliness of the publications, affirming the currency and relevance of the research in this fast-paced field. This research's scholarly impact and depth are evident, with an average of 11.73 citations per document and a staggering 118,957 references.

Seven thousand four hundred sixty-six authors have contributed to these articles, highlighting the collective effort and collaboration in exploring Block-chain technology. International co-authorships, constituting 32.85% of collaborations, demonstrate researchers' global reach and interconnectedness in advancing Block-chain knowledge. Furthermore, 6583 author-provided keywords and 13894 Keywords Plus entries signify the comprehensive and nuanced understanding of this technology encapsulated within the articles.
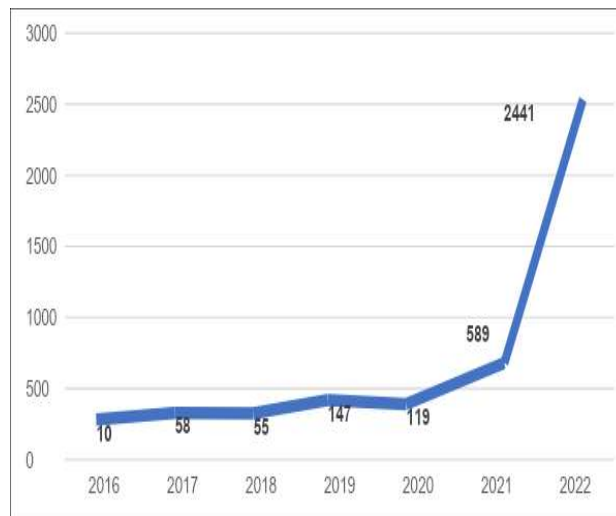
Fig 1. Number of articles published on Block-chain
Technology from 2016 to 2022

The research on Block-chain started gaining traction in 2013. However, from 2013 to 2015, the number of published papers was limited, primarily centered around Bitcoin, and this period marked the initial stage of exploration and development in Block-chain research. In 2014, a notable increase in the growth rate of research publications was observed. Since then, the growth has been nearly exponential, signifying a rapid and sustained expansion in Block-chain research [11].

## 3 MeanTCperArt and MeanTCperYear

These 3419 articles received 40117 citations during the study period of 2016 to 2022, with an average of 11.73. Table 1 provides the MeanTCperArt and MeanTCperYear

Table 1. MeanTCperArt and MeanTCperYear for the articles published on Block-chain Technology from 2016 to 2022

| Year | MeanTCperArt | N | MeanTCperYear | CitableYears |
|------|--------------|-----|---------------|--------------|
| 2016 | 178.7 | 10 | 22.34 | 8 |
| 2017 | 165.02 | 58 | 23.57 | 7 |
| 2018 | 104.22 | 55 | 17.37 | 6 |
| 2019 | 12.16 | 147 | 2.43 | 5 |
| 2020 | 14.71 | 119 | 3.68 | 4 |
| 2021 | 11.12 | 589 | 3.71 | 3 |
| 2022 | 5.3 | 2441 | 2.65 | 2 |

Mean Citations per Article (MeanTCperArt) metric denotes the average number of citations each research article receives annually. It is a vital indicator of the impact and recognition the articles have garnered within the academic community. The mean Citations per Year (MeanTCperYear) value represents the average number of citations received per year, considering all the articles published in a specific year. It provides an overall view of the articles' enduring impact over time.

In this tabulation, it can be seen that both the MeanTCperArt and MeanTCperYear are decreasing every year. Some of the reasons for this are:

- In earlier years, such as 2016 and 2017, the field of Block-chain technology was relatively new and rapidly evolving [12]. Seminal and groundbreaking research might have received higher citations during

this period due to the novelty and significant impact on the academic and practical communities. [13] The citation growth rate may slow down as the field matures, decreasing the mean citations per article.

- As the years progressed, the number of research articles on Block-chain significantly increased. The increasing volume of publications might have led to a dilution [14] of citations across more articles. More articles competing for attention may result in lower average citations per article.

- Initially, research in Block-chain technology may have focused on fundamental concepts and significant applications. Over time, research diversified into various subfields [15], use cases, and specializations, attracting a broader range of researchers and topics. This diversification might have resulted in a wider distribution of citations across many articles, decreasing the average number of citations per article.

- Researchers may have engaged [16] more in scholarly communication as the field matured, citing a broader range of articles rather than primarily focusing on a few seminal works. That can spread citations across a larger pool [17] of articles, impacting the mean citations per article.

## 4 Year-wise authorship distribution

Table 2. Presents a comprehensive examination of the year-wise authorship patterns in research articles related to Block-chain. This analysis contributes to a better understanding of how the research community is approaching the study of Block-chain technology, fostering collaborative efforts and extensive exploration.

| Table 2. Year-Wise Authorship Distribution of Publication | | | | | | | | |
|------|--------|-----|-------|------|----------|----------------------|------------------------|------------------|
| Year | Single | Two | Three | Four | Multiple | Multi Authored papers | Total number of Authors | Total Articles |
| 2016 | 1 | 4 | 2 | 1 | 0 | 7 | 21 | 10 |
| 2017 | 12 | 12 | 12 | 5 | 17 | 46 | 190 | 58 |
| 2018 | 6 | 11 | 12 | 11 | 15 | 49 | 190 | 55 |
| 2019 | 12 | 29 | 45 | 22 | 39 | 135 | 524 | 147 |
| 2020 | 8 | 19 | 27 | 32 | 33 | 111 | 444 | 119 |
| 2021 | 47 | 94 | 107 | 120 | 221 | 542 | 2356 | 589 |
| 2022 | 129 | 346 | 452 | 450 | 1064 | 2312 | 10462 | 2441 |
| Total | 215 | 515 | 657 | 641 | 1389 | 3202 | 14187 | 3419 |

2016, there were 21 articles, with the majority being multi-authored (seven articles), followed by two-authored papers (4 articles). The year 2022 saw a significant increase in articles (2441) and the proportion of multi-authored papers (1064 articles), highlighting collaboration and a matured research landscape.

The number of unique authors involved in these publications shows a notable increase each year, reflecting researchers' growing engagement and participation in Block-chain. The number of articles on Block-chain increased significantly over the years, reaching 3419 in 2022, indicating the growing interest and research activity in this domain. Multi-authored papers represent a substantial portion of the publications, consistently increasing over the years, indicating a collaborative approach and diverse perspectives in Block-chain research.

The distribution of single to four authors in papers fluctuates over the years, but most papers have more than four authors, especially from 2019 onwards. The data suggests a shift towards more collaborative and extensive research efforts, particularly in recent years (2021 and 2022), with a significant rise in articles and authors. This analysis underscores the evolution of authorship patterns in Block-chain research, displaying a progression toward collaborative and extensive multi-authored research. The significant increase in both the number of articles and the number of authors over the years highlights the growing interest and engagement of the research community in Block-chain technology. "The author and the citation statistics showed the path followed by the publications over the years and the relationships between these entities. Thus, researchers working on Block-chain can discover which authors are important and should be followed in the field. Country and institution statistics and their related connections contribute to the growing body of literature on Block-chain technology by presenting leading institutions in this field that have the potential to advance research or careers in Block-chain technology." [18]

## 5 Collaboration Index

The Collaboration Index (CI) is a metric used to quantify the research collaboration level based on the authorship patterns within scholarly articles [19]. It provides insights into the extent to which research articles result from collaborative efforts among authors.

| Table 3. Collaboration Index | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Single | Two | Three | Four | Multiple | Multi Authored papers | Total number of Authors | Total Articles | CI |
| 2016 | 1 | 4 | 2 | 1 | 0 | 7 | 21 | 10 | 2.1 |
| 2017 | 12 | 12 | 12 | 5 | 17 | 46 | 190 | 58 | 3.275862069 |
| 2018 | 6 | 11 | 12 | 11 | 15 | 49 | 190 | 55 | 3.454545455 |
| 2019 | 12 | 29 | 45 | 22 | 39 | 135 | 524 | 147 | 3.56462585 |
| 2020 | 8 | 19 | 27 | 32 | 33 | 111 | 444 | 119 | 3.731092437 |
| 2021 | 47 | 94 | 107 | 120 | 221 | 542 | 2356 | 589 | 4 |
| 2022 | 129 | 346 | 452 | 450 | 1064 | 2312 | 10462 | 2441 | 4.285948382 |
| Total | **215** | **515** | **657** | **641** | **1389** | **3202** | **14187** | **3419** | **3.48743917** |

In Table 3, the Collaboration Index (CI) was calculated for each year in block-chain research. The table presents the breakdown of authorship patterns, including the number of single-authored papers, two-authored papers, three-authored papers, four-authored papers, and multiple-authored papers for each year. The Collaboration Index (CI) provides a numerical value that indicates the average number of authors per article, normalized for the level of multi-authorship, for a particular year. A higher CI suggests a higher degree of collaboration and co-authorship in the research articles for that year.

Table 3 provides the calculated Collaboration Index (CI) for each year from 2016 to 2022. The gradual increase in the Collaboration Index over the years reflects a growing trend of collaboration within the Block-chain research community, highlighting the cooperative nature of scholarly work in this field.

## 6 Degree of Collaboration

The Degree of Collaboration (DC) is a metric used to quantify the extent of collaborative research within a specific field or domain [7]. It offers valuable visions into the grade of co-authorship and collaboration in scholarly publications—table 4. Provide the Degree of Collaboration in the publications on Block-chain from 2016 to 2022.

| Table 4. Degree of Collaboration | | | | |
|---|---|---|---|---|
| Year | Single | Multi Authored papers | Total number of Authors | DC |
| 2016 | 1 | 7 | 21 | 0.9 |
| 2017 | 12 | 46 | 190 | 0.793103448 |
| 2018 | 6 | 49 | 190 | 0.890909091 |
| 2019 | 12 | 135 | 524 | 0.918367347 |
| 2020 | 8 | 111 | 444 | 0.932773109 |
| 2021 | 47 | 542 | 2356 | 0.920203735 |
| 2022 | 129 | 2312 | 10462 | 0.947152806 |
| **Total** | **215** | **3202** | **14187** | **0.900358505** |

The Degree of Collaboration (DC) provides a numerical value between 0 and 1, representing the proportion of authors involved in multi-authored papers relative to the total number of authors (including single-authored papers) for a given year. A higher DC value signifies a higher level of collaboration and co-authorship within the research articles for that year. The DC values reflect how much collaboration is prevalent in Block-chain research. The DC values, ranging from approximately 0.79 to 0.95, affirm a robust collaborative [20] ethos within the research community, emphasizing teamwork and cooperative endeavors within the Block-chain domain.

## 7  Collaboration Coefficient

The Collaboration Coefficient (CC), a metric explored in this study, offers a numerical measure of collaboration within the academic research domain. Calculated as the proportion of multi-authored papers to the total number of articles, the CC provides insights into the collaborative dynamics shaping scholarly work. The Table 5. Illustrates the Collaboration Coefficient (CC) for 2016 to 2022 in Block-chain research.

| Table 5. Collaboration Coefficient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Single | Two | Three | Four | Multiple | Multi Authored papers | Total number of Authors | Total Articles | CC |
| 2016 | 1 | 4 | 2 | 1 | 0 | 7 | 21 | 10 | 0.40833 |
| 2017 | 12 | 12 | 12 | 5 | 17 | 46 | 190 | 58 | 0.54766 |
| 2018 | 6 | 11 | 12 | 11 | 15 | 49 | 190 | 55 | 0.617879 |
| 2019 | 12 | 29 | 45 | 22 | 39 | 135 | 524 | 147 | 0.63437 |
| 2020 | 8 | 19 | 27 | 32 | 33 | 111 | 444 | 119 | 0.660604 |
| 2021 | 47 | 94 | 107 | 120 | 221 | 542 | 2356 | 589 | 0.662375 |
| 2022 | 129 | 346 | 452 | 450 | 1064 | 2312 | 10462 | 2441 | 0.694235 |
| **Total** | **215** | **515** | **657** | **641** | **1389** | **3202** | **14187** | **3419** | **0.60364** |

The Collaboration Coefficient (CC) values range from approximately 0.41 to 0.69, indicating substantial collaboration within the Block-chain research community. The trend portrays an escalating culture of collaboration, underscoring this dynamic domain's collective effort and joint exploration [21]. Understanding the Collaboration Coefficient in Block-chain research offers valuable insights into the collaborative fabric of this innovative field. As we forge ahead in Block-chain technology, fostering and promoting collaboration will be pivotal in driving transformative breakthroughs and propelling the boundaries of knowledge.

## 8  Modified Collaboration Coefficient

The Modified Collaboration Coefficient (MCC) is computed as the ratio of the total number of multi-authored papers to the total number of authors involved. Unlike traditional collaboration coefficients, the MCC presents a more granular view by considering the unique authors contributing to the articles. Table 6 outlines the Modified Collaboration Coefficient (MCC) for each year from 2016 to 2022 in the context of Block-chain research.

| Table 6. Modified Collaboration Coefficient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Single | Two | Three | Four | Multiple | Multi Authored papers | Total number of Authors | Total Articles | MCC |
| 2016 | 1 | 4 | 2 | 1 | 0 | 7 | 21 | 10 | **0.4537** |
| 2017 | 12 | 12 | 12 | 5 | 17 | 46 | 190 | 58 | **0.55727** |
| 2018 | 6 | 11 | 12 | 11 | 15 | 49 | 190 | 55 | 0.629321 |
| 2019 | 12 | 29 | 45 | 22 | 39 | 135 | 524 | 147 | 0.638715 |
| 2020 | 8 | 19 | 27 | 32 | 33 | 111 | 444 | 119 | 0.666203 |
| 2021 | 47 | 94 | 107 | 120 | 221 | 542 | 2356 | 589 | 0.663502 |
| 2022 | 129 | 346 | 452 | 450 | 1064 | 2312 | 10462 | 2441 | 0.69452 |
| **Total** | **215** | **515** | **657** | **641** | **1389** | **3202** | **14187** | **3419** | **0.61475** |

The MCC values range from approximately 0.45 to 0.69, revealing substantial collaboration within the Block-chain research community. This emphasizes the cooperative and team-oriented approach that

characterizes scholarly work in this dynamic field. A higher MCC value indicates a higher proportion of multi-authored papers concerning the total number of authors. This points to the strength [22] derived from collaboration, where multiple minds converge to enhance the rigor and depth of research. With its multifaceted applications and complexities [23], the Block-chain field benefits immensely from the collective wisdom that collaboration brings.

The MCC values also shed light on the inclusivity of the Block-chain research ecosystem. A rising MCC signifies a growing number of authors collaborating on research papers. This inclusivity is essential for embracing diverse perspectives, nurturing creativity, and ensuring a comprehensive understanding of Block-chain and its potential.

## 9 Conclusion

Collaboration is the cornerstone of progress, innovation, and meaningful impact in Block-chain technology. As we traverse the years from 2016 to 2022, exploring the intricacies of collaborative dynamics through metrics like the Collaboration Coefficient (CC) and the Modified Collaboration Coefficient (MCC), a resounding narrative of cooperation and collective wisdom unfolds. The tale told by the Collaboration Coefficient (CC) portrays an inspiring journey of scholarly collaboration within the Block-chain research community. The values steadily climb from 0.41 to 0.69, underscoring a culture of shared exploration and collective achievement. This upward trajectory signifies a burgeoning research landscape where researchers converge to dissect the intricacies of Block-chain, decode its potential, and construct a future enhanced by this transformative technology.

Beyond traditional collaboration metrics, the Modified Collaboration Coefficient (MCC) offers a refined lens to perceive co-authorship. It unveils a narrative of inclusivity, where an increasing number of authors actively participate in collaborative endeavors. This inclusivity is not just a numerical trend but a testament to the richness derived from diverse voices, perspectives, and talents, all converging to push the boundaries of Block-chain understanding. Block-chain research is one of hope, potential, and the promise of a future where collective intellect propels us toward a new era of technological marvels.

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