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Department of  
Education & Training

# Identification and application of new and emerging technologies in private cloud computing

**David Brooks**

2014 Higher Education and Skills Group International Fellowship

**An ISS Institute Fellowship sponsored by**

Higher Education and Skills Group,  
Department of Education and Training





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## i. EXECUTIVE SUMMARY

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The purpose of this Fellowship was to explore the ongoing innovation in the development of solutions for the private cloud sector. Whilst many organisations are looking at cloud based solutions to add functionality to help with the development of various applications for their enterprises; they are not always prepared to use public cloud infrastructure. This could be for a variety of reasons including security, data sovereignty and ease of access to name but a few.

There are several viable private cloud solutions currently available to organisations that wish to keep their development in-house. Many IT vendors are positioning themselves in this area of the market and the Fellow will be evaluating and exploring the various solutions that are becoming the mainstream platforms in use today and also attempting to look ahead at what may become the dominant platform in the not too distant future.

One of the skills enhancement areas that the Fellow has identified is that there are currently no specific training programs available for a data centre engineer/cloud engineer. The main reason for this is that a data centre/cloud engineer has a very unique set of skills. He or she needs to be proficient in a combination of server administration, networking, virtualisation, enterprise storage and Linux technologies. The recent advent of Software Defined Networking has also added another challenging skill requirement; network engineers will now require the ability to code, to this already crowded and complex skillset.

Of the research conducted, there are two standout areas that this Fellow has identified that should be advanced in the shortest time possible to ensure that students graduating from IT and ICT training institutions leave with the necessary skill sets to work in the cloud era. These are the ability to design, create and manage a private cloud infrastructure and the ability to design, program and manage a software defined network.

The Fellow will soon begin work on developing units of competencies for the various IT and ICT training packages that are used in the vocational training sector in Australia. Once complete, these will be submitted for feedback from both the academic community and also various industry bodies that operate in this sector.

For the cloud training, the Fellow has identified OpenStack as the most likely platform to be in use in private cloud environments; other alternatives are The Citrix Cloud Platform (which includes Apache CloudStack) and also offerings from VMware such as vCloud Director and vCloud automation center.

Developing training programs for this will take some time, but many of the required resources are already being developed and several commercial IT training vendors have already begun moving into this space.

The SDN skill set is more difficult to pin down at this stage. Offerings from Cisco and VMware will lock in a specific vendor solution to SDN that may not fulfil the total skillset required to fully embrace this exciting new technology. The Fellow is identifying other open source resources, which over time can be developed into a comprehensive SDN training program. Examples of this are already on offer through Georgia Institute of Technology via the free online Coursera MOOC (Massive Open Online Course) training programs.

After beginning this journey with some preconceived ideas, the Fellow has been pleasantly surprised that there is much more development occurring in this space than he previously thought.



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## ii. ABBREVIATIONS/ACRONYMS

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<b>NAS</b>	Network Attached Storage
<b>SAN</b>	Storage Area Network
<b>PaaS</b>	Platform as a service
<b>IaaS</b>	Infrastructure as a Service
<b>SaaS</b>	Software as a Service
<b>SDN</b>	Software defined networking
<b>DaaS</b>	Desktop as a Service
<b>VDI</b>	Virtual desktop infrastructure
<b>LAN</b>	Local Area Network
<b>SDDC</b>	Software Defined Datacentre
<b>VET</b>	Vocational Education and Training
<b>BYOD</b>	Bring Your Own Device
<b>NFV</b>	Network Function Virtualisation
<b>DevOps</b>	Developer Operations



## **iii. DEFINITIONS**

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### **IaaS**

Infrastructure as a Service (IaaS) – Cloud infrastructure services or 'Infrastructure as a Service (IaaS)' delivers computer infrastructure, typically a platform virtualisation environment, as a service. Rather than purchasing servers, software, data centre space or network equipment, clients instead buy those resources as a fully outsourced service. The service is typically billed on a utility computing basis and amount of resources consumed (and therefore the cost) will typically reflect the level of activity. It is an evolution of web hosting and virtual private server offerings.

### **PaaS**

Platform as a Service - Cloud platform services, whereby the computing platform (operating system and associated services) is delivered as a service over the Internet by the provider. The PaaS layer offers black-box services with which developers can build applications on top of the compute infrastructure. This might include developer tools that are offered as a service to build services, or data access and database services, or billing services.

### **SaaS**

Software as a Service - Cloud application services, whereby applications are delivered over the Internet by the provider, so that the applications don't have to be purchased, installed, and run on the customer's computers. SaaS providers were previously referred to as ASP (application service providers). In the SaaS layer, the service provider hosts the software so you don't need to install it, manage it, or buy hardware for it. All you have to do is connect and use it. SaaS Examples include customer relationship management packages such as Salesforce.

### **SDN**

Software-defined networking (SDN) is an approach to networking in which control is decoupled from hardware and given to a software application called a controller.

The goal of SDN is to allow network engineers and administrators respond quickly to changing business requirements. In a software-defined network, a network administrator can shape traffic from a centralised control console without having to touch individual switches. The administrator can change any network switch's rules when necessary, prioritising, de-prioritising or even blocking specific types of packets with a very granular level of control. This is especially helpful in a cloud computing multi-tenant architecture because it allows the administrator to manage traffic loads in a flexible and more efficient manner. Essentially, this allows the administrator to use less expensive, commodity switches and have more control over network traffic flow than ever before.

### **NFV**

Network function virtualisation (NFV) takes an existing network function such as a router, a switch, a firewall or other network service and recreates it in a virtualised form. The benefit of this is that a network administrator is able to create multiple instances of NFV appliances and use them within a virtual environment to isolate groups of virtual machines and create multi-tenant environments. NFV and SDN solutions are frequently used together to provide a fully software controlled network environment.

### **iii. DEFINITIONS**

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#### **NAS**

NAS (Network Attached Storage) systems are networked appliances which contain one or more hard drives, often arranged into logical, redundant storage containers or RAID. Network-attached storage removes the responsibility of file serving from other servers on the network. They typically provide access to files using network file sharing protocols such as NFS, SMB/CIFS. NAS systems are typically used in a small to medium enterprise.

#### **SAN**

A storage area network (SAN) is a dedicated network that provides access to consolidated, block level data storage. SANs are primarily used to enhance storage devices, such as disk arrays, accessible to servers so that the devices appear as locally attached devices to the operating system. SANs can also provide access to files using network file sharing protocols such as NFS, SMB/CIFS. SANs would usually be found in the datacenter of a medium to large enterprise.

#### **DaaS**

Desktop as a Service (DaaS) is a cloud or locally hosted service in which the back-end of a virtual desktop infrastructure (VDI) is hosted by a cloud service provider or in a local data centre.

#### **VDI**

Virtual desktop infrastructure (VDI) is the practice of hosting a desktop operating system within a virtual machine (VM) running on a centralised server. VDI is a variation on the client/server computing model, sometimes referred to as server-based computing. The term VDI was coined by VMware Inc.

#### **SDDC**

A software-defined data centre (SDDC) is a data facility in which all elements of the infrastructure: networking, storage, CPU and security are abstracted and delivered as a service. Deployment, provisioning, configuration and operation of the entire infrastructure is abstracted from hardware and implemented through software.

#### **DevOps**

An integration of Software Development, Technology Operations and Quality Assurance. The term DevOps started appearing in online articles in 2010 and is now a mainstream term for a continual service improvement model based development program. DevOps is frequently linked to cloud based services where software developers will dynamically create highly automated development environments on demand to meet their needs.

# 1. ACKNOWLEDGEMENTS

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David Brooks thanks the following individuals and organisations that have generously given of their time and their expertise to assist, advise and guide him through this Fellowship program.

## Awarding Body – International Specialised Skills Institute (ISS Institute)

The International Specialised Skills Institute (ISS Institute) is an independent, national organisation. In 2015 it is celebrating twenty-five (25) years working with Australian governments, industry education institutions and individuals to enable them to gain enhanced skills, knowledge and experience in traditional trades, professions and leading edge technologies.

At the heart of the ISS Institute are our individual Fellows. Under the Overseas Applied Research Fellowship Program the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

- Preparing a detailed report for distribution to government departments, industry and educational institutions
- Recommending improvements to accredited educational courses
- Delivering training activities including workshops, conferences and forums.

Over 300 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas conduct training activities and events. To date, 25 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010'.

*Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change. International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills and knowledge, but also multiple and higher level skills and qualifications. Deepening skills and knowledge across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher-level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills and knowledge across a range of industries and occupations.*

In this context, the ISS Institute works with our Fellows, industry and government to identify specific skills and knowledge in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional knowledge, which they then share with their peers, industry and government upon their return. This is the focus of the ISS Institute's work.

For further information on our Fellows and our work see <http://www.issinstitute.org.au>.

David Brooks also thanks the CEO (Bella Irlicht AO) and staff (Ken Greenhill and Paul Sumner) of ISS Institute for their assistance in planning and development of the Fellowship and completion of this report.

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## **1. ACKNOWLEDGEMENTS**

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### **Fellowship Sponsor**

The Higher Education and Skills Group (HESG), of the Department of Education and Training (formerly Department of Education and Childhood Development), Victorian Government, is responsible for the administration and the coordination of programs for the provision of training and further education, adult community education and employment services in Victoria and is a valued sponsor of the ISS Institute. The Fellow would like to thank them for providing funding support for this Fellowship.

### **Supporters**

#### **Box Hill Institute**

- Dr Andrew Barnden, Academic Business Unit Leader, Centre for Communications and Information Technology
- Debra Hardy, Operations Manager, Centre for Communications and Information Technology
- Simon Taylor, Centre Manager, Centre for Communications and Information Technology
- George Adda, Manager, Curriculum Maintenance: Electro Technology
- Giovanni Italiano, Executive Manager – Advisor, Chief Executive Officer

#### **IBSA**

- Patricia Neden, Chief Executive, Innovation and Business Skills Australia

#### **CITT**

- Dominic Schipano, National Executive Officer, Communications & Information Technology Training Limited

#### **Cisco Systems**

- Emma Broadbent, Academy Area Manager, Cisco Networking Academy program
- Gary Coman, Global Director of Corporate Affairs
- Dean Colcott, Snr Network Consulting Engineer - Cisco Advanced Services

#### **ANZ Bank**

- Paul Edwards, Manager, Global Operations Strategy, ANZ Banking Group Limited

#### **Microsoft**

- Kim Rubbo, Microsoft Learning, ASIA Pacific IT Academy Channel Manager

#### **Citrix Systems**

- Dan Myers, Worldwide Academic Programs Manager, Citrix Systems
- Gina Alesse, Senior Manager, Learning Design and Development, Citrix Systems

## **1. ACKNOWLEDGEMENTS**

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- Dave Nelson, IT Academic Program Director, VMware Inc.

### **NetApp Inc.**

- Mark Conway, Sr. Program Lead, NetApp Academic Alliances Program, NetApp Inc.
- Lynne Welke, Director NetApp University, NetApp Inc.
- Chodi McReynolds, Senior Director, NetApp University, NetApp Inc.

### **Employer Support**

The Fellow especially acknowledges the support of the Centre Manager, Operations Manager, Industry Programs Manager and other staff at the Centre for Communications and Information Technology, Box Hill Institute during the entire Fellowship candidature.

### **Organisations Impacted by the Fellowship**

The following list of organisations/companies will benefit from the findings of this Fellowship:

#### **Government**

- Department of Education and Training (DET), formerly Department of Education and Early Childhood Development (DEECD), State Government of Victoria
- State Government of NSW, Department of Education and Communities
- State Government of Queensland, Department of Education, Training and Employment
- State Government of South Australia, Department of Further Education, Employment, Science and Technology
- State Government of Western Australia, The Department of Training and Workforce Development
- State Government of Tasmania, Department of Education

#### **Industry**

- |                 |                       |             |                         |
|-----------------|-----------------------|-------------|-------------------------|
| • Cisco Systems | • Amazon Web Services | • EMC2      | • NextDC                |
| • VMware        | • NetApp              | • Telstra   | • Other Cloud providers |
| • Microsoft     | • IBM                 | • Optus     |                         |
| • Citrix        |                       | • Rackspace |                         |

#### **Professional Associations**

- Australian Computer Society (ACS)
- Storage Network Industry Association (SNIA)

#### **Education and Training**

- Centre for Communications and Information Technology, Box Hill Institute
- Innovation and Business Skills Australia
- E-Oz Energy Skills Australia



## 2. ABOUT THE FELLOW

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### **Name**

David Brooks

### **Employment**

- Teacher, Higher Education Lecturer (Computer Systems and Information Technology), Centre for Communications and Information Technology, Box Hill Institute, Melbourne.

### **Qualifications**

- Master of Networking and Systems Administration, Charles Sturt University, Wagga Wagga, Australia, 2014
- Diploma of Vocational Education and Training Practice, Box Hill Institute, Box Hill, Australia, 2012
- Graduate Certificate in Networking and Systems Administration, Charles Sturt University, Wagga Wagga, Australia, 2011
- Advanced Diploma of IT (Network Security), Box Hill Institute, Box Hill, Australia, 2009
- Advanced Diploma of Computer Systems Engineering, Box Hill Institute, Box Hill, Australia, 2007

### **IT Certifications**

- Microsoft Certified Trainer
- Microsoft Certified Solutions Associate – Windows Server 2003/08/12
- VMware IT Academy Instructor – Instructor Trainer
- VMware Certified Professional – Data Center Virtualisation 4/5/5.5
- VMware Certified Professional – Desktop Virtualisation 5
- Cisco Certified Academy Instructor – Instructor Trainer
- NetApp Certified Data Management Administrator

### **Membership/s**

- Australian Computer Society (ACS)
- Storage Network Industry Association (SNIA)
- VMware Users Group (VMUG)
- OpenStack Users Group

## **2. ABOUT THE FELLOW**

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### **Short Biography**

David Brooks has been employed as a teacher at the Centre for Communications and Information Technology, Box Hill Institute since 2008. His main areas of interests include virtualisation and cloud computing technologies.

Brooks was the author of many of the virtualisation units in the current Information Technology (ICA11) qualifications used in the National TAFE IT qualifications.

He was a panel member on the Australian National Cloud Computing/Virtualisation VET Qualification Project, which has added multiple cloud computing units to the newly revised National IT training package in late 2013.

Brooks holds many IT vendor certifications including those from VMware, Microsoft, and Cisco Systems and currently teaches and co-ordinates their academy programs at Box Hill Institute.

### **3. AIMS OF THE FELLOWSHIP PROGRAM**

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The prime purpose of the Fellowship was to gain leading-edge knowledge and skills about the current and emerging worldwide trends in cloud computing, software defined networking and workforce mobility technologies. Part of this was achieved by attending two leading US technology conferences, supplemented by visits to various technology organisations or meetings with their representatives as well as attending several online conferences.

#### **Aims of the Fellowship**

The Fellow aimed to gain new internet-related and pedagogical knowledge and skills by attending two international technology conferences in the USA (Anaheim and San Francisco) and visiting several leading IT companies in the Silicon Valley area of California. Conference themes include Bring Your Own Device (BYOD), Workforce Mobility platforms, Software Defined Networks, Software Defined Data Centres and Storage Area Networks.

The Fellow will build strong relationships with leading international IT businesses offering vocational students' access to Academy Training Curriculum at minimal cost. IT Academy programs can be and are frequently used in the VET environment to ensure graduating information technology students become the professionals of the future and have the skills to support industries' adoption of the latest emerging cloud technologies.

The emerging technologies skills that will be focused on (but not limited to) that are critical to ensuring vocational teachers and IT students are well prepared for the future are:

- Using Cloud to diversify data and network access across multiple geographical areas
- Ensuring the learning environment supports 'Bring Your Own Device' and diverse 'Mobility platforms'
- Using Virtualisation and workforce mobility technologies to deliver an 'Open Classroom' or 'Classroom anywhere, anytime' environment
- Identifying the evolution of 'Software Defined Network' (SDN) technologies
- Identifying the evolution of 'Software Defined Data Centre' platforms
- Managing the evolution of 'Storage Area Networks'.

By investigating leading organisations that are driving these technologies, the Fellow intends to gain an insight into their technology roadmaps, and the skills and knowledge a graduate would require implementing these technologies. Some of the global IT vendors that have been identified as leaders in the area of Cloud and SDN are:

- |                       |                   |                    |                    |
|-----------------------|-------------------|--------------------|--------------------|
| • Amazon Web Services | • NetApp          | • CSC              | • Infoblox         |
| • Google              | • EMC2            | • Dell             | • Juniper Networks |
| • Microsoft           | • Pivotal         | • Broadcom         | • NEC              |
| • VMware              | • HP Cloud        | • Ericsson         | • Brocade/Vyatta   |
| • Citrix Systems      | • IBM (SoftLayer) | • Extreme Networks | • Mirantis         |
| • Cisco Systems       | • Rackspace       | • Intel            | • Puppet Labs      |

### **3. AIMS OF THE FELLOWSHIP PROGRAM**

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Closer to home, a number of companies are all offering various cloud based services to business and individuals in Australia. These include:

- Telstra
- Dimension Data
- Area9
- Ninefold
- Optus PowerOn
- Data#3
- Fujitsu
- OrionVM
- Macquarie Telecom
- Summit IT
- ZettaGrid
- NextDC
- CloudCentral
- UltraServe

In addition to the vendor driven technologies, there are several open source driven initiatives that are also gaining wide acceptance in the IT community, these are but some:

#### **Cloud Platforms**

- OpenStack
- Apache CloudStack
- Cloud Foundry
- OpenShift Origin

#### **Software Defined Networking**

- OpenFlow
- OpenDaylight

#### **Data Center Reference Designs**

- Open Compute Project



## 4. THE AUSTRALIAN CONTEXT

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The Australian information technology sector covers a vast collection of varying skills and knowledge of which cloud computing is but one area that has recently emerged. International companies such as Google and Amazon Web Services have begun to establish bases of operation here to compete with local offerings from Telstra and Optus to name but a few. With this in mind, developing a robust workforce capable of working in this dynamic environment has been identified as a priority. For this to occur, suitably trained individuals need to be available. For them to be fully prepared, we need to identify precisely what skills they will need to compete on a global stage.

Innovation and Business Skills Australia conduct various working groups to analyse needs within the IT training sector of which the Fellow is a member. Various industry stakeholders are regularly invited to evaluate the current state of vocational qualifications within the national framework and provide feedback as to any perceived shortcomings or new skill sets that may be of benefit.

Over the past few years, cloud related skills have been identified as an area in need of new units of competencies to accommodate these new skill sets; culminating with the recent release of a series of new units specifically aimed at the cloud computing field.

Upon further analysis of these newly released units, the Fellow has identified several emerging areas that require further investigation and development of resources to add to the existing body of knowledge.

Cloud technologies continue to evolve at a rapid rate and there are many new start-ups breaking into this area as well as ongoing innovation from the existing market leaders.

Having a skilled workforce that is proficient in the development and management of these technologies will ensure that the Australian IT landscape is populated with local talent that has the skills that meet a growing market demand.

Many of the companies mentioned have low cost ‘Academy’ programs that can support the delivery of training in Cloud, Virtualisation and their related technologies. By visiting the US to meet with the developers and managers of these Academy programs the Fellow aims to identify their value to the Australian educational market.

Upon his return the Fellow will provide input into the development of programs with the intention to ensure the programs are highly suitable for use in an Australian vocational training environment.



## 5. IDENTIFYING THE SKILLS AND KNOWLEDGE ENHANCEMENTS REQUIRED

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There are examples of areas in Australian industries where there are weaknesses in innovation, skills, knowledge, experience, policies and/or formal organisational structures to support the ongoing successful development and recognition of individuals and the particular sector.

The focus of all ISS Institute Fellowships is on applied research and investigation overseas by Australians. The main objective is to enable enhancement and improvement in skills and practice not currently available or implemented in Australia and the subsequent dissemination and sharing of those skills and recommendations throughout the relevant Australian industry, education, government bodies and the community.

The areas of applied research for this Fellowship are therefore defined as follows:

### **Skills Enhancement 1. Managing Virtual Computing Environments (Software Defined Datacentres):**

The Fellow will document and investigate how various cloud providers manage their virtual datacentres. Datacenters managed by cloud service providers use a wide range of 'off the shelf hardware' coupled with custom applications as well as proprietary solutions to manage their dynamically changing environment.

The Fellow intends to identify from various organisations the technologies resources and practices used that could be developed into dedicated cloud training programs.

**Action:** Use the results gained to recommend skills that need to be addressed in IT and ICT Training Packages.

Identify access to any relevant training resources that could be utilised to support training for skills enhancement; should such resources already exist. In the event there are no existing training resources, the Fellow will endeavour to develop new training resources with the assistance of the various stakeholders.

Brooks will identify and build international colligate relationships that can be used to support the development of local training programs in emerging datacenter and cloud technologies.

### **Skills Enhancement 2. Software Defined Networks:**

The Fellow will document and investigate how various cloud providing organisations manage their virtual computing networks. As these can span many disparate locations or require a datacenter network engineer to manage dynamically changing workloads, SDN is a very new technology and each organisation currently has their own method of implementation and management. Leading network vendors such as Cisco Systems are presently contributing to an open standard known as OpenFlow. Recently acquired VMware subsidiary Nicira have their propriety NSX suite and are also a contributor to OpenFlow. Google use an internally developed network management platform and are also contributing to the OpenFlow standards.

**Action:** Use the results gained to recommend skills that need to be addressed in IT and ICT Training Packages.

Identify access to any relevant organisations' training resources that could be utilised to support training for skills enhancement. Should such resources already exist? Should no training resources exist, the Fellow will endeavour to develop new training resources with the assistance of the various stakeholders.

## **5. IDENTIFYING THE SKILLS AND KNOWLEDGE ENHANCEMENTS REQUIRED**

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The Fellow will identify and build international colligate relationships that can be used to support the development of local training programs in emerging datacenter and cloud technologies.

### **Skills Enhancement 3. Storage Area Networks:**

Document and investigate how various cloud-based organisations manage their Storage Technologies. This is an area that over the last few years has been identified as needing more focus on training for our graduates. Leading companies in this area include EMC, NetApp, HP, IBM as well as many new innovative start-ups.

The Fellow sought to identify from various organisations, the technologies resources and practices used that could be developed into dedicated storage area network training programs.

**Action:** *Use the results gained to recommend skills that need to be addressed in IT and ICT Training Packages.*

Identify access to any relevant training resources that could be utilised to support training for skills enhancement; should such resources already exist. In the event there are no existing training resources, the Fellow will endeavour to develop new training resources with the assistance of the various stakeholders.

The Fellow will identify and build international colligate relationships that can be used to support the development of local training programs in emerging datacenter and cloud technologies.

### **Skills Enhancement 4. Virtualisation of Server and Desktop platforms:**

Document and investigate the current use of virtualisation technologies that are used to virtualise both server and desktop systems. The leaders in this area are VMware, Citrix and Microsoft. The Fellow will attempt to meet with each of these companies to gain further insight in to where they see the technology moving and what innovations and obstacles they foresee in the immediate future. This also ties in with the mobility and bring your own device technologies that leverage virtualisation.

Seek to identify from each organisation the technologies used and the best practice methodology from that organisation.

Interpret the results of the research to determine possible training strategies.

**Action/s:** *Use the results gained to recommend skills that may need to be addressed in IT and ICT Training Packages.*

Identify the possibility of access to organisational training resources that can be utilised to support training for skills enhancement should such resources exist. Identify and build international colligate relationships that can be used to support the development of local training programs in software defined networks and emerging cloud technologies.

## 6. THE INTERNATIONAL EXPERIENCE

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The overseas program was based in the USA, where much of the cutting-edge work in the field of the cloud computing and its underpinning technologies are currently taking place. Online attendance of several USA hosted conferences that were running during the Fellowship period were also used to augment much of the knowledge gained during the visits as geographic locations and timing constraints meant the Fellow was unable to attend these conferences in person.

The program was designed to explore the identified skills and knowledge gaps and obtain the information necessary for the Fellow to return to Australia equipped with the knowledge and ideas to advise, instruct, promote and improve local understandings of the technologies and teaching and learning.

The following conferences and meetings were undertaken as part of the Fellowship research.



### Destination 1: Open Networking Summit 2014

Online Attendee, March 3-5, 2014, Santa Clara Convention Center, California, USA

(<http://www.opennetsummit.org>)

#### Objectives

The Open Networking Foundation is the custodian of much of the development in the Software Defined Networking (SDN) space. Its origins began with the development of OpenFlow protocol at Stanford University.

One of the newer spins offs from this is the Linux Foundation's OpenDaylight project where the OpenFlow protocol forms the foundation for an open source SDN framework. Backed by the who's who of Linux distributions as well as major networking vendors, OpenDaylight is an attempt to define a standard software based control framework for SDN.

The Fellow had already booked visits in person to two technology conferences in May so decided to attend this conference as a virtual attendee. This allowed the Fellow to access each technology session of interest and gain a more thorough insight into ongoing SDN technology developments.

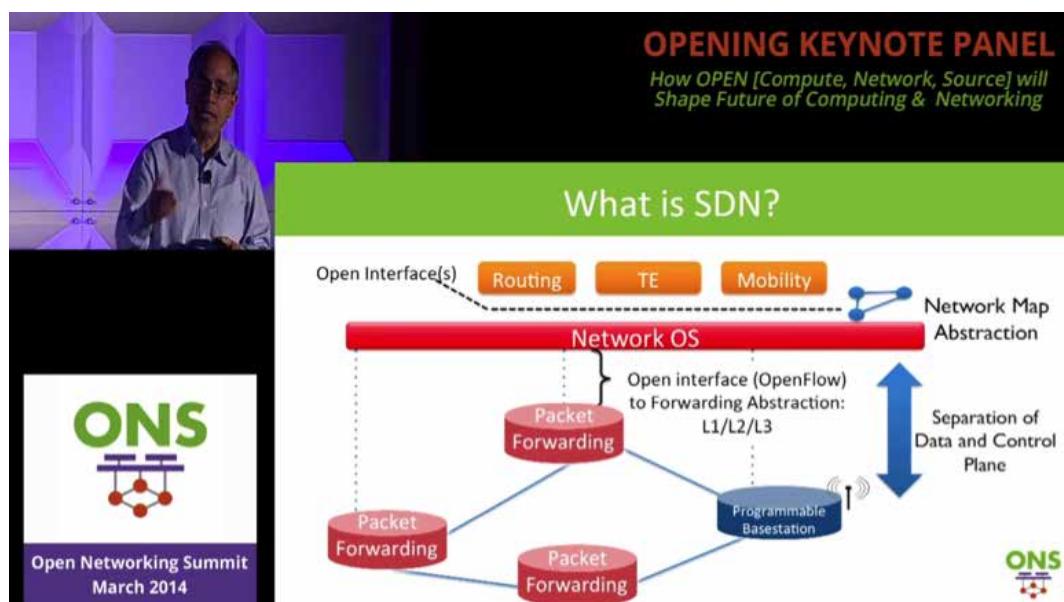
## 6. THE INTERNATIONAL EXPERIENCE

### Sessions attended

#### Opening Keynote Panel: How Open [Compute, Network, Source] will Shape Future of Computing and Networking

##### Speakers:

- Guru Parulkar, Stanford University
- Najam Ahmad, Facebook
- Dan Pitt, Open Networking Foundation
- Jim Zemlin, The Linux Foundation
- Jono Bacon, Canonical Ltd.



The opening keynote address began with Stanford University's Guru, Parulkar describing the disruptive influence that Open source based technologies are beginning to achieve in the datacenter.

Najam Ahmad from Facebook then followed with a short presentation on the development of the Open Compute Project (OCP), which is being shared with datacenter architects all over the world to create more energy efficient datacentres and lower overall operational costs. Other OCP projects in development include an Open Network Switch to more easily facilitate the use of OpenFlow protocols. Companies such as Broadcom and Mellanox have already developed prototype switches that support this specification. These switches are currently under review.

BigSwitch networks have developed a Linux Platform for OCP switches that will allow a user to buy any supported OCP switch and then run Open Network Linux on it. Intel is also developing an OCP compliant switch, but is further behind in their development cycle.

## 6. THE INTERNATIONAL EXPERIENCE

The collage includes:

- A photo of Najam Ahmad speaking on stage.
- The title slide for the "OPENING KEYNOTE PANEL: How OPEN [Compute, Network, Source] will Shape Future of Computing & Networking".
- A slide for the "OCP Network Project" with the quote: "create a set of networking technologies that are disaggregated and fully open, allowing for rapid innovation in the network space".
- The ONS logo and the text "Open Networking Summit March 2014".
- A diagram titled "Initial focus on datacenter Top-of-Rack switch" showing a network architecture with multiple servers connected to a central switch.
- A document titled "Proposed Charter for Open Network Switch" with the "OPEN" logo.

(Ahmad, Bacon, Pitt, & Zemlin, 2014)

### SDN for Cloud

#### Speaker:

- Martin Casado - CTO of Networking, VMware

Martin is one of the pioneers of software defined networking and is one of the early contributors to the OpenFlow protocol and a co-founder of Nicira, which is now part of VMware.

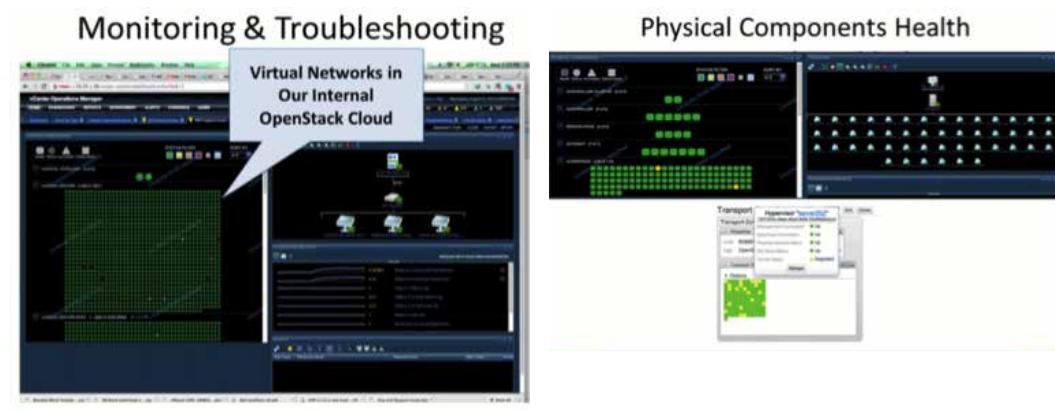
The collage includes:

- A photo of Martin Casado speaking on stage.
- The title slide for the "PLENARY SESSION: SDN for Cloud".
- A slide titled "What is Network Virtualization?" showing a diagram of a physical network layer with multiple virtual network overlays.
- The ONS logo and the text "Open Networking Summit March 2014".

## 6. THE INTERNATIONAL EXPERIENCE

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Martin gives a very informative overview of how SDN can be used in the datacenter to virtualise the network and create a layer of abstraction that then allows better visibility of data flows within the network. It also allows the creation of multiple isolated self-contained networks within the larger network framework.



Monitoring the network state becomes much more granular as the ability to monitor network flows and identify bottlenecks; points of failure and an overall global view of network health are presented to the network admin from a single dashboard. From here, a network admin can also drill down to the physical state of the network components.

Once a network has been virtualised, other uses become possible. Updates and upgrades can be streamlined by using snapshots and cloning methods. Modelling in a test and development environment can be performed and then deployed seamlessly into production. Performance characteristics can be altered in real time, monitored and altered again.

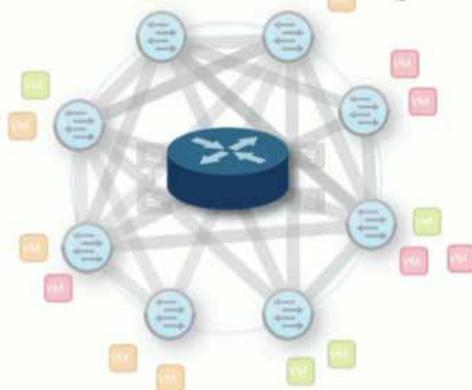
A basic example of how this was demonstrated is on the following page.

Virtual network interconnected via a single router.

Results of this design introduce large bottlenecks and increased latency across the network.

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### Example: Runtime Deployment of Distributed Routing



## 6. THE INTERNATIONAL EXPERIENCE

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By introducing virtualised routers at each endpoint, the workload is now spread across the entire network.

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### Example: Runtime Deployment of Distributed Routing

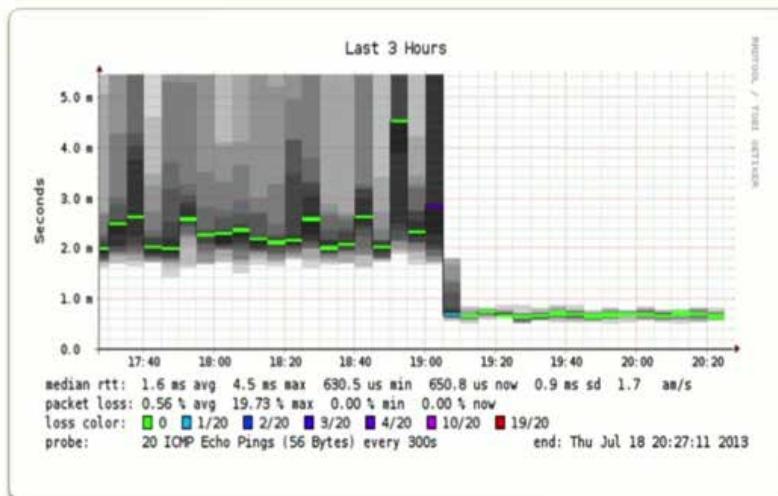


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The resulting performance improvements displayed below are a massive improvement with latency reduced to insignificant levels.

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### Latency Impact on Production Network



## 6. THE INTERNATIONAL EXPERIENCE

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One of the final points of this presentation that came up during the Q&A session, is that while current SDN solutions introduce a lot of new functionality to a network in a datacenter, it is not necessarily suitable for use in all networks as it can add additional layers of complexity to what may already be a very complex environment. This appears to be the case for geographically disparate networks linked via a WAN structure (Casado, 2014).

However, solutions to this appear to be on the horizon with various research projects and the development of SDN based solutions are underway. Some of these potential solutions were presented during the research presentation sessions over the three days of the conference.

The Fellow was able to access the following research presentation sessions during the conference:

- Cross-Entrance Consistent Range Classifier with OpenFlow, Yehuda Afek (Tel Aviv University)
- SFA: Stateful Forwarding Abstraction in SDN Data Plane, Jun Bi (Tsinghua University)
- Serial Composition of Heterogeneous Control Planes, Kirill Kogan (Purdue University)
- On the Necessity of Time-based Updates in SDN, Tal Mizrahi (Technion, Marvell)
- Towards a Reliable SDN Firewall, Hongxin Hu (Delaware State University)
- Try Before you Buy: SDN Emulation with (Real) Interdomain Routing, Brandon Schlinker (University of Southern California)
- Extending SDN to Handle Dynamic Middlebox Actions via FlowTags, Seyed Kaveh Fayazbakhsh (Carnegie Mellon University)

(Open Networking Summit - Research Track Part 1, 2014)

- SDN and Optical Flow Steering for Network Function Virtualization, Ming Xia (Ericsson Research Silicon Valley)
- Proof-based Verification of Software Defined Networks, Chen Chen (University of Pennsylvania)
- RadioVisor: A Slicing Plane for Radio Access Networks, Li Erran Li (Bell Labs, Alcatel-Lucent)
- SDN for dense WiFi networks, Yiannis Yiakoumis (Stanford University)

(Open Networking Summit - Research Track Part 2, 2014)

- Soft Jive: Performance Driven Abstraction and Optimization for SDN, Aggelos Lazaris (University of Southern California)
- Enabling SDN in old school networks with Software-Controlled Routing Protocols, Laurent Vanbever (Princeton University)
- Coherent SDN Forwarding Plane Programming, Haoyu Song (Huawei Technologies)
- Accelerating SDN/NFV with transparent offloading architecture, Koji Yamazaki (NTT Microsystem Integration Laboratories)
- ESPRES: Easy Scheduling and Prioritization for SDN, Peter Peresini (EPFL)
- SODA: Enhancing the Data Plane Functionality of Software Defined Networking, Dan Li (Tsinghua University)
- SoftMoW: A Dynamic and Scalable Software Defined Architecture for Cellular WANs, Mehrdad Moradi (University of Michigan)
- Control Exchange Points: Providing QoS-enabled End-to-End Services via SDN-based Inter-domain Routing Orchestration, Rowan Klöti (ETH Zurich, Switzerland) ware-Defined Networks as Databases, Anduo Wang (UIUC)

(Open Networking Summit - Research Track Part 3, 2014)

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Many of the presentations related to technology research that was still in its infancy and the sessions were designed to give the attendees a taste of what was to come. The results presented demonstrated that SDN is here to stay and will undoubtedly impact almost all areas of networking in the future.

### **Outcomes**

The Fellow gained major insights into SDN from this conference and when combined with the knowledge gained from the other conference visits will enable him to drive the development of several new networking units in the IT and ICT training packages.

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### Destination 2: Citrix Synergy 2014



In person Attendee, May 6-8, 2014, Anaheim Convention Center, California, USA

<http://www.citrixsynergy.com/>

Citrix Systems are a well-established technology vendor that markets products in the Cloud, Server, Desktop and Application Virtualization, Networking and Workforce Mobility areas.

They are the market leader in Desktop, Application and Workforce Mobility solutions and their NetScaler product is one of the most widely used networking solutions used by cloud providers.

Citrix Synergy is a yearly event where Citrix and its technology partners present the latest technology innovations and trends to several thousand attendees from all around the world.

#### Objectives

Workforce Mobility and Cloud technologies were the primary focus of the research conducted here as well as investigating developments in Desktop/Application virtualization and Citrix networking products.

In addition to attending multiple technology breakout sessions, the Fellow was invited to participate in a higher education round table discussion.

The Fellow attended the following technology sessions:

#### How XenMobile integrates with NetScaler, XenDesktop and XenApp for complete enterprise mobility.

##### Presenters:

- Prashant Batra, Senior Product Manager, Citrix Systems, Inc.
- Gabriel Smyth, Sr. Mobility Sales Engineer, Western Canada, Citrix Systems, Inc.

A presentation slide titled "Citrix Mobility &amp; Desktop Integration" with the subtitle "How XenMobile integrates with NetScaler, XenDesktop and XenApp for complete enterprise mobility". The slide features the Citrix logo and the names Prashant Batra and Gabriel Smyth at the bottom.

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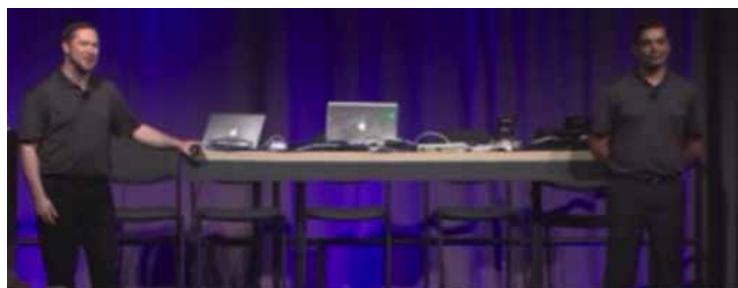
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### Session Description:

Citrix NetScaler, Citrix XenDesktop and Citrix XenApp help companies reap the benefits of virtualization for mobile users by providing secure access to Windows desktops and apps. Learn how Citrix XenMobile fits into the equation by allowing companies to securely deliver a complete enterprise app store to any device.

In this session, participants learnt about the following systems and architecture:

- How NetScaler provides a secure and scalable network connection for apps and desktops delivered through XenDesktop, XenApp and XenMobile
- How XenApp and XenDesktop integrate with XenMobile to allow IT to deliver Windows desktops and apps, as well as web and native mobile apps
- The backend architecture for a complete enterprise app store that can be delivered to any device.



(Batra & Smyth, 2014)

Citrix NetScaler is one of the most widely used network security appliances currently in use by IT organisations the world over. It is a favourite with the majority of cloud providers.

Whilst not being a network expert, the Fellow wished to gain some insight as to where and when this technology was being implemented as well as best uses cases.

### Is XenMobile just like any other MDM solution?

#### Presenters:

- Brian Robison, Principal Technology Evangelist, XenMobile, Citrix Systems, Inc
- Chandra Sekar, Director, Product Marketing, Citrix Systems, Inc.

#### Session Description:

With their similar marketing messages, it's not easy to tell the difference between mobile device

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management (MDM) products. This session will highlight the key advantages of Citrix XenMobile compared to other MDM solutions - including containerised email with integrated file share/sync/edit that users won't reject and a business-grade calendar app that lets users forward meeting invites and allows one-click access to virtual meetings without having to enter meeting IDs.



### Topics covered during this session were as follows:

- How to look for proof points (or the lack thereof) behind the marketing messages
- Why XenMobile delivers more than MDM
- Why customers select XenMobile over other products.

This session dealt with how Citrix have tackled the complexities of managing consumer grade devices such as mobile smartphones and tablets in a security conscious corporate environment. While being a bit heavy on the marketing spin, it did clearly demonstrate the advances that have been made in this technology. According to the latest research conducted by Gartner, Citrix XenMobile is one of the leading Mobile Device Management (MDM) solutions (Cosgrove, et al., 2014).



The Fellow has been analysing the current XenMobile reference architecture to determine the requirements for developing a training lab environment for training in this area. At the present time, the hardware and software requirements that would be needed per student are quite onerous. Further research will be required to develop a cost effective lab solution.

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### Mobile, secure and compliant!

#### **Presenter:**

- Connie Barrera, Director of Information Assurance and Chief Information Security Officer, Jackson Health Systems

#### **Session Description:**

Mobility is no longer an isolated trend. Recently mobile subscriptions worldwide topped \$6.8 billion. Unfortunately, data breaches are also increasing, resulting in huge losses for businesses. Meanwhile compliance requirements for HIPAA, PCI and other regulations continue to expand, leaving organizations scrambling to address mobile security and compliance – which at times are mutually exclusive. Citrix allows organisations to meet these compliance demands by establishing a defence-in-depth approach to security, keeping data in the datacenter while enabling mobile access to apps and desktops.

In this session the following were covered:

- The security and compliance risks of mobility
  - How to create an effective defence-in-depth and compliance strategy
  - Perimeter security policies that provide levels of protection against remote malicious activity
- (Barrera, 2014).

### Ultimate guide to implementing your Citrix mobility solution

#### **Presenter:**

- Anton van Pelt, Consultant, PQR

#### **Session Description:**

There is a lot going on in the enterprise mobility market and it can be confusing. If you are puzzling about how to provide access to apps and data or manage mobility in the enterprise, this session will help. Anton van Pelt, a technical consultant at PQR, will provide the latest tips and best practices from the field on designing, building and maintaining Citrix XenMobile and Citrix ShareFile components optimized with Citrix NetScaler.

In this session the following topics were covered:

- Cover different mobility scenarios and their requirements
- Provide practical guidance on XenMobile, ShareFile, StoreFront and XenDesktop
- Supply a checklist to get started building your own Citrix mobility solution

This session dealt with some of the best practice methodology used to ensure everything runs smoothly and Anton had some very pertinent advice and helpful tips.

The Fellow gained some significant insight into the evolution of Mobile Device management technology that enterprises use to retain a level of control over devices brought from outside the workplace. The BYOD evolution has meant that many users are expecting to be able to use their own phones, tablets and laptops within the corporate landscape. For this to occur, there needs to be some level of control in place to protect corporate data.

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### From the field: A customer's journey towards private cloud computing with Citrix CloudPlatform

#### Presenters:

- Jason Smathers, Autodesk
- Shannon Williams, VP, Market Development, Cloud Platforms Group, Citrix Systems, Inc.



#### Session Description:

A world leader in 3D design, engineering and entertainment software and services, Autodesk used Citrix CloudPlatform to build a private cloud for its Enterprise Cloud Services (ECS) program. By providing on-demand development and test resources for engineering groups worldwide, the company has been able to boost R&D productivity, execution speed and workforce flexibility by simplifying IT with on-demand cloud services. In this session, Jason Smathers, manager of Autodesk's private cloud, will describe the business rationale that drove the project, how they architected and implemented their vision, some of the challenges they ran into during the process and the results they have realised over the course of the project.

In this session, participants gained an insight into the following areas:

- Insights into the business case Autodesk used to build and prove out the enterprise private cloud
- An understanding of how a large IT organization went about designing and implementing a private cloud project
- Visibility into the benefits and challenges Autodesk realized from this project, at both the IT and Business levels.



(Smathers & Williams, 2014)

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Having only read about the Citrix CloudPlatform, the Fellow was very interested in how it was deployed in a large enterprise environment, Jason's presentation was very informative on the challenges of being an early adopter of new technologies.

### Qualcomm ITNET: a network virtualization and private cloud case study

#### Presenters:

- Mike Richter, Senior Staff Network Engineer, Qualcomm
- Irfan Siddiqui, Staff Manager IT, Qualcomm



#### Session Description:

Enterprise IT organisations are striving to make datacenter infrastructure more flexible while driving down costs. Qualcomm – the largest provider of wireless chipset and software technology – has created a network cloud solution supporting a diverse array of business units using network virtualisation infrastructure from Citrix and its alliance partners.



Attendees to this session heard directly from Qualcomm about:

- The business problem Qualcomm faced and how the network cloud business case was built
- The building blocks selected and the architecture that was put in place
- Benefits delivered to Qualcomm and its constituent.

With a project lasting nearly three years, Richter & Siddiqui managed a large complex global project and had to manually create a lot of the virtual infrastructure in the beginning. Starting with a proof

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of concept, they eventually finished with a fully automated Private cloud solution. They were an early adopter of the Citrix Cloud platform and worked closely with Citrix to ensure everything ran as advertised.

### What's new in Citrix CloudPlatform

#### Presenters:

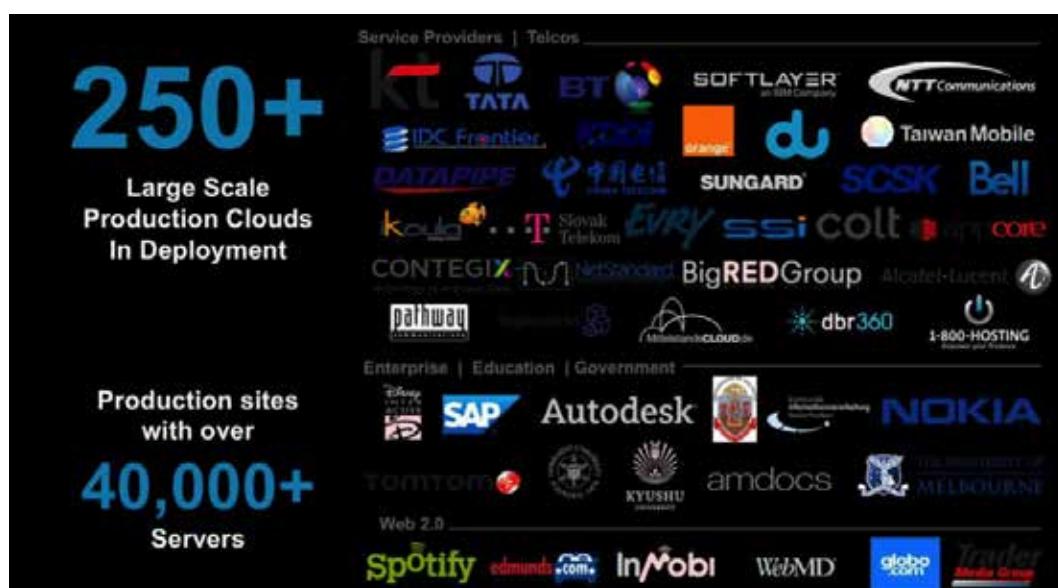
- Ken Lee, Sr. Director of Worldwide Product Marketing, Cloud Platforms Group, Citrix Systems, Inc.
- Manan Shah, Principal Product Manager, Cloud Orchestration, Citrix Systems, Inc.

#### Session Description:

The latest features and customer use cases for Citrix CloudPlatform, the industry-leading cloud orchestration, provisioning and management platform were presented. This session highlighted enhanced support for the latest and most widely used virtualisation platforms, including Hyper-V and vSphere, enhanced VPN support and software-defined networking (SDN) and improved capabilities for management, high availability and scalability.

In this session, attendees learnt about:

- What's new in the latest release of CloudPlatform
- How CloudPlatform 4.3 features enhance agility and operational and cost efficiencies
- About expanded CloudPlatform use cases for Citrix XenDesktop cloud provisioning and SDN.



(Shah & Lee, Sr, 2014)

The open source Apache CloudStack platform makes up a good part of the Citrix CloudPlatform and Citrix are one of the original developers of this highly regarded cloud solution. The Fellow was able to gain an insight into how Citrix are progressing with the development with this package and how it currently sits in the market today.

Training resources have also been identified that can be used to develop a cloud training program.

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### **Real World Pavilion: Become a Citrix IT Academy: Free Training and Student Career Preparation**

#### **Presenter:**

- David Brooks, Teacher, Higher Education Lecturer, Centre for ICT, Box Hill Institute

#### **Session Summary:**

The Fellow, Brooks, Industry Program Coordinator and Instructor at Box Hill Institute in Melbourne, Australia, presented the benefits an institution can gain by becoming a Citrix IT Academy. The Citrix IT Academy is a multi-week program that leverages the same best practices that Citrix uses to train customers, partners and its own technical staff. Students take Citrix courses as a part of a degree or certificate program at the college or university by faculty that are authorised by Citrix to deliver.

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### Destination 3: Citrix Systems Inc

Meeting with Gina Alesse, Senior Manager, Learning Design and Development, Citrix Education, May 8, 2014, Anaheim, CA.



#### Objectives

During this meeting the Fellow sought to establish an ongoing collegiate relationship with Gina's team to gain access to programs and courses being developed for Citrix Education. These programs could then be integrated into various units within the IT and ICT training packages.

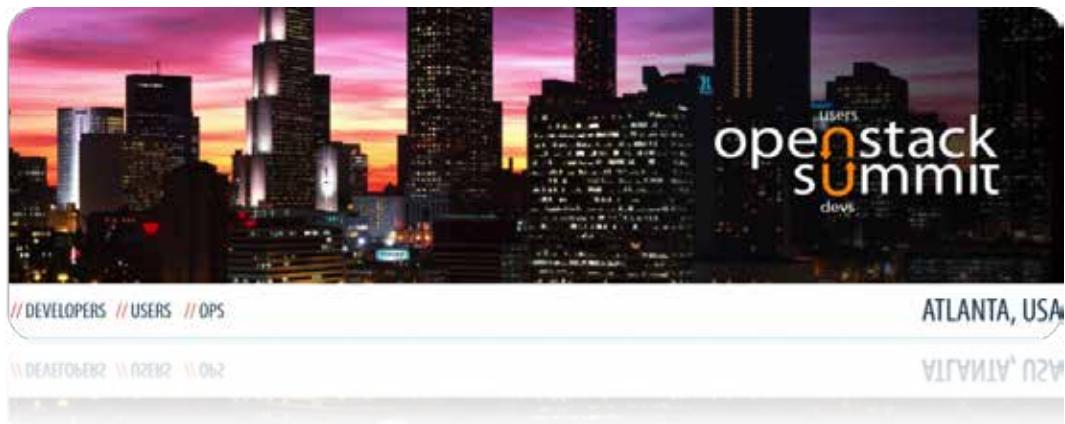
#### Outcomes

The Fellow has now established an ongoing consultative relationship with the Citrix Education team and is now providing a contribution into the development of various courses within the Citrix education program.

As new suitable training materials become available, Citrix will make available access to resource material via their Citrix IT Academy program.

The Fellow would also especially like to thank Dan Myers, Worldwide Academic Programs Manager of Citrix Systems for his help in facilitating this component of the Fellowship research including access to individuals within Citrix and allowing the Fellow to participate in the round table discussions.

### OpenStack Summit 2014



Online Attendee, May 12-16, 2014, Georgia World Congress Center, Atlanta, Georgia

<https://www.openstack.org/summit/openstack-summit-atlanta-2014/>

The Fellow became aware of this conference while attending Citrix Synergy and as it was on the other side of the USA, attending in person wasn't logically possible. Given OpenStack appears to becoming the de facto choice for open source cloud solutions, it was imperative that any outcomes from this conference be included in this research. Fortunately, the Fellow was able to register as an online attendee and obtain access to the four days of technology sessions and keynotes that were presented.

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### Objectives

OpenStack began life as a joint project in 2010 between cloud provider Rackspace hosting and NASA.

Soon after it was released to the open source community with the OpenStack Foundation being formed in 2012. Presently, over 200 companies are now contributing to the OpenStack project. They include almost all of the leading technology vendors such as Arista Networks, AT&T, AMD, Avaya, Canonical, Cisco, Citrix, Dell, eBay, EMC, Ericsson, Fujitsu, Hewlett-Packard, IBM, Intel, Microsoft, NEC, NetApp, Nexenta, Nokia, Oracle, Red Hat, SUSE Linux, VMware and Yahoo!

OpenStack is a cloud operating system that allows an organisation to build their own private or public cloud infrastructure. It's modular by design and consists of a series of components that make up the entire package. These services include:

- Compute (Nova)
- Object Storage (Swift)
- Block Storage (Cinder)
- Networking (Neutron)
- Dashboard (Horizon)
- Identity Service (Keystone)
- Image Service (Glance)
- Telemetry (Ceilometer)
- Orchestration (Heat)
- Database (Trove)
- Elastic Map Reduce (Sahara)

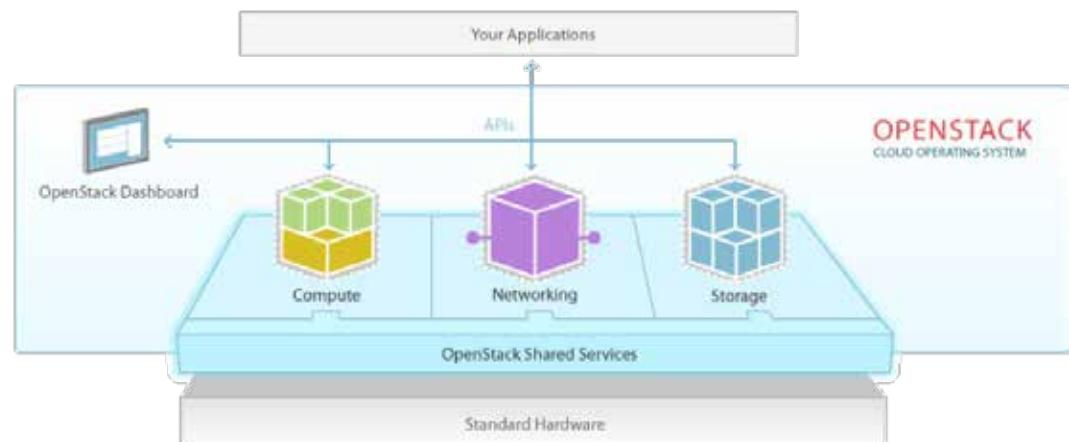


Image copyright: [www.OpenStack.org](http://www.OpenStack.org)

OpenStack has gone through a continual development process since its inception and is now becoming a mainstream solution for many organisations looking to embrace cloud based technologies. The ability to communicate with public cloud providers such as Amazon Web Services has also seen a wide adoption of the platform by companies looking to balance workloads between privately managed infrastructure and publicly hosted cloud providers.

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The Fellow attended the following technology sessions:

### Opening Keynote: Rise of the Superuser

#### Speakers:

- Jonathan Bryce, Executive Director, OpenStack Foundation
- Glenn Ferguson, Head of Private Cloud Enablement, Wells Fargo Bank
- Chris Launey, Director, Cloud Services & Architecture, Walt Disney Company

#### Keynote Summary:

Over the last year, there has been a shift in the OpenStack community, as users are speaking up directly and with the help of their technology partners to make an impact on the software produced. There has also been significant learning in how these users are pioneering changes in their own organisations and helping them become more competitive. In this session, Jonathan Bryce introduced the growing community of OpenStack Superusers, including special guests Glenn Ferguson of Wells Fargo Bank and Chris Launey of Walt Disney Company.



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(Bryce, Ferguson, & Launey, 2014)

This session gave a broad overview of how large organisations are developing their own cloud capability using OpenStack and its associated technologies. The key takeaway from this session that the Fellow observed is that OpenStack is now well and truly a viable platform for organisations wanting to create and manage their own private cloud infrastructure.

The Fellow did note that Disney is not placing all its eggs in one basket as they are also using the Citrix CloudPlatform as well.

### Rackspace Keynote: Just Rebels? Or A Rebel Alliance?

#### **Speaker:**

- Troy Toman, Rackspace

OpenStack's remarkable progress, traction with users and vibrant community changed the course of computing. But that's not enough to keep this thing going in the face of intensified competition and mounting complexity. Now we have to get big. That means extending what the cloud can be, embracing interoperability and engaging more diverse contributors. It means coming together to define what users need and making it strong enough to scale.



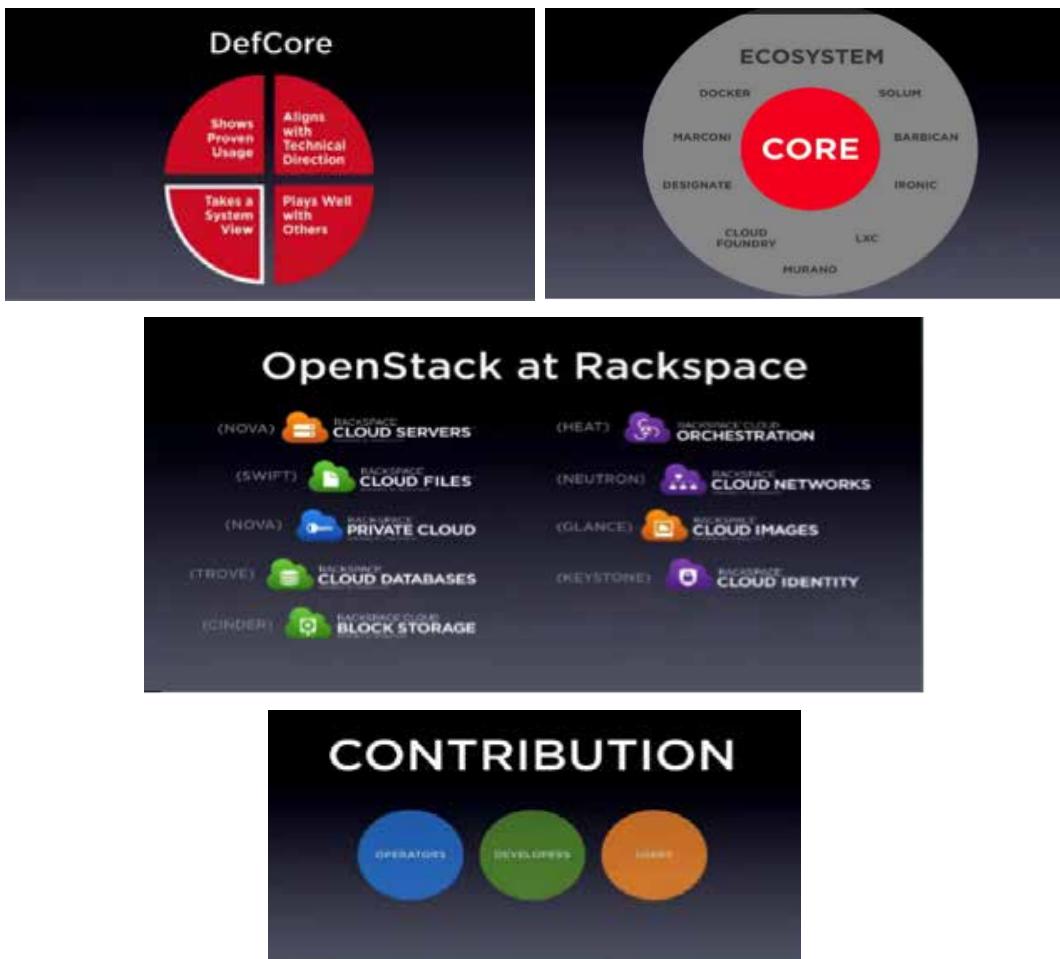
(Toman, 2014)

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This session delved into not only what the OpenStack foundation is doing, but also what its competitors are doing to keep open source solutions out of the cloud solutions marketplace. Troy's vision is for a planet scale cloud OS and his presentation included multiple testimonials from OpenStack adopters from around the world including CERN, Internet2, Argonne National Laboratory and the University of Notre Dame. Troy's biggest challenge is ensuring interoperability between multiple cloud platforms and providers. To this end a process known as DefCore has established a minimum baseline that must be met to ensure interoperability.

To achieve this broad this aim, Troy is planning to engage the operator and user community to ensure developers are giving the OpenStack community what they need and want.



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### Dell Keynote: Innovation in the Enterprise, Powered by OpenStack

#### Speakers:

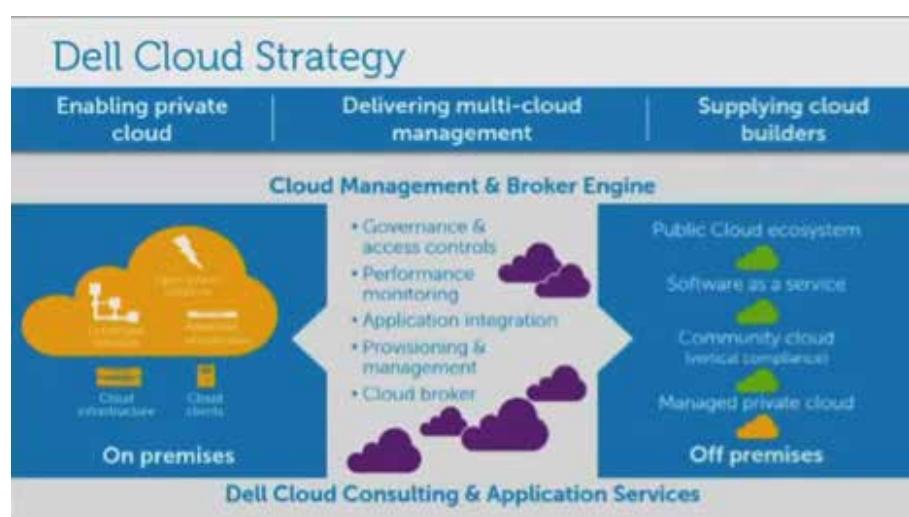
- Sam Greenblatt, VP & Chief Technology Officer, Enterprise Solutions Group,
- Tim Yeaton, SVP Red Hat

#### Session Content:

This session covered Dell's perspective for how OpenStack is creating innovation in the enterprise today and in the future. Sam was joined by Tim Yeaton, SVP Red Hat, to discuss how Red Hat and Dell will collaborate to provide upstream contributions to OpenStack and how they will make enterprises of all types successful with OpenStack.



(Greenblatt & Yeaton, 2014)



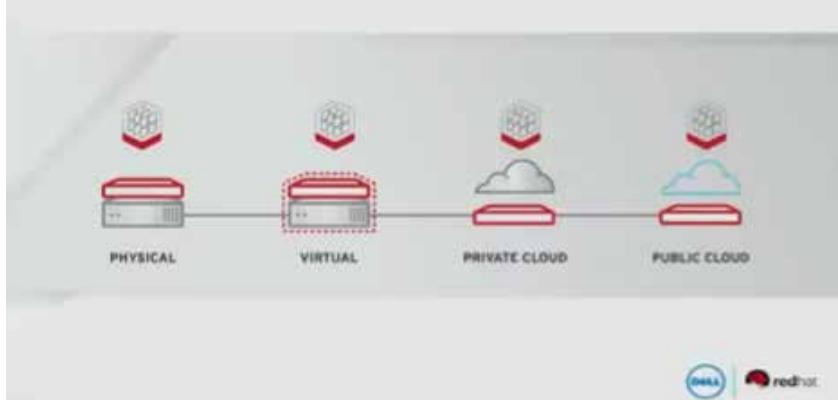
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As one of the largest server hardware providers in the world today, Dell is positioning itself to become a major player in the OpenStack and private cloud industry.

The diagram illustrates the integration of Dell and Red Hat technologies. It features a central horizontal bar representing the OpenStack architecture, with icons for each of its major components: Nova, Glance, Swift, Neutron, Cinder, Heat, and Octavia. Above this bar is the Dell logo, and to its right is the Red Hat logo. To the far right, the OpenStack logo is also present.

## Technology vision: open hybrid cloud



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By partnering with Red Hat, Dell has established itself as a bona fide cloud solutions provider. The Fellow's employer (Box Hill Institute) is a Dell partner, so he will be investigating the possibility of bringing Dell on-board to help develop OpenStack training resources.

### The Future of OpenStack Networking

#### **Speakers:**

- Kyle Mestery - Neutron Core and Principal Engineer at Cisco
- Chris Wright - Red Hat SDN Team leader
- Dan Conde - Director of Products at Midokura
- Nils Swart - Director of Business Development and Strategy at Plexxi

#### **Session Content:**

This panel discussion brought together a group of industry and thought leaders to look back on where OpenStack Neutron has gone and discussed where networking can evolve in the future. The panel explored topics such as:

- Neutron vs Nova network
- Support for new APIs and policy models
- Requirements for network services
- Interactions with Open Daylight
- Network operational requirements.



(Mestery, Wright, Conde, & Swart, 2014)

Neutron and Nova are the two modules that provide network connectivity to OpenStack with Neutron being the newer of the two and also the module that provides greater functionality when managing a multi-tenant cloud environment. From an educational standpoint the Fellow has observed that getting things up and running using the Nova module is the best option when first introducing students to an OpenStack environment. Once all the pieces of the puzzle are in place, then installing the Neutron module will allow the addition of greater network functionality.

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### Under the Hood with Nova, Libvirt, and KVM

#### **Speaker:**

- Rafi Khardalian, CTO, Metacloud

#### **Session Content:**

The Libvirt driver for Nova is one of the most comprehensive implementations across all supported hypervisors. It is quite common for new functionality to be added Libvirt before it hits the others. API calls to manage instances generally translate to a complex set of interactions between Nova, Libvirt and QEMU/KVM.

During this talk, Rafi went under the hood to explain what KVM hypervisors are doing when various requests are made. This included a deep dive into the sequence of operations when an instance is spawned, resized, migrated (live and cold), rebuilt amongst others. Also covered were some of the new functionality recently added for OpenStack Ice House as well as the new Libvirt and KVM capabilities driving Nova-related development.



(Khardalian, 2014)

The most common function of the Nova module is the Compute function. This allows OpenStack to communicate with the various supported Hypervisors that provide the virtual machines that cloud users can access to build and create cloud services.

Libvirt and QEMU/KVM are some of the more popular hypervisors as they are usually bundled with the various Linux distributions that make up the more popular implementations of OpenStack. These include Red Hat, Ubuntu and Suse, just to name a few.

Larger enterprises may be running more proprietary hypervisor solutions such as VMware's ESXi or Microsoft's Hyper-V and these were not discussed during the session.

The Fellow's observation of this session is that there is a strong bias to using open source solutions being pushed by the various Linux vendors as this gives them a greater level of control as well as a common platform. This however is being resisted by many of the larger enterprise users who already have a great deal invested in hypervisor solutions from the two largest vendors in this space, namely VMware and Microsoft. Both VMware and Microsoft are also members of the OpenStack foundation with the former working rapidly to fully integrate OpenStack based solutions into their cloud solutions.

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### OpenStack and the Transformation of the Data Center

#### Speaker:

- Lew Tucker, Vice President and Chief Technology Officer, Cloud Computing, Cisco Systems Vice President, OpenStack Foundation.

## OpenStack and the Transformation of the Data Center

Lew Tucker, VP/CTO Cloud Computing, Cisco

#### Session Content:

As virtualisation and cloud computing moves forward, the traditional data centre as we know it is being transformed; changing into a large, highly automated fabric of physical systems and virtualised services. Now controlled by software API's and automation, past systems for managing the complexity of data centre operations are being replaced by cloud platforms with new models driven by software, DevOps, analytics and big data.

### The Growth of the Internet Is Impacting All Aspects of IT



OpenStack is right in the centre of this transformation. As a collection of loosely coupled services, not only is OpenStack creating a rich platform for building and deploying applications, it's changing the way in which the data centres themselves are operated. OpenStack is quickly becoming a new layer in the software stack in the data centre, managing infrastructure below and orchestrating applications above.

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OpenStack itself keeps evolving, introducing new services and capabilities with each new release. It is now playing a role orchestrating anything that can be deployed as a virtual machine including virtualised network functions (NFV) such as firewalls, VPN's and load balancers. Major ISP's and others in the telecom industry are therefore looking to NFV to not only lower the operational cost of deployments and upgrades, but to also provide a basis for offering innovative new services to their customers. Lastly, these trends also intersect with the exploding interest in big data and network analytics. When combined, OpenStack, NFV, big data, and analytics together are driving this transformation of the data centre and change the very definition of infrastructure services across our industry.

(Tucker, 2014)

While this session was primarily about Cisco's observations and predictions of where they believe OpenStack is headed, it also gave great insight into where the world's largest network vendor is attempting to position itself to ensure that any future plans that many vendors or enterprises have will include Cisco technologies as a core solution. Cisco is developing SDN controllers that will add a layer of abstraction and programmability at both the control plane and data application level within the data centre. Their newly announced InterCloud service is pitched at providing a bridge between various cloud platforms and is already being adopted by large global enterprises.

Cisco Systems are also a foundation member of both the OpenStack foundation and the Open Networking Foundation.

Other sessions the Fellow attended over the four days of the OpenStack Summit included:

### Day One

#### Cloud Foundry, OpenStack, and the Enterprise Developer

##### **Speaker:**

- Nick Walker, Hewlett Packard.

##### **Session Content:**

Enterprise developers want the ability to easily develop and seamlessly deploy applications across

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a variety of cloud-based platforms. Sounds simple but in order to achieve this we will need open and flexible architectures. This session discussed the importance of open source technology for the enterprise developer and the role of Cloud Foundry and OpenStack.

(Walker, 2014)

Cloud foundry is yet another cloud solution, in this case from EMC/VMware spinoff Pivotal. Cloud Foundry offers a platform as a service solution and with the increasing adoption of OpenStack; they have positioned themselves to ensure that their offerings will integrate with OpenStack based cloud platforms.

### Bridging the Gap - OpenStack for VMware Administrators

#### Speakers:

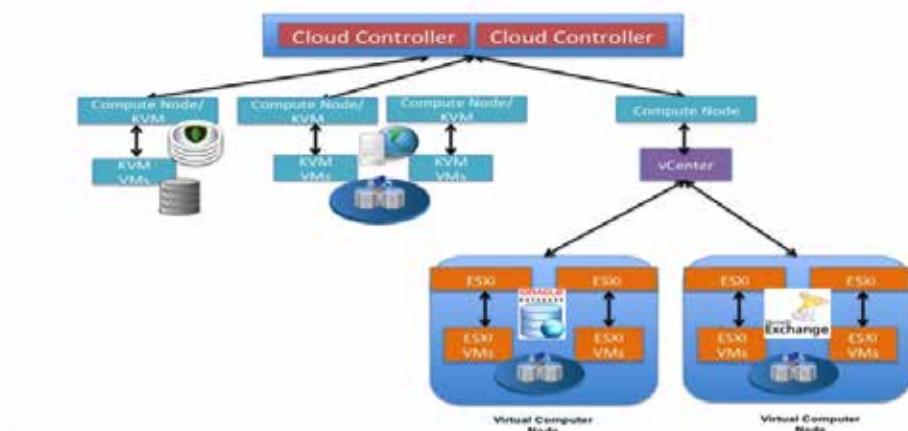
- Kenneth Hui – Technology Evangelist, Rackspace
- Scott Lowe – Engineering Architect; VMware

#### Session Content:

As OpenStack continues to grow, Enterprises are beginning to explore and to implement OpenStack as their Cloud platform of choice. Often, these companies have existing investments and expertise with VMware technologies. In order to prepare for this new world, these people who are familiar with VMware concepts and terminology will need to understand the parallel concepts and terminology in OpenStack. In this keynote, a VMware veteran who has moved from the VMware space into the OpenStack space talked about how to bridge the gap between vSphere and OpenStack concepts.

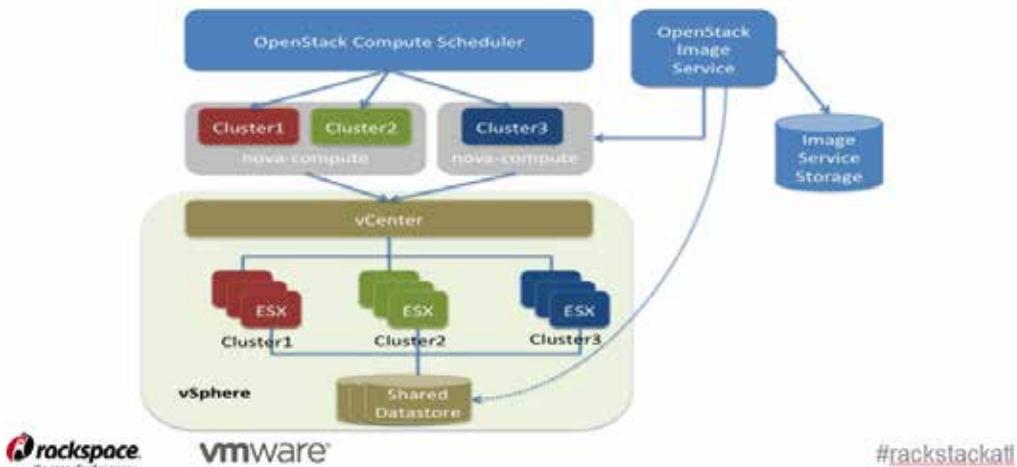
This session was of great benefit to anyone who needs a better grasp of how to talk about both VMware and OpenStack in an enterprise context. Also explored was the concept of Cloud-native applications and the differences between operating a VMware environment and an OpenStack Cloud platform. Finally, Scott discussed how VMware, as a company, has been bridging these two worlds by integrating their technologies with OpenStack in both the Havana and Icehouse releases.

### Multi-hypervisor OpenStack architecture



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### vSphere in OpenStack



(Lowe & Hui, 2014)

Scott Lowe is considered an expert in VMware technologies and has written many books for and about VMware products over the years. He has also been a keynote speaker at the last three VMware user group conferences in Melbourne that the Fellow has attended. The presentation delivered here has gone a long way to demonstrating that the OpenStack and VMware vSphere technologies can not only co-exist, but they can be fully integrated to complement each other.

As the Fellow has come from a very similar IT background and hearing this information from someone of Scott's calibre has reinforced the Fellow's hypothesis on where the private cloud technology area is headed.

### Software Defined Networking Performance and Architecture Evaluation

#### Speakers:

- Jason Venner, Symantec
- Vijay Seshadr, Symantec

#### Session Content:

This presentation covered architectural and performance characteristics of what an Overlay network is compared to a straight VLAN based environment on a cluster size of 100+ nodes. Over the last three months, Symantec has run extensive performance and diagnostics tests across multiple overlay providers as well as against the base Neutron VLAN configurations and have come to several insights into CPU penalties, Network design issues at scale as well as performance comparisons using different encapsulation techniques. The presenters explained what their architectural design was, the results of their testing as well as their design insights into how Symantec's cloud will be affected by the outcome of the evaluation.

(Venner & Seshadri, 2014)

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### New OpenStack Tools and Solutions

#### **Speakers:**

- Pete Johnson, CliQr Technologies
- Uri Cohen, GigaSpaces.

#### **Session Content:**

HP Cloud development partners showcased their latest OpenStack based tools, solutions and contributions. In this panel presentation, these pacesetters presented their newest offerings and explained how OpenStack is facilitating a new groundswell of ideas to power success in the cloud.

(Johnson & Cohen, 2014)

### OpenStack as the Key Engine of NFV

#### **Speakers:**

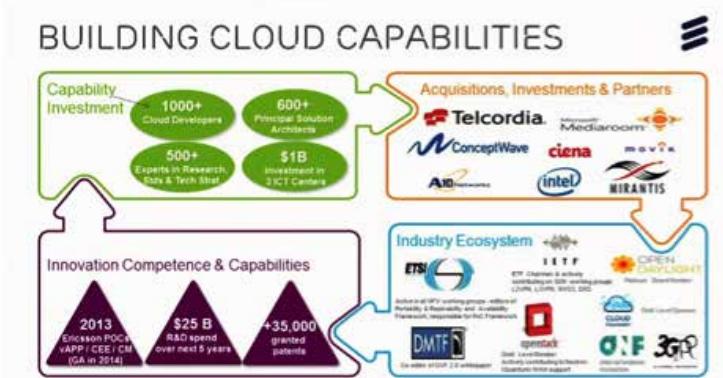
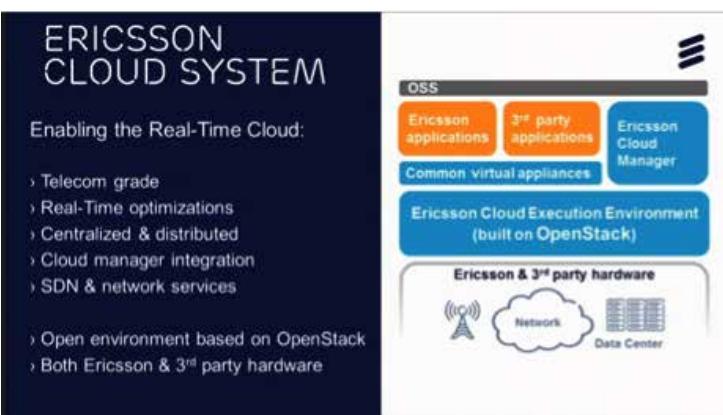
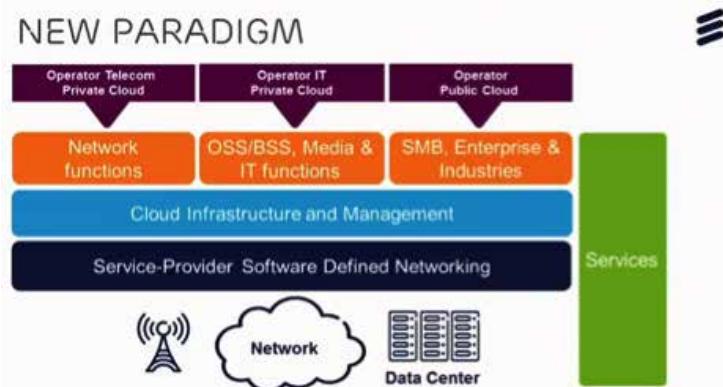
- Alan Kavanagh, Ericsson
- Jan Söderström, Ericsson.

#### **Session Content:**

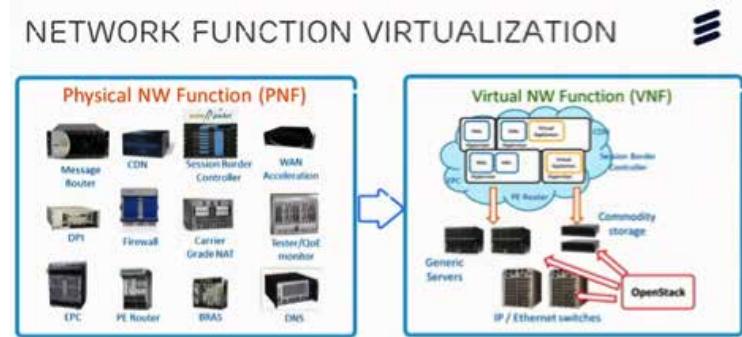
Understanding the building blocks of a carrier-grade OpenStack as the key foundation of a state of the art NFV.



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As a provider of network technology to the Telco/carrier community, Ericsson are no longer in the phone business. That business was sold to Sony. Today they are a well-established cloud service provider. Alan Kavanagh proceeded to detail Ericsson's contribution to the OpenStack foundation in the form of Network Function virtualisation (NFV) appliances that replicate the functions of a typical data centre network infrastructure. Most of these proposed changes are due for release in the next version of OpenStack (Juno).

(Kavanagh & Söderström, 2014)

### Day Two

#### OpenStack Training - Community Created and Delivered Training for OpenStack

##### Speakers:

- Colin McNamara, Chief Cloud Architect, Nexus/Dimension Data
- Sean Roberts, OpenStack Release Manager, Yahoo



(McNamara & Roberts, 2014)

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As an educator, the Fellow was very interested in how an open source organisation would be able to organise training given the constraints that would be present in this environment.

Most vendor based education and training programs are funded with a view to selling more products and are then budgeted accordingly. They are essentially an extension of the vendors marketing department.

Some examples of this are the Cisco Networking Academy program, VMware IT Academy and the Microsoft IT academy program. Rackspace do provide limited instructor training to individual teachers, but only in the USA.

McNamara and Roberts have come up with a very innovative idea in that they have engaged the OpenStack user group community to get on board and create 'Meetup' groups around the world. These groups meet on a regular basis and using detailed training resources created by McNamara and Roberts and donated to the OpenStack foundation, are able to deliver community based training programs.

Commercial trainers are also encouraged to use the materials for profit, should they choose to, providing they adhere to the Creative Commons licenses attached to the training materials.

The programs are designed for:

- OpenStack Associate Engineer.
- OpenStack Operations Engineer.
- OpenStack Development Engineer.
- OpenStack DevOps Architect (still in development).

A Melbourne chapter of the OpenStack user group meets regularly and the Fellow will engage this community in using the materials and developing training programs for the local market.

### Demo (IBM) Build an OpenStack Cluster before Lunch, Scale Globally by Supper with IBM & SoftLayer

#### Speakers:

- Michael Fork, IBM
- Nina Goradia, IBM



(Fork & Goradia, 2014)

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This brief 15-minute demonstration showed how to build and configure an OpenStack cloud environment using IBM's SoftLayer cloud platform. From initial provisioning to ready for use took roughly nine hours from start to finish. The SoftLayer model uses a pay by the hour model for access to either bare metal or virtual hardware and can be hosted in data centres around the world. Costing to build a three node OpenStack cloud lab is quite cheap and worked out to roughly \$US10 per day. Use of such a platform for classroom training would be cost prohibitive over a typical 10 week term or 13 week semester. However, the SoftLayer model would be very cost efficient if classes were run in a boot camp style environment over three to five consecutive days.

### **Planning Your OpenStack Cloud Project**

#### **Speaker:**

- Francesco Paola , CEO, Solinea

#### **Session Content:**

Drawing on their experience planning, integrating and operating OpenStack clouds for large enterprises, the speakers presented sample scopes, project plans, budgets and staffing levels to build and operate moderate sized clouds. Along the way, they shared best practice and common pitfalls in the process.

(Paola, 2014)

### **Leveraging OpenStack to Solve Telco Needs (Intro to SDN NFV)**

#### **Speakers:**

- Toby Ford, AT&T
- Mats Karlsson, Ericsson.

#### **Session Content:**

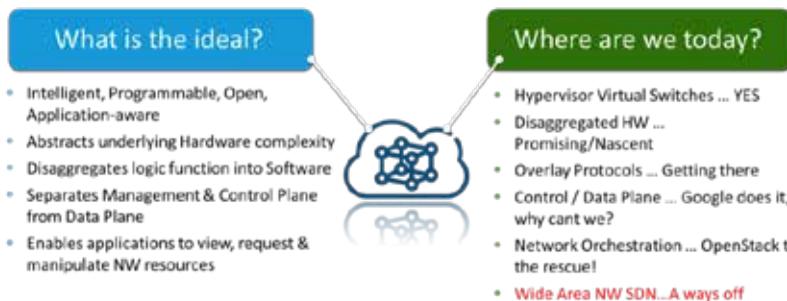
AT&T and Ericsson co-presented a keynote on the topic of leveraging OpenStack to Solve a Telco/Cable Company's needs, with an introduction to NFV (Network Function Virtualization) and SDN (Software Defined Networks). By providing this basic information, they are trying to drum up support for making OpenStack cover these unique requirements and to kick off building a community around driving Telco/Cable company requirements/blueprints into OpenStack.

(Ford & Karlsson, 2014)

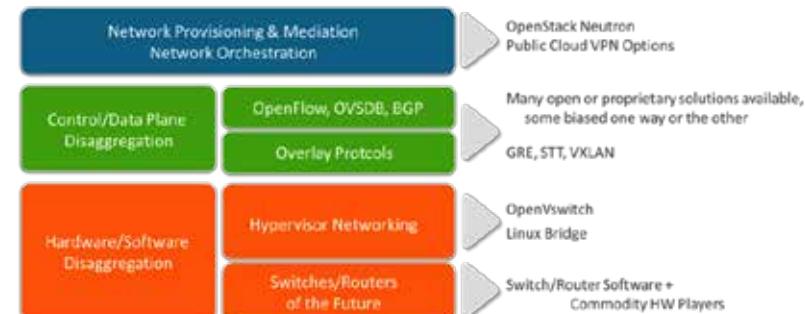
## 6. THE INTERNATIONAL EXPERIENCE

### Software Defined Networks

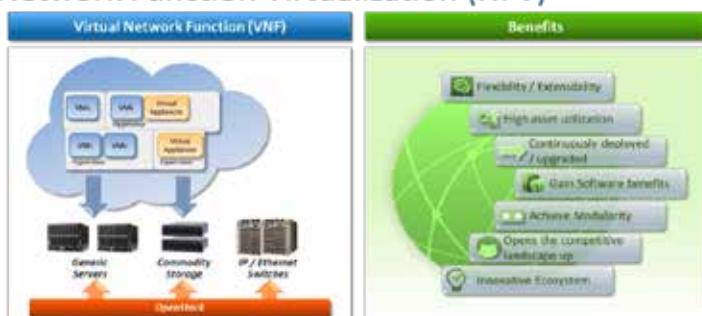
A Carrier Perspective



### "SDN" in a Data Center context



### Network Function Virtualization (NFV)



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This session was a good insight into how a large Telco is attempting to drive innovation and encourage the wider OpenStack community to embrace their way of thinking when designing new network features in the OpenStack platform. Ericsson is also contributing to this development and the Fellow attended an earlier session on their technology roadmap for SDN and NFV. The benefits of embracing NFV and SDN are enormous and the Telco/Carrier industry will definitely be pushing hard for their feature requests to be adopted. Both AT&T and Ericsson are foundation members of the OpenStack foundation, so the likelihood of the NFV features appearing in the not too distant future are very high.

### Open Networking and SDN for OpenStack Cloud

#### **Speaker:**

- Adnan Bhutta, Dell.

#### **Session Content:**

This session discussed how today's software defined enterprises need agile networks and discuss the shift toward disaggregation of the operating system: from networking hardware and its key benefits. Adnan also took a closer look at how Open Networking could help enable Software Defined Networks (SDN) and Network Virtual Overlay (NVO).

(Bhutta, 2014)

Adnan's session covered some of the developments that Dell has been working on. Namely a series of generic 'white box' switches/network appliances that can be loaded with various network operating systems and then used to implement SDN related services.

### Day Three

### Building an OpenStack Community in your Neighbourhood

#### **Speaker:**

- David Medberry, OpenStack User Group

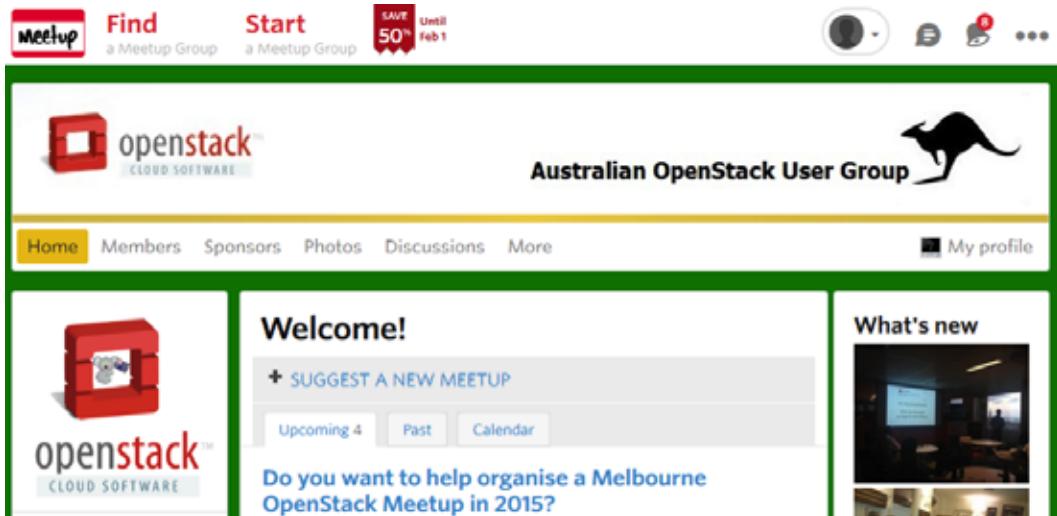
#### **Session Content:**

Colorado is one of the hubs of OpenStack development, though it is not as natural as it is in Austin, San Antonio, or the greater Bay area. They are fairly distributed and they've had to do a little work to create a presence. By using personal connections, IRC and Meetups, they've built a community. This session talked about what 'community' means in a region where there is no natural centre point. OpenStack expertise and interest is sprinkled broadly throughout the Denver Metro, Boulder and Northern Colorado area and they do some things to make it feel like a tighter community.

(Medberry, 2014)

David's presentation was being streamed live via YouTube for the OpenStack summit and also to his local OpenStack group back in Colorado. Use of the resources at Meetup.com to arrange the meetings is common and helps to bring together a community of users with common interests. Google Hangouts is also used to record and stream the meetings live online. There is already a local OpenStack users group in Melbourne and the Fellow is in the process of engaging with them.

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The screenshot shows the homepage of the Australian OpenStack User Group on Meetup.com. At the top, there are navigation links for 'Find' and 'Start' Meetup Groups, and a 'SAVE 50% Until Feb 1' promotional banner. The main header features the OpenStack logo and the text 'Australian OpenStack User Group' next to a silhouette of a kangaroo. Below the header, a navigation bar includes 'Home', 'Members', 'Sponsors', 'Photos', 'Discussions', 'More', and 'My profile'. The 'Home' tab is selected. The main content area has a green header 'Welcome!' with a 'SUGGEST A NEW MEETUP' button and tabs for 'Upcoming 4', 'Past', and 'Calendar'. A call-to-action message reads 'Do you want to help organise a Melbourne OpenStack Meetup in 2015?'. To the right, a 'What's new' section shows thumbnail images of recent meetups.

### The Battle of the Distros - Which One is better for My Cloud



The screenshot shows a presentation slide titled 'The Battle of the Distros' by Edgar Magana, Principal Engineer, at the May 14, 2014 Atlanta OpenStack Summit. The slide features the Cisco logo and the subtitle 'Which one is better for my Cloud'. It includes a bio for Edgar Magana and the date of the presentation.

#### Speakers:

- Edgar Magana, Principal Engineer, Cisco Systems
- Robert Stoermer, OneCloud.

#### Session Content:

OpenStack is a powerful open-source cloud management system. Multiple services, databases, configuration files, messaging queues and runtime agents are needed to realise its full potential. This is obviously not easy to deploy in production and, even more important, to monitor and troubleshoot potential issues. OpenStack distributions provide a solution to all the above-mentioned problems. In this session Edgar explored the most popular OpenStack distributions on the market. He talked openly about pros and cons for each, with clear fair parameters for all of them. OpenStack users attending this session got a better idea of all available distributions and clarity around the important questions to ask when they look for a distribution and what is beneficial for all users. Edgar evaluated whether it is possible to independently support an OpenStack deployment, without any company behind their data centres and if it is how much investment is needed.

(Magana & Stoermer, 2014)

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Edgar's presentation was interesting as it came from an individual who had no ties to any of the vendors offering an OpenStack distribution (while Cisco is a contributor to OpenStack they don't offer an OpenStack distribution). With over twenty different vendors offering OpenStack distributions, deciding on which vendor to choose can be fraught with risks.

### OpenStack Distros vs Products - Are they the same?

- Distribution: It is basically the open source "trunk" code that is packaged without a "lot" of proprietary components on top of it ready for production.
  - » Mirantis
  - » RDO
  - » Suse
  - » Rackspace
  - » ...
- Product: It is a personalised version of the "released" code with :proprietary" feautres and unique deployment model considered as a final product.
  - » Nebula
  - » CloudScaling
  - » PistonCloud

### Factors to consider when choosing a vendor

- Hardware - OS - Hypervisor
- Reference Architecture (High Availability)
- Code Upgrades & Scalability
- Licensing - Cost Model
- Plugin and Drivers

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- Customer Support - Documentation
- Easy to use - Time to deploy

Edgar's methodology for choosing an OpenStack distribution is very thorough and he deliberately doesn't favour one particular vendor. The factors to consider are well thought out and give a user a good framework to base a well informed decision when deciding which distribution to adopt.

### **Getting from Enterprise Ready to Enterprise Bliss - Why OpenStack and IBM is a Match Made in Heaven**

#### **Speaker:**

- Todd Moore, Director for Open Technologies and partnerships, IBM

#### **Session Content:**

As a founding sponsor of the OpenStack Foundation, IBM's approach to OpenStack is simple - deliver high value contributions to OpenStack to make it THE best in class IaaS open source offering and then build IBM offerings on this foundation to deliver exceptional enterprise value to our clients. In this kick off presentation for the IBM Track, Todd Moore, Director of Open Technologies and Partnerships, provided the answer to one of the most frequently asked questions - how is IBM adopting OpenStack across IBM Cloud Offerings? This presentation detailed the imperative of an Open Cloud Architecture to ensure interoperability and to avoid vendor lock in and sets the context for the IBM track sessions which provide a deeper dive on some of the IBM offerings shipping with OpenStack today including SmartCloud Orchestrator and SoftLayer.

(Moore, 2014)

### **NetApp Storage for OpenStack**

#### **Speaker:**

- Robert Esker, NetApp

#### **Session Content:**

NetApp has been polishing and expanding its OpenStack integration over the last five OpenStack releases. Rob Esker detailed how NetApp has combined its rich set of storage; efficiency, data protection and security features for critical enterprise requirements with the power of OpenStack. Esker outlined how to consistently meet stringent SLAs for classic application infrastructures delivered; as a service; and deploy native cloud applications in a manner that is scalable, efficient, and cost effective and demonstrated the value of NetApp over a 'do-it-yourself' storage experiment that uses the lowest common denominator of components. The session was also an opportunity to discover how, together, OpenStack, the open-source cloud platform, and NetApp; Data ONTAP, the world's #1 storage operating system, are greater than the sum of their parts.

(Esker, 2014)

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The Fellow is a NetApp certified data administrator and was very interested in how NetApp would manage to integrate their proprietary technologies into an Open source architecture without giving away their valuable IP. Given NetApp has been involved in the last six releases of OpenStack, they have succeeded in fully integrating their Data ONTAP features seamlessly into both the block based storage module (Cinder) and also the object based storage module (Swift). As far as an OpenStack administrator is concerned, they are simply accessing the OpenStack plugin APIs to facilitate storage functions, the advanced NetApp features simply handle the workloads in the backend.

The Fellow also attended the following technology sessions that have not been summarised in this report:

- Linux Containers - NextGen Virtualization for Cloud
- Case Study: Georgia Tech - University Private Cloud for researchers.
- OpenStack Integration with OpenDaylight State of the Union and Future Directions
- Deploying OpenStack in a Multi-Hypervisor Enterprise Environment
- Open Cloud System 3.0 - OpenStack Architected Like AWS
- From Infrastructure Administrator To Cloud Architect
- VMware + OpenStack: Accelerating OpenStack in the Enterprise
- Deep-dive Demo for OpenStack on VMware
- Deploying OpenStack with Cisco Networking, Compute, and Storage
- OpenStack Distribution Support for vSphere plus NSX
- User Experience in the OpenStack Community
- Preparing to Deploy a Private Cloud
- Getting Started with OpenStack
- Integrating OpenStack with Active Directory (Because AD != LDAP)
- Hybrid Cloud with OpenStack - Bridging Two Worlds
- Leveraging VMware Technology To Build an Enterprise Grade OpenStack Cloud - It's Not Always About KVM!

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### **Outcomes**

Of all the cloud research conducted by the Fellow, it has become apparent that the OpenStack platform is well on the way to establishing itself as the de facto standard for many enterprises when choosing to create and manage a private cloud. The challenge now will be putting together a comprehensive cloud training program based around the OpenStack platform. Vendor lock in is another pitfall that will need to be avoided when developing this program as the OpenStack platform is being offered by over 20 different IT vendors. The Fellow is not trying to pick a winner and will keep an open mind during this process. At the present time, the most logical solution is to engage the OpenStack user community and draw on their experience to develop a comprehensive training program that meets the need of this emerging market segment.

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### Destination 4: Cisco Live! 2014

In person Attendee, May 18 - 22, 2014, Moscone Center, San Francisco, California

<http://www.ciscolive.com/us/>



Cisco Live! is one of the world's largest technology events with a focus on technology solutions driven by Cisco Systems.

#### Objectives

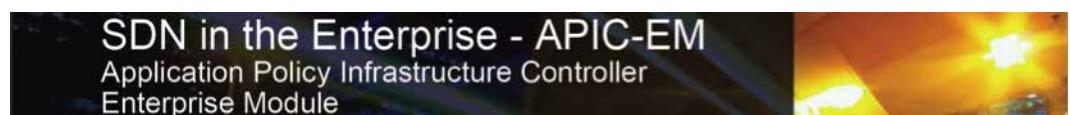
Software Defined Networking and Cloud technologies were the focus of the research conducted here. Over 25,000 in person attendees were at this event with another 200,000 attending online.

The Fellow attended multiple technology sessions including the following:

#### APIC-EM (Application Policy Infrastructure Controller - Enterprise Module) - SDN in the Enterprise

##### Speaker:

- Wolfgang Riedel - Principal Engineer - Engineering, Cisco Systems



##### Session Content:

After all the recent industry trends like Cloud Computing, Open Flow Networking, Software Defined Datacenter and Open Network and Compute Environment the idea of Software Defined Networks is still prevalent. Part one of the breakout session started with an overview of the different SDN controllers and techniques, available on the market and outline on the strategy Cisco pursues. Part two explained what Cisco is doing with Application Policy Infrastructure Controllers (APIC) in the Datacenter and what is happening with SDN controllers in the Enterprise. Part three focused on Enterprise SDN. Introducing

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the APIC Enterprise Module and explaining how it reduces network complexity, amplifies network intelligence and how it paves the way for heavy networking in the Next Generation of IT. (Riedel, 2014)

### The SDN Acronym Decoder Ring

- ✓ MSDC - Massive Scale Data Center
- ✓ EPDC - EnterPrise Data Center
- ✓ SDN - Software Defined Networking, Stanford Defined Networking, Still Don't Know, ...
- ✓ OF - Open Flow
- ✓ ODP, ODL - Linux Foundation OpenDaylight Project
- ✓ NFV - Network Function Virtualization, Services Chaining
- ✓ OS - OpenStack
- ✓ XNC - eXtensible Network Controller
- ✓ ONE - Open Networking Environment
- ✓ ACI - Application Centric Infrastructure
- ✓ onePK - Cisco ONE Platform Kit
- ✓ oneOK - Cisco ONE Developer Kit
- ✓ ESP, APIC-VTP - [Cisco Evolved Services Platform for Service Providers](#)
- ✓ Northbound-API - Application API (REST, WebSockets, OSGi)
- ✓ Southbound-API - Device APIs (onePK, OpenFlow, CLI, NetConf, ...)
- ✓ SAL - Service Abstraction Layer
- ✓ MDSAL - Model Driven SAL (Netconf, OF-Config/OVSDB, OF x.y, PCEP, BGP-LS, ...)

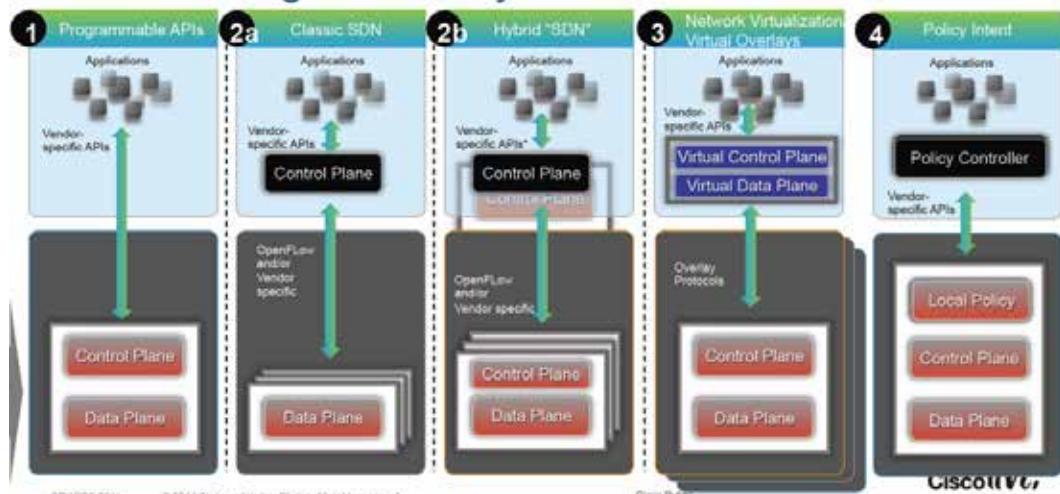


Cisco live!

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### Network Programmability Models



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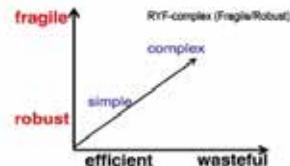
### SDN Controllers – Types

**There's nothing like "a SDN controller"**

- **SDN Config-Pusher**
  - Orchestration (robot micromanaging manual to-do's)
  - NCM (Network Configuration Management)
  - Customers may see or edit any part of the config
  - ✓ Prime Infrastructure, Action Packed, Solarwinds
  - ✓ Puppet, Chef
  - ✓ Openstack
  - ✓ Netconf
- **SDN Policy-Compiler**
  - Customer is never exposed to nor has access to nor influence over direct snippets of configuration elements.
  - They express their intent only – like in a programming language – and the conversion to machine language is invisible.
  - ✓ Cisco APIC-EM
- **SDN Policy-Enabler**
  - ✓ Cisco APIC-DC
- **SDN Overlay Controller**
  - ✓ VMWare: VCS, VCD, NSX
  - ✓ Cisco: VSM (N1kv), EVP
  - ✓ IBM: DOVE, MS (Windows Server, Microsoft System Center)
- **SDN Open Flow Controller**
  - ✓ next slide

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Five dimensions of robustness in complex systems  
 (1) Reliability  
 (2) Efficiency  
 (3) Scalability  
 (4) Modularity  
 (5) Evolvability

Addison and Doyle identify four kinds of constraints on system robustness:  
 (1) Component-level  
 (2) System-level  
 (3) Protocols  
 (4) Emergent constraints

Complex systems science as conflicting constraints  
 John C. Doyle, HOT and SF networks

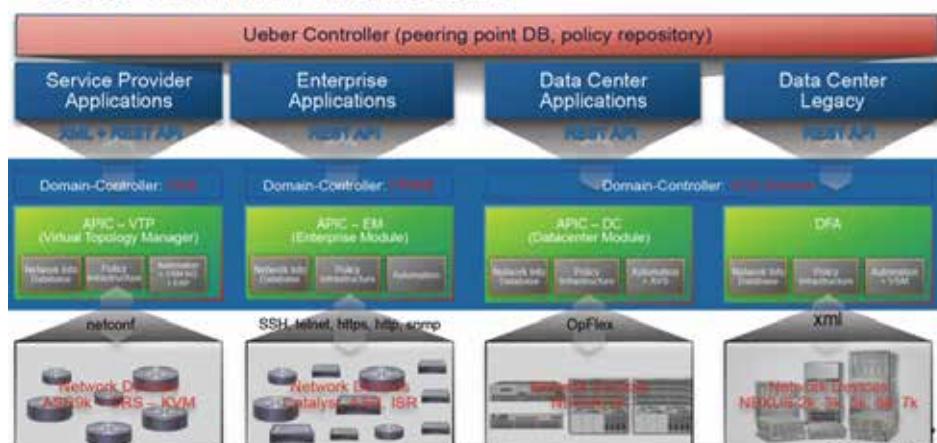
Cisco live!

### SDN Controllers – Types

**There's nothing like "a SDN controller"**

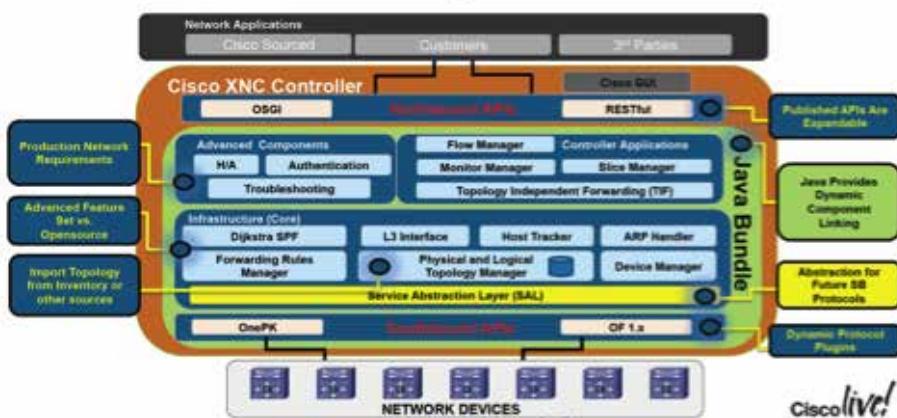
- **SDN Open Flow Controller**
  - ✓ **NOX** (C++/Python) NOX was the first OpenFlow controller.
  - ✓ **Pox** (Python) Pox is a general SDN controller that supports OpenFlow. It has a high-level SDN API including a queriable topology graph and support for virtualization.
  - ✓ **Jason** (Java) Jason is a NOX-dependent Java-based OpenFlow Controller.
  - ✓ **Trans** (C/Ruby) Trans is a full-stack framework for developing OpenFlow controllers in Ruby and C.
  - ✓ **Beacon** (Java) Beacon is a Java-based controller that supports both event-based and threaded operation.
  - ✓ **loodflow** (Java) The Floodlight controller is Java-based OpenFlow Controller. It was forked from the Beacon controller, originally developed by David Erickson at Stanford.
  - ✓ **Maestro** (Java) Maestro is an OpenFlow "operating system" for orchestrating network control applications.
  - ✓ **OpenOSS** (Java) OESS is an application to configure and control OpenFlow Enabled switches through a very simple and user friendly User Interface.
  - ✓ **Ryu** (Python) Ryu is an open-sourced Network Operating System (NOS) that supports OpenFlow.
  - ✓ **NodeFlow** (JavaScript) NodeFlow is an OpenFlow controller written in pure JavaScript for Node.js.
  - ✓ **microvisor** (C) Trivial reference controller packaged with Open vSwitch.
  - ✓ **RouteFlow** is an open source project to provide virtualized IP routing services over OpenFlow enabled hardware. RouteFlow is composed by an OpenFlow Controller application, an independent RouteFlow Server, and a virtual network environment that reproduces the connectivity of a physical infrastructure and runs IP routing engines (e.g. Quagga).
  - ✓ **FlowVisor** (Java) FlowVisor is a special purpose OpenFlow controller that acts as a transparent proxy between OpenFlow switches and multiple OpenFlow controllers.
  - ✓ **SNAC** (C++) SNAC is an OpenFlow controller built on NOX, which uses a web-based policy manager to manage the network.
  - ✓ **Resonance** Resonance is a Network Access Control application built using NOX and OpenFlow.
  - ✓ **OFlops** (C) OFlops (OpenFlow Operations Per Second) is a standalone controller that benchmarks various aspects of an OpenFlow switch.
  - ✓ **RouterFlow** RouterFlow is an open source project to provide virtualized IP routing services over OpenFlow enabled hardware. RouterFlow is composed by an OpenFlow Controller application, an independent RouterFlow Server, and a virtual network environment that reproduces the connectivity of a physical infrastructure and runs IP routing engines (e.g. Quagga).
  - ✓ **FlowVisor** (Java) FlowVisor is a special purpose OpenFlow controller that acts as a transparent proxy between OpenFlow switches and multiple OpenFlow controllers.
  - ✓ **XNC** Cisco Extensible Network Controller (XNC) is the first commercial version of the **microvisor** controller.
  - ✓ **OVS** Linux-Foundation: community-driven, open source controller framework (Brocade, Cisco, Citrix, Ericsson, IBM, Juniper, Microsoft, RedHat)

### Cisco Controller Architecture

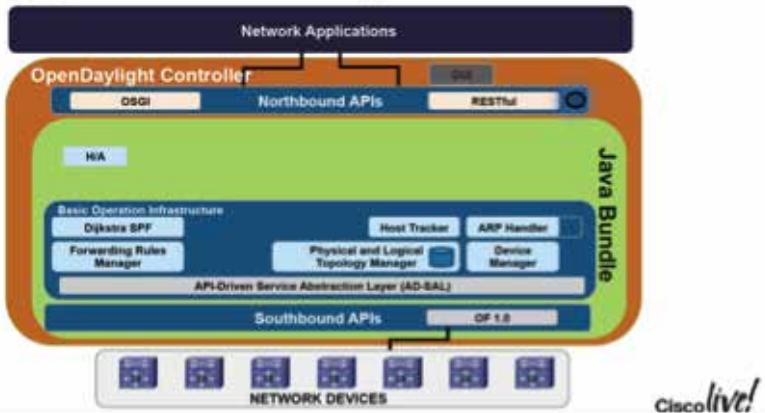


## 6. THE INTERNATIONAL EXPERIENCE

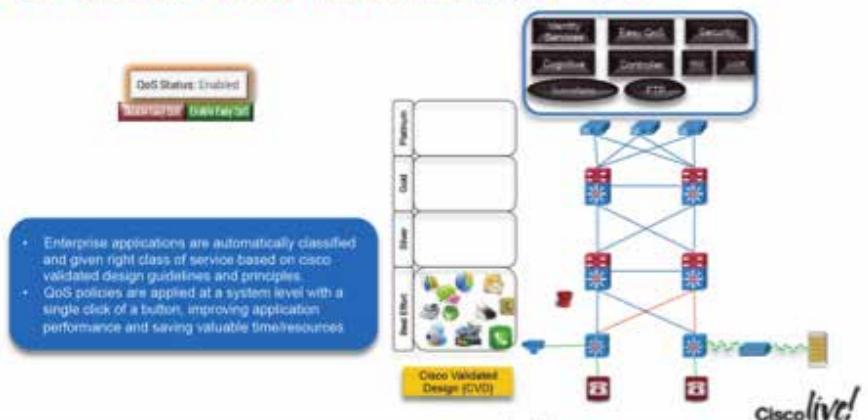
### Cisco XNC Controller - Java Application



### Open Daylight Controller - Java Application

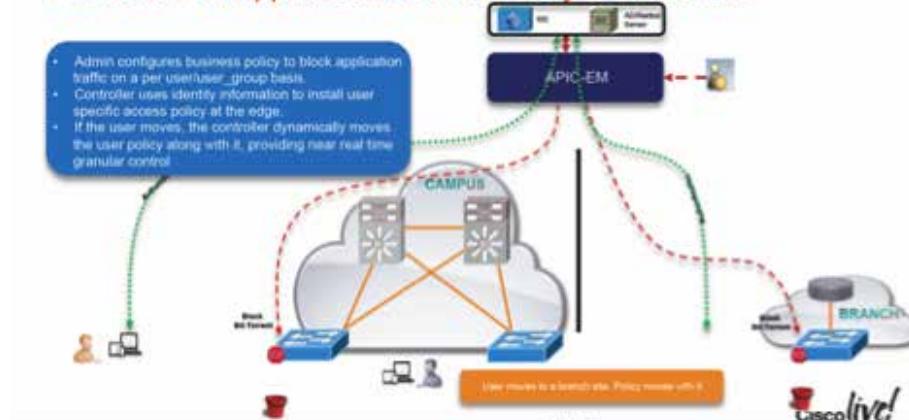


### Use Case: Traffic Prioritization One Click QoS Policy Enforcement (Easy QoS)



## 6. THE INTERNATIONAL EXPERIENCE

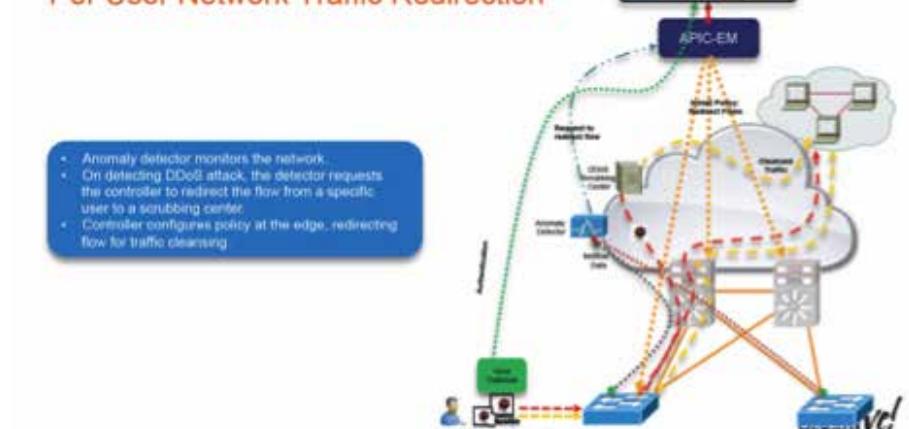
### Use Case: Granular Control Per User Per Application Access Policy Enforcement



### Use Case: Next Generation Security Management Sourcefire and APIC-EM

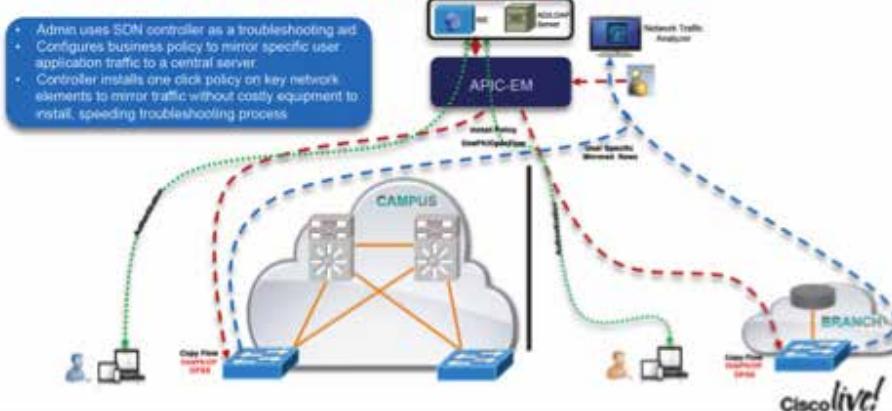


### Use Case: DDoS Protection: Per User Network Traffic Redirection

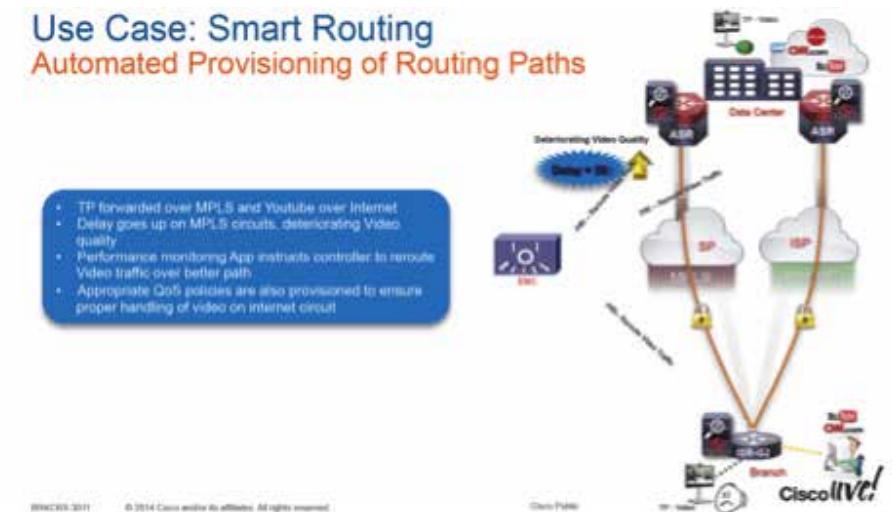


## 6. THE INTERNATIONAL EXPERIENCE

### Use Case: Traffic Monitoring Per User Per Application Network Traffic Tapping



### Use Case: Smart Routing Automated Provisioning of Routing Paths



This was the first of many technology sessions attended by the Fellow over the next four days and it was an interesting observation of how a large incumbent vendor has been effectively dragged into a new technology area by the weight of demand from the market. Many of the problems that SDN was designed to solve had already been solved by Cisco proprietary technologies and now they were being asked to contribute to the development of open source solutions that would eventually compete with their own offerings. To its credit, Cisco has taken a pragmatic approach and whilst contributing to the Open Networking foundations SDN developments; it has also ramped up development of their own solutions that will seamlessly integrate into this new open source driven world. Wolfgang's colourful presentation and honest appraisal of the current state of SDN was one of the highlights of the conference. The various use cases discussed also put into perspective where SDN could be used to best effect.

## 6. THE INTERNATIONAL EXPERIENCE

### Solving Real Network Challenges using SDN

## Solving Real Network Challenges Using SDN

Manny Garcia, Member of Technical Staff, Cisco

#### Speaker:

- Manny Garcia - Member of Technical Staff, Cisco Systems

#### Session Content:

This session provided an overview of Cisco IT's approach to SDN by presenting the opportunities and challenges faced in the integration of Cisco ONE technologies across their internal network. Examples of use cases with detailed, in depth under the hood discussions on how they are implemented were backed up by live demos. (Garcia, 2014)



### Cisco IT Lessons Learned...



"...In the SDN architecture, the control and data planes are decoupled, network intelligence and state are logically centralized, and the underlying network infrastructure is abstracted from the applications..."  
<https://www.opennetworking.org/images/stories/downloads/white-papers/wp-sdn-newnorm.pdf>



"...open standard that enables researchers to run experimental protocols in campus networks. Provides standard hook for researchers to run experiments, without exposing internal working of vendor devices....."  
<http://www.openflow.org/wp/learnmore/>



"Cisco Open Network Environment (ONE) is a comprehensive solution to help networks become more open, programmable, and application-aware. The broad capabilities of Cisco ONE help meet the needs of numerous market segments, including emerging concepts such as software-defined networking (SDN)." [www.cisco.com/go/one](http://www.cisco.com/go/one)

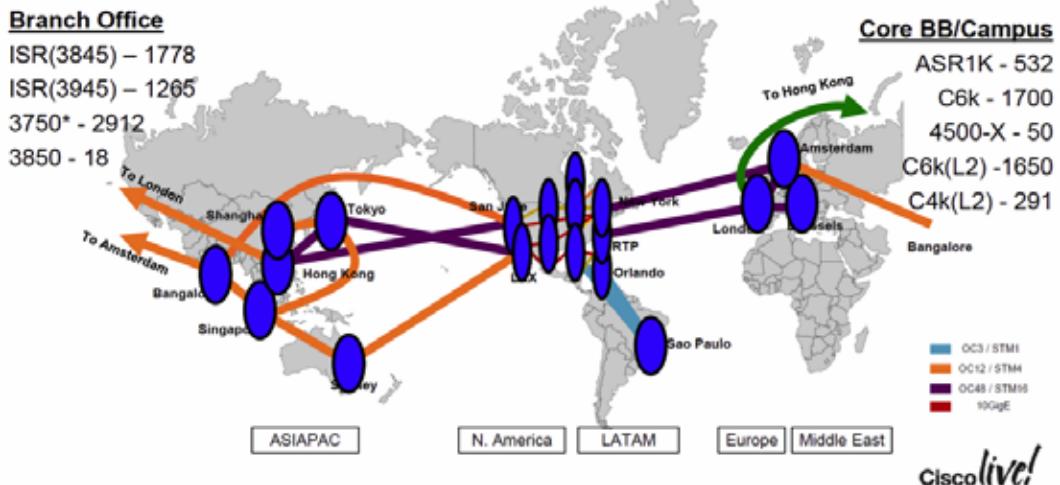
Cisco IT :

Sharing Lessons Learned...

Cisco live!

## 6. THE INTERNATIONAL EXPERIENCE

### Cisco IT Global Tier One WAN Backbone



Manny's presentation along with colleague Michael Anderson detailed Cisco's move in the SDN world by redesigning and implementing a SDN framework across the entire Cisco global corporate network. A phrase often used in IT development is "eating your own dog food" which basically means implementing the very technology you are trying to sell in your own infrastructure. Cisco has done precisely this across their entire WAN backbone.

That they did this over an eighteen-month period is all the more impressive as they were developing a lot of the technology along the journey. This initial implementation is just the start of a larger roadmap of development that will be ongoing for several years to come.

### Cisco IT Infrastructure Programmability Use Cases



As new API's are introduced into the Cisco product lines, more programmability and functionality is added which then opens up even more new possibilities. The above graphic details the timeline and expected features that Cisco hope to achieve.

## 6. THE INTERNATIONAL EXPERIENCE

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### SDN – From Concepts to Reality

**Speaker:**

- Frank Brockners - Distinguished Engineer, Cisco Systems

**Session Content:**

Software Defined Networking (SDN) is a new approach to networking, complementing traditional network architectures. SDN aims at the normalisation of network configuration and control through open programmatic interfaces to individual network devices as well as to the whole network. SDN incorporates concepts for network and network topology virtualisation, and enables customized control planes. The latter allows close alignment of the network forwarding logic to the requirements of applications. OpenFlow is a specification being developed by the Open Networking Foundation (ONF) that defines a flow-based forwarding infrastructure and a standardised application programmatic interface (API) that allows a controller to direct the functions of a switch through a secure channel. The session supplied an overview of the different concepts present in SDN, discussed contributing technologies, and reviewed OpenFlow as a protocol. The SDN concept is put into perspective with existing and evolving network architectures and principles.

### Software Innovations and Control Plane Evolution in the new SDN Transport Architectures

**Speaker:**

- Loukas Paraschis - TSA, Cisco Systems

**Session Content:**

In this session, the presenter looked to identify important software innovations and SDN control-plane evolution characteristics, that jointly enable more efficient capacity utilisation and enhanced SLA for IP/MPLS and WDM transport. The session detailed the analysis of the significant benefits of these future programmable WAN transport architectures that leverage SDN to advance traffic engineering, optimisation of converged multi-layer transport and novel restoration techniques. The session also focused on the main SDN transport technologies becoming available in the market place, including SDN controllers like Open Daylight, and new protocol extensions like PCE-P/C, BGP-LS, Open Flow, Segment Routing, GMPLS and WSON.

### Introduction to Software-Defined Networking (SDN) and Network Programmability

**Speaker:**

- Jason Davis - Distinguished Services Engineer, Cisco Systems

**Session Content:**

SDN is an exciting new approach to network IT Service Management. The session attempted to answer questions about SDN, Controllers, APIs, Overlays, OpenFlow and onePK.

This introductory session covered the genesis of SDN, what it is, what it is not and Cisco's involvement in this space. Cisco's SDN-enabled Products and Services were explained. Since SDN extends network flexibility and functionality which impacts Network Engineering and Operations teams, it also

## 6. THE INTERNATIONAL EXPERIENCE

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covered the IT Service Management impact.

### Software-Defined Networking: People, Process, and Evolution

#### **Speakers:**

- Matthew Oswalt - Blogger / Data Center Network Engineer, General Datatech
- Richard Kiles, Sr Network Consultant, General Datatech.

#### **Session Content:**

The concept of Software-Defined Networking (SDN) is generating a lot of buzz in the industry. There is an overwhelming amount of information and opinions about SDN hitting the web and social media every day. While SDN is certainly a popular subject of conversation, it is still a topic that is constantly changing. Every organisation and engineer has varying definitions of what SDN means to them and how they can apply these concepts to their infrastructure. This session explored the fundamental building blocks that one must consider when looking at SDN or network automation technologies, rather than specific implementations.

### Beyond the hype – A pragmatic view of the future of programmable networks,

#### **Speakers:**

- Patrick Hubbard, SolarWinds®
- Christian Malone, Discovery Communications

#### **Session Content:**

As the increase in network complexity continues to accelerate, the complexity of monitoring and management is growing in parallel. IT Pros must follow developments in infrastructure, security and SDN more closely than ever before.

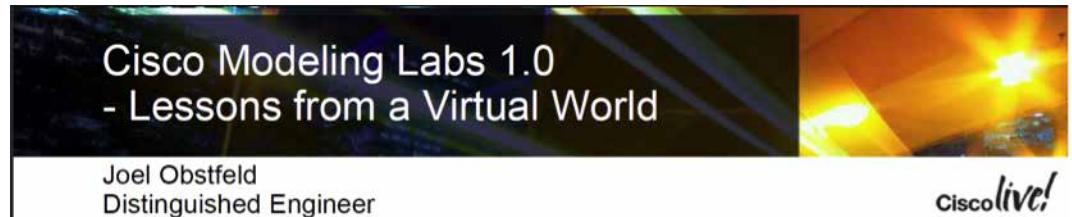
In this session, SolarWinds' Head Geek, Patrick Hubbard shared real-world lessons learned from accelerated change cycles, discussed the promise and pitfalls of SDN hype and discussed Cisco's Application Centric Infrastructure (ACI) initiative. IT Professionals armed with practical knowledge find it easier to tackle the change complexity within their networks.

A SolarWinds customer joined Patrick to share personal examples of how rapid adoption of new technology is reshaping his day-to-day operations and discussed the following:

- Which tech trends are exacerbating network complexity and what to do about them
- How to provide the best network support amidst training, budgetary and bandwidth challenges
- Different SDN vendor strategies: Cisco vs. VMware vs. Open source SDN Solutions
- Cisco's ACI whole network approach vs. VMware's datacenter-centric gamble.

## 6. THE INTERNATIONAL EXPERIENCE

### Cisco Model Labs - lessons from a virtual world



#### Speaker:

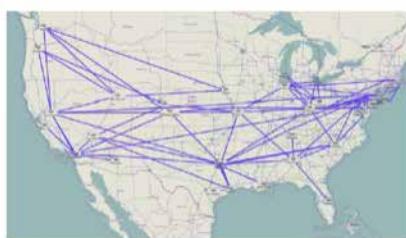
- Joel Obstfeld - Distinguished Engineer, Cisco

#### Session Content:

The ever-increasing demand to provide new services on the network, or make changes to the live environment is driving the need to design, test and deploy quickly and consistently. Testing and verifying network services in topologies at scale is a challenge; there's never enough equipment for all of the people who want to use it! Network virtualisation technologies enable a highly flexible environment in which users can create models of current or future networks. The platform can be used for network change validation, training and education as well as network-aware applications development. With the ability to test and verify changes before they are applied to a live network, the risk of production-affecting errors can be reduced. This session will look at the network virtualisation technologies required in Virtual Routing Labs, including virtual machines, VM orchestration and how context-aware configuration engines combine to create a virtual world in which a network can be modelled.

### Network Virtualization

- The challenge -
- How do you deploy new services, make changes, or troubleshoot in the live network
  - Quickly, Consistently, Efficiently
  - And at scale



The Fellow had the opportunity to see this product a few years ago at a private briefing at the Cisco offices in Melbourne. At the time it was still in development, but the potential was huge, especially for the education sector.

## 6. THE INTERNATIONAL EXPERIENCE

New features, new capabilities

- Build, test, experiment and learn SDN technologies – new paradigms create new challenges
- Cisco OnePK network programmability framework – developers must be able to test and validate applications before deploying to the real network
- How do you test and trial new control-plane capabilities such as 'Segment Routing' if you don't have a lab?

Segment Routing – hand's on

SDN Technologies testbed

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The slide features two diagrams. The top diagram shows a network topology with four hosts (vpagent-1, vpagent-2, vswitch-1, vswitch-2) connected via switches. The bottom diagram shows a more complex SDN testbed with various controllers (ONE\_Controller, PCE\_Controller, OF\_sw1, OF\_sw2, Router1, Router2, Router3, Router4) and switches (OF\_sw1, OF\_sw2, OF\_sw3, OF\_sw4). A legend indicates that blue lines represent Segment Routing paths.

Cisco modelling lab is a complete virtual network modelling and design platform. It contains virtual versions of the majority of Cisco's frontline products and it is all presented in a user friendly graphic environment.

Openstack for VM orchestration

openstack

APIs / CLI

User Workspace Management

Nova (Compute Services)

Swift (Object Services)

Cinder (Block Storage Services)

Neutron / Quantum (Networking Services)

Keystone (Identity Services)

Glance (Image / Repository Services)

Openstack creates, links, and deletes virtual compute and network resources according to API- or CLI-based instructions

Cisco live!

The diagram illustrates the OpenStack architecture. It shows a central stack of services: Nova (Compute), Swift (Object Storage), Cinder (Block Storage), Neutron (Networking), and Glance (Image/Repository). Keystone (Identity) sits at the bottom. APIs/CLI and User Workspace Management are shown on the sides, connected to the central stack by double-headed arrows. A callout box at the bottom states: "Openstack creates, links, and deletes virtual compute and network resources according to API- or CLI-based instructions".

The almost finished product was on full display here and the room was totally full of very eager network engineers dying to get their hands on this product. Using a mid-level computer a user can model large complex networks in real time and then make changes. These changes can then be applied to a real production network if so desired.

## 6. THE INTERNATIONAL EXPERIENCE

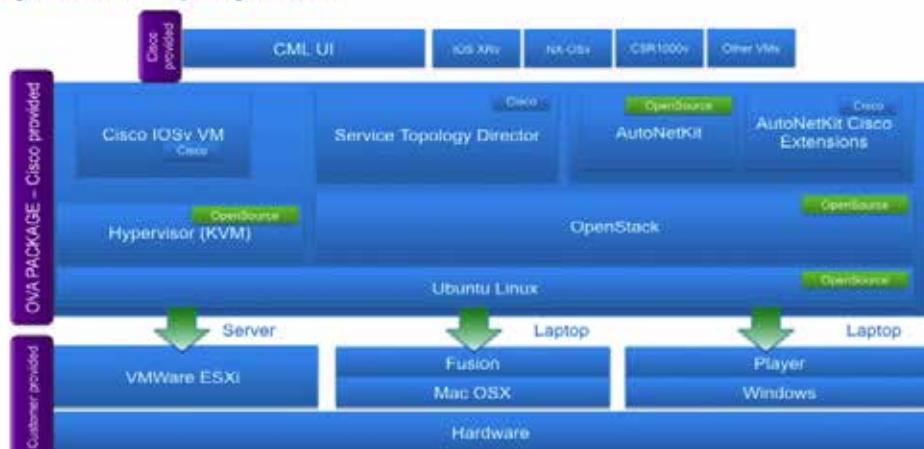
### Virtualized Platform Operating Systems

IOS XR	NX-OS	IOS XE	IOS	Servers
Virtualized in IOS XRV	Virtualized in NX-OSv	Virtualized in CSR1000v	Virtualized in IOSv	Ubuntu, Cirros, 3rd party appliances

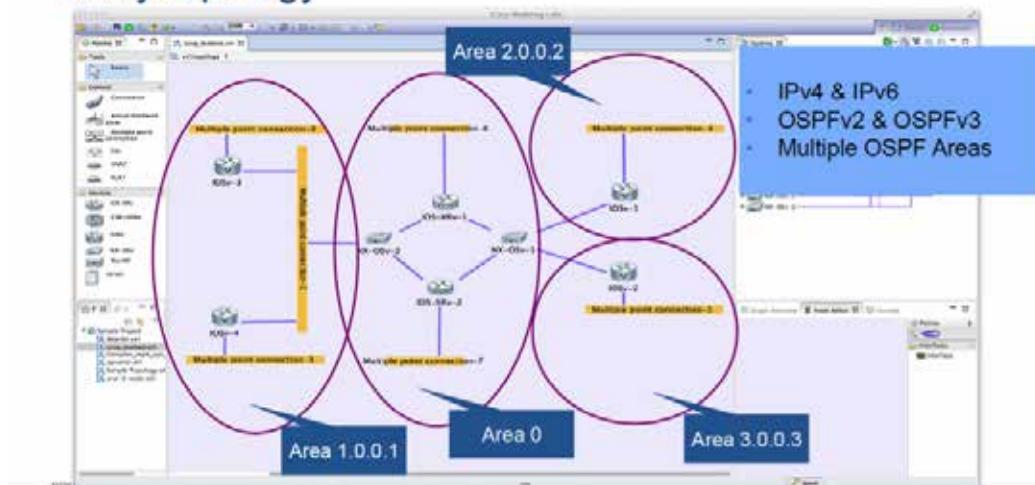
Virtual Machines run the operating system but are NOT representations of a particular hardware platform – no fans, no switch fabric, no ASIC models

Cisco live!

### System deployment



### Study topology



## **6. THE INTERNATIONAL EXPERIENCE**

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From an educational standpoint, this modelling lab can be a game changer for teaching complex network topics as well as being an ideal framework for SDN related training. The Fellow will be keeping a keen eye out for its impending release.

Note: in late December 2014, Cisco VIRL (as it is now known) was released to the public. Educational pricing is reasonable at \$79 per year for an academic license.

The Fellow also met with various stakeholders within Cisco as well as the many vendors who were in attendance to discuss Cloud and SDN technology roadmaps.

### **Outcomes**

After spending four days attending various SDN related sessions, the Fellow is confident that over time, training resources will become available to help develop well-rounded educational outcomes in this continually evolving technology.

## 6. THE INTERNATIONAL EXPERIENCE

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### Destination 5: NetApp Inc.



Location: Sunnyvale, California. May 27, 2014,

NetApp are one of the world's largest enterprise storage vendors and work closely with all major players in the cloud and virtualisation space.

The Fellow met with various members of the NetApp University Team including:

- Lynne Welke - Partner and Customer Training
- Ivel Burton - Program Manager, Customer Enablement and Learning Partner Management.
- Ray Chong - Director, Learning Technologies, Platforms, and Services
- Chodi McReynolds - Sr. Director NetApp U.

## **6. THE INTERNATIONAL EXPERIENCE**

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Topics discussed included technology roadmaps and NetApps' education offerings and how they could be embedded into vocational training back in Australia, followed by a tour of one of their datacenters.

One outcome of this meeting was the development of a Storage Area Network unit for the National IT training package. Work on this began as soon as the Fellow returned home. This new unit of competency should be included in the current training package technology refresh that is expected to be completed during early 2015.

### **VMware Inc.**

Palo Alto, CA

Planned meeting cancelled due to the Memorial Day long-weekend.

### **EMC Corporation**

Santa Clara, CA

Planned meeting cancelled due to the Memorial Day long-weekend.

# 7. KNOWLEDGE TRANSFER: APPLYING THE OUTCOMES

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As the Fellow researched multiple technology pathways, the knowledge transfer recommendations will be broken down into several sections. These are:

## **1. Software Defined Datacenter (private cloud technologies).**

- VMware vCloud Director and vCloud Automation Center
- Citrix CloudPlatform (including Apache CloudStack)
- OpenStack

Training in the VMware offerings are already available via the VMware IT Academy program to participating schools that have suitably qualified instructors.

Citrix also offer a CloudPlatform course to members of the Citrix IT Academy program that can be used to train individuals in the various Citrix cloud technology solutions.

The biggest challenge here is developing training solutions for the OpenStack platform. As the Fellow believes that this will be the most widely adopted of the private cloud platforms, identifying and developing training resources to deliver to budding cloud engineers will be of the greatest priority. The Fellow will engage the various OpenStack vendors as well as the user community to ensure that a suitable training program can be developed that will deliver the required outcomes for all concerned.

The initial starting point will be to begin development on a private cloud architecture unit for the various IT and ICT training packages in use in the vocational training sector today. The Fellow will collaborate with various institutions and the associated skills councils to design and author such units. Such a unit would target the Diploma or Advanced Diploma level or even higher.

## **2. Software Defined Networking.**

For this area, there are several competing offerings that should be investigated, these are:

- Cisco APIC EM, ONE PK
- VMware NSX
- Citrix NetScaler
- OpenFlow, Open Daylight.

Cisco, at this stage, is not offering any structured training for their SDN related products. Undoubtedly this will change in the future and the Fellow will keep apprised of this via relationships that he has with the Cisco networking community.

Training in VMware NSX is now available via the VMware IT Academy program to participating schools that have suitably qualified instructors.

Citrix have several courses devoted to their NetScaler product line. At this stage it is not widely available to the academic community, but can be requested on a case-by-case basis.

Since 2013, Georgia Institute of Technology have been offering a Software Defined Networking course using OpenFlow and to a lesser extent OpenDaylight via the Coursera learning platform. This can be viewed here. [www.coursera.org/course/sdn](http://www.coursera.org/course/sdn)

Its author, Professor Nic Feamster, has been open and very generous about sharing his resources with various educational institutions around the world with due credit being given. (Note: Professor Feamster is now a Fellow at Princeton University, but his program is still being offered at Georgia Institute.)

## **7. KNOWLEDGE TRANSFER: APPLYING THE OUTCOMES**

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The Fellow participated in this online course during 2014 and found it to be very detailed, but academically focused so it may need some modification to add some vocational outcomes to it. It also assumes a level of programming proficiency that will need to be accommodated in any training design plan.

The Fellow will also reach out to the Open Networking Foundation to ascertain if any training resources are in development by the Foundation.

During 2015, the Fellow will engage the network engineering community in the vocational training sector to help author a unit of competency for the ICA and ICT training packages.

### **3. Storage Area Network technologies.**

Development in this area has already progressed with the Fellow collaborating with like-minded colleague, Peter Drake, at Victoria University to develop a unit of competency for the ICA11 training package. This unit is expected to be included in the upcoming refresh of ICA11 during 2015.

Both NetApp and EMC2 offer comprehensive training programs for storage area networks. Access to these programs can be obtained by joining the NetApp Academic Alliances program or the EMC Academic Alliance program.

IBM also offers freely available resources to members of their IBM Academic Initiative program. This includes a very comprehensive textbook on the subject.

### **4. Workforce Mobility technologies.**

Citrix has training programs for their XenMobile product line that covers the workforce mobility requirements in great detail.

The biggest challenge for this topic is the lab requirements for delivering training in this product, the Fellow has studied the reference architecture required to implement this technology solution and building a suitable lab environment to ensure each student has the required resources needed to design, build and manage this is currently beyond the budget of most training providers. Citrix have a fully remote cloud based lab environment to deliver this training, but it is not suited for delivery over an academic calendar. This may change in the future and the Fellow will maintain contact with Citrix should a cost effective solution present itself.

VMware has recently acquired a workforce mobility technology company called AirWatch. It has a product offering similar to the Citrix solution. Over time, training resources for this product should become available via the VMware IT Academy program. The Fellow is unable at this time to provide an opinion on the architecture of this solution or the resources required to deliver training in it.

The Fellow will author/co-author a unit of competency to ensure that this unit is covered in upcoming ICA and ICT training packages, but he will also recommend that it be an elective unit at this point in time.

## **8. RECOMMENDATIONS**

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### **New Units of Competencies for ICA and ICT training packages**

The Fellow recommends the creation of several new units of competency be created to accommodate these new technology areas. Note that some of this work has already begun and will development and implementation will continue in the short-term.

These are:

- Configure and Manage a Storage Area Network (already begun)
- Design, implement and manage a private cloud solution
- Design, implement and manage a Software Defined Network
- Design, implement and manage a workforce mobility solution.

### **Development and distribution of training materials**

Once the units of competencies are created, the development of training resources to accompany these new units should also occur. This may require the total development of an entire training curriculum or adopting a vendor supplied training program that could then be augmented with additional assessment tasks, case studies and other resources to meet the needs of the unit.

### **Engage Industry Stakeholders**

To ensure wide adoption of these new units, the industry stakeholders should be consulted and feedback sought to ensure that they meet their requirements.

The Fellow has been over the years, a member of various industry course advisory committees that evaluate and provide guidance on many IT and ICT related units. The same process will be used here.

### **Present the findings of this report to various interested parties**

Plans to present the findings of this report will begin with presentations at the various IT, ICT and Electro technology senate meetings that take place in the vocational training sector throughout the year. All three of these groups drive the development and continual improvement of IT and ICT programs in Australia.

The Fellow will also run one or more sessions at Box Hill Institute and also the Centre for Adult Education campus in the CBD to present and discuss his findings.



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