QUESTION & ANSWER: OPENFLOW AND SOFTWARE-DEFINED NETWORKING

Q: Can you provide more details on OpenFlow?
A: OpenFlow is a networking technology that enables innovative network solutions based on centralized, controller-based management of multiple physical network devices using “forwarding instruction sets” rather than traditional system-level networking protocols. The growing OpenFlow ecosystem now includes routers, switches, virtual switches, and access points from a range of vendors, like HP.

OpenFlow is an open standard that enables researchers to run experimental protocols in the campus networks we use every day. OpenFlow is added as a feature to commercial Ethernet switches, routers and wireless access points – and provides a standardized hook to allow researchers to run experiments, without requiring vendors to expose the internal workings of their network devices. OpenFlow is currently being implemented by major vendors, like HP with OpenFlow-enabled switches now commercially available.

Q: How does OpenFlow work?
A: In a classical router or switch, the fast packet forwarding (data path) and the high level routing decisions (control path) occur on the same device. An OpenFlow Switch separates these two functions. The data path portion still resides on the switch, while high-level routing decisions are moved to a separate controller, typically an external server. The OpenFlow Switch and Controller communicate via the OpenFlow protocol, which defines messages, such as packet-received, send-packet-out, modify-forwarding-table, and get-stats.

The data path of an OpenFlow Switch presents a clean flow table abstraction; each flow table entry contains a set of packet fields to match, and an action (such as send-out-port, modify-field, or drop). When an OpenFlow Switch receives a packet it has never seen before, for which it has no matching flow entries, it sends this packet to the controller. The controller then makes a decision on how to handle this packet. It can drop the packet, or it can add a flow entry directing the switch on how to forward similar packets in the future.

Q: What can I do with OpenFlow?
A: Today, networking researchers use OpenFlow to easily deploy innovative routing and switching protocols against a test or in-production network. For service providers and enterprise customers, OpenFlow allows new and innovative controller-based solutions across a wide range of networking environments for applications such as virtual machine mobility, high-security networks and next generation IP based mobile networks.

Q: Where can I learn more about OpenFlow?
A: You can learn more about OpenFlow at the following URLs:

- Open Networking Foundation website: [https://www.opennetworking.org/](https://www.opennetworking.org/)
QUESTION & ANSWER: HP AND OPENFLOW

Q: What is HP’s involvement in the research behind OpenFlow? Can you go into more detail about HP’s relationships with the educators and researchers presenting on February 2 at the OpenFlow media event?

A: HP and Stanford University began collaborating on Ethane, which was the predecessor to OpenFlow, in 2007. Together, they presented at the SIGCOMM conference in 2008 to demonstrate the first commercial hardware-based switch implementation of OpenFlow. Since then, HP’s OpenFlow-enabled switching technology has been deployed by academic and commercial researchers worldwide to achieve simplified management by consolidating both campus as well as data center network operations. HP partners involved in the February 2 event include Indiana University, Stanford University and The Global Environment for Network Innovations (GENI) Project.

- The Open Networking Foundation is a nonprofit, mutually beneficial trade organization that HP works closely with. Most recently, HP’s Jean Tourrilhes, a chair on the Extensibility workgroup was given two awards by ONF – one for his technical work and one for his overall leadership with OpenFlow.
- GENI Project, operated by BBN Technologies and funded by the National Science Foundation, is a virtual laboratory that explores new opportunities in advancing global networks – by experimenting and advancing research on new network technologies. HP has worked with the GENI Project on two occasions – one was a firmware licensing and test bed optimization project, and the other was the submission of research proposals in which HP received funding for three projects from GENI.
- Indiana University is very active in GENI and works closely with Stanford while running the Internet-2 network operations center (NOC). The university utilizes HP switches on their campus, for operations and research in their Interoperability Lab. Indiana University has visited HP Labs twice.

Q: What allows HP to offer OpenFlow free of charge to its enterprise customers and partners?

A: For several years, HP has been enabling and advancing OpenFlow in the research community and want to make OpenFlow’s benefits accessible for developers and researchers who are interested in the technology or simply wants to try it out. Therefore, HP is offering the OpenFlow-enabled switch software for download free of charge.

Q: Who (if any) are some of the customers that rely on OpenFlow today. Are they finding it useful?

A: OpenFlow is being used primarily by early adopters in the research community and hasn’t been widely taken on by mainstream enterprises at this time. That said, HP expects widespread OpenFlow and SDN adoption over time with a wide range of vendors (including HP) offering OpenFlow-enabled products and solutions.

Q. HP does not yet have a controller for their OpenFlow-enabled switches, why not?

A. To date, HP has focused on OpenFlow standards-based interoperation and testing of its switch portfolio with third party, open source controllers. Leveraging collaboration between HP and other vendors in the context of OpenFlow standards development, any third party vendor’s controller adhering to the OpenFlow standard can interoperate with HP’s OpenFlow-enabled switches.
QUESTION & ANSWER: OPENFLOW COMPETITIVE LANDSCAPE

Q: Which networking vendors are actively contributing to the OpenFlow research conversation?
A: OpenFlow and Software-Defined Networking (SDN) are hot trends in the networking industry, so virtually every major player is beginning to define their position, and some are contributing through industry organizations. The Open Network Foundation is a good example, as is the GENI Project – both of which HP has been long involved with. We fully expect that OpenFlow and Software-Defined Networking will continue to evolve into a major networking component during 2012.

Enterprise Strategy Group (ESG) analyst Jon Oltsik recently said, “While the jury is still out on OpenFlow, there is no question that the future of provisioning, management, and control planes will be software-based. The network must become a virtual platform a la VMware, Xen, KVM, etc. It is likely that SDN, OpenFlow, and vendor support from companies like Big Switch, Brocade, HP, IBM, Juniper, and NEC will get a lot of attention in 2012” (Network World).

Q: What is the status of OpenFlow offerings among competitors?
A: Most major networking vendors are talking about OpenFlow, although few have yet to announce substantial offerings for an enterprise customer-base. Across the industry, the discussion is centered on the future development of products and solutions. Vendors currently engaging in OpenFlow development include: Arista Networks, Big Switch Networks, Cisco, Embrane, IBM, Juniper, Nicira and NEC.

Overview of competing vendors’ approach to OpenFlow:

Big Switch:
- Big Switch Networks was founded in 2010 to bring virtualization and cloud innovation to enterprise networks using OpenFlow-based Software-Defined Networking.
- In January 2012, Big Switch Networks announced the release of Floodlight, a Java-based, Apache-licensed OpenFlow controller. This open-sourced controller is designed for companies that want to build applications on top of the controller in an environment where network intelligence is in the software-based controller rather than in the physical hardware of routers and switches. Floodlight is currently available on OpenFlowHub.
  - Created by Big Switch Networks, OpenFlowHub is an online community of developers leading and/or contributing to open source OpenFlow projects. This community is open to all developers promoting OpenFlow or Software-Defined Networking. In addition to Floodlight, OpenFlowHub also supports the following projects:
    - Beacon – a Java-based OpenFlow controller built on an OSGI framework, allowing OpenFlow applications built on the platform to be started, stopped, refreshed and installed at run-time – without disconnecting switches.
    - FlowScale - a project to divide and distribute traffic over multiple physical switch ports by replicating the functionality in load balancing appliances but using a Top of Rack (ToR) switch to distribute traffic.
• **Indigo** – an open source OpenFlow implementation based on the OpenFlow Reference Implementation from Stanford that runs on physical switches and uses the hardware features of switching chipsets to run OpenFlow at line rates.

• **RouteFlow** – a project geared toward the development of an open-source framework for virtual IP routing solutions over commodity hardware implementing the OpenFlow API.

• **SNAC** – an open source OpenFlow controller for LANs with a graphical user interface and a policy definition language that allows configuring of the network using a formal modeling language (FML).
  
  o According to Kyle Forster, co-founder of Big Switch, most of the company’s products are still in beta; however, they will begin to become available in 2012 (Network Computing).

**Cisco:**

- In October 2011, Cisco announced that it will eventually add OpenFlow to its Nexus switches, beginning with the low-latency Nexus 3000 line. The company also says it’s formulating a response to the OpenFlow discussion, but has not yet provided an official stance or integration roadmap. (Network World).

**IBM:**

- In November 2011, IBM launched a switch based on OpenFlow specifications provided by the Open Networking Foundation. According to IBM, “The IBM BNT RackSwitch G8264 is a 10 and 40 Gigabit Ethernet (GbE) switch specifically designed for the data center, providing speed, intelligence and interoperability on a proven platform.”

- The RackSwitch G8264 offers up to 64x10 GbE and up to four 40 GbE ports in a 1U footprint, while providing line-rate, high-bandwidth switching, filtering, and traffic queuing without delaying data flow.

- In January 2012, IBM teamed up with NEC to deploy an OpenFlow solution on the networks of select enterprise customers.

**Juniper:**

- In October 2011, Juniper announced that it is making the source code of its OpenFlow application accessible to developers for its Junos operating system software. Juniper is also supporting OpenFlow version 1.0 on its Junos SDK, in order to make the company’s routers and switches programmable through software.

- Juniper demonstrated the OpenFlow protocol running on its MX 3D edge routers at the Carrier Ethernet World Congress, as well as the Open Networking Summit that was held at Stanford University in October 2011.

- The OpenFlow application is available for Junos SKD development organizations, and is said to soon be made available to select Juniper customers.

**NEC:**

- In December 2011, networking and biometrics solution provider NEC announced the UNIVERGE(R) ProgrammableFlow PF5820 10/40 Gigabit Ethernet (GbE) OpenFlow switch. Designed for building high performance, secure, programmable networks, this switch provides a high throughput, low latency, energy-efficient hardware design that delivers 1.28 Terabits of switching performance.

- The PF5820s an extension of NEC’s ProgrammableFlow Software-Defined Network Architecture (SDN), which also includes the NEC ProgrammableFlow Controller and PF5240 1/10 GbE Switch.
In January 2012, NEC teamed up with IBM to deploy an OpenFlow solution on the networks of select enterprise customers.

**Q: What is HP's position on the joint OpenFlow efforts recently announced by IBM and NEC?**

**A:** On January 24, IBM announced a partnership with NEC, which highlighted how IBM and NEC have integrated IBM’s OpenFlow-enabled RackSwitch G8264 10/40Gb top of rack switch with NEC ProgrammableFlow Controller, NEC PF5240 1/10 Gigabit Ethernet Switch and NEC’s PF5820 10/40 Gigabit Ethernet Switch.

This marks the first announcement of commercial networking vendors partnering to deliver a certified OpenFlow solution. IBM and NEC have referenced Stanford University and enterprise customers Tervela and Selerity as deploying their joint solution. By means of this announcement, IBM is positioning itself among high-end proprietary vendors like HP, Cisco and Juniper, as well as many open source start-up solutions.

Unlike efforts by IBM and NEC to deliver an OpenFlow switch and controller, HP has implemented OpenFlow as a standard, so it will work with all controllers, including open source. HP is the only tier-one networking vendor to offer OpenFlow across their networking ecosystem, HP FlexNetwork architecture – which is the only converged networking architecture that spans from the virtualized data center to the virtual workplace for cloud, multimedia, and mobile services with integrated security solutions.

According to IBM, Stanford University will deploy the IBM/NEC joint solution in a parallel network; however, HP has had OpenFlow equipment deployed at Stanford since 2008. In fact, HP has more than 60 OpenFlow implementations worldwide at various academic and commercial research institutions. HP was first to the market with the broadest portfolio of OpenFlow-enabled switches, a total of 16 models, which span the FlexNetwork ecosystem. Additionally, the entry cost offered by HP to start researching with OpenFlow is also much lower than IBM or NEC.

**Q: What is currently being said about OpenFlow in the media?**

**A:** OpenFlow is a hot-topic in the networking industry, and many top-tier trade publications are writing on the subject. Below is a synopsis of recent OpenFlow coverage featuring HP competitors:

- **IBM and NEC Leverage OpenFlow for High-Performance Networking** – Mike Fratto, Network Computing (January 24, 2012)
  - The article details the companies’ decision to team up to enable enterprise clients Tervela and Selerity Corp. to transform their networks using a new OpenFlow solution. Tervela, a data fabric provider, says that this new solution delivers a breakthrough in dynamic networking to ensure predictable performance of Big Data for complex and demanding business environments. Selerity, an ultra-low latency event data provider, will employ IBM and NEC’s OpenFlow solution to accelerate real-time decision-making for global financial markets.

- **OpenFlow start-up aiming at Cisco’s dominance** – Jim Duffy, Network World (January 13, 2012)
  - The article discusses Big Switch Networks’ submission of its controller software to the open-source community in order to catalyze an ecosystem of application developers to work on applications based on the platform. As vendors like Big Switch view OpenFlow as a way to infiltrate Cisco’s
networking hold, the company says it’s formulating a response to the solution. Cisco has voiced future plans to add OpenFlow to its Nexus switches, beginning with the low-latency Nexus 3000 line.

- **Software-Defined Networks could create auction-based bandwidth bazaar** – Stacey Higginbotham, GigaOM (January 13, 2012)
  - The article provides an overview of an article written by Tinniam V. Ganesh, an infrastructure architect at IBM India, which suggests using Software-Defined Networking to create an auction-based bandwidth bazaar.

- **Big Switch open-sources Floodlight, an OpenFlow controller** – Stacey Higginbotham, GigaOM (January 11, 2012)
  - The article details the announcement that Big Switch Networks open-sourced its controller software, Floodlight. According to Stacey, companies like Big Switch, Nicira, Embrane and Juniper have helped the idea of Software-Defined Networking gain ground by promoting the concept of adding flexibility and agility to networks by making them programmable.

- **The application tier of a Software-Defined Networking architecture** – Amy Larsen DeCarlo, Current Analysis (January 5, 2012)
  - The article mentions Juniper’s OpenFlow initiatives. In October 2011, Juniper opened the source code that drives OpenFlow on its routers and switches to developers who use Junos SDK. This has allowed third-party developers to start experimenting with controller-based applications for a Software-Defined Network.