Middleware for Multicloud

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As cloud computing evolved to a widely used computing as a service model, limitations of single cloud provider offerings emerged. Moreover, specialized computing power such as clusters, graphics processing units, solid state storage, and specific applications at different service levels can now be acquired as services from different providers, at different prices, and with different characteristics and application programming interfaces (APIs).

The use of a combination of cloud services from various providers can be utilized to address the limitations of a single provider and enable richer applications that can combine services and on demand resources from different providers. Multicloud Middleware has a central role in providing a combination of resources and services from different cloud providers by enabling a distributed system platform that can efficiently coordinate them.

Multicloud management brings challenges that the middleware must resolve in a transparent manner, ideally, to both the application and the developer. Combining heterogeneous resources from different administrative domains; providing interoperability including managing data locality and latency; incentivizing resource sharing; implementing easy-to-use authentication and authorization mechanisms; analyzing and combining a variety of billing models at different service levels, and yet offering a good performance-cost compromise, are among the challenges to be solved by a Multicloud middleware.

Although standardization for Multicloud is under development, many questions still remain to be answered if the vision of fully transparent integration between cloud providers is to be achieved. This issue is exacerbated when the middleware also needs to integrate in-house platforms, solutions, resources, specialized hardware, and legacy applications to the full solution, and suddenly a multitude of new needs emerge that makes difficult the development of Multicloud middleware.

The recent emergence of edge computing, where distributed clouds can offer services closer to the users, will potentially increase the amount of cloud data centers that can be combined in a Multicloud to fulfill application requirements. In such a scenario, mechanisms to provide a more dynamic infrastructure to cope with requirements of mobile users that generate and consume data at the edge are necessary, including the dynamic association of clouds to provide elastic services according to a mobile and variable demand. Network performance becomes a primary issue.

The fact that Multiclouds will cross different administrative domains underscores the need for federation management. Identity and authorization must be properly enforced across a Multicloud middleware to be useable in the real world. Users of a Multicloud may come from different organizations and present different types of identity credentials. This will require federated identity management on the “front-end”. Multiclouds will potentially integrate many different types of resources—from virtualized hardware resources to application-level services. This will require federated resource management on the backend. For real-world adoption and deployment, this must include secure resource discovery, accounting, and auditing.

From all the above discussion, it can be seen that new challenges are emerging that need to be addressed by Multicloud middleware, while some of the basic issues are still to be satisfactorily solved. What constitute cloud resources and services are a moving target: from the provider’s side, more types of hardware and services at different abstraction levels are supported every day; from the consumer’s side, particular needs that require unique solutions to enable Multicloud integration emerge as popularity of clouds grows. As a result, the requirements of Multicloud middleware are likely to continue constantly changing, and more challenges will emerge that need to be tackled by the research community.

This special issue contributes to the advancement of the area of Multicloud middleware by presenting concrete solutions and ongoing efforts to address different aspects of Multicloud middleware development and operation discussed so far. We present five papers that cover different aspects of Multicloud middleware, from authorization to support for edge computing. They provide a broad picture of recent developments in the area and help in identifying remaining challenges to be addressed by the research community, industry, and standardization initiatives.
Summary of the Contributions
The contributions selected for this special issue tackle fundamental problems concerning Multicloud middleware. Submitted papers went through a rigorous review process, with a round of at least three reviews plus guest-editors’ metareviews. Decisions were made over the metareviews and a second round of careful reviews, which resulted in the following contributions.

Carrega, Repetto, Gouvas, and Zafeiropoulos: "A Middleware for Mobile Edge Computing". The authors describe and prototype a system for the development, deployment, orchestration, and lifecycle management of distributed applications over cross-domain infrastructures, such as edge computing platforms. ARCADIA, the utilized framework, provides support to orchestration over multiple virtual heterogeneous infrastructures, as for example in the combination of geographically-distributed sites and legacy cloud infrastructures.

Sette, Chadwick, and Ferraz: "Authorization Policy Federation in Heterogeneous Multicloud Environments". This contribution addresses the authorization problem in federated cloud environments. The proposed solution, named Authorization Policy Federation, aims at managing heterogeneous cloud accounts through a shared centralized policy based on a cloud-independent ontology. This allows the translation of policies back-and-forth between local cloud formats and the utilized Disjunctive Normal Form. The proposal is validated through a prototype that shows a high level of semantic equivalence.

Chard, Chard, Wolski, Madduri, Bubendorfer, and Foster: "Cost-Aware Cloud Profiling, Prediction, and Provisioning as a Service". Three crucial tasks for multicloud decision-making are addressed in this paper, namely application profiling, prediction of market conditions, and infrastructure provisioning. Considering these three aspects, the authors propose SCRMIP—Scalable Cost-Aware Cloud Infrastructure Management and Provisioning, which is able to reduce costs and improve performance of applications execution by performing the above tasks and automatically provisioning according to user-defined policies and real-time conditions.

Foschini, Acquaviva, Bellavista, Bosi, Corradi, Monti, and Sabbioni: "NoMISHAP: A Novel Middleware Support for High Availability in Multicloud PaaS". Multicloud infrastructures can be managed at different service levels. In this paper, the authors describe a middleware at the PaaS level to support highly available services in multiple clouds. The proposed middleware, NoMISHAP, enables software developers to integrate equivalent services from different cloud vendors to avoid lock-in and also to increase application resilience. The authors evaluate NoMISHAP with three different PaaS platforms, showing it is possible to achieve multi-PaaS high availability with a limited overhead.

Costa, Ramos, and Correia: "On the Design of Resilient Multicloud MapReduce". With similar objectives to the paper above, this contribution focuses on integrating multiple clouds to increase resilience and availability. The authors describe replication and scheduling techniques for MapReduce to achieve higher resilience without compromising performance. The proposed techniques can be deployed using traditional MapReduce solutions without modifications.

References

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RODRIGO N. CALHEIROS is a lecturer in the School of Computing, Engineering and Mathematics at the Western Sydney University, Australia. He has been conducting research in the area of Cloud computing since 2008, and contributed to diverse aspects in the field including Multiclouds, energy-efficient cloud computing, and efficient scheduling of diverse application models in cloud resources. He is also one of the original designers and developers of CloudSim, a widely used simulator of Cloud environments. He
CRAIG A. LEE is a senior scientist at The Aerospace Corporation, a nonprofit, federally funded R&D center. Dr. Lee has worked in parallel and distributed computing for 35 years. He has conducted DARPA and NSF sponsored research in the areas of grid computing, optimistic models of computation, active networks, and distributed simulations, in collaboration with USC, UCLA, Caltech, Argonne National Lab, the College of William and Mary, and others. Dr. Lee served as the president of the Open Grid Forum (OGF) from 2007 to 2010. During this time OGF produced the Open Cloud Computing Interface (OCCI), an open standard API for infrastructure clouds, which is now on the DoD Information Technology Standards Registry (DISR). He contributed to the NIST US Government Cloud Computing Technology Roadmap, and currently contributes to NIST efforts in cloud federation. Dr. Lee is on the steering committee for the ACM/IEEE International Conference on Utility and Cloud Computing (UCC) and the ACM/IEEE International Symposium on Cluster, Cloud and Grid Computing (CCGrid). He has served on the program committee for many other conferences and workshops, and has served as a panelist for the NSF, NASA, DOE, and as an international evaluator for INRIA. Dr. Lee has published over 80 technical works, and sits on the editorial boards of Future Generation Computing Systems (Elsevier) and the Journal of Cloud Computing (Inderscience). Dr. Lee holds a PhD in computer science from the University of California, Irvine. Contact him at Craig.A.Lee@aero.org.