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Virtualization and Resource Sharing in Optical Clouds using IP-over-WDM Networks with Quality of Service Requirements

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Abstract: *Virtualization is an essential concept which plays a major role in Cloud computing for resource sharing on the global internet. This paper proposes the optical cloud virtualization platform (OCVP), as the mediation layer which provides Network as a service (NaaS) to cloud computing by exploiting the functionality provided by optical control plane (CP) enabled IP-over-WDM networks. The optical CVP adopts a different approach that may be called undirected signalling to the optical CP. In fact, an application requests end-to-end network services in terms of end user addresses and perceived QoS parameters such as throughput, transfer delay, blocking probability and the average load share, to the service elements controlling the edge node of the transport network serving its access networks without any knowledge of the transport network infrastructure. The simulation of optical CP on optical CVP shows that the performance of optical cloud is good in terms of end-to-end delay and related QoS parameters.*

Keywords*:* WDM Optical, Virtualization, Resource sharing.

INTRODUCTION

Cloud computing is a novel paradigm to share resources over the Internet. It is based on the concept of resource virtualization, which enables a transparent access to information and Communication Technology (ICT) services such that the users do not need to know the location and characteristics of the relevant resources. Grid and Cloud Computing [1] models pursue the same objective of constructing large-scale distributed infrastructures, although focusing on complementary aspects. While grid focuses on federating resources and fostering collaboration, cloud focuses on flexibility and on-demand provisioning of virtualized resources. Virtualization provides the ability to run legacy applications on older operating systems, and faster job migration within different virtual machines running on the same hardware. From the security point of view, since virtual machines run isolated in their sandboxes, this provides an additional protection against malicious or faulty codes. Clouds provide access to inexpensive hardware and storage resources through very simple APIs, and are based on a pay-per-use model, so that renting these resources is usually much cheaper than acquiring dedicated new ones. Moreover, people are becoming comfortable with storing their data remotely in a cloud environment. Therefore, scientists are increasingly using clouds, small and medium sized enterprises, and casual users [2], [3].

The rest of this paper is organized as follows. Section II reviews the literature available and section III describes the problem statement with emphasis on QoS requirements. Section IV describes the layered architecture of the proposed system, its approach, design methodology. Section V discusses the implementation and analysis of results obtained. Section VI summarizes our contributions and discusses our future plans.

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Related work

Cloud computing [1] is a model generally defined as the clusters of scalable and virtualized resources like distributed computers, storage, system software, etc which makes use of internet to provide on-demand services to the user. The National Institute of Standards and Technology (NIST) has described as, " Cloud computing is a model for enabling convenient, on demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics: on demand self service, broad network access, resource pooling, rapid elasticity and measured service."

In cloud computing model, user requires the internet-enabled devices like desktop, smart phone, etc to access the cloud computing services. The service provider is required to maintain various computers, servers, data storage system and high-speed network, etc to provide the computing service. The essential characteristics of clouds are: flexibility, virtualization, scalability, pay-per-use model, and SLAs [1]. The flexibility refers to the easy access to, and the deployment and configuration of the resources used. Scalability is also one of the main drivers for cloud a deployment, exploiting a pay-as-you-grow approach, which leads to cost-effective deployment as well as success of cloud computing .Virtualization, allow the cloud service providers to operate cost-effectively, avoiding over provisioning. This virtualization is a key difference that clouds bring to the table, compared to grids. Virtualization allows them to share resources in a secure manner, facilitating to respect the performance SLAs agreed with their users. Virtualization furthermore enables migration to other servers, both for performance and resilience against failures. Virtualization is the concept exists in WDM optical networks [2] for provisioning and sharing of resources in a logical way as well as for topology reconfiguration. Also, monitoring in clouds is quite challenging, whereas grids [3] apply a different trust model where users, via identity delegation, can access and browse resources at various sites that contain resources. In grids, these resources are typically not that much neither abstracted nor virtualized. The essential characteristics of cloud are described below.

On demand self-service - A customer can access or use the cloud computing services as and when needed without any help or interaction with the cloud services provider. Easy to use intuitive interface enables him to select services as per requirement. The web-based email is an example.

Virtualization- It is an important characteristic of the cloud. User accesses the computing services without being aware about the complexity of the infrastructure. Virtual resources are assigned to the services and need not to be bound to one physical resource. Moving virtual resources from one physical to another does not affect the user.

Access from anywhere - Cloud computing is a network based service. This makes accessibility to the cloud services location independent. The only prerequisite is the use of standard internet enabled devices like low cost desktop computers, mobile handsets etc at client side with high speed network.

Resource pooling- The availability of uninterrupted quality services at customer site requires good planning and resource management by the service provider. In cloud computing, resources are pooled to accomplish the demand of all the consumers using a multi- tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. Consumers use the resources like storage, processing, memory, network bandwidth, and virtual machines as per their need.

Rapid elasticity- A consumer can purchase computing power and other available services as per need without worrying about investing in additional resources at site. The service provider on the other hand can monitor the usage of its resources in a dynamically changing scenario. Additional resources can be added or arranged in case of increase in demand and similarity, scaled down or leased to third party when not in use.

Measures services- the usage of cloud computing services is measurable. Based on usage, cloud services are controlled and metered per client on daily, weekly, monthly and annual basis. The service provider uses this measurement for billing, resource optimization, capacity planning and other task. In terms of architectures, the many attempts ([4,5,6]) to classify various cloud paradigms seem to converge to a layered architecture with "everything as a service" (XaaS) taxonomy, comprising the following layers.

Software as a Service (SaaS): This layer provides on demand use of application software running on cloud infrastructure. It comprises all applications that run on the cloud and provide a direct service to the cloud user. This layer can be further subdivided according to the application level offered. On top, we have the actual *Applications* which are basically the final service offered to an end user. Clearly, they can be composed of. a service-oriented approach of lower level services [4] and *Composite Application Services.*

Platform as a Service (PaaS): Computational resources via a platform upon which applications and service can be developed and hosted. Some of the std platforms are OS, database, queuing services and middleware services etc. The PaaS layer can be further decomposed into *Programming Environments* and *Execution Environments*. The former provides programming-language-level environment, whereas the latter offers the run-time execution environment that can take care of automatic scaling and load balancing.

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Infrastructure as a Service (IaaS): This lowest level provides the underlying resources, i.e. storage, computing and networking, which PaaS / SaaS rely on. Here, the consumer shares the cloud infrastructure on demand basis but does not manage or controls it, making it appears like a virtual machine to deploy and run arbitrary software. The user has limited control over OS, storage and deployed applications. The "resources" can refer to physical resources, but these often are virtualized. Hence we distinguish both virtual and physical resources. These resources can be further abstracted into what [4] calls "basic infrastructure services" providing higher level functionality than that offered by a typical OS. Offering database functionality is an example of "higher infrastructure services".

The Hardware as a Service (HaaS) [5], refers to providers that offer server infrastructure and take care of operation, management and upgrades of the hardware. On top of SaaS, [4] also introduces an extra human-as-a-service (HuaaS) layer, which rely on interaction and actual data processing by multiple collaborating people. Also, from an architectural perspective, the intermediate layers especially PaaS as well as basic application services in SaaS) can be seen as "cloud middleware", which [6] categorizes in *User Level* and *Core Middleware*. The standard grid technology seems to be situated on this "middleware" layer, which one could position on the PaaS level. The evolution to web-service based access to grids [7] could be seen as more SaaS-like grid offerings. Thus, from a conceptual point of view, it seems that grids are converging to the same layered architecture. While clouds can be seen as an evolution of grids towards high performance computing.

Youssef et al. [5] coin the term "Communication as a Service (CaaS)", as one of the three types of infrastructure, offering dynamic provisioning of virtual overlays for traffic isolation or dedicated bandwidth with QoS guarantees etc. They mainly refer to interfaces for the creation of on-demand communication services or channels. Lower layer virtualization is not addressed there. *Optical Network virtualization* [8, 9] has seen numerous studies and implementations in the form of virtual topology reconfiguration, Virtual Private Networks (VPNs), which connect a number of known end-points over a dedicated communications infrastructure. VPNs create isolated logical networks on a common physical substrate, recent work introduces virtualization in most if not all network elements, such as the switching fabric, the routing and forwarding engine, and the control plane .

IT resources are made up of multiple components such as a central processing unit, storage devices and working memory. *Virtualization of computer systems* [10] results in a virtual machine (VM) that offers all the capabilities of the host resource. These VMs can be instantiated and configured on-demand and introduce a relatively limited overhead. Furthermore, partitioning and aggregating of, for instance, storage resources, leads to the desirable properties of granularity and scalability, respectively.

Only recently, *combined virtualization* of both networking and IT resources has gained widespread attention, mainly due to the popularity of the grid and cloud computing concepts. The idea is to introduce a Logical Infrastructure Composition Layer (LICL) that manages the physical infrastructure consisting of both network and IT resources, and exposes these as virtual resources in a generic way. These, in turn, are combined to form virtual infrastructures that operate independently from each other, and each deploys its own control plane solution as desired. Additional features include dynamic up/down-grading of these infrastructures, as well as guaranteed end-to-end service delivery over diverse resources and complex different technologies.

In parallel, several higher-level cloud management toolkits have been proposed to handle aspects of IT resource virtualization combined with advanced job scheduling, monitoring, storage and user management. The examples of the latter are OpenNebula or Eucalyptus besides several others [11, 12, 13]. These software solutions allow transforming a network of cluster nodes to cooperate in managed cloud network. In general, virtualization can offer a number of *qualitative advantages* over more traditional models, including stricter isolation between users, more flexible enforcement of security policies and higher levels of trust [14]. However, one should not assume these advantages to be implied by virtualization, as careful design remains essential to successfully operate these services. In particular, the study in [15] demonstrates the trade-off inherent to WDM optical network virtualization, and specifically the effect of isolating virtual networks on network dimensions and the control plane scalability. Revisiting the cloud and grid requirements, virtualization mainly caters for *elasticity* and *scalability*, and addresses diversity of applications in terms of *granularity* of their resource needs. The flexibility of on-demand resource provisioning of virtualized resources, due to the less stringent dependence on the availability of a particular physical resource, also enables extra *resilience* opportunities.. To enable on-demand, end-to-end network services across multiple, independent, high-performance transport domains, one solution is based on the Generalized Multi-Protocol Label Switching (GMPLS) protocol suite, which is frequently deployed to bridge the gap between optical transport technology and the IP layer.

OPTICAL CLOUD AND VIRTUALIZATION

This paper proposes the optical cloud virtualization platform (OCVP), which provides Network as a service (NaaS) to cloud computing by exploiting the functionality provided by control plane (CP) enabled networks. The OCVP adopts a different approach that may be called undirected signaling to the CP. In fact, an application requests end-to-end network services in terms of end user addresses and perceived QoS parameters to the service elements controlling the edge node of the transport network serving its access networks without any knowledge of the transport network infrastructure.

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A distributed set of service elements collaborates for collecting and correlating network status information about both the transport and the access networks. The collected information is used to map the applications connectivity requests into a set of CP directives. NaaS is composed and orchestrated to provide connectivity on demand to cloud users or to enhance existing cloud services.

Cloud users			
Physical & Virtual network	**Infrastructure service, physical & virtual resources**	**Programming & Execution environments**	**Basic & Composite application services**
NaaS	**IaaS**	**PaaS**	**SaaS**
Virtual Infrastructure Composition Layer (VICL)			
ONVP	**OCVP**	**OSVP**	
Optical Network Control plane (ONCP)			
Network Resources	**Computing Resources**	**Storage Resources**	

Figure 1 Optical Cloud User Interaction with Virtualization platform

The virtualization for cloud computing is done for various Resources such as Network resources, Computing resources and Storage resources. The resources are shared through optical Cloud Virtualization platform (OCVP), Network Virtualization Platform (ONVP) and Storage Virtualization Platform (SVP). The network connectivity to various virtualization platforms are done through IP based logical connection i.e. virtual connection. In turn, the virtualization platforms provide NaaS, IaaS, PaaS and SaaS to the cloud user on shared resource basis. The cloud user interaction through different virtualization platforms is depicted in the layered architecture shown in figure 1. The user QoS requirements are satisfied through these virtualization platforms in terms of higher network Utilization, higher throughput, lower latency, lower transfer delay, reduced message overhead and the guaranteed bit rate.

RESOURCE VIRTUALIZATION

The virtualization of resources of optical cloud involves the interaction between different logical layers as shown in figure 2.

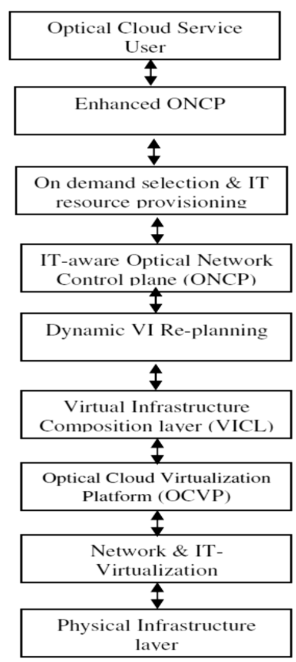

Figure 2 Virtualization of Resources in Optical Cloud

The physical infrastructure layer has physical resources such as WDM channels, network elements, topology and IT resources such as CPU, storage elements, etc. The network resources and IT resources are virtualized to access them logically anywhere. The virtualized resources are brought to the global internet through a common infrastructure called optical cloud virtualization platform

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(OCVP). The resources under OCVP are accessed and managed through virtual infrastructure composition layer (VICL). Any updates in the physical or IT resources are then done through dynamic re-planning layer. Pay per use as well as on demand provisioning and selection of IT resources to the cloud users are deployed through optical network control plane (ONCP) and enhanced ONCP. The functions of Optical network control plane include collecting routing information, distributing the optical network topology (physical) information, calculation of optimal path, etc. The routing protocols used by optical clouds:

i. Link state routing: OSPF,IS-IS
ii. Distance vector routing: RIP, IGRP

The ONCP calculates optimal path using hierarchical Path computing element protocol (PCEP), which is scalable for large number of optical nodes in the cloud. The network resources are reserved through the use of resource reservation protocol RSVP. Multi-domain optical cloud uses hierarchical PCEP on the enhanced NCP, which deploys Generalized Multi-Protocol Label Switching (GMPLS), which is using the traffic engineering (TE) with OSPF routing protocol for dynamic resource allocation. It also applies this GMPLS over optical data plane between inter-domain TE for multi-domain optical clouds. Topology aggregation for the optical cloud uses star mesh aggregation by assigning the length of shortest path as link weight. It also uses full mesh topology aggregation for comparing the performance.

Optical Link weight = Shortest path distance / WDM wavelength availability

RESULTS AND DISCUSSION

In this section, we describe the performance measurement of WDM optical cloud using simulation environment. The following assumptions are made to make the evaluation simpler.

i. All nodes are assumed to have full wavelength conversion.
ii. Each traffic demand requires 20 servers with one wavelength channel.
iii. The resource provisioning select the resource based on the shortest distance and minimum load to balance the load between the cloud servers.

Simulation parameters:

i. 3 domains, 21 nodes, 2 data centers
ii. Intra-domain: 16 wavelengths
iii. Inter-domain: 32 wavelengths
iv. 50 servers per data center

With the chosen input parameters, the following QoS parameters of the optical cloud network are analysed.

i. End to end delay
ii. Packet delivery ratio
iii. Packet loss ratio

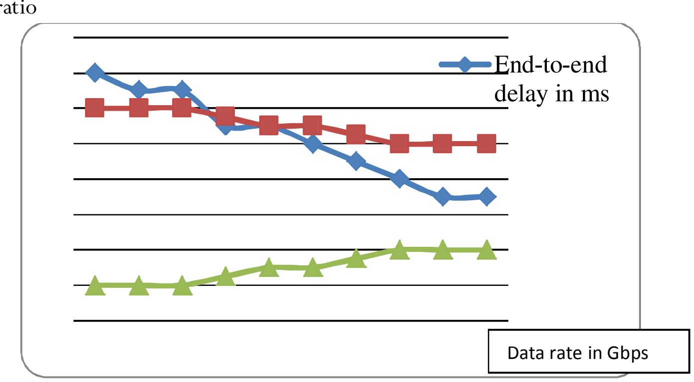

Figure 3 Data rate versus QoS parameters

It is observed from the figure 3 that while increasing ehe data upload / download rate, the end-to-end delay is varying within a limit of 0.5ms, packet delivery ratio is confined within 80% with the loss ratio of 20% maximum. These values are lying within the tolerance level of the WDM optical network, not affecting its QoS performance.

Parameters for measuring QoS performance of Optical cloud are:

i. Path compute time (τ)
ii. Number of control messages (m)
iii. Blocking probability (ρ)
iv. Ave Cloud Resource load (l)

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By varying the network load / server, we measured the above performance parameters as tabulated in Table 1. It is observed that the path computation time is limited within a fraction of second, even for the maximum load. This is due to the hierarchical PCE protocol, with the expense of little overhead messages.

TABLE I
LOAD VS QOS PARAMETERS

Load / server in Erlangs	**QoS Parameters**			
	τ ms	*m*	ρ	*l* %
2	347	152	0.0001	07
4	383	175	0.0001	11
6	422	190	0.0001 3	17
8	455	215	0.0003	23
10	498	242	0.0004 3	39
12	521	263	0.0006 1	51
14	570	290	0.0008	60
16	613	315	0.0009 2	72
18	635	337	0.0015	81
20	657	345	0.0018	92

The blocking probability is also restricted to the maximum value of 0.0018. This is due to efficient topology aggregation and hence the virtualization of the topology and network resources. Since the blocking probability is much less, the average cloud resource load attains upto 92% when the load per cloud server is maximum. This shows that the optical cloud resources are efficiently used. It also shows that the load is distributed in such a way that the cloud servers are balanced. This is due to the WDM physical topology aggregation and distribution of routing information to all nodes and cloud servers. Thus, cloud users are sharing the resources of the cloud with maximum efficiency.

CONCLUSION

In this paper, we propose optical cloud virtualization platform (OCVP) to deploy on demand provisioning and selection of IP-over-WDM optical network resources as well as IT resources in an efficient way with the help of enhanced optical network control plane (ONCP) which makes easier access and management of cloud resources. The performance of the WDM optical cloud and QoS parameters were studied through simulation setup.The simulation results show that the proposed virtualization platform for the WDM optical cloud is achieving good performance values satisfying its QoS requirements. The end-to-end delays observed as well as the packet loss ratio are within the tolerance of the WDM network. This is evident from the QoS parameters measured respectively path computation delay, blocking probability, message overhead and average cloud load. These QoS parameters are achieving the required performance for sharing of resources of IP-over-WDM optical cloud, managed through optical NCP by making use of virtualization of its resources with optical CVP. In future, the interaction between optical control plane and data plane, energy efficient sharing of resources can be dealt out.

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