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Research paper

Proposal of a data model for consumption and service adaptation (IaaS – PaaS and SaaS) in cloud computing

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Abstract

In this paper, we are proposing a data model to help improve the quality of service and the satisfaction of cloud service consumers. To do this, we proposed 2 sub-models:

- A 1st sub -model for identifying users consuming cloud services, cloud services and the different consumptions that are made according to the context of the users.
- A 2nd sub-model for adapting the services consumed, while evaluating the level of satisfaction based on the metrics per service. Also differents formalizations associated with these sub-models are proposed.

Implementing the final data model could allow the cloud provider to ensure that the adaptation activities of the different services take into account users and their service consumption context.

Keywords: *Cloud Computing; Cloud Service Adaptation; Consumption Model; Adapted Service Model.*

1. Introduction

Talking about a data model for a service adaptation in cloud computing deserves a lot of explanation. In fact, cloud computing is a concept that consists in deporting, to remote servers storage and computer processing that are located in local servers or on the user's workstation. According to NIST [1], "Cloud computing is an internet based access model of access to a set of digital resources, which can be allocated and released on request , and for which the service provider ensures all maintenance, support and operation activities [2]". Thus, the services offered by cloud platforms can be classified into 3 categories [1] which are:

- IaaS: Infrastructure as a Service;
- PaaS: Platform as a Service;
- SaaS: Software as a Service.

As for adaptation, according to the “Littré” dictionary, it consists of adjusting one thing to another. In our case, dynamic adaptation allows the adjustment of cloud computing services to the user's context. If we must take into account the definition proposed by this dictionary, it is about adjusting Cloud services (first element) to the contexts of users (second element). So, adaptation implements the elements that are: the user's context, the user himself and the Cloud computing services offered to him. This adaptation consists of a process that would allow the user to experience the feeling and to see that the services are made for him.
In other words, dynamic adaptation refers to the ability of systems to change their behavior or configuration in response to changes in the environment or user requirements. In cloud computing, this flexibility is essential to ensure efficient use of resources while ensuring an appropriate quality of service (QoS).
In our case the services for which we propose an adaptation are the IaaS services. Furthermore, the context in the IT domain, refers to tools capable of perceiving a set of conditions of use in order to adapt accordingly their behaviour, their content and their presentation in terms of delivery of information and services [4]. Also, the user "context" includes information related to the user, the environment and the state of the system. In a cloud system, the main dimensions of the user context include:

[1] National Institute of Science and Technology
[2] Definition adapted from the work of AFNOR, ISO, IEC and ITU-T. The ISO organization has recently adapted within the ISO/IEC 17788:2014 standard the definitions of Cloud computing established in 2011 by NIST.

- The user profile, which includes preferences, usage history, permissions and security policies.
- The user's environment consisting of their location, the terminal used, and network conditions.
- The status of cloud resources: current load, server availability, latency, etc.

Today with the advent of cloud, computing where several services are offered to the user (SaaS, PaaS and IaaS) with a pay-per-use, the acquisition and representation of the context becomes a necessity and takes several forms. In fact, the context in the Cloud could refer to:

- to the hardware characteristics (disk space, RAM memory, processor frequency) and software offered by the Cloud provider to users,
- to the user's location (longitude and latitude) ,
- to the user profile (needs and preferences), to the network conditions (connection type, bandwidth) etc.

Nowadays, given the heterogeneity and massification of services offered by Cloud providers; also taking into account the high rate of variation in the context of users (due to their high degree of mobility), adapting services to the different contexts of the user becomes an essential challenge, a guarantee of the comfort of the latter (user).
The remainder of our paper is organized as follows:

- In section 2 we present the state of the art
- In section 3 we identify our problem
- In section 4 we will present our contribution
- In section 5, we will conduct a discussion to conclude and announce the perspectives in section 6.

2. State of the art

Works related to service adaptation exist. However, very few of them have focused on the field of dynamic service adaptation to the profile and preference of Cloud users apart from Ta Nguyen Binh et Al. In [10] to our knowledge. In fact, some have based their work on the implementation of service adaptation architectures [1] in traditional web environments. Others just use web services for the implementation of application adaptation platforms without taking into account the dynamicity of user needs and preferences [2], even though Cloud computing services since these works have not experienced a Cloud-type experimental framework. As for Dorra ZAIBI et al., they focused on finding solutions for adapting ergonomics in a mobile HMI context [9]. BACHA [12] in turn proposes adaptation solutions based on content personalization.
In [6], the authors propose an interlayer PaaS-IaaS adaptation in a cloud environment taking into account energy. They started from the observation that cloud service providers use various techniques to improve energy consumption at each level of the cloud and that most of these techniques take into account energy optimization at the level of the IaaS layer resources. The results of their work show that such an adaptation allows dynamic energy management in each of the PaaS and IaaS layers of the cloud. But, at no time does the energy adaptation take into account the context of use, the metrics related to each service. As for the authors of [7], they proposed a tool for the dynamic provisioning and adaptation of IaaS services in the cloud. They also started from the observation that IaaS allows dynamically acquiring additional computing resources or releasing existing resources on demand in order to adapt to dynamic workloads of applications. Faced with this situation, they offer a set of tools for the provisioning and adaptation of IaaS services.
This set of algorithmic tools is capable of making informed provisioning decisions to adapt to workload fluctuations. It was designed to manage multiple sets of resources acquired from different cloud providers and interact with different local resource managers.
In this work, its authors have not considered a model allowing the materialization of interactions between users and services in adaptation contexts.
Other authors [8] proposed the use of web services to manage adaptation activities. In [19][20][21], the authors proposed mathematical formulas to model the adaptation of IaaS resources. In these papers, excellent mathematical models are proposed but the associated data models are lacking.
In a previous paper [13] we proposed data models allowing the selection of cloud services according to their different contexts. In that paper we did not consider the consumption of services and metrics associated with these services. Based on the above mentioned , we can deduce that none of these research works has addressed the problem of adapting services consumed according to the context, taking into account activity evaluation metrics. To do this, we propose an approach aimed at highlighting Cloud computing users, their profiles and preferences as well as the different Cloud computing services in order to initiate suitable adaptations based on algorithms manipulating data models that we develop for this purpose.

3. Problematic

When analyzing the various existing works in the literature, it was discovered that initiatives and orientations have been carried out concerning service adaptation. However, these works were not carried out in a cloud computing framework. Also, even if these works could be oriented in ubiquitous environments, they do not take into account users and their respective context. Faced with this situation, the question that arises is what strategy to implement to improve the quality of service in cloud computing environments? How to improve the quality of service in these ubiquitous environments? In other words, how to deal with the saturation of the IaaS space allocated to each service by user context in order to dynamically obtain an IaaS space necessary for the consumption of cloud computing services?

4. Contribution

Our contribution to the adaptation of cloud computing service by service consumed consists of:

- Propose a data model for cloud service consumption with an associated formalization
- Propose a model for adapting consumed cloud services with also an associated formalization

Also from these TWO52° data models with their formalization, we have deduced a general model of cloud service adaptation in order to contribute to the satisfaction of consumers and users of cloud services.

4.1. Cloud service consumption model (Fig 1)

a) Presentation and description

The proposed model includes the following classes:

- User: Using the Cloud service requires user authentication. As such, a certain amount of information is required. We materialize this through the “User” class. This class includes the following attributes: login, name, email, date of birth and account status “account_status” because it can be active or inactive.

Service : Each cloud service is characterized by:

- Service ID (unique identifier) to avoid confusion in the use of said services.
- Name: characterizing the name of the service
- Type of Service (which could be storage, computation, database service)
- Features (JSON, including capacity, performance, costs)
- Context: In the Cloud users are classified by context which could be:
- Location (latitude, longitude),
- Device Status (device type, battery level),
- Network conditions (connection type, bandwidth),
- Status indicating whether the service is active (available) or under maintenance.

In the cloud, each use (consumption) of a service is done over a period (use start date, use end date generating the usage duration). After use, some cloud providers perform an evaluation of user satisfaction. This evaluation represents a satisfaction score with respect to the SLA contract governing the collaboration between the provider and the user. All this data relating to service consumption is represented in the class called "use ".

It serves as a link between the “user” class and the “service” class.

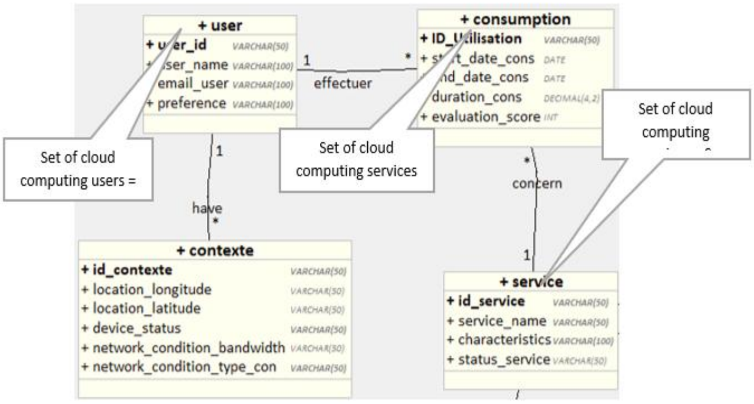

Fig. 1: Service Consumption Sub-Model.

b) Formalization of the sub-models

Formally, users' service consumption is made up of three sets. These are:

- U = {U 1 , U 2 ,…U n } the set of users or clients of the Cloud (with n = the maximum number of users)
- C = {C 1 , C 2 ,…C k }: the set of service consumptions (k = the maximum number of consumptions)
- S = {S 1 , S 2 ,…S m }: the set of defined services (m = the maximum number of cloud computing services)

We define the matrices:

- UC (Ui , Cj) with ($1 \leq i \leq n$, $1 \leq j \leq k$). which allows to determine the different consumptions associated with a user
- CS (Pj , Sx) with ($1 \leq j \leq k$, $1 \leq x \leq m$). which allows to determine the consumptions made by services
- US (Ui , Sx) with ($1 \leq i \leq n$, $1 \leq x \leq m$). allows to determine by composition of the two previous matrices the services consumed by a user

Which are such as:

$$UC(Ui, Cj) = \begin{cases} 1 \text{ } if \text{ } Ui \text{ } consumed \text{ } Cj \\ 0 \text{ } otherwise \end{cases}$$

$$CS(Cj, Sx) = \begin{cases} 1 \text{ } if \text{ } Cj \text{ } is \text{ } linked \text{ } to \text{ } service \text{ } Sx \\ 0 \text{ } otherwise \end{cases}$$

$$US(Ui, Sx) = \begin{cases} 1 \text{ } if \text{ } \big((UC(Ui, Cj) = 1) \text{ } and \text{ } (CS(Cj, Sx) = 1)\big) \\ 0 \text{ } otherwise \end{cases}$$

With :

- Ui representing the rows of the UC and US matrices
- Cj representing respectively the columns of the UC matrix and the rows of the CS matrix
- Sx representing respectively the columns of the CS and US matrix

For example:

U = {U_1 , U_2 , U_3 , U_4 , U_5 } a set of five (5) users

S = {S_1 , S_2 , S_3 , S_4 } a set of four (4) services

C = {C_1 , C_2 , C_3 , C_4 , C_5, C_6 } a set of six (6) consumptions

$$UC\ (Ui, Cj)=\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{pmatrix}$$

The rows of this matrix designate a set U of five (5) users and the columns designate a set C of four (4) consumptions.
With $1 \leq i \leq 5\ et\ 1\ \leq j \leq 4$such that i, j are integers
And

$$CS\ (Cj, Sx)=\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 \end{pmatrix}$$

The rows of this matrix designate a set C of four (4) consumptions and the columns designate a set S of six (6) services.
With

$$1 \leq j \leq 4\ and\ 1\ \leq x \leq 6\ such\ that\ j, x\ are\ integers$$

So by deduction we have:

$$US\ (Ui, Sx) = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 \end{pmatrix}$$

The rows of this matrix designate a set U of five (5) users and the columns designate a set S of six (6) services.
With:

$$1 \leq i \leq 5\ and\ 1\ \leq x \leq 6\ such\ that\ i, x\ are\ integers$$

In our example the application of our model gives the following preferences:

- User U1 consumed service S 1 ,
- U2 consumed services S 1 , S 4 and S6
- U3 consumed services S 1 , S 2 and S4
- U4 consumed services S1 , S2 , S4 and S6
- U5 consumed the services S1 , S4 , S6

c) Algorithm for determining the services consumed

Our proposed algorithm allows to identify cloud service users based on the knowledge of the information they provide during their authentication to access the Cloud platforms. It takes as input, the set U of users and produces as output the set S of consumed services.

Table 1: Algorithm for Determining Consumed Cloud Services

```
Algorithm: Determining cloud services consumed
Input: U = set of users
Output: S'= set of services consumed =∅
Beginning
// path of all users
 For all U i ∈ U TO DO
// path of all consumptions
 For all C j ∈ C d
 // test if Ui has consumption C j
 If (U i , C j ) = 1 then
// browse the set of all services
 For all S x ∈ S do
 If (C j , S x ) = 1 then
 S' = S'+S x
 Show ("user "Ui "consumed the service "S x )
 End if
 End for
 End if
 End for
Show ("user "Ui " has consumed all services "S')
End for
END
```

4.2. Sub-model of adaptation of services (IaaS – PaaS – SaaS) consumed (fig 2)

a) Presentation and description

On our adaptation model (figure 1), we have the class called " adaptation_service ". This class is linked to the " service " class through 2 links (initial and final). These 2 links materialize the initial and final states of adaptation of the services as well as the reasons associated (change of preference, network conditions) with this adaptation. On our proposed class diagram, there is a class called " metric ". This class allows us to identify the metrics associated with each cloud computing service. These metrics allow us to evaluate and know the level of satisfaction following the use of a service adapted by user and by service. This " metric " class is characterized by the following attributes:

- id_metrique : representing the identifier of the metric;
- libelle_metrique : representing the name (latency, error rate, etc.) of the metric;
- metric_value : representing the value of the metric;
- the period (start and end) of measurement.

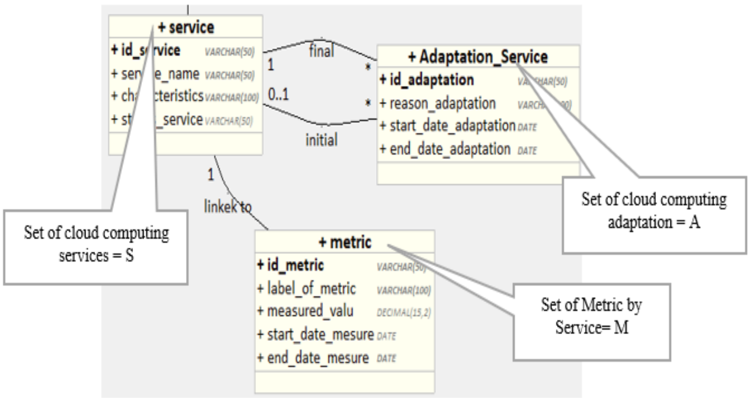

Fig. 2: Service Adaptation Sub-Model (Iaas-Paas-Saas).

b) Formalization of the service adaptation sub-models

Formally, let A, M be the new data sets added to those we defined in point 4.1-b.
These sets are such that:

- A = {A 1 , A 2 ,…A n } the set of cloud service adaptations (with n = the maximum number of adaptations)
- M = {M 1 , M 2 ,…M k }: the set of service consumptions (k = the maximum number of consumptions)
- S = {S 1 , S 2 ,…S m }: the set of defined services (m = the maximum number of cloud services)

We define the matrices:

- SA (S i , A j) with (1 ≤i ≤n, 1 ≤j ≤k). which allows to determine the different adaptations by service
- MS (M x , S i) with (1 ≤x ≤k, 1 ≤i ≤n). which allows to determine the metrics by services
- MA (M x , A j) with (1 ≤x ≤k, 1 ≤j ≤k). allows to determine by composition of the two previous matrices the metrics evaluating the quality of service following an adaptation.

Which are such as: $SA(Si, Aj) = \begin{cases} 1 \; if \; Si \; has \; undergone \; adaptation \; Aj \\ 0 \; otherwise \end{cases}$

$$MS(Mx, Si) = \begin{cases} 1 \; if \; Mj \; is \; linked \; (or \; evaluate) to \; service \; Sx \\ 0 \; otherwise \end{cases}$$

$$MA(Mx, Aj) = \begin{cases} 1 \; if \big((SA(Si, Aj) = 1) and \; (MS \; (Mx, Si) = 1)\big) \\ 0 \; otherwise \end{cases}$$

With :

- Si representing the rows of the matrices $SA$and the columns of the matrix MS
- Mx representing the rows of the MA and MS matrices
- Aj representing respectively the columns of the matrices MA and SA

For example:
A = {A_1 , A_2 , A_3 , A_4 } a set of four (4) adaptations
M = {M_1 , M_2 , M_3 } a set of three (3) metrics
S = {S_1 , S_2 , S_3 , S_4 } a set of four (4) services

$$SA\,(Si, Aj) = \begin{matrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 1 & 0 \end{matrix}$$

The rows of this matrix designate a set S of three (3) services among the 4 services of the set S undergoing adaptation activities and the columns designate a set A of three (3) adaptation activities which involved the 3 services.
With $1 \leq i \leq 3 \; et \; 1 \; \leq j \leq 3$ such that i, j are integers
And

$$MS\ (M_x, S_i) = \begin{matrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 \end{matrix}$$

The rows of this matrix designate a set M of four (4) metrics evaluating the four (4) services of the set S.
With

$1 \leq X \leq 4$ *and* $1 \leq I \leq 4$ *such that* j, x *be integers*

So by deduction we have:

$$MA\ (M_x, A_j) = \begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 1 & 0 \end{matrix}$$

The lines of this matrix designate a set M of three (3) metrics having evaluated the quality of service during 3 service adaptation activities of the set S

With$1 \leq j \leq 3$ *et* $1 \leq x \leq 3$ *tels que* j, x *des entiers*

In our example, the application of our model gives the following results:

- The metric M1 evaluated the adaptation of the service S1 ,
- The metric M2 evaluated the adaptation of the service S2 and S3 ,
- The M3 metric evaluated the adaptation of service S1 and S2 .

4.3. General model of cloud service consumption and adaptation

This model is an association of the 2 previous sub-models (figure 1 and figure 2). It combines the functionalities assigned to the latter. In its formalization, it also comes from the two(2) differents formalisms. It allows:

- -To know the services consumed by cloud computing users, their consumption context and also the adaptation activities of these consumed services (this functionality involves the context – user – consumption – service classes)
- - the different metrics having evaluated the different adaptation activities of each service consumed after consumption (this functionality involves the metric – service – adaptation classes)

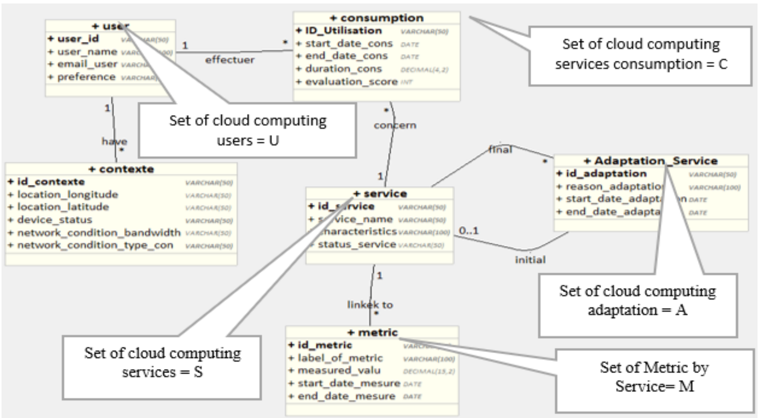

Fig. 3: General Model of Cloud Service Consumption and Adaptation.

5. Discussion

In this paper, the objective is to propose a data model to improve the quality of service offered by a cloud provider to a user or consumer. To do this, we have proposed two(2) sub-models which are:

- A service consumption submodel. This submodel contains the classes "users ", «context ", "consumption" and "service ". This submodel could find an implementation in a nosql environment to integrate bigdata databases. Indeed, with the volume of data processed and stored by cloud service consumption; also given the speed with which adaptation activities must be executed, this submodel could be used to store data from these classes.
- A sub-model of adaptation of services consumed to be adapted.

Here this submodel contains the classes “metric”, “service ” and “ adaptation_service ”.
The combination of these 2 sub-models presents and allows to have a complete model of consumption and service adaptation taking into account the metrics associated with each service. This data model serves as a basis for implementing dynamic adaptation systems in the cloud. It allows to capture user-service interactions, analyze the context in real time and make adaptation decisions to optimize the user experience.

6. Conclusion and perspective

The objective of this work was to contribute to the improvement of the quality of service offered by cloud computing providers to their users. To do that, we proposed a data model to identify the different cloud services according to the consumption context. This data model is the association of two sub-models that could find an implementation in a nosql environment for big data databases. To these sub-data models, we associated and defined formalisms for identifying consumed services as well as consumed services that have undergone adaptation activities. These adaptation activities by service find evaluation metrics through the "metric" class. The use of our proposal by cloud providers could allow them to evaluate the level of user satisfaction after consuming an adapted service.
Future work could focus on modeling adaptation demand, allocated capacity and minimizing adaptation costs taking into account resources (CPU, memory, and bandwidth).

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