Analysis of Research Trends in Maritime Communication

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***Abstract*—Maritime industry plays an important role in the transport of various goods and passengers; it is the major contributor to global trade. With the advent of new communication technologies, advances in Artificial Intelligence, and the ubiquitous Internet of Things, the maritime industry is evolving day by day. Effective communication plays a key role in ensuring the smooth operation of maritime activities. However, the researchers in this domain need to understand and analyze various research trends that can offer various insights. In this view, this paper provides a clear understanding of the scientific landscape in maritime communication based on the data available in the Scopus database. Scopus is the largest abstract and citation database from Elsevier which provides comprehensive detail about the literature in various subject fields. This research considers the last 10 years data, i.e. from 2013 to 2023 for the analysis. A total of 505 publications were obtained from the database. These publications include various document types such as articles, conference papers, reviews, etc. The analysis is carried out from various perspectives including year, country, subject area, funding sponsor, document type, affiliation, author, and source. Further, to understand the mutual relations, collaborations between different countries, the co-occurrence of various keywords, and the bibliographic coupling among diverse sources are also analyzed. This analysis provides a clear view and serves the researchers willing to work in this area and other stakeholders to understand various perspectives in this domain.**

***Keywords*—Artificial intelligence (AI); internet of things (IoT); maritime communication; maritime research trends; Scopus**

I. Introduction

In recent years, with the growth in economic trade, ocean transportation has become popular [1]. This is the vital mode for international trade, which is accountable to the majority of the world trade by volume. This mode of transportation has several advantages such as cost-effectiveness, more capacity, and less environmental impact. In the context of sustainable development, maritime plays an important role in addressing the challenges posed by the environment and continuing to the United Nations Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 14 (Life Below Water) [2]. The use of alternative fuels helps in reducing the emissions from the ships. International Maritime Organization (IMO) is an important agency for maritime operations that is responsible for the safety and security of ships. It was established in 1948, and in 2013, it introduced regulations related to the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) [3]. These regulations help to attain the SDGs to a greater extent. With the advent of Industry 4.0 (fourth industrial revolution), various advanced technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) are helping to improve the efficiency of maritime operations [4]-[7]. The ships are equipped with various sensors to collect real-time data that are related to fuel consumption, engine efficiency, emissions, etc. As shown in Fig. 1, data can be exchanged directly between devices in peer-to-peer mode or can leverage the existing communication infrastructure for broader reach. Once the data is collected, it can be used to train the machine learning models for various applications. Many advances are happening in the field of AI, with various latest technologies emerging day by day, such as Explainable AI and Federated Learning [8], [9]. AI can offer a wide range of benefits in maritime scenarios including predictive maintenance, collision avoidance, route optimization, crew assistance and training, port operations optimization, and more [10]-[12]. Predictive maintenance helps in predicting equipment failures and recommends maintenance before they occur, reducing breakdowns [13]-[15]. The data collected from the sensors helps to detect potential collisions and recommend evasive maneuvers, reducing the risk of accidents. Route planning can be effectively done using AI to make safe and optimal routes, thereby saving time and fuel. AI can assist crew members in decision-making in critical situations. In addition, training simulations can be used to enhance the skills of maritime professionals. Port operations, which include scheduling arrivals and departures, and coordination of the movement of vessels within the port, can be done effectively with the help of AI. This results in improved efficiency and reduced waiting times for ships.

Communication is an important aspect of maritime operations, facilitating a wide variety of applications [16]. To achieve this, maritime communication utilizes a spectrum of frequencies to ensure reliable data exchange. The bands allotted by internationally followed regulatory bodies such as the International Telecommunication Union (ITU), guarantee global standardization and prevent interference. For distress and safety communications, the Very high frequency (VHF) band is widely employed. However, other channels facilitate routine ship-to-ship and ship-to-shore communication [17]. Notably, High Frequency (HF), Ultra High Frequency (UHF), and Medium Frequency (MF) bands also play key roles [18].

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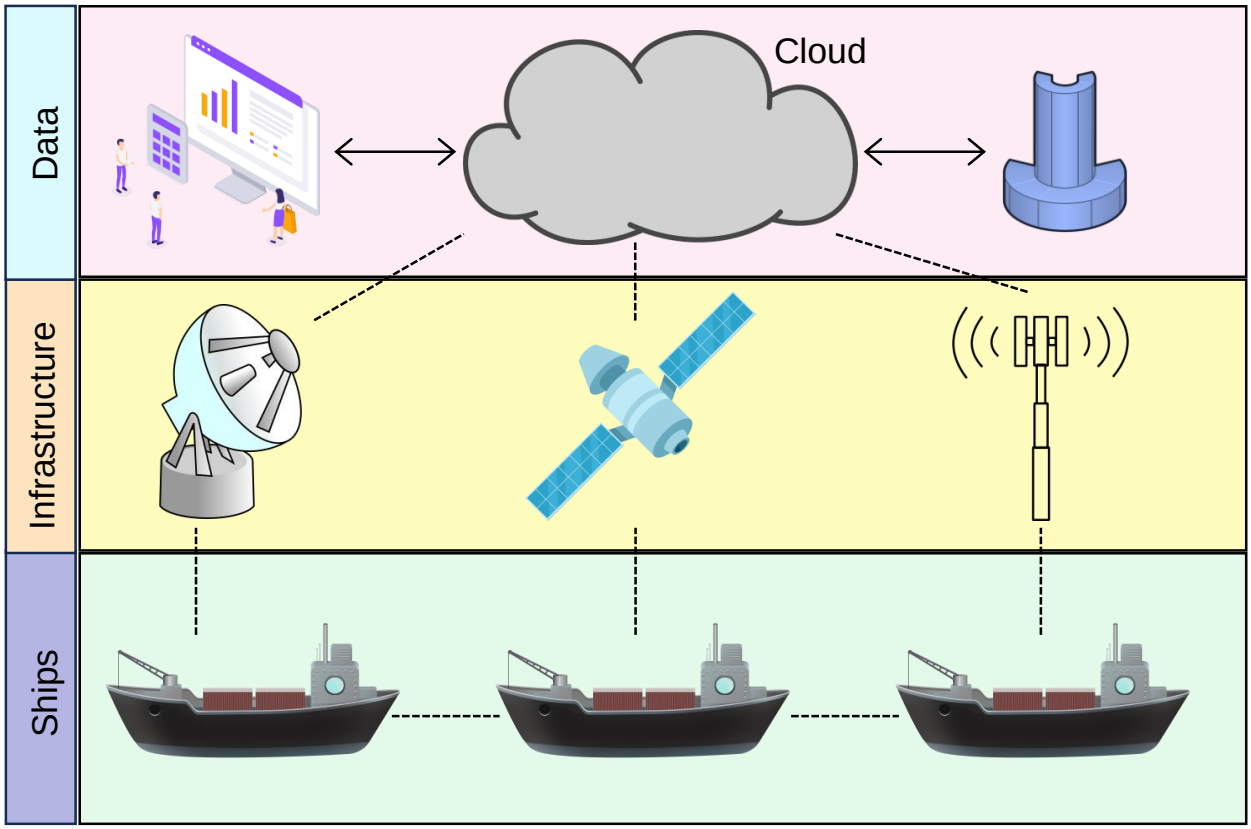

Fig. 1. Information exchange in the maritime scenario

While satellites provide global connectivity across vast oceans, their operational costs remain relatively high.4G/5G cellular networks are also used for various applications, such as real-time weather updates and remote vehicle control [19]. Further, other wireless technologies, for example, Wi-Fi and Wi-Max operating in industrial, scientific, and medical (ISM) bands, enable data transfer between various shipboard systems [20]. Even within a single vessel, short-range wireless technologies like Bluetooth connect devices for instance smartphones and tablets. Low-power wide-area network (LPWAN) technologies are emerging in maritime applications, offering unique advantages like low power consumption and long range [21]. Long Range Wide Area Network (LoRaWAN) can be used for tracking cargo containers across long distances or monitoring remote environmental conditions [22]. Narrowband Internet of Things (NB-IoT) integrates with existing cellular networks and can be used in port security applications where more reliable and secure data is crucial [23]. Sigfox, another LPWAN technology, can be used for keeping track of basic environmental changes [24]. Beyond radio frequencies, wired communication technologies such as optical communication are also used in maritime applications. Although various technologies are available, the choice of technology depends on several factors including distance from the shore, communication needs, and the cost involved. In most cases, a combination of these technologies is used for the robust and flexible communication network at sea.

In the last decade, there has been growing attention from researchers towards maritime communication. However, statistical analysis is not given importance. In this view, this paper aims to provide a comprehensive analysis from various perspectives that will help stakeholders understand and make better decisions in this domain.

The rest of the paper is organized as follows. Section II discusses the importance of indexing and publication processes in academic research. Section III details the methodology employed in this research. Section IV presents the results and their discussion. Finally, Section V concludes with a summary of the key findings and proposes directions for future research.

II. Importance of Indexing and Publication Process in Academic Research

Indexing plays a significant role in scientific research that helps to understand the landscape of knowledge. In scholarly publications, the process involves extracting important attributes such as keywords, author names, and citation details. This helps the researchers to quickly identify the relevant articles or studies within the specified area of interest. Further, having indexed in a reputable indexing platform gives credibility to the researchers, as it indicates that the research paper has undergone a certain level of screening and meets the standards. Most of the indexing platforms offer dynamic nature of services, they regularly monitor the quality of the journals. Even if a journal is initially indexed, if it later does not maintain quality, the indexing platforms will discontinue the indexing for that particular journal. Various abstract and citation databases utilize their indexing systems to organize vast amounts of information. Abstract and citation databases serve as a repository of scholarly information that provides the

essence of research articles through summaries. These databases enable scholars to stay updated on the recent developments in their field. Further, the databases are crucial for grant proposal preparation, quality assurance, collaborative initiatives, and setting benchmarks for policymakers. Some of the popular and widely used abstract and citation databases are Scopus, PubMed, Web of Science, and Google Scholar [25]. While each database offers unique features, Scopus excels in its breadth of coverage. By indexing journals from diverse publishers and disciplines, it empowers researchers with deeper insights into the impact and reach of their work. Scopus was launched in 2004, and developed by Elsevier. Elsevier is a Dutch academic publishing company specializing in scientific research. Scopus covers a large number of titles from various publishers and evolved at a rapid pace over the years as shown in Fig. 2. It covers four major types viz., Journals, Book Series, Conference Proceedings, and Trade Publications. The high-quality and comprehensive data in Scopus facilitates the identification of potential research collaborations [26]. Further, it also enhances the research visibility. Various metrics are defined by Scopus to give a trustworthy way to understand the impact. These metrics are given at various levels such as journal level, author level, and document level. CiteScore is one of the important metrics that help to analyze the journal's influence. At the author level, the h-index (a metric that measures the researcher's performance based on the publications in his career) is given. To understand the importance of the particular document, Scopus defines various PlumX metrics. Recently, Scopus released Scopus AI to further enhance the insights at a much faster pace and clarity.

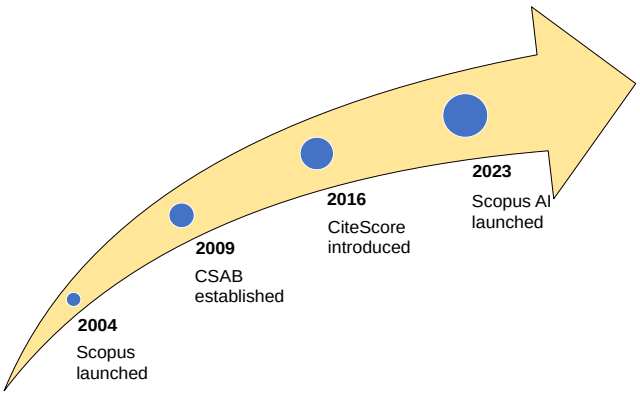

Fig. 2. Scopus evolution over the years

When it comes to the publication process, most journals have similar procedures, although some may have minor variations. However, regarding the specific steps it undergoes, the publication process may differ slightly. Especially for journals, the peer review process and publication often involve few additional steps compared to other types of publications. Some of the major stakeholders in research publications are authors, reviewers, publishers, and readers. Once the author is ready with the manuscript, authors look for suitable journals/conferences/book chapters, etc., to which it is to be submitted. The key point for the acceptance of the manuscript, whether it is a conference paper, journal paper, etc., is the novelty of the research work presented in the manuscript. When an author submits a manuscript to a particular journal, the editor initially checks and see whether the manuscript meets the basic requirements (scope, plagiarism, quality of the work, etc.) of the journal or not. If it meets, the editor assigns reviewers to the manuscript. The reviewers review the manuscript and give their recommendations to the editor. The editor then decides on whether to accept, reject, or revise the paper. If the paper is accepted, it will be published in the journal. If the paper is rejected, the author can revise the paper and resubmit it to the journal or submit it to another journal. If the reviewers give some comments, then the authors have to address those comments and submit the revised manuscript again for consideration. In this case, sometimes the editor will decide on the revised manuscript, or it can be sent to the reviewers again for checking. So, accordingly, the decision will be taken. If the decision is positive, the manuscript will be published in the journal and made it available for the readers. In most cases, the process of listing published papers from the journal involves automated indexing by Scopus's systems. Alternatively, some journals may submit metadata manually. Upon receiving the data, Scopus initiates processing. This includes checking for completeness, formatting the data according to their internal standards, and ensuring it meets their quality criteria. Once processed, Scopus indexes the articles, making them searchable in their database and building connections between them based on author names, keywords, citations, and other factors. Author profiles and article abstracts may also be generated. Finally, the articles become publicly searchable and accessible within a designated timeframe, typically ranging from a few days to several weeks. This timeframe can vary depending on the data delivery method and any processing issues encountered.

III. Methodology

The Scopus database was considered for the analysis to understand the research trends. The search word selected was "maritime communication" from the years 2013 to 2023, and the language selected was "English".

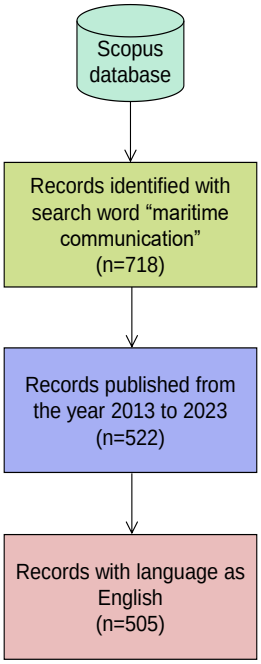

Fig. 3. Methodology for the selection strategy

The query string used for the search strategy was “TITLE-ABS-KEY ("maritime communication") AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE , "english"))”, in the first step i.e., after entering the search word “maritime communication”, the number of documents identified was 718. In the next step, the “year” filter was used to consider the documents from the past 10 years, i.e., from 2013 to 2023, after this, the number of documents identified was 522. Further, only the documents in the English language are selected, after this selection, the final documents considered for the research are 505 as shown in Fig. 3. These documents include various types such as articles, conference papers, reviews, book chapters, books, conference review, short survey, etc.

IV. Results and Discussion

This section presents the analysis of the research considered from the Scopus database in various aspects. Fig. 4 depicts the progress of the research publications in the field of maritime communication for the last decade. In 2013, the number of documents published was 21 and it reached 93 by 2023, this indicates the growth in the field.

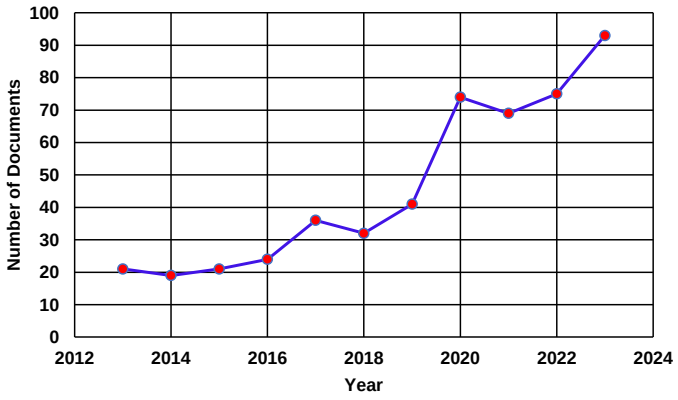

Fig. 4. Annual publications

The country-wise publications in the field were analyzed and the top 10 countries are shown in Fig. 5. Based on the analysis, China has got highest number of documents published i.e., 236, followed by South Korea with 39 documents. Further, documents published in various subject areas are analyzed and shown in Fig. 6. From these results, it is understood that the majority of maritime communication research is focused on the computer science area and engineering.

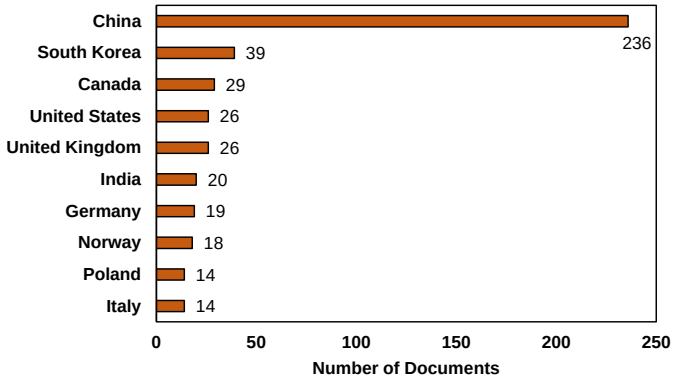

Fig. 5. Top 10 countries contributing to the field

Funding agencies play an important role in the research ecosystem by providing the required financial support to the research organizations. This helps to have access to the tools and other sources required for the researchers to work effectively. The top 10 funding sponsors in the maritime communication research are shown in Table I. From the analysis, it’s understood that the National Natural Science Foundation of China sponsored more funds compared to other agencies, followed by the National Key Research and Development Program of China.

Various types of documents considered are “Conference Papers”, “Articles”, “Book Chapter”, etc., and are shown in Table II. Out of all these document types, the majority of the documents published are “Conference Paper” type which corresponds to 48.3%, followed by “Article” which corresponds to 41%.

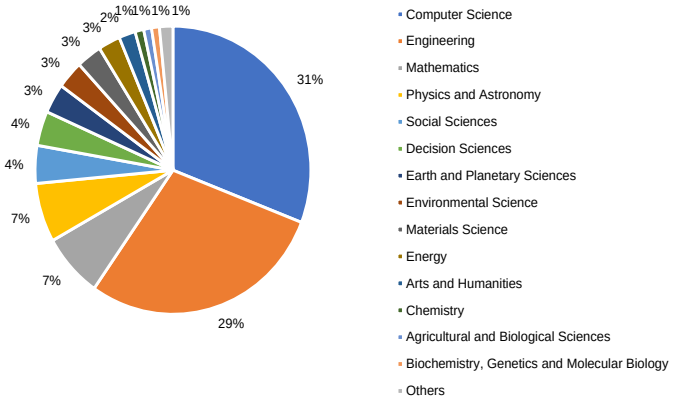

Fig. 6. Documents by subject area

TABLE I. Top 10 Funding Sponsors in the Maritime Communication Research

Funding Sponsor	Number of Documents
National Natural Science Foundation of China	113
National Key Research and Development Program of China	35
Fundamental Research Funds for the Central Universities	20
China Postdoctoral Science Foundation	14
Horizon 2020 Framework Programme	12
Beijing Innovation Center for Future Chip	10
Ministry of Education of the People's Republic of China	9
Liaoning Revitalization Talents Program	8
Ministry of Oceans and Fisheries	8
Norges Forskningsråd	7

The research identified 160 different organizations that contributed to the selected documents and the top 10 contributors are mentioned in Table III. Among these, Dalian Maritime University stands first with 43 documents followed by Tsinghua University with 29 documents.

TABLE II. PUBLICATIONS BY THE DOCUMENT TYPE

Document Type	Number of Documents
Conference Paper	244
Article	207
Book Chapter	27
Conference Review	8
Editorial	8
Review	6
Book	2
Note	2
Short Survey	1

TABLE III. TOP 10 AFFILIATIONS CONTRIBUTING TO THE MARITIME COMMUNICATION RESEARCH

Affiliation	Number of Documents
Dalian Maritime University	43
Tsinghua University	29
Beijing National Research Center for Information Science and Technology	17
Southeast University	16
University of Waterloo	16
Peng Cheng Laboratory	16
Shanghai Maritime University	15
Nantong University	14
Beijing University of Posts and Telecommunications	11
Xiamen University	11

The most impactful authors who made significant contributions to the field of maritime communication are shown in Fig. 7. Among the authors, T. Yang published the highest number of documents i.e. 24, followed by B. Lin with 14. The top 10 sources where the documents are published are shown in Table IV. Among these, the journal that has the highest number of documents is "China Communications" with 19 documents, followed by "IEEE Access" with 16 documents.

Collaboration between various countries refers to the collaboration between various researchers from different countries who have jointly published research papers together. In Fig. 8, the size of a circle corresponds to the number of publications the country, and lines connecting the circles represent co-authorship between the corresponding countries. The thickness of the lines indicates the strength of the collaboration. From Fig. 8, its understood that China has collaborated with a greater number of countries and has highest collaboration with Canada and UK.

Co-occurrence indicates how frequently keywords appear together and helps to identify the thematic relationships. Each keyword is represented by a circle, with the size reflecting its frequency of occurrence. Lines connect keywords that frequently co-occur, with thicker lines indicating stronger relationships. From Fig. 9, its understood that the occurrences of the keywords "maritime communication" and "ships" more. There is another keyword "antennas" that has similar impact with the keyword "maritime communication".

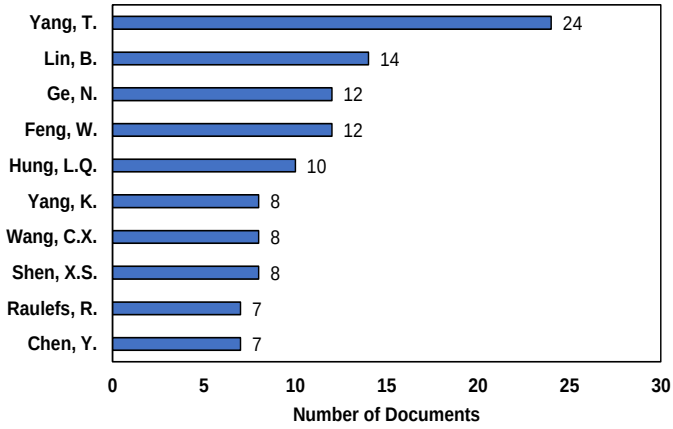

Fig. 7. Major contributing authors

TABLE IV. TOP 10 SOURCES OF PUBLICATIONS IN THE MARITIME COMMUNICATION RESEARCH

Source	Number of Documents
China Communications	19
IEEE Access	16
Journal Of Marine Science And Engineering	13
Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	8
Sensors	8
Springerbriefs In Computer Science	8
IEEE Internet Of Things Journal	7
Wireless Networks United Kingdom	7
IEEE Transactions On Vehicular Technology	6
IEEE Vehicular Technology Conference	6

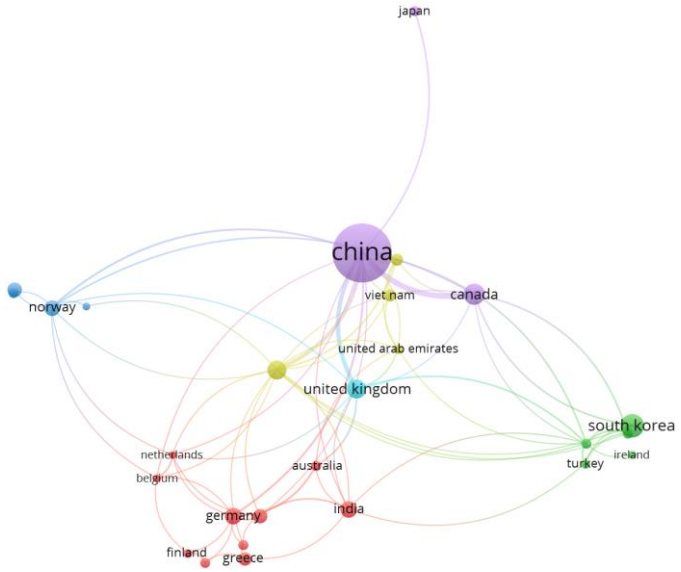

Fig. 8. Collaboration between various countries

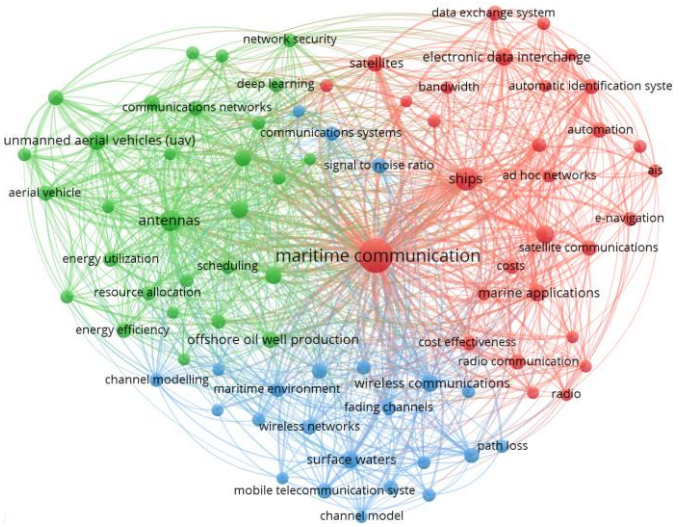

Fig. 9. Co-occurrence of keywords

Bibliographic coupling refers to the number of shared references between two articles. If two articles cite the same reference, they are said to be bibliographically coupled. The more references two articles have in common, the stronger their bibliographic coupling is. In Fig. 10, each node corresponds to a source, and each link indicates bibliographic coupling between the two sources it connects. The thickness of the links can vary, with thicker links indicating a stronger relationship between the sources based on the number of shared references. From Fig. 10, it's understood that "IEEE Access" has the good bibliographic coupling with the "IEEE Internet of Things Journal" and "China Communications".

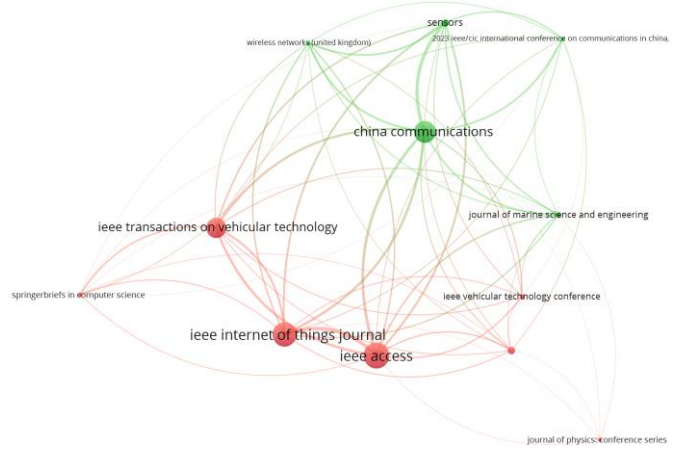

Fig. 10. Biblographic coupling between the sources

V. Conclusion

This paper presents a comprehensive analysis of maritime communication research trends over the past decade using 505 documents from the Scopus database. Examination of annual publications reveals a steady increase in the number of research works on this topic over time. Further, the research focus of various top-performing countries in the field is observed, and identified that China is contributing more. Furthermore, various subject areas are investigated, indicating a notable interest in "computer science" and "engineering". Research fund enables researchers to explore new things, make discoveries, and develop innovative solutions to complex problems. This has a significant impact on the advancement of research across various fields. Top funding sponsors in the field are explored and understood that the "National Natural Science Foundation of China" is supporting more. Regarding publication types, conference papers and articles dominate the field. Understanding the affiliations contributing is useful in several aspects such as identifying opportunities for collaboration, various affiliations are analyzed and identified that "Dalian Maritime University" is encouraging more in this field. Recognizing the major contributing authors in the field is essential for staying informed about the latest research developments, top performing authors are analyzed, its noticed that "Yang, T." had the highest number of publications in this field. "China Communications" emerged as the leading source of publications, potentially reflecting a focus on research filed. From the analysis with respect to collaborations, China has collaborated with a greater number of countries and has the highest collaboration with Canada and the UK. Interestingly, co-occurrence analysis revealed a strong link between "maritime communication" and "ships" as expected. Furthermore, bibliographic coupling analysis suggests a strong connection between "IEEE Access", the "IEEE Internet of Things Journal", and "China Communications", indicating potential areas of research synergy. Overall, the analysis of maritime communication shows the growing nature of maritime communication as a field, with increasing interest among researchers.

Future research can extend the analysis beyond the last 10 years, providing a more comprehensive historical perspective on maritime communication trends. Additionally, the specific impacts of emerging technologies, such as AI and IoT, on the maritime industry can be explored.

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