

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

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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 PaaSage¹ 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

¹ 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

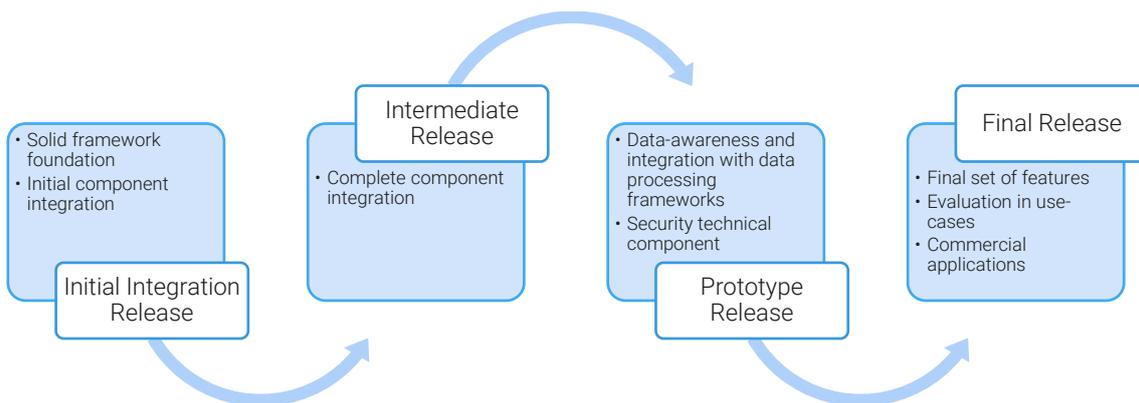


Figure 1: The Melodic Platform Releases during the project tenure

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 ² |
| 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 |

² <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 ³ 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 |

³ <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 |
|--|---|
| <p>Extensibility and Openness</p> | <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>Upperware</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>Executionware</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> |
| <p>Software Maintainability</p> | <p>Software maintainability is achieved through effective code reviews and quality assurance measures throughout the project life cycle.</p> |
| <p>Reliability</p> | <p>High-Availability (HA) platform deployments are possible for the fault-tolerance.</p> |
| <p>Flexible orchestration</p> | <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 |
|-----------------------------|---|
| System Monitoring | 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. |
| Unified deployment | All components of the Melodic platform are deployed in containers empowering unified platform deployment. |
| Security | 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 |
| Platform Scalability | 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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