EUROPEAN COMMISSION
Research Executive Agency
Marie Curie Actions – Networks for Initial Training

Project No: 607584

Project Acronym: CleanSky

Project Full Name: Network for Cloud Computing Eco-System

Marie Curie Actions

Periodic Report

Period covered: from 01/09/2016 **to** 31/08/2018

Period number: 2nd

Project coordinator name:
Prof. Xiaoming Fu

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Project coordinator organisation name:
GEORG-AUGUST-UNIVERSITAET GOETTINGEN STIFTUNG OEFFENTLICHEN RECHTS

Periodic Report

PROJECT PERIODIC REPORT

Grant Agreement number:	607584
Project acronym:	CleanSky
Project title:	Network for Cloud Computing Eco-System
Funding Scheme:	FP7-MC-ITN
Periodic report:	2
Period covered - start date:	01/09/2016
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Project co-ordinator:

Organisation PIC:	999845640
Organisation legal name:	GEORG-AUGUST-UNIVERSITAET GOET TINGEN STIFTUNG OEFFENTLICHEN RECHTS

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DECLARATION BY THE PROJECT COORDINATOR

I, Prof. Xiaoming Fu, as co-ordinator of the project (607584, CleanSky), hereby confirm that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;

- The project has fully achieved its objectives and technical goals for the period;

- The project Website is up to date.

- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project and if ap plicable with the certificate on financial statement.

- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, re search organisations and SMEs, have declared to have verified their legal status. Any changes have been repor ted under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

PUBLISHABLE SUMMARY

Comments:

As a paradigm for information technology (IT), cloud computing is “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” Cloud computing is evolving and supported not only in small data centers but also over large scale, energy-efficient new computing in frastructures. Example scenarios of large-scale cloud computing include scientific computing and telecommunication services, where big data and traffic are generated and need to be processed in a cost-efficient manner.
CleanSky ITN (http://www.cleansky-itn.org/) aims to develop innovative ideas in the emerging areas within the “eco-system” of cloud computing: data center evolution, consolidation and service migra tion, and beyond, via structural training of young researchers. To achieve this goal, a unique combin ation of academic institutions and industrial organizations will collaborate together and create a mul tidisciplinary (computer science, telecommunications, scientific computing and optimization theory), international (four European countries plus USA and China) and intersectoral (public and private; education and industry) environment to embed a pool of young researchers for innovative research in cloud computing.
The specific objectives of CleanSky are to develop innovative methodologies and approaches to satis fy application requirements and ensure efficiency within the emerging cloud computing paradigm and to optimize the energy and provisioning costs of individual data centers. In particular, Cleansky aims at improving the network infrastructure that supports the cloud eco-system, where in Software Defined Networking (SDN) and Network Function Virtualization (NFV), two new paradigms have a big impact on efficiency and resource provisioning, especially in data centers and cloud environ ments.

In the second half of the project, Cleansky fellows have been working and collaborating on new net working cloud relevant technologies such as edge and optical cloud networks, network function virtu alization and microservices. They have proposed solutions that deal with data management, balan cing multiple objectives, renewable energy based deployment, energy-aware provisioning, long-term energy efficient storage, energy efficient network path usage of edge resources, root cause analysis, the development of a mathematical model that jointly considers multiple factors. More specifically, we have the following key contributions:
1) Managing Data in Computational Edge Clouds: Edge clouds are becoming an important architec tural element in networks. We argue that existing solutions are not sufficient for efficient data man agement at the edge and propose a solution.
2) Balancing Multiple Objectives for NFV Resource Allocation: In NFV resource allocation, we look at the problem of optimizing the resource management of NF service chains.
3) Resource Management Framework for NFV-based Service Function Chaining: We consider a vari ety of design choices for the framework and through evaluation and experiments verify the perform ance of our framework and show that our semi-distributed approach outperforms the other candid ates.
4) Efficient Dynamic Service Function Chaining: Dynamic service function chaining investigates merging of SDN and NFV for the purpose of managing service function chains.
5) Renewable Energy Based Deployment of Virtual Network Functions: We investigate the reduc tions in energy use by optimizing VNF placement according to the availability of renewable energy.
6) Dynamic Backpressure and Scheduling for NFV Service Chains: We developed an NFV manage ment framework that provides fair and efficient resource allocations to service chains. The design

centers on assisted pre-emptive scheduling where network functions provide hints to the OS regard ing their utilization. The paper was published at the ACM SIGCOMM 2017 conference.
7) Energy-Aware Provisioning in Optical Cloud Networks: We focused on reducing energy use of optical networks in the cloud.
8) On the topic of optimizing resource utilization of complex services the improved RConfPD allows for fast decisions (in many cases <1ms), while maintaining RConf's solution quality. Based on the optimization scheme, pricing schemes have been studied in RAERA and ERM.
9) Regarding long-term storage of gene sequencing we designed a reliability-aware VM/data storage scheme, developed a latency sensitive data placement strategy and an energy-aware provisioning paradigm for optical cloud networks.
10) Extending the work on Edge-Fog Cloud, we explored energy and efficient network path usage of edge resources, as well as crowdsourced sharing and SFC deployment in Edge Clouds.
11) On the topic of service availability and disaster recovery we developed
SENATUS, a joint traffic anomaly detection and root cause analysis approach, and explored options for deploying network functions as microservices.
12) The research into robust cloud services and management started with an analysis of service fail ures which yielded that five-nines service availability is not yet in reach. In order to reach this goal we develop a mathematical model that jointly considers dynamic network service composition strategies, scalable network function placement and carrier grade redundancy.

These results have been published in top conferences such as ACM SIGCOMM, ACM CONEXT, Cloudnet and top journals such as Transactions on Service and Network Management and LNCS Springer.

As an initial training network, CleanSky also aims at providing excellent training to the twelve fel lows that contributed to the research described above. In this regard, Cleansky has organized the final summer school at Tsingua University, Beijing, China in September 2017. Along with this summer school, we also co-organized a workshop on transferable research skills. The summer school and workshop was open to external students and attracted close to 40 students and also included a visit to a startup incubator company. We also organized two conferences in Goettingen (March 2017) and Helsinki (March 2018). These conferences were also open to external members and also had talks from external speakers. CleanSky has also actively disseminated the results via publications, talks at conferences/workshops as well as poster sessions on the sidelines of the conferences and summer schools organized by Cleansky.

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