# CloudWave: Agile Service Engineering for the Future Internet


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**Abstract.** After achieving initial market penetration, Cloud Computing stakeholders now call for a next generation of Infrastructure and Software as a Service offering (IaaS and SaaS). CloudWave, an EU-funded FP7 research project, looks to dynamically adapt cloud services to their environment, resulting in improved service quality and optimized resource use. This is supported with an enhanced cloud monitoring that provides holistic analytics of IaaS and SaaS layer services running on the cloud, leading to CloudWave's innovative, automated adaptation of the infrastructure and application, as well as enabling DevOps-like data and interfaces for the developer.



**Keywords:** Cloud Computing, IaaS, Monitoring, DevOps, QoS, Optimization


## 1 Introduction

Cloud computing's initial success and impact in the IT sector is undeniable, but as its service offerings continue to evolve, both cloud infrastructure providers and application developers alike look toward a significant improvement in terms of performance, reliability and agility.

Cloud providers selling Infrastructure as a Service (IaaS) look for ways to better optimize their infrastructure and drive down OpEx (Operating Expense). Meanwhile, their customers, cloud application developers selling Software as a Service (SaaS), seek quicker time-to-market, shortened development/maintenance cycles and increased QoS/QoE (Quality of Service and Quality of Experience) for the end-user.

Holistic and cloud-specific engineering methods are needed to address the pain points of both stakeholders. Trends such as cloud-based monitoring and DevOps (tak-


adfa, p. 1, 2015.

ing the role of software Developers and Operators) seek to better facilitate interactions between operations with development, but current solutions fall short in integrating such services between the infrastructure and application layers of the cloud.

CloudWave (www.cloudwave-fp7.eu) is an EU-funded FP7 research project that advances these areas in cloud computing provision, enabling a next generation of cloud infrastructure operations and agile development for their hosted applications.

## 2 Objectives of the Project

While other solutions such as OPTIMIS are focused only on an optimized infrastructure management[1], CloudWave research advances cloud infrastructure operations and agile development by dynamically adapting cloud services to their environment, improving service quality and optimizing resource utilization. Inspired by the emerging concept of DevOps for facilitating application development, CloudWave empowers cloud infrastructure providers (IaaS) and their hosted applications developers (SaaS) to transparently collaborate to obtain high levels of service at lower costs.

**Execution Analytics:** CloudWave improves existing cloud monitoring solutions with a more holistic and efficient approach towards IaaS and SaaS services. Unified monitoring consolidates infrastructure vs. application data, as well as virtual infrastructure vs. physical hardware. Programmable monitoring enhances filtering and delivery of data for analysis, allowing for better management of resources.

**Coordinated Adaption:** CloudWave enables reconfiguration of the infrastructure and application in real-time to compensate for a variety of performance factors, resulting in an increasingly resilient, automated and optimized cloud deployment.

**Feedback-driven Development:** CloudWave advances current DevOps solutions with developer-oriented data based on monitoring. It mixes automation (coordinated adaptation) with customizable feedback for improved agile development, resulting in quicker time-to-market, shortened maintenance cycles and more reliable applications.

In the case of an application for communication through VoIP (Voice over IP), CloudWave will detect there are quality issues in the calls because of cuts in the voice and, therefore, it will trigger an adaptation action. One of the options could be to increase the number of resources allocated for the application (VMs and network bandwidth), while another one could be to use a compression algorithm which would have less quality but which requires fewer resources. CloudWave will take a decision which involves both the application and the infrastructure, generating feedback about the adaptation for the developers, so they will be able to improve their application.

## 3 Proposed Solutions

Since CloudWave aims at providing tools for DevOps, its architecture has been organized in such a way that it differentiates design time and runtime components.

[1] Ana Juan Ferrer et al: OPTIMIS: A holistic approach to cloud service provisioning. Future Generation Comp. Syst. 28(1): 66-77 (2012)

While the design time components are focused on tools for applications development (definition of the basic architecture, monitoring metrics, enactment points and non-functional properties, and validation and feedback handling), runtime components are in charge of the monitoring, coordinated adaptation and feedback generation.

But the architecture complexity increases taking into account that CloudWave is oriented to work in a close integration with OpenStack[2], which means that the runtime components must interact with OpenStack components (Ceilometer and Heat, mainly), so the runtime architecture is customized in such a way the provided APIs and communication mechanisms (i.e. AMQP[3] queues) are available for key components.

### 3.1 Monitoring Data Collection and Analytics

The monitoring solution is the more advanced one, since the initial efforts focused on gathering as much monitoring data as possible. CloudWave proposes to use a 3D monitoring approach[4], where physical machines metrics, virtual machines metrics and application metrics are put together providing a full context of the execution environment. This information is gathered through several tools and a library running in each Virtual Machine (VM), allowing applications even to define their own metrics.

The monitoring metrics are sent to a Complex Event Processing (CEP) engine, in order to detect the activation of enactment points, in such a way that the CEP engine will notify the components in charge of the coordinated adaptation, so they may decide which actions to perform. For doing so, developers may define statements, which are built in an automatic or semi-automatic way (depending on the complexity) by using CloudWave tools. An example of automatic construction of statements is the definition of Service Level Agreements (SLAs), where CloudWave will generate statements for triggering adaptation actions when the SLA is going to be violated.

### 3.2 Coordinated Adaptation

The coordinated adaptation consists on enabling the possibility that the infrastructure and the applications synchronize the way in which the application execution can be optimized[5]. For doing so, from the design-time perspective, some metadata are provided together with the application deployment, so potential enactment points are defined, together with dependencies and other aspects (i.e. preferred hardware).

From the runtime perspective, CloudWave maintains an object model with the status of the infrastructure and the deployed applications. Using information and an ad-

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[2] https://www.openstack.org/

[3] https://www.amqp.org/

[4] Clarissa Cassales Marquezan et al. 3-D Cloud Monitoring: Enabling Effective Cloud Infrastructure and Application Management. In Network and Service Management (CNSM), 2014 International Conference on, page 9, 2014.

[5] Clarissa Cassales Marquezan et al. Towards exploiting the full adaptation potential of cloud applications. In In Proceedings of 6th International Workshop on Principles of Engineering Service-Oriented and Cloud System (PESOS 2014), page 10, 2014.

aptation model, it is possible to generate dependency trees which will support decision making when adaptation events arrive from the monitoring tools.

### 3.3 Feedback Provision

Taking into account some monitoring data and the information about the adaptation actions performed, CloudWave aims at providing DevOps feedback about how to improve the code of their applications, the way to deploy them or even the way to manage adaptation (i.e. by defining better enactment points).

The feedback tools will provide information about anti-patterns (patterns to avoid) and execution trace points (usual points of failure), and they also may provide information about application monitoring metrics and SLAs fulfillment.

## 4 Implementation

As mentioned before, CloudWave is very integrated with OpenStack and, therefore, it makes use of some existing OpenStack components and extends others. Moreover, other independent components are under development, complementing OpenStack functionalities. This means that certain components are implemented in Python, while others are implemented in Java. But, still, the interaction among them is possible thanks to the communication through REST APIs and AMQP queues (re-using the main interaction mechanism in OpenStack).

Ceilometer is used as monitoring collector in CloudWave, so it gathers all the monitoring data, stores it in a MongoDB database and forwards monitoring metrics to the wrapper created for the Esper CEP engine.

In the case of the coordinated adaptation, developers are working on extending Heat by adding the proposed features.

Finally, for the feedback provision, the consortium is working on an integrated IDE based on Eclipse, in such a way that all the tools related to feedback visualization and applications development will be available in a single environment.

## 5 Conclusions

CloudWave represents a new approach in which the Cloud infrastructure and the applications running on the Cloud coordinate themselves for optimizing applications execution. For doing so, CloudWave is based on three main pillars: monitoring all the aspects available, defining a coordinated adaptation mechanism and providing feedback to DevOps about their application and the way it is executed on the Cloud.

Although it is still a work in progress, CloudWave already provides a set of basic tools which are integrated with OpenStack, providing additional features to the Cloud and integrating quite heterogeneous tools which coexist for a common purpose.