*International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970)*
*Volume 2 Number 2 June 2012*

# Cloud Computing Services Accounting

Igor Ruiz-Agundez, Yoseba K. Penya and Pablo G. Bringas

DeustoTech, Deusto Institute of Technology,
University of Deusto
Bilbao, Basque Country
{igor.ira,yoseba.penya,pablo.garcia.bringas}@deusto.es

## Abstract

***Cloud computing provides a new promising parading to offer services. It brings the opportunity to develop new business models in the Internet. Classic accounting solutions fail to full fill the new requirements of these services due to their structural design. To understand these new constrains, we study the different actors and processes that interact in the Internet Economics. Specifically, we focus on cloud computing introducing a methodology that allows the deployment of cloud services. Further, we present an Infrastructure as a Service (IaaS) use case that applies the proposed system.***

## Keywords

***Cloud computing, accounting Internet economics, services***

## 1. Introduction

Cloud computing is an emerging technology that promises to change the paradigm of computer services. Besides, the underlying ideas and concepts of cloud computing are not new. In this way, Buyya R. et al define cloud computing as "a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements" [1].

The cloud computing business models (the rationale of how an organization creates, delivers, and captures value) are still to be defined. In this way, the provisioning of technologies and models that enable the development and economization of cloud services is essential.

In the case of cloud computing, each service provider has developed its own proprietary accounting solution according to a limited set of requirements. A change on the requirements (e.g. the apparition of a new service) implies a change on all the accounting system, and hence, the business model as well. This approach is not flexible and limits the expansion and growth of cloud computing.

Against this background, the contribution of this paper is two-fold. First, we introduce an accounting model for cloud computing. Second, we detail a possible implementation of the previous model running a specific service of cloud computing.

The remainder of this paper is structured as follows. Section 2 introduces the problem domain and defines the Internet Economics. Section 3 presents a literature review in the area detailing the existing work on cloud computing services accounting. Section 4 proposes our methodology to account cloud computing services. Section 5 presents the results of a cloud computing accounting systems through a use case illustrating how it could be implemented. Finally, Section 6 concludes and draws the avenues of future work.

## 2. Problem domain

The Internet Economics deals with the services that users can consume attempts to understand the Internet as an economic system. These services are managed, deployed and exploited, trying to make it as efficient as possible. More accurately, it is a research area that overlaps concepts and procedures of Economics, Engineering, and Policy, creating new semantics and ideas from them.

This area provides an improvement in interoperability, revenue management, pricing policies, custom care, content deployment, and so forth.

The economic aspects of service usage is one of the main tasks of service providers in their operation and management processes, since it provides them with the necessary information for all the related functions.

## 3. Literature Review

Accounting of the Internet joint many concepts from several disciplines such as economics or engineering. In this section we introduce the actors that take play in the Internet Economics, detailing the existing pricing schemes that form the basic blocks of the business models. We also specify how the services are consumed in an economic process. We define the accounting requirements of those services and finally, describe the specifications and the existing work in cloud computing accounting.

**Internet Economics**

The Internet as an economic system is a scenario with multiple system stakeholders that interoperate. Each one of them will have a goal, that can be the same or opposite to other actors.

These players have different roles that can be characterized as follows [2]:

- Customer: is the user of the service. It can be an individual or an organization.
- Provider: is the organization that creates and offers the service.
- Administration: regulates and stipulates how the exchanges between the stakeholders take place.
- Carrier: it offers the required infrastructure to run the services.
- Service access utility: the software or hardware required to use the service.
- Trust center: the point where all the actors can trust in order to ensure the correct functionality of the economic exchanges.
- Financial clearing center: provide financial services if needed by the services.

Some authors address the terms accounting, pricing, charging, or billing to represent the complete process of detecting the specific usage of a service.

The concept of pricing schemes emerges at this point. They provide the price of the users' usages and are represented as a formula that expresses the pricing function. This formula consists of the pricing variables (consumption measure metrics of the session records) and several pricing coefficients [3] that can be organized in many ways:

- Time-based: pricing based on how long a service is used.
- Volume-based: pricing based on the volume of a metric (e.g. downloaded bytes).
- QoS-based: pricing depends on the hired quality of service.
- Flat-rate: a fixed tariff for a specified amount of time.
- Paris-Metro pricing: used for shared resources. Resources are split by the amount of users per split.
- Priority pricing: services are labeled and priced according to their priority.
- Smart market pricing: services are priced in an auction.
- Edge pricing: calculation is done based on the distance between the service and the user.
- Responsive pricing: charging is activated only on service congestion.
- Effective bandwidth pricing: charging is based on an expected usage function.
- Proportional fairness pricing: it is according to the user's willingness to pay and service optimization costs.
- Cumulus pricing: based on flat pricing and dynamically priced by using a credit point system.
- Session-oriented: based on the use given to the session.
- One-off charge per service: one charge per service session.
- Usage-based: based on the general use of the service for a period of time, e.g. a moth.
- Content-based: based on the accessed content.
- Location-based: based on the access point of the user.
- Service type: based on the usage of the service.
- Differentiation on time-of-day: pricing based on the hour when the service is used.

In addition, there also exist the following related concepts:

- Free of charge: no charge is applied for the services.
- Periodical fess: payment of time to time quantities for the use of a service.
- Discounts: reduction in the usual price
- Pre-paid: the payment of the service is done in advance.
- Post-paid: the payment of the service is done after the use.
- Online: the accounting performed while the user makes use of a service.
- Offline: the accounting process is done after a service is used.
- Static pricing: the pricing function does not change.
- Dynamic pricing: the pricing function changes on the fly, being adapted to the usage of the users.

Furthermore, many of these schemes can be combined to create new ones that inherit the properties of the originals. The possibilities are endless as new pricing schemes can be created to model more complex business models.

Moreover, depending on the application area of each author, they employ different terminology and semantics as shown for instance in accounting on packet-switched networks [4], micro-payments [5], grid services [6], mobile networks [7], VoIP services [8] or Wi-Fi connections [9].

In the case of cloud computing, due to its peculiarities, the most used pricing schemes so far are time-based and utility-based pricing (charge by allocation) [1]. Time-based schemes in cloud computing pricing varies from service to service but the business formula is always the same: multiplying a fix price by a consumption time. In the case of utility-based pricing in cloud computing, the scheme may also vary from service to service. Please note that, it is not the same to model Software as a Service (SaaS) provider or a Infrastructure as a Service (IaaS) provider. In the first one, SaaS, the utility is the service itself and consumption time is normally measured in number of uses. As for IaaS, time is measured in hours.

On the other hand, utility-based scheme charges the user on a per-use basis and its complexity relies in controlling the operating costs.

These models have been working properly in this early stage of cloud computing. Business requirements, though, are changing and the introduction of other pricing schemes is essential. In order to enable this process in a flexible way, new engineering efforts are required.

**The Internet Economics process**

The Internet services accounting is one of the main challenges of service providers. Since it involves several motions and terminology that normally are not clearly defined, the semantics of some terms (e.g. pricing, charging or billing) is not always properly defined leading to confusion [2] [10].

In a previous work [11], we defined a taxonomy that outlined the Internet Economics process. This taxonomy introduced a common vocabulary, which helps to develop accounting models. Figure 1 summaries this integrated vision of the process.

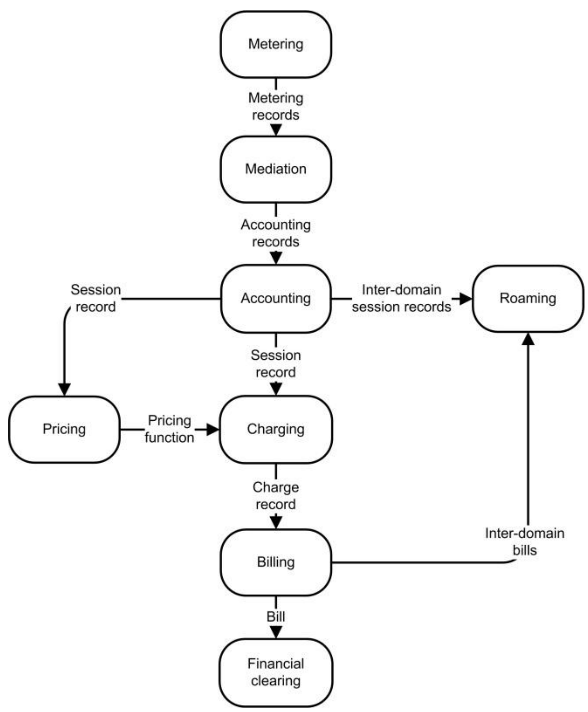


Figure 1 An integrated vision of the Internet Economics process.

The process starts when a resource is used, registered by the metering function in its records. Afterwards, the mediation function intercedes by generating the accounting records for the accounting function. It issues session records, sent both to the pricing and charging functions. The first one generates a formula to define how to price session records, which is used by the second function. The flow continues with the charging step, which generates charge records for the billing function. There, the financial clearing function receives the final bill.

Throughout the whole process, there may be inter-domain exchanges between organizations. These interchanges may happen at the accounting and billing steps, enabling roaming capabilities and inter-organization collaboration.

Once settled a clear process that unifies and controls the vocabulary involved on the Internet Economics, we focus on developing the accounting requirements of new systems, applications and systems such as cloud computing.

**Accounting requirements**

Multiple service providers may take part simultaneously during the same session in cloud computing (e.g. service request or data transfer) with users roaming through several networks and service providers. This fact implies that, consequently, a significant number of different charging schemes may also be involved simultaneously within a single session.

In this way, cloud computing demands new working paradigms and new billing requirements to suit all the requirements that providers may have. Finding a billing model for cloud computing is a real challenge due the operator structure and processes, being a key factor for their correct deployment. Despite the fast evolution of technologies, many service providers think that classic billing systems are enough for the emerging networks [12], [13]. Their use implies adapting them with the subsequent possibility of revenue reductions, system instability and slow new service introduction.

Within traditional models, the billing system operates in batch mode. It stores the so-called Usage Detail Record (UDR)-s and in this period there is a time window in which the provider has no control over the user behavior. There should not be this time window since it may leave records of services unprocessed. This is why real-time billing is preferred: it allows to process information every time it is generated, enabling immediate business support systems operations. The real-time efficiency will depend on the available processing time and the available processing cost.

Further, traditional models present a centralized architecture: all UDRs are processed by only one rating engine and one invoicing engine that limit the scalability of the system. On the contrary, cloud computing requires high scalability levels in order to support a large number of customers and inter-carrier settlement activities. With a centralized architecture, data can be accessed from any business application. The processing time, however, is long and management complicated. On the other hand, with a distributed architecture, the system loads are balanced but maintaining consistency between different instances increases the complexity of the system.

Moreover, classical billing systems are designed service-specific. That is, traditional systems lack of flexibility and are not capable of accommodating content-based pricing that will replace current flat-rate charging models. Due to this flaw, in case a new service is introduced, it would require a new billing system. Cloud computing will have heterogeneous data from a larger number of systems. The end user requires a convergent billing system that provides a unified view of the services that it consumes.

Further, it requires complex pricing capabilities fitting the emerging business models of cloud computing [14]. Specifically, the system should support any definition of the so-called Service Level Agreement (SLA) between the user and the provider. Additionally, such needs include security (all data and processes need to be reliable), adaptability (new services and business models may emerge), multi-service and multi-domain capability (in order to use a unified accounting model), and deployment possibility (being able to integrate it into an existing accounting system).

**Accounting in cloud computing**

Accounting in cloud computing is a recent discipline. Nevertheless, there have been many attempts to find a model that fits all the accounting requisites.

For instance, the Diameter protocol [15] provides an Authentication, Authorization and Accounting (AAA) framework to work with. It allows connecting, authorizing and accounting of any component. There is an extension of this protocol that also supports charging options, the A4C protocol [16].

The Common Reliable Accounting for Network Element (CRANE) protocol enables efficient and reliable delivery of any kind of data, and mainly accounting data from Network Elements to any systems, such as mediation systems and Business Support Systems (BSS)/ Operations Support Systems (OSS) [17]. This protocol is designed to manage data from network elements, and not cloud computing services specifically.

The Management Information Base (MIB) protocol provides a framework for the exchange of messages which convey management information between the agents and the management stations [18]. This MIB protocol has been used in cloud computing to manage the usage information generated by the services [19].

Furthermore, there are other resource management and billing frameworks that have focused on presenting distributed resource usage metering as well as an accounting and account balancing mechanism, for instance, the Condor/G [20], Nimrod/G [21], GRASP [22], Tivoli [23], or TeraGrid [24].

It is worth mentioning existing solutions of cloud computing accounting do not normally allow situations where the providers are discovered and selected on the fly [25]. That is, there is not support of providers roaming. Nevertheless, the model we put forward here can implement roaming capabilities.

Still, none of these attempts have met all the requirements of cloud computing accounting for many different reasons. Some of them were not specifically designed for the cloud while others just consider some of the requisites and were not an integrated solution.

## 4. Proposed Work

Our goal is to develop a flexible model that enables accounting of cloud computing usage. Within this model, any use of cloud services, platforms or infrastructure can be accounted by the provider in accordance with the consumption of the users.

Ideally, any event that a user performs during the use of a service must be represented on the accounting system. Normally each service and each provider defines the usage record in a different and proprietary format. Therefore, it is necessary to use an open standard to handle any type of records.

In this section, we introduce the cloud computing services that can be accounted, a specification to format usage record of service usages, and an accounting platform to implement all the requirements of the model.

### Accountable services in cloud computing

Cloud computing can be structured in different layers, considering its different functionalities [26]. The first layer involves the cloud clients that enable the access to the cloud. Examples include some computers, phones and other devices, operating systems, and browsers. The next layer is formed by the applications, also known as Software as a Service (SaaS), and delivers software as a service over the Internet. There is no need to install or run the applications in the client equipment, and hence, the support and maintenance is simplified. A layer beyond, we find the platforms or Platform as a Service (PaaS). They provide the possibility to deploy applications without the cost and work that implies managing the required hardware and software. In the upper layer, we find the infrastructure services or Infrastructure as a Service (IaaS). Here, the provider offers outsourcing of servers, software, data-centre space or network equipment via a platform of environment virtualization. Finally, in the last layer we find servers that are specifically designed for the delivery of cloud services.

Each of these layers generates different information that can be considered as usage records. These records can be classified as communication data, computational data or information data [16]. Unfortunately, each layer offers different type of information to the provider augmenting the complexity of the business support systems operations such as accounting. Furthermore, each layer can be implemented using different products and technologies from various providers and manufacturers.

We have to face a heterogeneous scenario in which each service presents different usage records both in format and in content. Next section introduces a standard that aims at solving these heterogeneity problems offering a standardized way of formatting usage records of any service, including those of cloud computing.

**Internet Protocol Detail Record (IPDR)**

The Internet Protocol Detail Record (IPDR) has the potential to become the standard protocol for exchanging service usage and for managing control information between IP networks, hosting elements and operations or business support systems. It provides a standardized framework that enables network and service accounting comprehensively [27].

This standard is defined by the Internet Protocol Detail Record Organization and the TeleManagement Forum. It is designed to enable cost-effective usage measurement and exchange for services across the entire value chain. Figure 2 shows the IPDR reference model. The data flow is similar to the one introduced in Section II. A. The user consumes a service and the metering function collects these records in IPDR format through the IPDR Recorder. These records can be stored o transmitted to the business support system by the mediation function using the IPDR Transmitter. The rest of the accounting process functions are allocated in the business support system, similarly to other functions such as user management, report generation, fraud management, error management or network elements configuration [28].

Moreover, the IPDR covers the billing requirements of cloud computing providing converged billing, avoiding provider dependence, and reducing the required interfaces. Real-time billing is allowed, and therefore charging is performed faster. Finally, as it offers great flexibility to define new services, it can be adapted to any emerging requirement of cloud computing accounting. According to its service specifications [29], the IPDR is capable of collecting usage characteristics of any IP-based network or application service. All service specifications have five common attributes in their records. The first one describes the person in charge of the usage of a service, defining user identification. The second attribute tells when a certain service is used. The

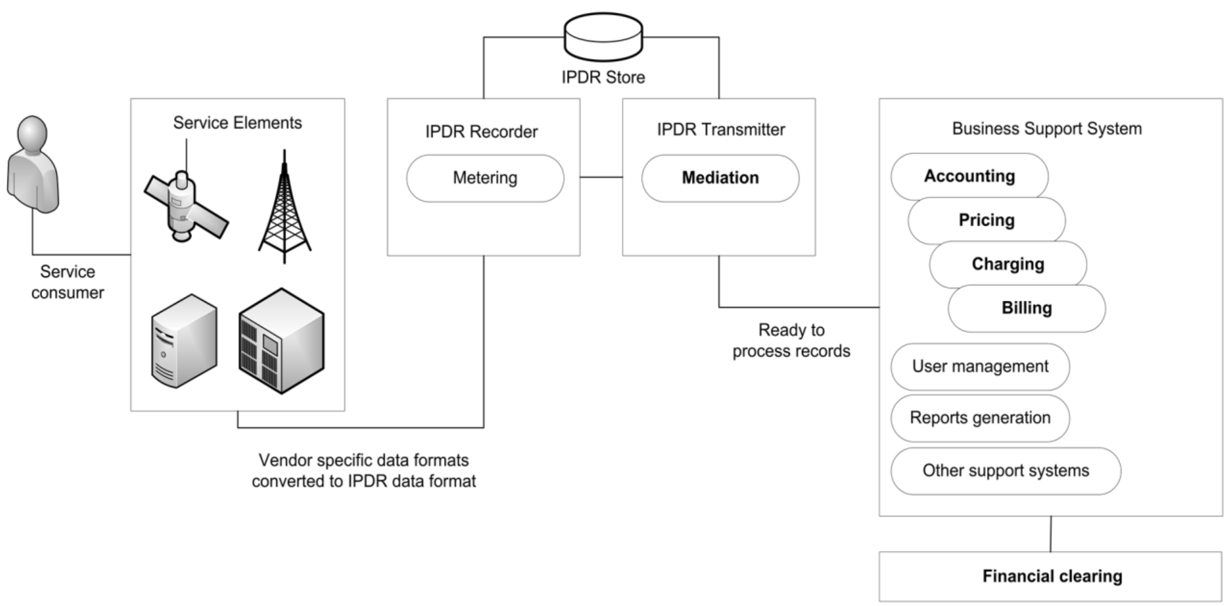


Figure 2 IPDR reference model.

third attribute defines what service is being measured (e.g. quality of service, state information, event codes, connection state, etc.). The next attribute contents information to allow traceability by providing context, source, and destination, defining in this way the place the service is consumed. The final attribute informs about the reason that triggered the event.

So far and officially supported, the IPDR specifies services for Internet Protocol Television (IPTV), Public Wireless LAN (WLAN) access, Streaming Media (SM), Voice over IP (VoIP) or any other service specified by the service designer.

In this paper, we focus on service specification of a cloud computing service defining our own specification for this use case. This specification will provide us a standard matter to format these cloud computing service usage records and keep track of the service usage. Our methodology can be extended to incorporate any other cloud service just adapting the service to a new specification.

**An accounting platform**

We propose the use of jBilling as an accounting platform [30]. It answers to all the requirements of Internet accounting as defined in Section II-B. Specifically, it is supports functions of mediation, those included in the business support systems, and the financial clearing as highlighted in Figure 2.

The jBilling solution gives the flexibility to centre on the provider business model; there is no need to develop an ad hoc solution with the subsequent costs. Further, it offers freedom from proprietary solution dependencies. This fact gives us a full control of the accounting platform that can be adapted to the requirements of each service and provider. Further, it has no license cost and its source code is available, hence, the adaptability and maintenance is guaranteed at a reasonable cost.

Additionally, the system is ready to process big quantities of records that could be generated during the use of certain services, such as telephony. The system can manage to reach thousands of events per second. jBilling can handle these records in batch mode, in real time or combining both. Mediation is possible through files, data bases, or applying the principles of the Software Oriented architecture (SOA) enabling the integration with other systems. Besides, each function can work independently in different systems, and hence, scalability is guaranteed.

The mediation module can handle any type of service records: telephone calls, text messages, download, VoIP, IPTV, streaming video, etc. Any service that generates usage records can be implemented in this accounting platform, including cloud computing.

The pricing and charging functions use a Business Rules Management System (BRMS). These rules may be able to use all the information defined in the usage records. The billing function is also flexible, enabling all types of options. Billing live cycle can be performed per month o at a fixed period, by user o group of users. More advanced options such as discounts, offers and promotions are also possible to use.

## 5. Results of a cloud computing accounting system

At this point, we have introduced all the puzzle pieces. We have presented the accounting process, its requirements and the existing pricing schemes. Moreover, we have showed which cloud computing services can be accounted and which data format should be used to represent the usage records of these services. Finally, we have introduced an accounting platform that makes use of the information provided by the rest of the components enabling cloud computing accounting.

**An implementation example**

As aforementioned in the different possible services available in cloud computing are vast. For the sake of simplicity, we are going to focus on an IaaS implementation. More accurately, we are going to use the Eucalyptus solution [31].

Eucalyptus is a software solution that implements scalable IaaS-style in private and hybrid clouds. The Eucalyptus architecture is highly modular with internal components consisting of Web services, which make them easy to replace and expand.
Eucalyptus' flexibility enables it to export a variety of APIs towards users, via client tools. Currently, Eucalyptus implements the Amazon Web Service (AWS) API, which allows interoperability with existing AWS-compatible services and tools. This

also allows Eucalyptus users to group resources drawn both from an internal private cloud and external public clouds to form a hybrid cloud.

This solution provides some facilities that allow monitoring of the running components, virtual machines and storages. Specifically, it can integrate the Ganglia Resource Usage information gatherer [32].

Ganglia is a scalable distributed monitoring system for high-performance computing systems. It is based on a hierarchical design with federations of clusters in mind. It leverages widely used technologies such as XML for data representation, XDR for compact, portable data transport, and RRDtool for data storage and visualization [33]. This solution has many other characteristics; however, those are the ones we are using in our experiment. The data represented in this XML files gives a full report of the state of the resources informing the use the client makes of them.

The resource usage records include attributes of CPU, memory, network, cache, disk or load use. In particular, the attributes are the following: Boottime, Bytes-in, Bytes-out, Cpu-aidle, Cpu-idle, Cpu-nice, Cpu-num, Cpu-report, Cpu-speed, Cpu-system, Cpu-user, Disk-free, Disk-total, Gexec, Load-fifteen, Load-five, Load-one, Load-report, Machine-type, Mem-buffer, Mem-cached Mem-free, Mem-report, Mem-shared, Mem-total, Mtu, Network-report, Os-name, Os-release, Packet-report, Part-max-used, Pkts-in, Pkts-out, Proc-run, Proc-total, Swap-free, Swap-total, Sys-clock.

Further, these attributes can be extended with new metrics via gmetric extension [34]. This monitoring solution may reach aspects such as transaction rate of a database, number of databases, number of disks, used TCP ports or any other attribute that could have interest when defining a business model.

**Flexible adaptation to our system**

In this section we are going to show the deployment of a cloud computing service in a flexible way using our proposed model.

Thanks to Eucalyptus we may offer a cloud computing service. We also have Ganglia, which provides us with usage records in a proprietary format.

Now we have to convert these records to the IPDR data format to be able to manage them according to our reference model. This can be automatically performed with a small converter. Figure 3 shows an example of a record in IPDR format representing Eucalyptus usage records information gathered by Ganglia.

In a regular use scenario, many records are generated. Therefore, we consider that real-time accounting is more adequate. In this way, the period between resource usage records generation and its accounting is the shortest possible. The system manages the records in real time the system towards a Simple Object Access Protocol (SOAP), since it allows invoking the mediation function at any time and place.

Once the platform has completed the mediation function the accounting process starts. This process will represent the business model of the system provider through the pricing and charging functions. As mentioned before, these functions use a BRMS system that has records as the one introduced in Figure 3 as input. Then, the rule-based system implements, executes, monitors and maintains the complexity of the business rules.

For instance, suppose that the business model is based on a time-based and usage-based pricing scheme. In concrete, the usage measures the number of CPUs used by the user. With these rules, the BRMS will check the values of the CPUs and Uptime attributes of the IPDR record.

Then, the pricing function will give a monetary value to charge the resource usage and the flow of the accounting process will continue.

Finally, the accounting platform generates a bill and sends it to the financial clearing functions, thus completing all functions of the accounting process.

In order to use other pricing schemes, new rules in the BRMS could be designed. These rules will use the required metrics and generate new pricing functions.

```
<IPDRCreationTime>2010-10-17T13:11:06.031+02:00</IPDRCreationTime>
    <seqNum>1</seqNum>
    <subscriberID>i1.Millennium.Berkeley.EDU</subscriberID>
    <Location>Unknown</Location>
    <heartbeat>19 seconds</heartbeat>
    <Uptime>27 days, 14:36:33</Uptime>
    <Load>0.02;0.01;0.00</Load>
    <CPU-Utilization-user>1.1</CPU-Utilization-user>
    <CPU-Utilization-sys>0.1</CPU-Utilization-sys>
    <CPU-Utilization-idle>98.7</CPU-Utilization-idle>
    <CPUs>2</CPUs>
    <CPU-power>2.99 Ghz</CPU-power>
    <Memory-RAM>1.98 GB</Memory-RAM>
    <Local-Disk>96.621 of 137.380 GB</Local-Disk>
    <Most-Full-Disk-Partition>70.4%</Most-Full-Disk-Partition>
    <OS>Linux 2.6.26-2-686-bigmem (x86)</OS>
    <Booted>September 20, 2010, 10:57 am</Booted>
    <Uptime>27 days, 14:36:33</Uptime>
    <Swap>Using 0.0 of 7812.8 MB swap.</Swap>
    <Bytes-in>720</Bytes-in>
    <Bytes-out>5.5</Bytes-out>
    <Cpu-aidle>99.9</Cpu-aidle>
    <Cpu-idle>99.9</Cpu-idle>
    <Cpu-nice>0</Cpu-nice>
    <Cpu-system>110</Cpu-system>
    <Cpu-user>1.25</Cpu-user>
    <Disk-free>41</Disk-free>
    <Disk-total>140</Disk-total>
    <Mem-buffer>170</Mem-buffer>
    <Mem-cached>420</Mem-cached>
    <Mem-free>1.4</Mem-free>
    <Mem-shared>0</Mem-shared>
```


Figure 3 A records in IPDR format showing eucalyptus usage records information gathered by ganglia.

## 6. Conclusion

We have introduced an accounting parading for cloud computing services. This model enables the deployment of different cloud business models.

The proposed model is based on the Internet Economics process and its requirements. Thanks to its flexibility, the model can fit any pricing scheme and any cloud computing service through the use of IPDR and the jBilling accounting platform. Finally, we have introduced a demonstration of the model in a system that implements an IaaS application.

This flexibility enables the operators to easily apply different pricing schemes and tariffs, while the impact of change is smaller than with traditional accounting models. On turn, it also enables better accounting on the usage of the cloud computing.

Furthermore, this model could be expanded by including other business support systems such as client management or network operations. Future work will focus on testing the performance of the methodology over a in company scenario. The application of this method to other cloud services is also planned.

## References

[1] Buyya, R., Yeo, C., Venugopal, S., Broberg, J. and Brandic, I. "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility," Future Generation Computer Systems (25:6), 2009, pp. 599-616.

[2] Stiller, B., Fankhauser, G., Plattner, B. and Weiler, N. "Pre-study on “Customer Care, Accounting, Charging, Billing, and Pricing”," Computer Engineering and Networks Laboratory TIK, ETH Zurich, Switzerland, Pre-study performed for the Swiss National Science Foundation within the “Competence Network for Applied Research in Electronic Commerce, 1998.

[3] Zseby, T., Zander, S. and Carle, C. "RFC3334: Policy-Based Accounting," Internet RFCs, 2002.

[4] Karsten, M., Schmitt, J., Stiller, B. and Wolf, L. "Charging for Packet-switched Network Communication - Motivation and Overview," Computer Communications (23), 2000, pp. 290-302.

[5] Párhonyi, R. "Micro payment gateways", 2005.

[6] Morariu, C., Waldburger, M. and Stiller, B. "An Integrated Accounting and Charging Architecture for Mobile Grids" 3rd International Conference on Broadband Communications, Networks and Systems, 2006., 2006, pp.

[7] Koutsopoulou, M., Kaloxylos, A., Alonistioti, A., Merakos, L. and Kawamura, K. "Charging, accounting and billing management schemes in mobile telecommunication networks and the internet," IEEE Communications Surveys (6:1), 2004, pp. 50-58.

[8] Ruiz-Agundez, I., Penya, Y. K. and Bringas, P. G. "Tarificacion flexible de servicios en Internet" Proceedings of the XX Jornadas de Telecom I+D, Telefonica, Valladolid, Spain.

[9] Detal, G., Leroy, D. and Bonaventure, O. "An adaptive three-party accounting protocol", Proceedings of the 5th international student workshop on Emerging networking experiments and technologies, ACM, 2009, pp. 3-4.

[10] Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R. and Wittrock, J. R. M. C. , Andersonand, L. W. and Krathwohl, D. R., (eds.) A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Allyn & Bacon, 2000.

[11] Ruiz-Agundez, I., Penya, Y. K. and Bringas, P. G. "A Taxonomy of the Future Internet Accounting Process"'Proceedings of the Fourth International Conference on Advanced Engineering Computing and Applications in Sciences', Florence, Italy, 2010, pp. 111-117.

[12] Bihina Bella, M. A., Eloff, J. H. P. and Olivier, M. S. "Using the IPDR standard for NGN billing and fraud detection", in Hein S Venter, Jan H P Eloff, L. L. and Eloff, M. M., ed.,'Proceedings of the Fifth Annual Information Security South Africa Conference (ISSA2005)', Sandton, South Africa, Research in progress paper, http://mo.co.za/abstract/ipdrfraud.htm, 2005.

[13] Takuji, T. "Backend systems Architectures in the age of the next generation network," NEC Technical Journal (1:2), 2006, pp. 51-55.

[14] Elmroth, E., Marquez, F., Henriksson, D. and Ferrera, D. "Accounting and billing for federated cloud infrastructures"'2009 Eighth International Conference on Grid and Cooperative Computing', IEEE, 2009, pp. 268-275.

[15] Calhoun, P., Loughney, J., Guttman, E., Zorn, G. and Arkko, J. "Diameter base protocol," .

[16] Meier, R. "Design and Implementation of a Charging Component and a Formal Tariff Specification for Grid Services".

[17] Zhang, K. and Elkin, E. "XACCT's Common Reliable Accounting for Network Element (CRANE) Protocol Specification Version 1.0,", 2002. [33] Zhang, Q., Cheng, L. and Boutaba, R. "Cloud computing: state-of-the-art and research challenges" Journal of Internet Services and Applications (1:1), 2010, pp. 7-18.

[18] Presuhn, R., Case, J., McCloghrie, K., Rose, M. and Waldbusser, S. "Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)", STD 62, RFC 3418, December 2002, 2002.

[19] Han, H., Kim, S., Jung, H., Yeom, H. Y., Yoon, C., Park, J. and Lee, Y. "A RESTful Approach to the Management of Cloud Infrastructure," International Conference on Cloud Computing, 2009, pp. 139-142.

[20] Litzkow, M., Livny, M. and Mutka, M. "Condor-a hunter of idle workstations" 8th International Conference on Distributed Computing Systems, IEEE, 2002, pp. 104--111.

[21] Buyya, R., Abramson, D. and Giddy, J. "Nimrod/G: An architecture for a resource management and scheduling system in a global computational grid", Published by the IEEE Computer Society, 2000, pp. 283.

[22] Kwon, O., Hahm, J., Kim, S. and Lee, J. "GRASP: a grid resource allocation system based on OGSA". Proceedings of the 13th IEEE International Symposium on High performance Distributed Computing, IEEE, 2004, pp. 278--279.

[23] Press, S. "IBM Tivoli Usage and Accounting Manager V7.,".

[24] Dahan, M., Roberts, E. and Boisseau, J. "TeraGrid User Portal v1. 0: Architecture, Design, and Technologies"'International Workshop on Grid Computing Environments', 2007.

[25] Rings, T., Caryer, G., Gallop, J., Grabowski, J., Kovacikova, T., Schulz, S. and Stokes-Rees, I. "Grid and Cloud Computing: Opportunities for Integration with the Next Generation Network," Journal of Grid Computing (7:3), 2009, pp. 375-393.

[26] Buyya, R., Pandey, S. and Vecchiola, C. "Cloudbus toolkit for market-oriented cloud computing," Cloud Computing, 2009, pp. 24-44.

[27] Programme, I. "IPDR Service Specification. Design Guide", TeleManagement Forum, Technical report, TMForum, 2008.

[28] Baluja, W. and Llanes, A. "Estado actual y tendencias del enfrentamiento del fraude en las redes de telecomunicaciones," Ingeniería Electrónica, Automática y Comunicaciones (XXVI), 2005, pp. 46-52.

[29] Programme, I. "IPDR Business Solution Requirements", TeleManagement Forum, Technical report, TMForum, 2009.

[30] Offermann, P. and Hoffmann, M. and Bub, U., "Benefits of SOA: Evaluation of an implemented scenario against alternative architectures," 13th Enterprise Distributed Object Computing Conference Workshops, 2009. EDOCW 2009., IEEE, 2009, pp. 352-359

[31] Nurmi, D., Wolski, R., Grzegorczyk, C., Obertelli, G., Soman, S., Youseff, L. and Zagorodnov, D. "The eucalyptus open-source cloud-computing system"'Proceedings of the 2009 9th IEEE/ACM International Symposium on Cluster Computing and the Grid', IEEE Computer Society, 2009, pp. 124-131.

[32] Massie, M.L. and Chun, B.N. and Culler, D.E., "The ganglia distributed monitoring system: design, implementation, and experience," Parallel Computing (30:7), Elsevier, 2004, pp. 817-840.

[33] Fenn, M., Murphy, M., Martin, J. and Goasguen, S. "An Evaluation of KVM for Use in Cloud Computing"'Proc. 2nd International Conference on the Virtual Computing Initiative, RTP, NC, USA', 2008.

[34] Planning, C. "Operations," United States Government.

Igor Ruiz-Agundez received his degree in Computer Science Engineering by the University of Deusto in 2008, after an international stay in the University of Bath. His main research areas are Internet Economics, Computer security, Artificial Intelligence and Next-

Generation Networking. He is currently doing a PhD research in the area of Internet Economics and Artificial Intelligence. He has worked as an assistant teacher intern at programming courses and as a research intern in a research group, within the University of Deusto. He joined the DeustoTech, University of Deusto research centre in 2008 as a researcher and lecturer.

Dr. Yoseba K. Penya (1977, Basque Country). Senior IEEE member, IES and TC BACM member since 2008. He received his diploma degree in Computer Science from the University of Deusto (Bilbao, Basque Country) in 2000 and he joined the Institute of Computer Technology (Vienna University of Technology), where he had also completed his diploma thesis. In 2004, he changed to the the Vienna University of Economics and Business Administration (Department of Information Systems - New Media Lab) as assistant. In April 2006 he promoted with honours under the supervision of Prof. Dietmar Dietrich (Austrian IEEE President, Institute of Computer Technology, TU Vienna) and Prof. Nick Jennings (School of Electronics and Computer Science, University of Southampton). Since September 2007 he is back with the University of Deusto and DeustoTech where he leads the Smart Grids group of the Energy research area.

Dr. Pablo Garcia Bringas: PhD in Computer Science and Artificial Intelligence, in the field of Information Security. He also has a Master's Degree in Telecommunications and a Master's Degree in Information Technology CAD/CAM. Engineer in Computer Science. He is the head of unit of the S3Lab laboratory (Laboratory for Smartness, Semantics and Security) at Deusto Institute of Technology - Deustotech. He is also the director of a Master in Information Security. Professor, in the Department of Physics and Applied Mathematics, Faculty of Engineering (currently), and the departments of Software Engineering and Computer Architecture, Automation and Telecommunications (in the past). He is a promoter of R&D in cooperation at regional, national and international levels.