Cloud Orchestration at the Level of Application

Project Acronym: **COLA**

Project Number: **731574**

Programme: **Information and Communication Technologies**
Advanced Computing and Cloud Computing

Topic: **ICT-06-2016 Cloud Computing**

Call Identifier: **H2020-ICT-2016-1**
Funding Scheme: **Innovation Action**

Start date of project: 01/01/2017 **Duration: 30 months**

Deliverable:

D1.4 First Interim Report

Due date of deliverable: 30/06/2018 **Actual submission date: 29/08/2018**

WPL: Gabor Terstyanszky

Dissemination Level: PU

Version: final

Table of Contents

Status, Change History and Glossary

Status:	Name:	Date:	Signature:
Draft:	Gabor Terstyanszky	15/06/18	Gabor Terstyanszky
Reviewed:	Tamas Kiss	15/07/18	Tamas Kiss
Approved:	Tamas Kiss	29/08/18	Tamas Kiss

Table 1 - Status Change History

Version	Date	Pages	Author	Modification
V41	15/06	5	G Terstyanszky	report template
v1.1	18/06	12	G Terstyanszky	WP1 inputs
	19/06	15	G. Pierantoni	WP5 inputs
	23/06	19	N. Paladi	WP7 inputs
	30/06	24	N. Fantini	WP4 inputs
	30/06	27	G Terstyanszky	WP3 inputs
	03/07	30	A Ocklenburg	WP2 inputs
	03/07	33	J. Kovacs	WP6 inputs
	04/07	37	J. M. M. Rapun	WP8 inputs
	04/07	40	T. Kiss	WP9 inputs
v2	07/07	42	G Terstyanszky	meeting project objectives
	07/07	47	G Terstyanszky	project objectives
v3	10/07	50	G Terstyanszky	report review
final	15/07	51	T. Kiss	final review

Table 2 - Deliverable Change History

1. Explanation of the work carried out by the beneficiaries and overview of the progress

1.1 Objectives

Objective 1: Designing, prototyping, testing and demonstrating a set of services in a generic framework that cloud application developers can utilise from their application source code in support of developing highly scalable and dynamic cloud applications.

The COLA project will utilise available low level container-based technologies, open source cloud orchestration solutions and monitoring tools, and existing cloud standards for topology and orchestration specification to prototype, test, demonstrate and pilot a pluggable cloud service optimisation framework that is easily applicable by application developers. Using MiCADO services in application logic will result in more flexible and resource-effective cloud solutions. The project will design and implement the multi-layered MiCADO architecture based on the concept of microservices to enable plugging in multiple technological components when fulfilling a specific task and to avoid dependence from a particular technology. Measurable indicators of Objective 1 are collected in Table 1.1.

Objective 1 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 Targeted	M18 achieved	M30
WP5 WP6 WP7	MiCADO prototype reference implementations developed, tested and demonstrated.	1	4+2	2
WP5 WP6 WP7	Peer reviewed publicatons on the generic MiCADO framework concept and its implementation.	3	7 conference, 7 journals papers , 1 book chapter	6

Table 1.1.1.Measurable indicators of Objective 1

Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

MiCADO is a generic pluggable framework that supports flexible and optimal deployment and run-time orchestration of applications in the Cloud. It is generic because its services are not restricted to particular technologies and can be implemented using different technologies and services. This framework provides the missing link between existing non-cloud aware applications and the dynamic capabilities of IaaS Clouds by allowing connecting to multiple technology implementations on demand. MiCADO can be connected to multiple cloud middleware (e.g. EC2, CloudSigma, OpenStack, OpenNebula, etc.) and generic cloud access layers (e.g. CloudBroker Platform) via well-defined standardised interfaces to avoid dependence on one particular cloud technology. It is based on existing low-level cloud container technologies (e.g. Docker, Swarm, etc.), management and orchestration solutions (e.g. Occopus), and existing standards (e.g. TOSCA). COLA followed an iterative approach to create the MiCADO framework. The project designed, implemented, deployed, tested and released 4 versions of the MiCADO framework:

- MiCADO v0 - applications are deployed in Docker containers inside VMs on worker nodes controlled by Occopus, and Prometheus running on master nodes;
- MiCADO v1 - orchestrator layer has a master node (Docker Swarm+ Prometheus), an Occopus node and multiple worker nodes (applications in Docker container) either using Docker Swarm load balancing service or a separate load balancing service;
- MiCADO v2 - v1 version has been extended with container monitoring on the worker nodes and support for auto-scaling based on CPU consumption;
- MiCADO v3 + v3.1- in v3 Docker Swarm, Occopus and Prometheus are deployed on the master node and in v3.1 configuration on scaling of Docker containers has been improved;

There are further two versions in development (v4) and pre-release (v5) phase:

- MiCADO v4 - incorporates two major components, jqueuer and autoscaler, to run job type applications under MiCADO;
- MiCADO v5 - MiCADO Submitter and Policy Keeper has been added to the MiCADO orchestration layer

MiCADO v0-v2 are presented in D6.1 "Prototype and documentation of the cloud deployment orchestrator service", MiCADO v3 in D6.2 "Prototype and documentation of the monitoring service", and MiCADO v3.1, v4 and v5 in D6.3 "Prototype and documentation of the scalability decision service" deliverable.

As the last version MiCADO v5 is the best example to summarize achievements in creating a generic framework. This version processes TOSCA descriptions of COLA applications, deploys and executes them using these descriptions in the Cloud. The MiCADO Submitter parses and validates the TOSCA descriptions and forwards them to adaptors, such as Docker, Occopus and Policy Keeper Adaptor. The Scalability Decision Maker component is realized by the Policy Keeper microservice. It is able to scale virtual machines and containers through Occopus and Docker Swarm based on the information gathered by Prometheus and given in the TOSCA policies. The MiCADO framework can be deployed as Ansible playbook to make deployment effortless as much as possible. To support Application Developers and End Users MiCADO was extended with a dashboard including Docker Visualizer, Prometheus and Grafana to provide information about the application executed by the MiCADO orchestration layer.

WP8 started using the MiCADO framework from version 2 to develop and test COLA use case applications. Currently, use case 1 (audience finder application) and use case 3 (analysing public databases and social media data) uses version 5 and use 2 (evacuation simulation) applies version 4.

WP5-WP6 published 7 papers at conferences, 7 papers in journals, 1 book chapter on TOSCA based application descriptions and the MiCADO framework. Details of 10 papers have been uploaded to the NEF portal. The other papers will be uploaded as soon as the missing information will be available. Details of these publications are available in 6.1 Summary of Scientific Publications in Part A of the COLA Interim Report.

Objective 2: Piloting, demonstrating and validating the technical feasibility of the MiCADO framework in SME and public sector case-studies.
The project will analyse SME and public sector use cases that require highly flexible and resource effective cloud solutions. COLA will pilot and demonstrate the applicability of the MiCADO framework when optimising these application scenarios to utilise the scalable, flexible and elastic capabilities of cloud infrastructures. The project will develop demonstrators in real-life operational settings for typical and demonstrative application scenarios by both SMEs and public sector organisations where efficiency of the cloud solution will be significantly improved via MiCADO. The selected use-cases represent a wide range of typical application areas of the SME and the public sectors, and have the potential of making significant impact in the represented areas well beyond current project partners. As an output of the project three full scale demonstrators and twenty further proof-of-concept prototypes will be implemented. Measurable indicators of Objective 2 are collected in Table 1.2.

Objective 2 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 targeted	M18 achieved	M30
WP8	Number of analysed SME and public sector use-cases that require highly flexible and resource effective cloud solutions	7	3 use cases 11 prospective demonstrator	23
WP8	Fully developed demonstrators in real-life close to operational settings.	0	0	3
WP8	Proof of concept demonstrators for real-life use-cases of COLA technology provider partner customers (customers of Saker, CloudSME UG, Inycom and Outlandish)	0	11 prospective demonstrators investigated	20

Table 1.1.2 Measurable indicators of Objective 2
Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

COLA proposal listed 3 use cases that need highly flexible and cost effective cloud services:

- use case 1: audience finder application – collects and analyses audience data to build up audience preferences locally and nationally (Outlandish + The Audience Agency);

- use case 2: - evacuation planning – defines a cohesive and robust strategy for the evacuation of personnel from a site under threat (Saker + Brunel University);
- use case 3: improving services for citizens based on analysis of public databases and social media data (Inycom + SARGA).

WP8 analyzed these applications focusing on their financial and technical requirements, presented in D8.1 "Business and technical requirements of COLA use-cases". The work package created a proof of concept of these applications and tested them on the MiCADO framework. WP8 described these three use applications in D8.2 "Customisation and further development of software applications".

COLA partners identified several further applications that require highly flexible and cost effective cloud services that the MiCADO framework can offer. They selected and analysed the following applications:

CloudSME:

- investigation of how to use OpenStack with HKN Cloud and Rechenzentrumsservice
- investigation of TYPO3-Clusters with Rheinschafe
- investigation of a WordPress-Plugin for the cloudSME App Center

CloudSME + SZTAKI:

- efficient and fast data transfer among different type of distributed storages using Data Avenue

Brunel + Saker

- Flexim simulation software to be used in manufacturing
- Repast simulation software to be used in manufacturing

Outlandish:

- generic WordPress CMS hosting environment for simple content-based websites;
- generic React and Node.js bridge environment for WordPress REST API;
- dynamic scaling of a composer repository for WordPress plugins and themes;
- SAAS-style deployment of School Councils web app across UK schools;
- using the British Councils social media analysis tool to the German Goethe Institute and other clients.

These applications are prospective COLA demonstrators that could be implemented in M19-M30.

Objective 3: Validating economic feasibility of the implemented use-cases.
Besides the technical implementation, COLA will analyse and validate the economic feasibility of applying MiCADO services when improving the efficiency of the selected representative SME and public sector case-studies. Aspects and implications of increased performance, reliability and scalability, and optimisation of costs will be considered and measured. The economic impact of the implemented cloud-based solution will be quantified and clearly highlighted for the selected use-cases. Measurable indicators of Objective 3 are collected in Table 1.3.

Objective 3 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 targeted	M18 achieved	M30
WP3	Economic impact and feasibility of fully implemented demonstrators in real-life close to operational settings is analysed.	0	0	3
WP3	Economic impact and feasibility of proof of concept demonstrators is analysed.	0	0	20

Table 1.1.3 Measurable indicators of Objective 3

Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

No indicators were defined for M01-M18 but WP3 collected existing business models, IPR policies and sustainability plans from COLA partners, presented in D3.1 "First commercial exploitation and sustainability report". Partners described their market, customers they target, the market size, their position in the in the market, how their market might evolve, what product/service they offer, what their selling point is, who the competitors are. Further, they outlined the current exploitation plan and what their expectations are in 2.5 and 5 years. Having these inputs WP3 will develop the commercial exploitation plans and business models.

Objective 4: Defining common and widely applicable application templates.
COLA will investigate and develop application definitions for common cloud-based application scenarios. Derived from the requirements of its real-life case-studies, the project will define common application templates and identify how these templates can be mapped to typical real life use-case scenarios within and beyond the project. It will develop a template description language based on existing standards, such as the Tosca standard by OASIS, and it will store and describe these templates with rich metadata in a suitable repository from where companies can use them to quickly port their applications into clouds in a scalable, secure and robust way. Measurable indicators of Objective 4 are collected in Table 1.4.

Objective 4 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 targeted	M18 achieved	M30
WP5	Template and application description language developed.	1	1	1
WP5	Common, widely applicable application templates defined and described.	3	3	6
WP8	Application templates validated via the implementation of real-life case-studies.	0	0	4
WP5	Peer reviewed publications on application description and ttemplates	1	3	2

Table 1.1.4 Measurable indicators of Objective 4
Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

WP5 selected TOSCA to use for application description in COLA. The analysis of the first three use cases highlighted some high priority challenges which required an extension of the TOSCA specifications. First, there should be a simple and user-friendly support for containerized/virtualized applications. Second there should also be a simple and user-friendly support for the description of policies that regulate the various facets (QoS) of the application lifecycle. Although TOSCA does not provide a direct mechanism for these issues, its specification can be extended to this aim. Accordingly, WP5 developed the concept of an Application Description Template (ADT) which extends TOSCA to define application descriptions based on a two-level topology (container-level and Virtual Machine-level) which is enriched by a policy hierarchy that contains policies that regulate deployment and execution of applications. WP5 extended the TOSCA policy specification adding several security-related policies and several scaling-related policies. As an example, we have extended a Simple Consumption-based Policy with Advanced Consumption Based and Consumption Based Budget Constrained policy. To support standardization and interoperability, the ADT is technology agnostic, (i.e. it specifies functionalities of the application but no assumptions are made on how these functionalities will be implemented) an element of the MiCADO architecture developed within WP6 translates the information contained in ADT into the specific syntaxes required by the various components.

WP5 elaborated 3 generic templates to be used to describe applications: one for resource based scalability, one for deadline based scalability and one for performance based scalability. The first two templates have been used to describe COLA use case applications based on ADT and the extended policy hierarchy in two phases. In the first phase they created the initial version of the application description. COLA use case applications were deployed and tested on the MiCADO framework using this description. In the second phase the application description was modified considering feedback from tests. Application descriptions have been reported in D5.3 “Integration of the templates with the selected application description approach” and D5.4 “First set of templates and services of use cases”.

WP5 published 3 conference papers to disseminate ADT and the extended policy hierarchy. Details of these publication are available in 6.1 Summary of Scientific Publications in Part A of the COLA Interim Report.

Objective 5: Providing access to heterogeneous, federated and distributed cloud resources.
MiCADO services will interface with a wide variety of heterogeneous and distributed cloud resources. MiCADO will be connected to the CloudBroker Platform, the commercial offering of CloudBroker GmbH and integral component of the CloudSME Simulation Platform (developed in the FP7 CloudSME project and now exploited by COLA project partner CloudSME UG) that provides access to multiple heterogeneous cloud solutions based on a variety of cloud

middleware. Connection to direct cloud APIs and to cloud federations (e.g. EGI Federated Cloud) will also be supported. The resulting solution will facilitate the utilisation of cloud resources from multiple IaaS clouds and/or the seamless migration of applications between different commercial or private cloud resource providers. As a result by using the MiCADO services companies can avoid cloud vendor lock-in. Measurable indicators of Objective 5 are collected in Table 1.5.

Objective 5 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 targeted	M18 achieved	M30
WP4	Types of IaaS clouds supported by the reference implementation of the MiCADO framework.	6	4	8
WP8	Seamless application migration between different private and public cloud resource providers is demonstrated.	0	0	4

Table 1.1.5 Measurable indicators of Objective 5

Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

The MiCADO framework provides access to the following academic and commercial clouds via the CloudBroker Platform:

academic clouds:

- OpenNebula with EC2 interface at SZTAKI
- OpenStack with Nova interface at SICS and UoW

commercial clouds:

- Amazon with EC2 interface
- CloudSigma

WP4 created the COLA development testbed (reported in D4.1 "COLA development testbed infrastructure"). It incorporates all the above listed clouds. WP5-WP7 use this testbed to test the MiCADO framework's microservices, such as the MiCADO Submitter, the MiCADO Policy Keeper, the MiCADO Security Enforcer, etc. In WP8 use case owners and technology providers also deployed and ran the COLA use case applications in this to create the first prototypes.

Objective 6: Developing solutions to address security, reliability and trustworthiness of MiCADO services in the context of application migration between different cloud resources.

COLA will specifically address issues of security, reliability and trustworthiness in relation to the developed MiCADO services. Specific security problems and aspects of dynamic scaling of cloud infrastructure resources and application migration between resources of a particular cloud, a cloud federation, or distributed heterogeneous clouds will be investigated and solutions will be developed. Advanced security policy management mechanisms will be built at orchestration level that will decouple the detailed security management from application developers. Developers and application domain owners will only provide high-level security policies and security credentials, and will use high level APIs to "mark" security levels of applications and/or data that applications handle. These inputs will be used by an enforcement layer to apply the security policies at the orchestration level. Measurable indicators of Objective 6 are collected in Table 1.6.

Objective 6 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 targeted	M18 achieved	M30
WP7	Advanced security policy management mechanisms	2	Security Enforcer + 2 security enablers	4
WP7	Peer reviewed publications on application level security mechanisms	2	2 papers 1 PhD	3

Table 1.1.6 Measurable indicators of Objective 6

Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

WP7 collected security requirements needed for the MiCADO framework to efficiently and securely deploy orchestrate applications using advanced security management. The work package identified and ranked the security requirements of the COLA use cases to drive the design and development of the COLA security services. The security requirements were reported in D7.1 "COLA security requirements". Having these requirements WP7 analyzed the security landscape in cloud orchestration, identified the prospective security threats in the MiCADO framework, developed the required security model and defined the security architecture for the MiCADO framework to deliver the required security services. The security architecture is based around the MiCADO Security Enforcer. It manages several security enablers, such as Image Integrity Verifier to check container image, CryptoEngine to provide cryptographic functions, Security Policy Manager to provide central management for security components, Credential Manager to provide authentication and credentials storage that help to hinder user impersonation attacks, Credential Store to provide sensitive information storage and Zorp to provide firewall and TLS/SSL. These security enablers are the key security services to implement the required security mechanisms in the MiCADO framework to make it a secure deployment and execution environment. WP7 implemented two of the security enablers: the Credential Manager and the Credential Store. D7.2 "MiCADO security architecture specification" and D7.3 "MiCADO application security classification specification" deliverable describes the MiCADO security architecture, threat surfaces in the MiCADO framework and prospective security counter measures.

WP7 published 1 conference paper and 1 journal paper and one PhD was completed on cloud security. Details of 2 papers have been uploaded to the NEF portal. Details of these publication are available in 6.1 Summary of Scientific Publications in Part A of the COLA Interim Report.

Objective 7: Maximising the impact of the piloted, demonstrated and validated market-ready offering by focused dissemination and marketing campaign targeting specifically SME and public sector use-cases beyond project partners.

COLA will specifically address commercial exploitation and sustainability of project results. Business models for commercial exploitation will be developed. Potential user communities, especially within SMEs and public sector organisations will be identified and targeted with dissemination and marketing activities. Multiplier organisations representing SME clusters and public sector domains will be utilised to reach large number of potential end-user organisations. Measurable indicators of Objective 7 are collected in Table 1.7.

Objective 7 indicators – COLA achieved by M18

WP	Measurable Indicator	M15 targeted	M18 achieved	M30
WP3	Commercial exploitation plans and business models developed	0	0	5
WP2	Dissemination events to disseminate the MiCADO framework and its applicability within the SME and public sectors.	5	>20	15
WP2	Multiplier organisations successfully disseminating the results of the COLA project.	6	9	12
WP2	Best practice cases studies for disseminating the utilisation of the MiCADO framework within SMEs and public sector organisations.	0	0	4
WP2	Press releases.	5	6	10
WP2	Specific training courses to train application developers to apply the MiCADO framework when developing cloud-aware applications.	1	5	2

Table 1.1.7 Measurable indicators of Objective 7

Colour code: green achieved yellow – almost achieved white – not relevant in M01-M18

CloudSME UG designed the COLA brand, for example the COLA logo. (See at https://project-cola.eu/). They set up the COLA website, reported in D2.1 "Dissemination plan and project public website", and available at https://project-cola.eu/. They produced a number of dissemination materials, such as printed brochures, flyers, roll-up banners and posters to promote the COLA project and the MiCADO framework. They identified multiple dissemination channels, such as, Facebook, LinkedIn, Twitter, websites and created COLA pages on these dissemination channels.

WP2 ran two types of dissemination activities. The first type are events that either WP2 organized, for example the Cloud Computing Experience Day in Germany, or CloudSME UG represented COLA, for example the COLA booth at the Hannover Messe in Germany. The second type included events that COLA partners attended, for example IWSG 2017 and IWSG 2018. More than 20 COLA dissemination activities have taken place. Details of these events are available in D.2. "First periodic dissemination report" and in section 6.2 Dissemination and communication activities in Part A of the Interim Report.

Multiplier organizations and dissemination partners that COLA has liaised with include: The I4MS initiative, CSA CloudWatch2, EC CDB Project Group, DigiPro - Euregio, Digital Innovation Hub.Ruhr GfW – Regional agency for economic development, Ruhr.Valley Cluster, Networker.NRW, CAE-Forum.

WP2 coordinated six press releases (incl. 1x Global PR, 1x UK PR, 2x Germany PR, 2x Spain PR) for which COLA has received media coverage in newspapers and (online) magazines in Germany, Spain and the UK – also with European visibility (see D2.2 for more details).

WP2 and WP5-WP7 developed four on-line tutorials related to the MiCADO framework that explain how to use MiCADO v0-v3 to deploy and run applications in the Cloud. Additionally, these WPs ran three on-line training courses as webinars related to the deployment and utilisation of the MiCADO framework, the descriptions of applications using the TOSCA-based Application Description Templates, and to relevant products of Balabit that can be applied in the MiCADO Security Framework.

1.2 Explanation of the work carried per WP

In this section we outline activities, achievements and results of work packages and how they met the work package objectives in M01-M18.

1.2.1 WP1 - Project Management

Overview of activities in WP1

T1.1 Establishing and running the project management structure M01-M30

Task Leader UoW Participants: none

UoW presented the project management structure at the kick-off meeting in London. The **project partners** discussed and finalized this structure at the kick-off meeting. They defined three levels of the project management structure. At the top-level are the Project Management Board (PMB) and the Technical Management Board. At the middle level there are work package level coordination activities, such as Application and Technical Task Force, and work package management. Finally, at the bottom level there are project partners with their own management solutions.

Project partners nominated the members of the project boards and committees at the kick-off meeting. They defined the project information infrastructure and agreed upon setting up the COLA mailing and storage facility. Based on this decision UoW set up the project mailing lists and storage facility. UoW coordinates activities of the COLA project management structure, and manages the COLA mailing lists and the COLA storage facility leading administrative, dissemination and technical efforts of the COLA project.

UoW led administrative, dissemination and technical activities and efforts of the COLA project. **UoW** managed the COLA mailing lists and the COLA storage facility leading administrative, dissemination and technical efforts of the COLA project. **UoW** coordinated all COLA activities through regular skype and webex meetings, organised by **CloudSME** UG, COLA mailing lists and the COLA storage facility

UoW managed the two partner changes, i.e. replacing Now Pension with The Audience Agency and BalaBit with BalaSys as project partner. The first partner change was less complicated than the second one because Now Pension left COLA at the very beginning of the project. We consulted and helped BalaBit revising their financial and technical report and defining BalaSys' tasks and adding them as new partner to Part A and Part B of the Grant Agreement. Finally, UoW and BalaBit created the termination report that is under final revision.

T1.2 Monitoring the project progress M01-M30

Task Leader UoW Participants: All partners

UoW defined the COLA quality management strategy and implemented it. The quality management strategy defines how deliverables must be compiled, reviewed and submitted, how risks will be identified, analysed and mitigated, and how conflicts will be resolved. This strategy also defines the project communication structure, the reporting procedures and document standards. UoW also elaborated and finalized the COLA Consortium Agreement collecting COLA project partners' feedbacks and inputs. The agreement was signed by all partners by March 2017.

To monitor technical development and implementation of COLA use cases UoW created two task forces: Application Task Force (ATF) and Technical Task Force (TTF). Inycom and UoW lead the ATF) and TTF to monitor the project progress. Each task force had a webex meeting every second week to monitor progress of research and technical development and implementation of COLA use cases, identify open issues and problems, and discuss solutions. Gabor Terstyanszky leads TTF and Jose Manuel Martin Rapun ATF. Tamas Kiss as the Project Coordinator and task force leaders attend all TF meetings. At the TTF meetings WP4, WP5, WP6 and WP7 WP Leaders and researchers involved in these work packages outlined progress achieved in on-going tasks, reported problems identified with prospective solutions and gave a short overview of further tasks. At the ATF meetings use case owners and Independent Software Providers (ISV), involved in WP8, presented the latest status of the use case implementation. **CloudSME UG** hosted the webex meetings of the Application Task Force (ATF) and the Technical Task Force (TTF)

CloudSME UG, ScaleTools, CloudSigma, UoW, SZTAKI, SICS and Inycom as WP Leaders led WP2-WP8 respectively. They developed WP work plan and procedures, organised regular teleconferences with project partners to coordinate their activities, compiled and distributed WP meeting logs among project partners and monitored WP progress. UoW, as WP5 Leader, SZTAKI as WP6 Leader and SICS as WP7 Leader organised bi-weekly work package meetings to discuss progress in the development of the MiCADO framework and define next developments tasks.

All project partners set up their own project team, elaborated project plans and assigned efforts to tasks and monitored the progress at project partner level, such as achieving milestones, submitting internal reports and project deliverables. They ran activity management and reporting (e.g. tracking and documenting resources and activities to compile partner reports further). For example **CloudSigma**'s internal project management software (JIRA) was extended to include a project section for planning and tracking all contributions to the COLA project by CloudSigma staff. Further, **Outlandish** set up a comprehensive internal project reporting structure and operating it smoothly. They have an appropriate risk and issue management process in place. Project partners attended meetings as well as regular bi-weekly Application and Technical Task Forces webex meetings.

T1.3 Coordinating of the financial management of the project M01-M30

Task Leader UoW Participants All partners

UoW set up a network of Financial Officers who manage finances of the COLA project. Having this network UoW transferred the first instalment of the COLA budget each COLA partner.

All project partners nominated a Financial Officer who manages the project finance. They have their own comprehensive internal financial management and reporting structure setup that is being used in COLA. They monitored continuously that the expenses and personnel efforts incurred are within the budget allocated to their budget. The Financial Officers collected costs and expenses in the period of M01-M18 and filled in Form Cs on

the NEF portal. The Financial Officers worked together with the Local Project Managers who handle timesheets and collect receipts for project related costs and expenses, such as travel costs.

CloudSigma and **CloudBroker** investigated how cloud resources used by COLA project partners can be accounted and charged considering the resource pre-financing payment. **CloudSigma** also developed a script in WP4 to monitor resource usage to avoid overspending.

T1.4 Organizing project administrative meetings M01-M30

Task Leader UoW Participants: none

T1.4 has organized three project meetings:

- kick-off meeting, London, United Kingdom, 25-27 January, 2017
- 2nd project meeting, Cracow, Poland, 26-28 September, 2017 and
- 3rd project meeting, Sofia, Bulgaria, 19-21 June 2018.

UoW organized the kick-off meeting, **ScaleTools** the 2nd and **CloudSigma** the 3rd COLA project meeting **CloudSME UG,** as WP2 Leader, and UoW, as Project Coordinator, contributed to organization of all these meetings. These meetings combinedf WP sessions, training sessions, live demonstration and PMB meeting,

Further, **UoW** organized two COLA code camp meetings in London:

- 1st code camp meeting, London, United Kingdom, 27-28 January 2017 and
- 2nd code camp meeting, London, United Kingdom, 31 January – 02 February 2018

At these meetings WP4-WP7 presented the MiCADO framework focusing on application description, application deployment and execution and security issues. WP8 presented the COLA use cases. The participants discussed how the COLA use cases can be described, deployed and executed on the MiCADO framework.

T1.5 Defining, implementing and monitoring the project's Data Management Plan M01-M30

Task Leader: UoW Participants: All partners

UoW coordinated the development of the COLA Data Management Plan in collaboration with all COLA project partners. This plan outlines how COLA collects, processes, publishes and stores data at project and work package level. **Project partners** collected requirements of activity-level DMPs: user, technology, dissemination & marketing, exploitation and project management. They provided inputs about their application data and how they manage it. They also were involved in writing the D1.3 (Data Management Plan) report. The Data Management Plan describes the two DMP levels: activity- and project-level. DMP also outlined a framework for managing COLA data to assure full lifecycle data management both during and beyond the project's lifetime.

G. Terstyanszky, UoW as the COLA Quality Manager, monitored any activities that might affect DMP and upgraded it accordingly. He also modified DMP considering BalaSys, (new project partner replacing BalaBit) , requirements.

T1.6 Communication with organizations and other projects M01-M30

Task Leader: UoW Participants: All partners

CloudSME UG attended several European events to promote the COLA project and establish contacts with other projects:

- DECIDE Project Meeting Berlin 21-22.2.2017, EC Cloud Project Concertation Meetings Brussels, Belgium, 28/06/2017,
- Net Futures 2017 Conference, Brussels, Belgium, 29/06/2017
- I4MS Digital Innovation Hubs Event Madrid, Spain 22.09.2017, meeting with partners from CloudFlow project Darmstadt, Germany, 13/10/2017,
- Research in Europe Day Dortmund, Germany, 05/12/2017
- EC Digital Assembly Sofia, Bulgaria, 25.-26/06/2018

cloudSME has established and maintained contact with national and international organizations and other project to promote the project vision.

Brunel established and maintained contact with national and international organisations and other projects to promote the project vision. They were communicating with FORD MOTOR COMPANY to promote the project vision and investigate adoption by FORD MOTOR COMPANY and the strong simulation community in Singapore (including the SME D-SIMLAB).

Achievements and results of WP1

T1.1 Establishing and running the project management structure M01-M30

COLA project management structure has been set up and runs:

- COLA project management structure consists of:
- Project Management Board (PMB)
- Technical Management Board (TMB)
- Ethical Advisory Committee (EAC) and
- Industrial Advisory Board (IAB)
- COLA storage facility is available at:
  https://cola.fst.westminster.ac.uk
- COLA mailing lists has been created:
  cola-all@lists.cpc.wmin.ac.uk
  cola-pmb@lists.cpc.wmin.ac.uk
  cola-tmb@lists.cpc.wmin.ac.uk
  cola-ttf@lists.cpc.wmin.ac.uk
  cola-atf@lists.cpc.wmin.ac.uk

COLA mailing lists provided efficient and reliable communication channels among project partners. COLA pydio repository offered 24/7 access to all project documents allowing document upload and download.

WP7 progressed as planned in the Grant Agreement because BalaSys replaced BalaBit and was involved and contributed to WP7 research before joining the COLA project

T1.2 Monitoring the project progress M01-M30

Task forces have been set up to coordinate and monitor technical development and implementation of use cases:

- Application Task Force (ATF) and
- Technical Task Force (TTF)

Consortium Agreement:

- COLA project partners signed and exchanged the COLA Consortium Agreement.
- COLALA achieved all milestones as specified in the Grant Agreement.

Project monitoring:

- WP Leaders developed a work plan for their work packages. They performed continuous management of work activities. This included organizing teleconferences, keeping meeting logs and monitoring task progress.

Project reports:

- The project progress was documented in the Partner and WPL reports and these reports were submitted on time.
- Mock-interim report completed at M11 and
- Interim report completed at M18 (technical report) and-M19 (financial report).

The project management structure and the monitoring enabled that COLA:

- met all aims and objectives as defined in the Grant Agreement in M01-M18,
- submitted all deliverables but two before the deadline specified in the Grant Agreement (these two deliverables have been submitted with only minor delay) in M01-M18 and
- achieved all milestones scheduled in M01-M18

T1.3 Coordinating of the financial management of the project M01-M30

- first instalment of the project budget has been transferred COLA project partners.
- project partners use their own financial management and monitoring structure in COLA
- project partners nominated a Finance Project Officer who manages the COLA finances.
- project partners continuously monitored expenditure to ensure expenses and effort are within budget as a result, no any financial problem occured
- CloudSigma developed a script to monitor total cloud resource usage on a daily basis (reported in WP4).

T1.4 Organizing project administrative meetings M01-M30

Three project administrative and technical meetings organized and held:

- kick-off meeting, London, United Kingdom, 25-27 January, 2017
- 2nd project meeting, Cracow, Poland, 26-28 September, 2017
- 3rd project meeting, Sofia, Bulgaria, 18-21 June 2018, 2018

COLA organized two code camp meetings:

- 1st code camp and technical meeting, London, United Kingdom, 27-28 January 2017 and
- 2nd code camp and technical meeting, London, United Kingdom, 31 January – 02 February 2018

T1.5 Defining, implementing and monitoring the project's Data Management Plan M01-M30

- COLA Data Management Plan has been elaborated and published
- upgraded COLA DMP considering changes and new requirements raised by project partners

T1.6 Communication with organizations and other projects M01-M30

- Participation and contribution to EC liason and concertation meetings, e.g.:
  - EC Stakeholder Forum on Digitising Europe, Essen, DE, 31.1-1.2.17
  - IraSME Partnering Event Aachen, DE, 31.01.2017
  - Succesful R&I in Europe 2017 Düsseldorf, 02-03.3.2017
  - Digitising Manufacturing in the G20, Berlin, 16-17.3.2017
  - Hannover Trade Fair Hannover, DE, 24.-28.4.17
  - EC ICT Proposers Day 2017, Budapest, Hungary, 9-10.11.2017
  - EC Digital Assembly Sofia, Bulgaria, 25.-26/06/2018
- Activities with national and international organizations and other project to promote the project vision, e.g.
  - EC Cloud Project Concertation Meetings Brussels, Belgium, 28.06.2017
  - Net Futures 2017 Conference, Brussels, Belgium, 29.06.2017
  - I4MS Digital Innovation Hubs Event, Madrid, Spain, 22.09.2017
  - Research in Europe Day. Dortmund, Germany; 5.12.2017
  - Hannover Messe 2018, Hannover, DE 22.-27.4.2018

Brunnel Contact has been established with FORD MOTOR COMPANY, the Singapore simulation community and D-SIMLAB.

WP1 Deliverables submitted

Four deliverables have been submitted before the deadline:

- D1.1 Project management structure and project manage M01
- D1.2 Project progress monitoring and Quality Management M02
- D1.3 Data Management Plan M06
- D1.4 Interim report M18+01

WP1 Milestones achieved

Three milestones have been achieved as planned in DoW:

- MS1.1 All work packages started and well directed M01
- MS1.2 All management procedures operational M02
- MS1.3 Indicators and objectives achieved, deadlines met, and project budget spent as planned in M01-M18

M18

Meeting W1 objectives

O1.1 To create and run the project management structure including administrative and financial aspects of the project.

UoW presented the project management structure at the kick-off meeting in January 2017. Next, the project partners discussed and finalized the management structure. They agreed to set up a three-level project management structure: project-, work package- and partner-level structure. Finally, UoW set up the Project Management Board (PMB), Technical Management Board (TMB), Ethical Advisory Committee (EAC) and Industrial Advisory Board (IAB). To support day-to-day management of the project UoW created two task forces: Application Task Force (ATF) and Technical Task Force TTF) to coordinate application support and development activities. UoW also set up the COLA mailing list to support communication among project partners and the COLA storage to handle project documents, such as technical manuals, use case descriptions, deliverables, etc. Further each COLA partner set up its own management structure to run the project locally. This project management structure enabled smooth running of the COLA project. Both the development of the MiCADO framework and implementation of the COLA use cases progressed as planned. The first prototype of the MiCADO framework and COLA use cases have been completed by M18.

The major challenge for the project management was two partner changes: The Audience Agency replaced Now Pension, and BalaSys BalaBit.

O1.2 To monitor the project overall progress and check resource usage considering the Grant Agreement and handle any problem or risk identified.

Considering the project management structure, outlined above there are three levels of progress monitoring. At the highest level PMB monitored project activities. PMB check the progress in the project at strategic level. It evaluates the progress at project level and sets the objectives for the next period. There were three PMB meetings organised parallel with the project meetings. At the next level ATF and TTF checks progress in development of the MiCADO platform and implementation of the COLA use cases. These task forces had bi-weekly webex meeting led by Inycom and UoW. CloudSME UG organised these meetings. At these meetings project partners presents what have been completed, identify outstanding issues and define tasks to be completed. At the third level project partners organised team meetings to discuss the progress achieved, problems occurred and how to address them and defined next tasks and their schedule. This monitoring approach is a bottom-up approach where project partners pass information task forces that forward it to PMB.

The progress of the project was presented in deliverables and milestones. COLA submitted all deliverables but two ones with minor delays by the submission deadlines and achieved all milestones as scheduled in the Grant Agreement. Project partners also produced a mock interim report at M11. This mock report made significantly simpler to complete the Interim Report at M18-M19.

O1.3 To coordinate and organize administrative and financial reporting and submit reports to EC.

UoW set up a network of Financial Officers who manage finances of the COLA project. Having this network UoW transferred the first instalment of the COLA budget each COLA partner. **All project partners** nominated a Financial Officer who manages the project finance. They have their own comprehensive internal financial management and reporting structure setup that is being used in COLA. They monitored continuously that the expenses and personnel efforts incurred are within the budget allocated to their budget. The Financial Officers filled in and submitted Form C on the NEF Portal.

O1.4 To organize and run project administrative meetings and review meetings.

Since the project management has three levels project meetings have been organized along these three levels. At the highest level UoW with CloudSME UG, CloudSigma and ScaleTools organised three project meetings and two code camp meetings. At the middle level project ran bi-weekly ATF and TTF meetings involving WP8 and WP4-WP7, respectively. At the lowest level project partners had their weekly meetings.

O1.5 To define, implement and monitor the project's Data Management Plan.

UoW collected the data management requirements of COLA partners and developed the COLA Data Management Plan that was outlined in D1.3 deliverable. UoW monitored activities that affect DMP and modified it accordingly. For example the DMP has been modified because BalaBit left and BalaSys joined the project. The revised version contains data management requirements of BalaSys.

O1.6 To communicate the project vision at European and international events, and establish and keep contacts with national and international organizations and projects.

WP1 and WP2 participated and contributed to EC concertation and liason meetings. Project partners attended several European, national and regional events. These events and meetings helped to promote the vision of the COLA project, particularly focusing on public sector and SMEs. The aim of these activities was to dismantle hurdles of using Cloud Computing.

1.2.2 WP2 - Dissemination, communication, training and standardisation

Overview of activities in WP2

T2.1 Brand management and dissemination plan M01-M03

Task Leader: CloudSME Participants: All partners

cloudSME has prepared, written and coordinated the deliverable D2.1 Brand management and dissemination plan which was submitted in time in M3. The project website has been set up and is available with general information about the project (http://www.project-cola.eu), press releases, news and events. In addition, the project became active in several social media channels including Twitter, Facebook and LinkedIn.

CloudSigma researched the iconography of the main project topics and created a number of mockup logo designs. This was then reduced to the 3 best ideas. The hexagon was chosen as it is commonly used to represent the concept of microservices, which is the underlying architecture of the MiCADO framework. The All partners contributed to the discussion on the COLA logo design. The final design was voted at the kick-off meeting. The winning design resembles a hexagonal origami container or rose bud. This represented the containerised service nature of the COLA innovation.

INYCOM and **SARGA** provided Information for the COLA project website, specifically on Inycom and the Social Media Data Mining use case in which the companies participate. A webpage with project information was included in Inycom website.

CloudSME and **CloudBroker** contributed to the D2.1 "Brand management and dissemination plan" by providing a project-internal review. The deliverable has been reviewed, QA Sheet completed, improvements suggested.

T2.2 General dissemination activities M01-M30

Task Leader: CloudSME Participants: All partners

cloudSME has designed and produced a number of dissemination materials such as printed brochures / flyers. In addition, roll-up banners and posters were designed and produced to be used at exhibitions and trade fairs. **cloudSME** attended a number of events (see details in D2.2) and supported partners with material and logistics for their own dissemination activities and successfully coordinated. Further, **cloudSME** has co-organized the first Cloud Computing Experience Day together with the Digital Innovation Hub Ruhr and the regional agency for Business Development on March 13th at TechTower, Germany. They also had COLA booth to present, market and disseminate COLA results at the world-largest industry fair Hannover Messe 2017 and 2018.

SAKER has created a video to present the COLA Evacuation Simulation use-case for Hannover Messe 2018 which cloudSME presented at the COLA booth.

SZTAKI and **UoW** researchers attended several dissemination events to promote the COLA project, particularly the MiCADO platform and COLA use cases. See details in Section 6.5 Part A. **SICS, SZTAKI** and **UoW** researchers published several peer-reviewed articles related to the COLA project. Plus, a PhD thesis partly based on the COLA research was completed on 2017. See details in Section 6.1 in Part A.

CloudSigma wrote an article entitled "Cloud Orchestration at the level of the Application" which was published Nov 5, 2017 in the corporate blog. It provides a high-level introduction to the main concept of the project and outlines CloudSigma participation and the potential impact for existing and potential CloudSigma customers. The article was reproduced as a profile page in the community section of the CloudSigma marketing website under Research and Innovation Projects. Links to future project related blogs will be added to this profile.

INYCOM has prepared and send out press releases to advertise COLA project taking advantage of project meetings and attended to an I4MS Conference in in Madrid, Spain in September 2017. Internal presentations of the project and the technology platform have been given to Inycom's developers, technology managers and sales representatives. **SARGA** has actively participated in the dissemination of the project on social networks. They and the Aragon government have published two press releases in both regional and national media. The Inycom + SARGA use case is part of the modernization strategy of the Aragon government's eGovernment.

UBRUN disseminated and promoted the project's achievements among SMEs and public sector organisations, and the general public by (i) attending the I4MS conference in Madrid, Spain and discussing possibilities for utilising MiCADO for simulation, (ii) starting collaboration with FORD MOTOR COMPANY and discussing possibilities for the MiCADO framework adoption, and (iii) discussing collaboration possibilities with researchers from Nanyang Technological University (NTU) and D-SIMLAB Technologies, Singapore for auto-scaling IoT for Smart Cities and Semiconductor Manufacturing applications and (iv) attending and presenting a paper at the 10th International Workshop on Science Gateways.

cloudSME wrote and submitted the D2.2 "First Periodic Dissemination Report" at M12.

T2.3 Organising training events M04-M30

Task Leader: SZTAKI Participants: CloudSME, UoW, SICS, CB, ST, CS

UoW and **SZTAKI** developed on-line tutorials to promote the MiCADO platform and train prospective COLA users. Six tutorials have been uploaded to the COLA website:

- MiCADO v0.A and v0.B tutorials,
- MiCADO v1.A and v1.B tutorials,
- MiCADO v2 tutorial,
- MiCADO v3 tutorial (called as User guide and Advanced user guide)

Further**, UoW** created a video that explains how developers can use the MiCADO platform to port, deploy and run application on the Cloud. These two partners also developed and published an on-line training course on TOSCA that is available on the COLA website. These were two live webinars (one on MiCADO and another one on TOSCA). These were then published as on-line videos on the website.

Balabit organised a demo where its Shell Control Box product was presented. The demo aimed to provide information on how to control and monitor remote access to the cloud orchestrator framework. The demo was focused to the SSH related capabilities as the MiCADO framework is heavily using this remote access method for administrative access. The demo itself was available for all project members.

cloudSME has supported T2.3 training activities by providing logistics for webinars and training events, uploading the user-guides and tutorials to the main project website, uploading the training material to SlideShare and YouTube. cloudSME described T2.3 training activities in the D2.2 deliverable.

T2.4 Collecting community feedback M13-M30

Task Leader: CloudSME Participants: All other partners

cloudSME has defined and elaborated the process of collecting user and community feedback. In collaboration with selected use-cases and proof-of-concepts, the initial methodology to collect user feedback was prepared and a first implementation was developed. Collection of user-feedback using (GDPR-compliant) Google forms has started and will be feed back to the technical work packages (WP5-WP7) regarding how to improve and/or further develop the framework, and also for WP3 regarding potential commercial exploitation and sustainability.

INYCOM developed and gave internal presentations about the project and the technology platform to Inycom's developers, technology managers and sales representatives and follow up contacts done in I4MS Conference in Madrid, Spain in September 2017

UBRUN contributed to collecting community feedback about the quality and applicability of the MiCADO framework and the COLA project results from SMEs and public sector organisations by holding brainstorming sessions at the attended disseminations events.

T2.5 Contribution to standardisation M1-M30

Task Leader: UoW Participants: SZTAKI, SICS, CS, UBRUN, CloudSME

UBRUN contributed to the standardisation of cloud orchestration at application level by identifying gaps at the TOSCA standard relevant to the COLA use cases.

cloudSME in cooperation with WP5-WP7 Leaders presented standardization efforts and results in COLA dissemination and communication activities.

In WP5 **UoW** has defined the Application Description Template based on the standardized TOSCA language specification that supports separation of concerns and technology agnosticism. This approach helps to adopt or propose standard descriptions. UOW has contacted OASIS to further discuss how COLA can participate in the process of the standards definitions.

Achievements and results of WP2

T2.1 Brand management and dissemination plan M01-M03

- Project website designed, implemented and set-up.
- Project logo delivered in a number of formats (Ai vector, pdf, PNG, JPG etc.)
- Project templates designed and delivered.
- Project branding implemented and communication channels established.

T2.2 General dissemination activities M01-M30

Supporting dissemination activities:

- Design and production of a number of dissemination materials such as printed brochures / flyers, roll-up banners and posters
- Design and implementation of multiple dissemination channels incl. Website, Twitter, Facebook and LinkedIn.

COLA dissemination events:

- Promoting COLA, MiCADO and Occopus at various workshops and conferences
- Presenting how COLA use cases are described in TOSCA;
- cloudSME: Co-organizing a first Cloud Computing Experience Day together with the Digital Innovation Hub Ruhr and the regional agency for Business Development
- cloudSME: Co-organising a joint booth to present, market and disseminate COLA results at the world-largest industry fair Hannover Messe 2017 and 2018.
- SAKER: Video created for Hannover Messe

Collaborations:

- Establishing first contacts with Melodic and PrEstoCloud H2020 project to start research cooperation;

- Collaboration with the I4MS initiative to promote the utilisation of MiCADO.
- Establishing contacts with prospective users of the MiCADO framework at various events.
- Brunel: Discussions and collaboration with I4MS initiative, FORD MOTOR COMPANY, NTU researchers, and scientists at IWSG'18.
- INYCOM: Awareness about the project has been raised, especially at a regional level with the use case with the Regional Government of Aragon and new opportunities for MICADO are being detected in other applications commercialized. Presentation and Video for Hannover Messe 2018
- New opportunities for MICADO are being detected in other applications commercialized by Inycom.

COLA related publications:

- SICS: Doctoral dissertation published: Paladi, N.: Trust but Verify: Trust Establishment Mechanisms in Infrastructure Clouds, Lund University, 2017.
- SICS: Journal article accepted: Paladi, N. and Gehrmann, C.: Bootstrapping trust in software defined networks, EAI Transactions on Security and Safety, 2017.
- SICS: workshop article: Paladi, N and Michalas, A. and Dang, H-V.: *Towards Secure Cloud Orchestration for Multi-Cloud Deployments*, Proc. 5th Workshop on CrossCloud Infrastructures & Platforms, 2018
- CloudSigma: Article entitled "Cloud Orchestration at the Level of Application" published Nov 5, 2017 in the CloudSigma blog. https://www.cloudsigma.com/cloud-orchestration-at-the-level-of-application/?nabe=5119729909104640:0
- SZTAKI + UoW: Article entitled "Cloud Orchestration at the Level of the Application" published Nov 10, 2017 in the Community Section of the CloudSigma marketing website under Research and Innovation Projects. https://www.cloudsigma.com/community/research-and-innovation-projects/?nabe=5119729909104640:0
- UoW: 3 conference papers and 2 extended abstracts presenting the MiCADO framework and how applications can be described in TOSCA at IWSG 2018
- UoW: 1 keynote speech on cloud scalability and the MiCADO framework at MIPRO 2018

T2.3 Organising training events M04-M30

- On-line tutorials demonstrating how to use MiCADO v0, v1, v2 and v3;
- Three live webinars:
  - On-line training course on MiCADO
  - Presentation explaining the security issues of remote access to cloud orchestrators
  - On-line training course on TOSCA
- Video explaining developers how to use the MiCADO platform
- Video explaining the security issues of remote access to cloud orchestrators
- Demos about MiCADO platform on YouTube

T2.4 Collecting community feedback M13-M30

- Brainstorming sessions for collecting community feedback.
- Preparation of user & community feedback process
- Suggestion of methodology and approach
- Implementation of user & community feedback channel
- Testing of GDPR-compliant web-forms for feedback collection

T2.5 Contribution to standardisation M01-M30

- Investigation of the needs for standardisation at the application level.

WP2 Deliverables submitted

Two deliverables have been submitted before the deadline:

- D2.1 "Brand management and dissemination plan". M03
- D2.2 "First Periodic Dissemination Report" M12

WP2 Milestones achieved

Two milestones have been achieved as planned in DoW:

- MS2.1 Project website implemented M01
- MS2.2 Dissemination and training events in M01-M12 completed M12

Meeting W2 objectives

Objective 2.1 To create a business-oriented image of the project and raise awareness of the project's achievements within business, industry and academia, especially within SMEs and public sector organisations.

Task T2.1 activities and results shaped the business-oriented image of the project with the creation of a brand identity. The project logo and project website has been designed and set up, as well as document templates with the project's brand. Communication channels such as the social media profiles and electronic newsletter have been created and regularly used since the beginning of the COLA project.

Objective 2.2 To disseminate and promote the project's achievements among SMEs and public sector organisations, and the general public.

Task T2.2 activities and results have successfully contributed to the dissemination and promotion of the project's achievements, including the design and production of a number of dissemination materials such as printed brochures / flyers. In addition, roll-up banners and posters were designed and produced to be used at exhibitions and trade fairs. The project has actively attended a number of events (see details in deliverable D2.2). In addition, COLA dissemination events were (co-)organized, such as the first Cloud Computing Experience Day together with the Digital Innovation Hub Ruhr and the regional agency for Business Development on March 13th at TecTower, Germany. Finally, cloudSME as work package leader has co-organised a joint booth to present, market and disseminate COLA results at the world-largest industry fair Hannover Messe 2017 and 2018. Project partners wrote several conference and journal papers to promote the MiCADO framework and how it can be used by public sector organisations and SMEs.

Objective 2.3 To organise training events for application developers to get them familiar with the MiCADO framework to develop cloud-aware applications.

Task T2.3 has organised training on-line and physical events targeting cloud application developers both inside and outside the project. User guides and manuals have been developed and customized for the targeted users considering their specific requirements.

Objective 2.4 To collect community feedback from SMEs and public sector organisations about the quality and applicability of the MiCADO framework and the COLA project results.

Task T2.4 has prepared and initialized the process of collecting user and community feedback. In collaboration with selected use-cases and proof-of-concepts, the methodology to collect user feedback was prepared and a first implementation was developed. Collection of user-feedback using (GDPR-compliant) Google forms has started and will be feed back to the technical work packages (WP5-WP7) regarding how to improve and/or further develop the framework, and also for WP3 regarding potential commercial exploitation and sustainability.

Objective 2.5 To drive and significantly contribute to the standardisation of cloud orchestration at application level.

Task T2.5 has conducted an investigation of the needs for standardisation at the application level. Based on this investigation this task will contact standardisation bodies and be involved in standardisation.

1.2.3 WP3 - Commercial Exploitation and Sustainability

Overview of activities in WP3

T3.1 Validating economic feasibility of the COLA use cases M01-M30

Lead partner: CB Participants: Outlandish, Inycon, Saker, CloudSME UG, Sarga, Now, UBRUN

Under **CloudBroker** lead **ScaleTools** and **CloudSME** started working on definition of COLA use cases' business models. These partners created business model and value proposition canvas templates to define these business models. The templates (questionnaires) were forwarded the use case owners and technology providers so that they were able to provide their requirements and vision of the business models.

CloudSME, TAA, Outlandish, Inycom, Sarga and **Saker** provided inputs for the use case business models. They populated and submitted business use case documents **CloudBroker, ScaleTools** and **CloudSME**. The documents were based on the Business Model Canvas and Value Proposition Canvas and required by WP3 to determine and analyse the use cases BM and potential sustainability. **CloudSME, TAA, Outlandish, Inycom, Sarga** and **Saker** completed and returned these template with their requirements. Having these inputs **CloudBroker** and **ScaleTools** developed the first version of business models of COLA use cases using the Business Model Canvas and the Value Proposition Canvas. These were discussed during the workshop at the project meeting held in Cracow to refine the business models. The business models were reported in D3.1 "First commercial exploitation and sustainability report".

cloudSME have contributed to T3.1 by pre-validating economic feasibility of the MiCADO framework discussing it with external CloudSME users.

T3.2 Commercial exploitation, IPR management and sustainability of the SME use cases, the public sector solutions, and the MiCADO architecture and its reference implementation M01-M30

Lead partner: CB Participants: All other WP participants

CloudBroker in cooperation with **ScaleTools** and **CloudSME** coordinated collecting exploitation and IPR information from each COLA partner involved in use cases. **CloudBroker, ScaleTools** and **cloudSME** created questionnaire to collect the general partner IPR information, business models and value proposition. Also, the specific metrics to measure the potential impact of the COLA project onto their business models were included in the questionnaire.

CloudSME, TAA, Outlandish, Inycom, Sarga and **Saker** provided inputs needed to define commercial exploitation and sustainability by completing the questionnaire. They forwarded the questionnaire with their individual exploitation, IPR and sustainability inputs **CloudBroker ScaleTools** and **Cl,oudSME** to enable them to elaborate the commercial exploitation, IPR management and sustainability of COLA use cases. **UBRUN** investigated sustainability and generalisation of use of the parameter sweep functionality of the MiCADO framework. **CloudSME** and **SZTAKI** discussed the commercial exploitation of MiCADO, Occopus and Data Avenue products. **Inycom** checked out different commercial opportunities for new use cases feasibility studies to be developed in T8.4. Having these inputs **CloudBroker** and **CloudSME** investigated IPR issues and licensing requirements and proposed strategies how to manage them.

CloudSME approached several prospective customers that can use the MiCADO framework to run their application in the Cloud.

CloudBroker and **ScaleTools** wrote D3.1 "First commercial exploitation and sustainability report" submitted at M12. It includes the COLA business model with the commercial exploitation and sustainability plan.

T3.3 Marketing campaign to commercialise and sustain project results M01-M30

Task Leader: CloudSM E Participants: All other WP participants.

CloudSME aligned the WP2 Dissemination Strategy with WP3 marketing activities by:

- Co-creating a Business Innovation Process (together with **CloudBroker**) using Business Model Canvas and Value Propositions Methodology (cf. Osterwalder et al.).
- Collecting Business Model & Value Proposition requirements from all use-cases.

- Co-organising an all partner Innovation Workshop in Krakow, Poland to discuss, validate and iterate the Business Model propositions of the COLA use-cases.
- Preparing initial Value Propositions for the MiCADO framework and its exploitation.
- Pre-validating the proposed Value Propositions in Technology Demonstration with external users.

Achievements and results of WP3

T3.1 Validating economic feasibility of the COLA use cases M01-M30

- Methodology and approach to collect business models for the use cases were elaborated, related material (questionnaires) was created.
- Business models relevant for each COLA use case were collected, discussed and refined.
- Pre-validation of economic feasibility by applying the developed MiCADO framework within cloudSME with external users has been done.
- A set of updated questionnaires was created to monitor the current status of use cases in a scope of WP3. Updated information is expected to be received and gathered till the end of M19.
- A discussion session on WP3 was organized at the project meeting in Sofia. All the related issues were discussed and future steps for improvement of the Projects' economic feasibility were defined.

T3.2 Commercial exploitation, IPR management and sustainability of the SME use cases, the public sector solutions, and the MiCADO architecture and its reference implementation M01-M30

- MiCADO initial business model was defined.
- Methodology and approach to collect business models, IPR and exploitation data per partner were elaborated, related material (questionnaires) was created.
- Business models relevant for each COLA partner were collected.
- Partner IPRs and tentative exploitation data/metrics were collected.
- A discussion session on WP3 was organized to discuss sustainability questions.

T3.3 Marketing campaign to commercialise and sustain project results M01-M30

- Aligning the WP2 COLA Dissemination Strategy with WP3 marketing activities.
- Preparing initial Value Propositions for the MiCADO framework and its exploitation
- Pre-validating the proposed Value Propositions in Technology Demonstration with external users
- Starting an iterative co-design process with selected use-cases
- Iterating the initial Value Propositions and potential Business Models with first use cases
- Presenting the project vision to potential end-users and customers (incl. Hannover Messe)
- Organizing the first CloudComputing experience day in Duisburg, Germany
- Co-organising an all partner Innovation Workshop in Krakow, Poland to discuss, validate and iterate the Business
- Co-organising a follow-up session on Sustainability and Business Models at the project meeting in Sofia, Bulgaria

WP3 Deliverables submitted

One deliverable has been submitted before the deadline:

- D3.1 "First commercial exploitation and sustainability report" M12

WP3 Milestones achieved

One milestone have been achieved as planned in DoW:

- MS3.1 "Draft commercial exploitation and sustainability plan" M12

Meeting W3 objectives

O3.1 To contribute to the commercial exploitation and sustainability of products and services developed in the COLA project within the SME sector.
O3.2 To contribute to the commercial exploitation and sustainability of products and services developed in the COLA project within public sector organisations.

To meet these two objectives questionnaires to collect requirements for commercial exploitation and sustainability of each partner were created. Information gathered via them and two canvases (Business Model and Value Proposition) was used to define current status and potentials of the products and services to be developed in the COLA project within public sector organisations and the SME sector. Information on partners' exploitation plans and value propositions was gathered. It will be used to develop successful market strategy. Questionnaires to check all the information for deviations and changes were prepared. They will be used to monitor project's economic feasibility and sustainability. T3.1 and T3.2 will check status of economic feasibility and sustainability at M19.

O3.3 To contribute to the commercial exploitation and sustainability of the MiCADO platform as major output of the COLA project.

Business analysis of the MiCADO framework was performed. The value proposition of the framework was defined. A work on defining the project's business-driven scalability policy was started. Discussion among the partners was organized to gather their inputs and to characterize the MiCADO framework both from technological and market-oriented sides.

O3.4 To develop and execute an integrated marketing campaign in support of the successful commercialisation of the project.

Market and technology readiness assessments were made to define the go-to-market strategy for COLA, as well as for making the project successful in terms of sustainability. Based on the analysis, a number of marketing and sales recommendations (e.g. the most suitable dissemination channels) were given to COLA partners to help the project to develop successful market strategy as well as sustain its results.

1.2.4. WP4 - Cloud Access Layer and Testbed Infrastructure

Overview of activities in WP4

T4.1 Collecting and refining requirements of MiCADO microservices M01-M03

Lead partner: CS Participants: UoW, SZTAKI, SICS, CB

CloudSigma created an online form to gather the resource requirements of the MiCADO microservices and the COLA use case applications. The form was revised and distributed after M15 to define the resource requirements and optimal VM configurations. CloudSigma has worked with use-case owners to optimize their deployments for testing their applications. The feedback was used to ensure efficient utilization of resources.

SZTAKI performed a detailed investigation of the CloudBroker platform and specified new functionalities needed for the orchestration layer of MiCADO. The requirements included functionalities such as cloud-init support and porta range handling. Once the functionalities had been implemented, SZTAKI provided the related feedback.

As task leader, **CloudSigma** worked on integrating outputs from other work packages. D8.1 was examined to extrapolate the high-level requirements of the four use cases (incl. CloudSME use case). D5.4 was examined to understand the Application Description Templates (ADTs) and how it describes services relating to each use case. There has been additional communication with use case owners to help WP4 understand the functional requirements and performance expectations relating to their specific applications. This analysis was shared with **all other task partners** in preparation for D4.2 and will continue to inform WP4 ahead of D4.3.

T4.2 Deployment, operation and support of development testbed infrastructure M01-M30

Lead partner: CS Participants: UoW, SZTAKI, SICS, CB, ST

CloudSigma leads this task and is responsible for the deployment, maintenance and operation of CloudSigma's development testbed infrastructure. Cloud resources (100Ghz CPU, 100GB RAM, 1500GB SSD) were allocated

to the project according to the Grant Agreement. Multiple CloudSigma accounts were set up for partners as a temporary measure while the CloudBroker Platform was being upgraded and partner clouds were being integrated. The resources were re-allocated to the CloudBroker Platform. A number of additional CloudSigma accounts and subaccounts were created for specific testing (e.g. SZTAKI testing if Occopus still runs optimally on CloudSigma). CloudSigma then performed all the Occopus tutorials and provided feedback to SZTAKI. An audit was carried out to assess the total resource usage at CloudSigma. This resulted in a script being developed to monitor resource usage. SSD storage has been exceeding the set threshold by approximately 1TB. However, CloudSigma has allowed for some flexibility.

SZTAKI setup and operated the development testbed infrastructure located in Budapest. They designed, implemented and documented the access mechanism for the COLA participants to the SZTAKI Opennebula cloud through CloudBroker. They also contributed to D4.1 by providing a detail description of the SZTAKI Opennebula cloud. **UoW** operated, maintained and provided support for its OpenStack based cloud as part of the COLA development testbed infrastructure. **SICS** assisted other task partners in integrating its cloud infrastructure with the CloudBroker service. This included analysis of integration interfaces, troubleshooting and monitoring of the integration.

CloudBroker contributed to the migration of the CloudBroker Platform used by the COLA partners to the new up-to-date technologies. They created a COLA server back-up procedure and performed the respective testing activities. They provided support to all partners to use the CloudBroker Platform. **CloudBroker** developed QA, documentation and support creating API documentation for the platform usage. The new and upgraded documentation can be used by the partners. It substitutes the old documentation that was outdated and was not user friendly. **ScaleTools** migrated the ClouBroker Platform (CBP) to the up-to-date technologies (cookies / session store, JQuery, authorization/API migrated) and tested CBP after migration to new technologies. They set up a test CloudBroker Platform for COLA. A number of integrations to the new COLA CloudBroker Platform were performed and support for the integration provided to various partners, in particular **SICS, SZTAKI** and **UoW**. SZTAKI cloud was integrated into the new COLA CBP. ScaleTools developed and added new adapters to CBP to support access to OpenNebula and SZTAKI storage. SICS cloud (v.1) was 90% integrated after a number of iterations were performed. It was eventually depreciated by the SICS team. As a consequence, the SICS cloud (v.2) has been integrated. **ScaleTools** also integrated the OpenStack based cloud deployed at the University of Westminster to CBP and provided support UoW for using CloudSigma images and setting up new Amazon account.

All task partners have participated in multiple task related discussions via monthly teleconferences. Partners have worked with each other to resolve technical problems. This has required additional ad hoc communication between the relevant partners.

T4.3 Deployment, operation and support of production infrastructure M13–M30

CloudSigma leads the task and is responsible for transitioning CloudSigma's testbed infrastructure to a fully functional production infrastructure located in Zurich. A roadmap has been drafted to detail all the work required for this task. So far it includes the enabling of additional security functionality and planning for a security audit of the CloudSigma cloud to be performed by **SICS**. It also includes assessment of the different hardware configurations available which will help to determine any possible hardware upgrades and/or further optimisations. **SZTAKI** has been operating its cloud as production infrastructure by ensuring its full-time availability for all beneficiaries. The behaviour of the MiCADO framework on the various production clouds is also being monitored.

T4.4 Microservices performance benchmarking M03-M30

Lead partner: CS Participants: UoW, SZTAKI, SICS

CloudSigma leads the task and is responsible for coordinating the performance benchmarking of the core components of the MiCADO framework. Partners worked together to devise a plan for the automated testing and set up and configure a Jenkins test environment. **UoW** and **SZTAKI** designed and implemented multiple tests for the COLA testbed infrastructure that were used for benchmarking the core MiCADO services comprised

of (1) Occopus, (2) Prometheus, (3) Docker Swarm. These tests were undertaken and the results documented in D4.2. **SICS** outlined a test plan for the security components being developed in WP7, comprised of the Crypto Engine, Credential Manager, Credential Store and the Security Policy Manager.

T4.5 Implementation of enhancements of the cloud access layer M03-M30

Lead partner: CB Participants: ST

CloudBroker leads this task and is responsible for the implementation and enhancements of the cloud access layer. They have set up the server for the COLA CloudBroker Platform. A number of technology upgrades have been implemented and tested (e.g. for improving the instance management of the CloudSigma cloud). The API documentation has subsequently been updated and transferred to the new online format. New user manuals have also been created. The pricing mechanism has also been updated. CloudBroker prepared the technical WP4-related presentations and reporting for the project meeting in Cracow and Sofia.

ScaleTools has performed multiple implementation and QA activities, as well as some activities related to the technical documentation. The activities are listed below.

enhancements of the cloud access layer:

- CloudInit support for Amazon and CloudSigma added. Now it is possible to configure an instance using a CloudInit script provided on instance launch from CBP.
- Platform for new version of API documentation was setup.
- OpenStack Nova image generation has been upgraded.
- Instance management features upgraded for COLA CBP.
- SSH key pairs are no longer restricted by IP. Previously it was possible to connect to an instance in a cloud via SSH using the key pairs from specific IP only. Now it is possible to connect via SSH to an instance without being restricted by specific IP.
- Several SSH key pairs can be used to connect to an instance. When launching an instance from CBP, it was possible to attached only one key pair to the instance and then use it to connect to the instance. Now it is possible to attach several key pairs to an instance and use them for connection.
- Instance password autogeneration on launch was added. When instance is launched, each time a new password for instance access is generated making the instance more secure.
- Usage of Key Pair mechanism has been introduced for CloudSigma.
- Handling of the security groups has been upgraded for CloudSigma.
- Control over instance stopping has been enhanced for CloudSigma.
- Flexible prices display through API introduced
- Functionality to run script on instances through Platform API added

Documentation:

- API documentation update
- User Manuals update according to the new features

Testing activities:

- New CloudInit functionality testing
- Testing of the Platform after migrating to the new technologies
- Testing of the Platform after implementing partner requests (e.g. SZTAKI requests)
- Testing after new features implementation such as storage adapter update, instance password autogeneration on launch, CloudSigma stopping mechanism enhancement, Amazon enhanced failures handling, etc.

Achievements and results of WP4

T4.1 Collecting and refining requirements of MiCADO microservices M01-M03

- A resources requirements form was created and distributed (updated and redistributed in M15)
- A summary of the high-level performance requirements was created and used to compare with the performance benchmarking results documented in D4.2.
- Application-level requirements have been collected and summarized.
- Requirements have been defined by SZTAKI towards the CloudBroker platform (functionality such as cloud-init support ,porta range handling and similar)

T4.2 Deployment, operation and support of development testbed infrastructure M01-M30

- New API documentation is created
- Partner support performed in timely manner that contributed to the efficient work of the partners using the CBP
- The COLA CBP server uses the latest technologies needed for better performance, security, etc.
- New technologies are now used by the COLA CloudBroker Platform that enables better performance, security, etc.
- Partner cloud infrastructure has been integrated successfully to the COLA CloudBroker Platform.
- Multiple upgrades to the adapters used for the partner clouds were done enabling better operation of the integrated clouds.
- Support related to the testbed development has been performed when partners required it.
- Inputs for the D4.1 provided that enable the deliverable to be submitted on time.
- The reporting about the ScaleTools activities on the 2nd project meeting has been done.
- Multiple new features that extend the COLA CBP has been implemented and tested. Thus, partners get the upgraded cloud access layer as needed for their activities.
- User manuals were updated according to the new features that keep them up to date in case partners need to find the most relevant information they need.
- Multiple testing activities has been done to assure the quality of the COLA CBP and the related implementations.
- SICS cloud infrastructure was integrated with the CloudBroker
- Account created (@ zrh.cloudsigma.com) for SZTAKI for testing if Occopus still runs optimally on CloudSigma. The following resources were provided: 2GHz CPU, 2GB RAM, 100GB SSD storage, all for the period of 6 months. CloudSigma provided support throughout the process.
- The agreed subscription (@ zrh.cloudsigma.com) was applied to the COLA associated CloudBroker account. The following resources were provided according to the Grant Agreement (100Ghz CPU, 100GB RAM, 1500GB SSD).
- CloudSigma created separate test accounts for project partners from CloudSME, UoW, Saker Solutions, Inycom and Brunel University. Each account was upgraded when necessary.
- Created a subaccount for inycom and linked it to the CloudBroker COLA account. Some adjustments were necessary, e.g. Remove as subaccount, adjust subscriptions and add funds.
- Created subaccounts for UoW and extended the subscription for another 3 months.
- CloudSigma performed all the Occopus tutorials (1. Hello world; 2. Ping; 3. Docker Swarm cluster; 4, Apache Hadoop). Once complete, feedback was provided to SZTAKI.
- Created a spreadsheet of all cloud deployments (STAKI, SICS, UoW, CloudSigma) for the purpose of keeping testbed descriptions up-to-date and tracking progress of integrations into CloudBroker. This required many discussions with Scaletools about integration requirements.
- An investigation was required into the UoW test server on CloudSigma due to outgoing traffic leakage. Evidence suggested the servers had been compromised. The servers were consequently destroyed and new ones set up.

T4.3 Deployment, operation and support of production infrastructure M13–M30

- A roadmap detailing the work required to ensure production ready infrastructure has been drafted.

- The first results are available regarding the performance comparisons between the various hardware configurations of CloudSigma

T4.4 Microservices performance benchmarking M03-M30

- The high-level performance requirements common to the use-cases were extrapolated in correlation to the outputs of WP8, and summarised in D4.2.
- The application-level performance requirements were extrapolated in correlation with the outputs from WP5, and summarised in D4.2
- A testing environment was set up.
- Performance benchmarking of the core MiCADO services was undertaken and documented in D4.2.
- A test plan for the security components which are being developed in WP7 has been devised and documented.

T4.5 Implementation of enhancements of the cloud access layer M03-M30

- Assisted project partners from Scaletools to resolve a problem with one of our API calls.
- Compiled a DMP document for UoW
- Assisted project partners from UoW to run CloudInit script with new Ubuntu images. We were required to recreate the Ubuntu 16.04 image. Further troubleshooting was required to solve other issues with Ubuntu 16.04. The Ubuntu 14.04 image in ZRH was modified so that the hostname is set from the guest definition.
- Created an initial table of contents and document structure for D4.1. Made draft contributions and distributed the document among WP4 partners to gather contributions.
- An audit was carried out to understand the total resource usage (compute and storage) and compare with the total resources dedicated to the project according to the Grant Agreement.
- Initiated the creation of a document describing the cloud access for the academic clouds.
- A script for monitoring resource usage is being developed. It will output usage statistics.
- COLA CBP server was kept operational all the time the partners needed it.
- New features valuable for the partners have been tested to assure the quality (e.g. CloudInit, migration to the newest technology).
- New API documentation is created and also transferred to the new online format.

WP4 Deliverables submitted

Two deliverables have been submitted D4.1 before the deadline while the submission deadline of D4.2 was extended by one month:

- D4.1 “COLA development testbed infrastructure” M12
- D4.2 “Requirements gathering and performance benchmarking of Microservices M14

WP4 Milestones achieved

One milestone have been achieved as planned in DoW:

- MS4.1 “Development testbed infrastructure successfully deployed.” M09

Meeting W4 objectives

Objective 4.1: To collect and refine functional and non-functional cloud infrastructure and access layer requirements.

WP4 has utilised the outputs from WP5 and WP8 to compile a series of high-level and application-level requirements respectively. These have been summarised and used to form decisions relating to the expected functionality and performance of the underlying infrastructure and cloud access layer. This has resulted in a number of modifications and upgrades to the clouds comprising the development testbed infrastructure and the CloudBroker Platform. The upgrade to the production cloud infrastructure is partly informed by the requirements collected in this task.

Objective 4.2: To create a production and a testbed cloud infrastructure consisting of commercial and academic cloud resources.

All the academic clouds provided by UoW, SZTAKI and SICS, as well as the one commercial cloud provided by CloudSigma have been successfully integrated with the ClouBroker Platform. Each organisation has been providing support for their respective cloud to the various partners using the infrastructure. The production cloud is currently being defined as "one that replicates real-world deployment". A roadmap has been created to outline the upgrades and optimisations necessary to achieve this definition. The resulting production cloud will be realised, assessed and documented in D4.3.

Objective 4.3: To investigate optimal container size and infrastructure requirements of microservices.

There have been a number of ad hoc discussions between the application owners and infrastructure providers about provisioning and optimal configuration of cloud resources. For example, the testing of the simulation software being run by SAKER Solutions being undertaken by Brunel University directly on CloudSigma's development testbed infrastructure. We now have a better understanding of the resource configuration (e.g. number of CPU cores allocated) for certain applications and will be documenting a number of recommendations in D4.3.

Objective 4.4: To assess infrastructure performance for optimisation of cloud applications.

We have undertaken performance testing of the core MiCADO services and documented the results in D4.2. There have also been tests done to determine the optimal VM and container sizes (e.g for the simulation software being run by the SAKER Solutions use-case). There will be more application specific testing as we transition to the production cloud infrastructure.

Objective 4.5: To enhance the cloud access layer based on the requirements of the COLA use-cases as well as from the upper and lower layers.

CloudBroker and ScaleTools have already implemented and tested a number of technology upgrades to the CloudBroker Platform. These include; (1) CBP pricing mechanism, (2), CBP registration process, (3) Improved monitoring, (4) Upgraded adapters, as well as a number of smaller but essential enhancements.

1.2.5 WP5 - Application Description Templates

Overview of activities in WP5

T5.1 Investigating existing applications descriptions approaches M01-M04

Task Leader UoW Participants: SZTAKI, SICS

UoW analysed the state of the art and common approaches for the description of applications. **SZTAKI** contributed to the analysis of the existing application description solutions by providing detailed overview of some technologies. This survey took into account the requirements of the COLA project as well as the most common approaches to the problem. SZTAKI and UoW decided to use TOSCA as the language specification to develop the application descriptions in COLA. After selecting TOSCA, **SICS** investigated how TOSCA can be used to specify and express security policies in COLA.

UOW wrote and submitted the related **Deliverable (D5.1)** which describes the findings of T5.1 within the required deadline.

T5.2 Developing the concept of the application template M03-M07 + M13-M14

Task Leader UoW Participants: SZTAKI, SICS

UoW in cooperation with **SZTAKI** elaborated a three-layer architecture to describe applications in TOSCA. The three layers are as follows: application layer, platform layer and resource layer. The major idea behind this architecture is to support usability of previously described applications, services and resources. **SZTAKI** and **UoW** also investigated how TOSCA can support application, service and resource virtualisation. These two partners defined the first draft of the structure of the application description. **UoW** has also drafted an extension of the TOSCA policy hierarchy to describe the various facets of the application lifecycle (scalability, security, etc.). **UoW** has also analysed in cooperation with **SZTAKI** and **SICS** the relevant components of the MICADO

framework that will process the information contained in the application descriptions and defined the general principles of a component capable of submitting the application description to MICADO.

SICS formulated a set of security policy definitions that include the plain text description of the policies, policy properties including parameters, and policy targets. The set of policies includes policies on authorization, workload colocation, storage encryption, geolocation, integrity attestation and workload teardown. **UoW** has incorporated these policies in the extended TOSCA policy hierarchy to enable definition of application behaviour.

UoW has written deliverable D5.2 "Specification of the application template concept" which was submitted within the required deadline at M07. **MS5.1** "Concept and formal description of the application template and **MS5.2** "Integration of the application template with the selected application description approach" milestone have been achieved.

T5.3 Integrating templates with the application description approach M07-M10 + M15-M16

Task Leader UoW Participants: SZTAKI

UoW in cooperation with the use case owner partners (Outlandish and The Audience Agency for use case 1, Brunel and Saker for use case 2, Inycom and Sarga for use case 3) analysed COLA use cases considering application description requirements focusing on application architecture, its services used and features delivered. The partners defined the application topology and policies of each COLA use case. **SZTAKI** also contributed to the analysis of the COLA use cases considering application description requirements focusing on their architecture, services used and features delivered. Having these descriptions **UoW** created some sample TOSCA application descriptions of these use cases. During this process **UoW** in cooperation with SZTAKI upgraded the abstract COLA policy hierarchy adding use case specific policies, furthermore, based on the results of this design and implementation exercise, **UoW** has started evaluating how the initial three-layered architecture could be simplified whilst keeping its support to re-usability.

UoW has compiled deliverable D5.3 "Integration of the templates with the selected application description approach" which was submitted at M10 with a few days of delay.

T5.4 Specification and publication of templates and service descriptions M09-M30

Task Leader UoW Participants: SZTAKI

UoW in cooperation with Outlandish and The Audience Agency (use case 1), Brunel and Saker (use case 2) and Inycom and Sarga (use case 3) developed Application Description Templates for each of the three COLA use cases. The ADTs for each use case were implemented based on the user requirements specifications of D8.1, and the definition of the Application Description Templates described in D5.3. The developed ADTs are described in detail in D5.4 and the ADTs are uploaded to the GitHub repository (https://github.com/COLAProject/COLARepo). **SZTAKI** also contributed to the development of the TOSCA based application descriptions of the TOSCA use cases.

UoW has edited deliverable D5.4 "First set of templates and services of use case" which was submitted within the required deadline at M12. **MS5.3** "First set of application templates and the relevant service descriptions of the COLA use cases" has been achieved.

Achievements and results of WP5

T5.1 Investigating existing applications descriptions approaches M01-M04

- Completed an analysis of the current approaches and tools to describe applications,
- Completed a comparison of technology dependent and technology independent application description solutions,
- Selection of the TOSCA application description language to define and specify COLA use cases.

T5.2 Developing the concept of the application template M03-M07

- Definition of a generic three-layered architecture (applications, services and resources) based on the TOSCA language specification to guide the design of the application template. Such design aims at supporting re-usability of previously application, services and resources,
- Definition of a generic and an abstract policy structure capable of supporting the different facets of the deployment and execution of the applications on the Cloud,
- Check that the approach taken for the description of policies can support the various Use Cases requirements.

T5.3 Integrating templates with the application description approach M07-M10

- Re-assessed the three-layered architecture design to reduce its complexity whilst keeping it expressiveness.
- Definition of the structure of the application description named Application Description Template (ADT) capable of describing the structure of the COLA applications and the various aspects of their lifecycle (deployment, execution, etc…) such as scalability, deployment constraints and security-related aspects.
- Updated COLA use case descriptions presented in D8.1 adding TOSCA topology and policy specific details;
- Described the three Use Cases using the application description approach developed (ADT) comprising a topology to define the application structure and policies to define the various aspects of the application lifecycle.
- Extended the TOSCA Policy Hierarchy with policies needed to describe and implement the various lifecycle modalities required by the COLA Use Cases

T5.4 Integrating templates with the application description approach M10-M30

- First TOSCA based ADTs of the three COLA use cases;
- Application Description Templates uploaded into the Application Description Templates repository: https://github.com/COLAProject/COLARepo
- Three-layer structure reduced in complexity to better describe use case applications

WP5 Deliverables submitted

Four deliverables have been submitted before the deadline and one (D5.3) with minor delay:

- D5.1 “Analysis of existing application description approaches” M03
- D5.2 “Specification of the application template concept” M07
- D5.3 “Integration of the templates with the selected application description approach” M10
- D5.4 “First set of templates and services of use case” M12

WP5 Milestones achieved

Three milestones have been achieved as planned in DoW:

- MS5.1 “Concept and formal description of the application template” M06
- MS5.2 “Integration of the application template with the selected application description approach” M10
- MS5.3 “First set of application templates and the relevant service descriptions of the COLA use cases” M12

Meeting W5 objectives

O5.1 To investigate existing application description approaches and analyse how these enable developers to specify use-cases considering the selected public sector and SME use-case requirements

UoW in cooperation with **SZTAKI** (WP6) and **SICS** (WP7)has lead an investigation into the current approaches and best practices for the description of applications to support the best design to describe applications in COLA. This investigation has considered multiple aspects: current work carried on in academia and industry, the constraints and requirements expressed by WPs that are most relevant to WP5, such as WP6 and WP7 which include the need to describe scalability and security policies. Finally, the adopted solution should be capable of supporting the COLA conceptual approach based on theidea of three layered architecture: Application, Service

and Implementation Templates and also be compatible with current practices in the industry and the academia. The outcome of this investigation offered strong evidence that a good candidate to describe the applications in COLA is the OASIS standard, TOSCA (https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=tosca). As TOSCA is a standard language description, its adoption is also beneficial to Task T2.5 (Contribution to Standardization) led by **UoW**.

O5.2 To develop the concept of application template to allow developers to create extensible and shareable descriptions of use cases.

Based on the findings of T5.1, WP5 decided to adopt and use TOSCA to achieve the goals of O5.2, **UoW** has investigated how TOSCA can be used to implement the application descriptions following a three-layered architecture (applications, services and resources) to support re-usability. **UoW** has worked closely with WP6 and WP7 to design the application descriptions in accordance of the development of the MICADO components, security aspects, and, to ensure that the application description would be both compatible with the MICADO functionalities and capable of expressing the various facets of the application structure (application topology) and the modalities of its execution (application policies). An approach to the policy description and a related set of design guidelines was also defined. The definition of this structure has also been matched against the specifications of COLA use cases. O5.2 was pursued with a constant cooperation among the main partners of WP6, WP7 and WP8: regular and ad-hoc contacts were organized to ensure that the activities related to O5.2 would be consistent with the work brought on in the other WPs.

O5.3 To integrate the application template with the selected application description approach to describe applications that can be seamlessly deployed and managed in the cloud.

To address O5.3, **UoW** worked closely with **SZTAKI**, **SICS** and the COLA **use case owners of WP8**. **UoW** organized a set of teleconferences with the use case owners to ensure that the use case description was up to date. The partners compiled and disseminated a document which described the application services and policies. They identified two types of services: ones to be deployed in the MiCADO framework and ones would remain external and not deployed in the Cloud. The same document was also used to collect information about the policies. The description of the three use case applications brought to a first assessment of the initial three-layered architecture whereby it was considered the possibility to reduce its complexity. The initial three-layer architecture was simplifies to the concept of an Application Description Template which comprehends Container Images, Virtual Machines and Policies. The ADT was introduced to match more closely the nature of the COLA use cases which are composed of Docker Images deployed into Virtual Machines. COLA partners also assessed the structure of the Application Description Template and a first set of policies which were originally proposed in D5.2 and provided feedback on whether these could be used in use cases and if new policies needed to be added Finally, UoW evaluated and decided which TOSCA parsing tools had to be used to check validity of the syntactical consistency of the application descriptions.

O5.4 To set-up a repository for storing, publishing and searching application templates and their artefacts.

In order to achieve O5.4, UoW has created a Github repository (https://github.com/COLAProject/COLARepo) where WP5 has uploaded the application templates and their components to help re-usability. **UoW** has structured the repository to foster code re-usability as much as possible.

O5.5 To specify and publish descriptions of basic services and their implementations needed in different public sector and SME use-cases.

To achieve O5.5, **UoW** led T5.4 andT5.5 and worked on the output of T5.3 (D5.3) to implement the TOSCA-based Application Description Templates. This activity was been performed in close cooperation with **SZTAKI** (WP6) to ensure the suitability of the application templates to components of MICADO. **SICS** (WP7) and **UoW** cooperated closely to ensure the support of security and **CloudSigma** (WP4) participated to ensure the compatibility of the application description to the Infrastructure layer. **UoW** has also tested different rich GUI IDE environments for the development of the application templates but has found that development with a simple coding IDE sufficed. The application templates developed have been published in the COLA GitHub repository.

1.2.6 WP6 - Microservices deployment and execution layer

Overview of activities in WP6

T6.1 Development of the cloud deployment orchestrator service M01-M06

Task Leader: SZTAKI Participants: none

SZTAKI and **UoW** has investigated existing cloud orchestration tools and container management solutions. Docker Swarm, Occopus and Prometheus has been selected for developing five versions of the MiCADO orchestration layer:

- MiCADO v0.a - application are run inside VMs that controlled by Occopus and Prometheus
- MiCADO v0.b - applications are deployed in Docker containers on worker nodes controlled by Occopus, and Prometheus running on master nodes
- MiCADO v1. - orchestrator layer has a master node (Docker Swarm+ Prometheus), an Occopus node and multiple worker nodes (applications in Docker container) either using Docker Swarm load balancing service or a separate load balancing service
- MiCADO v2 - v1 version has been extended with container monitoring on the worker nodes and supports auto-scaling based on CPU consumption
- MiCADO v3 - Docker Swarm, Occopus and Prometheus are deployed on the master node

The results of this task has been described in details and reported in deliverable D6.1.

T6.2 Development of the Measurement and Metrics Collection microservice M03-M09

Task Leader: SZTAKI Participants: UoW

UoW and **SZTAKI** investigated existing monitoring services and selected Prometheus to be used in the MiCADO platform. Prometheus can continuously monitor the status of containers and VMs. This monitoring tool has been integrated with the MiCADO framework at two levels. How to use Prometheus was successfully demonstrated in MiCADO v3.

UoW also defined the deployment and scalability policy for the MiCADO platform and forwarded the description of these policies to WP5.

The results of this task has been described in details and reported in deliverable D6.2.

T6.3 Development of the first version of the Scalability Decision Maker microservice M10-M18

Task Leader: SZTAKI Participants: UoW, ST

UoW and **SZTAKI** investigated the extension of MiCADO to support scalability decisions in case of parameter sweep/job submission type of applications. Existing solutions for queue management and their suitability for MiCADO have been analysed and the first design specification has been elaborated. These two partners were further extending and improving MiCADO v3 and v4 but the focus of this task was on MiCADO v5.

MiCADO v3 related works:

- UoW elaborated load tests for MiCADO v3 to show and demonstrate how MiCADO behaves in various scaling scenarios.
- SZTAKI has improved MiCADO v3 and released MiCADO v3.1. Improvements cover several bugfixes and making several parameters user-defined. Documentation created, published on the project website.

MiCADO v4 related works:

- SZTAKI and UoW designed, then UoW implemented MiCADO v4 that incorporates two major components called jqueuer and cautoscaler, to run job type applications under MiCADO.

MiCADO v5 related works:

- UoW developed the first prototype of the MiCADO Submitter including adopting the OpenStack TOSCA Parser and Validator, elaborating the Mapper, implementing the Docker Adaptor and integrating them into MiCADO v5.
- UoW and SZTAKI specified, then SZTAKI implemented a new dashboard including three pages (Docker Visualizer, Prometheus, Grafana) initially.

- SZTAKI has designed and implemented a Scalability Decision Maker microservice called Policy Keeper. Policy Keeper is able to scale virtual machines and containers through Occopus and Swarm based on the information gathered by Prometheus.
- SZTAKI implemented a new Ansible playbook for MiCADO to make deployment easier and more recoverable in case of errors.
- UoW started working on a translation library which is intended to translate from the MiCADO v4 JSON format into the MiCADO v5 TOSCA format to support seamless integration between MiCADO v4 and v5
- SZTAKI investigated the possibility to execute jobs with CQueue. Several experiments have been investigated, policies were elaborated.
- SZTAKI created a maintained (together with UoW) a github organisation called "micado-scale" Each component and all necessary materials are stored under sub-repositories.
- SZTAKI created and managed a slack organisation to support quick and efficient communication among partners in WP6.

The results of this task has been described in details and reported in deliverable D6.3.

Achievements and results of WP6

T6.1 Development of the cloud deployment orchestrator service M01-M06

- Architecture of the orchestration layer in the MiCADO platform has been defined
- Three versions with several sub-versions of the MiCADO platform (MiCADO v0, v1 and v2) have been developed, tested and released focusing on cloud orchestration and container orchestration
- MiCADO v3 has been developed focusing on integrating monitoring/alerting system.
- New Occopus version has been developed to improve support for the CloudBroker platform and the CloudSigma cloud

T6.2 Development of the Measurement and Metrics Collection microservice M03-M09

- Deployment and scalability policy for the MiCADO platform has been specified
- Measurement and Metrics Collection microservice has been implemented using Prometheus

T6.3 Development of the first version of the Scalability Decision Maker microservice M10-M18

- Design specification on scalability for job execution has been elaborated
- First design of the queue management solution has been designed and implemented in MiCADO v4 to support deadline-based job execution
- Scalability Decision Maker component has been implemented.
- MiCADO v5 has been implemented to support the entire life-cycle of an application. It contains all components that has been designed for the MiCADO framework including cloud orchestration, container orchestration, monitoring, automatic scaling, TOSCA based topology and policy descriptors, submission engine and visualisation by dashboard.
- Deployment with Ansible playbook, Github repositories and Slack communication have been applied
- Possible alternatives for implementing price/performance optimisation has been investigated

WP6 Deliverables submitted

Three deliverables have been submitted before the deadline and D6.3 a few days later than the deadline:

- D6.1 "Prototype and documentation of the cloud deployment orchestrator service" M06
- D6.2 "Prototype and documentation of the monitoring service" M09
- D6.3 "Prototype and documentation of the scalability decision service" M18

WP6 Milestones achieved

Three milestones have been achieved as planned in DoW:

- MS6.1 "Running prototype of the cloud deployment orchestrator service" M06

- MS6.2 "Running prototype of the monitoring service" M09
- MS6.3 "Running prototype of the of the scalability decision service" M18

Meeting WP6 objectives

O6.1 To develop a cloud deployment orchestrator service by which the application templates can be deployed in the most simple and user-friendly way (typically by one click) in various types of cloud and multicloud systems.

After the architecture of MiCADO framework has been designed, cloud orchestrator tools have been investigated and evaluated. Occopus as cloud orchestrator has been integrated with the framework to implement the first version of MiCADO (v0 and v1). Occopus supports various cloud and multi cloud deployment of applications. In the next step, container orchestrator tools have been also investigated and evaluated and finally, Docker Swarm has been selected. In the next MiCADO versions (v2-v3), Docker Swarm has been integrated to perform the container orchestration for MiCADO. The results towards this objective has been described in details in deliverable D6.1.

O6.2 To develop the monitoring microservice by which the status and health of the application services can continuously be monitored.

Several monitoring systems have been investigated and evaluated. As a result, Prometheus monitoring system has been selected and integrated to the MiCADO framework to provide a flexible, extendable monitoring microservice which is able to monitor various parameters of the hosts and the application by different exporters. The results towards this objective have been described in details in deliverable D6.2.

O6.3 To develop the scalability decision service by which MiCADO can decide based on the monitoring information if application services should scaled up or down.

The scalability decision service has been successfully realised with implementing the Policy Keeper microservice and integrating it to the MiCADO framework. Policy Keeper is able to continuously evaluate a user submitted scaling policy containing the list of monitoring parameters and the scalability rules to define when the application services should be scaled up or down. The results towards this objective has been described in details in deliverable D6.3.

1.2.7 WP7 - Security, privacy and trust at the level of cloud applications

Overview of activities in WP7

T7.1 Specification of security requirements M01-M04

Task Leader SICS Participants: UoW, Balabit, SZTAKI

SICS collected, formulated, analysed and described the security-related COLA use cases identified by other project partners. SICS described the threat analysis; subsequently, in collaboration with UoW, SICS described a use case and security requirements classification. Finally, SICS compiled the template for deliverable, incorporated all inputs and edited the deliverable.

Balabit provided inputs on the real-life security issues of cloud usage as well as the current trends of cloud adoption of enterprises and SMEs. It also contributed in the definition of high-level description of the main security components from the product perspective.

UoW described the process that WP7 adopted in order to collect the security requirements of COLA use cases. UoW and SICS provided a high-level description of the main security components. They identified core security requirements and created a prioritization table based on the opinion of use-case partners. Finally, UoW internally reviewed the deliverable before sending it for a final review. **SZTAKI** has attended the WP7 teleconferences and contributed to the specification with its expertise on the MiCADO architecture.

T7.2 Security architecture design M05-M10

Task Leader SICS Participants: UoW, Balabit, SZTAKI

SICS led the WP7 and participated in all activities related to task T7.2 and implicitly in the final deliverable D7.2. In particular, SICS conducted a pre-study of related work on cloud orchestrator security in a broader perspective and described the threat landscape and regulatory aspects of cloud orchestration. **SICS** and **UoW** formulated the security architecture of COLA. This included selecting and describing the security components of COLA (Crypto Engine, Credential Manager, Image Verifier and the Integrity Attestation Authority). Furthermore, SICS conducted a traceability analysis of the requirements and their implementation in the security architecture. **SICS** actively managed the completion of the final deliverable, D7.1: collected the inputs of the task partners, compiled the final document and addressed reviewer comments in all inter-partner review rounds.

UoW extracted some valuable insights on Cloud security by studying related work on Cloud Orchestration security. UoW and SICS selected and described all the security components that will be part of COLA (Crypto Engine, Credential Manager, Image Verifier and the TTP that will be responsible for the remote attestation). We also described the functionality and the algorithms that the aforementioned security components will run to protect the COLA use cases. **SZTAKI** has contributed to the Security Architecture Design with its expertise on the MiCADO architecture. SZTAKI has attended the teleconferences and visited Balabit to design the security architecture in details. SZTAKI has also reviewed the deliverable and helped in finalising the document.

Balabit had several technical meetings with **SZTAKI** on the MiCADO framework to plan the security architecture according to the D7.1 and to find the best way to implement its product into this framework. As a result, it identified the key issues that need to be solved with its products. Balabit also contributed in the description of the overall security architecture.

T7.3 Design of application level security classification formats and principles M10-M18

Task Leader UoW Participants: SICS

UoW analysed the messages exchanged between different components of the MiCADO framework. This analysis revealed several attacks that can be carried out by a malicious adversary. This comprehensive list of flaws will be addressed in T7.5 to pave the way to secure the communication between the different components that will be part of the final architecture.

SICS contributed to identifying the capabilities of the TOSCA policy language for formulating security policies and communicating them among the cloud orchestration components. SICS has produced the open specifications for the Image Integrity Verifier and the Crypto Engine, as well as contributed to deliverable D7.3 with two Open Specifications and edited the content in the document. **SZTAKI** has co-reviewed deliverable D7.3 and helped in finalising the document

BalaSys made several meetings with SICS and UoW to discuss the MiCADO security architecture and to plan the functional interactions of the identified security components according to the D7.2. As a result, it described the functional requirements that need to be implemented in T7.5. BalaSys also reviewed the description of the components to be implemented by SICS and UoW.

T7.4 Security policy formats specification M10-M18

Task Leader UoW Participants: SICS, Balasys

UoW defined the security enforcement in MiCADO and classified security features into basic (mandatory) and advanced (optional). They described how basic features fit the underlying infrastructure and illustrated a tentative overall component interaction to deploy security features. UoW described business logic of two sets of security features: application security features and infrastructure security features. This research was presented in Deliverable 7.4.

SICS contributed to defining the security policy format specifications for the roles and security features in the MiCADO framework, application security feature settings in the TOSCA template, and the security enforcement flow. Finally, SICS extensively edited the document and addressed the comments of the reviewers.

BalaSys had several meetings with WP5-WP7 partners to discuss the services the MiCADO security architecture should provide to end users and how to describe the above functionality using security policies compliant to the TOSCA descriptor format. As a result, the open specification of network security policies has been completed with an example on how to describe it in TOSCA format.

T7.5 Design and implementations of security modules M16-M28

Task Leader UoW Participants: SICS, Balasys

SICS participated in all activities related to task T7.5. In particular, they initiated work on two security enablers for MiCADO: image integrity verifier and crypto engine. The initial work included detailing the design specification of the enablers and preparing the development and test environments.

UoW is exploring the open-source options to implement security components defined in T7.4 and will report the results in Deliverable 7.5. Based on this investigation UoW started implementing the Credential Manager security enabler and submitted the source code into the common GitHub repository MiCADO-scale. Furthermore, UoW created automated tests for Credential Manager component using the Robot framework.

BalaSys has collaborated with UoW and SICS on creating an implementation plan. They implemented the basic firewalling capabilities for the MiCADO master node and integrated it to the toolchain used by other WPs for deployment. BalaSys provided assistance to other task participants on implementation details.

SZTAKI has worked jointly with Balasys and UoW on the design and implementation of security modules in MiCADO and revised the solutions to ensure compatibility with the MiCADO framework.

Achievements and results of WP7

T7.1 Specification of security requirements M01-M04

- Security requirements of the COLA use cases have been collected;
- Threat analysis based on the assets, use cases and threats identified by project partners.
- Main security components identified for implementation and high level functionality described;
- Main security components were amended by the product perspective;
- Collaboration with use-case partners in order to identify the most important assets in their organization;

T7.2 Security architecture design M05-M10

- Security components required in COLA use cases were identified;
- Functionality of security components was defined and described;
- Architecture of the security components has been developed;
- Traceability of security requirements in the security architecture specification.
- COLA security architecture specified and described.

T7.3 Design of application level security classification formats and principles M10-M18

- Analysis of capabilities of the TOSCA policy language for security policies within the orchestration system.
- Analysis of the messages exchanged between the MiCADO components;
- Existing flaws identified and created a concrete list of attacks.
- Defined and described functional requirements of security components, Interaction of security and other MiCADO components, as well as security workflows supporting the above mechanisms;
- Open Specification for the COLA security enablers has been defined

T7.4 Security policy formats specification M10-M18

- COLA security classification and security policy formats and principles developed, specified and documented
- Application security feature settings in the TOSCA template specified
- Security enforcement flow in COLA defined

T7.5 Design and implementations of security modules M16-M28

- Detailed definition of the security enabler design
- Preparation of the test and development environment for module development
- Credential Manager integrated to the MiCADO framework
- Docker packaging and initial provisioning of a firewall through Ansible on MiCADO master node deployment has been developed;
- Basic application level fw for master node (no authentication) has been completed and submitted as a GitHub pull request to the micado-scale repository (integration pending)

WP7 Deliverables submitted

Four deliverables have been submitted before the deadline:

- D7.1 "COLA security requirements" M04
- D7.2 "MiCADO security architecture specification" M10
- D7.3 "MiCADO application security classification specification" M18
- D7.4 "MiCADO security policy formats specification" M18

WP7 Milestones achieved

Three milestones have been achieved as planned in DoW:

- MS7.1 "Security architecture requirements gathered and documented M04
- MS7.2 "Security architecture specified M10
- MS7.3 COLA security classification and security policy formats and principles developed, specified and documented M18

Meeting WP7 objectives

O7.1 To collect the security requirements of the COLA use cases and define how they affect the MiCADO framework.

Contributors to WP7 have conducted extensive requirements elicitation interviews with the COLA use case partners and thoroughly analysed the architecture of MiCADO. This resulted in an extensive set of security requirements a use case and security requirements classification. This was further complemented with a threat model of the MiCADO framework. The threat model, along security requirements addressing various aspects of the MiCADO security model were documented and reported in D7.1

O7.2 Create a novel security architecture for MiCADO, allowing efficient and secure deployment of arbitrary applications as well as advanced security policy management and enforcement on orchestration level.

The results documented in D7.1, along with a further extensive analysis of the security landscape of cloud orchestration as well as a review of the existing set of regulatory frameworks for cloud data handling were used as a basis for defining the novel security architecture for MiCADO. This was complemented by a review of the MiCADO security architecture principles and considerations, a set of security enablers and finally a security architecture implementation for MiCADO, traceable to the collected MiCADO security requirements. The results were document and reported in D7.2.

O7.3 To develop security application and data classification principles and formats.

Based on the analysis of the core components of MiCADO and their data security requirements, as well as the earlier defined threat model, a set of attack vectors highly relevant for MiCADO was decribed. The attack vectors were mitigated through a set of security enablers described in the format of open specifications. For each security enabler the open specifications included information on main interactions, architectural drivers, test plan and reutilized technologies. The results were document and reported in D7.3.

O7.4 To design security application domain policy formats based on existing suitable standards.

A review of the roles and security features of MiCADO has been performed. Based on this review, on the state of the art in cloud orchestration security and on the existing standards, MiCADO security feature settings were defined. These included security features for the initial infrastructure deployment and for the subsequent

application deployment based on the TOSCA policy template. Furthermore, a flow for the enforcement of the MiCADO security features has been defined. The results were document and reported in D7.4.

1.2.8 WP8 - SME and public sector use-case pilots and demonstrators

Overview of activities in WP8

T8.1 Business and technical requirements collection M01-M04

Task Leader: UBRUN Participants: Inycom, Sarga, Saker, The Audience Agency, Outlandish, CloudSME

In Task 8.1 technology providers, ISVs and end-users have collected business, usability and technical requirements to take as much advantage as possible of the functionalities of the MiCADO framework in the implementation of the use case pilots. Thus, a set of requirements and expectations from application developers and end users have been compiled in deliverable D8.1 to be considered in the development of the MiCADO framework and on how the demonstration applications will use it. Individual contributions from the different partners involved in this task are compiled next.

Inycom, as the WP Leader, organized the Application Task Force and ran webex conferences with all the WP participants to follow up the work, share experiences and prevent/solve outstanding issues. **UBRUN** led this task.

SARGA has worked with Inycom on the definition and search of data related to the pilot experiment for the Regional Government of Aragon. They also investigated the employability of the data to be used in the pilot case. Sarga in cooperation with the Government of Aragon and its different departments to defined the use case for its developers. **Inycom** contributed to "D8.1 Business and technical requirements of COLA use-cases" preparing business and technical requirements for the Social Media data mining use case they have with the Regional Government of Aragon. The WP5-WP7 will consider these requirements to design and implement the MICADO framework.

Saker completed of the COLA Requirements Questionnaire for Deliverable 8.1. They created a 'conceptual model' defining the requirements for an evacuation model. Saker elaborated the functional specification or bursting from SakerGrid onto the Cloud. They reviewed of evacuation conceptual model internally within Saker and the functional specification within Saker. **UBRUN** contributed to the collection of the evacuation use case's requirements.

The Audience Agency (TAA) discussed infrastructure requirements and scope of project with Outlandish, specifically in relation to Audience Finder (AF), based on current barriers and performance. They contributed to the development of Attendance Analytics Service (AAS) They liaised with Outlandish to determine feasibility, TAA provided summary report for next steps with senior management feedback for sign off. They ran presentations and workshops for feedback (methodology of metrics & outputs, tool requirements for staff and output requirements for clients) from The Audience Agency consultancy teams. TAA was involved in development of Insight for Touring Organisations (ITO); liaised with Outlandish to determine feasibility. **Outlandish** captured the infrastructure requirements of the established Audience Finder (AF) application, and ran brainstorming sessions to establish the requirements for the less well established TAA applications (Attendance Analysis Service, Insights for Touring Organisations). They looked beyond the specifics of the TAA use case to understand a developer's requirements for a cloud orchestration service. We presented our findings to the rest of COLA project team. Outlandish compiled all the previous information about the use case with The Audience Finder and the developer's cloud orchestration service in a template to be included in D8.1.

CloudSME UG has collected business, usability and technical requirements for a use case with two German companies to deploy Typo3 (a Content Management Server) in MICADO. Those requirements have been included in deliverable D8.1.

UBRUN produced deliverable D8.1 (Business and technical requirements of COLA use-cases) with the contribution of use case partners.

T8.2 Customisation and further development of applications M03-M15

Task Leader: Inycom Participants: UBRUN, Sarga, Saker, The Audience Agency, Outlandish, ST, CB, UoW, SZTAKI

The task utilises the outcomes of T8.1 and also the specification of MiCADO services from WP5-WP7. Based on this input, T8.2 is porting the applications to the Cloud (that in T.8.3 will be further extended with MiCADO services and API calls). The volume and nature of this development and customisation is rather different from use case to use case based on the readiness of the application. **Inycom** led this task and was supported by the partners from the three use cases. MiCADO and platform provider partners provide technical advice and support.

Inycom liased WP8 with framework development WPs, particularly attending the fortnight Technology Task Force teleconferences. Inycom developers were trained in containers technology (Docker). They prepared a cloud instance in the CloudSigma cloud, deployed the Magician application (the one provided by Inycom for Social Media data mining Spanish use case) for customization and successfully tested it. They defined the architecture for the SARGA use case based on the MICADO platform. They also designed an interface to display Magician results. Inycom developers deployed and tested MICADO v3 in CloudSigma. They also prepared and successfully tested a Docker container with the Magician semantic processor in CloudSigma cloud. Inycom also cooperated with WP5 to create the TOSCA based application templates of the SARGA use case. Finally, they in cooperation with SARGA finalized the design of the Magician use case based on public information collected by Magician to be developed in T8.3. **SARGA** worked together with Inycom to customize the Magician social data mining application to ensure its usability in the pilot case for the Aragon public administration. They evolved some applications used by the Regional Government to align them with the use case and studied the current Aragón Government IT applications to embed the results of the use case.

UBRUN contributed to customisation and further development of the MiCADO framework according to evacuation use case requirements. Specifically, a requirement for the evacuation use case using simulation is to be able to run parameter sweep applications. To do so, an open source simulation software is used as a test software to develop auto-scaling functionality for parameter sweep applications. **SAKER** developed a platform to facilitate developing simulation models in version 17 so that they are compatible with the existing SakerGrid platform. They elaborated an evacuation simulation model (demonstrated in detail at the meeting in Cracow 25-28/09/17). This was written in FlexSim 17 and featured a fictitious evacuation of the central area in the city of Worcester, UK. It contains thousands of agents that evacuate the city on foot and by car. The model is full data driven and links to a Simulation Manager front-end. Saker also developed a plug-in module for the Simulation Manager application for use with the FlexSim evacuation model. This plug-in is the user interface that enables a user to construct scenarios by editing a series of parameters. It also presents the results from the evacuation model in graphical and tabular formats. They elaborated a SQL Server database to store all of the parameters and results pertaining to the simulation model. The Simulation Manager plug-in is the interface that enables this data to be viewed / edited. Saker also reviewed the Microsoft Docker application for the purpose of containerising FlexSim to run on MiCADO. Investigation of other technologies, including Wine, to enable Windows applications to be run in Linux.

The Audience Agency TAA liaised with Outlandish in relation to *Audience Finder* (AF), based on current barriers and performance. They contributed to the development of *Attendance Analytics Service* (AAS) and liaised with Outlandish to determine feasibility They extracted data from AF, statistical analysis of AF data, set up of metrics and scripts. TAA designed system architecture and reviewed likelihood of compatibility with MiCADO, They also designed the metrics database and created scripts to calculate metrics and summary statistics. TAA was involved in development of *Insight for Touring Organisations* (ITO); liaised with Outlandish to determine feasibility, create scripts querying AF and populating the staging DB, discuss implications of changes with relevant suppliers. **Outlandish** ran an Internal training and research into dockerisation technologies and techniques. They defined standard Docker templates for Outlandish projects. Further they analysed the performance of the Audience Finder data processing to understand where the bottlenecks are and how best to leverage cloud infrastructure to futureproof the application against future growth. Outlandish applied Docker templates to the Audience Finder application. They completed a detailed review of an early release of MiCADO. Outlandish tackled first, the challenge of dockerised applications interacting with large databases second, the challenge of persistent databases within the development lifecycle. They investigated existing cloud orchestration services and implemented an OpenShift cluster, integrated with Outlandish's Gitlab CI. Outlandish has run a series of engagement and training

sessions with the Outlandish dev teams to help disseminate Docker/Cloud technologies developed by the Outlandish COLA team across all projects. They deployed the "full stack" (Docker and OpenShift) with one significant Outlandish project. This makes it leading proof of concept for a fully cloudified development lifecycle. They started development of a starter project for simple WordPress websites that will allow quick-and-easy deployment of WordPress website on Outlandish tech. Finally, they added support for copying and syncing database content and media files between environments using a command line interface to allow changes to content to be shared between environments.

CloudSME UG has contributed to Task 8.2 liaising the external companies developing the Typo3 use case with the COLA partners, specially providing technical and management support. They also deployed and tested MiCADO components.

CloudBroker studied and analysed the use cases description collected by WP8 in D8.1. This was needed to proceed with the WP3 work on commercial sustainability of the use cases. Some information provided by the partners in T8.1 was taken by CloudBroker for D3.1 "First commercial exploitation and sustainability report" since the information was valuable in terms of partner and use case description. It also helped to better understand the business models of the use cases.

SZTAKI and **UoW** has given support for the development of application and testing of MiCADO for the use cases owned by InyCom, CloudSME and SAKER during the period.

Inycom coordinated the writing of "D8.2 Customisation and further development of software applications", contributing specifically to prepare the section dedicated to the Social Media Data Mining use case that Inycom and the Regional Government of Aragon provide to the project. All partners involved in T8.2 contributed to D8.2. SZTAKI reviewed D8.2 and finalized it Inycom.

T8.3 Development of near to operational level pilots and demonstrators M13-M30

Task Leader: Inycom
Participants: UBRUN, Sarga, Saker, The Audience Agency, Outlandish, ST, CB, UoW, SZTAKI
Task 8.3 is still on-going and will finalise by the end of the project in June 2019. Individual contributions from the different partners involved in this task are compiled next:

Inycom provided a Magician docker container, docker swarm file and support to UoW WP5 team. As a result, UoW has been able to describe this application and run the container through MiCADO Submitter and MiCADO Policy Keeper to support autoscaling depending on TOSCA parameters. They have been integrating other data sources for recommendation (electronic administration procedures and institutional web sites) to develop Regional Government of Aragon use case. Inycom has developed a pilot test case allow the Regional Government of Aragon to make recommendation with a simple web interface.

UBRUN has contributed to development of near to operational level pilots and demonstrators using MiCADO services for the targeted use cases and provided feedback based on usability, security and cost/performance ratio of the targeted use cases to further improve the MiCADO framework, respectively. To this end, a demonstrator of the parameter sweep extension of MiCADO has been developed and tests have been conducted in order to study cost/performance and usability. This use case does not have security requirements since it is intended to run in a private cloud. **Saker** had several meetings with project partners to understand the best way to update SakerGrid to support MiCADO. As a result of these meetings first, they identified a technology to replace the Windows file shares used by SakerGrid. Second, they developed a design for enhancing/redeveloping SakerGrid to make it compatible with VMs / Cloud. Third, they updated the Simulation Manager to support Flexsim 17 and Flexsim 18, of SakerGrid to support Flexsim 17 and 18 and of the SakerGrid client service to a web API. They also developed FlexSim 18 templates to run on SakerGrid / Cloud and a module to create a DLL for a FlexSim to reference a database hosted on the Cloud. Saker tested the DLL on a VM and Cloud.

Outlandish identified key areas of research in order to speed up the Caching Process for the Audience Finder application. They ran performance testing against different database infrastructure comparing the speed of the Audience Finder Boxoffice data caching process. Compared the performance between a vertically scaled database setup and horizontally scaled database setup and developed further plans for implementation of both scenarios. They identified cost-cutting possibilities to Audience Finder by moving some larger, data-heavy databases onto separate database server so that they can be scaled separately to the database required for the web application. Investigated task and identified key areas of risk to work. Outlandish added a Job Queue to the Audience Finder application for the purpose of managing the caching process. This job queue defines the data needing to be recached as a series of jobs that can be run by the caching process. They also elaborated a plan that has been put in place to develop the job queue to support a horizontally-scaled worker architecture that could be run on Micado v4 to provide scaleable caching to meet the demand of new data. Outlandish updated the Audience Finder application in order for it to run on custom-built docker images using docker-compose v3 template files. They also developed custom scripts to make using Audience Finder on docker better for developers, including: syncing Audience Finder content between environments to allow us to deploy to those environments with the same content that the production environment has; two custom docker images to run the application in a docker environment. These images are built automatically on every change to the application and stored in a private docker registry; customer node.js based wrapper for docker-compose to make some complicated docker-compose commands easier to manage for developers - such as running test frameworks - within the docker environment and identified key risks with moving media files for Audience Finder onto AWS S3 infrastructure for better support for MICADO. Investigation to mitigate risks to appear in next phase of work. **The Audience Agency** provided support to Outlandish in their work researching and testing speed and efficiency improvements to the weekly data caching process in Audience Finder. The Audience Agency also developed a new data access and import procedure for the Show Stats application in Audience Finder which addresses some of the infrastructure challenges identified in dialogue with Outlandish in WP8.1, by building an optimised, indexed view of the Audience Finder data warehouse views required to run the application which is better able to support the development of the *Attendance Analytics Service (AAS)* application and the *Insight for Touring Organisations (ITO)* application – these new views negate the requirement of the applications to directly query the Audience Finder data warehouse in order to access the required data, by instead having the data output to flat files in Amazon S3 buckets. The Audience Agency also started the development and scoping of the scripts and templates which will create the reporting outputs which are drawn from the metrics databases for AAS and ITO

UoW has supported Saker Solutions when designing the integration of SakerGrid with the MiCADO architecture. UoW, together with SZTAKI, proposed and elaborated possible integration approaches and supported Saker solutions with practical investigation regarding the execution of the Flexim simulator on virtual machines. They also collaborated with Inycom to run the Magician application on MiCADO V3 and MiCADO V5. UoW created the TOSCA description of the application and conducted the tests when porting Magician to MiCADO.

T8.4 Proof of concept feasibility studies M18-M30

Task Leader: UBRUN

Participants: Saker, Inycom, Outlandish, CloudSME UG, SZTAKI

The task has just started in the last month of the first reporting period and will finalise by the end of the project in June 2019. Individual contributions from the different partners involved in this task are compiled next:

UBRUN, as task leader, has briefed the consortium on how this task will be carried out and the responsibilities of each involved partner.

Inycom had several internal meetings how to start looking for the new use cases that could benefit from COLA technology.

SZTAKI has performed customisation of the Data Avenue software in order to make it fully operational under MiCADO. SZTAKI has significantly further developed Data Avenue in the topic of user interface, swift storage support and performance.

Outlandish ran a series of engagement and training sessions with the Outlandish dev teams to help disseminate Docker/Cloud technologies developed by the Outlandish COLA team across all projects. All Outlandish devs have now got Docker installed on their machines with a plan for future projects to use docker wherever possible. They started development of a starter project for simple WordPress websites, that will allow quick-and-easy deployment of WordPress website on Outlandish tech. This starter project is now part of 4 live projects and ensures that our knowledge and skills base is growing as we increase the number of client projects that use this infrastructure. They have developed further understanding of our additional use cases by carrying out multiple interviews with other similar companies and understanding their ideal requirements both as hosting provider and as a hosting consumer.

UoW supported UBRUN to collaborate with Trumcreate using the job submission mode the of MiCADO framework. Trumcreate is one of the five proof of concept case-studies provided by Brunel University and Saker Solutions to demonstrate the feasibility of MiCADO. Trumcreate are developing a driverless car. They use CityMoS simulation software package to simulate car traffic. The current implementation is executed locally using the dockerized application. We proposed multiple application architecture to run this simulation on the MiCADO framework. UoW in cooperation with Brunel University also tested how to run different simulation models built in the Repast agent-based simulation package using the job submission mode of the MiCADO framework (MiCADO V4). UoW deployed another server in order to use Brunel and Westminster accounts on CloudSigma together to have more resources to run the experiments.

CloudSME UG is working on the proof-of-concept Data Avenue running user and GUI Testing of Data Avenue prototypes and iterating Data Avenue proof-of-concepts use-case

Achievements and results of WP8

T8.1 Business and technical requirements collection M01-M04

- requirements analysis of the COLA use cases helped to get a better understanding of use case for partners participating in those use cases and partners not directly involved in the use cases, to consider these reuqirements in the development of MICADO components and business models.
- management structure for WP8 and collaboration with other WPs has been set up and organized by Inycom.

T8.2 Customisation and further development of applications M03-M15

- developers working on COLA use cases have trained how to use Docker containers
- partners customized the applications to be dockerized and used with MICADO.
- demo versions of the different applications were already demonstrated in the Krakow project meeting in late September 2017.
- additional feedback (more detailed than in D8.1) has been provided about use case requirements WP3 and WP4-WP7
- MICADO v2, v3 and v4 have been deployed and tested by the use case partners to prepare the deployment and execution of the use cases applications over 2018.
- technology partners provided efficient support to use case partners on application customization for the MiCADO framework, particularly TOSCA templates have been prepared for the use cases and supporting upport parameter sweep applications and applications using Windows (Flexim, Repast) has been done in MiCADO
- T8.2 organized a workshop for developers of the COLA use cases in London in January 2018.
- T8.2 created some dissemination materials that have been facilitated to WP2
- "D8.2 Customisation and further development of software applications" has been generated during the period describing the modifications done in the 3 use cases applications and some testings with other applications (Repast) to enable their integration in Task 8.3 with MiCADO framework. Requirements provided in D8.1 have been refined and extended for their consideration in Technical WPs.

T8.3 Development of near to operational level pilots and demonstrators M13-M30

- A demonstrator application with MiCADO parameter sweep functionality has been developed with Repast application and experiments for obtaining cost/performance results have been conducted.

- Flexim simulation tool used in Evacuation modelling use case has been deployed to the MiCADO framework and test simulations have been run using the job submission framework of the MiCADO.
- Development of changes to SakerGrid modifications to externalise database and replace file shares complete, to be used in Evacuation modelling use case.
- Magician application used in Social Media data mining use case has been successfully deployed on MiCADO V3 and the on the current MiCADO V5 prototype.
- There is already a simple pilot of the recommendation use case for Regional Government of Aragon using Magician.
- WordPress (used in The Audience Finder application) database and uploads folder synced between environments when bringing a local development environment up, allowing developers to start work on the project straight away.
- The Audience Finder application has been dockerised and deployed to two docker-hosting environments - Micado and OpenShift.

T8.4 Proof of concept feasibility studies M18-M30

- UoW and Brunel deployed Repast simulation software to the MiCADO framework and test simulations.
- SZTAKI and CloudSME UG have done a first description and updated requirements a proof-of-concept with MiCADO using Data Avenue application to transfer files.
- CloudSME UG has been working with prospective customers to use Typo3 Opensource CMS with MiCADO.
- Outlandish and Inycom have had internal meetings and presentation with customers identifying a couple of new use cases each already

WP8 Deliverables submitted

Two deliverables have been submitted before the deadline:

- D8.1 “Business and technical requirements of COLA use-cases” M04
- D8.2 “Customisation and further development of software applications” M15

WP8 Milestones achieved

Two milestones have been achieved as planned in DoW:

- MS8.1 Requirements from the use-cases collected M04
- MS8.2 Use cases software applications available on COLA platform M15

Meeting WP8 objectives

Objective 8.1: To collect requirements on how technology providers/ISVs and end-users in public sector and SMEs expect to use the MiCADO framework.

At the beginning of the project, Task 8.1 helped to achieve Objective 8.1 collecting from the use cases a list of requirements at different levels (business, functional, security…) which were compiled in deliverable D8.1 in Month 4. These requirements were used by technical work packages as a target for MiCADO implementation, so Objective 8.1 can be considered as completed.

Objective 8.2: To customise and further develop applications of targeted public sector and SME use cases considering the MiCADO specific requirements.

Task 8.2, already finished, has helped to achieve Objective 8.2 through the development and/or customization of the 3 applications provided by the software vendors to be used in the use cases by the public sector organizations and SMEs. With the help of the technical work packages experts, software vendors’ developers have learnt how to adapt their applications to the MiCADO framework and implemented it, and have provided feedback on how their applications work to find out the best way to integrate them with MiCADO. The three applications have been already made compatible with MiCADO fulfilling Objective 8.2.

Objective 8.3: To develop near to operational level pilots and demonstrators using MiCADO services for the targeted use cases.

In Task 8.3, the use case partners have started to integrate the applications implemented in Task 8.2 with the MiCADO versions released by the technology work packages, helping to achieve Objective 8.3. As described in Task 8.3 implementation and achievements, there are already some applications already integrated at some level working with MiCADO.

Objective 8.4: To provide feedback based on usability, security and cost/performance ratio of the targeted use cases to further improve the MiCADO framework.

Additionally to the list of requirements initially collected in deliverable D8.1 by Task 8.1 to fulfil Objective 8.1, during the implementation of the use cases applications and proof of concepts in WP8, additional requirements and feedback is going to be collected both from developers and from applications' users.

Specifically, in deliverable D8.2 generated in Task 8.2, this initial list of requirements compiled when the project started has been refined and extended based on the experience acquired by the use cases participants customizing their applications, helping to achieve Objective 8.4.

Finally, the fortnight teleconferences to follow up WP8 implementation also help to share feedback from developers and end users to the technical experts developing and improving MiCADO framework.

Objective 8.5: To investigate the feasibility of 20 additional use-case scenarios based on the MiCADO framework for public sector and SME customers of the COLA software providers.

Objective 8.5 is addressed by Task 8.4, which has started recently, although as reported in Section 1.3 of this document some of the additional use cases have been already identified, and in three of them even implementation has started (Repast, Data Avenue, Typo3).

1.2.9 WP9 – Ethics requirements

Overview of activities in WP9

T9.1 Specification of ethics requirements for the COLA project M01-M04

This task was responsible for setting out the 'ethics requirements' that the project must comply with. The work was based on the ethics review that was conducted by experts appointed by the European Commission, and that highlighted potential ethical issues that the project must take care of.

The Ethical review of the COLA project raised two areas where ethical issues need to be considered and addressed:

- Protection of personal data
- Involvement of humans

In order to address these issues, WP9 Ethics requirements had to produce two deliverables:

D9.1 addresses POPD – Requirement No. 1 regarding identification/recruitment of research participants. The document describes the procedures and criteria when identifying and recruiting human research participants, and provides detailed information regarding the applied informed consent procedures and forms. The involvement of human research participants in the COLA project is restricted to participation in surveys and filling in questionnaires. These surveys, collecting market information and user/customer feedback help evaluating the efficiency of the COLA results. The data in these questionnaires does not include any sensitive personal information and will only be utilised in aggregated and anonymised format to support market analysis. Individual participants will not be able to be identified from the published information. All participants are provided with Participant Information Sheets and need to agree to Informed Consent Forms before participating in the surveys.

D9.2 addresses POPD – Requirement No. 2 regarding the collection and/or processing of personal data The document analyses the COLA use-cases and the COLA user community feedback process with regards to collecting and processing of personal data. In cases where personal data need to be collected, procedures that a implemented for data collection, storage, protection, retention and destruction will be provided. Moreover, confirmation that these processes comply with national and EU legislation will be given. The document also provides description of informed consent procedures including templates for

informed consent forms and information sheets. Finally, in case the data used are not confirmed to be publicly available, the necessary authorisation procedures are detailed. Ethical issues related to the protection of personal data are potentially raised by the core COLA use-cases: Inycom/Sarga, Outlandish/Audience Agency, and Saker/Brunel use-cases. Besides the implementation use-case demonstrators, the COLA project will also collect user and community feedback from humans in WP2 task T2.4 "Collecting community feedback" that can also potentially raise ethical issues related to the protection of personal data. This deliverable analyses the three COLA use-cases and the community feedback process with regards to the collection, storage and handling of personal information.

The task also set up the Ethical Advisory Committee (EAC) that is responsible for continuous monitoring and execution of the policies set out in the two deliverables. The EAC is chaired by Tamas Kiss from UoW as Work Package Leader and Project Coordinator, and includes Andreas Ocklenburg from CloudSME UG and Marcos Rubio from Inycom as members.

Achievements and results of WP9

WP9 Deliverables submitted

Two deliverables have been submitted before the deadline with the content explained above::

- D9.1 "POPD Requirements No.1" M04
- D9.2 "POPD Requirements No.2" M04

Meeting WP9 objectives

Objective 9.1: To ensure compliance with ethics requirements in the COLA project.

WP9 has analysed and defined the appropriate procedures how the COLA project can assure compliance with ethics requirements. The two ethical aspects that were raised during the evaluation of the project (involvement of research participants and handling of personal data) were analysed in case of both the COLA use-cases and also the collection of community feedback. Guidelines and recommendations how the project should deal with these issues were defined in the two deliverables of the work package. Finally, the EAC monitored and assured the execution and necessary review of these guidelines.

1.3 Impacts

Even if most of the indicators are expected to be delivered at M30 and impacts to be generated by M30 and over,COLA has made a significant progress both in creating the MiCADO framework and deploying and running applications in the Cloud. We are summarizing progress made in COLA towards the expected impacts in M01-M18 in Table 1.3.1-1.3.6.

Expected Impact 1:	**Increase Europe's technological capacity and competitiveness through the development of advanced cloud solutions.**
Contribution by the COLA Project	The COLA project will significantly **enhance the state of the art in cloud technologies** by developing a generic framework to support cloud application developers when utilising the dynamic elastic capabilities of underlying heterogeneous distributed IaaS cloud solutions. The project will demonstrate via relevant industry case-studies how **Europe's technological capacity and competitiveness will be increased** in key areas as a result of the MiCADO framework. The project case-studies will cover four distinct application areas (manufacturing companies, web application developer companies, local authorities, and evacuation planning) that are widely relevant to a large number of SMEs and public sector organisations. Although the case-studies will be implemented for COLA project partners directly, their relevance for other similar organisations in the same sector will also be highlighted. Furthermore, the project will elaborate additional potential application areas where a large number of SMEs and public sector organisations will be targeted with focused marketing and dissemination campaign (for details please see Section 2.2). Moreover, as the reference implementation of the MiCADO framework will be open-source, it will be easily available and accessible for the larger developer community.

Indicator Target	Number of impact case studies on how Europe's technological capacity and competitiveness will be increased in key areas. 4 impact case studies (for the four targeted areas) to be published by the end of the project (M30). For detailed measures regarding the impact of each case-study please see section 2.2.1.
Achieved by M18	COLA designed and implemented the MiCADO framework to deploy and execute existing non-cloud aware applications in IaaS Clouds using their dynamic capabilities on demand focusing on the orchestration layer. By M18 WP5-WP7 created 4 releases (v0-v3), 1 (v4) is under development and another (v5) is in the pre-release phase. The framework can be connected to multiple cloud middleware (e.g. EC2, CloudSigma, OpenStack, OpenNebula, etc.) and generic cloud access layers (e.g. CloudBroker Platform) to avoid dependence on one particular cloud technology. It is based on existing low-level cloud container technologies (e.g. Docker, Swarm, etc.), management and orchestration solutions (e.g. Occopus), and existing standards (e.g. TOSCA). The MiCADO framework is a generic pluggable, technology agnostic and open source framework. It enhanced the state of the art in cloud technologies supporting flexible and optimal deployment and run-time orchestration of applications in the Cloud. Running application in the Cloud in some application areas, such as public sector organizations and Small- and Medium-sized Enterprises (SME), is still relatively low due to limited application-level flexibility and shortages in cloud specific skills. MiCADO accelerates take up of cloud computing in these areas addressing application- and infrastructure-level complexity. It allows Application Developers to describe their applications in TOSCA and upload these descriptions into a publicly available repository. Application Developers and End Users can download these descriptions and submit them to the MiCADO framework that deploys and runs the applications in the Cloud. WP8 created prototypes of 3 COLA use case applications (use case 1: audience finder application – Outlandish + The Audience Agency; use case 2: evacuation planning- Saker + Brunel University; and use case 3: improving services for citizens based on analysis of public databases and social media data - Inycom + SARGA) and 1 proof of concept application (efficient and fast data transfer among different type of distributed storages using Data Avenue – CloudSME UG + SZTAKI) by M18.

Table 1.3.1 - Contribution to impact 1 set out in the work programme

Expected impact 2:	**Increased and predictable performance of cloud offerings, facilitating deployment of critical applications and services.**
Contribution by the COLA Project	The COLA project, based on existing technologies, tools and standards, will develop a generic framework that will enable cloud applications to fully utilise the dynamic and elastic capabilities of underlying IaaS clouds. As a result, the **performance** of these applications can be **optimised** taking both **execution/response time** and also **economic cost and viability** into consideration. Application developers and operators will be able to set quality of service, security, performance and economic requirements towards applications that will be monitored and the deployment will automatically adopt in case of any violation. Moreover, operators can review and modify these pre-set requirements any time. As a result of this optimised price/performance ratio, cloud applications will be more feasible and attractive for SMEs. Moreover, mission critical applications by public sector organisations, such as local authorities and the evacuation of public places, will be efficiently and reliably run on cloud computing infrastructures.
Indicator Target	Performance benchmarking and analysis of production quality near operation level demonstrators. **4** performance benchmarking experiments and their subsequent analysis to be published by M30. (3 from the demonstrators and 1 from the proof of concepts).

Achieved by M18	Public sector organisations and SMEs want to run applications in the Cloud in a cost-efficient, flexible, seamless and secure way. See requirements of COLA use case applications presented in D8.1. To meet these requirements COLA selected and extended TOSCA to describe applications. Since the MiCADO framework runs applications in containers deployed in virtual machines WP5 elaborated the Application Description Template (ADT) to manage two-level topologies of containers and virtual machines and QoS properties as policies. The work package extended the TOSCA Policy Specification by security policy and scaling sub-policies. The Advanced Consumption Based and the Consumption Based Constrained Policy describes how to scale up and down applications considering costs, execution and response time. The Security Policy contains authentication, authorisation firewalls and secret data management sub-policies to specify QoS properties to make application deployment and execution secure. In MiCADO v5 the MiCADO Submitter forwards the parsed and processed application descriptions to the MiCADO Policy Keeper that guarantees cost, performance and execution QoS properties specified in the policies. The next MiCADO version will be extended with the Security Enforcer that will guarantee security QoS properties. WP5 and WP8 specified 3 COLA use case applications in TOSCA and uploaded these application descriptions to a GitHub repository. Use case owners deployed and ran the evacuation simulation and the public services for citizens application in the Cloud submitting the TOSCA descriptions to the MiCADO framework. The use case test results proved that the new scaling policies can assure the expected cost, performance and execution parameters.

Table 1.3.2 - Contribution to impact 2 set out in the work programme

Expected Impact 3:	**Increased trust in clouds through stronger security and data protection practices, including open and auditable solutions for data security. Increased control by users of their data and trust relations.**
Contribution by the COLA Project	The COLA project will work with novel principles for security policy enforcement using the MiCADO framework. This includes principles for verification of cloud resources such as computing nodes *prior-to* deployment of applications in cloud infrastructures as well as transparent (from end-user point of view) encryption of data at rest on cloud storage resources. This implies a **thoroughly auditable and open solution** with high level of data protection when execution of arbitrary applications is taking place in open cloud environments. Even though similar approaches have been developed in previous research projects, they have not yet been integrated into production-ready cloud orchestration SW – a gap that COLA project aims to cover. Furthermore, various applications have different requirements with respect to data protection and cloud resource verification. To address this, we plan to develop a security enforcement module that will interpret novel formats and principles regarding application security specifications. This will help application domain security to express cloud execution and data protection requirements to cloud development. Consequently, this enables data owners to exercise **direct control** of the trust and protection level of the applications executing in a heterogeneous cloud infrastructure. Finally, automation of security services will both optimize the overall infrastructure in an organization and allow security administrators to focus on more proactive tasks. As a result, the solid security controls to be offered by COLA will have a significant impact on the deployment of trusted distributed architectures.
Indicator Target	Detailed security analysis of implemented COLA case-studies to showcase the achieved increased trust by stronger security and data protection practices, and control by users of their data and trust relations. **4** security analysis case-studies (3 from the demonstrators and 1 from the proof of concepts) to be published by M30.

Achieved by M18	COLA identified the security requirements of the COLA use case and one proof of concept application in D7.1 report. The description of these security requirements will be further extended into security case studies considering lessons learnt from running these applications through the MiCADO framework by M30. Having the security requirements of COLA applications WP7 analyzed the security landscape in cloud orchestration, identified the prospective security threats in the MiCADO framework, developed the required security model and defined the security architecture for the MiCADO framework to deliver the security services required by public sector organisations' and SMEs' applications. The key component of the security architecture is the MiCADO Security Enforcer that manages security enablers that guarantee meeting security requirements specified in security sub-policies. WP7 designed the MiCADO Security Enforcer and started its implementation and integration with the MiCADO framework.

Table 1.3.3 - Contribution to impact 3 set out in the work programme

Expected Impact 4:	**Experimentation across a variety of settings that enhance Quality of Experience and contribute to standardisation and interoperability. Integration with other international initiatives for large-scale global experimentation.**
Contribution by the COLA Project	The MiCADO concept plays a very similar role in cloud computing as to MPI (Message Passing Interface) played in parallel computing on supercomputers. MPI provides a high level API that can be added to the business logic of parallel applications without changing their business logic. This resulted in a very successful and revolutionary change in the development and spread of parallel computing applications. Beyond that application development became much simpler than it was before it also made parallel applications highly portable among different kind of parallel computers. At the end MPI became an accepted standard and all supercomputing vendors implemented the MPI API in an optimized way to achieve the highest possible performance of MPI applications on their supercomputers. The goal of MiCADO is very similar to MPI. We would like to define a high level API that can be added to the business logic of applications without changing their business logic in order to enable their execution on various cloud systems in a portable and efficient way. If the MiCADO concept is successful it can lead to a similar **standardization process** that was used for the MPI concept. As a consequence MiCADO's impact could be much higher than simply providing usable cloud solutions for several industrial and public sector applications. In a long term it can revolutionise how to create portable and efficient cloud applications with minimal development effort. From the cloud **interoperability** point of view it will also have significant impact showing that from the usability and scalability points of view the most important aspect is to access as many cloud resources as needed without changing the business logic of the application, without deep learning of cloud technology, and without forcing existing clouds to intercommunicate to each other and exchange tasks and jobs. There is a significant difference between the MPI and MiCADO concepts. MPI has never targeted scalability and the ability to run the same parallel application simultaneously on several supercomputers in a dynamic and scalable way. However, in case of clouds this is the most important objective and since it requires the simultaneous access of several clouds it has to be able to handle the different security mechanisms of the various cloud systems. This issue can be solved at two levels: standardizing the security mechanisms of the various cloud systems or hiding the difference of these security mechanisms at a higher level layer like the MiCADO layer. In this project we will follow the second approach but as a result we will be experts of understanding the differences and similarities of the different security approaches and hence members of the COLA project can significantly **contribute to future standardization efforts** of cloud security mechanisms.
Indicator	Large scale experimentation via a set of proof of concept case studies that will demonstrate the applicability and advantages of the MiCADO framework in wide variety of application areas.

Target	**20** proof of concept experiments to be implemented by M30.
Achieved by M18	The MiCADO concept manages applications as black boxes. First, Application Developers create either container or virtual machine images of the application and upload these images to a repository. Next, they describe the application topology and policies using the standard. Finally, they submit the application description to the MiCADO framework that deploys and runs the application. None of these steps require modification of the application itself. Since the MiCADO framework is technology agnostic the MiCADO API must be able to manage different cloud and container orchestrators, policy submitters and enforcers. Gaining experience with the MiCADO API in handling different services that deliver the same functionality COLA can contribute to **standardisation** in cloud orchestration. WP5 extended the TOSCA Policy Specification and defined the TOSCA Policy Template. This research can contribute to TOSCA standardisation efforts. Since one of the design guidelines of the MiCADO framework was technology agnosticism micro-services can be replaced by other micro-services of the same functionality. This design guideline enables **interoperability** of micro-services. In M19-M30 COLA, particularly WP7, will investigate how interoperability can be achieved in security services. WP8 identified 11 applications (See details on objective 2 in section 1.1) that cover wide range of applications areas as prospective MiCADO demonstrators. The work package will analyse these applications as proof of concept demonstrators in M19-M30.

Table 1.3.4 - Contribution to impact 4 set out in the work programme

Expected Impact 5:	**Increased readiness for adoption of trustworthy cloud-based solutions for SMEs and public sector organisations, spanning from generic enabling services to specific applications.**
Contribution by the COLA Project	The COLA project will develop and demonstrate **production or near production quality services both at the level of generic enabling services and also specific applications**. The MiCADO framework and its reference implementation will consist of a set of open-source services that application developers can utilise to make their cloud applications more adaptive. MiCADO will address both the dynamic scalability of these applications and also the application of suitable security solutions to enable trustworthy cloud solutions. MiCADO services will **generically enable a wide range of applications** to utilise clouds in a more secure and efficient way. In order to demonstrate the applicability of such generic enabling services, the COLA project will design and implement **large scale demonstrators in close to operational settings involving both SMEs and public sector organisations**. The demonstrators will showcase how specific applications can be developed on top of the MiCADO framework and will illustrate what benefits SMEs and public sector organisations can gain when utilising the framework in their applications.
Indicator Target	Number of SME and public sectors demonstrators implemented and disseminated to illustrate increased readiness for adoption of trustworthy cloud-based solutions. **3** near operational and **20** further proof of concept SME and public sector demonstrators are implemented and widely disseminated by M30.
Achieved by M18	COLA developed the MiCADO framework as a generic cloud enabler service. The framework is open source and technology agnostic built on open source solutions, for example Docker Swarm, Occopus and Prometheus, and standard such as, TOSCA. The latest version of the framework, MiCADO v5, can process TOSCA based application descriptions, deploy and execute the applications on multiple clouds through the CloudBroker Platform. This version is able to scale up and down applications in the cloud based on their cost, execution and

	performance requirements. The next versions will enforce security requirements specified in TOSCA security policies using the MiCADO Security Enforcer. WP8 created the proof of concept implementation of COLA use case applications using MiCADO by M18. These applications cover a wide range of applications from evacuation simulation and improving citizen services (public service application) to audience finder (SME application). These implementations will be used as demonstrators to promote the MiCADO framework among public sector organisations and SMEs until the near- or full-production level implementation of COLA use case applications have been available.

Table 1.3.5- Contribution to impact 5 set out in the work programme

Expected Impact 6:	**Demonstration, through appropriate use cases, of the potential to improve the competitive position of the European cloud sector and to facilitate the emergence of innovative business.**
Contribution by the COLA Project	The COLA project has **carefully selected** its **use-cases** in order to demonstrate potential application areas of the developed technology that have large impact and wide coverage. The application areas are represented by appropriate project partners. However, each of the use-cases is relevant and important for a wider sector of SMEs and/or public sector organisations, and not only for the actual project partners. These specific sectors, including manufacturing SMEs, web developer companies, local authorities and evacuation planners, will be specifically targeted by dissemination and marketing campaigns. As a results, European companies can use European cutting edge technology, in the above four sectors and beyond, to **improve their competitive position via offering innovative cloud based services and solutions**.
Indicator Target	Near operational level and proof of concept demonstrators of real-life industry use-cases. **3** near operational and **20** further proof of concept SME and public sector demonstrators are implemented and widely disseminated by M30.
Achieved by M18	WP8 created prototypes of 3 COLA use case applications (use case 1: audience finder application – Outlandish + The Audience Agency; use case 2: evacuation planning- Saker + Brunel University; and use case 3: improving services for citizens based on analysis of public databases and social media data - Inycom + SARGA) and 1 proof of concept application (efficient and fast data transfer among different type of distributed storages using Data Avenue – CloudSME UG + SZTAKI) by M18. These applications will be extended near operational level or operational level in M19-M30. COLA partners identified further 11 applications that can be considered to be deployed and executed through the MiCADO framework in the Cloud.

Table 1.3.6 - Contribution to impact 6 set out in the work programme