Singapore-based Nanyang Technological University (NTU) is one of the world’s fast-rising universities, ranked 39th globally and No. 1 among the world’s best young universities. The university boasts 3,800 teaching and research staff providing high-quality global education to about 33,000 undergraduate and postgraduate local and international students. To address its growing compute-intensive workloads, NTU sought a cloud-based platform solution utilizing Red Hat® Cloud Infrastructure and Intel Xeon processor E5-4650L-based servers to achieve high-performance computing and scalability for its public and private computing resources.

**Challenge**

- **Improve performance of computing resources.** Enable computing resources with unlimited capacity, platform abstraction, and the ability to achieve economies of scale to cater to the large-scale computing projects of researchers and students.
- **Maximize existing computing resources.** Allow better resource utilization while reducing overhead costs from manual provisioning and approval processes.
- **Address unexpected compute demand.** Tackle unanticipated compute demand from growing research workloads while tapping the elastic compute resources of Amazon Web Services® (AWS®).

**Solution**

- **Build open-source hybrid cloud.** Design a stable, flexible, high-performance, scalable, and cost-effective cloud infrastructure platform that allows public and private computing resources.
- **Utilize Red Hat Cloud Infrastructure.** Build the software infrastructure platform on open-source Red Hat Cloud Infrastructure running on Intel Xeon processor E5-4650L-based servers and NetApp SnapMirror® for storage to implement private, on-premise cloud within the university.

**Technology Result**

- **Harness Red Hat Cloud Infrastructure solution products.** Utilize Red Hat Enterprise Linux OpenStack Platform to handle scale-out workloads, Red Hat CloudForms® to ensure unified management across all the technologies as well as workloads running on AWS, and Red Hat Enterprise Virtualization® to provide functionality for traditional scale-up workloads.
- **Deploy servers based on Intel Xeon processor E5-4650L.** Using Intel Xeon processor E5-4650L-based servers allowed maximum flexibility to stack up compute density for the Red Hat Cloud Infrastructure as well as enable efficient usage of energy even for compute-intensive workloads. Since AWS also uses Intel Xeon processor E5-4650L extensively, this allowed seamless integration between private and public clouds running on Red Hat Cloud Infrastructure.
- **Utilize NetApp SnapMirror.** Using NetApp SnapMirror enabled replication of volume from private NetApp storage to another NetApp storage, mirroring data to one or more network filers at high speed over LAN or WAN connections.

**Business Value**

- **Reaped benefits of elastic computing.** Building a new hybrid cloud IT architecture increased scalability of resources without compromising data security while achieving greater efficiency through automated resource provisioning.
- **Reduced overhead costs.** Utilizing a hybrid cloud model allowed better use of existing resources, resulting in cost savings.
- **Designed an innovative cloud model that can be adopted for other institutions.** The seamless integration of the Red Hat, Intel, and NetApp solutions into AWS made it possible for NTU to architect a hybrid cloud model that can be used as a cloud adoption framework for other academic institutions.
Large-scale computing demands limit performance of computing resources

As a research-intensive university, NTU requires high-performance computing resources to address the computing needs of the College of Science, Engineering, and Earth Observatory. The university’s existing computing resources could no longer handle the large-scale computing projects of its researchers and students.

The university also needed to maximize the utilization of its computing resources to minimize unnecessary overhead costs derived from manual provisioning and approval processes. On top of this challenge, it also needed to cope with unexpected compute demand, which is a predictable outcome in research and high-performance computing (HPC).

"We also needed to find a solution that will allow us to move workloads very quickly from NTU to AWS, so we can tap its elastic compute resources via AWS Direct Connect® and at the same time, preserve and ensure data outside of the public cloud," added Professor Yeng Chai Soh, founding director of the High-Performance Computing Center (HPCC) of NTU.

Apart from these requirements, NTU also needed an infrastructure solution that will allow users to affordably set up remote disaster recovery from data and selected services, and harness high-performance I/O and network for more responsive virtual machines, with latency that is close to physical machines. The infrastructure solution should also allow unified management of resources that can reside within HPCC’s premises or in an external cloud, while enabling end users to perform basic self-service functions for faster deployment and reduced admin overhead.

To address all these challenges, the HPCC team sought a solution based on open source. “We needed a secure, open solution that will be able to implement a hybrid IT cloud architecture seamlessly to allow us to have computing resources with unlimited capacity and platform abstraction as well as the ability to achieve economies of scale to address the growing computing requirements of our researchers and students,” explained Professor Soh.

Utilizing open-source hybrid cloud solution to improve compute performance

To build a private, on-premise cloud within the university, NTU worked with Red Hat to take advantage of its Red Hat Cloud Infrastructure solution. The solution consists of the Red Hat CloudForms, Red Hat Enterprise Virtualization®, and Red Hat Enterprise Linux OpenStack Platform®.

"After carefully evaluating several vendors, we chose Red Hat since it has one of the most versatile and complete solutions in initiating hybrid cloud models," said Professor Soh.

Red Hat Enterprise Virtualization provided the functionality needed for traditional scale-up workloads. Since the Red Hat Cloud Infrastructure utilizes Intel Xeon processor E5-4650L-based servers, the hybrid cloud solution is able to maximize flexibility to stack up compute density. The Intel Xeon processor E5-4650L-based server platform also allowed the Red Hat Cloud Infrastructure to achieve efficient energy usage for compute-intensive workloads.
Using Red Hat Enterprise Linux OpenStack Platform allowed the hybrid cloud model to handle scale-out workloads. Red Hat CloudForms, on the other hand, ensured unified management across the technologies, as well as workloads running on AWS. Since AWS uses Intel Xeon processor E5-4650L-based solutions extensively, they assured seamless integration between private and public clouds running on the hybrid cloud.

"Intel has been very innovative in its product and we highly value their assistance in making this deployment project seamless," said Professor Soh. "They even held a two-day hackathon to allow our developers to test their skills in building applications and apps. On top of this, Intel has also worked with local institutions to provide Arduino*-certified development and prototype boards, which we find commendable in bridging education to technology."

The hybrid cloud also utilizes NetApp SnapMirror to enable NTU to replicate volume from its private NetApp storage to another NetApp storage, which is linked to AWS via AWS Direct Connect facilities. SnapMirror mirrors data to one or more network filers at high speed over LAN or WAN connections, allowing NTU's data to be written and replicated in the remote NetApp storage. This also allowed NTU to tap AWS for its elastic computing resources.

### Increased compute efficiency and performance with a hybrid cloud

By building a hybrid cloud based on Red Hat Cloud Infrastructure and Intel Xeon processor E5-4650L, NTU was able to seamlessly integrate private cloud with public cloud while keeping its data local within its internal storage. The hybrid cloud also allowed NTU to take advantage of elastic computing and integrate both public and private cloud resources. By seamlessly integrating solutions from Intel, Red Hat and NetApp into AWS, NTU designed an innovative cloud model that other universities can adapt to their cloud requirements.

Utilizing the hybrid cloud solution allowed NTU to achieve performance improvements as well as time and cost savings. Users can now quickly access resources through the service catalog when needed, without manually provisioning virtual machines and constantly monitoring resources. NTU can now also flexibly manage data volume spikes for both the cloud and data center with the hybrid cloud's automated resource provisioning.

Since users can now provision independently, and since the self-service portal is rich in analytics and reports, NTU administrators can now focus more on creating strategic projects. "Utilizing this solution allowed us to showcase ingenuity that can positively impact day-to-day research initiatives globally. This solution can also be applied and adopted by research agencies and business entities with specific needs for real-time management and resourcing," shared Professor Soh.

With the success of the project, NTU now sets its sights on further harnessing the features of the Red Hat Cloud Infrastructure and Intel Xeon processor E5-4650L to develop a single sign-on module for federated sign-on.

### Lessons Learned

- In large-scale deployment, take a phased approach and start with a pilot to sort out any potential issues. Harness open standards and open source to ensure interoperability and prevent lock-in with single vendors.
- NTU’s hybrid cloud model is an alternative cloud model that integrates both private and public clouds while using local storage.
- Intel Xeon processor E5-4650L allows efficient usage of energy and large scaling of cores in a single image.
- Since AWS uses Intel Xeon processor E5-4650L extensively, integration between private and public clouds is a bit tighter and better.

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