OpenCloud: A Unified Services Framework

Andy Bavier, Sapan Bhatia, Larry Peterson
Princeton University

The Cloud is rapidly changing the face of the Internet, building on two disruptive technologies: multi-tenant virtualized clusters and *Software Defined Networks (SDN)*. Multi-tenant virtualized clusters enable scale-out designs with flexible resource use and good cost/performance. SDN makes it possible to both manage complexity and customize the network. Equally important, these technologies are being deployed throughout the Internet; they are not limited to the data center. Network operators are migrating away from purpose-built hardware appliances and moving towards infrastructure that exploits virtualized commodity servers and SDN at the very edge of the Internet, a practice now being called *Network Functions Virtualization (NFV)*. Emerging applications that support the *Internet of Things (IoT)* also benefit from servers located at the edge of the network, closer to users and devices. In both cases, distributing virtualized servers across the breadth of the Internet opens a new dimension for innovation, where functionality migrates to its optimal implementation point.

OpenCloud [**1**] is a proposed research cloud designed to help keep the research community at the forefront of cloud innovation. The vision is that the cloud is evolving into a rich, multi-dimensional space. It includes virtualized clusters and software-defined networks; large data centers and smaller clusters deployed deeply in the network; specialized private clusters and commodity public facilities; building block services and creative new applications. This results in an exciting opportunity to innovate, especially when researchers have the means to seamlessly and easily work across the entire space (i.e., not be limited to narrow silos and not have to reinvent the wheel). OpenCloud will enable such innovation using a three-pronged approach, combining an architecture that unifies the space, open source software that provides a tangible means to explore the space, and an operational deployment that creates an opportunity to both deliver value to end-users and learn from that experience.

Unifying Architecture – OpenCloud is based on a coherent architecture designed around the idea of *composable services*. The architecture unifies across resources (compute, network, storage); across the network (data centers, backbone routing centers, edge access points); across service levels (IaaS, PaaS, SaaS), and across administrative boundaries (private, public). The architecture does this by adopting *Everything-as-a-Service (XaaS)* as its organizing principle.

Open Source Software – OpenCloud will provide an open-source software distribution that embodies the XaaS principle. This includes operationalizing and extending existing open source projects like OpenStack. It also includes two new software components—a Cloud Operating System called *XOS* and a Network Hypervisor called *OpenVirteX (OVX)* [**2**]. Figure 1 shows a high-level view of OpenStack's software architecture.

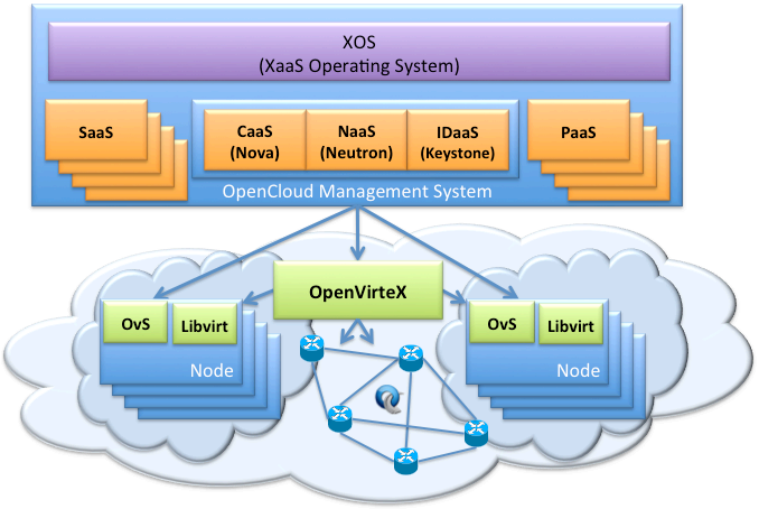

Figure 1: OpenCloud software architecture

Operational MetaCloud – OpenCloud will integrate XOS and OVX with existing cloud and network test-beds—most notably, NSFCloud, PlanetLab [**3**,**4**,**5**], GENI, and the SDN-capable switches deployed throughout Internet2—to build an operational logical cloud (a "meta-cloud") called *OpenCloud*. OpenCloud will *support long-running services* by providing them with seamless access to commodity clouds, research clouds, and network test-beds. Researchers will be able to access all of the capabilities of this underlying infrastructure through a coherent user interface, organized around the unifying principle of Everything-as-a-Service.

OpenCloud intends to build on the investment NSF is making in CloudLab and Chameleon Cloud (along with past investments in PlanetLab and GENI) by creating a new software layer that runs on top these infrastructures, with the goal of supporting research higher in the stack, specifically, on Cloud services. The key contribution of OpenCloud

is to raise the level of abstraction provided by the underlying infrastructure, thereby lowering the bar for Cloud service research. By adopting XaaS as a unifying principle, OpenCloud is positioned to demonstrate a new cloud architecture that could influence the cloud's evolution.

OpenCloud will support a broad range of research activities, including the following:

Research into long running services – OpenCloud supports experimental services by supporting a basic Infrastructure-as-a-Service (IaaS). Researchers will be able to acquire slices (a network-wide resource container that hosts a service) that include a set of VMs connected by one or more virtual networks (VNs). The goal is to lower the barrier to deploying and evaluating long running experimental services.

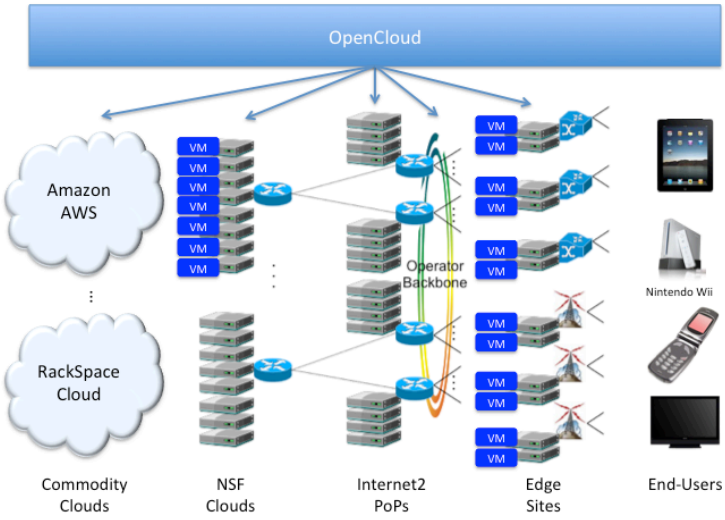

Figure 2: OpenCloud's proposed deployment

Research into widely distributed services – OpenCloud supports services running in slices that are distributed across the available data centers, wide-area networks, and access networks, leveraging SDN to dynamically create virtual networks between VMs. Figure 2 illustrates OpenCloud's proposed reach across four tiers of resource providers, with an set of VMs distributed across a combination of data center and edge nodes. At the far left are commodity clouds like Amazon's EC2 and Rackspace; next are data center clusters (provided by NSFCloud); then come medium-sized clusters embedded in Internet2 routing centers and regional PoPs; finally, many small clusters are located at the network edge and on campuses, close to end-users. The goal is to enable service researchers to control VM placement and VN topology across a widely distributed infrastructure.

Research into service composition – Going beyond PlanetLab's support for slices as simple resource containers, OpenCloud makes services a first-class abstraction by providing operations to manage and control services. Doing so lowers the barrier to creating new services through the composition of existing services. The goal is catalyze an ecosystem of services that provide value to end-users.

What would OpenCloud like from NSFCloud? The bottom line is that we want to operate OpenStack-based clouds on NSFCloud, supporting real users, in order to provide a useful resource to the research community as well as validate our novel cloud architecture. We would like the following: (1) to allocate a modest number (TBD) of bare metal machines at each NSFCloud site on a long-term basis, with the understanding that we could scale up in the future in response to demand from users; (2) to control OpenFlow switches in the intra- and inter-site networks using OVX; (3) to get access to NSFCloud resources as soon as possible, since it is our intent to stand up a production version of OpenCloud and start supporting users in short order. We are happy to be early adopters of NSFCloud to help shake out the infrastructure, and to lend our group's expertise with OpenStack and operations.

To sum up, OpenCloud is an operational meta-cloud built on top of resources provided by numerous testbeds. NSFCloud is an important component of the OpenCloud vision, providing the data center backbone of a widely distributed cloud. We believe that OpenCloud's unique software architecture and multi-tier deployment will help keep academic researchers at the forefront of cloud innovation.

References

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