

# Architecture Design for Management as a Service Cloud

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**Abstract**—This paper presents a novel Management-as-a-Service (MaaS) architecture which is based on cloud computing architecture and provides more scalable network management capabilities to network managers. Ontology based semantic information model which supports communications between management services described by heterogeneous information, and functional model which schedules the deployment of each management service are designed to support the cloud network management architecture by providing appropriate management information description and service deployment method. We realize a prototype of cloud network management architecture based on the MaaS model, evaluate the performance of cloud network management services and validate the functional model used in the MaaS cloud. Experiment results show that our functional model provides optimal deployment of each cloud service and the elasticity of cloud management services improve both the management efficiencies and the utilization of management resources.

**Keywords**- network management architecture; cloud computing; MaaS (Management as a Service); ontology; functional model

## I. INTRODUCTION

Network management architecture has kept evolving since the earliest standard centralized management architecture models were put forwarded. During the past 20 years, in order to meet the increasing requirements of network management, many new architectures have been proposed: to increase the scalability of the management architecture as well as to avoid the single point of failure, decentralized and distributed architectures have been proposed; to integrate as many functions as possible into the architecture, web service becomes a commonly used form to encapsulate management functions. Alongside with the development of architecture, information model is also evolved and ontology technique and semantic information models have been widely used, which benefit the autonomic network management.

In general, according to the latest researches on network management architecture [1-4], in order to achieve relatively better scalability, decentralized and distributed service-oriented

architecture has become a development tendency of organization model. However, the scalability of current network management organizational model is revealed only at management node level, and management services at service level do not reflect any scalability, which may induce the situation that although the management services are evenly distributed in the management nodes, the uneven volumes of service requests can also cause the unbalanced load of the management nodes. Therefore, not only the network management nodes but also the management services need to achieve scalability, hence the organizational model used in the network management architecture needs to be further improved.

Cloud computing architecture offers more scalable organizational models, many frameworks [5-7] have acquired better scalabilities by applying cloud computing technology in their designs, and some researchers have also proposed the idea of using cloud computing technology in network management [8]. This paper proposes a novel Management-as-a-Service (MaaS) model and designs a novel cloud network management architecture. Using cloud computing technology, the elastic management services over MaaS cloud show better scalability, which can dynamically change the management resources held by them. Ontology based management information model is also designed to enable the MaaS cloud to provide intelligent query of management information, and the functional model used in this cloud management architecture optimizes the deployment of each service over MaaS cloud, improves the management efficiency of the architecture.

The paper is organized as follows. Section II presents the architecture of the MaaS. Section III constructs an ontology-based semantic information model used in the MaaS cloud, providing intelligent queries of network management services. Section IV designs a functional model to support the cloud network management architecture by providing optimal deployment of each cloud service. Section V shows the experiments to evaluate the performance of cloud network management services and validate the functional model. Section VI concludes this paper.

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## II. CLOUD NETWORK MANAGEMENT ARCHITECTURE

Fig. 1 shows the cloud network management architecture, the whole architecture can be divided into 4 components: Service Manager, Resource Manager, Execution Manager and Communication Manager. Detailed architecture and functions of each component is designed as follows:

### A. Service Manager

In our MaaS architecture, all the network management functions are encapsulated as web services, and Service Manager provides management functions to these services, such as service publishing, service invoking, service query, etc. It works as an intermediary between the end users and network management services. All the registered management services are stored in the service repository with corresponding description files. To provide intelligent service query and interoperability of web services described using heterogeneous information, ontology based semantic information model is used, which will be further discussed in Section III. The service scheduler calculates the virtual resources used to execute a specific service, it also realizes the elasticity of services by increasing or decreasing the number of service replicas in the virtual resources beneath according to the load of the service. The elasticity of the MaaS service improves management efficiency of the cloud network management architecture and optimizes the utilizations of management resources.

### B. Resource Manager

Resource Manager manages the virtual resources used to execute a management service. The function of this component is almost the same as a controller in the traditional IaaS

(Infrastructure as a service) model. The cloud controller controls virtual machine controller to monitor physical and virtual resources, and allocates virtual resources according to the requests of the service scheduler module above and the execution results of the scheduling algorithm run in the resource scheduler module. Different kinds of virtualization technologies are supported by the virtual machine controller.

### C. Execution Manager

Execution Manager sets up specific management services on the scheduled virtual machines (VMs) and monitors the execution of each service on each virtual machine. To ensure the security of management information, the execution results, which belong to the same tenant from different virtual machines will be aggregated and stored in the Management Information Base. The end users can get the management information from the Management Information Base.

### D. Communication Manager

Interoperability is also provided by our MaaS architecture, the communication manager realizes information transmission between the management cloud and local management nodes; query information and management results are encapsulated by this module and transmitted between cloud and local management nodes. Therefore, single management node can cooperate with our MaaS architecture which enriches both their network management functions and resources. Furthermore, the other network management architectures can also exchange information with the MaaS cloud, thus the MaaS cloud can also act as a cooperation platform which benefits the construction of network management federation.

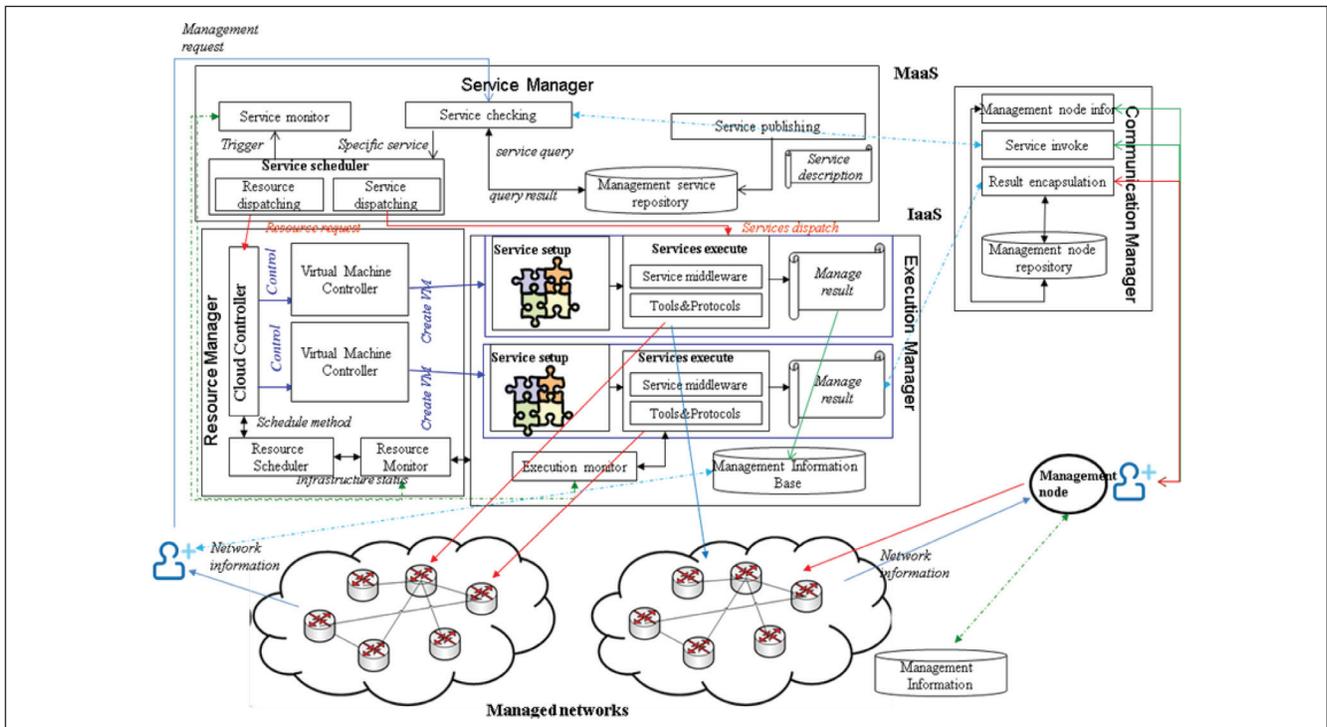


Figure 1. Cloud network management architecture

### III. INFORMATION MODEL DESIGN FOR MAAS CLOUD

The most significant goals of our information model are to provide accurate and intelligent queries of cloud services; and to strengthen the interoperability of services described by heterogeneous information. Ontology technique is a feasible method to satisfy these demands and this technique has been used in defining management information. Different with most of the existing researches [9-11] which model the management information to realize autonomic management, this paper focuses on modeling the index information of services and providing intelligent queries of services. Detailed design of this information model is shown as follows:

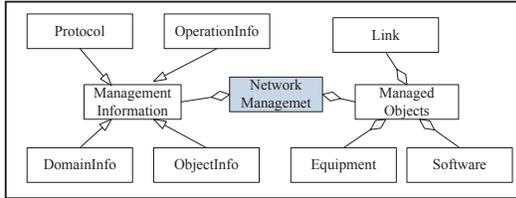


Figure 2. Top level concepts in OWL Model of Network Management

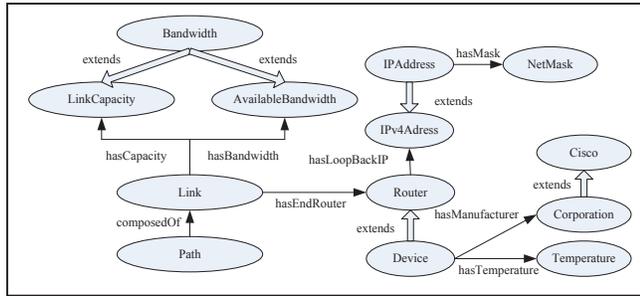


Figure 3. Relationships between some ontology concepts.

Network management elements are modeled as an OWL class, *Network Management*, which is composed of two OWL subclasses *Management Information* and *Managed Objects* representing the abstract management information and managed networks respectively. Top level concepts in the network management ontology are shown in Fig. 2. OWL class *ManagedObjects* describes all the elements in a managed network, such as hardware equipments, software and links of the network. OWL class *ManagementInformation* models all the used or produced management information when management operations are executed. Four kinds of management information have considered in our model, which are *DomainInfo*, *ObjectInfo*, *OperationInfo* and *Protocol*. Due to the page limitation, we do not introduce the subclass of each top OWL concept in detail.

Besides aggregation and derivation relationships, other relationships between different ontology concepts are also modeled. Fig. 3 shows a snapshot of some ontology concepts and the corresponding relationships between them. Based on this information model, intelligent query of network management service is realized using specific match filters and matching algorithms.

### IV. FUNCTIONAL MODEL DESIGN FOR MAAS CLOUD

The functional model of MaaS cloud is to provide optimal deployment of different network management services. Management services with different properties may be suitable for different deployment approaches, some suit to be deployed over MaaS cloud to achieve elasticity and the others may be more suitable to be deployed on local management nodes to minimize the transmission delay of service queries.

For a specific network management service  $s$ , suppose the execution efficiency of this service is  $\mu_s$ , and the arrival of service invoking requests satisfies Poisson Process with intensity  $\lambda_s$ , when the service is deployed locally, the scenario is similar to the  $M/M/1$  queuing model. However, when the service is deployed over cloud, the Service Manager component will change its elasticity according to the service load. This scenario is similar to the *MSQMS-LQ* (Multi-classes Single Queue to Multiple Servers with Local Queues) model and in our MaaS cloud, the number of replicas is increased in positive correlation with the number of requests, the execution efficiency of service  $s$  with load  $n$  can be modeled as:  $\mu_s(n) = f(n) \propto n$ . When a management service is migrated from local node to the cloud, it may suffer an additional transmission delay  $T_d$  from cloud to the managed networks compared with local management node.

TABLE I. COMPARISON RESULTS OF SOME PARAMETERS IN THE TWO MANAGEMENT SCENARIOS

Parameters	Comparison results	
	Service deployed over cloud	Local management service
Queue length not infinite	$\mu_s(n) > \lambda_s$	$\mu_s > \lambda_s$
Probability of empty queue	$\frac{\lambda_s}{e^{\mu_s}}$	$\frac{\mu_s - \lambda_s}{\mu_s}$
Average queue length	$\frac{\lambda_s}{\mu_s}$	$\frac{\lambda_s}{\mu_s - \lambda_s}$
Average response time	$\frac{1}{\mu_s} + T_d$	$\frac{1}{\mu_s - \lambda_s}$

Using the two stochastic models mentioned above, we get some QoS (Quality of Service) parameters in the two management scenarios, which are shown in Table 1. From these results, we can conclude which kind of service is more suitable to be deployed over MaaS cloud:

- Large number of service requests:  $\mu_s < \lambda_s < \mu_s(n)$
- Queue length of local services are too large
- Transmission delay between cloud and managed networks does not affect the execution efficiency obviously:

$$T_d < \frac{1}{\mu_s - \lambda_s} - \frac{1}{\mu_s} = \frac{\lambda_s}{\mu_s(\mu_s - \lambda_s)}$$

### V. EXPERIMENTS

This section introduces the environment of MaaS cloud infrastructure and presents some experiments comparing some QoS factors of cloud and local management services.

Six physical servers are used to build our MaaS cloud: Four of which has 16GB memory and 8 CPUs each, the other two has 96GB memory and 12 CPUs each. OpenStack software is used to build the IaaS platform of the MaaS cloud. Based on the IaaS platform and the architecture proposed in Section II, we realize a prototype cloud network management system, which contains 8 different management services, e.g., bandwidth measurement, loss packet measurement, etc. In this experiment, first we deploy all the 8 services on local management node, with time going on, the change trends of each service's average queue length and waiting time are shown in Fig. 4, A1 and A2. In the second scenario, we deploy all the services over cloud, the QoS factors of this scenario are shown in Fig. 4, B1 and B2. At last, we deploy the 8 services according to the calculation results of the functional model; some of these services (services 1, 2, 4 and 6) are deployed locally, and the others are deployed over cloud. The QoS factors are shown in Fig. 4, C1 and C2.

According to the experiment results, using the functional model, all the services' queue lengths are kept relatively small without loss of requests; at the same time, execution delay of each service is kept within 70 seconds (better than scenario 2), which improves the performance of the cloud network management system. The experiment results verify that the MaaS architecture can effectively improve both the management efficiencies and the utilization of management resources.

## VI. CONCLUSION

This paper proposed a novel cloud network management architecture. Cloud computing technique is used to construct the MaaS cloud, which provides various kinds of elastic network management services to the users. Using the ontology-based semantic information model, communications between services described by heterogeneous information are enabled; furthermore, intelligent queries of services are also provided. A function model is designed to optimize the deployment of management services over the MaaS cloud. Eight different management services are deployed over cloud according to the functional model, experiment results show that our functional model makes a significant improvement on the architecture's performance and as well as optimizes the utilization of management resources held by each service.

## REFERENCES

- [1] M. Zach, D. Parker, C. Fahy, et al. "Towards a framework for network management applications based on peer-to-peer paradigms," Proc *NOMS'06*, Vancouver, Canada, Apr. 2006.
- [2] K. R. Sollins, "An architecture for network management," *ReArch'09*, Rome, Italy, 2009.
- [3] T. Koponen, M. Casado, N. Gude, et al. "Onix: a distributed control platform for large-scale production networks," In Proc. of *OSDI 10*, Oct, 2010, Vancouver, Canada, pp. 351-364.
- [4] S. Latré, S. van der Meer, F. De Turck, J. Strassner, J. Won-Ki Hong, "Ontological generation of filter rules for context exchange in autonomic multimedia networks," In Proc. of *NOMS 2010*, Japan, Apr. 2010.
- [5] L. Yu, W. Tsai, X. Chen, et al. "Testing as a service over cloud," In Proceedings of *Service Oriented System Engineering (SOSE)*, 2010

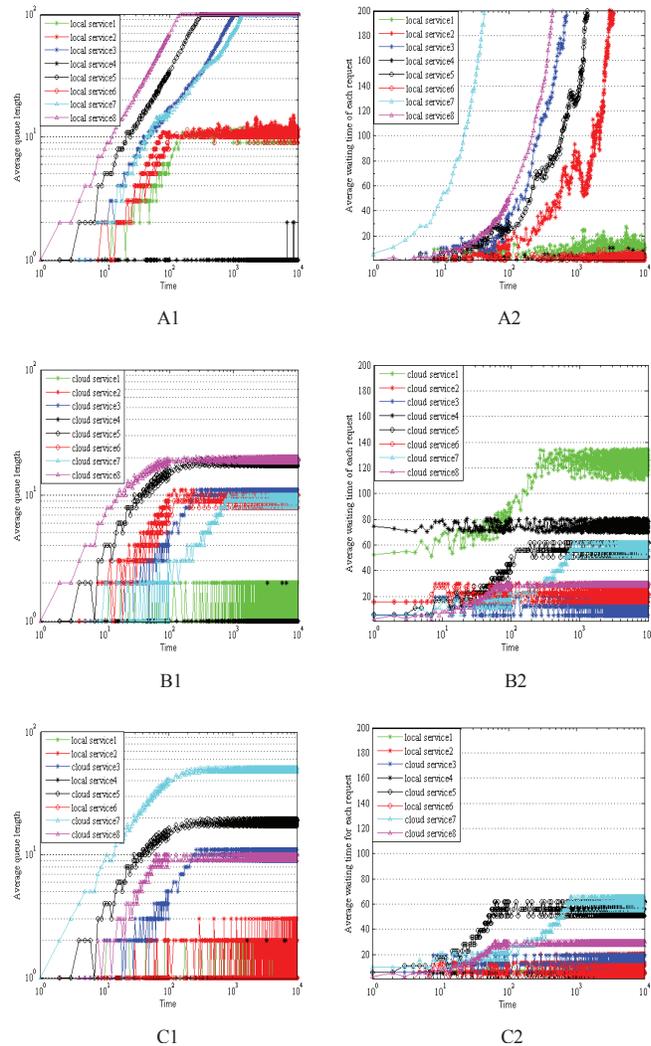


Figure 4. Performance comparison of different network management services deployed locally, over cloud and according to the functional model

- [6] Z. Huang, C. Mei, L.E. Li, and T. Woo, "CloudStream: Delivering high-quality streaming videos through a cloud-based SVC proxy," In Proceedings of *IEEE INFOCOMM* Conference, 2011
- [7] J. Mudigonda, P. Yalagandula, J. Mogul, B. Stiekes, Y. Pouffary, "Netlord: a scalable multitenant network architecture for virtualized data centers," In Proc. of the *ACM SIGCOMM'11*. New York, USA, 2011
- [8] C. Gkantsidis, H. Ballani, "Network management as a service," no. MSR-TR-2010-83, 24 June 2010
- [9] S. Latré, S. van der Meer, F. De Turck, J. Strassner, J. Won-Ki Hong, "Ontological generation of filter rules for context exchange in autonomic multimedia networks," In Proc. of *NOMS 2010*, Japan, Apr. 2010.
- [10] J. Keeney, C. Stevens, D. O'Sullivan, "Extending a knowledge-based network to support temporal event reasoning," Proc. *NOMS 2010*, Japan, Apr. 2010
- [11] J. Strassner, J. N. Souza, S. van der Meer, et al. "The design of a new policy model to support ontology-driven reasoning for autonomic networking," *J. Netw. Syst. Manage.*, vol. 17, no. 1-2, pp. 5-32, 2009