Management of Service Level Agreements for Cloud Services in IoT: A Systematic Mapping Study

Saad Mubeen, *Senior Member, IEEE,*, Sara Abbaspour Asadollah, *Student Member, IEEE*, Alessandro V. Papadopoulos, *Member, IEEE*, Mohammad Ashjaei, *Member, IEEE*, Hongyu Pei-Breivold, Moris Behnam, *Member, IEEE*

***Abstract*—Cloud computing and Internet of Things (IoT) are computing technologies that provide services to consumers and businesses, allowing organizations to become more agile and flexible. Therefore, ensuring Quality of Service (QoS) through Service Level Agreements (SLAs) for such cloud-based services is crucial for both the service providers and service consumers. As SLAs are critical for cloud deployments and wider adoption of cloud services, the management of SLAs in cloud and IoT has thus become an important and essential aspect. This paper investigates the existing research on the management of SLAs in IoT applications that are based on cloud services. For this purpose, a Systematic Mapping study (a well-defined method) is conducted to identify the published research results that are relevant to SLAs. The paper identifies 328 primary studies and categorizes them into seven main technical classifications: SLA management, SLA definition, SLA modeling, SLA negotiation, SLA monitoring, SLA violation and trustworthiness, and SLA evolution. The paper also summarizes the research types, research contributions, and demographic information in these studies. The evaluation of the results show that most of the approaches for managing SLAs are applied in academic or controlled experiments with limited industrial settings rather than in real industrial environments. Many studies focus on proposal models and methods to manage SLAs, and there is a lack of focus on the evolution perspective and a lack of adequate tool support to facilitate practitioners in their SLA management activities. Moreover, the scarce number of studies focusing on concrete metrics for qualitative or quantitative assessment of QoS in SLAs urges the need for in-depth research on metrics definition and measurements for SLAs.**

***Index Terms*—Service-level agreements, SLAs, internet of things, IoT, industrial IoT, IIoT, cloud computing, systematic mapping study.**

I. Introduction

Cloud Computing [1] provides huge virtualized computing resources as on-demand services to users, which makes it very attractive for many industrial application domains. Therefore, using cloud computing will change the way businesses and users interact with IT resources. Furthermore, the Internet of Things (IoT) [2], [3] adds another dimension, on top of computing resources, by including everything, i.e., also the physical devices. Optimization of operations at different levels can be achieved through collecting and analyzing data from physical and virtual world. As a result, combining cloud computing and IoT technologies can provide services to consumers and businesses, allowing organizations to become more agile and flexible in pursuing new revenue streams and new business models. These technologies provide major benefits in terms of using IT and business agility allowing a huge competitive advantage for industrial organizations. However, building new services in the cloud or designing cloud-based IoT solutions into existing business context in general is a complex decision process, involving many factors and concerns. One major problem is concerned with the reduced operational governance control, i.e., a cloud consumer has less control of the actual service level being offered by the cloud provider compared to on-premise services. As a result, the quality of service, integrated in the Service Level Agreement (SLA) [4], is an important issue for both service providers and service consumers who require efficient SLA management from the complete SLA lifecycle perspective.

In this paper we consider the SLA lifecycle meta-model that is discussed in the European Commission report on recent European and national projects covering cloud computing SLAs [4]. The SLA lifecycle, depicted in Figure 1, consists of six main phases that include service use, service modeling, SLA template definition, SLA management, SLA enforcement and SLA conclusion. The phases are numbered from 1 (first phase) to 6 (last phase) in Figure 1. The first phase handles the information that affects the cloud service usage by the service consumer. The second phase deals with the modeling of the service, relationship and dependencies within the service components, and information regarding the service provision. In the third phase, SLA templates are created and other related information is captured. The fourth phase deals with the management of SLA covering various aspects such as SLA definition, SLA modeling, SLA negotiation (including SLA re-negotiation after the service provisioning in cloud), SLA monitoring, SLA evolution and SLA violation and trustworthiness. The purpose of the fifth phase is to enforce the SLA. The sixth phase handles the termination of the SLA, which can happen for various reasons such as SLA violation and/or expiry of the service period.

There exists a large body of research on IoT, cloud computing and their application in industrial systems, e.g., [5]–[17]. The research community has developed several techniques and frameworks to address various phases in the SLA lifecycle; however, the management of SLAs has received less attention. According to Papadopoulos et al. [18] the management of

S. Mubeen, S. Abbaspour, A.V. Papadopoulos, M. Ashjaei, M. Behnam are with Mälardalen University, Västerås, Sweden, e-mail: {saad.mubeen, sara.abbaspour, alessandro.papadopoulos, mohammad.ashjaei, moris.behnam}@mdh.se.

H. Pei-Breivold is with ABB Corporate Research, Västerås, Sweden, e-mail: hongyu.pei-breivold@se.abb.com.

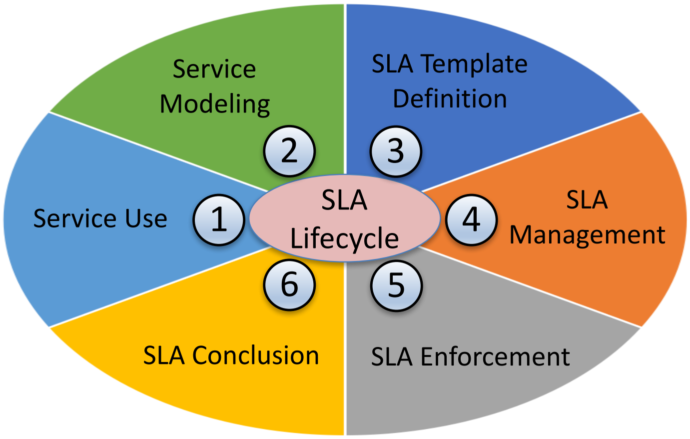


Fig. 1: SLA lifecycle.

SLAs for cloud services in IoT is still a very young area of research. Hence, there is a need to construct a structured map of the research area and perform a deeper analysis to better understand which aspects of SLA management for cloud services in IoT are mature and which aspects need more attention.

A. Paper Contributions

The main goal of this paper is to conduct a detailed investigation of the existing research on the management of SLAs in IoT applications that are based on cloud services. For this purpose, we construct a structured map of the available research literature (focusing on the above-mentioned goal) by conducting a systematic mapping study. We classify the relevant studies in relation to various aspects of SLA management. Moreover, we identify the distribution and trends of publication in the research area according to three classifications: (i) technical contributions that correspond to various aspects of SLA management for cloud services in IoT, (ii) research type and (iii) research contributions. Within the context of these classifications, we also identify the gaps in the existing research that need attention by the research community. In addition, we investigate the impacts on the state of the practice and future research directions.

B. Paper Layout

The rest of the paper is organized as follows. Section II discusses the process followed in this systematic mapping study. Section III discusses the related work. Section IV presents various classifications that are used in this study. Section V analyzes the collected data and presents the evaluation results. Section VI performs statistical analysis to evaluate the level of agreement among the researchers collecting data in this study. Section VII sheds light on threats to validity of the study. Finally, Section VIII concludes the paper and discusses the future work.

II. The Systematics Mapping Study

The systematic mapping study is a structured method to provide an overview of a research area [19], [20]. This type of study aims at identifying published research results that are relevant to the research area. Further, the study categorizes relevant published results according to a defined classification. This method has been recommended mostly when little relevant evidence is found during the initial study of the domain, or if the topic to be investigated is very broad [21]. In this paper we conduct a systematic mapping study following the guidelines that are discussed in [19], [20]. The work flow of the systematic mapping study used in this paper is depicted in Fig. 2.

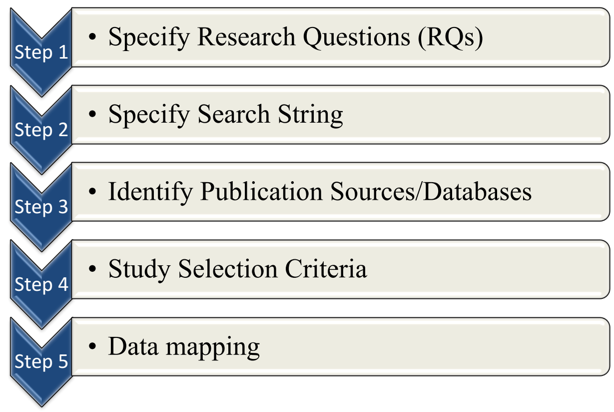


Fig. 2: Work flow of the systematic mapping study.

A. Specification of Research Questions

The first step in the systematic mapping study is to define concrete research questions. The answers to these questions provide an overview of the existing studies including the number of publications, publication venues and distribution of publications over the years in the research area. We formulate the following Research Questions (RQs) focusing on the research area of “SLA management in IoT applications that are based on cloud services”.

RQ-1: What is the number of publications per year in the research area?

RQ-2: What are the publication trends in the research area?

RQ-3: Which main venues include publications in the research area?

RQ-4: Which main research topics have been investigated in the research area?

A detailed discussion on the research topics will be provided in Section IV-A.

RQ-5: What is the number of publications per year on the main research topics in the research area?

RQ-6: Which main types of research have been employed in the research area?

A detailed discussion on the types of research will be provided in Section IV-B.

RQ-7: Which main types of research contributions have been provided in the research area?

A detailed discussion on the types of research contributions will be provided in Section IV-C.

RQ-8: Where are the gaps in the research area with respect to the main research topics, research types and research contributions?

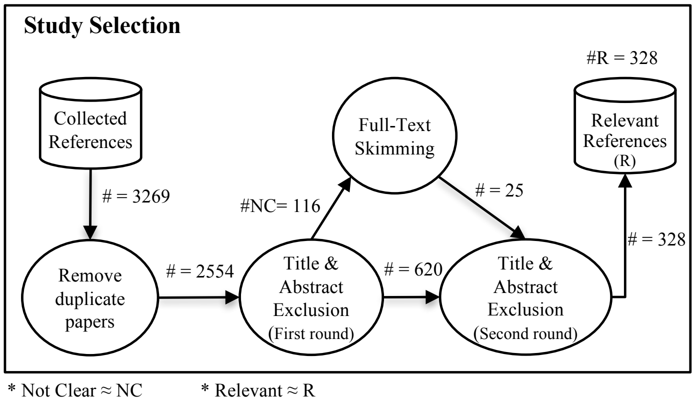


Fig. 3: Study selection process in the systematic mapping study.

B. Specification of Search String

After defining the research questions, the next step in the systematic mapping study is to specify the search string that is used to search relevant publications in known databases (discussed in the following subsection). In crux, the search string is based on the keywords and their alternative words that are in line with the main research goal of the paper (discussed in Section I). We use the Boolean operators OR and AND to join the keywords and their synonyms in the search string. The following string is used to search relevant publications in the known data bases:

`("service level agreement"` OR `sla)`
AND
`("internet of things"` OR `iot`
OR `"industrial internet of things"`
OR `iiot` OR `"cloud computing")`

In order to not miss any relevant publication for the study, we include the terms 'industrial internet of things" and "iiot" as part of the search string. Note that the term "cloud computing" is included in the search string together with the keyword IoT and its synonyms. This is because IoT extends the cloud computing concept beyond computing and communication by taking physical devices into account [2], [3].

C. Identification of Publication Sources/Databases

The next step in the systematic mapping study is to identify the most common scientific databases (sources of publications) in the research area. We identify the following online databases.

1) IEEE Xplore digital library[1]
2) Science Direct[2]
3) Web of Science[3]
4) Scopus[4]
5) ACM Digital Library[5]

After identifying the databases, we use the search string (presented in Section II-B) to find available publications in the research area. We perform an open-ended search with respect to the year of publication, i.e., we search all publications conforming to the search sting that have been published in the databases until the end of 2016. On the other hand, we restrict the search with respect to the type of publications by including journal, conference and workshop papers as well as peer-reviewed book chapters. Abstracts and the publications that are not peer reviewed are excluded from the search. The Endnote tool[6] is used to record the search results.

D. Study Selection Criteria

The search results in the previous step provide a pool of 3269 research publications. These publications indicate the current body of knowledge in the area of SLAs in IoT applications based on cloud services. However, the main goal of this systematic mapping study is focused on the "management" of SLAs in IoT applications based on cloud services. Hence, the collected pool of research publications should be filtered accordingly. For this purpose we provide a study selection criteria depicted in Fig. 3.

According to the criteria, in the first step, any duplicate publications should be removed from the pool. The collected pool of publications may contain duplicate publications mainly because several conferences in the research area are hosted by more than one database. For example, "the International Conference on Utility and Cloud Computing[7]" is hosted by both IEEE Xplore digital library and ACM Digital Library. In this step we identify 715 duplicate publications. After removing the duplicates, the pool reduces to 2554 publications.

Next, the remaining pool of publications (2554) is divided into three classes based on reviewing their titles and abstracts. The three classes are listed below. This step is identified by the oval with text "Title & Abstract Exclusion (First round)" in Fig. 3.

- Relevant (`R`) – If the title and abstract of a publication clearly indicate that it addresses the main goal of this systematic mapping study, the publication is categorized as `R`.
- Not Relevant (`NR`) – If the title and abstract of a publication clearly indicate that it does not address the main goal of this systematic mapping study, the publication is categorized as `NR`.
- Not Clear (`NC`) – A publication is categorized as `NC` if it cannot be classified as relevant or non-relevant.

[1]http://ieeexplore.ieee.org/Xplore/home.jsp

[2]http://www.sciencedirect.com/
[3]http://webofknowledge.com/
[4]https://www.scopus.com/
[5]http://dl.acm.org/
[6]http://endnote.com/
[7]http://ucc-conference.org/

This step results in 620 R and 1818 NR publications. Whereas, 116 publications could not be categorized as R or NR based on reading only the titles and abstracts. Hence, these 116 publications are categorized as NC. In the next step, we perform the full-text skimming of the collected set of NC publications. This step results in 25 R and 91 NR publications. Hence, the total number of R publications after these steps is equal to 645 (i.e., 620+25).

While performing the first exclusion step, we find out that many R publications are heavily focused on the scheduling and resource management, whereas the management of SLAs in IoT applications is sightly discussed. In order to filter out such publications from the ones that are focused on the main goal of this systematic mapping study, we perform a second exclusion step as shown in Fig. 3. The second exclusion step also exercises the inclusion/exclusion decision based on the titles and abstracts. In this step, we classify each publication in the remaining pool of 645 publications as R or NR. If a publication cannot be categorized based on its title and abstract then the full-text skimming is carried out. The second exclusion step results in 328 R publications as shown in Fig. 3.

E. Data Mapping

In this step, the collected data (i.e., the pool of 328 R publications) is classified independently in three classes. The classification is based on titles and abstracts of the publications. If a publication cannot be classified based on its title and abstract then the full-text skimming is performed. Each class is divided into several categories.

The first class is based on technical classification, which refers to the management of SLA's in IoT applications that are based on cloud services. Note that the term "management" in the context of SLAs is a broad term and contains many aspects [22]. The main goal of this systematic mapping study coincides with only few aspects of SLA management including SLA definition, SLA modeling, SLA negotiation, SLA monitoring, SLA evolution and SLA violation and trustworthiness. The details about these terms will be discussed in Section IV-A. Note that any R publication can belong to more than one category of the technical classification.

The second class is based on the research approach used in the publications. In this study, we are interested in the following research approaches: solution proposal, validation research, conceptual proposal, evaluation research and experience papers. The details about this classification will be discussed in Section IV-B.

The third class is based on the type of research contribution provided in the publications. Examples of research contributions include method (technique/approach), model (framework), metric, tools and others. The complete explanation about each category in this class will be discussed in Section IV-C.

III. Related Work

A few surveys, systematic reviews and systematic mapping studies relevant to the SLAs in cloud computing and IoT have been conducted. For example, the study [23] conducts a survey on Quality of Service (QoS) management techniques that are used for allocating resources to the applications to guarantee services based on performance, availability and reliability. Similar studies are done in [24], [25]. The study in [24] surveys the techniques and frameworks that handle resource management to ensure QoS in cloud computing; whereas the study in [25] surveys the mechanisms and methods used for measuring and ensuring QoS in cloud computing.

A systematic mapping study is conducted in [26] on the topic of QoS approaches in cloud computing. The study identifies the challenges and gaps that require future research explorations, e.g., tools, metrics and evaluation research are needed in order to provide cloud services with trustworthy QoS. The study looks into different focus areas with respect to (i) Software-as-a-service (SaaS) addressing QoS application requirements, application performance and monitoring management, and application scalability; (ii) Infrastructure-as-a-service (IaaS), addressing resource management, resource performance and monitoring management; (iii) Platform-as-a-service (PaaS). In addition, the study investigates QoS aspects related to (i) Cloud service provider (CSP) perspective, with respect to SLA support (i.e., methods and models that provide SLA support to service providers), SLA support profits (i.e., methods to increase revenue for service providers), and SLA support resources (i.e., resource assignment to minimize the cost and maximize the profit in the context of supporting SLAs); and (ii) Cloud service consumer (CSC) perspective, with respect to metrics models in order to determine the resources needed for allocation.

The study in [27] focuses on the resource allocation phase of the SLA life cycle. Based on the survey, the majority of research considers a minimum number of SLA parameters where the most studied parameters are performance, memory and CPU cycle. The study in [28] reviews the various models proposed for SLAs in different cloud service models, and analyzes how these models overcome the challenges related to performance, customer-level satisfaction, security, profit and SLA violation.

The study in [4] reports the research outcomes from the European and National projects, and discusses how these outcomes address the complete SLA life cycle, covering service use, service modeling, SLA template definition, SLA instantiation and management, SLA enforcement, and SLA conclusion. In addition, this report introduces a set of recommendations to support the on-going policy work on SLAs of the Cloud Select Industry Group (SIG), while identifying the research outcomes that can be exploited for the implementation of the recommendations.

These studies have surveyed the current and future challenges to QoS and SLA in cloud computing from different specific perspectives. However, a comprehensive overview of SLA management that spans the whole life cycle is missing from the state of the art and practice. In this context, this paper conducts a systematic mapping study on the available research literature on SLA management for IoT applications based on cloud services. The paper also classifies relevant studies in relation to the complete SLA life cycle.

TABLE I: Summary of the proposed classification categories.

Technical classification
SLA management
SLA definition
SLA modeling
SLA negotiation
SLA monitoring
SLA violation & trustworthiness
SLA evolution
Research type classification
Solution proposal
Validation research
Conceptual (philosophical) proposal
Evaluation research
Experience paper
Research contribution classification
Method (Technique/Approach)
Model (Framework)
Metric
Tools
Others

IV. Classification Criteria

In this section we describe the identified classification criteria used in the rest of this study. Table I summarizes the proposed classification categories, that are described in more detail in the following.

A. *Technical Classification*

1) **SLA management.** With "SLA management" we here refer to the general management of SLAs that covers two or more of the following categories. The SLA management is responsible for the SLA template generation, negotiation, configuration, enforcement, maintenance, and evolution [22].

2) **SLA Definition.** A cloud service provider can provide services such as Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS) to the consumer. Before the services can be provided to the consumer, both the provider and the consumer must agree on the metrics, level, quality, price and penalties (in the case of degraded service level or quality) regarding the services. A formal document containing all this information, which is agreed upon by both the provider and the consumer is called the SLA [29]–[31]. Various metrics that can be part of an SLAs are identified in [32]. For example, the metrics for IaaS include CPU capacity, boot time, storage, response time, just to name a few. Some examples of metrics for PaaS include deployment platforms, browsers and number of developers. Similarly, the examples of SaaS metrics include performance, availability, scalability and reliability. This category includes all the publications related to the definition of SLAs.

3) **SLA Modeling.** This category includes frameworks, templates, and modeling languages that have been proposed in the literature to model SLAs, see for example [33]–[36].

4) **SLA Negotiation.** SLAs are formally negotiated agreements between a service provider and a customer, e.g., the quality and reliability of the service, price, execution time or average response time, etc. There may exist a gap between the expected requirements (i.e., service level) from the consumer and the level of the service that the provider can provide. If this gap does exist, then the provider and consumer negotiate to reach a mutually-agreed service level. Once the negotiation process is successful then the agreed upon service level becomes part of the SLA. This process is called SLA negotiation [29]–[31].
It should be noted that an SLA can be non-negotiable or negotiable. A non-negotiable SLA is not subject to discussion or modification. This type of SLA is offered to the customer as take it or leave it. On the other hand, negotiable SLAs are open to negotiation before the service provisioning in the cloud. In addition, these SLAs can also be dynamically re-negotiated after the service provisioning in the cloud. Current cloud technologies offer a limited support for dynamic negotiation of SLAs between participants [37]. In this study, we group non-negotiable, negotiable and re-negotiable SLAs in one category, namely SLA negotiation.

5) **SLA Monitoring.** In the SLA contract, the expected level of service between the consumer and the provider is included. The QoS attributes that are generally part of an SLA (such as response time and throughput) however change constantly, and to enforce the agreement, these parameters need to be closely monitored to verify whether the offered service is meeting the QoS parameters specified in the SLA [29]–[31]. In order to monitor the QoS parameters, various techniques may be used to measure them [33], [38], [39]. This includes tools to measure, for example the network bandwidth, to check whether it follows the SLA.

6) **SLA Violation & Trustworthiness.** This category is related to the evaluation of whether the QoS of a service complies (meets the specified level) with an SLA or not. It also includes SLA enforcement, i.e., the management of the resources for minimizing the economic penalties derived from the possible SLA violations [40], and trustworthiness, i.e., the degree of compliance of a cloud service provider to the promised quantitative QoS parameters as defined in the SLA [41]. This category relates to different relevant problems, such as reliability, availability, dependability, security and performance.

7) **SLA Evolution.** This category relates to the lifecycle management of SLA, and to the adaptation of changing requirements between the different parties after the first agreement. In general, SLA lifecycle management consists of three general phases namely creation, operation and removal phases. Each phase can be further expanded

to sub-phases. The SLA creation includes three sub-steps, i.e., discover service provider, SLA definition and SLA establishment [42]. Once service providers are discovered, customers have to be aware of the detailed capacity of the service providers. Therefore, the service providers describe and define their services properly and deliver the definition of their services to the customers. Then, the customers further establish the agreement(s) with one or more service providers based on the service definition through a process of SLA negotiation.

B. Classification based on Research Type

This taxonomy reflects the research approaches used in the relevant publications. It serves the purpose of analyzing and understanding the maturity and weight of the state-of-the-art research. We use a reduced version of the classification scheme summarized in [43], that is a general taxonomy, independent from any specific focus area of research. In particular, we consider the following classes:

1) **Solution proposal.** The publications from this class propose a novel solution technique(s) for a problem and argue for its relevance. They can also propose a new significant extension to an existing technique. A proof-of-concept of the proposed technique may be offered by means of a small example, a sound argument, or by some other means.
2) **Validation research.** This class concentrates on investigating a proposed solution, which is novel and has not yet been implemented in practice. The publications from this class investigate the properties of a solution proposal. Investigations are carried out systematically, i.e., prototyping, simulation, experiments, mathematical systematic analysis and mathematical proof of properties.
3) **Conceptual (Philosophical) proposal.** The publications from this class describe a new way of looking at things by structuring a conceptual framework or taxonomy.
4) **Evaluation research.** The publications from this class focus on evaluating a problem or an implemented solution in practice, i.e., case studies, field studies and field experiments.
5) **Experience paper.** The publications from this class present personal experiences of the author(s), explaining how a research problem or a challenge is tackled in practice.

C. Classification based on Research Contribution

For categorizing the relevant publications based on research contribution, we use a classification similar to the one defined in [44], [45]. In particular, the categorization is as follows:

1) **Method (Technique/Approach).** This class includes the publications describing how to manage SLAs for cloud-based services in IoT applications. We can include publications with methods describing general concepts but also publications with more specific and detailed working procedures.
2) **Model (Framework).** This class focuses on representing the information to be used to support the actual SLA and QoS. Some examples of publications in this class can be models that aim to do resource optimization, recourse management, SLA monitoring or QoS computation.
3) **Metric.** This class can provide new or specific measurements for certain properties in QoS. An example of a measurement in this category can be measuring the time load that service provider acknowledges the receipt of reported problem.
4) **Tools.** This class refers to any kind of tool or tool support for the attributes included in the SLAs (like Linked USDL, tools for measuring performance, etc.).
5) **Others.** This class includes the remaining publications that include issues not covered by the other classes above.

V. Results and Evaluation

This section analyzes the collected data and discusses the evaluation results.

A. Identified Relevant Publications

The study selection process, discussed in Section II, has resulted in a pool of 328 relevant publications. These publications are referenced in Table II. It should be noted that the detailed analysis of the categories of the technical classification in this table will be discussed in Section V-D. The pool of publications represents the existing body of research in the area of management of SLAs for IoT applications based on cloud services.

B. Identified Relevant Venues

This subsection provides the map of the collected pool of relevant publications with respect to their venues of publication. Moreover, the most frequent venues of these publications are identified.

We note that the collected pool of relevant publications have been published in 216 different conferences and journals. Table III depicts the top seven venues, out of 216, in which approximately 29.6% of the relevant publications have been published. The share of the top seven venues in the pool of relevant publications is as follows. The International Conference on Cloud Computing and Service Science[8] has published 8.80% of the relevant publications. Therefore, this conference can be considered as the undisputed main conference in the research area. The second rank, in this context, belongs to the Elsevier journal on Future Generation Computer Systems[9]. The journal has published 7.41% of the relevant publications. Hence, the journal can be regarded as the most frequent journal for publishing research results in the research area. The remaining five venues in Table III are conferences

[8]http://closer.scitevents.org/Websites.aspx
[9]https://www.journals.elsevier.com/future-generation-computer-systems

TABLE II: Technical classification of all relevant publications collected from the systematic mapping study. Note that the references identified with blue-color bold text are common between two different categories of the technical classification.

SLA Management	SLA Definition	SLA Modeling	SLA Negotiation	SLA Monitoring	SLA Violation & Trustworthiness	SLA Evolution
[46], [47], [60], [61], [74], **[75]**, **[88]**, **[89]**, **[102]**, [103], [115], [116], [128], [129], [140], [141], [152], [153], [164], [165], [176], [177], [188], [189], [200], [201], [211], **[212]**, [223], [224], [235], **[236]**, [245], [246], [253], [254], [263], [264], [272], [273], [282], [283], [290], [291], [298], [299], [307], [308], [314], **[185]**, **[166]**, **[37]**.	**[48]**, [49], [62], [63], [76], [77], **[90]**, [91], [104], [105], [117], [118], [130], [131], [142], [143], [154], [155], **[166]**, [167], [178], [179], [190], [191], **[202]**, [203], [213], [214], [225], [226], **[215]**, **[237]**.	**[50]**, [51], [64], [65], [78], [79], [92], [93], [106], **[107]**, [119], [120], [132], [133], [144], **[145]**, **[156]**, [157], [168], [169], [180], [181], [192], [193], [204], [66], **[215]**, [216], [227], [228], **[114]**, [238], **[237]**, **[127]**, [255], **[256]**, [265], [266], **[274]**, [275], **[112]**, **[48]**, **[267]**, **[236]**, **[300]**, **[301]**.	[52], **[53]**, [66], [67], [80], **[81]**, [94], [95], [108], [109], [121], [122], [134], [135], **[146]**, [147], **[158]**, [159], [170], [171], **[182]**, [183], [194], [195], [205], [206], [217], [218], [229], [230], [239], [240], [247], [248], [257], [258], **[267]**, [265], [276], [277], [284], [285], [292], [293], [302], [303], [309], [310], [315], [316], [321], [322], [327], [328], [333], [334], [339], [340], **[37]**, [345], [350], [351], [355], [356], **[300]**, **[301]**, [361], [360], [360], **[50]**, **[90]**, **[145]**, **[212]**, **[202]**, **[256]**, [363], [364], [365], [366].	[54], [55], [68], [69], [82], [83], [96], [97], [110], [111], [123], [124], [136], [137], [148], [149], [160], [161], [172], [173], [184], **[185]**, [196], [197], **[207]**, [208], [219], [220], [231], [232], [241], [242], [249], [250], [259], [260], [268], [269], [278], [279], [286], [287], [294], [295], [295], [304], [38], [311], **[317]**, [318], [323], [324], [329], [330], [335], [336], [341], **[342]**, [346], [347], **[352]**, **[89]**, **[102]**, **[81]**, **[125]**, **[72]**, **[158]**, **[182]**, **[156]**.	[56], [57], [70], [71], [84], [85], [98], [99], **[112]**, [113], **[125]**, [126], [138], [139], [150], [151], [162], [163], [174], [175], [186], [187], [198], [199], [209], [210], [221], [222], [233], [234], [243], [244], [251], [252], [261], [262], [270], [271], [280], [281], [288], [289], [296], [297], [305], [306], [312], [313], [319], [320], [325], [326], [331], [332], [337], [338], [343], [344], [348], [349], [353], [354], [357], [358], [359], [360], [362], **[75]**, **[53]**, **[146]**, **[88]**, **[107]**, **[207]**, **[317]**, **[342]**, **[352]**, **[274]**.	[58], [59], **[72]**, [73], [86], [87], [100], [101]. **[46]**, **[114]**, **[127]**.

that have published around 4% down to 2% of the relevant publications. The rest of the venues, that are not listed in the table, have published three or less relevant publications. This means that 264 relevant publications, approximately 70.4% of the pool, are scattered in 209 different conferences and journals. Apart from the top seven publication venues, the wide-spread distribution of the relevant publications over the rest of the venues shows that the research community has not yet achieved focused publication venues. This indicates a need for more focused publication venues in the research area such as workshops, conferences and journals.

These results can provide guidance to new researchers in searching relevant publications and in identifying the most relevant publication venues for their results in this research area.

C. Distribution of all Relevant Publications

This subsection investigates the current publication trends in the research area by performing an analysis of the collected pool of relevant publications. Fig. 4 depicts a graph between

TABLE III: Top seven publication venues in the research area.

Rank	Publication channel	Publication venue	Number of publications	Percentage
1	Conference	International Conference on Cloud Computing and Service Science	19	8.80
2	Journal	Future Generation Computer Systems	16	7.41
3	Conference	International Conference on Services Computing	9	4.17
4	Conference	International Conference on Cloud Computing	6	2.78
5	Conference	International Conference on Utility and Cloud Computing	5	2.31
6	Conference	International Conference on Cloud Computing Technology and Science	5	2.31
7	Conference	International Symposium on Cluster, Cloud, and Grid Computing	4	1.85

the number of relevant publications that have been published in the known databases over the years. It is interesting to note that the first research results in this area were published in 2009. This indicates that the research area is fairly new. The trend, identified by the black line in Fig. 4, shows an increase in the attention received by the research topic of this study in the recent years. This is indicated by more than eleven-fold increase in the number of relevant publications from 6 in 2009 to 69 in 2015.

The graph in Fig. 4 shows that the number of relevant publications in 2016 is significantly lower than 2015. The reason is that the search in the databases is performed in the beginning of 2017. This means that the search results include the publications that have been published until the end of 2016. However, many conferences and journals take a considerable amount of time in processing the proceedings and issues respectively. For example, consider the International Conference on Utility and Cloud Computing[10], which is the fifth most frequent publication venue in the research area as shown in Table III. The recent instance of this conference took place from 6-9 December, 2016. Whereas, the proceedings were published in IEEE Xplore digital library on 20th March, 2017. Although the conference took place in 2016, the proceedings did not show up in our search. Considering this aspect, we believe, the exact number of relevant publications in 2016 will be similar or higher than 2015.

D. Distribution of Relevant Publications with respect to the Technical Contributions

This subsection investigates the current publication trends with respect to the technical contributions included in the relevant publications. We have discussed six technical categories in Section IV-A including the SLA definition, SLA modeling, SLA negotiation, SLA monitoring, SLA evolution and SLA violation and trustworthiness. The six categories actually represent various aspects of SLA management. All relevant publications are classified according to these technical categories in Table II. During the categorization process we identified that some publications do not address any specific technical category, rather they address the SLA management in general. Hence, we include one general category as "SLA management" in Table II. It should be noted that some publications belong to more than one technical category, e.g., publication [90] addresses both SLA definition and SLA negotiation. The publications that address more than one technical category are identified with the blue bold text in Table II.

Fig. 5 depicts a bar graph indicating the number of publications as well as the percentage of the pool of relevant publications targeting each category in the technical classification. It is obvious from the figure that SLA negotiation and SLA violation and trustworthiness are the most frequently addressed technical categories in the research area. These two contribution have been addressed in 21.58% and 21.04% of all relevant publications respectively. On the other hand, SLA evolution and SLA definition are the least addressed contributions in the research area. These two contributions have been addressed by only 3.01% and 8.74% of all relevant publications respectively. The smaller bars in Fig. 5 indicate that the definition, modeling and evolution of SLAs needs more attention by the research community.

The number of publications addressing each technical category is plotted against the publication years in Fig. 6. The figure shows that the first research results in the technical categories of SLA monitoring, SLA modeling, SLA definition, SLA negotiation and SLA violation and trustworthiness were published in 2009. Whereas, the first research results in the categories of SLA management (in general) and SLA evolution were published in 2010 and 2011 respectively. Fig. 6 shows that there is an increasing trend in the number of publications over the years in all categories of the technical classification. Fig. 6 also shows that SLA monitoring, SLA negotiation and SLA violation and trustworthiness have received most attention by the research community. Note that the reasoning and explanation about the lower number of publications in 2016 compared to 2015 discussed in Section V-C also applies to this subsection.

E. Distribution of Relevant Publications with respect to the Research Type

Fig. 7 depicts a bar graph indicating the number of publications as well as the percentage of the pool of relevant publications targeting each category in the research type classification (discussed in Section IV-B). It can be seen from the figure that an overwhelming majority of the existing research has adopted the solution proposal research type, constituting 81% of all relevant publications. Only 9% of the relevant publications have employed evaluation research. Whereas, 3%, 2% and 4% of the relevant publications employ validation research,

[10]http://computing.derby.ac.uk/ucc2016/

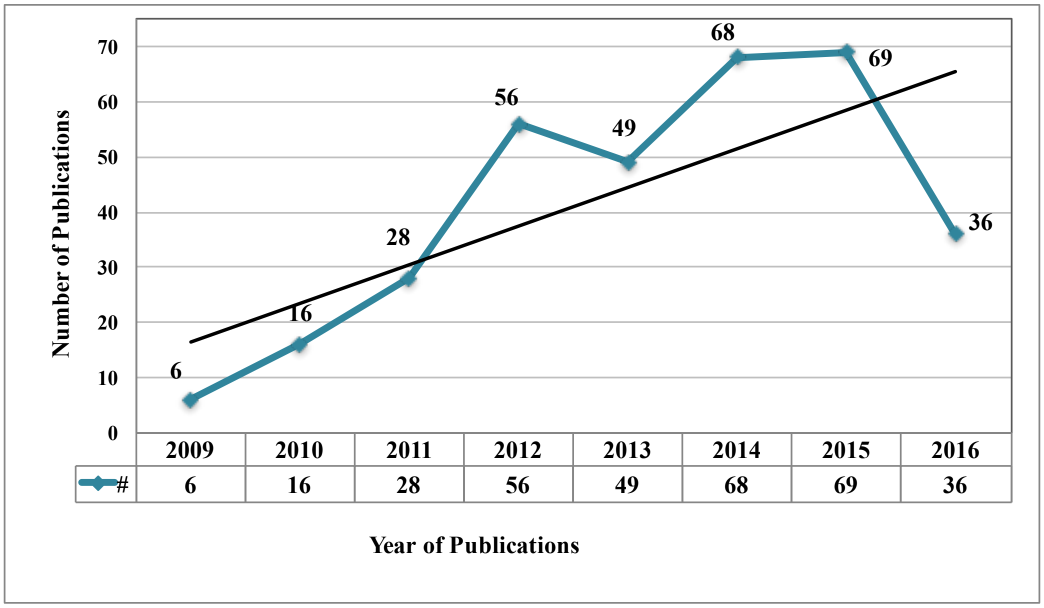


Fig. 4: Distribution of relevant research publications on the management of SLAs in IoT applications based on cloud services according to publication year. The black line represents the linear trend of the obtained data.

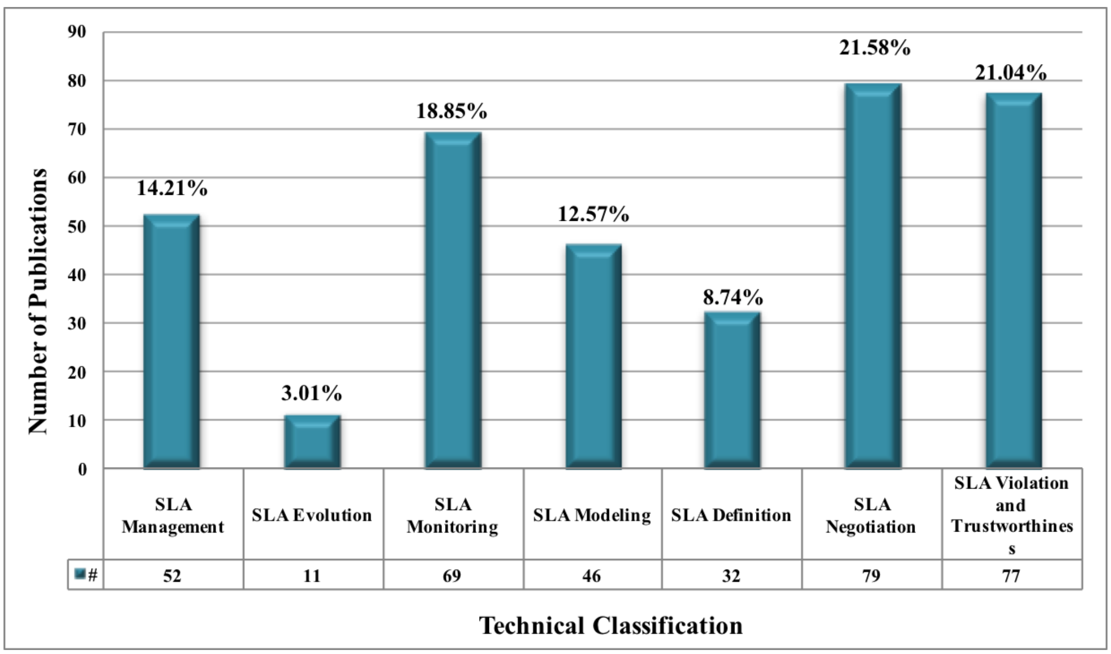
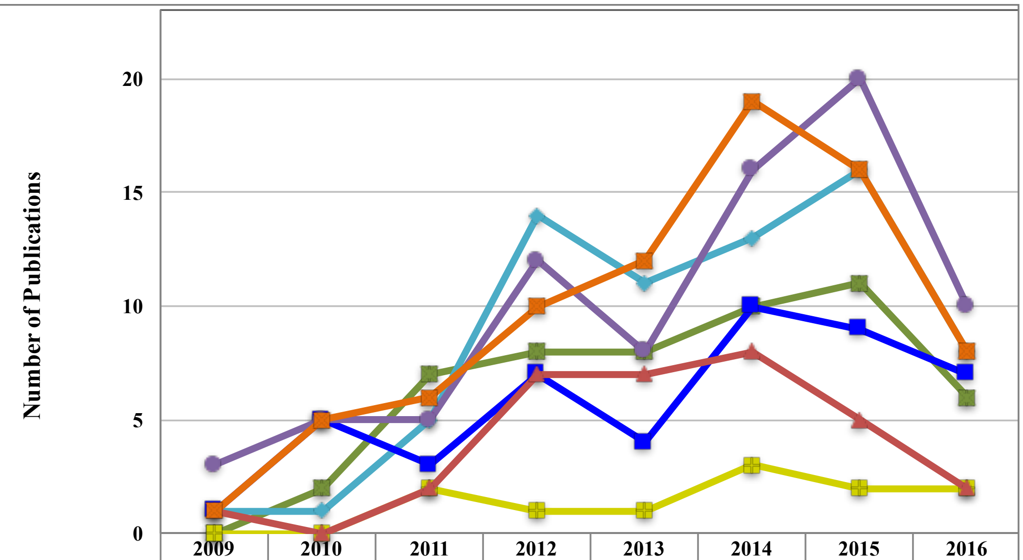


Fig. 5: Distribution of relevant publications according to the technical classification.

experience papers and conceptual proposals respectively. The results corresponding to the evaluation research show that only 9% of the research results in the area have been implemented and evaluated in practice. Note that the results achieved through the evaluation research have higher chances to find their way to the industry [44]. Fig. 7 shows that a large majority of research results in the area appear to be not yet mature to be adopted by the industry.

F. Distribution of Relevant Publications with respect to the Research Contribution

In this subsection we explore the distribution of all relevant publication with respect to the research contribution classification discussed in Section IV-C. Fig. 8 depicts a bar graph indicating the number of publications as well as the percentage of the pool of relevant publications that address each category in the research contribution classification. The figure shows that the research community has focused more on providing methods/techniques and models/frameworks as research contributions because these two categories constitute



	2009	2010	2011	2012	2013	2014	2015	2016
SLA Management	0	2	7	8	8	10	11	6
SLA Evolution	0	0	2	1	1	3	2	2
SLA Monitoring	1	1	5	14	11	13	16	8
SLA Modeling	1	5	3	7	4	10	9	7
SLA Definition	1	0	2	7	7	8	5	2
SLA Negotiation	3	5	5	12	8	16	20	10
SLA Violation and Trustworthiness	1	5	6	10	12	19	16	8

Fig. 6: Distribution of relevant publications in each technical category with respect to the publication year.

44% and 41% of all relevant publications respectively. On the other hand, the categories of metrics and tools have received very less attention as these categories contribute only 7% and 4% to the pool of relevant publications respectively. These results indicate that there is a lack of research regarding new solutions as metrics and tools for the management of SLAs in IoT applications that are based on cloud services.

G. *Relation among the Research Type, Research Contributions and Technical Contributions*

This subsection investigates the relationship among the three different classifications discussed in Section IV. The purpose of this investigation is to understand the main focus of the current body of research in the area as well as identify potential gaps that require immediate attention by the research community. In order to better understand the relationship among the three classifications simultaneously, we use a two-quadrant bubble plot as shown in Fig. 9. Each quadrant of the bubble plot is a two-axis scatter plot with bubbles at the intersection of any two categories belonging to different classifications. The size of the bubbles shows the number of relevant publications addressing the pair of categories intersecting each other. The left quadrant of the bubble plot illustrates the relationship between the technical contribution classification and the research type classification. Whereas, the right quadrant is plotted between the technical contribution classification and the research contribution classification.

It is obvious from the left quadrant that a large majority of the existing research has focused on solution proposals, while the rest of the categories in the research type classification have received very less attention. The largest bubble in the left quadrant has a size of 66. This bubble exists between the "solution proposal" and "SLA Negotiation" pair. This means, there are 66 relevant publications that address this pair. Note that the sum of the sizes of all bubbles in the left-most bubble column (equals to 290) in Fig. 9 is higher than the size of the left-most bar (equals to 266) in Fig. 7. The reason for the difference between the two numbers is that 24 publications (290 - 266) belonging to the solution proposal category are common in more than one category of technical classification. This means, the left-most column of bubbles in Fig. 9 contains 24 duplicates. The same reasoning applies to the rest of the bubble columns in Fig. 9.

The right quadrant in Fig. 9 shows that the majority of publications in the research area provide models/frameworks and methods/techniques as research contributions. Whereas, the metric and tool categories of the research contribution classification have not received much attention. This is evident from the gaps as well as the small size of the bubbles in the right quadrant of Fig. 9. The largest bubble in the right quadrant has a size of 43. This bubble indicates that there are 43 relevant publications that address the "method" and "SLA Violation and Trustworthiness" pair.

Fig 10 shows a pie chart of the largest bubble column in the left quadrant of Fig. 9, depicting the percentage of each technical classification category in the publications that provide solution proposals. SLA negotiation and SLA violation and trustworthiness are the most focused technical categories in the solution proposals. Whereas, SLA evolution is the least

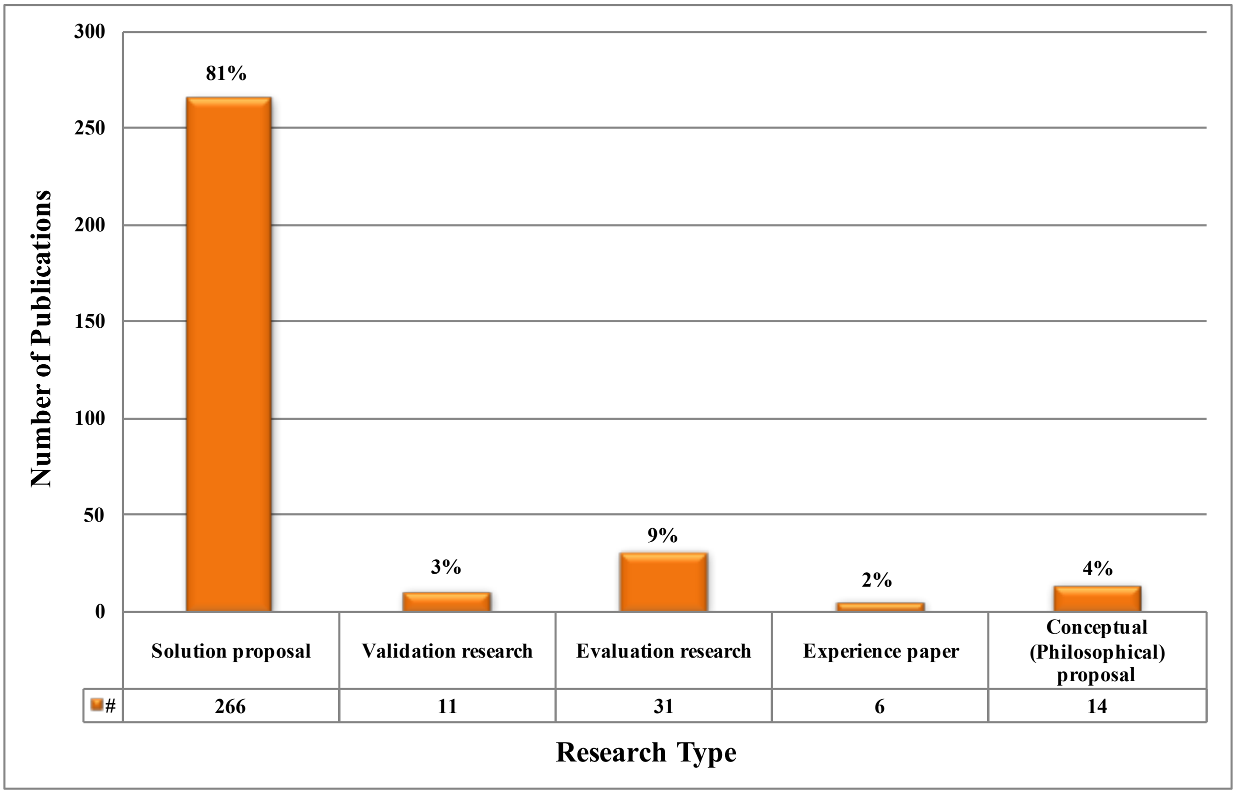


Fig. 7: Distribution of relevant publications according to the research type classification.

addressed category in the solution proposals. Similarly, Fig 11 shows a pie chart of the largest bubble column in the right quadrant of Fig. 9. This bubble column corresponds to the method category of the research contribution classification. The results indicate that the research community has mainly addressed SLA negotiation and SLA violation and trustworthiness when providing method as a research contribution. On the other hand, SLA evolution is the least addressed technical category in the existing research when providing method as a research contribution.

H. Discussion

This subsection revisits the research questions (posed in Section II-A) and answers them in relation to the evaluation results.

RQ-1: What is the number of publications per year in the research area?

The number of relevant publications per year in the research area are plotted in Fig. 4. Hence, this research question has been answered in Section V-C.

RQ-2: What are the publication trends in the research area?

The trend of relevant publications over the years in the research area is depicted in Fig. 4. Hence, this research question has been answered in Section V-C.

RQ-3: Which main venues include publications in the research area?

The main publication venues in the research area are discussed in Section V-B. The top seven publication venues are identified in Table III.

RQ-4: Which main research topics have been investigated in the research area?

The main research topics in the research area are identified in Table II. The number and percentage of relevant publications on the research topics are shown in Fig. 5. Table II can be very helpful for the researchers as well as practitioners who are interested in using, reusing or applying already developed methods, techniques and solutions in a specific category of the technical classification. For instance, if a researcher or a practitioner is interested in SLA modeling, the solutions presented in the publications listed in the third column (from the left side) of Table II can prove helpful.

RQ-5: What is the number of publications per year on the main research topics in the research area?

The number of relevant publications per year on the main research topics are plotted in Fig. 6. Hence, this research question has been answered in Section V-D.

RQ-6: Which main types of research have been employed in the research area?

The main types of research employed in this area are discussed in Section V-E.

RQ-7: Which main types of research contributions have been provided in the research area?

The main types of research contributions provided in this area are discussed in Section V-F.

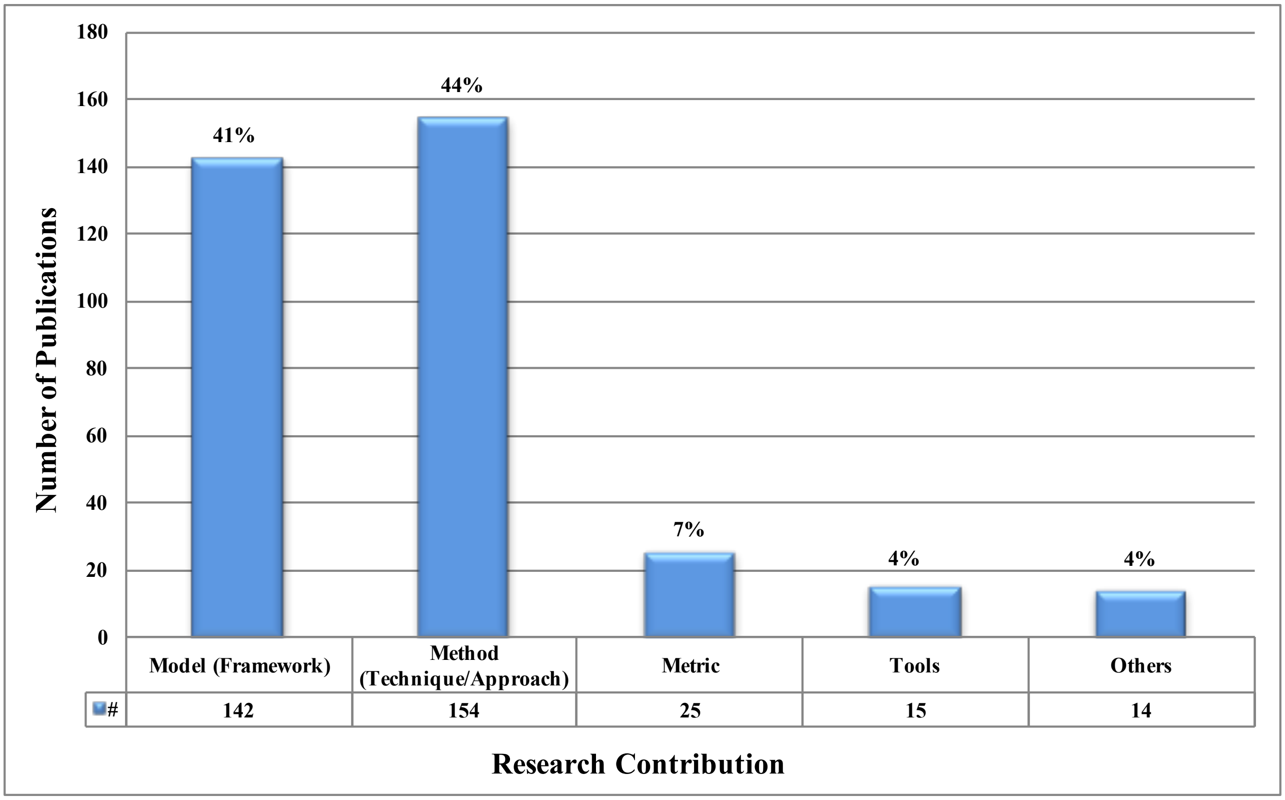


Fig. 8: Distribution of relevant publications according to the research contribution classification.

RQ-8: Where are the gaps in the research area with respect to the main research topics, research types and research contributions?

The relationship among the main research topics, research types and research contributions are discussed with a bubble chart in Fig. 9 and with a couple of pie charts in Fig. 10 and Fig. 11. This question has been answered in Section V-G.

VI. Fleiss' Kappa Statistical Analysis

In this section we perform statistical analysis to evaluate the level of agreement among the researchers collecting data in this systematic mapping study. Cohen [367] introduced a statistical method to measure the degree of agreement between two raters who rate a sample of a subject. He introduced the notion of Kappa in which the hypothetical agreement by chance is also taken into account. Later, the limitation of two-raters was eliminated by Fleiss [368], who generalized the method for multi-raters. In this work we use the Fleiss' Kappa analysis to show the degree of agreement when we decide on choosing the relevant publications.

Consider the study selection criteria that is discussed in Section II-D. In the first round of selecting relevant publications, six raters decide about the relevance of all collected publications. Each publication is classified as one of the three categories. These categories include Relevant (R), Not Relevant (NR) and Not Clear (NC). In order to perform the Fleiss' Kappa analysis, we randomly select 98 publications out of already rated publications. Therefore, from the Fleiss method point of view, there are 98 subjects (the randomly selected publications), 6 raters (computer scientists) and 3 categories of decision as mentioned above. We apply the statistical method and calculate the overall agreement over the 98 publications as 81.7%. This means, if a randomly selected subject is rated by a randomly selected rater and then the process is repeated, there is 81.7% chance to get the same rating decision the second time. Several researchers have provided interpretations of the Kappa analysis. According to McHugh [369], the Kappa value over 90% shows an *Almost Perfect* level of agreement among the raters. Whereas, the Kappa value between 80% and 90% indicates a *Strong* level of agreement among the raters. It can be concluded, based on the Kappa statistical results, that the researchers performing this systematic mapping study have a *Strong* level of agreement in deciding relevant publications in the research area.

VII. Threats to Validity of the Research Results

The main threats to validity in this mapping study are bias in our selection of the studies to be included, and the classification scheme based on data extraction. To be able to identify relevant studies and ensure that the process of selection was unbiased, discussions were undertaken to define research questions, inclusion and exclusion criteria, and search strategy. After these discussions, we agreed upon the formulation of research questions, whether the search string was appropriately derived from the research questions, and whether the data to be extracted would correctly address the research questions.

Although, we tried to reduce the bias, due to our choice of search terms, there is still a risk of missing some relevant

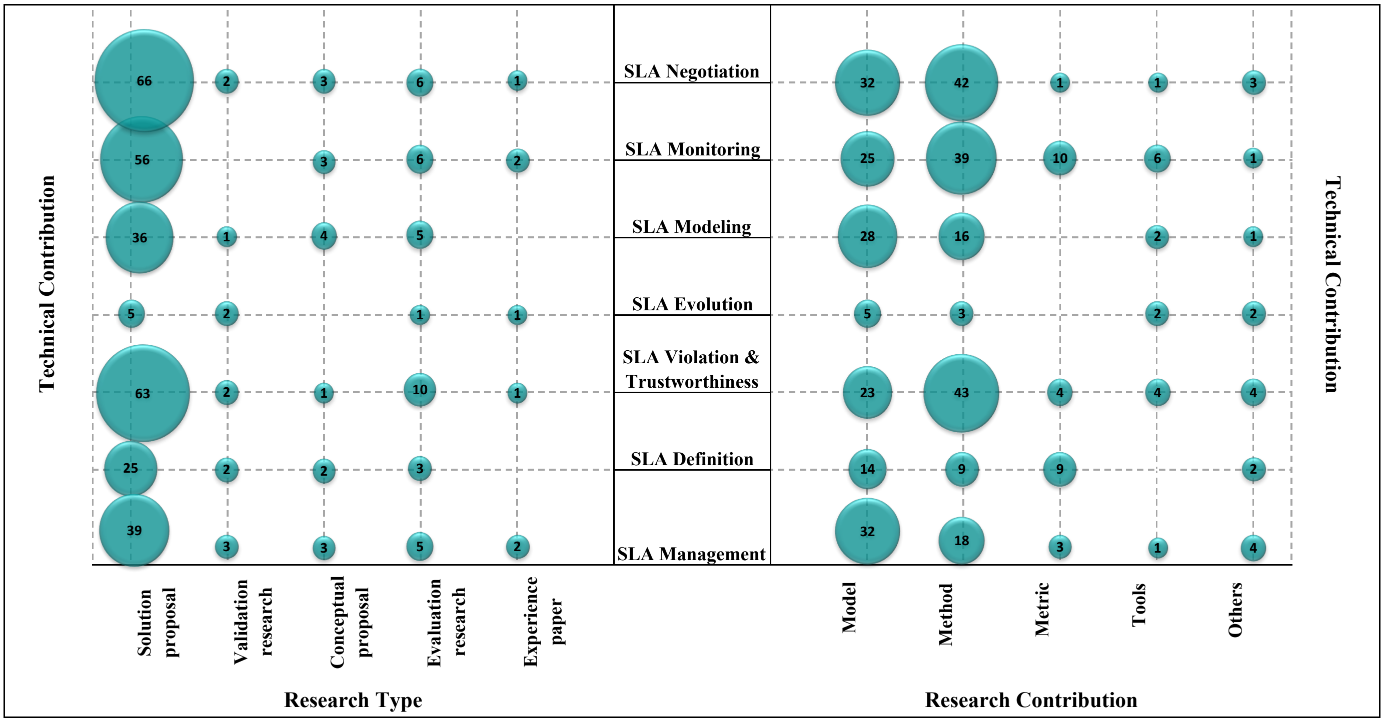


Fig. 9: Relationship among the categories of the research type, research contribution and technical contribution classifications in all relevant research publications.

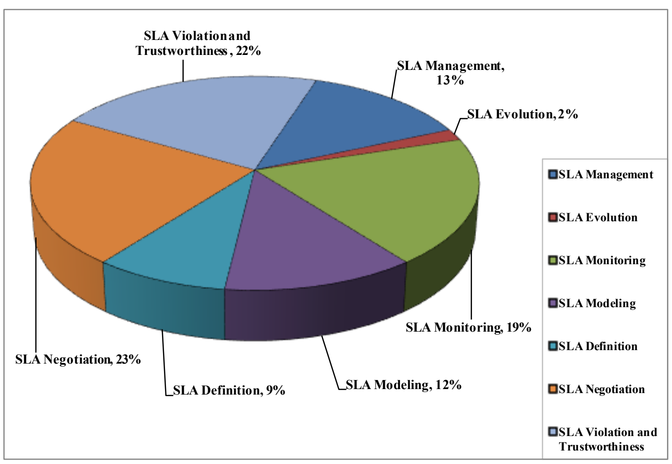


Fig. 10: Pie chart of the most frequent research type (Solution Proposal) with respect to the technical classification in Fig 9.

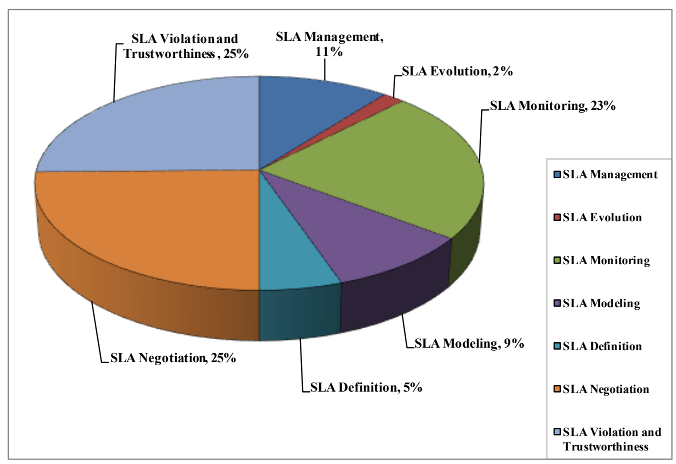


Fig. 11: Pie chart of the most frequent research contribution (Method) with respect to the technical classification in Fig 9.

studies, especially in the cases when some software engineering keywords are not standardized and clearly defined. We dealt with this threat by making sure that all researchers participating in this study understood and agreed to the same definition of the terms that were not clear before.

To further ensure the unbiased selection of publications, we performed a multi-step selection process to minimize the risk of excluding relevant studies. All the authors were involved in the study selection process based on the inclusion/exclusion criteria. The publications collected by performing the search were reviewed with respect to their titles and abstracts. If a publication could not be judged for relevance based on its title and abstract, the full-text skimming was performed to decide about its relevance in the research area.

To ensure the reliability of inclusion decisions, we applied the Fleiss Kappa statistic to measure the agreement among all the authors. The value of the Kappa statistics is 81.7%, which is within the range for significant agreement. Applying the Fleiss Kappa method provides us very good input for the degree of agreement on publications that should be included for the final full-text screening step.

To ensure correctness in classification scheme based on data extraction, we defined a data extraction form to obtain consistent extraction of relevant information for answering the research questions.

In the design and execution of this systematic mapping study, there are several considerations that need to be taken into account as they can potentially limit the validity of the obtained results. These considerations are listed below:

- The study includes the papers that are written in English, thus we may have missed relevant papers that are written in other languages.
- The presented classification scheme and obtained results are valid only in our context of computer science and software engineering and do not cover publications from the fields of electronics, mechanical engineering, medical sciences, physics and others.
- The study considers the papers that are available electronically. There is a chance that some relevant papers are not published on-line due to confidentiality or other reasons or have not been scanned and stored in the searched electronic databases. This systematic mapping study does not extend to such scenarios.
- We excluded non-peer reviewed scientific studies, book chapters, books and short papers because they would not provide reliable information for our study.
- The search string was used to search in keywords, titles and abstracts. It is possible - or even likely - that the search string may have failed to identify some relevant papers.
- We proposed a technical classification with clear definition for each category in the classification. Despite the experience of the researchers, some papers were difficult to categorize due to unclear boundaries between some classification categories, and also due to the way the information was presented in those papers.
- The comprehensive selection of included databases resulted in a huge set of potentially relevant publications. The number of analyzed and selected publications is still huge (328). We assumed that the selected pool of publications is representative for the aim of this study and can cover the objectives of the study. Thus, we did not apply any backward search in the references of the included publications.
- As it is known that abstracts do not always reveal the true content of publications, it is possible - or even likely - that we might have excluded a publication with poor abstract but valid content.

VIII. Conclusion and Future Work

The main objective of this systematic mapping study is to obtain a holistic view of the state-of-the-art research in managing service-level agreements (SLAs) for cloud services in the Internet of Things (IoT) context. We have identified 328 primary studies, covering a spectrum of approaches with specific perspective or focus. These approaches vary in terminology, descriptions, artifacts and involved activities, yet beyond these differences, we find approaches that share a lot in common, e.g., focus, goal and application context. We extract these commonalities and summarize the studies into seven main categories of technical classifications, i.e., SLA management, SLA definition, SLA modeling, SLA negotiation, SLA monitoring, SLA violation and trustworthiness, and SLA evolution. We have found that most of the studies address aspects related to SLA negotiation, SLA violation and trustworthiness, as well as SLA monitoring. Considerably few studies address the SLA evolution perspective. Addressing various perspectives, these primary studies contribute with models (frameworks 41%), methods (techniques/approaches 44%), metrics (7%), tools (4%) and others (4%). Of these 328 studies, we have identified five research types, which are solution proposal (81%), validation research (3%), evaluation research (9%), experience paper (2%), and conceptual (philosophical) proposal (4%).

The results of this systematic mapping study have implications for both practitioners and researchers. The practitioners can use this mapping study as a source to search relevant approaches for handling specific SLA management perspectives. For researchers, the analysis of the primary studies indicates a number of challenges and topics for future research. The classification of research types in this mapping study indicates that most of the approaches in managing SLAs are applied in academic or controlled experiments with limited industrial settings, rather than in real industrial environments. Thus, more evaluation research needs to be undertaken together with practitioners. The classification of contribution type in this mapping study indicates that many studies focus on proposing models and methods to manage SLAs, however, there is a lack of adequate tool support for managing the various aspects and complexities involved in the SLA management. Therefore, special research attention to developing good tool support would facilitate practitioners more effectively in their SLA management endeavor. Moreover, the multi-faceted aspects of SLA management with respect to, e.g., SLA definition, SLA monitoring, etc., implies the need for being able to qualitatively or quantitatively assess quality of service if it is provided on the same level as what has been defined in SLAs. However, very few studies (7%) look into concrete metrics to address this issue. To summarize, in future we can expect more evaluation research work, case studies, and more in-depth research on metrics definition and tool development to support SLA management in IoT applications based on cloud services.

Acknowledgement

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References

[1] B. Sosinsky, *Cloud Computing Bible*. Wiley Publishing, Inc., 2011, B. Sosinsky, Cloud Computing Bible, ISBN 978-0-470- 90356-8, Wiley Publishing, Inc., 2011.

[2] K. Ashton, "*That 'Internet of Things' Thing, in the real world things matter more than ideas*," http://www.rfidjournal.com/articles/view?4986, June 2009, [Online; Accessed 06-February-2015].

[3] IEEE Internet of Things, http://iot.ieee.org/about.html, accessed: January 2017.

[4] E. D. Kyriazis, "Cloud computing service level agreements - exploitation of research results," *European Commission Directorate General Communications Networks, Content and Technology Unit E2 – Software and Services, Cloud*, 2013. [Online]. Available: https://ec.europa.eu/digital-single-market/en/news/cloud-computing-service-level-agreements-exploitation-research-results

[5] O. Givehchi, H. Trsek, and J. Jasperneite, "Cloud computing for industrial automation systems - A comprehensive overview," in *18th IEEE Conference on Emerging Technologies & Factory Automation (ETFA)*, Sep. 2013.

[6] R. Langmann and L. Meyer, "Automation services from the cloud," in *11th IEEE International Conference on Remote Engineering and Virtual Instrumentation (REV)*, 2014.

[7] H. P. Breivold and K. Sandstrom, "Internet of things for industrial automation – challenges and technical solutions," in *2015 IEEE International Conference on Data Science and Data Intensive Systems*, dec 2015.

[8] T. Goldschmidt, A. Jansen, H. Koziolek, J. Doppelhamer, and H. P. Breivold, "Scalability and Robustness of Time-Series Databases for Cloud-Native Monitoring of Industrial Processes," in *7th IEEE International Conference on Cloud Computing (CLOUD2014)*, Jun. 2014.

[9] T. Hegazy and M. Hefeeda, "Industrial automation as a cloud service," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 10, pp. 2750–2763, Oct 2015.

[10] S. Mubeen, P. Nikolaidis, A. Didic, H. Pei-Breivold, K. Sandstrm, and M. Behnam, "Delay mitigation in offloaded cloud controllers in industrial iot," *IEEE Access*, vol. 5, pp. 4418–4430, 2017.

[11] A. Rachedi, M. H. Rehmani, S. Cherkaoui, and J. J. P. C. Rodrigues, "IEEE access special section editorial: The plethora of research in internet of things (iot)," *IEEE Access*, vol. 4, pp. 9575–9579, 2016.

[12] W. Wang, C. H. Lee, L. Chen, F. R. Yu, and H. J. Su, "Ieee access special section editorial: Emerging cloud-based wireless communications and networks," *IEEE Access*, vol. 3, pp. 3122–3124, 2015.

[13] A. Sajid, H. Abbas, and K. Saleem, "Cloud-assisted iot-based scada systems security: A review of the state of the art and future challenges," *IEEE Access*, vol. 4, pp. 1375–1384, 2016.

[14] Y. Sun, H. Song, A. J. Jara, and R. Bie, "Internet of things and big data analytics for smart and connected communities," *IEEE Access*, vol. 4, pp. 766–773, 2016.

[15] C. Zhu, V. C. M. Leung, L. Shu, and E. C. H. Ngai, "Green internet of things for smart world," *IEEE Access*, vol. 3, pp. 2151–2162, 2015.

[16] R. Morabito, "Virtualization on internet of things edge devices with container technologies: a performance evaluation," *IEEE Access*, vol. PP, no. 99, pp. 1–1, 2017.

[17] Z. Yan, X. Yu, and W. Ding, "Context-aware verifiable cloud computing," *IEEE Access*, vol. 5, pp. 2211–2227, 2017.

[18] A. Papadopoulos, S. A. Asadollah, M. Ashjaei, S. Mubeen, H. Pei-Breivold, and M. Behnam, "Slas for industrial iot: Mind the gap," in *The 4th International Symposium on Inter-cloud and IoT (ICI 2017)*. IEEE, August 2017.

[19] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson, "Systematic mapping studies in software engineering," in *Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering*, ser. EASE'08. Swindon, UK: BCS Learning & Development Ltd., 2008, pp. 68–77.

[20] K. Petersen, S. Vakkalanka, and L. Kuzniarz, "Guidelines for conducting systematic mapping studies in software engineering: An update," *Information and Software Technology*, vol. 64, pp. 1 – 18, 2015.

[21] S. Abbaspour Asadollah, D. Sundmark, S. Eldh, H. Hansson, and W. Afzal, "10 years of research on debugging concurrent and multicore software: a systematic mapping study," *Software Quality Journal*, pp. 1–34, 2016.

[22] N. Mavrogeorgi, V. Alexandrou, S. Gogouvitis, A. Voulodimos, D. Kiriazis, T. Varvarigou, and E. K. Kolodner, "Customized slas in cloud environments," in *2013 Eighth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, Oct 2013, pp. 262–269.

[23] H. A. Akpan and B. R. Vadhanam, "A survey on quality of service in cloud computing," *International Journal of Computer Trends and Technology*, vol. 27, no. 1, pp. 58–63, 2015.

[24] N. A. B. Mary and K. Jayapriya, "An extensive survey on qos in cloud computing," *International Journal of Computer Science and Information Technologies*, vol. 5, no. 1, pp. 1–5, 2014.

[25] M. Firdhous, S. Hassan, and O. Ghazali, "A comprehensive survey on quality of service implementations in cloud computing," *International Journal of Scientific and Engineering Research*, vol. 4, no. 5, pp. 118–123, 2013.

[26] A. Abdelmaboud, D. N. A. Jawawi, I. Ghania, A. Elsafi, and B. Kitchenham, "Quality of service approaches in cloud computing: A systematic mapping study," *The Journal of Systems and Software*, vol. 101, pp. 159–179, 2015.

[27] F. Faniyi and R. Bahsoon, "A systematic review of service level management in the cloud," *ACM Computing Surveys*, vol. 48, no. 3, 2016.

[28] U. Wazir, F. G. Khan, and S. Shah, "Service level agreement in cloud computing: A survey," *International Journal of Computer Science and Information Security*, vol. 14, no. 6, 2016.

[29] H.-J. Lee, M.-S. Kim, J. W. Hong, and G.-H. Lee, "Qos parameters to network performance metrics mapping for sla monitoring," *KNOM Review*, vol. 5, pp. 42–53, 2003.

[30] GIST Cloud Computing Research Group, "Automated cloud sla negotiation." [Online]. Available: https://sites.google.com/site/gistcloudresearchgroup/automated-sla-negotiation

[31] P. Patel, A. Ranabahu, and A. Sheth, "Service level agreement in cloud computing," in *OOPSLA Cloud Computing workshop*, 2009.

[32] M. Alhamad, T. Dillon, and E. Chang, "Conceptual sla framework for cloud computing," in *4th IEEE International Conference on Digital Ecosystems and Technologies*, April 2010, pp. 606–610.

[33] A. Sahai, V. Machiraju, M. Sayal, A. van Moorsel, and F. Casati, *Automated SLA Monitoring for Web Services*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2002, pp. 28–41.

[34] T. Chau, V. Muthusamy, H.-A. Jacobsen, E. Litani, A. Chan, and P. Coulthard, "Automating sla modeling," in *Proceedings of the 2008 Conference of the Center for Advanced Studies on Collaborative Research: Meeting of Minds*, ser. CASCON '08. New York, NY, USA: ACM, 2008, pp. 10:126–10:143.

[35] A. Keller and H. Ludwig, "The wsla framework: Specifying and monitoring service level agreements for web services," *Journal of Network and Systems Management*, vol. 11, no. 1, pp. 57–81, 2003.

[36] D. D. Lamanna, J. Skene, and W. Emmerich, "Slang: A language for defining service level agreements," in *Proceedings of the The Ninth IEEE Workshop on Future Trends of Distributed Computing Systems*, ser. FTDCS '03. Washington, DC, USA: IEEE Computer Society, 2003, pp. 100–.

[37] S. Venticinque, R. Aversa, B. Di Martino, M. Rak, and D. Petcu, *A Cloud Agency for SLA Negotiation and Management*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 587–594.

[38] D. Petcu and C. Crăciun, "Towards a security SLA-based cloud monitoring service," in *Proceedings of the 4th International Conference on Cloud Computing and Services Science*. Scitepress, 2014, pp. 598–603.

[39] M. Mohamed, O. Anya, T. Sakairi, S. Tata, N. Mandagere, and H. Ludwig, "The rsla framework: Monitoring and enforcement of service level agreements for cloud services," in *2016 IEEE International Conference on Services Computing (SCC)*, June 2016, pp. 625–632.

[40] M. Macías and J. Guitart, "SLA negotiation and enforcement policies for revenue maximization and client classification in cloud providers," *Future Generation Computer Systems*, vol. 41, pp. 19–31, 2014.

[41] S. Singh and J. Sidhu, "Compliance-based multi-dimensional trust evaluation system for determining trustworthiness of cloud service providers," *Future Generation Computer Systems*, vol. 67, pp. 109–132, 2017.

[42] K. Lu, R. Yahyapour, P. Wieder, E. Yaqub, M. Abdullah, B. Schloer, and C. Kotsokalis, "Fault-tolerant service level agreement lifecycle management in clouds using actor system," *Future Generation Computer Systems*, vol. 54, pp. 247–259, 2016.

[43] R. Wieringa, N. Maiden, N. Mead, and C. Rolland, "Requirements engineering paper classification and evaluation criteria: a proposal and a discussion," *Requirements Engineering*, vol. 11, no. 1, pp. 102–107, 2006.

[44] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson, "Systematic mapping studies in software engineering," in *Proceedings of the 12th International Conference on Evaluation and Assessment in Software*

Engineering, ser. EASE'08. Swindon, UK: BCS Learning & Development Ltd., 2008, pp. 68–77.

[45] E. Engström and P. Runeson, "Software product line testing – a systematic mapping study," *Information and Software Technology*, vol. 53, no. 1, pp. 2–13, 2011.

[46] K. Lu, R. Yahyapour, P. Wieder, E. Yaqub, M. Abdullah, B. Schloer, and C. Kotsokalis, "Fault-tolerant service level agreement lifecycle management in clouds using actor system," *Future Generation Computer Systems*, vol. 54, pp. 247–259, jan 2016.

[47] R. Trapero, J. Modic, M. Stopar, A. Taha, and N. Suri, "A novel approach to manage cloud security SLA incidents," *Future Generation Computer Systems*, jun 2016.

[48] K. Boukadi, R. Grati, and H. Ben-Abdallah, "Toward the automation of a QoS-driven SLA establishment in the Cloud," *Service Oriented Computing and Applications*, vol. 10, no. 3, pp. 279–302, nov 2015.

[49] I. Breskovic, M. Maurer, V. C. Emeakaroha, I. Brandic, and S. Dustdar, "Cost-efficient utilization of public SLA templates in autonomic cloud markets," in *2011 Fourth IEEE International Conference on Utility and Cloud Computing*, dec 2011, pp. 229–236.

[50] H. P. Borges, J. N. de Souza, B. Schulze, and A. R. Mury, "Automatic services instantiation based on a process specification," *Journal of Network and Computer Applications*, vol. 39, pp. 1–16, mar 2014.

[51] F. Faniyi, R. Bahsoon, and G. Theodoropoulos, "A dynamic data-driven simulation approach for preventing service level agreement violations in cloud federation," *Procedia Computer Science*, vol. 9, pp. 1167 – 1176, 2012.

[52] R. El-Awadi and M. Abu-Rizka, "A framework for negotiating service level agreement of cloud-based services," *Procedia Computer Science*, vol. 65, pp. 940 – 949, 2015.

[53] M. Macías and J. Guitart, "SLA negotiation and enforcement policies for revenue maximization and client classification in cloud providers," *Future Generation Computer Systems*, vol. 41, pp. 19–31, dec 2014.

[54] V. C. Emeakaroha, M. A. Netto, R. N. Calheiros, I. Brandic, R. Buyya, and C. A. D. Rose, "Towards autonomic detection of SLA violations in cloud infrastructures," *Future Generation Computer Systems*, vol. 28, no. 7, pp. 1017–1029, jul 2012.

[55] S. K. Garg, S. Versteeg, and R. Buyya, "A framework for ranking of cloud computing services," *Future Generation Computer Systems*, vol. 29, no. 4, pp. 1012 – 1023, 2013, special Section: Utility and Cloud Computing.

[56] F. Bahrpeyma, H. Haghighi, and A. Zakerolhosseini, "A bipolar resource management framework for resource provisioning in cloud's virtualized environment," *Applied Soft Computing*, vol. 46, pp. 487 – 500, 2016.

[57] P. H. Castro, V. L. Barreto, S. L. Corrêa, L. Z. Granville, and K. V. Cardoso, "A joint cpu-ram energy efficient and sla-compliant approach for cloud data centers," *Computer Networks*, vol. 94, pp. 1 – 13, 2016.

[58] N. R. Oktadini and K. Surendro, "SLA in cloud computing: Improving SLA's life cycle applying six sigma," in *2014 International Conference on Information Technology Systems and Innovation (ICITSI)*, nov 2014, pp. 279–283.

[59] X. Bai, M. Li, B. Chen, W.-T. Tsai, and J. Gao, "Cloud testing tools," in *Proceedings of 2011 IEEE 6th International Symposium on Service Oriented System (SOSE)*, dec 2011, pp. 1–12.

[60] I. U. Haq, A. A. Huqqani, and E. Schikuta, "Hierarchical aggregation of service level agreements," *Data & Knowledge Engineering*, vol. 70, no. 5, pp. 435–447, may 2011.

[61] M. Abbasipour, F. Khendek, and M. Toeroe, *A Model-Based Framework for SLA Management and Dynamic Reconfiguration*. Cham: Springer International Publishing, 2015, pp. 19–26.

[62] L. D. Marco, F. Ferrucci, M.-T. Kechadi, G. Napoli, and P. Salza, "Towards automatic service level agreements information extraction," in *Proceedings of the 6th International Conference on Cloud Computing and Services Science*, vol. 2. Scitepress, 2016, pp. 59–66.

[63] G. Di Modica and O. Tomarchio, "A semantic discovery frame work to support supply-demand matchmaking in cloud service markets," in *Proceedings of the 2nd International Conference on Cloud Computing and Services Science*. Scitepress, 2012, pp. 533–541.

[64] A. A. Falasi and M. A. Serhani, "A framework for sla-based cloud services verification and composition," in *2011 International Conference on Innovations in Information Technology*, April 2011, pp. 287–292.

[65] M. Alhamad, T. Dillon, and E. Chang, "Conceptual sla framework for cloud computing," in *4th IEEE International Conference on Digital Ecosystems and Technologies*, April 2010, pp. 606–610.

[66] A. Al Falasi, M. A. Serhani, and Y. Hamdouch, *A Game Theory Based Automated SLA Negotiation Model for Confined Federated Clouds*. Cham: Springer International Publishing, 2016, pp. 102–113.

[67] A.-R. Al-Ghuwairi, M. N. Khalaf, L. Al-Yasen, Z. Salah, A. Alsarhan, and A. H. Baarah, "A dynamic model for automatic updating cloud computing sla (dsla)," in *Proceedings of the International Conference on Internet of Things and Cloud Computing*, ser. ICC '16. New York, NY, USA: ACM, 2016, pp. 57:1–57:7.

[68] G. Katsaros, G. Kousiouris, S. V. Gogouvitis, D. Kyriazis, A. Menychtas, and T. Varvarigou, "A self-adaptive hierarchical monitoring mechanism for clouds," *Journal of Systems and Software*, vol. 85, no. 5, pp. 1029–1041, may 2012.

[69] M. Oriol, X. Franch, and J. Marco, "Monitoring the service-based system lifecycle with SALMon," *Expert Systems with Applications*, vol. 42, no. 19, pp. 6507–6521, nov 2015.

[70] A. G. García, I. B. Espert, and V. H. García, "SLA-driven dynamic cloud resource management," *Future Generation Computer Systems*, vol. 31, pp. 1–11, feb 2014.

[71] S. K. Garg, A. N. Toosi, S. K. Gopalaiyengar, and R. Buyya, "SLA-based virtual machine management for heterogeneous workloads in a cloud datacenter," *Journal of Network and Computer Applications*, vol. 45, pp. 108–120, oct 2014.

[72] J. S. Barbar, G. D. O. Lima, and A. Nogueira, "A model for the classification of failures presented in cloud computing in accordance with the SLA," in *2014 International Conference on Computational Science and Computational Intelligence*, vol. 1, mar 2014, pp. 263–267.

[73] J. Ding and Z. Zhao, "Towards autonomic SLA management: A review," in *2012 International Conference on Systems and Informatics (ICSAI2012)*, may 2012, pp. 2552–2555.

[74] F. Aijaz, S. J. Shaikh, and B. Walke, "Performance analysis of a framework for multi-interfaced service level agreements on mobile devices," in *17th European Wireless 2011 - Sustainable Wireless Technologies*, April 2011, pp. 1–8.

[75] M. Alhamad, T. Dillon, and E. Chang, "Service level agreement for distributed services: A review," in *2011 IEEE Ninth International Conference on Dependable, Autonomic and Secure Computing*, Dec 2011, pp. 1051–1054.

[76] A. L. Freitas, N. Parlavantzas, and J.-L. Pazat, "An integrated approach for specifying and enforcing SLAs for cloud services," in *2012 IEEE Fifth International Conference on Cloud Computing*, jun 2012, pp. 376–383.

[77] S. Frey, C. Lüthje, R. Teckelmann, and C. Reich, "Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud services," in *Proceedings of the 3rd International Conference on Cloud Computing and Services Science*. Scitepress, 2013, pp. 457–462.

[78] G. Baranwal and D. P. Vidyarthi, "A framework for selection of best cloud service provider using ranked voting method," in *2014 IEEE International Advance Computing Conference (IACC)*, Feb 2014, pp. 831–837.

[79] A. H. Busalim, A. R. C. Hussin, and A. Ibrahim, "Service level agreement framework for e-commerce cloud end-user perspective," in *2013 International Conference on Research and Innovation in Information Systems (ICRIIS)*, nov 2013, pp. 576–581.

[80] A. Amato, L. Liccardo, M. Rak, and S. Venticinque, "SLA negotiation and brokering for sky computing," in *CLOSER*, 2012, pp. 611–620.

[81] S. Anithakumari and K. Chandrasekaran, "Negotiation and monitoring of service level agreements in cloud computing services," in *Proceedings of the International Conference on Data Engineering and Communication Technology*, ser. Advances in Intelligent Systems and Computing. Springer Nature, aug 2016, vol. 469, pp. 651–659, dOI: 10.1007/978-981-10-1678-3_62.

[82] M. Sookhak, H. Talebian, E. Ahmed, A. Gani, and M. K. Khan, "A review on remote data auditing in single cloud server: Taxonomy and open issues," *Journal of Network and Computer Applications*, vol. 43, pp. 121–141, aug 2014.

[83] A. Adegboyega, "An adaptive resource provisioning scheme for effective qos maintenance in the iaas cloud," in *Proceedings of the International Workshop on Virtualization Technologies*, ser. VT15. New York, NY, USA: ACM, 2011, pp. 2:1–2:6.

[84] H.-W. Kim and Y.-S. Jeong, "Efficient auto-scaling scheme for rapid storage service using many-core of desktop storage virtualization based on IoT," *Neurocomputing*, vol. 209, pp. 67–74, oct 2016.

[85] M. Maurer, I. Brandic, and R. Sakellariou, "Adaptive resource configuration for cloud infrastructure management," *Future Generation Computer Systems*, vol. 29, no. 2, pp. 472–487, feb 2013.

[86] F. Faniyi and R. Bahsoon, "A systematic review of service level management in the cloud," *ACM Computing Surveys*, vol. 48, no. 3, pp. 1–27, dec 2015.

[87] A. Maarouf, A. Marzouk, and A. Haqiq, "Practical modeling of the SLA life cycle in cloud computing," in *2015 15th International Conference on Intelligent Systems Design and Applications (ISDA)*, vol. 2016-June, dec 2015, pp. 52–58.

[88] F. Alrebeish and R. Bahsoon, "Implementing design diversity using portfolio thinking to dynamically and adaptively manage the allocation of web services in the cloud," *IEEE Transactions on Cloud Computing*, vol. 3, no. 3, pp. 318–331, July 2015.

[89] S. Anithakumari and K. C. Sekaran, "Autonomic SLA management in cloud computing services," in *Communications in Computer and Information Science*, ser. Communications in Computer and Information Science. Springer Nature, 2014, vol. 420 CCIS, pp. 151–159, dOI: 10.1007/978-3-642-54525-2_13.

[90] I. Kafeza, E. Kafeza, and E. Panas, "Contracts in cloud computing," in *2014 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM)*, oct 2014.

[91] J. Kennedy, "Towards standardised SLAs," in *Euro-Par 2013: Parallel Processing Workshops*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2014, vol. 8374 LNCS, pp. 105–113, dOI: 10.1007/978-3-642-54420-0_11.

[92] V. Casola, A. D. Benedictis, J. Modic, M. Rak, and U. Villano, "Per-service security SLa: A new model for security management in clouds," in *2016 IEEE 25th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE)*, jun 2016, pp. 83–88.

[93] V. Casola, M. Rak, S. L. Porta, and A. Byrne, "Providing security SLA in next generation data centers with SPECS: The EMC case study," in *Proceedings of the 6th International Conference on Cloud Computing and Services Science*, vol. 2. Scitepress, 2016, pp. 138–145.

[94] P. Boiron and V. Dussaux, "Software services delivered from the cloud: A rising revolution for the implementation of healthcare workflows," *International Journal of Information Systems in the Service Sector*, vol. 7, no. 1, pp. 22–37, 2015.

[95] I. Brandic, D. Music, and S. Dustdar, "Service mediation and negotiation bootstrapping as first achievements towards self-adaptable grid and cloud services," in *Proceedings of the 6th international conference industry session on Grids meets autonomic computing - GMAC '09*. Association for Computing Machinery (ACM), 2009, pp. 1–8.

[96] S. Al-Shammari and A. Al-Yasiri, "Monslar: a middleware for monitoring sla for restful services in cloud computing," in *2015 IEEE 9th International Symposium on the Maintenance and Evolution of Service-Oriented and Cloud-Based Environments (MESOCA)*, Oct 2015, pp. 46–50.

[97] M. Alhamad, T. Dillon, and E. Chang, *A Survey on SLA and Performance Measurement in Cloud Computing*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 469–477.

[98] S. Singh and J. Sidhu, "Compliance-based multi-dimensional trust evaluation system for determining trustworthiness of cloud service providers," *Future Generation Computer Systems*, vol. 67, pp. 109–132, feb 2017.

[99] Z. Xu and W. Liang, "Operational cost minimization of distributed data centers through the provision of fair request rate allocations while meeting different user SLAs," *Computer Networks*, vol. 83, pp. 59–75, jun 2015.

[100] M. Smit and E. Stroulia, "Maintaining and evolving service level agreements: Motivation and case study," in *2011 International Workshop on the Maintenance and Evolution of Service-Oriented and Cloud-Based Systems*, sep 2011.

[101] M. Irfan, Z. Hong, T. Qamer, S. Hussain, and U. A. Qureshi, "Requirement analysis and design of service level integration layer for cloud computing services, to meet service level agreements and quality of service," *Journal of Computational and Theoretical Nanoscience*, vol. 11, no. 3, pp. 629–636, mar 2014.

[102] A. S and C. K, "Monitoring and management of service level agreements in cloud computing," in *2015 International Conference on Cloud and Autonomic Computing*, sep 2015, pp. 204–207.

[103] A.-F. Antonescu and T. Braun, "Service level agreements-driven management of distributed applications in cloud computing environments," in *2015 IFIP/IEEE International Symposium on Integrated Network Management (IM)*, may 2015, pp. 1122–1128.

[104] X. Liu and Z. Zhan, "The optimal design of service level agreement in IAAS based on BDIM," in *International Conference on Graphic and Image Processing (ICGIP 2012)*, Z. Zhu, Ed., vol. 8768. SPIE-Intl Soc Optical Eng, mar 2013.

[105] J. Luna, H. Ghani, T. Vateva, and N. Suri, "Quantitative assessment of Cloud Security Level Agreements: A case study," in *Proceedings of the International Conference on Security and Cryptography*, 2012, pp. 64–73.

[106] F. Aijaz, S. J. Shaikh, and B. Walke, "A framework for multi-interfaced service level agreements on mobile devices," in *2010 IEEE International Conference on Communication Systems*, Nov 2010, pp. 527–533.

[107] A. Amato and S. Venticinque, "Modelling, design and evaluation of multi-objective cloud brokering," *International Journal of Web and Grid Services*, vol. 11, no. 1, pp. 21–38, 2015.

[108] J.-H. Chen, F. Abedin, K.-M. Chao, N. Godwin, Y. Li, and C.-F. Tsai, "A hybrid model for cloud providers and consumers to agree on qos of cloud services," *Future Generation Computer Systems*, vol. 50, pp. 38 – 48, 2015, quality of Service in Grid and Cloud 2015.

[109] M. B. Chhetri, Q. B. Vo, and R. Kowalczyk, "Adaptive AutoSLAM - policy-based orchestration of SLA establishment," in *2014 IEEE International Conference on Services Computing*, jun 2014, pp. 472–479.

[110] K. Alhamazani, R. Ranjan, F. Rabhi, L. Wang, and K. Mitra, "Cloud monitoring for optimizing the qos of hosted applications," in *4th IEEE International Conference on Cloud Computing Technology and Science Proceedings*, Dec 2012, pp. 765–770.

[111] L. A. Alsulaiman and R. Alturki, "Monitoring multimedia quality of service in public cloud service level agreements," in *2012 International Conference on Multimedia Computing and Systems*, may 2012, pp. 605–609.

[112] M. Alhamad, T. Dillon, and E. Chang, "Sla-based trust model for cloud computing," in *2010 13th International Conference on Network-Based Information Systems*, Sept 2010, pp. 321–324.

[113] M. Alrokayan, A. V. Dastjerdi, and R. Buyya, "Sla-aware provisioning and scheduling of cloud resources for big data analytics," in *2014 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM)*, Oct 2014, pp. 1–8.

[114] E. Aljoumah, F. Al-Mousawi, I. Ahmad, M. Al-Shammri, and Z. Al-Jady, "Sla in cloud computing architectures: A comprehensive study," *International Journal of Grid and Distributed Computing*, vol. 8, no. 5, pp. 7–31, Oct. 2015.

[115] K. Boloor, R. Chirkova, T. Salo, and Y. Viniotis, "Management of SOA-based context-aware applications hosted in a distributed cloud subject to percentile constraints," in *2011 IEEE International Conference on Services Computing*, jul 2011, pp. 88–95.

[116] M. Boniface, B. Nasser, J. Papay, S. C. Phillips, A. Servin, X. Yang, Z. Zlatev, S. V. Gogouvitis, G. Katsaros, K. Konstanteli, G. Kousiouris, A. Menychtas, and D. Kyriazis, "Platform-as-a-service architecture for real-time quality of service management in clouds," in *2010 Fifth International Conference on Internet and Web Applications and Services*, 2010, pp. 155–160.

[117] J. Luna, T. Vateva-Gurova, N. Suri, M. Rak, and A. D. Benedictis, "SecLA-based negotiation and brokering of cloud resources," in *Communications in Computer and Information Science*, ser. Communications in Computer and Information Science. Springer Nature, 2014, vol. 453, pp. 1–18.

[118] N. Maher, P. Kavanagh, and M. Glowatz, "A vendor perspective on issues with security, governance and risk for Cloud Computing," in *BLED 2013 Proceedings*, 2013, pp. 103–114.

[119] V. Casola, A. D. Benedictis, M. Rak, and U. Villano, "SLA-based secure cloud application development: The SPECS framework," in *2015 17th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC)*, sep 2015, pp. 337–344.

[120] F. Jrad, J. Tao, and A. Streit, "SLA based service brokering in intercloud environments," in *Proceedings of the 2nd International Conference on Cloud Computing and Services Science*. Scitepress, 2012, pp. 76–81.

[121] G. Cosmin Silaghi, L. Dan Şerban, and C. Marius Litan, *A Framework for Building Intelligent SLA Negotiation Strategies under Time Constraints*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 48–61.

[122] A. V. Dastjerdi and R. Buyya, "An autonomous time-dependent SLA negotiation strategy for cloud computing," *The Computer Journal*, vol. 58, no. 11, pp. 3202–3216, jul 2015.

[123] G.-C. Apostol and F. Pop, "MICE: Monitoring high-level events in cloud environments," in *2016 IEEE 11th International Symposium on Applied Computational Intelligence and Informatics (SACI)*, may 2016, pp. 377–380.

[124] P. Bar, R. Benfredj, J. Marks, D. Ulevinov, B. Wozniak, G. Casale, and W. J. Knottenbelt, "Towards a monitoring feedback loop for cloud applications," in *Proceedings of the 2013 international workshop

on Multi-cloud applications and federated clouds - MultiCloud '13. Association for Computing Machinery (ACM), 2013, pp. 43–44.

[125] T. Atmaca, T. Begin, A. Brandwajn, and H. Castel-Taleb, "Performance evaluation of cloud computing centers with general arrivals and service," *IEEE Transactions on Parallel and Distributed Systems*, vol. 27, no. 8, pp. 2341–2348, aug 2016.

[126] J. Bi, H. Yuan, M. Tie, and W. Tan, "SLA-based optimisation of virtualised resource for multi-tier web applications in cloud data centres," *Enterprise Information Systems*, vol. 9, no. 7, pp. 743–767, sep 2013.

[127] G. Motta, L. You, D. Sacco, and N. Sfondrini, "Cloud computing: The issue of service quality: An overview of cloud service level management architectures," in *2013 Fifth International Conference on Service Science and Innovation*, may 2013, pp. 230–233.

[128] J. Butler, J. Lambea, M. Nolan, W. Theilmann, F. Torelli, R. Yahyapour, A. Chiasera, and M. Pistore, "SLAs empowering services in the future internet," in *The Future Internet*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2011, vol. 6656, pp. 327–338, dOI: 10.1007/978-3-642-20898-0_23.

[129] V. Casola, A. D. Benedictis, and M. Rak, "On the adoption of security SLAs in the cloud," in *Lecture Notes in Computer Science*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2015, vol. 8937, pp. 45–62, dOI: 10.1007/978-3-319-17199-9_2.

[130] S.-H. Na and E.-N. Huh, "A methodology of assessing security risk of cloud computing in user perspective for security-service-level agreements," in *Fourth edition of the International Conference on the Innovative Computing Technology (INTECH 2014)*, aug 2014, pp. 87–92.

[131] ——, "A broker-based cooperative security-sla evaluation methodology for personal cloud computing," *Security and Communication Networks*, vol. 8, no. 7, pp. 1318–1331, 2015, sCN-14-0044.R1.

[132] S. Klingert, T. Schulze, and C. Bunse, "GreenSLAs for the energy-efficient management of data centres," in *Proceedings of the 2nd International Conference on Energy-Efficient Computing and Networking - e-Energy '11*. Association for Computing Machinery (ACM), 2011, pp. 21–30.

[133] C. C. Marquezan, A. Metzger, R. Franklin, and K. Pohl, "Runtime management of multi-level SLAs for transport and logistics services," in *Service-Oriented Computing*. Springer Nature, 2014, pp. 560–574.

[134] F. De la Prieta, S. Heras, J. Palanca, S. Rodriguez, J. Bajo, and V. Julian, "Real-time agreement and fulfilment of SLAs in Cloud Computing environments," *AI Communications*, vol. 28, no. 3, pp. 403–426, 2015.

[135] M. B. Chhetri, Q. B. Vo, and R. Kowalczyk, "Supporting temporal aspects of SLA establishment in auto SLAM framework," in *2015 IEEE International Conference on Services Computing*, jun 2015, pp. 234–241.

[136] K. Bernsmed, M. Jaatun, and A. Undheim, "Security in Service Level Agreements for Cloud computing," in *Proceedings of the 1st International Conference on Cloud Computing and Services Science*, 2011, pp. 636–642.

[137] A. Bertolino, A. Calabrò, and G. De Angelis, *A Generative Approach for the Adaptive Monitoring of SLA in Service Choreographies*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 408–415.

[138] I. Brandic, V. C. Emeakaroha, M. Maurer, S. Dustdar, S. Acs, A. Kertesz, and G. Kecskemeti, "LAYSI: A layered approach for SLA-violation propagation in self-manageable cloud infrastructures," in *2010 IEEE 34th Annual Computer Software and Applications Conference Workshops*, jul 2010, pp. 365–370.

[139] V. Cardellini, E. Casalicchio, F. L. Presti, and L. Silvestri, "SLA-aware resource management for application service providers in the cloud," in *2011 First International Symposium on Network Cloud Computing and Applications*, nov 2011, pp. 20–27.

[140] A. L. Freitas, N. Parlavantzas, and J.-L. Pazat, "Cost reduction through SLA-driven self-management," in *2011 IEEE Ninth European Conference on Web Services*, sep 2011, pp. 117–124.

[141] A. Hammadi, O. K. Hussain, T. Dillon, and F. K. Hussain, "A framework for sla management in cloud computing for informed decision making," *Cluster Computing*, vol. 16, no. 4, pp. 961–977, 2013.

[142] T. Nodehi, S. Ghimire, and R. Jardim-Goncalves, "A computing resource selection approach based on Genetic Algorithm for inter-cloud workload migration," 2014, pp. 271–277.

[143] M. Parhi, B. K. Pattanayak, and M. R. Patra, "A multi-agent-based framework for cloud service description and discovery using ontology," in *Advances in Intelligent Systems and Computing*, ser. Advances in Intelligent Systems and Computing. Springer Nature, aug 2014, vol. 308 AISC, pp. 337–348, dOI: 10.1007/978-81-322-2012-1_35.

[144] A. Meskini, Y. Taher, A. E. gammal, B. Finance, and Y. Slimani, "Proactive learning from SLA violation in cloud service based application," in *Proceedings of the 6th International Conference on Cloud Computing and Services Science*, vol. 1. Scitepress, 2016, pp. 186–193.

[145] K. Oberle, M. Stein, T. Voith, G. Gallizo, and R. Kubert, "The network aspect of infrastructure-as-a-service," in *2010 14th International Conference on Intelligence in Next Generation Networks*, oct 2010.

[146] M. Macías and J. Guitart, "Analysis of a trust model for SLA negotiation and enforcement in cloud markets," *Future Generation Computer Systems*, vol. 55, pp. 460–472, feb 2016.

[147] F. Alsrheed, A. E. Rhalibi, M. Randles, and M. Merabti, "Intelligent agents for automated cloud computing negotiation," in *2014 International Conference on Multimedia Computing and Systems (ICMCS)*, vol. 0, apr 2014, pp. 1169–1174.

[148] R. Bose, S. Sahana, and D. Sarddar, "An adaptive cloud service observation using billboard manager cloud monitoring tool," *International Journal of Software Engineering and its Applications*, vol. 9, no. 7, pp. 159–170, jul 2015.

[149] P. Cedillo, J. Jimenez-Gomez, S. Abrahao, and E. Insfran, "Towards a monitoring middleware for cloud services," in *2015 IEEE International Conference on Services Computing*, jun 2015, pp. 451–458.

[150] S. Chakraborty and K. Roy, "An SLA-based framework for estimating trustworthiness of a cloud," in *2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications*, jun 2012, pp. 937–942.

[151] L. De Marco, F. Ferrucci, and M.-T. Kechadi, "SLAFM - a service level agreement formal model for cloud computing," in *Proceedings of the 5th International Conference on Cloud Computing and Services Science*. Scitepress, 2015, pp. 521–528.

[152] R. Karim, C. Ding, A. Miri, and X. Liu, "End-to-end QoS mapping and aggregation for selecting cloud services," in *2014 International Conference on Collaboration Technologies and Systems (CTS)*, may 2014, pp. 515–522.

[153] T. Kirkham, D. Armstrong, K. Djemame, M. Corrales, M. Kiran, I. Nwankwo, M. Jiang, and N. Forgo, "Assuring data privacy in cloud transformations," in *2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications*, jun 2012, pp. 1063–1069.

[154] J. M. Pedersen, M. T. Riaz, J. C. Junior, B. Dubalski, D. Ledzinski, and A. Patel, "Assessing measurements of QoS for global cloud computing services," in *2011 IEEE Ninth International Conference on Dependable, Autonomic and Secure Computing*, dec 2011, pp. 682–689.

[155] M. M. Qiu, Y. Zhou, and C. Wang, "Systematic analysis of public cloud service level agreements and related business values," in *2013 IEEE International Conference on Services Computing*, jun 2013, pp. 729–736.

[156] G. Peng, J. Zhao, M. Li, B. Hou, and H. Zhang, "A SLA-based scheduling approach for multi-tenant cloud simulation," in *2015 IEEE 19th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, may 2015, pp. 600–605.

[157] M. Risch, I. Brandic, and J. Altmann, "Using SLA mapping to increase market liquidity," in *Service-Oriented Computing. ICSOC/ServiceWave 2009 Workshops*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2010, vol. 6275 LNCS, pp. 238–247, dOI: 10.1007/978-3-642-16132-2_23.

[158] V. Binu and N. D. Gangadhar, "A cloud computing service level agreement framework with negotiation and secure monitoring," in *2014 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM)*, Oct 2014, pp. 1–8.

[159] I. Brandic, D. Music, P. Leitner, and S. Dustdar, "VieSLAF framework: Enabling adaptive and versatile SLA-management," in *Lecture Notes in Computer Science*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2009, vol. 5745 LNCS, pp. 60–73, dOI: 10.1007/978-3-642-03864-8_5.

[160] K. P. Clark, M. Warnier, and F. M. Brazier, "Self-adaptive service level agreement monitoring in cloud environments 1," *Multiagent and Grid Systems*, vol. 9, no. 2, pp. 135–155, Aug 2013.

[161] V. C. Emeakaroha, I. Brandic, M. Maurer, and S. Dustdar, "Cloud resource provisioning and SLA enforcement via LoM2his framework,"

Concurrency Computation Practice and Experience, vol. 25, no. 10, pp. 1462–1481, oct 2012.
[162] S. Ding, S. Yang, Y. Zhang, C. Liang, and C. Xia, "Combining QoS prediction and customer satisfaction estimation to solve cloud service trustworthiness evaluation problems," *Knowledge-Based Systems*, vol. 56, pp. 216–225, jan 2014.
[163] W. Iqbal, M. N. Dailey, D. Carrera, and P. Janecek, "Adaptive resource provisioning for read intensive multi-tier applications in the cloud," *Future Generation Computer Systems*, vol. 27, no. 6, pp. 871–879, jun 2011.
[164] Y. Kouki and T. Ledoux, "CSLA: A language for improving cloud SLA management," in *Proceedings of the 2nd International Conference on Cloud Computing and Services Science*. Scitepress, 2012, pp. 586–591.
[165] Y. Kouki, F. A. d. Oliveira, S. Dupont, and T. Ledoux, "A language support for cloud elasticity management," in *2014 14th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing*, May 2014, pp. 206–215.
[166] K. Radha, S. M. Babu, and B. T. Rao, "A relative study on service level agreements in cloud computing," in *2015 Global Conference on Communication Technologies (GCCT)*, apr 2015, pp. 66–71.
[167] M. Rady, "Parameters for service level agreements generation in cloud computing," in *Lecture Notes in Computer Science*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7518 LNCS, pp. 13–22, dOI: 10.1007/978-3-642-33999-8_3.
[168] D. Serrano, S. Bouchenak, Y. Kouki, T. Ledoux, J. Lejeune, J. Sopena, L. Arantes, and P. Sens, "Towards QoS-oriented SLA guarantees for online cloud services," in *2013 13th IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing*, may 2013, pp. 50–57.
[169] R. B. Uriarte, F. Tiezzi, and R. D. Nicola, "SLAC: A formal service-level-agreement language for cloud computing," in *2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing*, dec 2014, pp. 419–426.
[170] A. de Benedictis, M. Rak, M. Turtur, and U. Villano, "REST-based SLA management for cloud applications," in *2015 IEEE 24th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises*, jun 2015, pp. 93–98.
[171] A. L. Freitas, N. Parlavantzas, and J.-L. Pazat, "A QoS assurance framework for distributed infrastructures," in *Proceedings of the 3rd International Workshop on Monitoring, Adaptation and Beyond - MONA '10*. Association for Computing Machinery (ACM), 2010, pp. 1–8.
[172] V. C. Emeakaroha, T. C. Ferreto, M. A. S. Netto, I. Brandic, and C. A. F. D. Rose, "CASViD: Application level monitoring for SLA violation detection in clouds," in *2012 IEEE 36th Annual Computer Software and Applications Conference*, jul 2012, pp. 499–508.
[173] A. Chandrasekar, K. Chandrasekar, M. Mahadevan, and P. Varalakshmi, "QoS monitoring and dynamic trust establishment in the cloud," in *Advances in Grid and Pervasive Computing*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7296 LNCS, pp. 289–301, dOI: 10.1007/978-3-642-30767-6_25.
[174] J. Sidhu and S. Singh, "Compliance based trustworthiness calculation mechanism in cloud environment," *Procedia Computer Science*, vol. 37, pp. 439–446, 2014.
[175] R. Abdullah and A. M. Talib, "Towards integrating information of service level agreement and resources as a services (raas) for cloud computing environment," in *2012 IEEE Conference on Open Systems*, Oct 2012, pp. 1–5.
[176] T. Labidi, A. Mtibaa, and H. Brabra, "CSLAOnto: A comprehensive ontological SLA model in cloud computing," *Journal on Data Semantics*, vol. 5, no. 3, pp. 179–193, aug 2016.
[177] T. Labidi, A. Mtibaa, and F. Gargouri, "Ontology-based context-aware SLA management for cloud computing," in *Model and Data Engineering*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2014, vol. 8748, pp. 193–208.
[178] M. Rady, "Formal definition of service availability in cloud computing using OWL," in *Computer Aided Systems Theory - EUROCAST 2013*. Springer Nature, 2013, pp. 189–194, dOI: 10.1007/978-3-642-53856-8-24.
[179] ——, "Generating an excerpt of a service level agreement from a formal definition of non-functional aspects using owl," *JUCS - Journal of Universal Computer Science*, vol. 20, no. 3, pp. 366–384, Mar 2014.
[180] R. B. Uriarte, F. Tiezzi, and R. D. Nicola, "Dynamic SLAs for clouds," in *Service-Oriented and Cloud Computing*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2016, vol. 9846, pp. 34–49, dOI: 10.1007/978-3-319-44482-6_3.
[181] M. Wang, X. Wu, W. Zhang, F. Ding, J. Zhou, and G. Pei, "A conceptual platform of sla in cloud computing," in *2011 IEEE Ninth International Conference on Dependable, Autonomic and Secure Computing*, Dec 2011, pp. 1131–1135.
[182] A. Galati, K. Djemame, M. Fletcher, M. Jessop, M. Weeks, and J. McAvoy, "A WS-agreement based SLA implementation for the CMAC platform," in *Economics of Grids, Clouds, Systems, and Services*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2014, vol. 8914, pp. 159–171, dOI: 10.1007/978-3-319-14609-6_11.
[183] R. L. Gomes, L. F. Bittencourt, and E. R. M. Madeira, "A generic sla negotiation protocol for virtualized environments," in *2012 18th IEEE International Conference on Networks (ICON)*, Dec 2012, pp. 7–12.
[184] Í. Goiri, F. Julià, J. O. Fitó, M. Macías, and J. Guitart, "Supporting CPU-based guarantees in cloud SLAs via resource-level QoS metrics," *Future Generation Computer Systems*, vol. 28, no. 8, pp. 1295–1302, oct 2012.
[185] D. Serrano, S. Bouchenak, Y. Kouki, F. A. de Oliveira Jr., T. Ledoux, J. Lejeune, J. Sopena, L. Arantes, and P. Sens, "SLA guarantees for cloud services," *Future Generation Computer Systems*, vol. 54, pp. 233–246, jan 2016.
[186] A.-F. Antonescu, A.-M. Oprescu, Y. Demchenko, C. de Laat, and T. Braun, "Dynamic optimization of SLA-based services scaling rules," in *2013 IEEE 5th International Conference on Cloud Computing Technology and Science*, vol. 1, dec 2013, pp. 282–289.
[187] F. Bianchi and F. L. Presti, "QoS-aware application placement over distributed cloud," in *2016 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, may 2016, pp. 742–747.
[188] T. Labidi, A. Mtibaa, and F. Gargouri, "SLA ontology-based elasticity in cloud computing," in *Communications in Computer and Information Science*, ser. Communications in Computer and Information Science. Springer Nature, 2015, vol. 539, pp. 145–152, dOI: 10.1007/978-3-319-23201-0_17.
[189] A. Maarouf, M. E. Hamlaoui, A. Marzouk, and A. Haqiq, "Combining multi-agent systems and MDE approach for monitoring SLA violations in the Cloud Computing," in *2015 International Conference on Cloud Technologies and Applications (CloudTech)*, jun 2015.
[190] Y.-R. Shin and E.-N. Huh, "QoE metrics aggregation for hierarchical service level agreement in cross-layered SLA architecture," in *2015 Seventh International Conference on Ubiquitous and Future Networks*, vol. 2015-August, jul 2015, pp. 831–836.
[191] K. Stamou, J.-H. Morin, B. Gateau, and J. Aubert, "Service level agreements as a service: Towards security risks aware SLA management," in *Proceedings of the 2nd International Conference on Cloud Computing and Services Science*. Scitepress, 2012, pp. 663–669.
[192] Z. Wang, X. Tang, and X. Luo, "Policy-based SLA-aware cloud service provision framework," in *2011 Seventh International Conference on Semantics, Knowledge and Grids*, oct 2011, pp. 114–121.
[193] F. Zhu, H. Li, and J. Lu, "A service level agreement framework of cloud computing based on the cloud bank model," in *2012 IEEE International Conference on Computer Science and Automation Engineering (CSAE)*, vol. 1, may 2012, pp. 255–259.
[194] G. Zhien and D. Yiqi, "Security SLAs for IMS-based cloud services," in *2012 Seventh ChinaGrid Annual Conference*, sep 2012, pp. 57–60.
[195] W. Halboob, H. Abbas, K. Haouam, and A. Yaseen, "Dynamically changing service level agreements (SLAs) management in cloud computing," in *Intelligent Computing Methodologies*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2014, vol. 8589 LNAI, pp. 434–443, dOI: 10.1007/978-3-319-09339-0_44.
[196] O. Adinolfi, R. Cristaldi, L. Coppolino, and L. Romano, "Qos-monaas: A portable architecture for qos monitoring in the cloud," in *2012 Eighth International Conference on Signal Image Technology and Internet Based Systems*, Nov 2012, pp. 527–532.
[197] K. Alhamazani, R. Ranjan, K. Mitra, P. P. Jayaraman, Z. Huang, L. Wang, and F. Rabhi, "Clams: Cross-layer multi-cloud application monitoring-as-a-service framework," in *2014 IEEE International Conference on Services Computing*, June 2014, pp. 283–290.

[198] V. Casola, M. Rak, and G. Alfieri, "A cloud application for security service level agreement evaluation," in *4th International Conference on Cloud Computing and Services Science*, ser. CLOSER 2014, 2014, pp. 299–307.

[199] S. M. Ghoreyshi, "Energy-efficient resource management of cloud datacenters under fault tolerance constraints," in *2013 International Green Computing Conference Proceedings*, jun 2013.

[200] A. Maarouf, B. E. qacimy, A. Marzouk, and A. Haqiq, "A novel penalty model for managing and applying penalties in cloud computing," in *2015 IEEE/ACS 12th International Conference of Computer Systems and Applications (AICCSA)*, vol. 2016-July, nov 2015.

[201] N. Mavrogeorgi, V. Alexandrou, S. Gogouvitis, A. Voulodimos, D. Kiriazis, T. Varvarigou, and E. K. Kolodner, "Customized SLAs in cloud environments," in *2013 Eighth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, oct 2013, pp. 262–269.

[202] M. Su, H. Li, S. Yang, and J. Lu, "A service level agreement for the resource transaction risk based on cloud bank model," in *2012 International Conference on Cloud and Service Computing*, nov 2012, pp. 198–203.

[203] I. Ayadi, N. Simoni, and T. Aubonnet, "SLA approach for "cloud as a service"," in *2013 IEEE Sixth International Conference on Cloud Computing*, jun 2013, pp. 966–967.

[204] K.-C. Huang, M.-J. Tsai, S.-J. Lu, and C.-H. Hung, "SLA-constrained service selection for minimizing costs of providing composite cloud services under stochastic runtime performance," *SpringerPlus*, vol. 5, no. 1, mar 2016.

[205] M. Hamze, N. Mbarek, and O. Togni, "Self-establishing a service level agreement within autonomic cloud networking environment," in *2014 IEEE Network Operations and Management Symposium (NOMS)*, may 2014.

[206] ——, "Autonomic brokerage service for an end-to-end cloud networking service level agreement," in *2014 IEEE 3rd Symposium on Network Cloud Computing and Applications (ncca 2014)*, feb 2014, pp. 54–61.

[207] O. Anya, H. Ludwig, M. Mohamed, and S. Tata, "SLA analytics for adaptive service provisioning in the cloud," in *NOMS 2016 - 2016 IEEE/IFIP Network Operations and Management Symposium*, apr 2016, pp. 1093–1096.

[208] S. Bardhan and D. Milojicic, "A mechanism to measure quality-of-service in a federated cloud environment," in *Proceedings of the 2012 workshop on Cloud services, federation, and the 8th open cirrus summit - FederatedClouds '12*. Association for Computing Machinery (ACM), 2012, pp. 19–24.

[209] R. Houlihan, X. Du, C. C. Tan, J. Wu, and M. Guizani, "Auditing cloud service level agreement on VM CPU speed," in *2014 IEEE International Conference on Communications (ICC)*, jun 2014, pp. 799–803.

[210] O. Illoh, S. Aghili, and S. Butakov, "Using COBIT 5 for risk to develop cloud computing SLA evaluation templates," in *Service-Oriented Computing - ICSOC 2014 Workshops*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2015, vol. 8954, pp. 236–249, dOI: 10.1007/978-3-319-22885-3_21.

[211] G. Motta, L. You, N. Sfondrini, D. Sacco, and T. Ma, "Service level management (SLM) in cloud computing - third party SLM framework," in *2014 IEEE 23rd International WETICE Conference*, jun 2014, pp. 353–358.

[212] R. Rajavel and M. T, "SLAOCMS: A layered architecture of SLA oriented cloud management system for achieving agreement during resource failure," in *Advances in Intelligent Systems and Computing*, ser. Advances in Intelligent Systems and Computing. Springer Nature, 2014, vol. 236, pp. 801–809, dOI: 10.1007/978-81-322-1602-5_85.

[213] T. Aubonnet and N. Simoni, "Self-control cloud services," in *2014 IEEE 13th International Symposium on Network Computing and Applications*, aug 2014, pp. 282–286.

[214] B. R. Kandukuri, R. P. V., and A. Rakshit, "Cloud security issues," *2009 IEEE International Conference on Services Computing*, pp. 517–520, 2009.

[215] A. J. Gonzalez and B. E. Helvik, "System management to comply with sla availability guarantees in cloud computing," in *4th IEEE International Conference on Cloud Computing Technology and Science Proceedings*, dec 2012, pp. 325–332.

[216] H. Zhang, P. Li, and Z. Zhou, "Performance difference prediction in cloud services for SLA-based auditing," *9th IEEE International Symposium on Service-Oriented System Engineering (SOSE 2015)*, pp. 253–258, mar 2015.

[217] A. F. M. Hani, I. V. Paputungan, and M. F. Hassan, "Renegotiation in service level agreement management for a cloud-based system," *ACM Computing Surveys*, vol. 47, no. 3, pp. 1–21, apr 2015.

[218] O. Hussain, H. Dong, and J. Singh, "Semantic similarity model for risk assessment in forming cloud computing SLAs," in *On the Move to Meaningful Internet Systems, OTM 2010*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2010, vol. 6427 LNCS, pp. 843–860, dOI: 10.1007/978-3-642-16949-6_12.

[219] C. Bin, W. Zhijian, and W. Yu, "Performance collection model with agent and server interface for cloud computing," in *2012 7th International Conference on Computing and Convergence Technology (ICCCT)*, 2012, pp. 466–471.

[220] S. Ferretti, V. Ghini, F. Panzieri, M. Pellegrini, and E. Turrini, "QoS-aware clouds," in *2010 IEEE 3rd International Conference on Cloud Computing*, jul 2010, pp. 321–328.

[221] F. Jrad, J. Tao, I. Brandic, and A. Streit, "Multi-dimensional resource allocation for data-intensive large-scale cloud applications," in *Proceedings of the 4th International Conference on Cloud Computing and Services Science*. Scitepress, 2014, pp. 691–702.

[222] G. Landi, P. M. Neves, A. Edmonds, T. Metsch, J. Mueller, and P. S. Crosta, "SLA management and service composition of virtualized applications in mobile networking environments," in *2014 IEEE Network Operations and Management Symposium (NOMS)*, may 2014.

[223] M. Rak, R. Aversa, S. Venticinque, and B. D. Martino, "User centric service level management in mOSAIC applications," in *Euro-Par 2011: Parallel Processing Workshops*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7156 LNCS, pp. 106–115, dOI: 10.1007/978-3-642-29740-3-13.

[224] M. Rak, A. Cuomo, and U. Villano, "A proposal of a simulation-based approach for service level agreement in cloud," in *2013 27th International Conference on Advanced Information Networking and Applications Workshops*, mar 2013, pp. 1235–1240.

[225] L. Zhao, S. Sakr, and A. Liu, "Consumer-centric SLA manager for cloud-hosted databases," in *Proceedings of the 22nd ACM international conference on Conference on information & knowledge management - CIKM '13*. Association for Computing Machinery (ACM), 2013.

[226] K. Stamou, "Systematic SLA data management," 2014.

[227] D. Lučanin, F. Jrad, I. Brandic, and A. Streit, "Energy-aware cloud management through progressive SLA specification," in *Economics of Grids, Clouds, Systems, and Services*, J. Altmann, K. Vanmechelen, and O. F. Rana, Eds. Cham: Springer Nature, 2014, pp. 83–98.

[228] E. Mostajeran, B. I. Ismail, M. F. Khalid, and H. Ong, "A survey on SLA-based brokering for inter-cloud computing," *2015 Second International Conference on Computing Technology and Information Management (Icctim)*, pp. 25–31, apr 2015.

[229] F. Jrad, J. Tao, A. Streit, R. Knapper, and C. Flath, "A utility-based approach for customised cloud service selection," *International Journal of Computational Science and Engineering*, vol. 10, no. 1, pp. 32–44, 2015.

[230] L. Liccardo, M. Rak, G. D. Modica, and O. Tomarchio, "Ontology-based negotiation of security requirements in cloud," in *2012 Fourth International Conference on Computational Aspects of Social Networks (CASoN)*, nov 2012, pp. 192–197.

[231] A. M. Hammadi and O. Hussain, "A framework for sla assurance in cloud computing," in *2012 26th International Conference on Advanced Information Networking and Applications Workshops*, March 2012, pp. 393–398.

[232] J.-Y. Hu, C.-H. Wu, C.-C. Chu, K.-H. Liang, H.-C. Young, Y.-Y. Hsu, C.-H. Hu, and H.-G. Lin, "Constructing a cloud-centric service assurance platform for computing as a service," in *2011 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery*, oct 2011, pp. 139–145.

[233] C.-Y. Lee, K. M. Kavi, R. A. Paul, and M. Gomathisankaran, "Ontology of secure service level agreement," in *2015 IEEE 16th International Symposium on High Assurance Systems Engineering*, vol. 2015-January, jan 2015, pp. 166–172.

[234] D. Liu, U. Kanabar, and C.-H. Lung, "A light weight SLA management infrastructure for cloud computing," in *2013 26th IEEE Canadian Conference on Electrical and Computer Engineering (CCECE)*, may 2013.

[235] M. Rak, N. Suri, J. Luna, D. Petcu, V. Casola, and U. Villano, "Security as a service using an SLA-based approach via SPECS," in *2013 IEEE 5th International Conference on Cloud Computing Technology and Science*, vol. 2, dec 2013, pp. 1–6.

[236] D. Rane and M. Sarma, "CSLAT: an SLA template for cloud service management," *International Journal of Communication Networks and Distributed Systems*, vol. 14, no. 1, pp. 19–39, 2015.

[237] D. Stamatakis and O. Papaemmanouil, "SLA-driven workload management for cloud databases," in *2014 IEEE 30th International Conference on Data Engineering Workshops*, mar 2014, pp. 178–181.

[238] S. S. Wagle, "SLA assured brokering (SAB) and CSP certification in cloud computing," in *2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing*, dec 2014, pp. 1016–1017.

[239] K. Lu, R. Yahyapour, E. Yaqub, and C. Kotsokalis, "Structural optimization of reduced ordered binary decision diagrams for SLA negotiation in IaaS of cloud computing," in *Service-Oriented Computing*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7636 LNCS, pp. 268–282, dOI: 10.1007/978-3-642-34321-6-18.

[240] J. Luna, N. Suri, M. Iorga, and A. Karmel, "Leveraging the potential of cloud security service-level agreements through standards," *IEEE Cloud Computing*, vol. 2, no. 3, pp. 32–40, may 2015.

[241] W. Hussain, F. K. Hussain, O. Hussain, and E. Chang, "Profile-based viable service level agreement (SLA) violation prediction model in the cloud," in *2015 10th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC)*, nov 2015, pp. 268–272.

[242] A. I. Jehangiri, E. Yaqub, and R. Yahyapour, "Practical aspects for effective monitoring of SLAs in cloud computing and virtual platforms," in *Proceedings of the 3rd International Conference on Cloud Computing and Services Science*. Scitepress, 2013, pp. 447–454.

[243] Y. C. Lee, C. Wang, A. Y. Zomaya, and B. B. Zhou, "Profit-driven cloud service request scheduling under SLA constraints," *Journal of Information and Computational Science*, vol. 9, no. 14, pp. 4065–4073, 2012.

[244] M. Maurer, I. Brandic, V. C. Emeakaroha, and S. Dustdar, "Towards knowledge management in self-adaptable clouds," in *2010 6th World Congress on Services*, jul 2010, pp. 527–534.

[245] S. Sakr and A. Liu, "SLA-based and consumer-centric dynamic provisioning for cloud databases," in *2012 IEEE Fifth International Conference on Cloud Computing*, jun 2012, pp. 360–367.

[246] H. S. Salem, H. F. E. Yamany, and G. S. E. Tawel, "Towards service level agreements engineering process in cloud computing," *International Journal of Internet Manufacturing and Services*, vol. 3, no. 4, pp. 300–328, 2014.

[247] J. L. Garcia, T. Vateva-Gurova, N. Suri, M. Rak, and L. Liccardo, "Negotiating and brokering cloud resources based on security level agreements," in *Proceedings of the 3rd International Conference on Cloud Computing and Services Science*. Scitepress, 2013, pp. 533–541.

[248] A. Maarouf, M. E. Hamlaoui, A. Marzouk, and A. Haqiq, "MDE approach for the establishment of a service level agreements monitoring by trusted third party in the cloud computing," *International Journal of Grid and High Performance Computing*, vol. 7, no. 4, pp. 1–20, oct 2015.

[249] K. P. Joshi and C. Pearce, "Automating cloud service level agreements using semantic technologies," in *2015 IEEE International Conference on Cloud Engineering*, mar 2015, pp. 416–421.

[250] H. M. Khan, G.-Y. Chan, and F.-F. Chua, "An adaptive monitoring framework for ensuring accountability and quality of services in cloud computing," in *2016 International Conference on Information Networking (ICOIN)*, vol. 2016-March, jan 2016, pp. 249–253.

[251] M. Maurer, I. Brandic, and R. Sakellariou, "Simulating autonomic SLA enactment in clouds using case based reasoning," in *Towards a Service-Based Internet*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2010, vol. 6481 LNCS, pp. 25–36, dOI: 10.1007/978-3-642-17694-4_3.

[252] ——, "Enacting SLAs in clouds using rules," in *Euro-Par 2011 Parallel Processing*. Springer Nature, 2011, pp. 455–466, dOI: 10.1007/978-3-642-23400-2_42.

[253] N. Sfondrini, G. Motta, and L. You, "Service level agreement (SLA) in public cloud environments: A survey on the current enterprises adoption," in *2015 5th International Conference on Information Science and Technology (ICIST)*, apr 2015, pp. 181–185.

[254] K. Stamou, V. Kantere, and J.-H. Morin, "SLA data management criteria," in *2013 IEEE International Conference on Big Data*, oct 2013, pp. 34–42.

[255] J. Spillner and A. Schill, "Dynamic SLA template adjustments based on service property monitoring," in *2009 IEEE International Conference on Cloud Computing*, Sep. 2009, pp. 183–189.

[256] A. Longo, M. A. Bochicchio, and B. Livieri, "Does service composition suffice to define business contracts for IT services in networked organizations," in *Proceedings of the Fifth International Conference on Management of Emergent Digital EcoSystems - MEDES '13*. 2536153: Association for Computing Machinery (ACM), 2013, pp. 195–202.

[257] A. Maarouf, A. Marzouk, and A. Haqiq, "A review of SLA specification languages in the cloud computing," in *2015 10th International Conference on Intelligent Systems: Theories and Applications (SITA)*, oct 2015.

[258] M. Macías and J. Guitart, *Client Classification Policies for SLA Negotiation and Allocation in Shared Cloud Datacenters*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7150 LNCS, dOI: 10.1007/978-3-642-28675-9_7.

[259] S.-Y. Lee, D. Tang, T. Chen, and W. C.-C. Chu, "A QoS assurance middleware model for enterprise cloud computing," in *2012 IEEE 36th Annual Computer Software and Applications Conference Workshops*, jul 2012, pp. 322–327.

[260] X. Liu and F. Xu, "Cloud service monitoring system based on SLA," in *2013 12th International Symposium on Distributed Computing and Applications to Business, Engineering & Science*, sep 2013, pp. 137–141.

[261] I. S. Moreno and J. Xu, "Customer-aware resource overallocation to improve energy efficiency in realtime cloud computing data centers," in *2011 IEEE International Conference on Service-Oriented Computing and Applications (SOCA)*, dec 2011.

[262] F. Motavaselalhagh, F. S. Esfahani, and H. R. Arabnia, "Knowledge-based adaptable scheduler for SaaS providers in cloud computing," *Human-centric Computing and Information Sciences*, vol. 5, no. 1, jun 2015.

[263] M. Torkashvan and H. Haghighi, "CSLAM: A framework for cloud service level agreement management based on WSLA," in *6th International Symposium on Telecommunications (IST)*, nov 2012, pp. 577–585.

[264] L. Wu, S. K. Garg, and R. Buyya, "Service level agreement(SLA) based SaaS cloud management system," in *2015 IEEE 21st International Conference on Parallel and Distributed Systems (ICPADS)*, vol. 2016-January, dec 2016, pp. 440–447.

[265] M. Maurer, V. C. Emeakaroha, I. Brandic, and J. Altmann, "Cost-benefit analysis of an SLA mapping approach for defining standardized cloud computing goods," *Future Generation Computer Systems*, vol. 28, no. 1, pp. 39–47, jan 2012.

[266] A. Longo, M. Zappatore, and M. A. Bochicchio, "Service level aware - contract management," jun 2015.

[267] D. Marudhadevi, V. N. Dhatchayani, and V. S. Sriram, "A trust evaluation model for cloud computing using service level agreement," *The Computer Journal*, vol. 58, no. 10, pp. 2225–2232, nov 2014.

[268] H. Ludwig, K. Stamou, M. Mohamed, N. Mandagere, B. Langston, G. Alatorre, H. Nakamura, O. Anya, and A. Keller, *rSLA: Monitoring SLAs in Dynamic Service Environments*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2015, vol. 9435, dOI: 10.1007/978-3-662-48616-0_9.

[269] A. Maarouf, A. Marzouk, A. Haqiq, and M. E. Hamlaoui, "Towards a MDE approach for the establishment of a contract service level monitoring by third party in the cloud computing," in *2014 Tenth International Conference on Signal-Image Technology and Internet-Based Systems*, nov 2014, pp. 715–720.

[270] M. K. Muchahari and S. K. Sinha, "A new trust management architecture for cloud computing environment," in *2012 International Symposium on Cloud and Services Computing*, dec 2012, pp. 136–140.

[271] S. Mustafa, K. Bilal, S. A. Madani, N. Tziritas, S. U. Khan, and L. T. Yang, "Performance evaluation of energy-aware best fit decreasing algorithms for cloud environments," in *2015 IEEE International Conference on Data Science and Data Intensive Systems*, dec 2015, pp. 464–469.

[272] Z. Zhang, L. Liao, H. Liu, and G. Li, "Policy-based adaptive service level agreement management for cloud services," in *2014 IEEE 5th International Conference on Software Engineering and Service Science*, jun 2014, pp. 496–499.

[273] L. Zhao, S. Sakr, and A. Liu, "A framework for consumer-centric sla management of cloud-hosted databases," *IEEE Transactions on Services Computing*, vol. 8, no. 4, pp. 534–549, July 2015.

[274] L. Ye, H. Zhang, J. Shi, and X. Du, "Verifying cloud service level agreement," in *2012 IEEE Global Communications Conference (GLOBECOM)*, dec 2012.

[275] R. Alsoghayer and K. Djemame, "Resource failures risk assessment modelling in distributed environments," *Journal of Systems and Software*, vol. 88, pp. 42–53, feb 2014.

[276] N. A. Mehdi, A. Mamat, H. Ibrahim, and S. K. Subramaniam, "On the fly negotiation for urgent service level agreement on intercloud environment," *Journal of Computer Science*, vol. 7, no. 10, pp. 1596–1604, oct 2011.

[277] F. Messina, G. Pappalardo, C. Santoro, D. Rosaci, and G. M. Sarne, "An agent based negotiation protocol for cloud service level agreements," in *2014 IEEE 23rd International WETICE Conference*, jun 2014, pp. 161–166.

[278] T. Mastelic, V. C. Emeakaroha, M. Maurer, and I. Brandic, "M4cloud - Generic application level monitoring for resource-shared cloud environments," in *Proceedings of the 2nd International Conference on Cloud Computing and Services Science*. Scitepress, 2012, pp. 522–532.

[279] M. Maurer, I. Breskovic, V. C. Emeakaroha, and I. Brandic, "Revealing the MAPE loop for the autonomic management of cloud infrastructures," in *2011 IEEE Symposium on Computers and Communications (ISCC)*, jun 2011, pp. 147–152.

[280] B. Nagel, C. Gerth, E. Yigitbas, F. Christ, and G. Engels, "Model-driven specification of adaptive cloud-based systems," in *Proceedings of the 1st International Workshop on Model-Driven Engineering for High Performance and CLoud computing - MDHPCL '12*. Association for Computing Machinery (ACM), 2012.

[281] B. B. Nandi, A. Banerjee, S. C. Ghosh, and N. Banerjee, "Dynamic SLA based elastic cloud service management: A SaaS perspective," in *2013 IFIP/IEEE International Symposium on Integrated Network Management (IM 2013)*, 2013, pp. 60–67.

[282] K. Stamou, V. Kantere, J.-H. Morin, and M. Georgiou, "SLA information management through dependency digraphs: The case of cloud data services," in *2014 47th Hawaii International Conference on System Sciences*, ser. Proceedings of the Annual Hawaii International Conference on System Sciences, R. H. Sprague, Ed., jan 2014, pp. 5038–5047, dOI: 10.1109/hicss.2014.618.

[283] C. Redl, I. Breskovic, I. Brandic, and S. Dustdar, "Automatic SLA matching and provider selection in grid and cloud computing markets," *2012 Acm/Ieee 13th International Conference on Grid Computing (Grid)*, pp. 85–94, sep 2012.

[284] F. Messina, G. Pappalardo, C. Santoro, D. Rosaci, and G. M. Sarné, "A multi-agent protocol for service level agreement negotiation in cloud federations," *International Journal of Grid and Utility Computing*, vol. 7, no. 2, pp. 101–112, 2016.

[285] V. Nae, R. Prodan, and A. Iosup, "SLA-based operation of massively multiplayer online games in competition-based environments," in *Proceedings of the International C* Conference on Computer Science and Software Engineering - C3S2E '13*. Association for Computing Machinery (ACM), 2013, pp. 104–112.

[286] A. Mdhaffar, R. B. Halima, E. Juhnke, M. Jmaiel, and B. Freisleben, "AOP4csm: An aspect-oriented programming approach for cloud service monitoring," in *2011 IEEE 11th International Conference on Computer and Information Technology*, aug 2011, pp. 363–370.

[287] S. Mittal, K. P. Joshi, C. Pearce, and A. Joshi, "Automatic extraction of metrics from SLAs for cloud service management," in *2016 IEEE International Conference on Cloud Engineering (IC2E)*, apr 2016, pp. 139–142.

[288] M. A. Rahim, I. U. Haq, H. Durad, and E. Schikuta, "Generalized SLA enforcement framework using feedback control system," in *2015 12th International Conference on High-capacity Optical Networks and Enabling/Emerging Technologies (HONET)*, dec 2015.

[289] K. Ravindran, A. Adiththan, and M. Iannelli, "SLA evaluation with on-the-fly measurements of distributed service implementation over clouds," in *Proceedings of the 6th International Workshop on Principles of Engineering Service-Oriented and Cloud Systems - PESOS 2014*. Association for Computing Machinery (ACM), 2014, pp. 1–10.

[290] T. Guo-Chun and W. Yan-Ping, "Research on the model for cloud security based on SLA," in *Proceedings of the 1st International Workshop on Cloud Computing and Information Security*, ser. Advances in Intelligent Systems Research, A. Datta, Ed. Atlantis Press, 2013, vol. 52, pp. 473–476.

[291] P. A. Frangoudis, A. Sgora, M. Varela, and G. Rubino, "Quality-driven optimal SLA selection for enterprise cloud communications," in *2014 IEEE International Conference on Communications Workshops (ICC)*, jun 2014, pp. 545–550.

[292] A. Omezzine, S. Tazi, N. Bellamine, B. Saoud, K. Drira, and G. Cooperman, "Towards a dynamic multi-level negotiation framework in cloud computing," in *2015 International Conference on Cloud Technologies and Applications (CloudTech)*, jun 2015.

[293] L. Pan, "Towards a ramework for automated service negotiation in cloud computing," in *2011 IEEE International Conference on Cloud Computing and Intelligence Systems*, sep 2011, pp. 364–367.

[294] S. Moustafa, K. Elgazzar, P. Martin, and M. Elsayed, "Slam: Sla monitoring framework for federated cloud services," in *2015 IEEE/ACM 8th International Conference on Utility and Cloud Computing (UCC)*, 2015, pp. 506–511.

[295] J. Pavlik, V. Sobeslav, and A. Komarek, "Measurement of cloud computing services availability," in *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, ser. Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST. Springer Nature, 2015, vol. 144, pp. 191–201, dOI: 10.1007/978-3-319-15392-6_19.

[296] S. Ristov and M. Gusev, "A methodology to evaluate the trustworthiness of Cloud service providers' availability," in *IEEE EUROCON 2015 - International Conference on Computer as a Tool (EUROCON)*, sep 2015.

[297] G. Silvestre, S. Monnet, R. Krishnaswamy, and P. Sens, "AREN: A popularity aware replication scheme for cloud storage," in *2012 IEEE 18th International Conference on Parallel and Distributed Systems*, dec 2012, pp. 189–196.

[298] N. Mavrogeorgi, S. Gogouvitis, A. Voulodimos, D. Kiriazis, T. Varvarigou, A. Shulman-Peleg, and E. K. Kolodner, "Dynamic rule based SLA management in clouds," in *2013 IEEE Sixth International Conference on Cloud Computing*, jun 2013, pp. 964–965.

[299] L. Xuan and X. Feng, "The SLA framework based on cloud computing," in *Proceedings of the 1st International Workshop on Cloud Computing and Information Security*, ser. Advances in Intelligent Systems Research, A. Datta, Ed., vol. 52. Atlantis Press, 2013, pp. 6–9.

[300] S. Son, D.-J. Kang, and J.-M. Kim, "Design considerations to realize automated SLA negotiations in a multi-cloud brokerage system," *2014 International Conference on Collaborative Computing: Networking, Applications and Worksharing (Collaboratecom)*, pp. 466–468, 2014.

[301] D. Elmatary, S. Abd, W. Awad, and F. Omara, "SLA for e-learning system based on cloud computing," *International Journal of Advanced Computer Science and Applications*, vol. 6, no. 10, pp. 189–194, Oct. 2015.

[302] M. Parhi, B. K. Pattanayak, and M. R. Patra, *An Automated Semantically Enabled Fuzzy Based SLA in Cloud Computing Environment Using Multi-agent System*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2015, vol. 8947, dOI: 10.1007/978-3-319-20294-5_38.

[303] N. Ranaldo and E. Zimeo, "Capacity-aware utility function for SLA negotiation of cloud services," in *2013 IEEE/ACM 6th International Conference on Utility and Cloud Computing*, dec 2013, pp. 292–296.

[304] D. Petcu, "SLA-based cloud security monitoring: Challenges, barriers, models and methods," in *Lecture Notes in Computer Science*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2014, vol. 8805, pp. 359–370.

[305] S. Spicuglia, M. Bjorkqvist, L. Y. Chen, and W. Binder, "Catching the response time tail in the cloud," in *2015 IFIP/IEEE International Symposium on Integrated Network Management (IM)*, may 2015, pp. 572–577.

[306] I. Stankov, R. Datsenka, and K. Kurbel, "Service level agreement as an instrument to enhance trust in cloud computing - An analysis of infrastructureas-a-service providers," in *Proceedings of the Eighteenth Americas Conference on Information Systems*, vol. 5, 2012, pp. 3813–3822.

[307] Y. Kouki and T. Ledoux, "SLA-driven capacity planning for cloud applications," in *4th IEEE International Conference on Cloud Computing Technology and Science Proceedings*, dec 2012, pp. 135–140.

[308] I. U. Haq, I. Brandic, and E. Schikuta, "SLA validation in layered cloud infrastructures," in *Proceedings of the 7th International Conference on Economics of Grids, Clouds, Systems, and Services*, ser. GECON'10. Berlin, Heidelberg: Springer-Verlag, 2010, pp. 153–164.

[309] K. Saravanan and M. Rajaram, "An exploratory study of cloud service level agreements - state of the art review," *KSII Transactions on Internet and Information Systems*, vol. 9, no. 3, pp. 843–871, mar 2015.

[310] A. Sheshasaayee and T. A. S. Margaret, "SLA based utility analysis for improving QoS in cloud computing," in *Advances in Intelligent Systems and Computing*, ser. Advances in Intelligent Systems and Computing. Springer Nature, 2016, vol. 435, pp. 573–581, dOI: 10.1007/978-81-322-2757-1_56.

[311] M. A. Serhani, Y. Atif, and A. Benharref, "Towards an adaptive QoS-driven monitoring of cloud SaaS," *International Journal of Grid and Utility Computing*, vol. 5, no. 4, pp. 263–277, 2014.

[312] L. Sun, J. Singh, and O. K. Hussain, "Service level agreement (SLA) assurance for cloud services," in *Proceedings of the 10th International Conference on Advances in Mobile Computing & Multimedia - MoMM '12*. Association for Computing Machinery (ACM), 2012, pp. 263–266.

[313] Y. Taher, R. Haque, D.-K. Nguyen, and B. Finance, "PAEAN4cloud - a framework for monitoring and managing the SLA violation of cloud service-based applications," in *Proceedings of the 4th International Conference on Cloud Computing and Services Science*. Scitepress, 2014, pp. 361–371.

[314] O. Sukwong, A. Sangpetch, and H. S. Kim, "SageShift: Managing SLAs for highly consolidated cloud," in *2012 Proceedings IEEE INFOCOM*, mar 2012.

[315] M. Siebenhaar, T. A. B. Nguyen, U. Lampe, D. Schuller, and R. Steinmetz, "Concurrent negotiations in cloud-based systems," in *Economics of Grids, Clouds, Systems, and Services*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7150 LNCS, pp. 17–31, dOI: 10.1007/978-3-642-28675-9_2.

[316] T. S. Somasundaram, K. Govindarajan, U. Kiruthika, and R. Buyya, "Semantic-enabled CARE resource broker (SeCRB) for managing grid and cloud environment," *The Journal of Supercomputing*, vol. 68, no. 2, pp. 509–556, jan 2014.

[317] W. Tan, Y. Sun, L. Li, and A. Tang, "Multivariate quality control chart for monitoring SLA of workflow applications," in *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, may 2014, pp. 667–671.

[318] S. Tata, M. Mohamed, O. Anya, T. Sakairi, N. Mandagere, H. Ludwig, and N. Baracaldo, "Managing service quality at the platform and application levels with rSLa," in *2016 IEEE 25th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE)*, jun 2016, pp. 265–266.

[319] Y.-H. Tung, S.-S. Tseng, and Y.-Y. Kuo, "A testing-based approach to SLA evaluation on cloud environment," in *2015 17th Asia-Pacific Network Operations and Management Symposium (APNOMS)*, aug 2015, pp. 495–498.

[320] I. U. Haq, E. Schikuta, I. Brandic, A. Paschke, and H. Boley, "SLA validation of service value chains," in *2010 Ninth International Conference on Grid and Cloud Computing*, nov 2010, pp. 308–313.

[321] S. Son and S. C. Jun, "Negotiation-based flexible SLA establishment with SLA-driven resource allocation in cloud computing," in *2013 13th IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing*, may 2013, pp. 168–171.

[322] S. Son, G. Jung, and S. C. Jun, "An SLA-based cloud computing that facilitates resource allocation in the distributed data centers of a cloud provider," *The Journal of Supercomputing*, vol. 64, no. 2, pp. 606–637, jan 2013.

[323] A. Toueir, J. Broisin, and M. Sibilla, "A goal-oriented approach for adaptive sla monitoring: A cloud provider case study," in *2nd IEEE Latin American Conference on Cloud Computing and Communications*, Dec 2013, pp. 53–58.

[324] C.-M. Chituc, "Towards a methodology for trade-off analysis in a multi-cloud environment considering monitored QoS metrics and economic performance assessment results," in *2015 IEEE 7th International Conference on Cloud Computing Technology and Science (CloudCom)*, nov 2015, pp. 479–482.

[325] X. Xie, W. Wang, and T. Qin, "Detection of service level agreement (SLA) violation in memory management in virtual machines," in *2015 24th International Conference on Computer Communication and Networks (ICCCN)*, vol. 2015-October, aug 2015.

[326] H. Zhang, L. Ye, J. Shi, X. Du, and M. Guizani, "Verifying cloud service-level agreement by a third-party auditor," *Security and Communication Networks*, vol. 7, no. 3, pp. 492–502, feb 2013.

[327] S. Son, D.-J. Kang, S. P. Huh, W.-Y. Kim, and W. Choi, "Adaptive trade-off strategy for bargaining-based multi-objective SLA establishment under varying cloud workload," *The Journal of Supercomputing*, vol. 72, no. 4, pp. 1597–1622, mar 2016.

[328] S. Son and K. M. Sim, *An Adaptive Tradeoff Algorithm for Multi-issue SLA Negotiation*, ser. Communications in Computer and Information Science. Springer Nature, 2010, vol. 121 CCIS, dOI: 10.1007/978-3-642-17625-8_4.

[329] W. Chen, J. Chen, J. Tang, and L. Wang, "A QoS guarantee framework for cloud services based on bayesian prediction," *2015 Third International Conference on Advanced Cloud and Big Data*, pp. 117–124, oct 2015.

[330] A. A. Falasi, M. A. Serhani, and R. Dssouli, "A model for multi-levels sla monitoring in federated cloud environment," in *2013 IEEE 10th International Conference on Ubiquitous Intelligence and Computing and 2013 IEEE 10th International Conference on Autonomic and Trusted Computing*, Dec 2013, pp. 363–370.

[331] K. Ravindran, "Model-based engineering techniques for QoS auditing in distributed cloud services," in *2014 IEEE 34th International Conference on Distributed Computing Systems Workshops*, ser. IEEE International Conference on Distributed Computing Systems Workshops, jun 2014, pp. 146–153, dOI: 10.1109/icdcsw.2014.39.

[332] L. Wu, S. K. Garg, S. Versteeg, and R. Buyya, "SLA-based resource provisioning for hosted software-as-a-service applications in cloud computing environments," *IEEE Transactions on Services Computing*, vol. 7, no. 3, pp. 465–485, jul 2014.

[333] S. Son and K. M. Sim, "Adaptive and similarity-based tradeoff algorithms in a price-timeslot-QoS negotiation system to establish cloud SLAs," *Information Systems Frontiers*, vol. 17, no. 3, pp. 565–589, may 2013.

[334] I. ul Haq, K. Kofler, and E. Schikuta, "Dynamic service configurations for SLA negotiation," in *Euro-Par 2010 Parallel Processing Workshops*. Springer Nature, 2011, pp. 315–323.

[335] V. Casola, A. D. Benedictis, and M. Rak, "Security monitoring in the cloud: An SLA-based approach," in *2015 10th International Conference on Availability, Reliability and Security*, aug 2015, pp. 749–755.

[336] A. Maarouf, A. Marzouk, and A. Haqiq, "Automatic control of the quality of service contract by a third party in the cloud computing," *2014 Second World Conference on Complex Systems (Wccs)*, pp. 599–603, nov 2014.

[337] Y. Gu, W. Zhang, and J. Tao, "A study of SLA violation compensation mechanismin complex cloud computing environment," *Proceedings of the 2012 Second International Conference on Instrumentation & Measurement, Computer, Communication and Control (Imccc 2012)*, pp. 1448–1451, dec 2012.

[338] A.-F. Antonescu and T. Braun, "Improving management of distributed services using correlations and predictions in sla-driven cloud computing systems," in *2014 IEEE Network Operations and Management Symposium (NOMS)*, may 2014, pp. 1–8.

[339] P. Varalakshmi, K. H. Priya, J. Pradeepa, and V. Perumal, "SLA with dual party beneficiality in distributed cloud," in *Advances in Computing and Communications*, ser. Communications in Computer and Information Science. Springer Nature, 2011, vol. 190 CCIS, pp. 471–479, dOI: 10.1007/978-3-642-22709-7_46.

[340] B. Veloso, B. Malheiro, and J. C. Burguillo, "CloudAnchor: Agent-based brokerage of federated cloud resources," in *Advances in Practical Applications of Scalable Multi-agent Systems. The PAAMS Collection*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2016, vol. 9662, pp. 207–218, dOI: 10.1007/978-3-319-39324-7_18.

[341] Y. Zhang, H. Liu, Y. Lu, and B. Deng, "SLA-driven state monitoring for cloud services," in *2013 IEEE 10th International Conference on High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing*, nov 2013, pp. 428–433.

[342] R. Grati, K. Boukadi, and H. Ben-Abdallah, "A framework for iaas-to-saas monitoring of bpel processes in the cloud: Design and evaluation," in *2014 IEEE/ACS 11th International Conference on Computer Systems and Applications (AICCSA)*, Nov 2014, pp. 557–564.

[343] K. Ravindran and M. Iannelli, "SLA evaluation in cloud-based data-centric distributed services," in *2014 23rd International Conference on Computer Communication and Networks (ICCCN)*, aug 2014.

[344] A. Roy, R. Ganesan, and S. Sarkar, "Keep it moving: Proactive workload management for reducing SLA violations in large scale SaaS clouds," in *2013 IEEE 24th International Symposium on Software Reliability Engineering (ISSRE)*, ser. Proceedings International Symposium on Software Reliability Engineering, nov 2013, pp. 421–430.

[345] L. Wu, S. K. Garg, R. Buyya, C. Chen, and S. Versteeg, "Automated SLA negotiation framework for cloud computing," in *2013 13th IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing*, may 2013, pp. 235–244.

[346] A. Bertolino, A. Calabrò, and G. D. Angelis, "Adaptive sla monitoring of service choreographies enacted on the cloud," in *2013 IEEE 7th International Symposium on the Maintenance and Evolution of Service-Oriented and Cloud-Based Systems*, Sept 2013, pp. 92–101.

[347] Z. Haiteng, S. Zhiqing, Z. Hong, and Z. Jie, “Establishing service level agreement requirement based on monitoring,” in *2012 Second International Conference on Cloud and Green Computing*, nov 2012, pp. 472–476.

[348] C. E. A and A. N. Madheswari, “Performance optimized routing for SLA enforcement in cloud computing,” in *2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGCE)*, dec 2013, pp. 689–693.

[349] Y. Sun, W. Tan, L. Li, G. Lu, and A. Tang, “SLA detective control model for workflow composition of cloud services,” in *Proceedings of the 2013 IEEE 17th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, jun 2013, pp. 165–171.

[350] E. Yaqub, R. Yahyapour, P. Wieder, C. Kotsokalis, K. Lu, and A. I. Jehangiri, “Optimal negotiation of service level agreements for cloud-based services through autonomous agents,” in *2014 IEEE International Conference on Services Computing*, jun 2014, pp. 59–66.

[351] E. Yaqub, R. Yahyapour, P. Wieder, and K. Lu, *A Protocol Development Framework for SLA Negotiations in Cloud and Service Computing*, ser. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Nature, 2012, vol. 7714 LNCS, dOI: 10.1007/978-3-642-35194-5_1.

[352] P. Patel, A. H. Ranabahu, and A. P. Sheth, “Service level agreement in cloud computing,” 2009, pp. 1–10.

[353] S. Sasane, A. Bari, K. Memane, A. Pathak, and A. A. Deshmukh, “Resource Allocation Avoiding SLA Violations in Cloud Framework for SaaS,” *International Journal of Computer Science and Network Security*, vol. 15, no. 1, pp. 77–81, Jan. 2015.

[354] K. Hamadache and S. Rizou, “Holistic SLA ontology for cloud service evaluation,” *2013 International Conference on Advanced Cloud and Big Data (Cbd)*, pp. 32–39, dec 2013.

[355] X. Zheng, P. Martin, K. Brohman, and L. D. Xu, “Cloud service negotiation in internet of things environment: A mixed approach,” *IEEE Transactions on Industrial Informatics*, vol. 10, no. 2, pp. 1506–1515, may 2014.

[356] V. Stantchev and C. Schröpfer, “Negotiating and enforcing QoS and SLAs in grid and cloud computing,” in *Advances in Grid and Pervasive Computing*, ser. Lecture Notes in Computer Science, N. P. Abdennadher, D., Ed. Springer Nature, 2009, vol. 5529, pp. 25–35.

[357] C. Wu, Y. Zhu, and S. Pan, “The SLA evaluation model for cloud computing,” in *Proceedings of the International Conference on Computer, Networks and Communication Engineering (ICCNCE 2013)*, ser. Advances in Intelligent Systems Research, J. Zheng, D. Zhang, L., and Shi, Eds., vol. 30. Atlantis Press, 2013, pp. 331–334.

[358] K. Ravindran, “QoS auditing for evaluation of SLA in cloud-based distributed services,” in *2013 IEEE Ninth World Congress on Services*, jun 2013, pp. 247–254.

[359] K. Bernsmed, M. G. Jaatun, P. H. Meland, and A. Undheim, “Security SLAs for federated cloud services,” in *2011 Sixth International Conference on Availability, Reliability and Security*, aug 2011, pp. 202–209.

[360] G. Copil, D. Moldovan, I. Salomie, T. Cioara, I. Anghel, and D. Borza, “Cloud SLA negotiation for energy saving — A particle swarm optimization approach,” in *2012 IEEE 8th International Conference on Intelligent Computer Communication and Processing*, aug 2012, pp. 289–296.

[361] E. Badidi, “A cloud service broker for sla-based saas provisioning,” in *International Conference on Information Society (i-Society 2013)*, June 2013, pp. 61–66.

[362] Y. Gao, H. Guan, Z. Qi, T. Song, F. Huan, and L. Liu, “Service level agreement based energy-efficient resource management in cloud data centers,” *Computers & Electrical Engineering*, vol. 40, no. 5, pp. 1621–1633, jul 2014.

[363] R. Rajavel and M. Thangarathanam, “Adaptive probabilistic behavioural learning system for the effective behavioural decision in cloud trading negotiation market,” *Future Generation Computer Systems*, vol. 58, pp. 29 – 41, 2016.

[364] ——, “Optimizing negotiation conflict in the cloud service negotiation framework using probabilistic decision making model,” *The Scientific World Journal*, pp. 1 – 16, 2015.

[365] ——, “A negotiation framework for the cloud management system using similarity and gale shapely stable matching approach,” *KSII Transactions On Internet and Information Systems*, vol. 9, no. 6, pp. 2050 – 2070, 2015.

[366] ——, “Adslanf: A negotiation framework for cloud management systems using a bulk negotiation behavioral learning approach,” *Turkish Journal of Electrical Engineering & Computer Sciences*, vol. 25, pp. 563 – 590, 2016.

[367] J. Cohen, “A Coefficient of Agreement for Nominal Scales,” *Educational and Psychological Measurement*, vol. 20, no. 1, 1960.

[368] J. Fleiss, “Measuring nominal scale agreement among many raters,” *Psychological Bulletin*, vol. 76, no. 5, 1971.

[369] M. L. McHugh, “Interrater reliability: the kappa statistic,” in *Biochemia medica*, 2012.

AUTHORS’ BIOGRAPHY

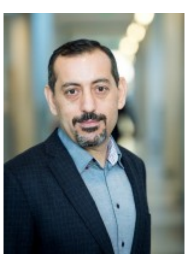
Saad Mubeen Dr. Mubeen is a Senior Member of IEEE. He is a Senior Lecturer (Assistant Professor) at the School of Innovation, Design and Engineering at Mälardalen University, Sweden. He has formerly worked in the automotive industry, where he was employed by Arcticus Systems AB, Sweden. He has also formerly worked as a consultant for Volvo Construction Equipment, Sweden. He received his PhD in Computer Science and Engineering from Mälardalen University in 2014. His main research interests include model-based development of vehicular embedded systems with a focus on timing models, end-to-end timing analysis and multi-core platforms. Saad has co-authored over 90 research publications in international peer-reviewed journals, conferences, workshops and book chapters.

Sara Abbaspour Asadollah is a Ph.D. student at Mälardalen University, Sweden. Her main research interests include debugging, testing and run time verification of concurrent, parallel and multicore software with a focus on concurrency bugs. She has completed her Masters Degree in Software Engineering at Faculty of Computer Science and Information, University of Malaya, Malaysia. The field of her research during the Masters Degree was Web Engineering. She also has work experience in various aspects of industrial environment such as Mobile Development Systems, Multimedia Technologies and ELearning application, RFID and Smart Cards Technologies.

Alessandro Vittorio Papadopoulos received his B.Sc. and M.Sc. (summa cum laude) degrees in computer engineering from the Politecnico di Milano, Milan, Italy, and his Ph.D. (Hons.) degree in information technology, systems and control from the Politecnico di Milano, in 2013. From 2014 to 2016, he was a Post-Doctoral Researcher with the Department of Automatic Control, Lund University, Lund, Sweden, and he was also a member of the Lund Center for Control of Complex Engineering Systems, Linnaeus Center, Lund University. He was a Postdoctoral Research Assitant at the Dipartimento di Elettronica, Informazione e Bioingegneria at the Politecnico di Milano (2016). He is currently an Assistant Professor in real-time and embedded systems at the Mälardalen University, Västerås, Sweden. His research interests include model reduction for hybrid systems, event-based control, and the application of control theory for the design and the implementation of computing systems, with a particular focus on cloud, real-time, and embedded systems.

Mohammad Ashjaei Mohammad Ashjaei is an Assistant Professor at the school of Innovation, Design and Engineering at Mälardalen University in Sweden. He has received his PhD degree in Computer Science and Engineering from the same university in November 2016. Mohammad was a visiting researcher at University of Aveiro, Portugal, for one month in 2013. Mohammad's main research interests are real-time distributed systems, scheduling algorithms, resource management and reservation. Moreover, he is interested in cloud computing, reservation mechanisms in cloud computing and admission controls.

Hongyu Pei-Breivold Dr. Pei-Breivold is a Principal Scientist within the Industrial Internet-of-things group at ABB Corporate Research, Sweden. She obtained her PhD degree in Computer Science and Engineering from Mlardalen University in 2011. She is also an adjunct researcher at Mlardalen University. She has published more than 30 peer-reviewed articles in journals, conferences and workshops. She is active in academia as program committee member, track co-chair, and industry-research chair in international conferences. Her main research interests are software evolution, cloud computing, internet-of-things technologies and their applications in industry.



Moris Behnam Dr. Behnam is a Senior Lecturer (Associate Professor) at the School of Innovation, Design and Engineering at Mälardalen University, Sweden. Currently, he is leading the Networked and Embedded Systems Division at Mälardalen University, Sweden. Moris received his PhD degree in Computer Science and Engineering from Mälardalen University in 2010. His main research interest is on resource virtualization for industrial distributed real-time systems. He has been working on virtualization techniques in both operating system level and communication level using resource reservation techniques. Moris has published 195 publications in international journals/conferences/workshops. Moris has organized and chaired several international conferences and workshops including VTRES 2013, VTRES 2014 and WFCS 2016.