New Series Annals on Economy, Law and Sociology, Volume 9, Number 1/2026
Romania, June, 2026 ISSN ONLINE 2067-5704

BIBLIOMETRIC ANALYSIS ON THE TOPIC OF COMMUNICATION PROTOCOLS FOR EMBEDDED SYSTEMS: A PRACTICAL APPROACH

Adrian Bogorin-Predescu[1], Călin Gheorghe Dan Neamțu[2] and Aurel Mihail Titu[3,4]
[1]National University of Science and Technology POLITEHNICA Bucharest, 313 Splaiul Independenței, București, Romania,
ORCID No. 0009-0000-5947-5041, adrian_bogorin@yahoo.com
[2]Technical University of Cluj-Napoca, 103-105 Muncii Boulevard, Cluj-Napoca, Romania,
ORCID No. 0000-0003-0899-0451, calin.neamtu@muri.utcluj.ro
[3]Lucian Blaga University of Sibiu, 10 Victoriei Street, Sibiu, România, Corresponding author,
ORCID No. 0000-0002-0054-6535, mihail.titu@ulbsibiu.ro
[4]Academy of Romanian Scientists, 3 Ilfov Street, Bucharest, Romania,

ABSTRACT: This paper explores through a bibliometric analysis the evolution and research directions associated with communication protocols used in embedded systems. The study uses data extracted from the main international bibliographic databases, applying visualization tools and scientometric metrics to identify dominant trends, high-impact authors and institutions, as well as connections between key concepts. The results show that interest in communication protocols has experienced an accelerated development in the context of the expansion of IoT applications, autonomous vehicles and intelligent industrial networks. The analysis highlights the diversity of the technologies investigated, from low-power protocols (such as ZigBee and BLE) to high-speed and reliable solutions (CAN, industrial Ethernet). At the same time, an increase in international collaboration is highlighted, with a significant contribution from the academic and industrial environment. By characterizing the structure of publications and emerging directions, the paper provides an integrated perspective on how communication protocols support innovation and performance of embedded systems.
KEYWORDS: Bibliometric analysis, Communication Protocol, VOSviewer, Web of Science, Scopus

DOI 10.56082/annalsarscieco.2026.1.50

1. INTRODUCTION

Bibliometric analysis is now a widely used, rigorous method for charting the evolution of research domains over time and synthesising extensive scientific literatures. By establishing methodical, transparent, and repeatable processes for identifying influential publications, authors, journals, and thematic frameworks, it enhances (and occasionally partially replaces) narrative reviews. Thanks to enhanced bibliographic databases, computational tools, and uniform reporting standards, this methodology has evolved over the past ten years (2015–2025) from highly specialised "science mapping" methods into a widely used research design spanning discipline [1].

The growing focus on transparent workflows - explicit search techniques, documented inclusion/exclusion rules, and repeatable preprocessing and analysis steps - is a significant state-of-the-art development from 2015 to 2025. Concurrently, evidence synthesis communities published revised reporting guidelines, most notably PRISMA 2020, which, although initially intended for systematic reviews, has had a significant impact on how bibliometric studies report search, screening, and dataset construction (e.g., flow diagrams, protocol clarity). Adopting PRISMA-style transparency has become a crucial quality indicator in several domains as bibliometric studies increasingly present themselves as methodical, repeatable mappings of a knowledge domain [2].

The proliferation of user-friendly software significantly reduced the entry barrier for bibliometric research between 2015 and 2025. The integration of end-to-end processes into open analytical ecosystems, particularly the R package bibliometrix, which formalised procedures for importing data (including Web of Science and Scopus exports), generating descriptive indicators, and creating networks for co-citation, coupling, collaboration, and co-word analysis, was a significant turning point. Simultaneously, systematic reviews of science mapping have clarified the conceptual underpinnings and best practices for such visual analytics, and CiteSpace continued to influence science mapping practice by supporting temporal and structural analyses (e.g., burst detection, timeline views, cluster labelling) [3] [4].

Another popular tool for creating and displaying bibliometric networks (co-authorship, co-citation, bibliographic coupling, term maps) is VOSviewer.

Significantly, VOSviewer's role as the main visualisation engine in modern bibliometric studies was strengthened by the 2020–2023 releases, which specifically increased compatibility with additional data sources and enhanced export handling (including fixes for Web of Science data and support for new data formats). Additionally, the tool ecosystem has expanded to include open bibliographic infrastructures. For instance, VOSviewer workflows are increasingly incorporating open sources like OpenAlex for creating term co-occurrence maps and bibliometric networks, which reflects a larger trend towards open and API-based metadata access [5] [6].

The reliance of results on database coverage (e.g., Web of Science vs. Scopus), which can impact corpus size, citation counts, and topic representation, is a recurring methodological problem in bibliometrics. The use of merged datasets, which incorporate Scopus and Web of Science records, increased between 2015 and 2025 in order to reduce database-specific bias. Deduplication and harmonisation came next. The suggestion of easy-to-use merging processes that maintain dataset integrity while lessening the manual labour of balancing disparate export formats is a notable contribution. In contrast to manual operations, complementary research suggests more automated methods for combining and deduplicating bibliographic exports, emphasising both accuracy improvements and notable time savings [7][8][9].

The establishment of "protocol papers" and detailed operational guidelines that formalise bibliometric operations, with an emphasis on institutional access constraints, data cleansing, and consistent parameterisation of tools like CiteSpace and VOSviewer, is a more recent change (approximately 2023–2025). This pattern shows maturation: bibliometrics is becoming more and more of a standardised research process that can be audited, replicated, and taught, rather than just a collection of methods. Additionally, this protocolization lessens frequent hazards (such as uneven keyword normalisation, unreported thresholds, or unclear deduplication procedures) and enhances comparability between research [10].

Using traditional narrative reviews alone to maintain an up-to-date, thorough understanding of any study subject has become more challenging due to the tremendous expansion of scientific output over the past ten years. As a result, bibliometric analysis has become a popular and repeatable method for statistically mapping academic landscapes, detecting key publications, collaborative mechanisms, and changing topic clusters. Because it allows researchers to create and visualise bibliometric networks (such as co-authorship, co-citation, bibliographic coupling, and keyword co-occurrence) in a way that is transparent and understandable for readers, VOSviewer has emerged as one of the most popular tools within this methodological family. Bibliometric studies in very different fields, like medicine and finance, clearly demonstrate this trend. The authors use VOSviewer to analyse large datasets retrieved from the Web of Science (WoS) and create knowledge maps that highlight key topics, actors, and future research directions [11].

2. "COMMUNICATION PROTOCOL" BIBLIOMETRIC ANALYZES KEYWORD

For researchers, bibliometrics serves as a vital methodological framework for mapping scholarly literature, enabling the identification of seminal works, prominent authors, emerging trends, and high-impact journals. This approach enhances scientific rigor by guiding research trajectories, informing the selection of collaborative partners, and strategically positioning research findings within the broader academic discourse. Furthermore, citation analysis provides objective feedback on the visibility and impact of individual publications, thereby refining dissemination strategies.

To investigate the communication mechanisms and interoperability processes between interconnected embedded systems, this study prioritized the analysis of the compound keyword "Communication protocol." The bibliographical research was conducted using the Web of Science (WoS) database, covering the period from 2010 to 2025. Data sets for each keyword were exported from WoS and subsequently analyzed using the bibliometric software VOSviewer (version 1.6.20). The volume of papers exported for bibliometric analysis is presented in Table 1.

Table 1. Number of papers subjected to bibliometric analysis

keyword	Number of papers	Period
"Communication Protocol"	6858	2010-2025

The records were extracted as "Tab Delimited Files" using the "Full Record and Cited References" option, ensuring a comprehensive dataset that encompasses complete metadata alongside the respective citation lists.

The research included the term "communication protocol," which appears more than five times in the primary WOS database. 1062 of the 17994 keywords met the required minimum of five occurrences. "Communication protocol" (total link strength of

1215), "internet of things" (1368), "security" (1302), "protocols" (1572), and "internet" (1153) were the most common keywords. The co-occurrence of terms in articles concerning "communication protocol" is shown in Figure 1. The nodes' sizes show how frequently they occur. Their co-occurrence in the same publication is shown by the curves connecting the nodes.

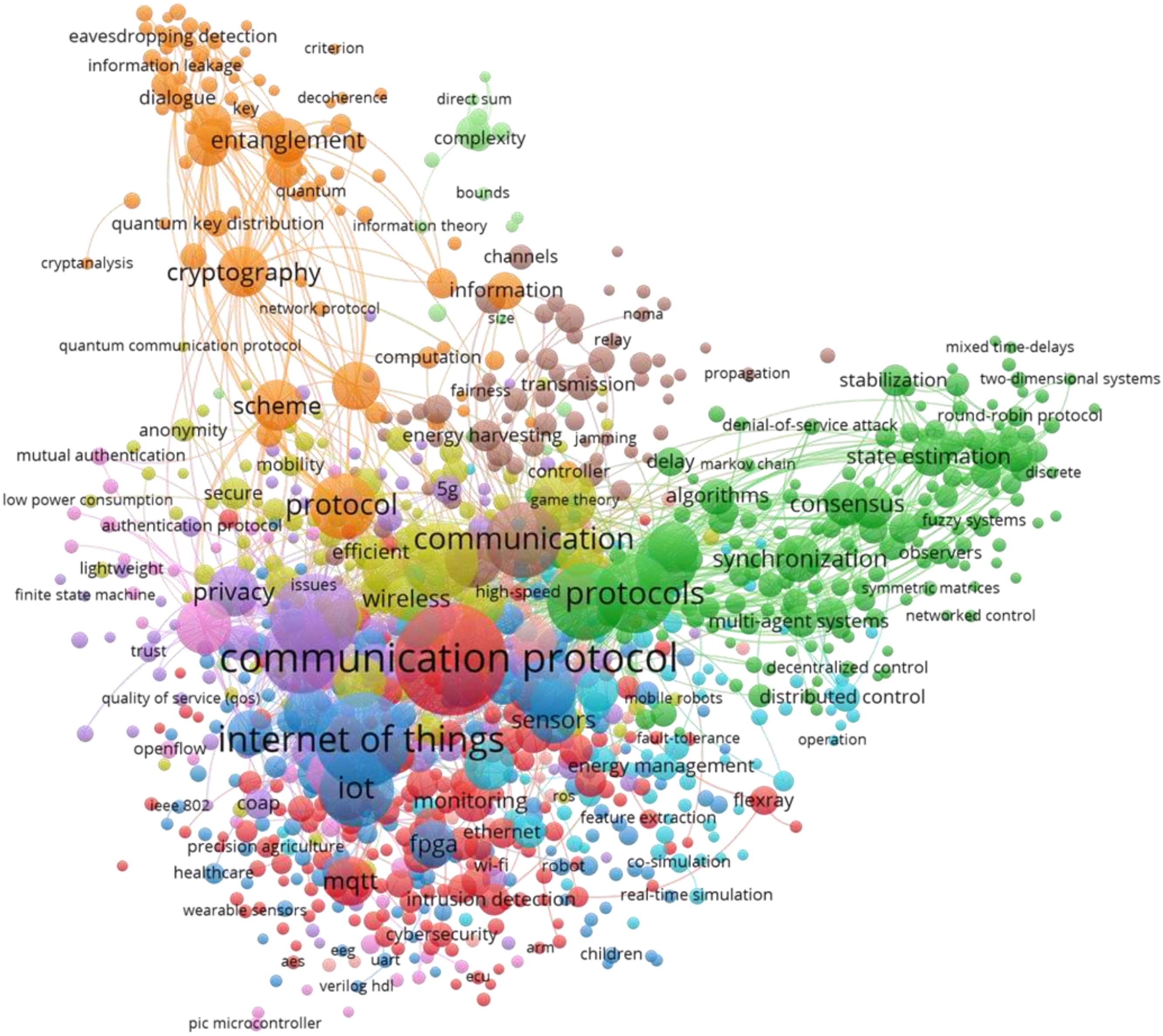

Figure 1. Bibliometric analysis of keywords in publications on "communication protocol". Co-occurrence of keywords (Generated by VOSviewer [12])

The distribution analysis reveals that 4,010 journals have published research pertaining to "communication protocol," with 164 of these outlets contributing more than five papers each. Collectively, the top ten most active journals indexed in the Web of Science (WoS) Core Collection accounted for 555 publications.

Figure 2 presents the top 10 most prolific journals regarding the "communication protocol" theme. The highest-ranked journal in terms of output was "IEEE Access," with 138 papers.

Conversely, "Sensors" emerged as the most influential publication in terms of citation count, garnering a total of 2,252 citations.

The top ten countries, organizations, and authors with the highest scientific output regarding the keyword "communication protocol" are detailed in Tables 2, 3, and 4. Notably, Zidong Wang from Brunel University London has authored 37 papers, which have garnered 2,074 citations. Furthermore, at the institutional level, the Chinese Academy of Sciences has contributed 104 publications, totalling 836 citations.

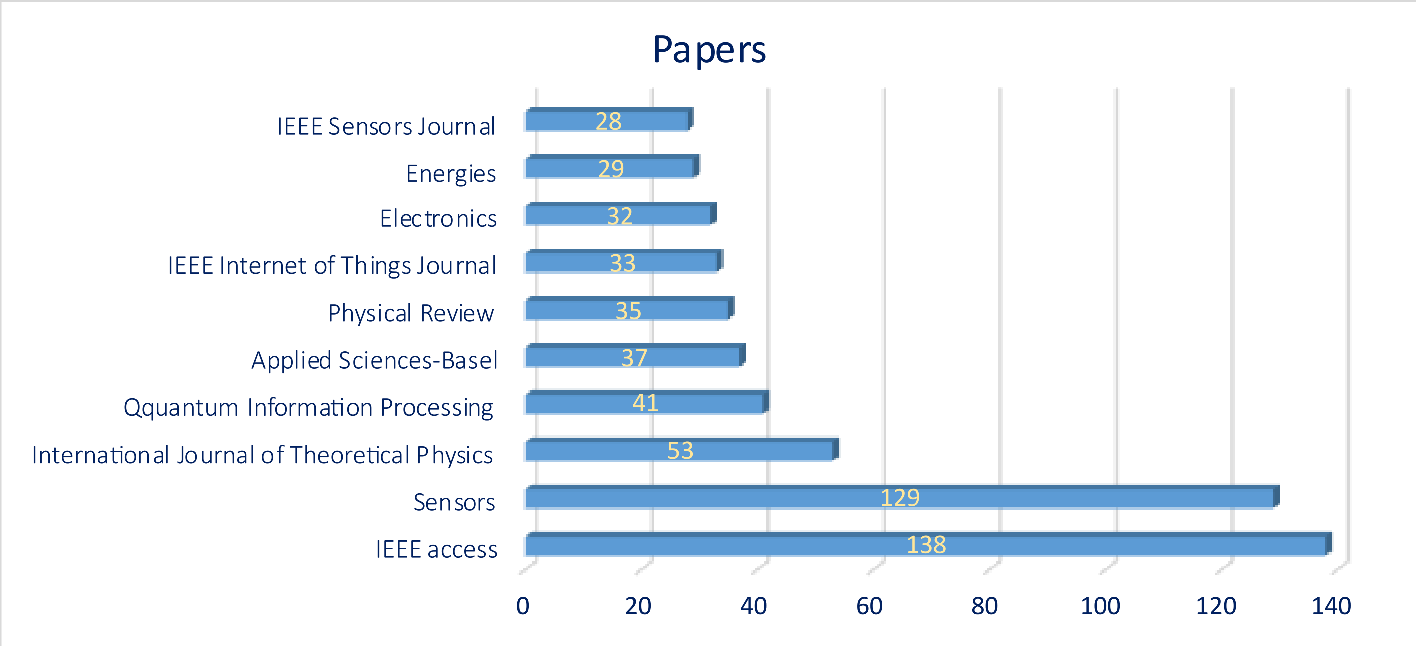

Figure 2. The most active Top 10 journals. Journals with the most published papers in the field of "communication protocol" (data extracted by VOSviewer [12])

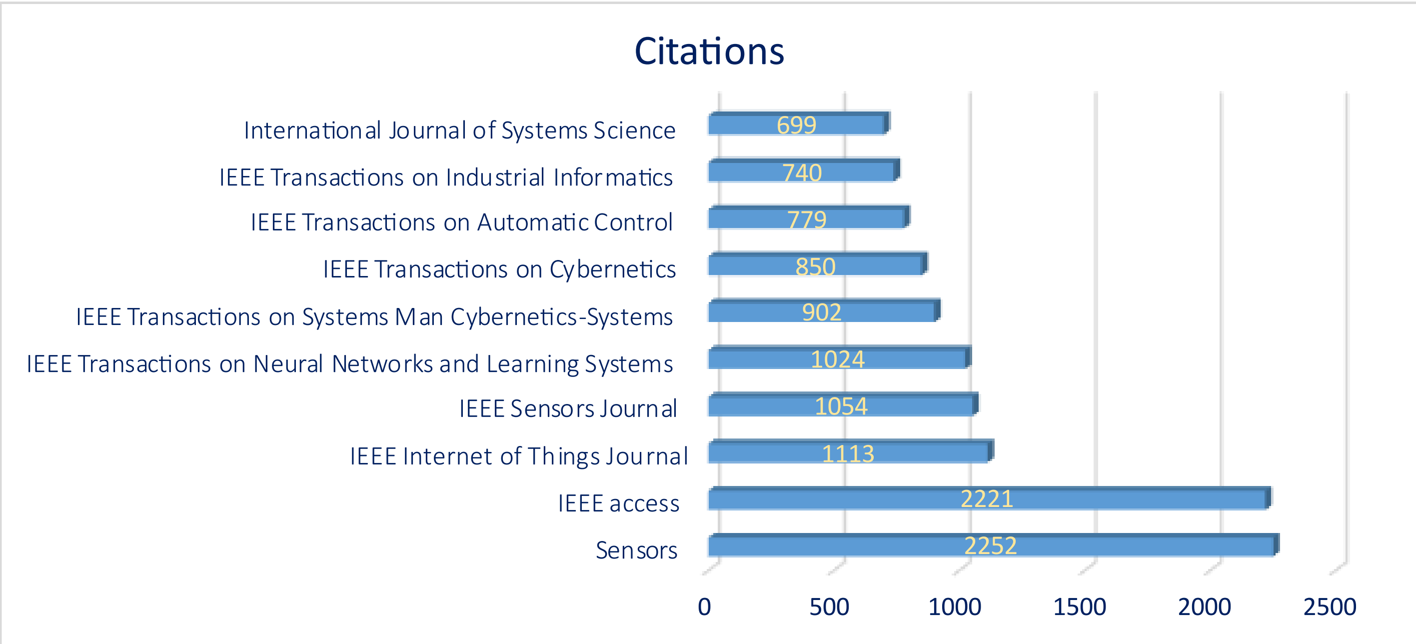

Figure 3. The most active Top 10 journals. Journals with the most cited papers in the field of "communication protocol" (data extracted by VOSviewer [12])

Table 2. The top ten most active countries in the field of "communication protocol"

Country	Number of papers	Number of citation
Peoples R China	2019	19929
USA	961	13845
India	509	4048
Germany	366	3933
Italy	349	5204
England	249	6343
South Korea	244	3175
France	240	1834
Japan	240	1873
Spain	223	2842

A highly concentrated research output in the "communication protocol" keyword is indicated by the country distribution. People's R China is the most productive country (2019 papers), followed by the USA (961) and India (509). However, the pattern changes when citations are normalized by the number of publications: Despite having fewer publications, England has the highest average citation impact (~25.5 citations/paper), whereas the USA and Italy have comparably high citation intensity (~14.9 and ~14.4 citations/paper, respectively). The citation rates of China (~9.9 citations/paper) and India (~8.0

citations/paper), on the other hand, indicate that publication volume does not directly convert into proportional citation influence. This could be due to variations in publication age, venue mix, and worldwide visibility.

Figure 4 indicates the graphical distribution of Citation-Countries in the field of "communication protocol".

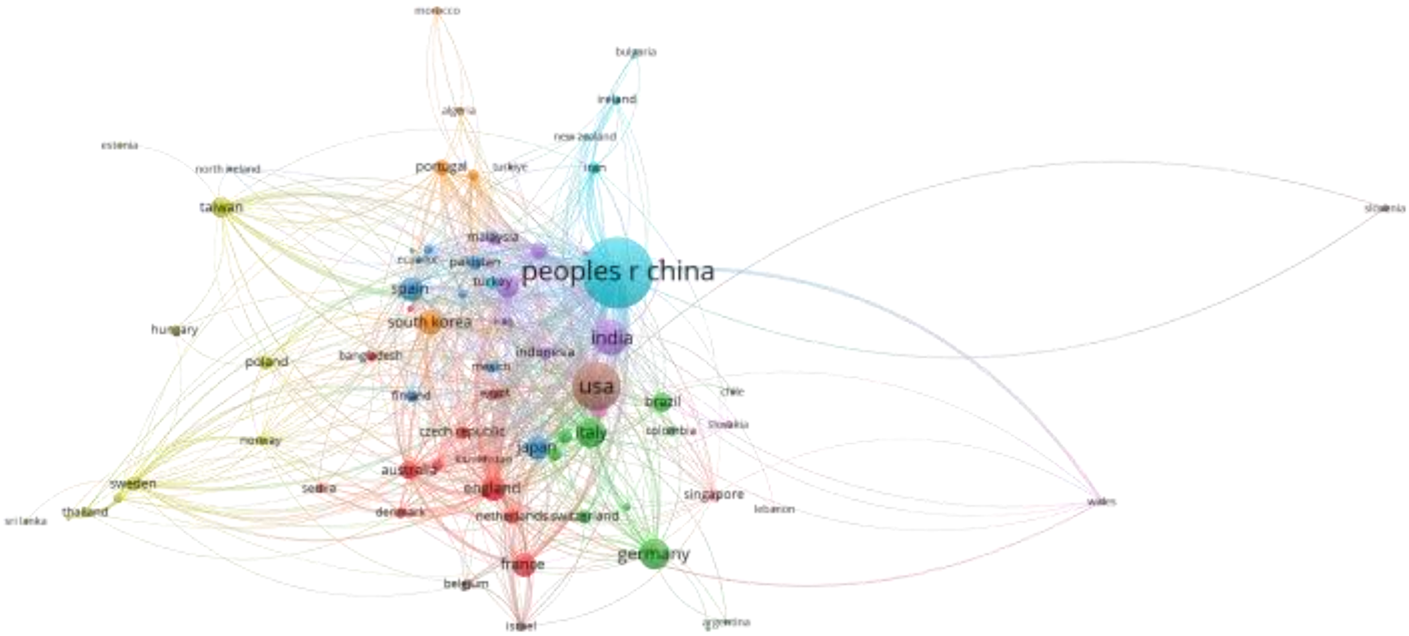

Figure 4. Citation-Countries in the field of "communication protocol" (Generated by VOSviewer [12])

Table 3. The top ten most active organizations in the field of "communication protocol"

Organization	Number of papers	Number of citation
Chinese Acad Sci	104	836
Beijing Univ Posts & Telecommun	69	854
Southeast Univ	58	954
Tsinghua Univ	55	1148
Univ Shanghai Sci & Technol	46	1143
Beihang Univ	42	147
MIT	39	382
Xidian Univ	39	738
Zhejiang Univ	39	1272
Brunel Univ London	38	2010

At the organisational level, seven of the ten most active institutions are Chinese, and the journal's output in the "communication protocol" keyword is heavily concentrated in China. With 104 publications, the Chinese Academy of Sciences is the most productive, demonstrating its strong research capabilities and consistent output. Impact-normalized indicators, however, paint a different picture: Zhejiang University and the University of Shanghai for Science and Technology both have high citation densities (≈32.6 and ≈24.8 citations/paper, respectively), but Brunel University London has the highest citation intensity (2010 citations over 38 works; ≈52.9 citations/paper). Conversely, a number of very productive organisations show lower average citation rates (e.g., CAS ≈8.0 citations/paper), indicating that citation influence is not directly correlated with institutional production. Overall, Table 3 shows a structure in which the most citation-intensive contributions are provided by fewer organisations with relatively smaller journal counts, whereas research volume is concentrated in a small number of Chinese universities.

Figure 5 indicates the graphical distribution of Citation-Organizations in the field of "communication protocol".

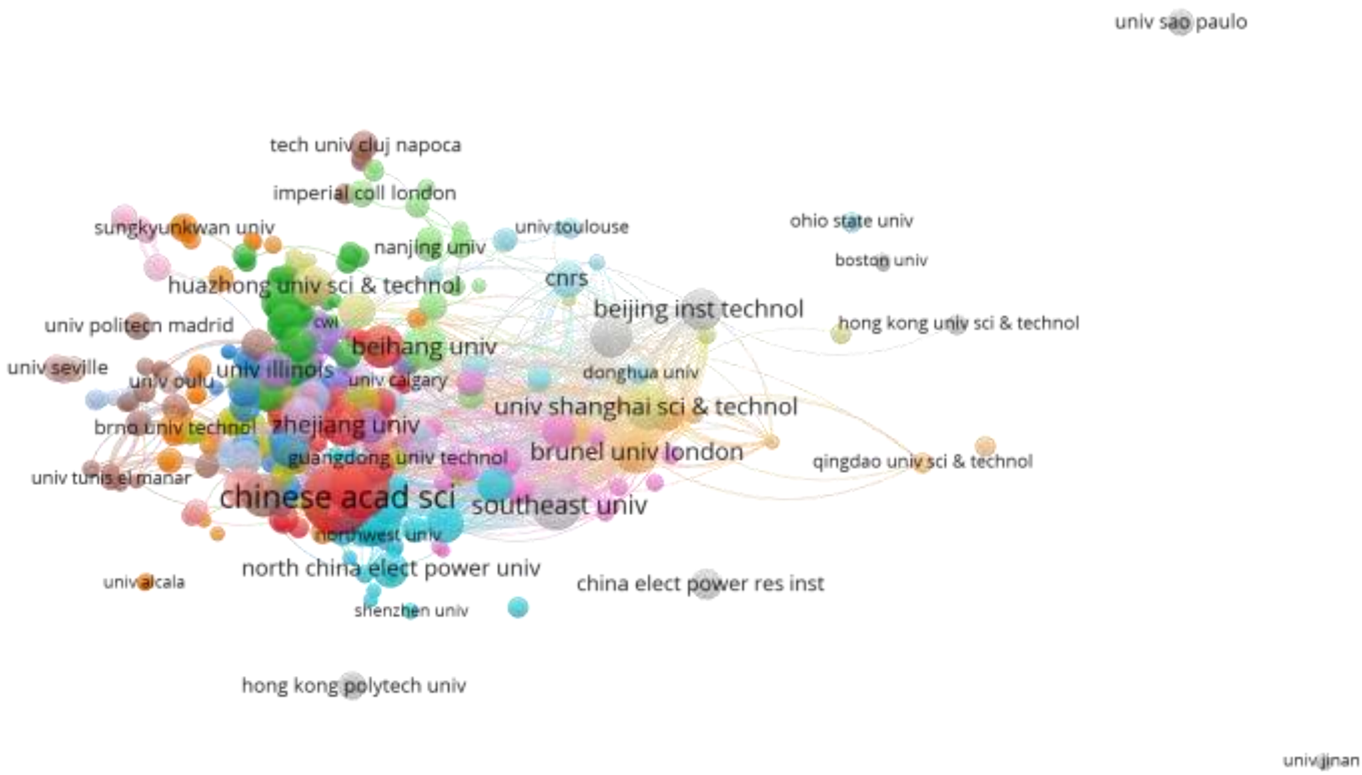

Figure 5. Citation-Organizations in the field of "communication protocol" (Generated by VOSviewer [12])

Table 4. The top ten most active authors in the field of "communication protocol"

Author	Number of papers	Number of citation
Wang, Zidong	37	2074
Takizawa, Makoto	18	78
Li, Jian	17	155
Liu, Hongjian	17	663
Wei, Guoliang	16	608
Hu, Jun	15	714
Khalgui, Mohamed	15	636
Dong, Hongli	14	373
Hovorka, Roman	14	622
Enokido, Tomoya	13	38

The results at the author level show that a small number of contributions have a significant concentration of effect. With over one-third of the citations and approximately one-fifth of the publications in the top-author set, Wang, Zidong has a disproportionately high level of influence and dominates both productivity and impact (37 papers; 2074 citations). Hu, Jun; Hovorka, Roman; Khalgui, Mohamed; Liu, Hongjian; and Wei, Guoliang are among the authors with moderate publication counts who show high citation intensity (≈38–48 citations per paper), indicating that their contributions form a highly visible knowledge base in the "communication protocol" literature. However, some productive authors (e.g., Takizawa, Makoto; Li, Jian) exhibit relatively low citation density, indicating that publication volume alone does not always translate into citation impact. This could be because of author-name disambiguation effects, topic specialisation, publication age, or venue mix.

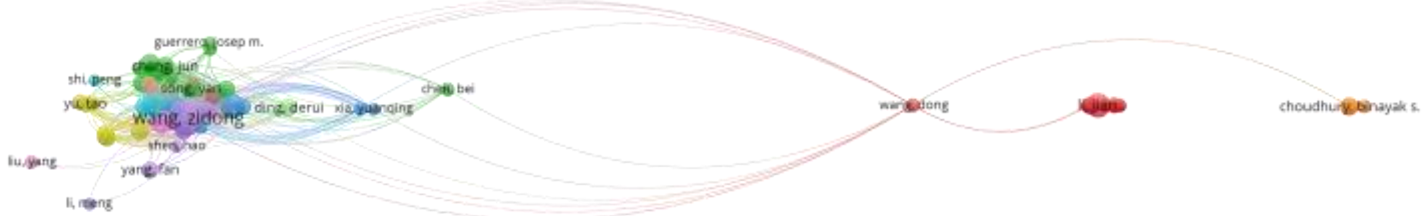

Figure 6. Citation-Authors in the field of "communication protocol" (Generated by VOSviewer [12])

Figure 6 indicates the graphical distribution of Citation-Authors in the field of "communication protocol".

3. CONCLUSIONS

Using records acquired from Web of Science and processed using VOSviewer (v1.6.20), this study produced a bibliometric and visual mapping of the research landscape linked with the compound keyword "communication protocol" throughout the period 2010–2025. As evidenced by the most common and closely related keywords (such as protocols, security, and internet of things), the resulting keyword co-occurrence networks, along with country, organisation, author, and source analyses, verify that "communication protocol" research is both extensive and highly interdisciplinary, with strong conceptual links to IoT, security, and protocol engineering themes. These results align with how VOSviewer is commonly used to produce co-occurrence and cooperation maps that highlight key subjects and structural relationships within a field.

From the standpoint of productivity and effect, the findings show a significant concentration of output among a select group of top nations and organisations. China is the country with the highest publishing volume, followed by the USA and India. However, citation-normalized trends show that some countries with lower volume could have higher citation intensity. The most citation-intensive contributions are not solely linked to the biggest publishers, indicating that productivity does not always translate into proportionate citation influence. At the organisational level, a number of Chinese institutions (such as the Chinese Academy of Sciences) dominate publication volume. This kind of "volume vs. citation-density" divergence is commonly seen in bibliometric maps, where publication counts may be outweighed by network position and highly referenced landmark contributions.

The data reveals a clear concentration of power among a small number of contributors at the author level, with Wang and Zidong leading the top-listed writers in terms of both productivity and total citations. A subset of contributions serves as a high-visibility knowledge base inside this corpus, as evidenced by the high citation intensity of a number of writers with moderate publication counts. These concentration patterns are consistent with more general protocol-centric scientific mapping in related fields, particularly in linked mobility systems and vehicles, where security and protocols are key research pillars. For instance, bibliometric studies on intelligent connected vehicles and the Internet of Vehicles emphasise the importance of security and protocol technologies (such as V2X-related communication) as current study areas [13][14]. The idea that protocol ecosystems evolve unevenly and focus on a few prominent standards is supported by protocol-focused bibliometric work in IoT application-layer communication, which shows unequal study interest across protocol families (e.g., MQTT and CoAP popularity) [15]. The strong "security + IoT + protocol" clustering seen in our keyword network is reflected in the growing coupling between protocol research, cybersecurity, and emerging edge/AI-enabled architectures in vehicular contexts, which is further highlighted by in-vehicle communication protocol bibliometrics [16].

4. REFERENCES

1. Župič, I., Čater, T. *Bibliometric Methods in Management and Organization*. Organizational Research Methods, 18(3), 429–472. https://doi.org/10.1177/1094428114562629 (2015).
2. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. *The PRISMA 2020 statement: an updated guideline for reporting systematic reviews*. BMJ, n71. https://doi.org/10.1136/bmj.n71 (2021).
3. Aria, M., & Cuccurullo, C. Bibliometrix: *An R-tool for comprehensive science mapping analysis*. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007 (2017).
4. Chen, C. *Science Mapping: A Systematic Review of the Literature*. Journal of Data and Information Science, 2(2), 1–40. https://doi.org/10.1515/jdis-2017-0006 (2017).
5. van Eck, N. J., & Waltman, L. (n.d.). *VOSviewer: Visualizing scientific landscapes* (software site and release notes). https://www.vosviewer.com/ last accessed in 2025.
6. van Eck, N. J. *Visualizing Science Using OpenAlex and VOSviewer (OpenAlex how-to webinar)*. Centre for Science and Technology Studies (CWTS), Leiden University. Retrieved from https://openalex.org/Visualizing_Science_Using_OpenAlex_and_VOSviewer.pdf (2023, December 14).
7. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. *How to conduct a bibliometric analysis: An overview and guidelines*. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070 (2021).
8. Caputo, A., & Kargina, M. *A user-friendly method to merge Scopus and Web of Science data during bibliometric analysis*. Journal of Marketing Analytics, 10, 82–88.

https://doi.org/10.1057/s41270-021-00142-7 (2022).
9. Kasaraneni, H., & Rosaline, S. Automatic Merging of Scopus and Web of Science Data for Simplified and Effective Bibliometric Analysis. Annals of Data Science, 11(3), 785–802. https://doi.org/10.1007/s40745-022-00438-0 (2022).
10. Du, Q., Zhao, R., Wan, Q., et al. *Protocol for conducting bibliometric analysis in biomedicine and related research using CiteSpace and VOSviewer software.* STAR Protocols, 5(3), 103269. https://doi.org/10.1016/j.xpro.2024.103269 (2024).
11. Sidna, J., Amine, B., Abdallah, N., & El Alami, H. Analysis and evaluation of communication Protocols for IoT Applications. In Proceedings of the 13th International Conference on Intelligent Systems: Theories and Applications (pp. 1–6). SITA'20: Theories and Applications. ACM. https://doi.org/10.1145/3419604.3419754 (2020).
12. VOSviewer. VOSviewer Visualizing scientific landscape. https://www.vosviewer.com/ (last accessed 2025.12.21)
13. Zhang, J., Cai, M., & Yang, W. Analysis of Internet of Vehicles Technology Evolution and Trends Based on Bibliometric Visualization. In Lecture Notes in Electrical Engineering (pp. 188–202). Springer Nature Singapore. https://doi.org/10.1007/978-981-99-0416-7_18 (2023).
14. Ji, W., Yu, S., Shen, Z., Wang, M., Cheng, G., Yang, T., & Yuan, Q. Knowledge Mapping with CiteSpace, VOSviewer, and SciMAT on Intelligent Connected Vehicles: Road Safety Issue. Sustainability, 15(15), 12003. https://doi.org/10.3390/su151512003 (2023).
15. Borysov, O. Scientific Publications' Bibliometric Analysis of Application-Level TCP/IP Models' Communication Protocols for the Internet of Things. Visnyk of Kharkiv State Academy of Culture, 66, 17–25. https://doi.org/10.31516/2410-5333.066.02 (2024).
16. Hussain, I., Reis, M. J. C. S., Serôdio, C., & Branco, F. A Bibliometric Analysis and Visualization of In-Vehicle Communication Protocols. Future Internet, 17(6), 268. https://doi.org/10.3390/fi17060268 (2025).