Research Trends in Enterprise Service Bus (ESB) Applications: A Systematic Mapping Study

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ABSTRACT In recent years, enterprise service bus (ESB) has become a favorable adoption as a technology category in the IT industry as it provides secure and guaranteed delivery of services. The elasticity of Enterprise Service Bus (ESB) enables numerous applications to exchange information makes it a significant middleware layer responsible for transferring information in a Service-Oriented Architecture (SOA). ESB is presently the utmost promising tactic for the integration of business applications in distributed and diverse environments. It also offers essential infrastructure support for transforming messages or data, intelligent routing, and protocol transformation. The idea of ESBs emerged from the requirements to move out from traditional integration patterns, that becomes difficult to manage with the passage of time. Our study aim is to understand and provide ongoing research topics, challenges and future directions concerning ESB applications. A systematic mapping study (SMS) is therefore implemented to categorize the selected papers into the following classification: contribution type, ESB applications, research type and their approaches. We have extracted a total of twenty-two papers for this systematic study and they are classified according to defined criteria. The findings of this SMS are discussed and researchers were provided with suggestions on possible directions for future research.

INDEX TERMS Enterprise service bus (ESB), applications, classification, service oriented architecture (SOA), systematic mapping study (SMS), criteria.

I. INTRODUCTION

Some important technology trends have been seen over the previous several years, Including service-oriented architecture (SOA), business-to-business (B2B), the services provided through the web (SPW) and enterprise application integration (EAI). These innovations have been used to address the challenges of improving performance and increasing the importance of integrated business procedures. The ESB framework is a modern integrated approach that can provide the basis for a loosely linked, highly decentralized integration network that can reach beyond the limits of an EAI broker with hub and spoke [1]. ESB reduces marketing time for new projects as well as improving organizational business agility as the backbone of IT infrastructure. The growing interest of industry in the integration and interoperability of various information sharing and application management systems has changed service-oriented architecture (SOA) as an emerging research area. An ESB is an ideal framework for the implementation of service-oriented architecture (SOA) because it offers a standard mechanism [2] that integrates all the facilities needed by organizational information solutions such as Supply Chain Management (SCM), Accounting and Finance (AF), Customer Relationship Management (CRM), Sales and Marketing (SM) and Human Resource Management (HRM) without compromising reliability, safety, performance, proficiency and scalability.

Architecture: In the absence of ESB products, heterogeneous applications could be integrated through alternative architecture as shown in figure 1. However, this application integration architecture is difficult to scale and maintain. Moreover, adding an application would mean interface customization of all other networking applications.

Enterprise service bus architecture: As shown in figure 2, applications are indirectly linked through ESB instead of being linked directly to each other. ESB is

The associate editor coordinating the review of this manuscript and approving it for publication was Dalin Zhang.
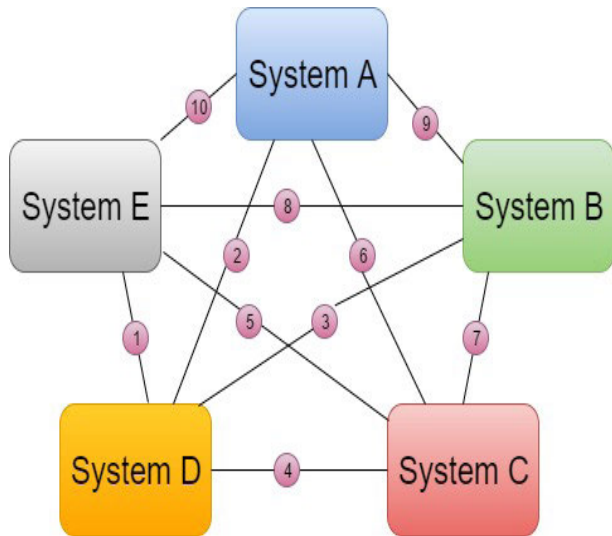
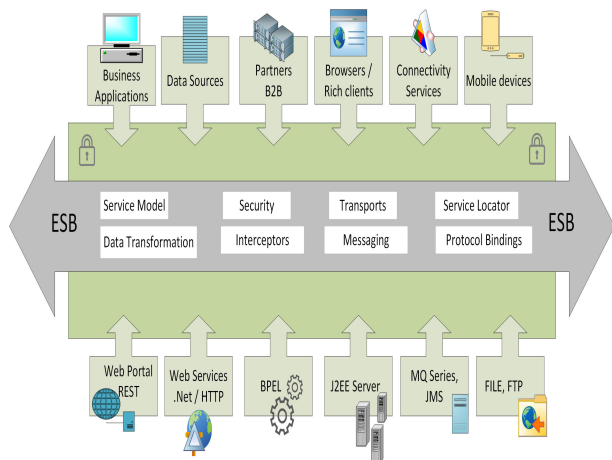**FIGURE 1.** Point to point integration architecture.

FIGURE 2. Enterprise service bus architecture.

responsible for all the built-in logic necessary to make the structures interact/integrate.

ESB core functionalities: Some core functionalities offered by enterprise service bus are [3]: uncoupling, Transport Protocol Conversion, high availability and scalability, Message Transformation, Routing, and Security.

There are no universal standards for implementations or principles of enterprise service buses [4]. Several suppliers / vendors of MOM (message-oriented middlelayer) have implemented the enterprise service bus model as de-facto standard for SOA architecture. Though, several IT companies re-rank current middle-layer and integration approaches as ESB without the basic characteristic of bus theory being introduced. By using an ESB, different software and event-based facilities are loosely connected together in SOA [1], that supports them to take action independently from each other, though still give importance to a wider business mode. The concept of ESB as a technology category started in 2002 with the application of Sonic ESB [5], since that time ESB developments have taken a life of their own.

Vendors / suppliers of software platform suite (e.g. IBM and BEA), suppliers of EAI (e.g. TIBCO and cloud technologies) as well as a provider of web services tool-set have all implemented the ESB mark. However, there are still numerous ESB vendors /suppliers competing constantly on: fundamental designs, connectivity selections, ease of access, and quality of service (QoS) issues such as constant accessibility. To the best of our knowledge, there is no systematic mapping research on the enterprise service bus has been published up to the present. A Systematic Mapping Study [6] is an emerging technique that can be used to construct a classification pattern and to plan an area of interest. Our study key aim is therefore to draw /present existing research on ESB application to attain valuable results for real-world use and also to discover gaps for further research. To achieve this goal, we applied search strings in digital libraries to identify the primary studies on ESB applications. From the initial set of 16400 articles (from 2011 to 2019), 214 articles were listed, 22 of which were chosen for this mapping study and then we categorized them according to the classification criteria: contribution type, ESB applications, research type and their approaches. From the obtained results, we conclude that ESB has gained greatest support since 2011 and most of the ESB studies showed in conferences and only a few studies reached in a journal. Solution proposal and implementation & evaluation research are the most common research types which were found in elected studies and most frequently used approach in selected studies is a method.

The remaining paper is organized in below listed sections: Sec. 2 "Brief background and selection criteria for ESB" Sec. 3 "Research methodology of selected study and the process of gathering related research articles" Sec. 4 "Results of systematic study obtained from extracted data" Sec. 5 "Main findings of selected study" Sec. 6 "Conclusion and Future work ".

II. EVOLUTION OF ESBS
The term "Enterprise service bus" is the new theory in the arena of application integration introduced by Gartner in 2002 and then supported by specialist Roy Schulte to describe software type [7]. Sonic ESB was the first application [5] presented with ESB mark. Gartner [8] defined it as "An ESB is a new approach of application integration that exploits intelligent routing, message transformation, middleware messaging, and web services". An ESB controls an SOA by decreasing the amount, size, and problems of interfaces between applications and services. From an organization perspective, an ESB addresses numerous enterprise application integration necessities defined in [9]. Intrinsically, it's a tool that used in both distributed computing and for component integration that can direct a message beside a particular route among application modules based on message contents and industry policies. Figure 3 illustrate some core features of ESB which are: **Routing-** ESB has the capability to convey a user request to a specific message provider established on deterministic or flexible routing standards.
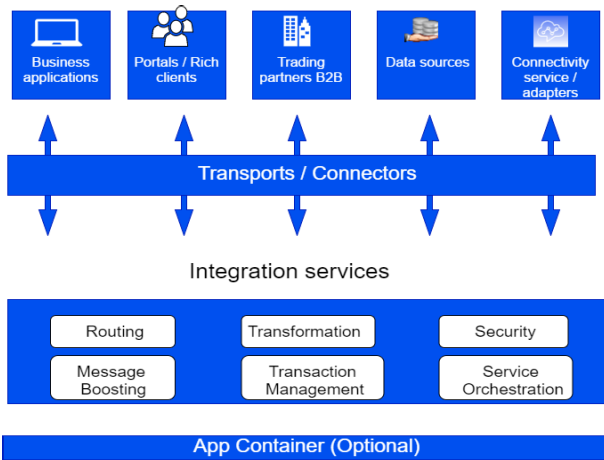
FIGURE 3. Core features of an enterprise service bus.

Transmutations- to transform the structure and payload of the user demand into a convenient method for the service supplier. ESB allows to transform received message into many forms and structure (e.g. XML to JSON and Java) **Message Boosting-** enhance, transform, or remove an info contained in a message to make it compatible with the service supplier. As, with this feature the bus can transform the layout of the date or add messages that were not put in the original. **Service Orchestration-** the ESB acts as a middleware layer (broker) that inspect the services and synchronizes the performance of numerous operations. It utilizes the standard BPEL (Business Process Execution Language), however, there's also the probability to use the Business Process modeling Notation (BPMN) or the WEB Service Conversation Language (WSCL). **Operation / transaction management-** Deal with business service demand like a distinct work unit. **Security-** offers the opportunity to protect services from unauthorized login. Hence: validation, authorization, assessing and control are all compulsory.

A. EVALUATION STANDARDS FOR ESB APPLICATION
Enterprise service bus (ESB) applications are divided into two categories.**Open Source ESBs** and **Commercial ESBs** [10]. The Open Source ESBs includes Mule ESB, Apache Service Mix, Fuse ESB from Red Hat, Apache Camel, JBoss ESB, Petals ESB, Apache Synapse, Open ESB, WSO2 ESB, Spring Integration, UltraESB, NetKernel and **Commercial ESBs** [10] includes IBM WebSphere ESB, Sonic ESB from Aurea, IBM Integration Bus, InterSystems Ensemble, Microsoft BizTalk Server, Microsoft Azure Service Bus, Information Builders iWay Service Manager, Progress Software Sonic ESB (acquired by Trilogy), Oracle Enterprise Service Bus, TIBCO Software ActiveMatrix BusinessWorks, SAP Process Integration, web-Methods ESB (acquired by Software AG). The ESB applications offer different functionalities. It is best to pre-define particular necessities and then assess which applications matched the requirements.

The selection of right ESB applications help organization to speed up integration of heterogeneous applications and drive to market faster. In order to select the particular ESB application a Subsequent criteria must be used: **Usability** - How hard is it to install? How many devices do need? Is the environment, intuitive for development? **Supportability** - How are managing the product? Is there a GUI in place to track and manage the services? **Functionality** - Can all the necessary features be obtained? **Mouldability** - could modify the product's functionality to suit requirements? **Expandability** - Is the expansion of the device promising? Is the software and its GUI design standards-based? **Enterprise Maintenance** - What maintenance possibilities are presented ("working hours", hotline "24/7" vs. email vs. on-site service, etc.)? Can the necessary agreements at the service level be guaranteed? Is there help in language want? **Community** - Are there flexible mailing lists or public settings? Are there several blogs, tutorials and videos that are available? Are numerous companies promoting the product? **Connectors** - Are adapters available for all the necessary technologies? Are there connectors like SAP or Salesforce for B2B products? How can just make own adapter? **Cost** - What is the full cost (ownership cost) of the product-including servicing, all necessary supplementary items, connectors, etc.? **Licensing** - Which type of licensing or participation is used? Which happens, if demands shift (more machines, more CPUs, virtual machine switching, etc.)? Were updates available free of charge? Are there exciting downgrades, too? Is the price "predictable" at all, is the list of rates even reasonable?

By using the described criteria above, we have created a Table 1 that shows the comparison of commercial vs. open source ESBs. So, we conclude that commercial ESBs usually provide more features and powerful support/maintenance. But it is compatibly higher in complexity, effort and cost. On the other hand, open source ESBs offers greater flexibility, ease of use, easier maintenance and lower cost.

III. RESEARCH METHODOLOGY
For the selected study, we have chosen a mapping study (SMS) analysis as research methodology. Figure 4 illustrates the mapping process followed to conduct this mapping study, which consist of 3 steps: preparation of the study, conduct of the study and results and analysis. A systematic study differs from the systematic literature reviews (SLR) [11], Which objects toward the development of the state of evidence, stresses the identification of the finest practices, as well as indicates wherever specific evidence gone or inadequately stated in current literature. However, it's not the purpose of the SMS method, as there is no detailed study of the research articles / papers. The main focus is on classification, thematic analysis and identification of publishing forums [12].

A. RESEARCH OBJECTIVES
Our selected study key objectives are listed below:

- To present a map of ongoing research on ESB applications in order to get results for real-world use and to find an inconsistency for further research.

TABLE 1. criteria wise comparison of commercial & open source ESBs.

| Criteria	Commercial	Open-Source
Usability	complicated installation procedure	Easy installation, cohesive platform
Supportability	powerful tool(e.g. for management and tracking), source code exploration not required	less powerful tool (e.g. for management and tracking), source code exploration not required.
Functionality	Integration structures (BAM, CEP, EDA, etc.)	integration structures plus more
Mouldability	Request for making changes that requires a lot time plus payable	change without making request, open source
Expendability	try it self or pay (difficult)	standardized, de facto standards
Enterprise maintenance	24/7 enterprise maintenance	24/7 enterprise maintenance, less assurance
Community	No unpaid community exist for help (purchase support)	their own community (open source)
Connectors / adaptors	for business implement	adaptors for business implement
Cost	too much	less than proprietary
Licensing	Composite price list, pay for all	open source, projecting costs (subscription)
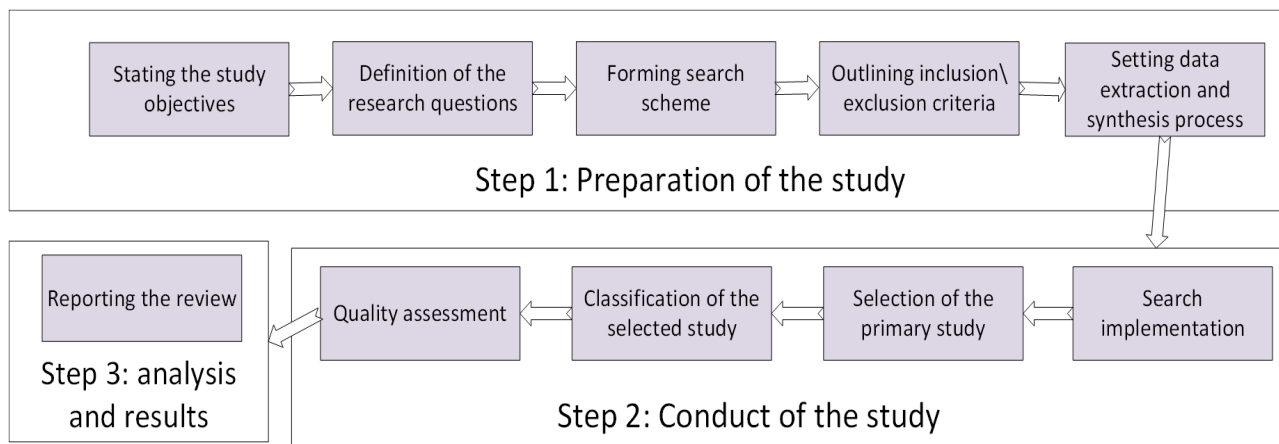
FIGURE 4. Systematic mapping process.

- Understand and present the existing research topics, threats and future directions concerning ESB applications.
- To give a summary of research trends as well as to determine if there is evidence for study and measure the amount of evidence available.
- Another goal may be to identify the field of publication of the study.

B. RESEARCH QUESTIONS

In the process to get a detailed view of the selected study, we defined the six (06) research questions (RQ). Table 2 listed all the 06 RQs designate for the selected study with their relevant motivations. The answers of these RQs will help us to classify existing research topics, threats and future directions concerning ESB applications.

C. SEARCH SCHEME

We used the following scientific Sources / databases to get the most relevant papers / articles for the selected study: Springer, Science Direct, IEEE Digital Library, ACM, Elsevier and Google Scholar also used for practical reports. The operational use of Google scholar has been developed to carry out bibliometric studies. The following two different search

TABLE 2. Research questions.

No.	Research question	Main motivation
RQ1	How has the frequency of approaches related to ESB applications changed over time?	to classify the publication trends over time of ESB research.
RQ2	Which publication channels are the main targets for ESB applications research?	to classify where ESB research can be devised as well as the best publication source for future studies.
RQ3	What are the study / research types of ESB applications?	to find out the different kinds of study reported in the mapping study regarding ESB
RQ4	What research topics have been addressed in current research on ESB applications?	to get an understanding of the current research topics, that will help in the process of future research on ESB applications.
RQ5	What are the current research gaps in ESB applications research?	support to recognize and determine unanswered research questions in existing ESB applications.
RQ6	What are the approaches that were reported in ESB research that address ESB problems?	to determine the existing ESB approaches reported in the existing ESB mapping study

TABLE 3. Search strings used in scientific libraries.

Database	Search String
Springer	only 2
IEEE Xplore	ESB AND ETL
ACM digital library	Both 1 & 2
ScienceDirect	Both 1 & 2
Elsevier	Both 1 & 2
Google Scholar	Both 1 & 2

TABLE 4. Inclusion/exclusion criteria used for the selected study.

Inclusion criteria	Exclusion criteria
IC1- Articles presenting concepts and implementation of ESB	**EC1-** Articles that are not focused on ESB applications
IC2- Articles that are focused on ESB applications and their implementation	**EC2-** Articles about microservices based software and approaches
IC3- Articles presenting ESB problems/goals	**EC3-** Articles presenting general focus on enterprise application integration (EAI) and SOA based model
IC4- Articles presenting ESB standards/architecture/tools	**EC4-** Books, thesis and published abstracts
IC5- Studies from any geographical location	**EC5-** Articles that are published pre 2011

strings were used to conduct the automatic search in the selected scientific repositories:

1) ("ESB" AND ("SOA" OR "EAI" OR "ERP" OR "microservices" OR "CRM" OR "ALM") AND ("applications" OR "tools" OR "software" OR "open source" OR "commercial software" OR "business integration software") AND ("E-commerce" OR "DWH")).

2) (("Enterprise service bus" OR "ESB") AND ("Extract* transform* load*" OR "ETL") AND ("SOA" OR "EAI" OR "ERP" OR "microservices" OR "CRM" OR "ALM") AND ("applications" OR "tools" OR "software" OR "open source" OR "commercial software" OR "business integration software") AND ("E-commerce" OR "DWH" OR "data warehouse")).

Table 3 demonstrated the search scheme applied in scientific databases to get the most relevant papers. Both search strings showed the null result in the IEEE Xplore library. Therefore, the keywords (ESB AND ETL) were used to get significant papers from IEEE Xplore as presented in table 3.

D. STUDY SELECTION PROCESS

The selection process aimed at identifying the research articles that are best related to the goal of this mapping study. When in more than one source the same article appeared, according to our research order it was regarded only once. We have evaluated each paper through deeply examined its

title, abstract, and keywords, in order to determine whether it should be included or not. The ïĄrst phase after the identification of research articles was to remove identical titles, and titles obviously not associated with the review. The second phase was to include/exclude research papers based on the inclusion criteria (IC) /exclusion criteria (EC) as described in table 4.

Figure 5 illustrates the result of a selection process. 22 articles were selected out of 214 identified articles.

E. QUALITY ASSESSMENT

One more significant phase in the review method was to determine the included study quality. Quality assessment (QA) is generally conducted in systematic reviews of literature and fewer in systematic mapping studies. Although, a questionnaire was planned [13] to evaluate the quality of articles selected for this SMS.

(1) Solution of the problem clearly stated in the papers. Promising responses were: Yes (+1), Moderate (+0.5), and No (+0).

(2) The contribution of the paper toward how ESB conducted clearly stated. Yes (+1), Moderate (+0.5), and No (+0).

(3) Limitations and future directions of the study clearly defined. Yes (+1), Moderate (+0.5), and No (+0).

(4) The paper was published in a well-known and reliable publishing channel. Considering the following
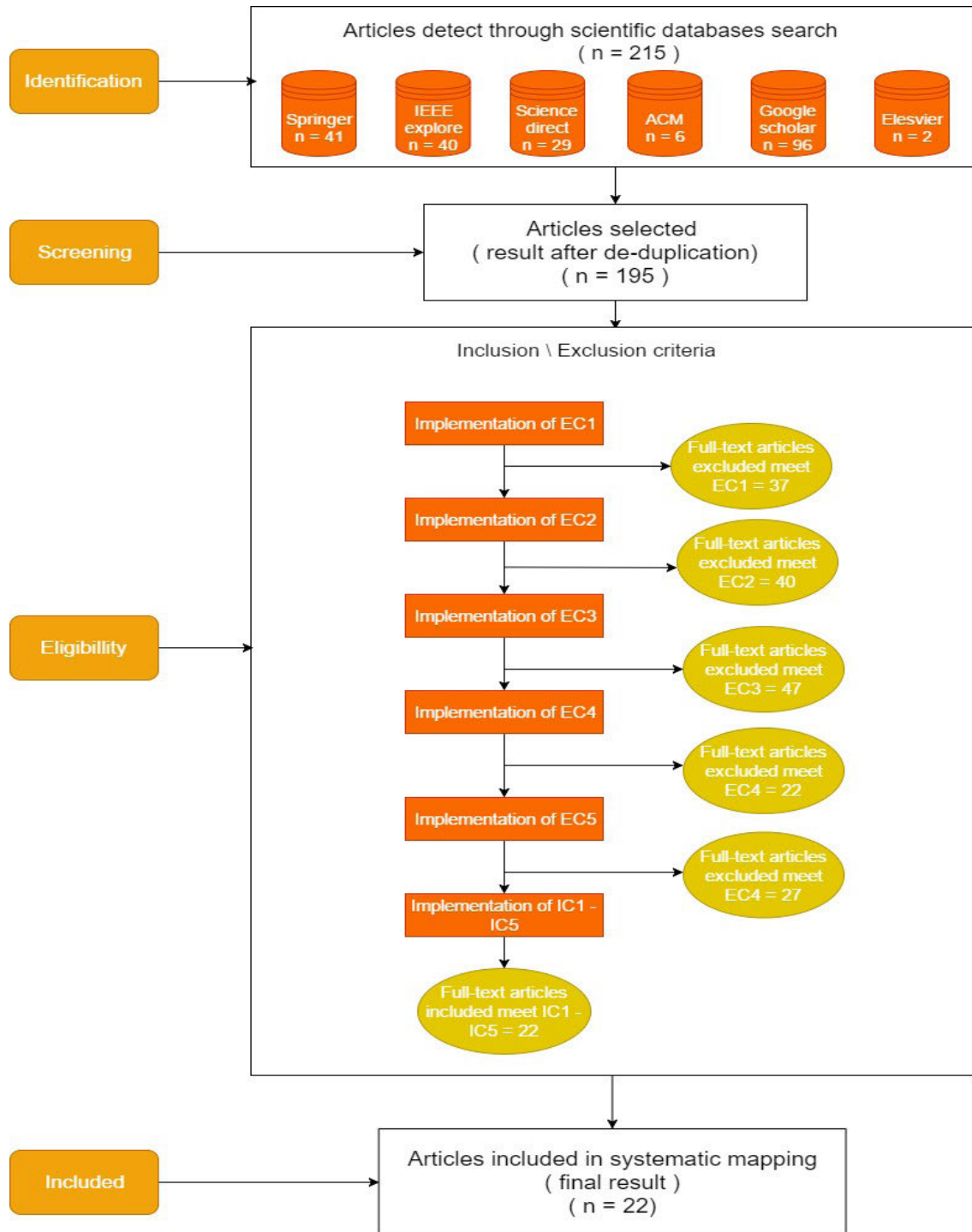
FIGURE 5. Study selection process.

conference ranking (CORE) and journal rankings websites: http://www.conferenceranks.com/ (A, B, and C) https://www.scimagojr.com/index.php (Q1, Q2, Q3, and Q4), and the Citation Reports for journal ranking (JCR), this question was rated. Possible responses to this question:

For the Conference, Symposium and Workshop ranking:
- If CORE A is ranked (+1.5),
- If CORE B is ranked (+1),

- If CORE C is ranked (+0.5),
- If it's not ranked in CORE (+0)

Journals ranking:

- Where Q1 is ranked (+2)
- Where Q2 is ranked (+1.5)
- Where Q3 and Q4 is ranked (+1)
- if not ranked in JCR list (+0)

We provided a final score of each study (integer value from 0 to 5) by calculating the sum of the score for every question.

F. DATA ABSTRACTION APPROACH AND SYNTHESIS METHOD

The data abstraction approach was focused on giving the collection of promising answers to the research questions (RQs).

RQ1. Papers should be categorized for each publishing year in order to draw the publication trend.

RQ2. To address this research query (RQ), it is necessary to ascertain the publishing source as well as a medium for the articles. **RQ3**. A type of research can be defined in the following categories [14]:

- Solution proposal: Solution for ESB problems is offered. It could be a new solution or an important expansion of an established method. Through some examples or with arguments, the potential benefits and relevancy of the solution are shown.
- Evaluation Research: Valuation and analysis of the ESB approach / methods is performed. This also involves recognizing problems in ESB applications.
- Conceptual Proposals: These studies clarified concepts by observing and examining information already present on the ESB applications. Any practical experiments are not included in this.
- Others: such as: Investigation, Development, analytical surveys, experimental, performance analysis, comparative analysis, reviews and case study.

RQ4. Understanding of current research trends of enterprise service bus (ESB) applications is the important research question of this mapping study. By accumulating all the appropriate studies from scientific journals, We might form a general understanding of the study on ESB applications and also plot the present research trends. This SMS (systematic mapping study) will enable new researchers and general practitioners to advance knowledge on existing research issues that will help in the process to further expand the work on ESB applications.

RQ5. This SMS helps in the way to recognize the current study gaps. Identifying these study gaps will allow new researchers and professionals to concentrate on areas where further investigation is needed. With existing ESB implementations, this will also help to understand and discover unanswered research questions.

RQ6. An approach can be categorized as suggested [14], in the following categories:

- Model: The system representation that enables the analysis of the ESB properties.
- Method: A process implies and a set of steps taken to gain ESB information.
- Infrastructure: Basic physical and administrative structures required for a corporation or business to function useful in ESB.

- Architecture: A process, planning or designing structures for ESB applications.
- Framework: A concrete or theoretical framework designed to support or direct the creation of something that extends the structure into something useful in ESB.
- Guideline: An example of a rule or practice that can be used to establish a course of action in ESB.
- Tool: Something used in ESB as a way to perform a task or function.
- others: platform, framework, etc.

The synthesis process is focused on including the key studies that are categorized in response to each research question, presenting the primary studies ranking on the basis of their QA and offering graphs for the purpose of classiïÄcation outcome.

IV. RESULTS

This section defines the outcomes that are associated with mapping questions described in Table 2. Many articles have been selected to show examples for each RQ's outcome. We assume they are important and make a significant contribution to ESB applications.

A. RESULTS OF SELECTION

Total 214 research articles deeply examined by its title, abstract and keywords, 192 articles were rejected and 22 papers were carefully chosen. The identification of 22 articles was examined to respond to the RQs described over. The listing of elected articles is presented in table 6 with the description of the classification outcomes and their QA.

B. RQ1. HOW HAS THE FREQUENCY OF APPROACHES RELATED TO ESB APPLICATIONS CHANGED OVER TIME?

Figure 8(a) shows overall distribution over the years of selected primary studies, fig 8(b) shows the trend of ESB applications by year, while fig 8(c) depicts the distribution of publication channels over the years. The quantity of studies published per year from 2011 to 2019 shown in figure 8 (a). Most of the studies were published in 2011 as it was an Enterprise Service Bus (ESB) year of growth and development. That could be explained as, the ESB is gaining adhesive friction with SOA architects focusing on application integration. The reader will also note that no articles were published in 2018. The decline in 2019 may be clarified by the period this mapping study was conducted and is unlikely to reveal the definite number of papers in 2019. 2011 to 2014 were the years in which most of the ESB applications found, as depicted in figure 8(b). figure 8(c) shows that, most of the ESB papers were published in conferences. Every year 2 to 3 studies were published in conferences as in fig 8(c).

C. RQ2. WHICH PUBLICATION CHANNELS ARE THE MAIN TARGETS FOR ESB APPLICATIONS RESEARCH?

Publication channel of the elected articles shown in figure 6. The conference, workshops, a symposium and journal were
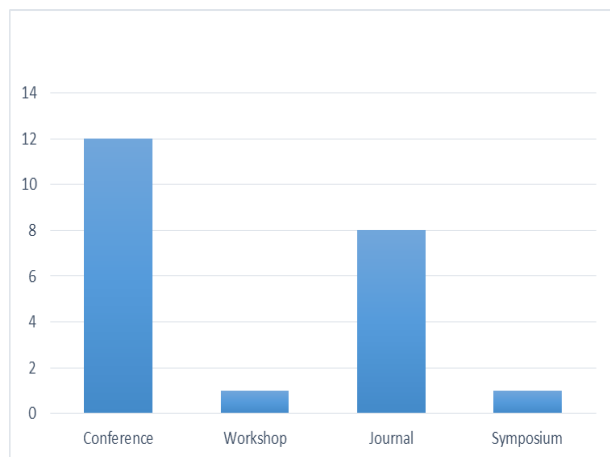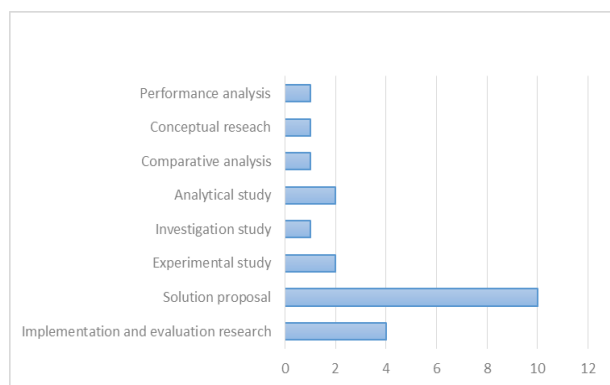
FIGURE 6. Publication channel.

FIGURE 7. Research types.

the publication channels involved in this systematic mapping study. As shown in fig 6, most of the papers were published in conference (12)(0.54%) and journal (8)(0.36%). The rest of the articles were published in workshops (1)(0.04%) or in a symposium (1)(0.04%). Furthermore, the table 5 lists all the publication source where the selected articles were published. Note that all the selected studies used different sources for publication as shown in table 5.

D. RQ3. WHAT ARE THE RESEARCH TYPES OF ESB APPLICATIONS?

In this mapping study, eight (8) types of research were identified, such as: Solution proposal (10 studies)(0.5%), Implementation and evaluation research (4 studies)(0.2%), analytical study (2 articles)(0.1%), Experimental study (2 articles)(0.1%), and only 1 article found as: conceptual research, performance analysis, investigation study, and comparative analysis as shown in figure 7. Most of the selected articles (Solution proposal) are consequently the solution to an ESB problem, whereas some implementation and evaluation of ESB applications presented. In the following paragraph, some examples of research types are listed:

[15] author proposed ESB based solution in service based system to resolve QoS issues. In general, the paper focuses on addressing issues related to response time and

TABLE 5. Publication source of the selected studies.

Publication source	References
Proceedings of the 6th Service Oriented Computing Workshop on Middleware	[15]
4th International Cloud Computing Technology and Science Conference of the IEEE	[16]
18th Conference on Information Systems in the Americas	[17]
Communications and Network	[19]
Information Systems	[20]
Fifth International Service-Oriented Computing and Software Conference (SOCA) of the IEEE	[22]
AASRI Conference on Bioinformatics and Computer Intelligence	[23]
International Journal of Software Engineering and Technology	[18]
8th International Conference on E-Trust in Developing Countries	[24]
18th International Conference on Complex Computer System Engineering	[25]
International Journal of Computer Applications	[26]
4th International Conference on the Deregulation and Restructuring of Electric Utilities and Energy Technologies (DRPT)	[21]
International Conference on Applications and Innovation in Information Technology (ICITSI)	[27]
Second International Conference on Smart Systems, Modeling and Simulation	[28]
European Cloud and Service-Oriented Conference	[29]
Journal of Chinese postal and telecommunications universities	[30]
European Network Engineering and Application Conference	[31]
International Symposium on Medicine and Education Information Technology	[32]
International Journal of Database Theory and Application	[33]
OTM Confederated International Conferences on the Move to Meaningful Internet Systems	[34]

service saturation. The result exploited the capabilities of ESB mediation and can be implemented at runtime automatically and dynamically.

The solution is also focused on widely accepted ESB patterns, which is why they're probably used in utmost ESB products. In this paper [16], the author examined the requirements for multi-tenant ESB solutions and to address these requirements proposed an implementation-agnostic ESB architecture. An author explored [17] a particular Enterprise Service Bus (ESB) known as a source of information
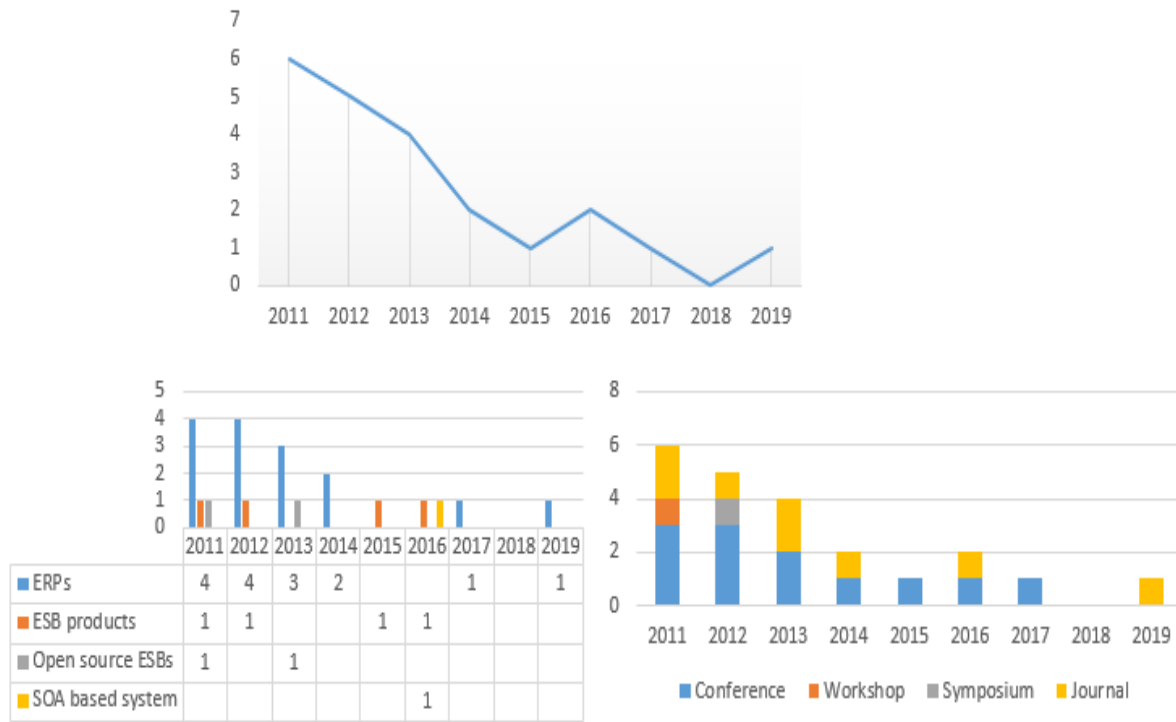
FIGURE 8. Trends in studies by year.

to an enterprise nervous system which interconnects business applications and processes. Reverse engineering is a vendor-specific ESB, data model and transformation rules are developed from three representative EA knowledge models. These principles of transformation are used to carry out automated model transformations, allowing the first step towards automated EA documentation. The productive ESB system taken as an example to evaluate the defined approach. In this paper [18], the author proposed a new methodology for carrying out functional testing of enterprise service buses based on different platforms and ESB testing protocols. The JMS Network system was used effectively for a single queue and multiple queue, HTTP network and REST protocol.

E. RQ4. WHAT RESEARCH TOPICS HAVE BEEN ADDRESSED IN CURRENT RESEARCH ON ESB APPLICATIONS?

Table 6 listed all the topics that have been addressed in selected studies. The results show that, most of the topics based on SOA systems, performance evaluation and evaluation of open source ESBs. Some examples are presented in the following paragraphs: In this paper [19], author evaluated three open source ESBs and compared them qualitatively as well as quantitatively. Statistically, empirical results have been tested to conclude the statistical significance of the results. This paper [20] provided an ESB empirical survey of various parameters influencing SOA's quality in the current evolving scenario and service patterns. In this paper [21], author investigated the structure and the way of exchanging

information between application systems as well as proposed a SOA based power Enterprise service bus design structure.

There are numerous commercial or Open-Source / public ESB based solutions provided. However, none of these solutions provided the function of integrating parallel processing via using multi-core / multiprocessor technology to advance the performance of ESBs. An innovative, massively parallel ESB (MPESB) structural design was introduced in this paper [22] to address this challenge. Also an author described some important features of an ESB. In addition, a first functional study carried out on the MPESB model showed promising performance results.

F. RQ5. WHAT ARE THE CURRENT RESEARCH GAPS IN ESB APPLICATIONS RESEARCH?

Four types of applications were discovered in the selected papers: Enterprise resource planning (15)(0.7%), ESB products (4)(0.2%), open source ESBs (2)(0.1%), and SOA based systems (1)(0.04%) as shown in figure 9.

Most of the applications found in this mapping study based on ERPs (enterprise resource planning). An ERP is a business type application software, also known as system integration suit which allows organizations / companies to gather, stock, manage and infer data through several business events as well as automate some back office tasks associated with tools, services, and human resources.

However, some research gaps have also been identified. The primary research gap is the current literature does not include working of ESB with cloud based systems and IOT

TABLE 6. Classification of the selected studies.

Ref.			Classification				Quality Assessment				
	P.year	P.Channel	Research type	Research Topics	Application	Approach	(1)	(2)	(3)	(4)	T.score
[15]	2011	Workshop	Solution proposal	Addressing QoS Issues in Service Based Systems	ESB products	Infrastructure	1	0.5	1	0.5	3
[16]	2012	Conference	Solution proposal	Enabling Multi-Tenancy in ESBs	ESB products	Architecture	1	1	0.5	1	3.5
[17]	2012	Conference	Investigation study	Automating Enterprise Architecture Documentation using an ESB	ERPs	Model	0.5	1	0.5	1	3
[19]	2011	journal	Evaluation research	ESB: A Performance Evaluation	Open source ESBs	Model	0.5	1	0.5	1.5	3.5
[20]	2016	journal	Analytical survey	A Performance Metric for ESB in SOA System	SOA based systems	Guideline	0.5	1	0.5	2	4
[22]	2012	Conference	Evaluation research	Performance Evaluation of a Massively Parallel ESB- Oriented Architecture	ERPs	Architecture	0.5	0.5	0.5	0	1.5
[23]	2012	Journal	Implementation research	Research and Implement on Using the Apache Synapse ESB platform for application integration	ERPs	Method	0.5	0.5	0.5	0	1.5
[18]	2014	Journal	Solution proposal	A Multi-Dimensional ESB Testing methodology	ERPs	Method	0.5	1	1	0	2.5
[24]	2014	Conference	Experimental research	An Approach to Reduce QoS Monitoring Overhead in ESB	ERPs	Method	1	1	1	0	3
[25]	2013	Conference	Solution proposal	Exploiting concurrency for the ESB architecture	ERPs	Architecture	1	1	0.5	1.5	4
[26]	2011	Journal	Solution proposal	CA-ESB: Context Aware Enterprise Service Bus.	ERPs	Framework	1	1	0.5	0	2.5
[21]	2011	Conference	Solution proposal	SOA-based development and implementation of ESB in the Power System	ERPs	Model	1	1	1	0	3

TABLE 6. *(Continued.)* Classification of the selected studies.

|											
[31]	2011	Conference	Analytical study	Study of an ESB-based method of data transformation	ERPs	Method	1	1	0.5	0	2.5
[28]	2011	Conference	comparative study	analysis of ESB(s) using the process of analytical hierarchy	ERPs	Method	0.5	1	1	0	2.5
[29]	2013	Conference	Implementation and Evaluation research	Implementation and review of an open source multi-tenant ESB	Open source ESBs	Method	1	1	1	0	3
[30]	2013	Journal	Conceptual research	Implementation of an enterprise network bus message conversion protocol based on XSLT	ERPs	Method	0.5	1	1	1	3.5
[27]	2017	Conference	Solution proposal	ESB usability as a middleware on the Smart Education Service Computing System Platform	ERPs	Model	1	1	0.5	0	2.5
[32]	2012	Symposium	Experimental research	Research and Application on Data Sharing and Exchange at the University	University data sharing and exchanging	Method	1	1	1	0	3
[33]	2013	journal	Solution proposal	Rapid development system for SOA-based business applications	ERPs	Platform	0.5	1	0.5	1	3
[35]	2016	Conference	Solution proposal	Semantic business service bus for cultural heritage	ESB products	Architecture	1	1	1	0	3
[34]	2015	conference	Solution proposal	SAIL: The Domain-Specific Language for Semantic-Aided Application	ESB products	Tool	1	0.5	1	0	2.5
[36]	2019	Journal	Performance analysis	Review of results to support the B2C program in Indonesia based on SOA using ESB	ERPs	Method	1	1	0.5	1	3.5
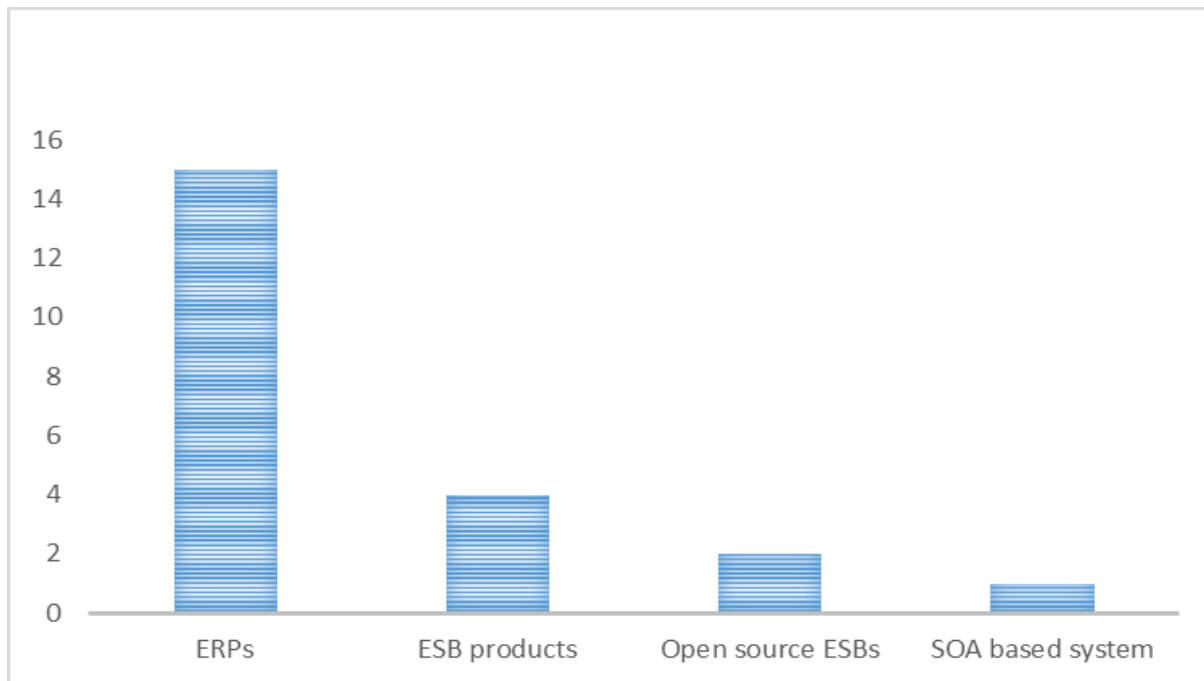
FIGURE 9. Applications found in selected studies.

(Internet of things) based methods, which requires more research in the future.

Another research gap is that most of the research is carried out in ERPs environments instead of other ESB environments like research on Extract transform load (ETL) needs to be carried out to enhance functionality of ESB. One more study gap is that the deficiency of research on comparison between commercial vs. public domain ESBs. Not a single study has been found on commercial ESBs and their comparison with public domain ESBs. All the studies found in current literature are on performance evaluation of open source ESBs. Therefore, it will require more research in the future. There is another study gap might be seen as the limited no of high-grade publications on journal-level publishing systems. At present, most of the literature is published in conferences. SO, high-grade journals are needed in which the emphasis on ESB.

G. RQ6. WHAT ARE THE APPROACHES THAT WERE REPORTED IN ESB RESEARCH THAT ADDRESS ESB PROBLEMS?

In figure 10, results show that most of all approaches to the research type present method (9)(0.4%), model (4)(0.2%) and architecture (4)(0.2%). Remaining approaches describe a framework (1)(0.45%), platform (1)(0.45%), tool (1)(0.45%), guideline (1)(0.45%) and infrastructure (1)(0.05%). Some of the ESB approaches found in selected studies are shown below.

The monitoring module has been put in ESB in the method described in this paper [24]. At the end, the quality of the

TABLE 7. Quality assessment score.

Ref.	T.score	No.
[22] [23]	1.5	2
[18] [26] [31] [28] [27] [34]	2.5	6
[15] [17] [24] [21] [29] [32] [33] [35]	3	8
[36] [30] [19] [16]	3.5	4
[20] [25]	4	2

approach was evaluated on a case study in Tehran Metro using simulation. The experimental results show that in the monitoring module this approach had low overhead. This research [27] seeks to make ESB features as a middle-layer based upon the notion of ''integration suite'' on a smart educational computing system platform. This framework includes 4 layers: Service Infrastructure, Business software, Product Merging and Service Source Layer. An ESB work as a middle-layer for the inclusion of intelligent educational facilities in the services system layer. This framework design is established for the high school education in Java province Indonesia. An author proposed innovative version of ESB [26] called Context Aware ESB (CA-ESB), which is used to publish and explore the services. The framework's key modules are: Context Provider (intellect location setting), Context Aware Logic Module (decide the location-based local service to choose) and Service Choreograph (choreography of selected services). To dynamically choreograph the facilities, a graphic model called Context
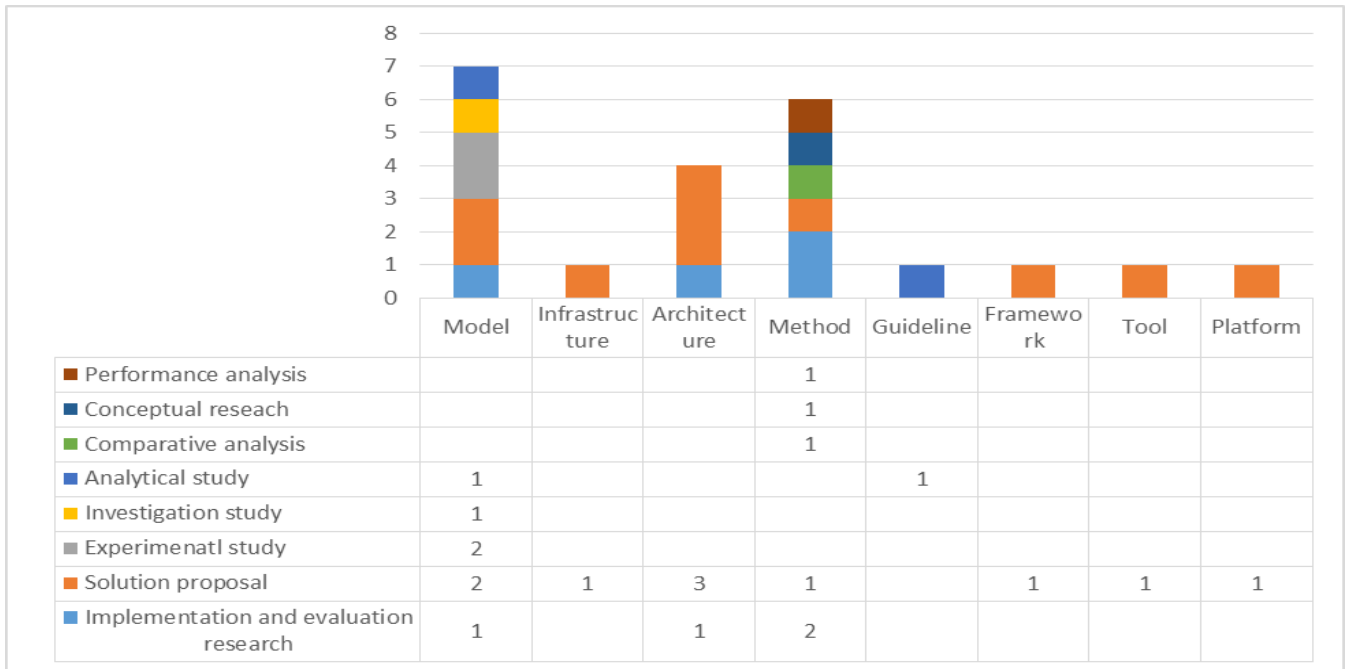
	Model	Infrastructure	Architecture	Method	Guideline	Framework	Tool	Platform
■ Performance analysis				1				
■ Conceptual reseach				1				
■ Comparative analysis				1				
■ Analytical study	1				1			
■ Investigation study	1							
■ Experimenatl study	2							
■ Solution proposal	2	1	3	1		1	1	1
■ Implementation and evaluation research	1		1	2				

FIGURE 10. Approaches used in selected studies.

Aware Graph (CA-Graph) was also introduced. Composed with other SOA reference architecture components, the proposed system components allow the ESB to the intellect user site, select the services needed, and dynamically choreograph those services. A case study of an Insurance System was used to demonstrate the proposed approach.

Furthermore, table 9 Summarizes the different ESB approaches applied in the selected papers.

H. QUALITY ASSESSMENT
The quality assessment score for each selected study listed in table 7. Approximately 63% of the selected study hold over average score, 27% hold average score, and 9% hold the lower score. This quality assessment could help ESB researchers and practitioner to select the relevant papers based on the criteria stated in Subsection E.

V. DISCUSSION
In this section, we summarized the results of our mapping study as well as also discussed the validity of the study and limitations at the end of this section.

A. MAIN FINDINGS
The purpose of this SMS was to examine the existing research trends in the ESB application via choosing 22 articles out of a total of 214. Then we have categorized them using the following criteria of classification: ESB applications, contribution type, topics covered in studies, research type and approaches adopted in studies. Our study's main results are listed below:
- In 2011, the ESB research field has acquired a growing interest as it was the year of growth and development

of Enterprise service bus. Approximately 54% of the elected articles were published in conferences. Though, only 36% had achieved a journal publication's maturity. However, we believe that in the future ESB will be likely to gain much more attention.
- We have found that, approximately 45% of selected studies identified solutions to ESB and about 18% of studies provide implementation and evaluation of ESB applications. However, This finding indicates that the ESB sector has not yet achieved adequate implementation maturity, and evaluation and that ESB researchers are mainly concerned with proposing approaches to enhance ESB functionalities. About 9% of the selected articles identified as experimental studies and analytical study. Just 4% of the studies, conduct performance analysis, which suggests that more work on performance analysis is needed in the future. This is also demonstrated by the point that the solutions proposed in the Application of ESB were the most common types of study / research found in the literature. The goal of the solutions found in this SMS to be primarily to direct the quality of service issues [15], [24] and to address challenges due to the complexity of monitoring and handling a large scale business process [18], [20].
- We also found that, in selected studies most of the topics based on Service oriented architecture [20], [21], [33], [36] and few studies on addressing Quality of service issues [15], [24], on performance evaluation of ESBs [19], [22]. Although, in the future more research is required in others environments too, such as: Internet of things (IOT), cloud based systems, real time ETL

TABLE 8. Summary of approaches used in selected studies.

Study Ref.	Approach
[19]	Evaluation Metrics used to define performance and efficiency of 03 examples open source ESBs (Mule, WSO2, ServiceMix).Then Student's Paired T-Test performed to examine the result. Expandability test and load handling test were performed using different Scenario: Direct Proxy, Scenario based on content, and Scenario for transformation routing.
[15]	Adaptive ESB infrastructure was used to address quality of service (QoS) issues: only two issues were addressed (Response time and service saturation). Different adaptive strategies, mechanisms and adaptation flow with YAWL (Yet Another Workflow Language) were used to address QoS issues.
[22]	Operational analysis of three open-sources ESBs: Fuse, Mule and Petal were performed in order to obtain application analysis results of MPAB (Massively Parallel Application Bus).
[31]	Oracle ESB was used as an example for exploring data transformation method. Also, traditional methods, structure analysis and property analysis were performed. For property analysis three methods were used: tradition ETL, Extraction and transmutation of remote data with SQL, and ESB method.
[23]	Firstly, the association between Web Services, SOA and ESB were discussed. Apache Synapse ESB was used for application integration.
[17]	The framework transformation approach was used for automated EA documentation. Also, reverse-engineered technique on SAP PI ESB was adopted.
[32]	Data sharing and exchanging suit approach was used, which consist of following technology: initiate, privilege, ETL and ESB.
[34]	DSL (domain-specific language) was used for interface mapping.
[28]	Multi-Criteria Analysis of Decision (MCDA) approach called Analytical Hierarchy Process (AHP) consist of defined criteria, i.e. Safety of data, interoperability and high accessibility was used for analysis between commercial and non-commercial ESBs. Also, tabulations and mathematical proofs were used for analysis.
[35]	Ontology-based integration, Information interoperability, schema matching techniques were used. Mule ESB was used for experimental purpose.
[36]	Implementation of SOA using ESB in order to ensure that it is a best solution for integration of large businesses. The B2C application system was used as an example to show the experimental results.
[25]	Firstly, important features of ESB were described Then, massively parallel ESB (MPESB) approach was introduced to integrate parallel processing.

TABLE 9. *(Continued.)* Summary of approaches used in selected studies.

[20]	An analytical survey performed to identify parameters inducing the presentation on SOA in varying situation and service designs.
[26]	The visual structural design called Context Aware Graph (CA-Graph) was used. An algorithm used to dynamically compose chosen services based on the locality context. An insurance system used as an example to assess the defined approach.
[21]	The structure of Enterprise Service Bus established using SOA was used. The Common Information Model (CIM) is used in this structure as a standard data exchange model, and XML is used to describe a file.
[27]	An integration suit was used. This functional design used for high school in Java province, Indonesia.
[29]	The experimental implementation of a multi-tenant-aware ESB is explored in particular, using an open source approach as the basis. Then, ESB benchmark technique to evaluate efficiency of defined approach.
[16]	Firstly, requirements for multi- tenancy ESB were considered. Implementation agnostic ESB consists of three layers (presentation, system logic, and resources) was used to address these requirements. Apache Service Mix ESB was used for realization and evaluation.
[33]	A platform which combines the design of service-oriented, model-driven, Ajax, BI was used. Through this platform PICC's (People's Insurance Company of China) evaluation method was established.
[18]	New methodology based on JMS Channel, HTTP Channel and REST Protocol was adopted. JMS channel was used for validation of web services. Test performed using HTTP channel. Workflow verification done by using REST protocol.
[24]	The time Series Forecasting approach in Neural Network was used to minimize QoS monitoring overheads Case study on Tehran Metro was performed in order to evaluate the approach.
[30]	Extensible style-sheet language transformations (XSLT) were used to design ESB message conversion protocol.

(extract transformation loading) and performance valuation of open source ESBs vs. commercial ESBs.

- We found that, ERPs were the most frequently described application in the selected articles. ERP systems are multi-modulated technology sets, such as human resources, marketing, finance, and development, offering cross-organizational data integration across integrated business processes [37]. About 68% of selected studies reported ERPs, only 18% of studies identified ESB products. The result shows that researchers were mainly concerned with developing ERPs applications which were used for medium and large-scale business/organizations. However, more attention will require for ESB products in the future. Also in RQ5, we have described all the research gaps that had been found in this SMS.

- In selecting studies, methods were the most commonly identified approaches. Approximately 40% of the approaches identified as a method, which were used for testing [18], analysis [28], [31], [36] and evaluation [29] of ESB applications. And one more categories of approaches that received attention were

the model (18%) and architecture (18%) which were used for the performance evaluation, design and implementation [19], [21], [22], [27].

B. LIMITATIONS OF THE STUDY

Limitations of the SMS analysis consist of: publication tendency, selection tendency, the incorrectness of data extraction, and incorrectly classified [13].

Publication tendency means that negative outcomes are less published than positive results also negative outcomes take more time to be published or not cited frequently in other publications. [6], [13]. In the search process, we used various familiar scientific sources to find as many papers as possible to address this problem. In several iterations, two researchers identified and implemented alternate search keywords in the way of inclusion of significant primary studies as much as possible. We used many terms related to the ESB and applications in the process of creating search strings. Although, the list might not be complete, more / extra or alternate words can be modified the list of selected articles [38]. The search was carried out using the ACM Scientific Library, IEEE Scientific Library, Elsevier, Springer, Science Direct, and Google Scholar. According to literature search engine information [39], we believe the majority of ESB applications work can be found in these digital repositories. We were therefore capable to gather papers that could have a higher value by using only the sources of scientific databases as a guide to finding relevant work.

Selection tendency refers to statistical analysis distortion because of the parameters given to choose the publishing [13]. We resolved this issue by sensible design the search procedure of this SMS We have used all the terms related to the ESB and applications in search scheme to include as many papers as possible. We established rigorous criteria for inclusion / exclusion 4 in the process toward making sure that each of the chosen articles were part of our study topic and responded to the RQs. Although, there is some key limitation which is important to be discussed. We have not included the articles which were published before 2011 as mentioned in table 4. We have selected the papers between 2011 and 2019 in order to find ESB application trends. It is possible that articles were missed because of the defined criteria for inclusion / exclusion. However, the guidelines provided in systematic reviews of software engineering monitored by us to describe this selection method [6] as well as a selection procedure adopted in similar studies [40]–[43].

The incorrectness of data extraction and incorrect classification refers to the capability of diverse reviewers to extract evidence in a different way [13]. By using two authors in the paper recovery process, we addressed this issue.

The two authors wisely go through the abstracts of the chosen articles and then shared their opinions for the inclusion / exclusion of the articles. In a situation when the views were not same, debate about whether to include or exclude the particular paper made. In addition, the papers were categorized in many face-to-face meetings, during which categorizations

and mappings for a total of 22 selected studies were directed and produced by two researchers.

The classification pattern and search string given in this mapping study can assist just as a preliminary point for ESB investigators and practitioner might search for additional papers and label them accordingly.

VI. CONCLUSION AND FUTURE DIRECTION

Enterprise Service Bus (ESB) is a middle-layer technology, which enables integration of business software in a service-oriented architecture.The purpose of an ESB is to offer Routing services between messages, message transformation, monitoring and controlling messages, Service Orchestration, security and management of operations.

In order to understand current research on ESB applications, We chose the systematic mapping approach to map all relevant research [6]. The object of this SMS was to inspect the existing study topics and summarizes existing research in ESB applications. Between 2011 and 2019, 214 articles were listed from the initial set of 16400 studies, 22 of which were selected and then categorized according to classification criteria: contribution type, research type, ESB applications, topics covered in their studies and approaches. In contribution type, publication trends and sources were identified.

The results obtained have shown that ESB has acquired viable attention since 2011. The majority of elective studies showed in conferences, and there were only few articles who attained a journal publication's maturity. Two kinds of research / study found that are: solution proposal, and implementation & evaluation research. Several authors have proposed solutions to address challenges due to the complexity of monitoring and handling a large scale business/organizations process and methods were most commonly identified approaches and few architectures, and models were also identified. The designs and implementations of ESB as SOA were the commonly addressed topics in the mapping process.

This work might be an initial point for finding improved techniques to develop ESB applications in future. In addition, an ESB methodology discussed in this SMS can assist other researchers in a way to recognize methodologies which might be taken to enhance performance of their applications. Based on the current research status, we include recommendations on future research directions of enterprise service bus as follows:

For future research on ESB applications more occurrence in journals has to be made and more emphasis should be given to the other environments to develop ESB applications for real-world such as: design and implementation of ESB in cloud systems, ESB solutions for real time ETL, ESB applications for geographically distributed environments (climate science, stock exchanges, social networking application, Electronic-mail system and data generated by multinational enterprises, etc), and research on ESB as internet of things (IoT). However, further evaluation research

should be conducted to evaluate existing ESB application approaches.

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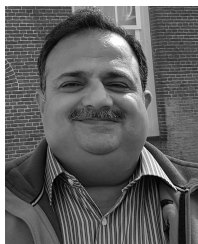
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