Accounting Models for Cloud Computing: A Systematic Mapping Study

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Abstract—Cloud services change the economics of computing by enabling users to pay only for the capacity that they actually use. In this context, cloud providers have their own accounting models including their billing mechanisms and pricing schemes to achieve this efficient pay-as-you-go model. Thus it is important to study this heterogeneity aiming to map out the existing accounting models to become possible new proposals or future standardizations. Therefore, this paper focuses on mapping accounting models for cloud computing, where a mapping study process was undertaken, and a total of 23 primary studies were considered, which evidenced 5 accounting models, 23 different pricing scheme types and 4 primary studies related to SLA (Service-Level Agreement) composition. Although the significant number of studies found address grid computing it was possible to identify one accounting model which was very complete from different points of view for cloud environments.

Index Terms—Cloud Computing; mapping study; pricing scheme; accounting model; Service Level Agreement.

I. INTRODUCTION

Cloud computing has become an established paradigm for running services on external infrastructure, where virtually unlimited capacity can be dynamically allocated. However this unlimited aspect in some cases can become expensive, and research projects have tried to mitigate it through the development of new architectures, exploring different accounting models [1] [2] [3] [4].

Accounting in cloud computing is a recent discipline, hence there have few attempts to find a model which considers all the accounting requirements, and none work has tried to address a mapping of the existing accounting models that could identify research gaps and encourage future proposals.

In this context, this paper introduces a mapping study performed between July and December, 2011, addressing accounting models for Cloud Computing environments and other aspects related also to Grid Computing.

We had to encompass the grid computing research field, mainly due to three considerations. The first point is the correlated aspects between cloud and grid computing, the second point is the older grid origin with probable relevant contributions and as final reason, the existing mature accounting models under this research area.

In [32] the authors perform a comparison between the six most known accounting systems in grid computing, evidencing the advantages and disadvantages of them whereas allowing to realise what aspects they have in common.

First, they use a proper taxonomy to describe their functions which make part of an accounting process (a set of operations that manages the data regarding the use of the resources [5]).

Next, they present a measurement unit mechanism to apply under the resource consumption and accordingly charge for it, called pricing scheme [6].

Finally, all of them worry about QoS Requirements and explores how to monitor this Quality of Service. In some cases establishing Service Level Agreements (SLA).

Based on aforementioned items and previous literature investigation, four research questions were derived to guide this mapping study, as follows:

- RQ1: Is there any taxonomy for concepts related to accounting process in cloud computing?
- RQ2: What are the existing accounting models for cloud computing?
- RQ3: What are the existing pricing schemes for cloud or grid computing?
- RQ4: What are the aspects taken into account to compose a SLA in cloud/grid computing scenario?

The remainder of the paper is structured as follows: Section II introduces the related work; Section III presents the systematic mapping study process; Section IV describes the main findings of the study; Section V presents the analysis of the results, studies classification and mapping; Section VI introduces some threats to validity. Finally, Section VII presents the conclusions and future research.

II. RELATED WORK

Basically our research started motivated by the evolution in federated cloud infrastructures field, which two works stands out (RESERVOIR and JiT Clouds).

RESERVOIR Project [2] presents an architecture (including an advanced accounting model) that allows providers of cloud infrastructures to dynamically partner with each other to create a virtually infinite pool of resources.

JiT Clouds Project [7] also allows providers of cloud infrastructures to dynamically partner with each other, but with the advantage where providers does not need keep dedicated computing resources.
resources to meet the service providers demands, however does not have an accounting model.

In [8] the authors present a comparative review of grid and cloud computing pricing models. Unlike our proposal, this paper is not a systematic study and related only with our RQ3.

III. SYSTEMATIC MAPPING STUDY PROCESS

A Mapping Study is a systematic process that provides an overview and summarizes published paper results of a particular research area, by answering questions and categorizing the studies. As main benefit, it can be used to identify gaps in the existing research that will lead to topics for further investigation [9].

Therefore, a Systematic Mapping Study was used in this research to “map out” the accounting models for cloud computing, performing five steps (Questions Definition, Search, Screening, Keywording and Extraction) [9].

A. Conduct Search

The strategy used to construct the search terms, follows the same approach used in [10], since it is systematized in essence and defines steps to derive the search strings from the questions and the viewpoints of experts in the area and relevant papers. The strategy steps are described as follows:

- Derive major terms from the questions by identifying the population, intervention, outcomes and study design;
- Identify, by inquiries with experts in the field, alternative spellings and synonyms for major terms; and
- Check the keywords in the relevant papers.

The complete list of search strings and their combination are presented in Table I.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>SEARCH STRING</th>
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<tr>
<td>SLA OR “Service Level Agreement” OR billing OR pricing OR payment OR accounting AND “cloud computing” OR ”grid computing” OR “Infrastructure as a Service” OR “Platform as a Service” OR “Software as a Service”</td>
<td></td>
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</table>

Firstly an automatic search was conducted in different search engines (IEEEXplore, ACM Digital Library, Scopus and ScienceDirect digital databases). It is important to mentioned that all search strings were calibrated regarding to each search engine. Next, a manual search was performed by visiting some important conference proceedings. As a results from the application of both search strategies 580 studies were collected.

At this point, the studies were excluded according to the exclusion criteria:

- Studies did not address or just mentioned accounting models/processes, pricing schemes, SLA composition on cloud/grid computing;
- Duplicate studies. When a study has been published in more than one publication, the most complete version will be considered.

B. Screening of Papers

Firstly, the exclusion criteria were applied on the title and abstract of the identified studies, resulting in 98 studies being selected. The large number of duplicated studies contributed to this large difference. Next, a second filter was applied, analysing the introduction and conclusion, which resulted in 23 studies ([1], [2], [3], [4], [5], [6], [8], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25] and [26]).

C. Keywording

A classification scheme was built which analysed the abstract, titles and keywords of the selected primary studies to identify different facets. This way, three different facets were used. They are described following:

- **Contribution Type**: Method, Process, Technique, Model and Framework [27];
- **Accounting Model Features**: Pricing, Metering, Media-

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>RESEARCH TYPE FACET [28]</th>
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<tr>
<td>Validation Research</td>
<td>Techniques investigated are novel and have not yet been implemented in practice. Techniques used are for example experiments, i.e., work done in the lab.</td>
</tr>
<tr>
<td>Evaluation Research</td>
<td>Techniques are implemented in practice and an evaluation of the technique is conducted. That means, it is shown how the technique is implemented in practice (solution implementation) and what are the consequences of the implementation in terms of benefits and drawbacks (implementation evaluation). This also includes identification of problems in industry.</td>
</tr>
<tr>
<td>Solution Proposal</td>
<td>A solution for a problem is proposed, the solution can be either novel or a significant extension of an existing technique. The potential benefits and the applicability of the solution is shown by a small example or a good line of argumentation.</td>
</tr>
<tr>
<td>Philosophical Papers</td>
<td>These papers sketch a new way of looking at existing things by structuring the field inform of a taxonomy or conceptual framework.</td>
</tr>
<tr>
<td>Opinion Papers</td>
<td>These papers express the personal opinion of somebody whether a certain technique is good or bad, or how things should been done. They do not rely on related work and research methodologies.</td>
</tr>
<tr>
<td>Experience Papers</td>
<td>Experience papers explain what and how something has been done in practice. It has to be the personal experience of the author.</td>
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D. Data Extraction

A data extraction form was designed in order to gather the required information to address the objectives of this study, classifying and answering the research questions. The full paper was read and the following information was extracted...
from each study: the research categorization (Contribution Type, Accounting Model Features and Research Type), in addition the information required to answer some of the research questions.

IV. RESULTS

In this section, each topic presents the findings regarding to a specific research question, highlighting the evidences gathered from the data extraction process.

A. RQ1 - Is there any taxonomy for concepts related to accounting process in cloud computing?

In our research only one primary study effectively answered this question. The study [5] presents a taxonomy of full accounting process and its functions from the resource usage to the financial clearing. It is not applied only to cloud computing, but other areas related to Services on the Internet (see Table III).

<table>
<thead>
<tr>
<th>Concept</th>
<th>Function</th>
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<tbody>
<tr>
<td>Pricing</td>
<td>Function of giving a price to a certain resource usage.</td>
</tr>
<tr>
<td>Metering</td>
<td>Collects raw information regarding the resource usage of a certain service by a consumer and its usage.</td>
</tr>
<tr>
<td>Mediation</td>
<td>Is intended to do a first treatment of raw technical data by transforming these metering records into a data format that can be used for storing and further processing.</td>
</tr>
<tr>
<td>Accounting</td>
<td>Has the function of filtering and treat more accurately the records passed by mediation function.</td>
</tr>
<tr>
<td>Roaming</td>
<td>Allows using more than one provider while maintaining a formal, customer-vendor relationship just with one.</td>
</tr>
<tr>
<td>Billing</td>
<td>Also called of invoicing, is the process of transforming charge records into the final bill, summarizing the charge records of a certain time period and indicating the amount of monetary units to be paid by the customer.</td>
</tr>
<tr>
<td>Charging</td>
<td>Is the process of calculating the cost of a resource usage, the function that translates technical values into monetary units by applying a pricing function to the session records.</td>
</tr>
<tr>
<td>Financial Clearing</td>
<td>Includes activities from a commitment for a transaction to its settlement. In the case of resource accounting, this function implies the payment of a bill.</td>
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</tbody>
</table>

Although it was found only this taxonomy formally defined, other terms are widely used with the same meaning. For example, monitoring has the same sense of metering. According to [25] the metrics generated by the monitoring function can be used both for accounting purposes as for performance analysis. In other study [5], monitoring is a sub-function of metering that collects the information of a resource usage as raw data and provides usage metrics to the metering function.

B. RQ2 - What are the existing accounting models for cloud computing?

When performing the analysis, were found five primary studies ([1], [2], [3], [4] and [25]) that proposed some kind of accounting model, summarized following:

a) Flexible Accounting Model [1] - This paper proposes a flexible accounting model suitable to any service of cloud computing. This model is based on the accounting process of the Internet and it can fit any pricing scheme using jBilling accounting platform and mainly through the use of IPDR (Internet Protocol Detail Record).

b) A Model for Federated Clouds [2] - This primary study presents a solution for an accounting and billing architecture for use in federated cloud environments like the RESERVOIR project (funded by European Union). The model is organized in layers(Accounting, Billing and Business Layer).

c) ABS for SOA [3] - This primary study presents a framework wherein authentication of the clients and billing of services used by client is carried out. So this paper threats the security as an essential requirement in billing services, like generates instances of virtual machines for a particular time period ordered by user (time-based pricing scheme) in safe mode.

d) THEMIS [4] - This model proposed a mutually (provider and user) verifiable billing system called THEMIS to Cloud Computing scenario in which has as main requirements the transparency, security and low latency in billing transactions. Thus, the system introduces the concept of a Cloud Notary Authority to supervise billing transactions, using a level of security that is identical to that of a Public Key Infrastructure (PKI), combating the malicious behaviour of users and providers.

e) Cloud Supply Chain [25] - This model proposes the Cloud Supply Chain concept, which represents a network of interconnected businesses in the cloud computing area involved in the end-to-end provision of product and aggregated service packages required by end cloud service customers. This includes the actual provisioning of infrastructure services and the Information Model supporting monitoring, accounting and billing processes.

C. RQ3 - What are the existing pricing schemes for cloud or grid computing?

Table IV summarizes all the pricing schemes found with their respective concepts and in which study they were discussed.

There is a lot of work that mention some type of pricing scheme. However it is used different terms to the same pricing scheme meaning. In [8], [15] and [16] the authors refers to pricing schemes as pricing models and specially in [8] the pricing models are grouped in a general way called economic models. For example, the economic model Commodity Market (price defined based on amount of resource that users used) has as pricing models: Usage Duration and Flat Fee.

D. RQ4 - What are the aspects taken into account to compose a SLA in cloud/grid computing scenario?

In order to cloud providers supply clients with services that meet their quality constraints, they both need to negotiate the clients requirements and the provider’s infrastructure capabilities. It is known as Service Level Agreement (SLA). However, this is not an easy task, according to [29] there are many difficulties to formalize a SLA, such as lack of flexibility and precision. This way, to compound a SLA it is important to know which aspects have to be taken into account.
When performing the analysis, few studies explicitly stated the formalization of SLA in Cloud/Grid Computing scenario. However 4 primary studies ([11], [12], [14] and [21]) are complementary. They are summarized following.

- **a)** In [11] is introduced a framework that enables dynamic specification and verification of SLAs on the Cloud. Its main contribution to our research is an format of SLA-Description based on XML specification which defines the main Quality of Services (QoS) along with their threshold values agreed on selection of cloud services. It also defines the period of service provision, the cost of using the service, and the possible actions that should be taken if QoS provision is frequently violated.

- **b)** In [12] is presented a framework which the SLA pa-
rameters are specified by metrics. These metrics define how cloud service parameters can be measured and specify values of measurable parameters. In addition to specific metrics this study also propose general metrics that can be defined for SLA with any or all types of cloud users.

c) In [14] the authors addressed the use of Cloud Computing for web hosting providers by creating a Cloud Hosting Provider (CHP). They designed an SLA-aware web servers management system in order to address the resources outsourcing mechanism on the provider’s part, defining important economic variables to this kind of technology.

d) In [21] is proposed an unambiguous and flexible language for formalizing SLAs and an architecture for specifying and monitoring SLA’s on grid computing scenario. It references a typical SLA formulated by Morris et al. [29] that includes the components: Purpose, Parties, Validity Period, Scope, Restrictions. Service-Level Objectives, Service-Level Indicators, Penalties, Optional Services, Exclusions and Administration.

V. ANALYSIS OF THE RESULTS AND MAPPING OF STUDIES

By analysing the results, it can enable us to present the number of studies tabulated in each category defined in this study. Thus, it is possible to identify what have been emphasized in past research and determine gaps and opportunities for future research [9].

A. Research Type Classification

Initially, let us analyse the studies distribution regarding to the research type classification (Table V).

B. Contribution Type Classification

Table VI shows the contribution type classification scheme, which we can observe the most of studies propose concrete “Models” or “Frameworks” instead of address activities related to accounting functions. This way, few “Processes”, “Techniques” and none “Method” was registered. One possible explanation may be the observation made earlier, regarding the lack of practical results disclosed by the industry. In this case, we can conclude that even small-scale, companies publish “what they did” (models and frameworks) but hide the “how they did” (processes, techniques and methods).

C. Research Types X Research Questions

There were an effort in analysing the relationship between the research questions and the research type, using a bubble plot to represent the interconnected frequencies (Figure 1).
the papers doesn’t discusses how the pricing schemes could be applied in a detailed way, unlike give just short concepts. So, as our research aims to give a general overview mapping the pricing schemes, future researches can focus on explain how the pricing schemes can works in practice.

D. Accounting Models Analysis

The accounting models collected by this research were categorized according to their features (see Table VII).

<table>
<thead>
<tr>
<th>Table VII</th>
<th>Accounting Models Analysis</th>
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<tbody>
<tr>
<td>Studies</td>
<td>Features</td>
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<tr>
<td>[2]</td>
<td>X X X X X X X X</td>
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<tr>
<td>[3]</td>
<td>X X X X</td>
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<tr>
<td>[4]</td>
<td>X X X X</td>
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<tr>
<td>[25]</td>
<td>X X X X</td>
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</tbody>
</table>

Firstly, we used the taxonomy proposed by [5], aiming to check what functions the proposed models used. Thus, the terms pricing, accounting and billing appeared in more than one paper and with the same meanings, which this homogeneity indicates a certain taxonomy validity. Related to accounting, two information stands out:

- In [1] the authors disambiguated the expressions accounting process and accounting function. Whereas accounting process refer to a meta-concept that includes all the taxonomy functions, accounting function is related to recording and summarizing technical data in terms of money, transactions and events;
- In [25] the accounting and billing functions are grouped as integrated sub processes forming a type of macro-process.

Lastly, it is important to highlight that the term billing was cited by all primary studies. We attribute this result to the influence of other areas such as telephony that has used largely this term before cloud computing became a research trend.

Other features were derived from the most relevant aspects found in primary studies. Cloud Federation was the first feature. In this case it was observed a research gap in which only one accounting model [2] were directed to federated cloud infrastructures, needing to stress that this paper and [25] belong to the same research group (the RESERVOIR project [31]), showing as pioneer researchers in the area.

The feature Just in Time Clouds is a recent concept in which providers only allocate resources when they are demanded and only for the duration they are needed by their clients [7]. To explore this mechanism showed promise, because none accounting model addressed this feature. Something previously expected, due to be a recent issue.

The User Interface Support was analysed, noticing that some proposed models own a user interface that gives the access control to managing accounting mechanisms on the systems, but not all worried with this feature, only 40% of them had a final user or admin user interface support.

In Security Support, just 60% of studies at least cited some security mechanism like user authentication or transaction authorization. When analysed SLA Support, it was verified if the studies had SLA monitoring or the customer would choose their service quality desired, noticing that, as such Security Support, 60% fit this requirement. Therefore, SLA and Security Support have been showed as relevant topics of interest in accounting model field for cloud computing.

As last feature, it was investigated if the models were prepared to support different payment models (Variable Payment Models) such as Pre-Paid, Pos-Paid or Hybrid. These models are in no way unique to clouds and on the contrary they are well known to customers after being used for years in other utility markets, most notably the mobile phone industry [25]. Hence some accounting models (40%) are ready, for example, to work with resource consumption based on previous purchased credits (Pre-Paid).

It has to be mentioned that initially it was thought to include the term monitoring, however was preferred to use the term SLA Support instead, due its less ambiguous concept. According to [25], SLA and monitoring are strictly related each other, because the metric concept (from a monitoring point of view) is very semantically close to the “Key Performance Indicators” concept (from a SLA point of view).

Concluding, observing the fourteen features, one paper had a greater coverage. The primary study [1] proposed a flexible accounting model which can fit any service of cloud computing that encompassed almost all features taken into account by our classification. Therefore this paper can be used as a starting point for future accounting models propositions.

VI. Threats to Validity

There are some threats to the validity of our study, which we briefly describe below.

- Research Questions: The research questions we defined cannot provide complete coverage of the accounting field related cloud and mainly grid computing, however, we had several discussions to validate the questions.
- Publication Bias: We cannot guarantee that all relevant studies were selected. We mitigated this threat as much as possible, by following references in the relevant studies.
- Data Extraction: The studies were classified based on our judgement, however, some studies could have been classified incorrectly. To mitigate this threat, the classification was performed by more than one researcher.

VII. Conclusion and Future Work

We have introduced the results of a systematic mapping study about accounting models for cloud computing investigating scientific literature. In the end, starting from 580 papers, 23 filtered studies answered the research questions.
As major contribution, this paper provides an overview of the area and specific findings related to i) taxonomy for accounting process, ii) accounting models, iii) pricing schemes and iv) SLA composition.

i) The terms pricing, accounting and billing are the most used terms. Among these, the term billing surely is the main term in the area. This result is influenced by other fields such as telephony that has used largely this word before cloud computing became a research trend.

ii) In general there are few studies related to accounting models for cloud computing, mainly in industry environment. Besides there is a need for new proposals in federated cloud infrastructures whereas the topics related to SLA and Security have gained considerable attention.

iii) Despite the large amount of existing pricing scheme types, there is a need in expose how they could be applied in a detailed way, unlike give just short concepts.

iv) Related to SLA composition there are studies that propose possible general items to compose the contract (e.g. Scope, Penalties, Restrictions), others propose specific metrics to monitor the services quality and others presents mechanisms based on XML to specify metrics. Thus studying these results it is possible to develop new solutions combining ideas.

Future work will focus on analyse more accurately these mapping study results in order to match mainly the SLA composition ideas with accounting processes/models found to develop a more advanced accounting model. Also we intend to study the use on real market of the pricing schemes identified.

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