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TECHNICAL INFORMATION TO FIRST OPEN CALL

Technical Information

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2 PRACTICAL INFORMATION

This document gives a technical description of the CloudiFacturing solution, in the state that is expected to be available for the experiments of the first open call in the CloudiFacturing project. All experiments are required to make use of this solution, with the aim of boosting their commercial and technical outcome as well as guiding the future development of the solution. This document is thus intended to give proposers the necessary information on how to relate their experiments to the CloudiFacturing solution and how to describe this relationship convincingly in their proposals. Further accompanying material for the first open call includes the [Proposal Template](#) and the [Guide for Applicants](#), including how to get help writing a proposal. These documents provide detailed information on the structure of the envisioned proposals and the rules for their submission.

For the homepage of the CloudiFacturing project, please visit <https://www.cloudifacturing.eu>. The initial experiments are described at: <https://www.cloudifacturing.eu/our-first-experiments/>.

3 INTRODUCTION TO THE CLOUDIFACTURING SOLUTION

The CloudiFacturing solution is designed to support manufacturing SMEs and their needs for advanced cloud- or HPC-based ICT solutions, both for time-limited experiments and for the commercial operation after the end of the experiments. Striving for maximal interoperability, the CloudiFacturing project and its solution, which is being developed within, integrate manifold software and hardware platforms which have emerged from previous projects and research initiatives. Through CloudiFacturing, end users (e.g. manufacturing SMEs) will be able to seamlessly access all these platforms as if it were just a single platform.

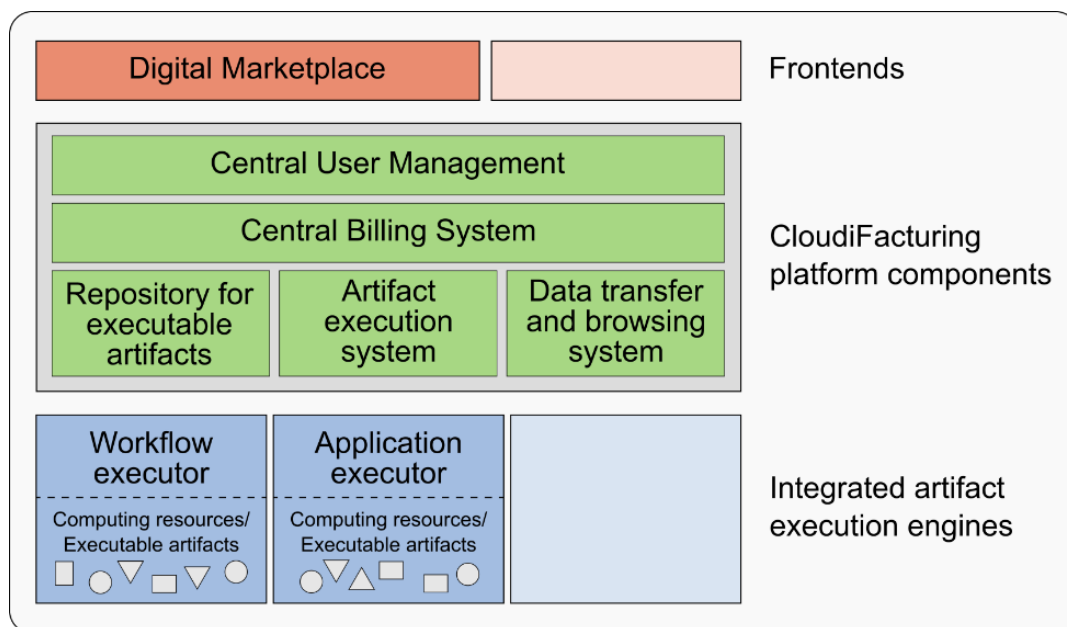


FIGURE 1: SCHEMATIC ARCHITECTURE OF THE CLOUDIFACTURING SOLUTION

Figure 1 illustrates the architecture of the CloudiFacturing solution. For end users, software deployed in CloudiFacturing will be accessible using the *Digital Marketplace* web application or vendor-specific frontends such as desktop applications or tailored web applications (red boxes). More than only a user interface to the CloudiFacturing platform components, the Digital marketplace is aiming to be a

commercialization hub and space for community-building around cloud-based engineering software for the manufacturing industry. The Digital Marketplace and its offers are described in more detail in chapter 4.

The CloudiFacturing solution focuses on software packages, applications, and workflows, which are executed on cloud and/or HPC resources. Here, all these are referred to under the generic name of *executable artifacts*. CloudiFacturing integrates several different types of such artifacts and their corresponding executing engines/platforms (blue boxes in Figure 1) and will make them harmoniously accessible. Chapter 5 gives an overview of the currently supported artifact types and their capabilities. Further types may be integrated into the CloudiFacturing solution in future.

Since the described artifact types originated from several different research and development initiatives, they are not necessarily interoperable on their own. The *CloudiFacturing platform* with its five core components (green boxes in Figure 1) homogenizes access to these artifacts and their platforms, creating a seamlessly usable "platform of platforms". *Central User Management* and *Central Billing* provides a single-sign-on experience across the complete CloudiFacturing solution with unified invoices for all used resources. The *Repository for executable artifacts* stores metadata of all applications, workflows, etc. deployed in CloudiFacturing, allowing for a single, *unified execution interface* used by the Digital Marketplace (or other future frontends). Since each executable artifact may use specific storage resources, a *data transfer and browsing* system is available to transfer data between all storages associated to any of the platforms. Technical details of the CloudiFacturing platform components are described in chapter 6.

Chapter 7 gives an overview of the cloud and HPC hardware resources currently available in CloudiFacturing. Finally, chapter 8 describes auxiliary services and technologies offered by existing project partners to all experiments in CloudiFacturing.

4 THE DIGITAL MARKETPLACE

The Digital Marketplace (DM) is a dynamic web application that enables customers to access the CloudiFacturing services. The DM is the reference frontend implementation to the CloudiFacturing platform and thus allows direct access and execution of all executable artifacts registered on the platform, regardless of the specific execution engine they are using.

The DM has a commercial purpose, aiming to showcase services, to directly sell services to customers, and to support the development of a community around the CloudiFacturing technology (e.g. cloud/HPC, big manufacturing data, data analytics, simulation software, engineering and manufacturing, etc.). In addition to showcasing services that can be accessed and executed from the DM, it will also be possible to explore technologies that could be provided by partners of the DM and that could be customized for the individual needs of the potential customers.

The DM provides the needed functionality to support the customers in exploiting and benefiting from the CloudiFacturing services. To achieve this, the main functionalities of the DM are clustered as (see Figure 2):

- *Information services* aim to keep the DM visitors informed, by providing general information about CloudiFacturing and its technology in form of presentations, news, webinars, etc. These services will help the DM visitors to learn from CloudiFacturing at a glance and to be up-to-date.

- *Community services* will facilitate the interaction and information exchange between community members. The community members are stakeholders related to the CloudiFacturing technology, aiming to learn more about the technology, use the technology, offer services based on the technology, or supporters of the technology. In order to facilitate the interaction, blogs, forums, and collaboration tools in general will be available.
- *Cloud / HPC services* will support the operation of executable artifacts within the DM. This support involves the access to documentation, training, and consultancy, as well as to the configuration of software offering and computing resources. Through these services, the DM visitors will be able to operate the executable artifacts and process the generated results.
- *Financial services* aim to provide the needed functionality to manage the orders, transactions, and history of the consumed services. This set of services should create transparency and accountability for members and within multiple users of organisations.
- *User management services* will enable the organisation managers to handle the profile, the users, and the roles for their corresponding organisation within the DM. In this way, the organisation managers can define what kind of services will be available for their users or delegate this responsibility to trusted users within their organisation.
- *Security services* will guarantee the lawful and secure processing and handling of data including personally identifiable data as well as organisational data (e.g. provided data for the operation of executable artifacts or generated data through the executed services). The security services should enable the organisation to define the expected sensitivity for its associated data.

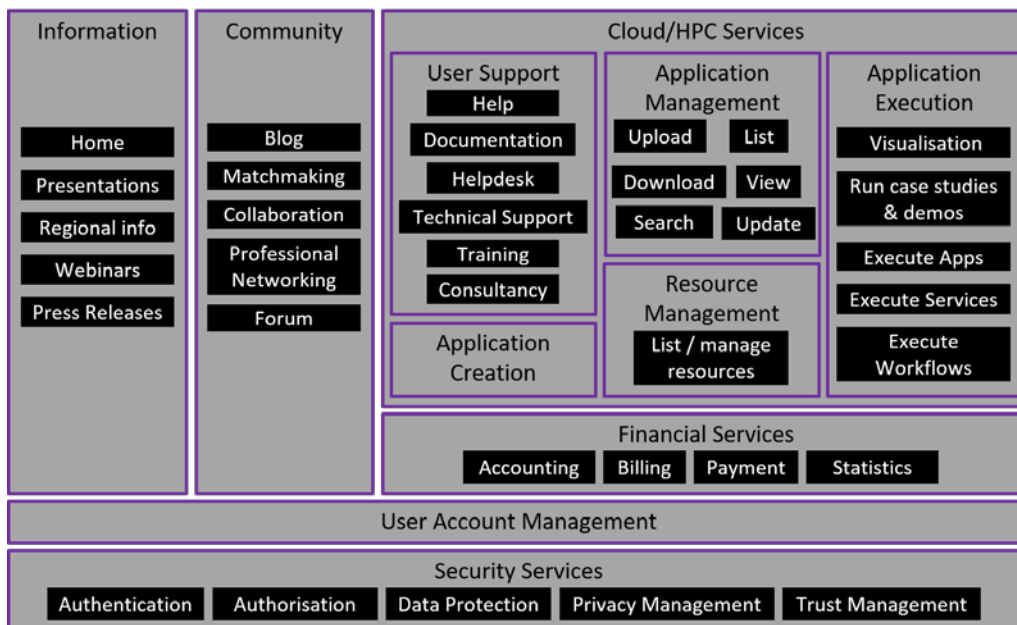


FIGURE 2: DESCRIPTION OF THE DIGITAL MARKETPLACE SERVICES

5 SOFTWARE ARTIFACTS SUPPORTED IN CLOUDIFACTURING

This chapter describes the different types of *executable artifacts* (cloud- or HPC-based applications and workflows from different existing platforms) which the CloudiFacturing project makes available in a single solution.

5.1 CloudFlow workflows

CloudFlow workflows are one of several types of artifacts which can currently be executed through the CloudiFacturing platform. Originating in the CloudFlow EU project, the *CloudFlow platform* provides a workflow execution tool, where a workflow is defined as a set of calculations, simulations, or analytics tasks, which are executed "in the cloud" for some specific user input. The scope of application of the CloudFlow platform are complex engineering and manufacturing workflows from simulation-based design all the way to analytics of production data and result visualization. In the CloudiFacturing project, CloudFlow is focused especially on computationally expensive workflows to be run on High-Performance-Computing (HPC) resources.

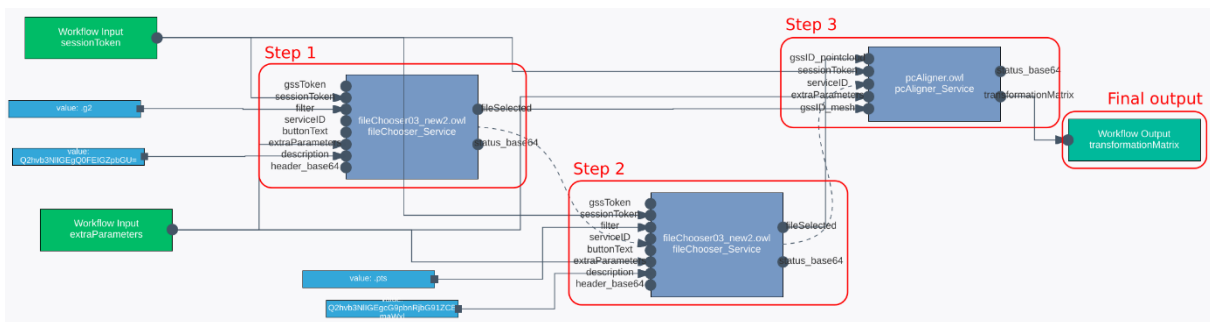


FIGURE 3: CLOUDFLOW WORKFLOW EDITOR SHOWING A THREE-STEP WORKFLOW

As shown in Figure 2, CloudFlow workflows are constructed via a graphical workflow editor. The shown example workflow comprises three steps, each of them representing the execution of one cloud-deployed software package called a *CloudFlow service*. Each service has a defined set of input and output parameters, the connections between which define the flow of data in the workflow. During workflow execution, the *CloudFlow Workflow Manager* automatically enforces this data flow and executes all steps in the right order. During the entire execution, the workflow can be monitored in the user's web browser, also when running calculations on an HPC cluster which is typically accessible only via an SSH command line. Depending on the individual execution step, the displayed feedback status ranges from simple text messages to complex and fully interactive html user interfaces.

5.1.1 Selected CloudFlow platform services

While the flesh of most workflows will use custom CloudFlow services which encapsulate individual simulation or analytics software (see section 5.1.2), several generic platform services are available, serving requirements shared by most workflows.

5.1.1.1 Cloud storage access through Generic Storage Services (GSS)

With a plethora of file and object storages available in the cloud, there is also a plethora of different APIs required to access those storages. *Generic Storage Services* or GSS simplifies this access by providing a single, generic API which can access several different cloud storage locations. On the

workflow level, CloudFlow-specific GSS URIs are passed as data references from service to service, while the actual data represented by these URIs is only accessed when necessary. Therefore, the flow of data in a CloudFlow workflow has virtually no overhead. Furthermore, a graphical file browser using GSS is available as a CloudFlow platform service which can be integrated into any workflow, making upload and selection of user input a no-brainer.

5.1.1.2 Obstacle-free HPC access with the CloudFlow HPC service

What GSS is for file access, the *CloudFlow HPC service* is for accessing High-Performance Computing (HPC) resources. One of the caveats when it comes to the utilization of HPC resources is possible vendor lock-in. HPC providers usually allow login via SSH with personal user credentials, have specific queueing systems, specific locations for data storage, and possibly restricted access to cloud file storages. The CloudFlow platform allows the utilization of HPC resources through a generic interface, without the need to adapt to the environment and configuration of a specific HPC provider. This decoupling is achieved through the "containerization" of computation software using Singularity¹ (kind of a "Docker for HPC"), which is then executed on the HPC cluster using the CloudFlow HPC service. For HPC providers, a working Singularity installation on the HPC cluster is enough for integration in the CloudiFacturing platform, without the need of installing further software from experiment partners. The CloudFlow HPC service is fully integrated with GSS and the CloudFlow workflow system, making HPC access completely seamless from a user's perspective.

5.1.1.3 Flow-control utility services

A set of simple utility services is available to allow some user interaction inside workflows. For example, the user can be shown a message or asked for a binary decision simply by adding ready-made building blocks (such as visible in Figure 2) to a workflow.

5.1.1.4 Automatic input-GUI creator service

Besides input files, a workflow often requires user input in the form of several numbers, ranges, or parameter selections. To streamline such user input, a service template which generates an html input mask from a simple, table-based description of the required input parameters (including input validation) is available.

5.1.1.5 Workflow Editor and Workflow Manager

The CloudFlow Platform provides basic services that make it easy to integrate new services and create workflows. For the deployment of new services and the creation or modification of workflows, a graphical, browser-based Workflow Editor tool is available. The user interface of the Workflow Editor is directly integrated in the Digital Marketplace, so no installation of additional Software components is needed. The execution and monitoring of workflows is performed by another platform component, the Workflow Manager, which can also be accessed via the Digital Marketplace.

Both Workflow Editor and Workflow Manager are furthermore addressable using a SOAP API, which makes it possible to create custom user interfaces integrated with a company's own website or

¹ <https://singularity.lbl.gov/>

desktop application. All interface descriptions are also available in the standardized Web Service Description Language (WSDL), which makes automatic client generation possible.

5.1.2 Custom CloudFlow services

The CloudFlow platform itself does not provide any simulation or calculation software packages, but it makes it easy for independent software vendors (ISVs) to use the platform and make their software available as custom CloudFlow services, which can then be integrated into CloudFlow workflows.

These custom services come in two flavours. Computationally demanding tasks are typically integrated as HPC jobs using the CloudFlow HPC service. Other tasks (including user input, pre- and post-processing of HPC jobs, data conversion, or results visualization) are commonly integrated as CloudFlow services which are made available as building blocks in the workflow editor. To do so, ISVs create simple SOAP web services encapsulating the desired functionality and deploy these services on the CloudFlow platform using Docker containers. After a simple registration procedure, the services can be used for workflow creation inside the workflow editors. Once services are integrated into the platform, they or also whole workflows can also be offered on a commercial basis to other users within the platform.

5.1.3 Platform documentation

Independent software vendors (ISVs) wishing to integrate their software into the CloudFlow platform are supported by an extensive documentation platform. This platform features descriptions of all CloudFlow concepts and platform services as well as tutorials and code examples for all relevant areas of service implementation and workflow creation.

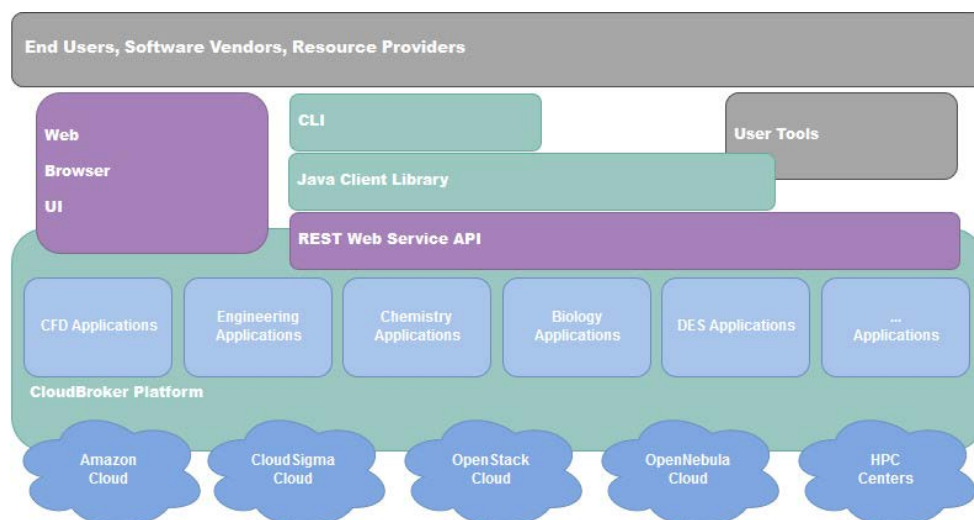
Link to the documentation: <https://github.com/CloudiFacturing/docs-and-training>

5.2 CloudBroker applications

One of CloudBroker's main products is the CloudBroker Platform, a backend tool for the deployment, management and running of compute intensive software on various cloud infrastructures.

The CloudBroker Platform uses IaaS from resource providers and provides PaaS to software vendors and SaaS to end users. It allows users to register, deploy, charge for and use their own cloud resources and application software or use resources and software provided by others (e.g., CB itself).

The architecture of the CloudBroker Platform is presented below.



The CloudBroker Platform incorporates adapters both to public and private cloud infrastructures, HPC centers, and both to compute and storage resources. Currently, the following cloud adapters are available on the Platform: Amazon EC2 compute and S3 storage resources, OpenStack, Eucalyptus, OpenNebula and CloudSigma compute and storage resources. Several European HPC centers can also be accessed, including the CINECA Galileo Cluster in Italy, the ROMEO Cluster in France, the ETH Euler Cluster in a Switzerland, and the HLRS NEC cluster in Germany. HPC access is possible only if the user has a separate account on a particular HPC center.

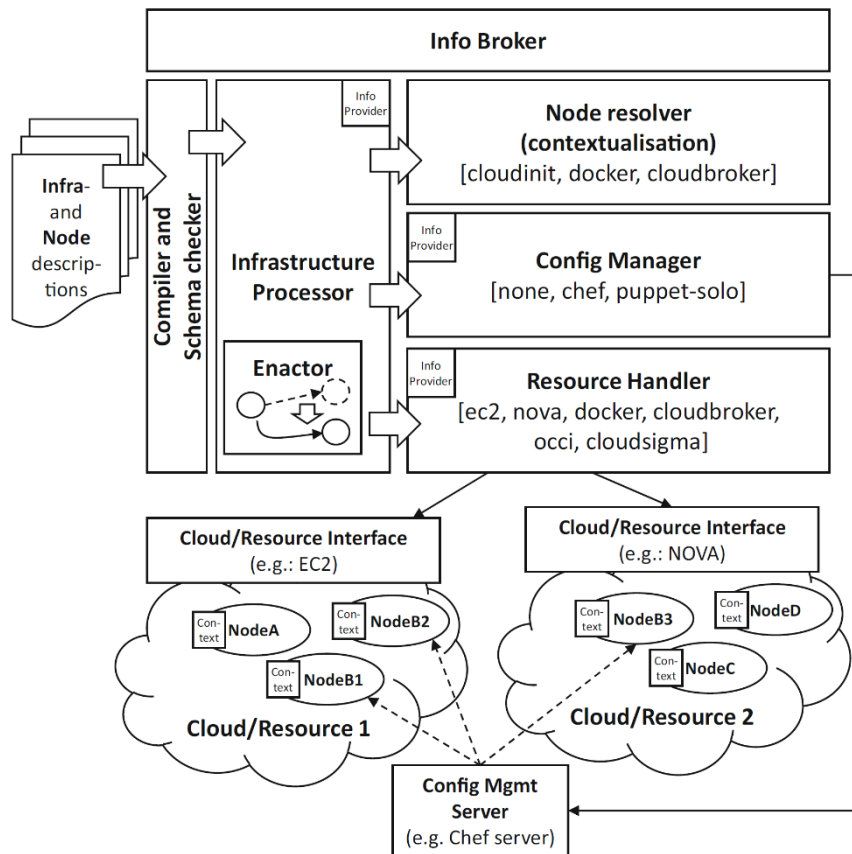
On the application side, the CloudBroker Platform is cross-domain and supports all kinds of interactive and non-interactive batch-oriented applications, both serial and parallel ones. One example of such interactive applications is ParaView⁴¹ that enables the visualization of CFD (Computational Fluid Dynamics) simulations.

The CloudBroker Platform can be accessed as a direct front-end or as a back-end middleware service. For the former, the platform is accessed with any regular web browser as a service via the internet. For frequent, advanced and automatic usage, programmatic accessibility via APIs is provided. These include a REST web service interface, a Java client library and a Linux shell command line interface (CLI). Via its different APIs, the CloudBroker Platform can be utilized by front-end software as middleware to allow access to applications in the cloud.

The CloudBroker Platform has been integrated with the WS-PGRADE/gUSE⁴² framework within previous projects to provide workflow capabilities. In the context of the CloudiFacturing project, its new generation, the Flowbster workflow framework with the Occopus orchestrator, will be used.

5.3 Occopus orchestrator

Occopus is a framework that allows configuring and orchestrating distributed applications (so called virtual infrastructures) on single or multi cloud environments in a cloud-agnostic way. The configuration and initial setup of nodes can be performed through contextualization and configuration management. The built-up infrastructure can then be continuously maintained, the health of nodes can be monitored and can be recovered if needed in an automatic way.



Occopus has a pluggable architecture (see below) to handle the following cloud interfaces: EC2 (e.g. OpenNebula), Nova (e.g. OpenStack), OCCi (e.g. EGI Fedcloud), and particularly CloudBroker Platform, and CloudSigma for CloudiFacturing applications. Moreover, Occopus also has a Docker plugin to build infrastructure based on software containers. The available plugins for config managers are Chef and Puppet solo. Finally, for contextualisation cloud-init plugin is the most widespread and usable, however CloudBroker and Docker have their own contextualisation plugins as there are different contextualisation mechanisms on these resources.

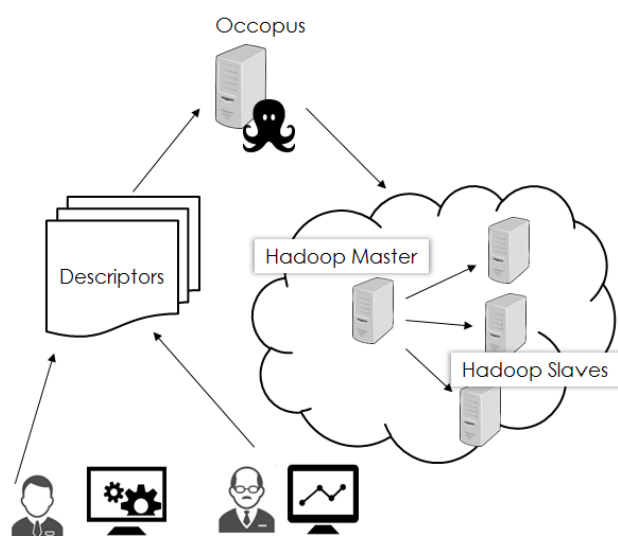
Occopus is based on descriptors and definitions. The infrastructure description contains the list of nodes, their descriptions and their dependencies. Node descriptions detail what to be instantiated including reference to a node definition and scalability rules.

The orchestration engine (infrastructure processor) in Occopus is designed in a way that it calculates the delta between the desired and actual status of the infrastructure and then performs various actions (start new node, destroy node, restart node, etc.) to eliminate the difference and to reach the desired state of the infrastructure. Based on this feature, Occopus performs life-cycle management of the virtual infrastructure by continuously monitoring and recovering the nodes of the infrastructure. When

a faulty node is detected, Occopus will replace it with a new healthy one. Occopus supports pluginable and configurable health monitoring. One may use currently implemented health-checking primitives like ping, port access, URL response, MySQL database connectivity or may implement new health-checking mechanism as a plugin for Occopus.

Manual scaling mechanism is also supported. Each node has its minimum and maximum quantity specified in the infrastructure description and Occopus takes care scaling up and down on external request within the limits. External scaling request can arrive through command-line functions or through a REST API. Automatic scaling can also be built on top of Occopus by attaching a monitoring and decision-making software like e.g. Prometheus.

A typical high level, Big Data analytical use case can be seen below, where Occopus is responsible for the orchestration of a Hadoop cluster in the cloud, and the data scientist or expert reuses the Occopus descriptors (created by e.g. a system operator) to build such virtual infrastructure.



5.4 Flowbster workflows

Flowbster is a cloud-oriented workflow system, the new generation of the earlier referenced WSPGRADE/gUSE framework on the top of the Occopus orchestrator. It was designed to create efficient data pipelines by which very large data sets can efficiently be processed in clouds. A Flowbster workflow can be deployed in the target cloud as a virtual infrastructure through which the data to be processed can flow and while it flows through the workflow, it is transformed according to the workflow's business logic. Instead of using an enactor-based workflow concept, Flowbster applies the so-called service-choreography concept where the workflow nodes directly communicate with each other. Workflow nodes recognize that they can be activated with a certain data set without the interaction of a central control service like the enactor in service-orchestration workflows. As a result, Flowbster workflows implement a more efficient data path through the workflow than service-orchestration workflows.

The Flowbster workflow approach is based on a layered concept. Here we distinguish four layers from bottom to top:

1. The Occopus (see previous section) Cloud Deployment and Orchestration Layer serves to automatically deploy and manage the data pipeline in the target cloud, e.g. using CloudBroker Platform.
2. The Flowbster Workflow System Layer defines its uniform building block (workflow node) and execution framework by which complex data pipelines can be built. Since Flowbster is based on the service-choreography concept, the services work autonomously while communicating with other services. These services realize the functional nodes of the data pipeline workflow.
3. The Flowbster Application Description Layer enables the user to define a graph topology of the data processing workflow by defining the required number of input and output data arcs of the individual nodes and their connections, and also define the functionality of the individual nodes.
4. The Flowbster Graphical Design Layer provides an easy and intuitive graphical user interface to design the workflow layout and also to define the functions for the various nodes.

Below you can find a typical example, a 3-node workflow tested on CloudBroker Platform.



6 TYING IT ALL TOGETHER: THE CORE CLOUDIFACTURING PLATFORM COMPONENTS

To allow for seamless access to all the different types of software artifacts listed in the previous chapter, the *CloudiFacturing platform* is being developed as a homogenization layer above these artifacts and their corresponding execution engines. The components of this "platform of platforms" are described in this chapter.

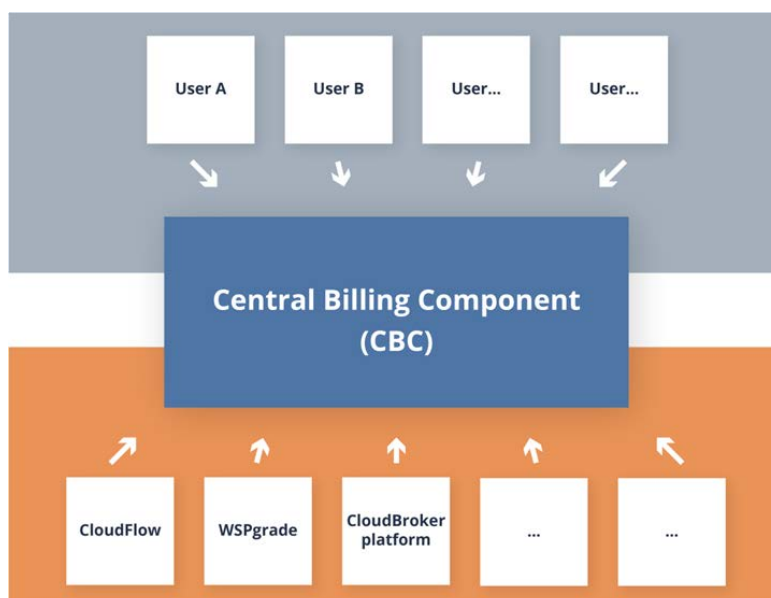
6.1 Central User Management

The main role of the **Central User Management** is to provide a common user authentication and single-sign-on solution across the platform, securing the data and computational resources. It provides a common database for all user types, including ISVs, end users and Marketplace operators. It also handles different access groups which is a prerequisite for information sharing across the platforms between different users. The Central User Management function relieves the end-user of the burden of handling multiple credentials and relieves other CloudiFacturing components from user and credentials management. In the next generation, the central user management module will also provide protection of credentials for access to external cloud resources. Experiment partners will usually not interact directly with the Central User Management, but rather rely on existing components to communicate with it and perform user authentication.

6.2 Central Billing System

The Central Billing System is provided by the Central Billing Component (CBC). It will use CloudSME's AppCenter as a base technology. Billing functionality will be extracted from the AppCenter into an independent API-accessible module for the CloudiFacturing project.

The general overview of the component is presented below.



The CBC collects usage information from executors (CloudFlow Platform, CloudBroker Platform, Workflow Managers, etc.) and allows to configure different business models for the final users. It keeps track of charges based on configured business models and collected usage information. Further, the CBC provides billing and usage-related reports and charges final users based on the business models defined.

All usage and billing reports are exposed through an API which will be accessed by the Digital Marketplace and other CloudiFacturing platform components.

The CBC keeps track of all the orders processed for each registered organization and all the generated bills for each organization. The history of the bills will be kept for as long as the organization exists in the system.

6.3 Artifact repository, execution, and data service

The CloudiFacturing platform integrates several different workflow and application engines targeted for cloud or HPC resources. The main orchestration service is responsible for managing these different engines such that all software artifacts can be executed, regardless of the specific execution engine(s) an artifact runs on.

All executable artifacts are described in a central repository, with meta-data defining how and by which execution engine they must be run.

For workflows that combine parts that need to be executed by different execution engines, the main orchestration service passes the results from one engine to the next (using the data transfer and browser system) and returns the final results to the user via the *Digital Marketplace*.

In the following sections, the different types of software artifacts supported by the CloudiFacturing platform are presented.

7 RESOURCE PROVIDERS IN CLOUDIFACTURING

This chapter gives an overview of the hardware infrastructure available in CloudiFacturing, provided by the project partners CloudSigma and IT4I.

7.1 CloudSigma

CloudSigma is a pure Infrastructure-as-a-Service cloud provider that provides an environment with the same degree of flexibility and customisation as equivalent private in-house environments. All functionality is available via an API or WebApp. Virtual machines can be provisioned in a matter of seconds (15 sec avg.) with a high degree of control. Users have the option of full API access with all account actions available, i.e. 100% API coverage, allowing complete automation and remote infrastructure monitoring, or the option of a feature-rich, yet intuitive web browser-based GUI. The CloudSigma WebApp allows for resource management via any web browser. Project partners can select CPU and RAM to the nearest MHz and MB. VM provisioning can be achieved via a simplified wizard or a custom server creation tool.

CloudSigma provides full availability of its production cloud to all beneficiaries. Any one of CloudSigma's European locations (e.g. Zurich, Frankfurt, Warsaw) can be used. Other non-European locations can be used on request. A discounted 3-year subscription for 100 GHz CPU, 100 GB RAM, 1500 GB SSD, 3000 GB HDD has been allocated to the project. GPUs have been purchased by CloudSigma and are currently in the process of integration. These resources are dedicated to the project at no cost to project partners.

Processing, storage, networking and other fundamental computing resources are not bundled, meaning CPU, RAM, storage and bandwidth can be combined independently. This level of flexibility is available to the CloudiFacturing project partners. However, usage will be monitored to ensure the total resource limits outlined in the Grant Agreement are not exceeded by a significant margin. We will offer solutions if they do.

All cloud servers and drives are persistent and modelled on the same methodology as physical dedicated server equivalents (i.e. drives, NICs etc.). VLANs and IP addresses are also controlled using standard behaviour and support all types of traffic including multicast and broadcast traffic, which is critical for high availability infrastructure in failover.

CloudSigma's IaaS cloud platform exposes several optimisation tools allowing for greater performance levels. CloudSigma's project team will be available to assist experiment owners with configuration. For performance sensitive workloads this is especially important.

7.1.1 Software

Any x86-based operating system and software can be used with complete administration/root control including all variants of BSD, Linux, and Windows. Raw ISO images can also be uploaded and attached to CPU and RAM allowing full backwards compatibility from the platform. The end user can choose from a wide selection of ready system images including a number of BSD, Linux, and Windows-based operating systems as well as being able to quickly and easily upload their own ready ISO image. End users can customise these marketplace images using cloud initialisation frameworks such as cloudinit (see <https://help.ubuntu.com/community/CloudInit>), allowing them to take a standard installation and contextualise/customise it to their specific requirements on-the-fly first boot-up.

7.2 IT4I

There are two systems available at the IT4Innovations national supercomputing center, Salomon and Anselm.

The Salomon cluster consists of 1008 computational nodes of which 576 are regular compute nodes and 432 accelerated nodes. Each node is a powerful x86-64 computer, equipped with 24 cores (two twelve-core Intel Xeon processors) and 128 GB RAM. The nodes are interlinked by high speed InfiniBand and Ethernet networks. All nodes share 0.5 PB /home NFS disk storage to store the user files. Users may use a DDN Lustre shared storage with a capacity of 1.69 PB which is available for scratch project data. User access to the Salomon cluster is provided by four login nodes.

There are two type of compute nodes. There are 576 compute nodes without accelerator equipped with two Intel Xeon E5-2680v3, 2.5 GHz (24 cores per node) and 128 GB of memory. Salomon consists of 432 MIC accelerated nodes equipped with two Intel Xeon E5-2680v3, 2.5 GHz (24 cores per node) and 128 GB of memory. Those nodes are accelerated by two Intel Xeon Phi 7120P, 61 cores, with 16 GB of RAM.

For remote visualization, two nodes with NICE DCV software are available. Each such node is equipped with two Intel Xeon E5-2695v3, 2.3 GHz (28 cores) and 512 GB of memory. Those nodes also contain NVIDIA QUADRO K5000 GPUs with 4 GB of memory.

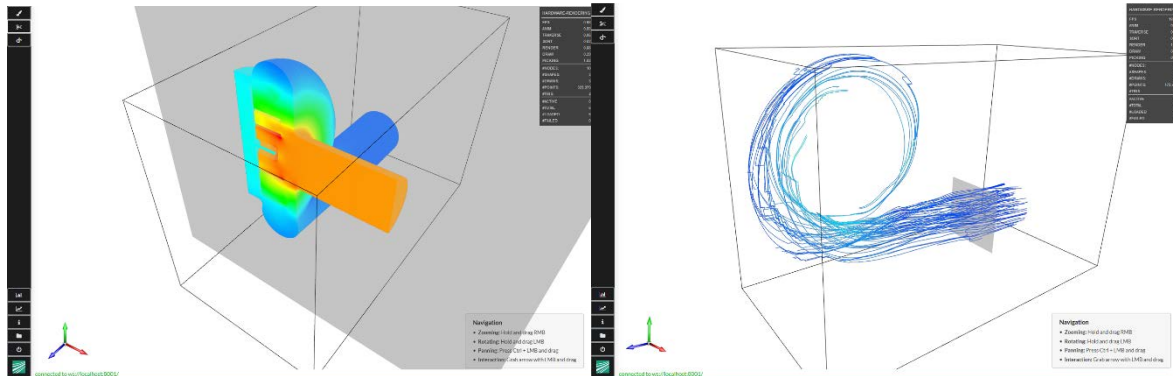
For large-memory computations, a special SMP/NUMA SGI UV 2000 server is available. This server is equipped with 14 Intel Xeon E5-4627v2, 3.3 GHz, 8 cores (112 cores in total) and 3328 GB DDR3@1866 MHz memory. It is also equipped with two 400GB local SSD disks and NVIDIA GM200 (GeForce GTX TITAN X) graphics card with 12 GB of memory.

The Anselm cluster consists of 209 computational nodes of which 180 are regular compute nodes, 23 GPU Kepler K20 accelerated nodes, 4 MIC Xeon Phi 5110P accelerated nodes and 2 fat nodes. Each node is a powerful x86-64 computer, equipped with 16 cores (two eight-core Intel Sandy Bridge processors), at least 64 GB RAM, and local hard drive. The user access to the Anselm cluster is provided by two login nodes. The nodes are interlinked by high speed InfiniBand and Ethernet networks. All nodes share 320 TB /home disk storage to store the user files. The 146 TB shared /scratch storage is available for the scratch data.

8 REUSABLE TECHNOLOGIES FROM EXISTING PARTNERS

This chapter describes auxiliary services and technologies offered by existing partners to all experiments in CloudiFacturing.

8.1 Remote Post-Processing – Visualization of 3D simulation results

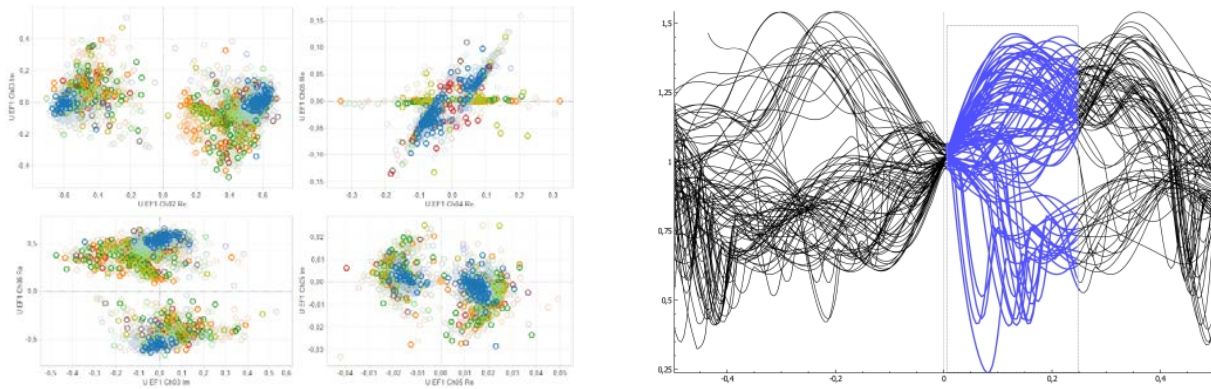


The overall goal of the Remote Post-Processing service (RPP) is to enable project partners to integrate visualization into their production process in an easy to use, fast, reliable and secure way, and therefore improve their production process.

The technology is realised via a client-server architecture in order to conduct computations on the server without the necessity to download the simulation results. The server-side computations comprise classical post-processing technology like, e.g. cross section, streamline generations or false coloring, and data transformation such that the results can be efficiently transferred to and visualised on the client. By only transmitting the necessary parts of the rendered image with some additional meta information, an efficient transmission is realised and the original simulation results can reside on the server, which might be advantageous if the original data should not be transmitted due to privacy reasons. Additionally, these techniques are combined with local (client-side) operations such as color mapping or streamline evaluation to ensure an interactive behavior on the client-side. Furthermore, the visualization techniques are optimized to support a low-bandwidth usage.

Currently, a set of visualization techniques is supported: color mapping, streamline computation, cross-section visualization, isosurface computation and value-probing. Moreover, more advanced visualization techniques will be implemented in the future. Currently, the following set of file formats is supported: VTK, OpenFOAM, and CGNS, however, with only a subset of the specifications (e.g. specific mesh types). Nevertheless, this subset can be extended, or other additional file formats can be supported in the course of the project.

8.2 Visual Analytics



Designing efficient manufacturing processes and high-quality products is a challenging task. Designs need to fulfill high demands concerning robustness, power, costs, scrap rates, durability and many others. Optimizing product and process designs can be significantly supported by the proposed Visual Analytics service. Its techniques are specifically designed to enable analysts to explore the effects of varying design parameters and to trade-off multiple quality criteria.

No matter if physical or virtual design, the design space is infinite. To actually improve the solutions, design options need to be carefully selected. A sound strategy for the optimization translates into the following advantages:

- Learn from *every* earlier simulation and physical prototype (failures and improvements)
- Minimize the number of simulations that need to be run and evaluated
- Minimize the number of physical prototypes that need to be built
- Sensitivity analysis to estimate tolerance levels in design

The analytical services from CloudiFacturing use the data from existing designs and prototypes to support the planning for the next improvement. This data may include:

- Design and environment parameters for documenting and distinguishing any earlier attempt for improvement
- Quality criteria derived from the aggregated simulation results (like torsional stiffness or elasticity of a construction, or throughput rate of a manufacturing process)
- Sensor data and/or quality criteria derived from data measured from physical prototypes or processes in operation

Data can be processed in the form of tables, representing a protocol of the entire optimizations process.

Automated methods like regression or interpolation models can be used to yield estimations of promising designs and promising changes to existing designs. Visualization techniques provide an overview over the different input parameters of the design space, support an exploration of how the different parameters influence the output and under which conditions, and trade-off different quality criteria with each other. Visualizations are generally based on visualization techniques for multidimensional data that are tailored in a way to cater for the specific requirements of the optimization process.

The result of the visual analysis is an overview about promising options or at least in indication of expected success rates for the implementation of a (yet) unknown design.

8.3 Factory integration

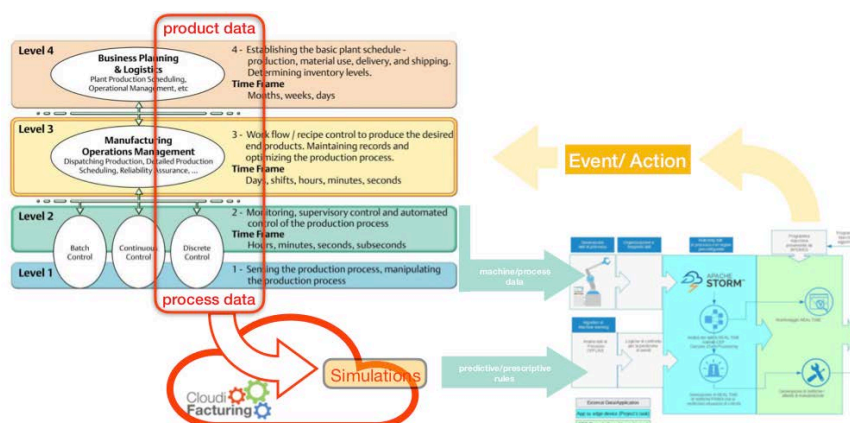
Due to the growing complexity of present products and the fast variation of volumes in time and quantity, manufacturing processes are constantly affected by low-predictable events. Moreover, in manufacturing SMEs, the used software for Factory Integration and Production Planning are usually driven from top-level business processes and order entry, and typically they are not designed to work in a predictive way using the machine data available at the work-floor. But the latest operative control-systems of manufacturing machines generate huge quantities of data whose value is not yet fully exploited, and for this reason CloudiFacturing will support experiments with adaptive and predictive tools based on the analysis of the available field and on-line generated data. These tools are based on simulation of manufacturing processes and will generate an optimized sequence of operative activities combining deterministic and predictive events.

The tool available in CloudiFacturing will enable manufacturing processes to be driven not only from the 'order entry' scheduling, but also from field data originated from operative processes or elaborated by simulated models, in order to adapt the behaviour of the manufacturing processes to the present and real situation of the production environment, by the integration of the traditional planning systems with predictive modules.

To test innovative models of manufacturing processes supported from predictive and adaptive modules, it may be used simulation tools with the target to:

- evaluate the advantages of forecasting the future behaviour of the processes by on-line simulation, for mitigating the influence of the process variability,
- model and modify the existing approach to manufacturing management in order to constantly interact with adaptive and predictive models,
- realize new user-centric workflows and interactions for the utilization of simulation,
- develop new skills and knowledge required for supporting the workers in managing successfully simulations and analytics tools.

The software module available in CloudiFacturing will receive predictive and prescriptive rules from the output of cloud-based simulations of manufacturing processes, both on-line or off-line.



As shown in the figure above, the module is listening to the on-line data from machines and processes, and it will constantly compare the real-time data flow with the rules, and if from this comparison will arise the occurrence of a possible future problem, an event will be signalled and an action will be proposed, organizing the stack of actions with an optimization logic between deterministic and predictive event-based actions.