

**Multi-cloud Execution-ware  
for Large-scale Optimised  
Data-Intensive Computing**

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**Final Features**

Abstract:

This document provides a feature list of the complete Melodic middleware platform as of the Melodic final release, presented in the deliverable D5.09 [1]. The final release concludes the last development phase of the Melodic in the scope of the H2020 research and innovation project.

There were in total three major releases, and one intermediate release during the tenure of the project. The first release, Release 1.0, was the integration release integrating the identified components of existing platforms developed by the previous European projects that Melodic is built on. The intermediate release, Release 1.5, ensured that the missing integration functionalities were added to the Melodic components borrowed from the previous projects. The code refactoring was also done to improve maintainability and build a solid foundation for the upcoming Melodic releases. The prototype release, Release 2.0, enhanced the first platform release with additional capabilities spanning data-awareness and security as well as encompasses initial integration with selected big data processing frameworks, thus making it capable to support the deployment of big data applications. The final release, Release 3.0, includes the feedback from the second release and incorporates the final set of features at the project end.

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# 1 Introduction

Cloud computing offers significant advantages over traditional cluster computing architectures including flexibility, high-availability, ease of deployments, and on-demand resource allocation - all packed up in an attractive pay-as-you-go economic model for the users. However, Cloud users are often forced into vendor lock-in due to the use of incompatible APIs, Cloud-specific services, and complex pricing models used by the Cloud service providers. Melodic is a middleware Cloud Management platform targeting the vendor lock-in problem by enabling easy Cross-Cloud deployments and optimizations of Cloud applications. Melodic provides a unified abstract interface to multiple Cloud platforms and offers a complete Cross-Cloud solution that enables modelling applications to use multi-clouds, automated resource selection based on the user requirements from various available Cloud platforms, cost optimization, security, and runtime adaptation of deployed applications and services.

In this document, we present the salient features of the Melodic platform that aspiring users can look at to judge the fitness and usability of Melodic for their Cloud applications.

## 1.1 Scope of the Document

This document presents the final list of features of the Melodic platform. The document is intended for the general audience interested in learning about the usability of the Melodic platform.

## 1.2 Structure of the Document

The rest of this document is structured as follows. In Chapter 2, we provide a brief overview of the major Melodic releases during the project period. The high-level Melodic capabilities are presented in Chapter 3. In Chapter 4, a comprehensive list of the Melodic functional and non-functional features is provided, extending on the initial feature list provided in Deliverable D2.2 [2]. Finally, we briefly describe use-case evaluations in Chapter 5, before concluding in Chapter 6.

## 2 Software Releases

There were four Melodic software releases during the tenure of the project including three major releases, Release 1.0, Release 2.0, and Release 3.0, and one intermediate release, Release 1.5.

### Initial Release – Release 1.0 – M12

The initial release was the *integration release* integrating the identified components of existing platforms developed by the previous European projects, with PaaSage<sup>1</sup> project being the main parent project. The Release 1.0 included:

- Integration of the selected components from the underlying frameworks
- New integration layer using Enterprise Service Bus (ESB) and Business Process Management (BPM) orchestration
- Introduction of the Docker containers and micro-service architecture
- Rewriting the Adapter component and improving the CP Generator component

### Intermediate Release – Release 1.5 – M16

The intermediate release was not originally planned as per the description of work of the Melodic project. However, it was added to ensure that the missing integration functionalities are added to Melodic components borrowed from the PaaSage project. The code refactoring was also done to improve maintainability and build a solid foundation for the upcoming Melodic releases. The main features of the Release 1.5 included:

- Performance efficiency by limiting the possible solution space to speed up the calculation of the application deployment solutions
- A flexible and advanced monitoring and reporting solution
- Flexible platform deployment based on Docker containers and Docker swarm
- Ability to define advanced utility functions for the managed application

### Prototype Release – Release 2.0 – M24

The prototype release enhanced the first platform release with additional capabilities spanning data-awareness and security as well as encompassing initial integration with selected big data

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<sup>1</sup> The PaaSage Project – <https://paasage.ercim.eu/>

processing frameworks, thus enable it to support the deployment of big data applications. The main improvements include:

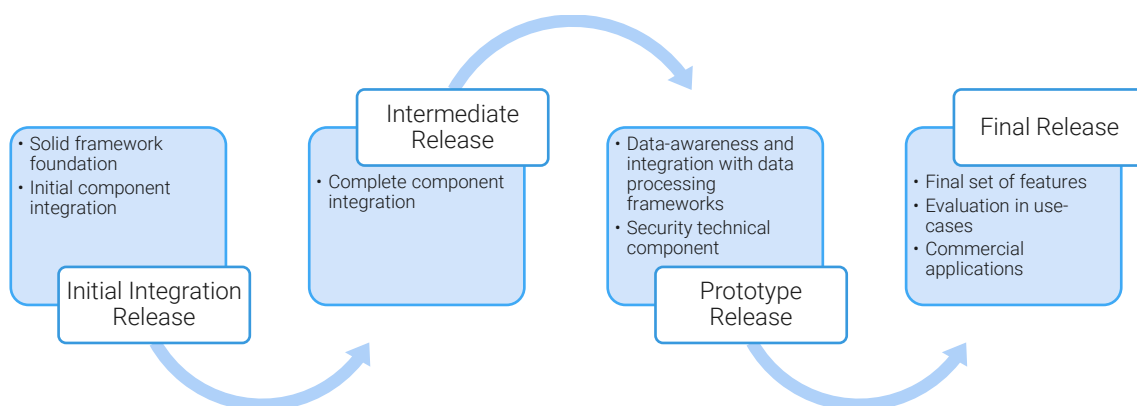
- Introduction of the extended version of the CAMEL language
- Initial support for the Spark data processing framework
- Ability to reconfigure the deployed solutions
- Enhanced Executionware based on Cloudiator 2.0
- Enhanced security with the introduction of authorization service
- Data-life cycle management system (DLMS)
- Advanced tiered event monitoring solution

### Final Release – Release 3.0 – M36

The final release includes the feedback from the second release and incorporates the final set of features at the project end. The main improvements of Release 3.0 are:

- Melodic Graphical User Interface and Visualization features
- Stability improvements
- Enhanced security based on security expert recommendations
- Comprehensive testing and quality assurance to get Melodic ready for the real-world

The timeline of the releases is depicted in Figure 1



*Figure 1: The Melodic Platform Releases during the project tenure*

### 3 High-Level Melodic Capabilities

In this chapter, we describe high-level capabilities of the final Melodic release. The requirements of the high-level capabilities were already gathered in the initial stage of the project and were reported as part of the Melodic System Specification Document, Deliverable D2.1 [3]. In the following, we enlist the salient high-level capabilities of the Melodic platform, categorized in relevant sub-sections.

#### 3.1 User Interfaces and Modelling Tools

The main Melodic capabilities related to the user interfaces and modelling tools are listed in Table 1.

*Table 1: Capabilities related to the User Interfaces and Modelling tools*

Capability	Relevant Modules	Remarks (if any)
An innovative user-friendly graphical user interface	User Interface, Upperware, Executionware	Melodic GUI is added in Release 3.0.
Secure user management	User Interface Executionware Security	
Interactive model deployments and Cloud credentials management	User Interface Upperware Monitoring	
Form-based and textual editors for modelling applications	Modelling Upperware	Syntax highlighting, parsing Mathematical expressions, CAMEL documentation integration, auto-completion



Capability	Relevant Modules	Remarks (if any)
Editor for enhancing modelling language to capture new requirements for the user applications	Modelling Upperware	This editor creates and manages Melodic Metadata Schema.

### 3.2 Transparent Deployment and Execution of Cloud Applications on Cross-Cloud infrastructures

The main capabilities corresponding to the transparent deployment and execution of Cloud applications on Cross-Cloud infrastructures are listed in Table 2.

*Table 2: Capabilities related to the transparent deployment and execution of Cloud applications*

Capability	Relevant Modules	Remarks (if any)
Support of provider-agnostic Cloud interfaces	Executionware	
Ability of automated deployment of applications in distributed Cloud environments	Upperware Executionware	
Support for major Cloud providers and platforms		Release 3.0 includes off-the-shelf support for AWS, OpenStack, Google Cloud Platform, and Microsoft Azure
Support for automated deployments of data processing frameworks	Executionware	Apache Spark and Hadoop MapReduce data processing frameworks are supported in Release 3.0.

Capability	Relevant Modules	Remarks (if any)
Support for using existing nodes in application deployments	Executionware	<i>Bring-Your-Own-Node</i> allows the usage with already existing nodes provisioned outside Melodic
Support for deploying multiple application components on a single virtual machine instance in the Cloud		Support added in Release 3.0.

### 3.3 Holistic Data Management

Melodic's capabilities related to the holistic data management are listed in Table 3.

*Table 3: Capabilities related to the holistic data management*

Capability	Relevant Modules	Remarks (if any)
Ability to comprehensively model specification and requirements for heterogeneous data sources	Modelling	Comprehensive support is added in CAMEL 2.0.
Data-awareness in Cross-Cloud application deployments	Upperware DLMS	
Efficient data placement and migration on Cross-Cloud platforms	Upperware DLMS	

Capability	Relevant Modules	Remarks (if any)
Support for a variety of data storage technologies	Upperware DLMS	Implemented via an abstract data virtualization layer based on Alluxio <sup>2</sup>
Ability to extend existing mechanism for calculating data penalties	Upperware DLMS	A plugin-based mechanism is supported in the DLMS to introduce new DLMS algorithms.

### 3.4 Runtime Adaptation of deployed cloud applications

Melodic enables advanced runtime adaptation of the deployed Cloud applications. The salient capabilities related to this are listed in Table 4.

*Table 4: Capabilities related to the advanced runtime adaption of the deployed cloud applications*

Capability	Related Modules	Remarks (if any)
Ability to calculate optimized Cross-Cloud resource allocations for data-intensive applications	Upperware DLMS	
Ability to introduce new optimization Solvers in the Melodic platform	Upperware	New optimization solvers can be added to customize calculation of the deployment solutions

<sup>2</sup> <https://www.alluxio.io/>



Capability	Related Modules	Remarks (if any)
Support for user-defined scalability rules for intra-Cloud application scaling	Utility Functions Upperware	
Ability to improve reasoning accuracy over time using historical data and statistical models	Upperware	
Availability of efficient re-configuration mechanisms	Upperware	Adapter component of the Upperware is heavily updated in the final release to allow efficient transformation of the constraint problem solution to a deployment model.
Advanced monitoring capabilities	Upperware Executionware	

### 3.5 Privacy and Confidentiality of the platform and applications deployed on Cross-Clouds

In the first Melodic review report requested further assessment of the security mechanisms designed and implemented in terms of the Melodic platform, via external security experts. The final Melodic release incorporates features as per the recommendation of the security experts. Main capabilities related to the security are listed in Table 5.

Table 5: Capabilities related to the security and confidentiality of the Melodic platform and deployed applications

Capability	Related Modules	Remarks (if any)
Context-aware access control mechanisms for distributed cross-domain deployments of data-intensive applications	Security	
Advanced user authentication and authorization mechanisms	Security User Interfaces	
Advanced Cloud-credentials security	Security User Interfaces	
Support for encrypted communication between platform components	Security Upperware Executionware	HTTPS-based security

### 3.6 Application Support

Table 6 lists the main capabilities of the Melodic platform related to the Cloud and data-intensive application support.

Table 6: Capabilities related to the cloud application support

Capability	Related Modules	Remarks (if any)
Support of big data processing frameworks	Upperware Executionware	Apache Spark and Hadoop MapReduce are supported
Support for distributed file-system deployment	Upperware Executionware	HDFS deployment is supported.

Capability	Related Modules	Remarks (if any)
Application components correctly mapped on heterogeneous Cross-Cloud infrastructures according to the application requirements	Modelling Executionware Upperware	CAMEL 2.0 supports capturing a rich set of design-time and runtime requirements.
Data-aware deployment of big data applications	Upperware DLMS	

### 3.7 Private Cloud Resource Management

Capabilities related to the private Cloud resource management in the Melodic platform are listed in Table 7.

*Table 7: Capabilities related to the private cloud resources*

Capability	Related Modules	Remarks (if any)
Optimal usage of private Cloud resources by exploiting, for instance, topology, and hardware-specific information unavailable on public Cloud platforms	Upperware	Partial support in Release 3.0,
Support for existing compute resources	Executionware	Bring-Your-Own-Node capability as discussed under Section 3.1

### 3.8 Application Availability and Scalability

Table 8 lists the main Melodic capabilities related to the application availability and scalability.

*Table 8: Capabilities related to the application availability and scalability*

Capability	Components	Remarks (if any)
Support for computational and data scaling	Upperware Executionware	
Utility-based scalability through global application reconfiguration	Modelling User Interfaces Upperware	Advanced utility functions are supported
Transparent exploitation of geographically dispersed Cloud locations to increase application availability	Modelling User Interfaces Upperware	Partial support in the platform. Application-level support can be enabled via modelling.

### 3.9 Cloud Cost Effectiveness

Table 9 lists main Melodic capabilities related to the Cloud cost-effectiveness.

*Table 9: Capabilities related to Cloud cost-effectiveness*

Capability	Related Modules	Remarks (if any)
Support for advanced pricing models	Upperware	The support is based on Cloud cost delivery mechanism
The pricing data model for major Cloud providers	Upperware	Support for AWS, Azure, Google Cloud Platform (GCP) is available.

## 4 Features List

In this chapter, we provide a detailed feature list of the Melodic platform. We build on the initial feature list provided in the deliverable D2.2 [2]. In Section 4.1, features corresponding to the use-case requirements are listed, while in Section 4.2, features related to the non-functional requirements are presented.

### 4.1 Features corresponding to the use-case requirements

Table 10 provides a list of the salient final Melodic features corresponding the use-case requirements. Not all these requirements could be fulfilled directly because they are supported by other features. There are two unsupported features:

- **Dynamic scalability within one Cloud platform:** This refers to using the Cloud platform mechanisms to scale components horizontally by adding copies of the virtual machines. Doing this at the platform level ignores possible side effects, like adding another component may also need the addition of a load balancer. It would also complicate the optimization process as the solvers would not be able to specify the number of instances of a component but will need to specify possible ranges by setting the least number of instances and the maximum number of instances of a component to be deployed. All scalability decisions are therefore taken by the Upperware, and although this may be slower than platform level scaling, it provides a cleaner scalability process and the time penalty for the Upperware based reconfiguration is negligible compared with the time it takes to start new virtual machines.
- **Ability to add application components or component instances during runtime:** This implies changing the application topology, making it necessary to reconnect the existing application components, at least with the newly added ones. There may also be necessary to change the constraints of the optimization problem when introducing the new components. The optimized solution for this extended application may be very different from the currently deployed model, leading to a significant reconfiguration of the running and deployed application. Adding a new component is therefore equivalent to deploying a completely new application, and the Melodic platform must therefore be re-started on the new application CAMEL model incorporating the new components.



*Table 10: Features corresponding to the use-case requirements*

Feature Specification	Category
Ability to manage platform users and their credentials	Platform Management
Ability to start/stop Melodic services	Platform Management
Application and deployment overview in a graphical user interface	User Interface
Efficient modelling of applications describing user case requirements	Modelling User Interface
Web based UI for application view / monitoring	User Interface
Eclipse based editor for the CAMEL model: CAMEL model validation	CAMEL Editors
Eclipse-based editor for the CAMEL model: Syntax completion	CAMEL Editors
Installation and deployment of applications on multiple Cloud providers	Upperware Executionware
Installation and deployment of dockerized applications on multiple Cloud providers	Upperware Executionware
Installation and deployment of applications with mixed dockerized and non-dockerized components	Upperware Executionware
Deployment requirements enforcement	Upperware
Non-functional requirement capturing and enforcement	Modelling Upperware
Deployment optimization with linear constraints	Upperware (MILP / LA Solvers)
Deployment optimization with non-linear constraints	Upperware (LA / CP Solvers)
Big data application deployment optimization	Upperware DLMS

Feature Specification	Category
Big data application deployment execution	Executionware
Ability of built-in raw metrics collection	Upperware Executionware
Ability of custom raw metrics collection	Upperware (EMS) Executionware
Ability to define composite metric collection	Upperware (EMS)
High Availability Component configuration	Melodic Platform
Dynamic scalability within one Cloud platform	Not supported
Dynamic scalability testing for multi-Cloud feature (using two different locations)	Upperware Executionware
Ability to backup Melodic platform configurations	Platform Management
Melodic platform recovery	Platform Management
Template-based Utility Function Creation	Modelling Editors
Ability to add application components or component instances during runtime	Not supported
Running big data frameworks over aggregated resources from the infrastructures of different Cloud providers	Executionware
Automatic configuration of the big data frameworks	Modelling Executionware
Efficient optimisation of the big data frameworks based on historical data from metrics	DLMS Upperware

Feature Specification	Category
Reconfiguration of big data frameworks based on user-specification	DLMS Upperware
Ability to use predefined big data metrics	DLMS Upperware
Ability to specify initial configuration for the big data frameworks	Executionware
Ability to use existing big data cluster	Executionware
Support of AWS as Cloud infrastructure provider	Executionware
Support of Google Cloud Platform (GCP) as Cloud infrastructure provider	Executionware
Support of Azure as Cloud infrastructure provider	Executionware
Support of ProfitBricks <sup>3</sup> as Cloud infrastructure provider	Executionware
Ability to define scalability rules in the web-based editor	Modelling CAMEL editors User Interfaces
Ability to define application and component requirements in the web-based editor	Modelling CAMEL editors User Interfaces
Ability to model application components in web-based editor	Modelling CAMEL editors User Interfaces
Cloud service provider pricing models	Upperware

<sup>3</sup> <https://www.profitbricks.com/>



Feature Specification	Category
Ability to specify utility and cost function for the Melodic Upperware	Upperware
Ability to utilise template utility profiles	Modelling User Interfaces
Support for advanced user-defined utility functions	Modelling
Support of Component Composition	Modelling Upperware
Support of multiple optimization solvers	Upperware
Ability to specify component co-location parameter in the application modelling	Modelling
Allow replication of the components across Cloud providers	Modelling
Ability to reconfigure applications based on the delta deployments	Upperware
Ability to evaluate reconfiguration utility and overhead before the actual reconfiguration	Upperware
Ability to optimise, reconfigure, scale application components	Upperware
Ability to integrate Melodic with other systems through an API	Melodic External Interfaces and APIs
Ability to simulate workload on the Melodic simulator	Melodic Simulator

## 4.2 Features corresponding to the non-functional requirements

Table 11 provides a list of the final Melodic features corresponding the non-functional requirements.

Table 11: Features corresponding to the non-functional requirements

Non-Functional Requirement	Feature(s) Specification
<b>Extensibility and Openness</b>	<p>The Melodic platform has been built in a way that it can cater the needs for the extensibility in the future. Each of the main component groups in the Melodic, Upperware, Executionware, and Modelling interfaces, are designed with clear interfaces so that both the platform maintainers and third-party developers can plug in new functionality.</p> <p><b>Upperware</b></p> <p>The main extensibility areas in the Upperware consists of adding new optimizations solvers for calculating Cloud application placement and optimization solutions, DLMS algorithms for data management algorithms, support for new storage technologies, and writing custom utility functions to optimize solutions as per users defined utility criteria.</p> <p><b>Executionware</b></p> <p>The modular architecture of the Executionware (i.e., the Cloudiator framework) relies on the well-established software technologies OpenAPI for its central REST interface and Apache Kafka for the internal message-based communication between Cloudiator agents. Supporting a new cloud provider or supporting a new data processing framework are the main extension points for the Executionware.</p>
<b>Software Maintainability</b>	<p>Software maintainability is achieved through effective code reviews and quality assurance measures throughout the project life cycle.</p>
<b>Reliability</b>	<p>High-Availability (HA) platform deployments are possible for the fault-tolerance.</p>
<b>Flexible orchestration</b>	<p>Thanks to the BPM process orchestration and well-defined component interfaces, most of the changes in functional requirements related to the flow of actions and data can be implemented without changing the underlying software.</p>

Non-Functional Requirement	Feature(s) Specification
<b>System Monitoring</b>	As Control and Data flow in the Melodic platform are integrated using ESB, BPM, and REST APIs, all requests are centralized and logged in one place, enabling efficient system monitoring. The graphical user-interface includes visualization tools for system data monitoring.
<b>Unified deployment</b>	All components of the Melodic platform are deployed in containers empowering unified platform deployment.
<b>Security</b>	Based on the recommendations of the security experts, the Melodic platform implements advanced security features to both secure the communication between the platform components and to authorize or authenticate requests. Each of the Melodic components implements JSON Web Token (JWT) based authentication in its interactions with other platform components
<b>Platform Scalability</b>	Containerized platform component deployment empowers the Melodic platform with high-level of scalability.

## 5 Summary of Use-Case Evaluations

The final evaluation of the Melodic platform is based on four use-case applications, i.e. Traffic Simulation (CE-Traffic), CRM and App Store (CAS Software), Secure Data Management FCR (7Bulls), and Genome Analysis (7Bulls). In the scope of the work package 6 (WP6), an evaluation framework was developed to assess the usability and availability of the Melodic features in connection with the defined use-case scenarios.

Based on the technical evaluation, the use-cases concluded that all the Melodic components fulfil the main use-case requirements, especially with regard to correctness, efficiency, completeness, availability and appropriateness. The use-case pilots outlined some potential improvements and feature requests especially under user error protection, error traceability and fault tolerance. However, from a consumer perspective, Melodic fulfils all the necessary functionality under the most relevant criteria. Moreover, business evaluation outcomes of the use-case evaluators are also very positive. Detailed use-case evaluation is presented in the Melodic deliverable D6.5 [4].

## 6 Conclusion

In this deliverable, a list of salient Melodic capabilities and features is presented for the final Melodic release, Release 3.0. The final release concludes the last development phase of the Melodic in the scope of the H2020 research and innovation project. However, the Melodic project has solid exploitation plan to ensure further platform development and usability beyond the H2020 project

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