A Systematic Review on the Use of DevOps in Internet of Things Software Systems

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ABSTRACT

Based on Systematic Literature Review (SLR), we search to investigate the relations of DevOps in IoT software systems. As a result, we characterize the benefits and challenges in the context of knowledge previously reported in primary studies.

CCS CONCEPTS

• **Software and its engineering** → **Agile software development**;

KEYWORDS

DevOps, IoT Software Systems, Internet of Things Software Systems

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1 INTRODUCTION

Development and operation teams have opposite goals and incentives. The goal of development teams is to respond to business needs quickly. On the other hand, the goal of the operation teams is to provide a stable, reliable, and secure service to the customer. To address these conflicts, organizations adopt a culture of collaboration between development and operations teams (DevOps). DevOps allows companies to integrate their workflow completed, increasing the frequency of deployments and the stability and robustness of the production environment [22].

Internet of Things (IoT) solutions share these conflicts, as they require changes in known ways of construction and maintenance. IoT solutions are composed of addressable objects (things) that interact with each other and with users, detecting and processing data to achieve specific goals [13]. IoT solutions have different software components, such as clients and servers, with their frontend and backend. They also include the essential software to the hardware (e.g., firmware), gateway, and edge computing.

Through a Systematic Literature Review (SLR), this study aims to identify, analyze, and interpret evidence available in the literature on the explicit relationship between DevOps and IoT software systems. We applied a qualitative analysis, including open coding technique, to answer two research questions. All results come from evidences in twenty-six primary studies found in this SLR.

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2 SYSTEMATIC LITERATURE REVIEW

Systematic Literature Review (SLR) is a study that provides identification, analysis, and interpretation of evidence related to a specific topic. The conduction of this study followed guidelines of Kitchenham [2]. It has three phases: (i) Planning, (ii) Execution, and (iii) Analysis. The focus of this SLR is on the explicit relationship between DevOps and IoT in software systems.

2.1 Planning

In this phase, we define: (i) the topic to be investigated, (ii) the electronic data sources used to search for primary studies, (iii) the search string to identify the relevant studies, (iv) the inclusion and exclusion criteria for selecting primary studies, and (v) timestamp in which this study has been conducted.

Research Questions. To identify the relationship between DevOps and IoT in software systems, we defined two Research Questions (RQs). **RQ1.** What are the reported benefits of adopting DevOps in IoT software systems? **RQ2.** What are the reported challenges of adopting DevOps in IoT software systems?

Electronic Data Sources (EDS). Different EDS can be used in literature reviews to search for primary studies. We used five of them: IEEE Xplore Digital Library, ACM Digital Library, ScienceDirect, Springer, and Wiley.

Search String. We conducted a pilot study with search strings composed of several different terms and applied them to each EDS. In the end, the consolidated search string was: *(("internet of things" OR iot) AND devops)*.

Inclusion and Exclusion Criteria. We applied the following inclusion criteria: English and complete papers published in the last five years. Exclusion criteria: duplicate and short papers (less than six pages) and book chapters. In this study, the strategy adopted was to select papers describing DevOps applied to IoT software systems after reading and analyzing the metadata (i.e., title, abstract, and keywords).

Search Source. We researched all studies published between 2015 and 2019, since the research process was carried out in the first half of 2020. We chose this period to focus on recently published work.

2.2 Execution

This phase consists of (i) applying the search string in the selected EDS, (ii) identifying the primary studies, and (iii) selecting the papers found by using the inclusion and exclusion criteria.

Study Selection Process. Three steps with a focus on the selection of relevant papers, discussed as follows: Step 1 - Inclusion and exclusion criteria. Criteria used to include the relevant studies and to discard those that are not relevant; Step 2 - Metadata reading. The strategy adopted to characterize the scope of this SLR; Step 3 - Snowballing. In our SLR, we run the backward snowballing.

Data Extraction. Research questions are the main factors from which information needs to be extracted. For each selected paper, we identified and extracted evidence about the benefits and challenges of DevOps applied to IoT software systems. We use the open coding technique and discussions between the authors to answer the research questions and to create categories [4].

Summarization. It is worth mentioning that all selected studies were published between 2015 and 2019, and the number of publications grew each year.

3 RESULTS

This section aims to answer the RQs presented in Section 2.1.

3.1 Overview of Primary Studies

Twenty-six studies were published in conferences, workshops, journals, and magazines, with a total of fourteen, five, five, and two, respectively. They were posted in twenty-two different venues. The higher number of studies published in conferences and workshops supports the novelty of these topics. The dispersion of these numbers may also indicate that there is still no specialized venue for the community to send this type of study (internet of things and software engineering).

3.2 RQ1. What are the reported benefits of adopting DevOps in IoT software systems?

Table 1 shows the benefits perceived with the use of DevOps in IoT software systems found in the selected studies. The second column contains the categories of benefits. The third column contains the references of studies that mention each benefit.

The benefit B01 is mentioned in eleven studies. With respect to B01, frameworks address different stages of a DevOps pipeline. In B02, the combination of Cloud and IoT technologies is known in the literature as a new IT paradigm, CloudIoT. In B03, packing and isolating the application with the entire runtime environment makes it possible to migrate that container to other development, test or production environments. B04 was conceived by discussions in papers that report that microservices promote an organization of small independent teams. B05 refers to proposing mechanisms for the initial preparation steps to configure a new resource in the context of telecommunications.

3.3 RQ2. What are the reported challenges of adopting DevOps in IoT software systems?

Table 2 shows the challenges perceived with using DevOps in IoT Systems. Some challenges can also be considered open questions in the context of DevOps and IoT. The second column contains the categories of challenges. The third column contains the references of studies that mention each challenge.

C01 is often mentioned because sometimes IoT solutions are monolithic and tightly coupled. C02 involves difficulties in configuring, updating firmware, and monitoring device status. About C03, there is an emphasis on studies of the operation cycle stages, which encourage the creation of tools and concepts to fill the gap of continuous feedback. The solution architecture is actively involved in the treatment of C04. The application of a deployment pipeline is taken into account in the studies as a challenge (C05). With respect to C06, this challenge is about developing continuous documentation. This can create a bottleneck and fail to offer higher value to customers. C07 addresses the need for e-shaped professionals. The assessment of the quality of service offered is a challenge, according to C08. It is discussed that to increase the popularity of any service, Quality of Service (QoS) metrics must be defined so that the users can understand and express their needs. C09 is mentioned in studies that explain the need for DevOps frameworks for IoT.

4 THREATS TO VALIDITY

We discuss the threat in term of four categories [10]: **Construct Validity:** The electronic data sources used may not return all relevant studies. To minimize this threat, we selected five different databases that aggregate papers from various publishers.

Internal Validity: Possible limitations may be related to the judgment of the information presented, which expresses only the authors' point of view. However, frequent meetings were held between all authors to discuss the relevance of papers that should continue in the remaining phases of our analysis.

External Validity: This threat is related to the representativeness of the selected studies published between 2015 and 2019 to the main goals of this SLR. Our findings on the relationship between DevOps and IoT systems during the selected study period are accurate to the best of our knowledge.

Conclusion Validity: The summary benefits and challenges presents the authors' point of view and may not give the actual definition published by the papers. To minimize this threat, the authors used open coding and discussed every study to reach an agreement.

5 CONCLUSION

The frequent use of DevOps in IoT software systems is not widely discussed in the literature. In this paper, we present the results of a SLR to identify the explicit relationship between DevOps and IoT in software systems. We found twenty-six studies showing five benefits, and nine challenges in DevOps and IoT software systems.

The main contributions of this SLR were: two lists of benefits and challenges found in the literature on the relationship between DevOps and IoT. As future work, we suggest a survey and an interview study with developers to understand the relationship between DevOps and IoT software systems from the perspective of professionals in the area.

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Table 1: Benefits categories after open coding.

Benefits	Categories	Studies
B01	DevOps framework proposals for IoT	[5] [8] [11] [12] [16] [20] [21] [26] [28] [30] [31]
B02	Use of cloud computing as a back-end	[3] [9] [12] [26] [27]
B03	Interoperability with the use of containers	[17] [23] [29]
B04	Microservices induce the formation of small teams	[14] [17]
B05	Support platform for solutions that use cellular network	[7] [6]

Table 2: Challenges categories after cpen coding.

Challenges	Categories	Studies
C01	Metrics of technological values	[6] [7] [11] [19] [24] [25] [27] [28]
C02	Heterogeneous and remote device management	[1] [6] [20] [25]
C03	Continuous feedback between ops and devs	[8] [21] [23] [30]
C04	Address different non-functional requirements	[14] [15] [29] [31]
C05	Apply a deployment pipeline	[23] [28] [31]
C06	Continuous documentation	[11] [18] [24]
C07	Need for e-shaped professionals	[16] [17] [24]
C08	Evaluate quality of service	[6] [7]
C09	Lack of reports and devops frameworks in IoT	[9] [16]

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