

Theory to Reality

SDN Deployments for Research Networks



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Colleges and universities are both high-expectation users and creative innovators when it comes to networking technology. Today, research and education networks connect faculty, researchers and students worldwide for projects that require extensive collaboration and transfers of enormous data volumes. Behind the scenes, university faculty and IT staff who specialize in networking continually explore how to advance the field with new designs and technologies.

Yet meeting the diverse and growing needs of these academic users is a challenge for university networks. With their fixed design and configuration, traditional networks simply can't support the unpredictable and dynamic flexibility required for emerging types of applications, advanced levels of collaboration and increasing speeds of data flow.

To solve this challenge — which also exists for businesses and government organizations — the networking industry is focusing on a new concept: software-defined networks (SDNs).

"This is the perfect time for SDN initiatives because the whole networking field is going through a big inflection point for business and academia," says Dr. Deniz Gurkan, associate professor at the University of Houston.¹ Gurkan is actively involved in encouraging development of SDN technologies, both through classroom projects with her students and participation in the National Science Foundation's Global Environment for Network Innovations (GENI)'s testbed infrastructure as well as Internet 2's SDN working group.

And universities across the nation are already realizing the many advantages that SDN offers. Just one example from the University of Houston: In a network programming course taught by Gurkan, students



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completed SDN-related projects such as applying the OpenFlow configuration standard to allow multiple parties to share a network switch, connecting virtual LANs and virtual machines with SDN, and programming OpenFlow-enabled switches through an SDN controller to monitor and enforce network quality of service (QoS) policies. Most testing has been conducted within a dedicated segment of the university's production network as the IT department develops its own plans for future SDN deployment.

This Center for Digital Education white paper goes into more depth about what SDN is, its benefits and provides several use cases that explain why it's becoming so appealing to higher education institutions.

What are Software-Defined Networks?

SDNs allow applications to use open programming interfaces to control and allocate network resources for the distinct needs of the application's users, processes and data types. As explained in an *IT World* article, "Software-defined networking works by essentially creating virtual networks that are independent from physical networks ... [SDN] makes applications think that they have the entire network to themselves, when in reality they are sharing it. As a result, more servers can use the network, which saves a company money."²

SDN technologies can be applied to support:

- Network bandwidth and services that are dedicated for scientific research (called Science DMZs), as a way to better support the demanding communication needs of these projects
- Scalability for the very large volumes of data involved in research and instructional activity across all academic disciplines
- Secure delivery of Internet-based or private cloud applications and services to all campus users
- Efficient use of server and storage resources in a university's data centers and high-performance computing (HPC) environments
- Research and development of new networking designs and technologies by an institution's faculty, students, spinoff companies and business partners

SDNs can serve these diverse needs by allowing applications and services to program a network's data communications and control and management capabilities independently of the physical configuration. SDN essentially separates the data from the network components that transport it, which overcomes the barriers of traditional network protocols for supporting massive collaboration and data transfer activity, as well as

specialized user needs. This flexibility "allows previously inflexible networks to be programmed and optimized for particular applications."³

SDN Advantages over Traditional Networking

SDN overcomes the limitations in current network architectures and operating models, such as:⁴

- Lack of real-time visibility into the network to accurately gauge traffic demand
- No standard way to alter traffic flows to handle the changing network usage patterns created by, for example, user mobility and newly activated applications
- No software tools available that enable network managers to test new services and features without impacting the production network
- Lack of operational flexibility to make dynamic network changes and create new service offerings

Given these limitations, any changes to a university's current production network are difficult, slow and risky to implement. As a result, researchers and other users typically must make do with the existing network performance and design, which may constrain their ability to work and innovate.

However, a higher education institution can realize several benefits from implementing SDN technologies.

Develop cost savings. SDN supports open and interoperable systems, which leads to more efficient network designs, targeted bandwidth and service delivery; as well as the ability to customize the network through internally developed, open source and vendor-developed applications.

Enable more collaboration among all institutions. Smaller, more teaching-focused colleges can use SDN to offer faculty and students many of the same network capabilities and performance levels that in the past have been available only in large research universities. With support for network connections up to 100 Gbps Ethernet, the speed of SDN technology enables real-time data transfer and video collaboration. This advantage is especially valuable for large scientific research projects that involve multiple investigators who may be accessing cyber instruments and remote systems for experimentation and data capture.

Improve network performance and flexibility. The volume of data generated by many research projects is so large and complex that it falls into the realm of “big data,” or content that is unable to be managed and processed by traditional applications. This large-scale data creates a tremendous impact on a university’s network and data center — SDN supports improvements in network capabilities and capacity to both handle the data volumes and deliver acceptable performance levels when that data is accessed by users.

Deliver more network-based services to users. Today’s trends point toward deploying and accessing applications in the network cloud. With SDN, an IT department can more effectively scale and manage cloud-based services, whether they are delivered over the Internet or the campus network.

Take advantage of open standards and software. The macro trend for networks is open interfaces, open application programming interfaces (APIs), open standards and open source software so that everything can work together. For higher education, this trend offers the ability to use open source software to create network-based applications and data services that enable potential cost savings and a gradual, controllable migration from current network designs and technologies. Open standards are also very important for simplifying the management of campus network switches and controller-based wireless networks.

Why Higher Education is Moving to SDN

Higher education institutions are already actively exploring the SDN concept and how it could benefit their academic and enterprise networks. This exploration is prompted in part by several trends that are now defining academia’s use of networking technologies.

Higher education as an active contributor to an innovation economy. Continuous innovation is vital in all aspects of an economy in order to sustain competitiveness and foster growth. Academic research and development (R&D) is a key contributor to this innovation by providing a significant foundation and catalyst for products of many types that are later commercialized by an institution’s business partners. The SDN approach of both dynamic and programmable network design supports the flexible, demanding communications that are vital to enabling innovations through R&D.

Greater collaboration throughout academia. In recent years, academic research has increasingly involved online

SDN and OpenFlow

Although the terms SDN and OpenFlow are often used as synonyms, they are not the same thing. SDN describes a network design while OpenFlow is the standard, open communications protocol that enables SDN. The OpenFlow protocol allows routing and switching functionality to be programmed by an independent controller instead of the proprietary software that’s embedded in the router or switch hardware. The OpenFlow standard is managed by the Open Networking Foundation, a group that includes representatives from major networking and computing system vendors.

collaboration among researchers, faculty and students working in multiple institutions and multiple countries. That research involves frequent transfers of data sets with file sizes measured in terabytes. Additionally, the use of videoconferencing and streaming video files for collaborative work and discussions adds to the data load on institutional networks.

This growth in collaboration work isn’t limited to just the big research universities or the science and engineering departments. Faculty, students and researchers from all subject areas are now looking for ways to connect with colleagues to support data analysis, specialized instruction and student projects.

“Creation and delivery of next-generation science, learning and university operations applications will increasingly rely on advanced networks. Research and education institutions of all types and sizes will need the ability to adapt and integrate SDN to harness the transformational impacts possible,” says Eric Boyd, deputy technology officer for network services, Internet2. “Ultimately, it’s really about creating a collaborative environment for innovation to come from anywhere.”⁵

Big data. Data in all its forms is playing a bigger role in all academic disciplines. This growth is especially noticeable in the sciences, including biosciences (environmental data, medical and genomics research), astrophysics, nuclear physics, engineering, weather forecasting and climate modeling, earthquake analysis and geology (oil and gas exploration and mining).

The flexibility of SDN allows networks to adapt more easily and dynamically to changing data volumes than traditional networks. It also allows data to be presented easily in different forms for different users.

SDN Use Cases for Education

Although SDN offers value for any enterprise, five use cases make this technology particularly appealing for higher education institutions.

Dedicated network resources for research and collaboration. For many institutions the first application for SDN is creating a Science DMZ, a dedicated network segment with a high level of data capacity and configuration flexibility. The Science DMZ concept was developed by engineers at ESnet, a scientific research network operated by the U.S. Department of Energy. According to ESnet:

“The Science DMZ is a portion of the network, built at or near the campus or laboratory’s local network perimeter that ... addresses common network performance problems encountered at research institutions by creating an environment that is tailored to the needs of high-performance science applications, including high-volume bulk data transfer, remote experiment control and data visualization.”

Further, “The Science DMZ is scalable, incrementally deployable and easily adaptable to incorporate emerging technologies such as 100 Gigabit Ethernet services, virtual circuits and software-defined networking capabilities.”⁶

Big data transfers. As discussed earlier, large and growing amounts of data are being transferred routinely for many academic research projects. Yet the network implications aren’t simply about having the bandwidth to transport that data from Point A to Point B in a reasonable amount of time. Users need better ways to access only the data they need out of often undifferentiated “data dumps.” They also need to obtain that data in a form that is ready for analysis and processing by their research tools. These capabilities are possible with SDN.

Cloud services delivery. Applications that run in a network cloud are becoming more popular as a way to reduce costs and IT demands as well as to access new features quickly. Although “cloud” often means the Internet, many of these applications can be easily hosted and delivered on a campus network with SDN.



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Eric Boyd, Deputy Technology Officer for Network Services, Internet2

Data centers and HPC environments. As more data, collaboration and cloud services are carried on the campus network, parallel demands are created for the resources in the institution’s data and high-performance computing centers. For the institution’s own benefit, SDN supports the flexible network connectivity necessary for IT to keep pace with growing demand for computing and storage resources.

Networking research and technology development. Academic and research institutions have long been the leaders in the development of networking and computing technology. Engineering and computer science faculty and students can use SDN to develop solutions to real networking problems in a technology lab, instead of negotiating with the IT department for access to the production network.

For example, Clemson University students have become something of a network development team for the campus IT department. “We can get a solution to a networking

problem from our students tomorrow, instead of waiting for a fix from the vendor," says Dan Schmiedt, executive director of network services and telecommunications at Clemson. Additionally, "With SDN, networking has once again become a true academic discipline because it can involve solution concepts and design as well as working with professional IT networking staff to test and implement the new capabilities developed by students and faculty."⁷

Individually or in combination, these use cases are already being explored by higher education IT departments.

Examples of SDN Exploration in Higher Education

One university and an education network consortium offer insights on current plans for SDN deployment in higher education.

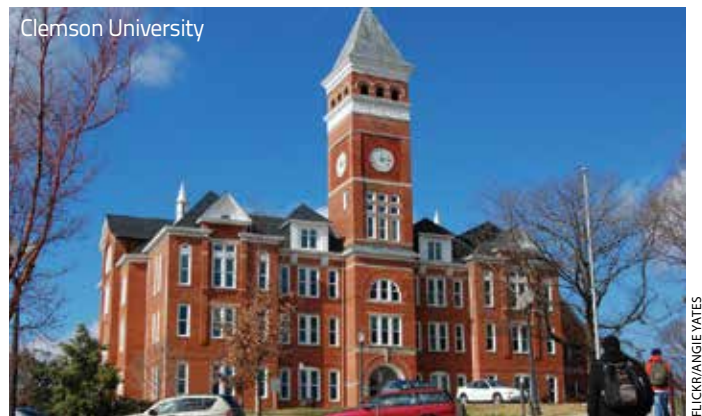
Clemson University

The Clemson University IT department started exploring SDN technologies in 2009 when a professor was working on a development project for the National Science Foundation's (NSF) GENI program and needed a virtual LAN connection to GENI's layer two services on the National LambdaRail (NLR) and Internet2.

This exploration continued into 2012 when Clemson received an NSF grant for building a Science DMZ. "This will be the first fully SDN-based production network at Clemson, serving 20 buildings on campus, each with 48 ports of 10 Gb Ethernet connections and operating in parallel to our enterprise network," says Schmiedt. "Initially, we will use 40 Gbps Ethernet uplinks from this campus Science DMZ to aggregation switches, and from there we will soon deploy a 100 Gbps Ethernet connection to Internet2's Advanced Layer 2 Services (AL2S) network."

Internet2

As a member-owned consortium, Internet2 provides an advanced network, enabling technologies and a collaborative environment that connects more than 66,000 U.S. research, education, business, government and nonprofit institutions with each other and with partners in over 50 countries worldwide. This environment includes a 100 Gbps network that delivers production network services for consortium members as well as a platform for developing new networking applications based on SDN and OpenFlow.



Clemson received a National Science Foundation grant for building a Science DMZ (term used when network bandwidth and services are dedicated for scientific research or whenever 'friction free,' maximum-bandwidth networking is required).

Internet2 also facilitates collaborative teams that use advanced technologies to solve problems in new ways, like the Dynamic Network System for Data Intensive Science (DYNES), a nationwide cyber instrument for nuclear physics and astrophysics research.

"The next generation of applications will increasingly rely on network connections, so every institution will need the ability to adopt and integrate technologies like SDN," says Internet2's Boyd. "Our focus at Internet2 is to create an environment of innovation by supporting SDN and ubiquitous network bandwidth to remove barriers and empower the research and education community to continue their heritage of making major impacts to our global economy and society."

Strategies for Moving to SDN

This is an ideal time for higher education institutions to begin defining strategies for bringing SDN to their campuses. Ideally, these strategies will cover updates to network plans and budgets as well as pilot projects to gain experience with this new approach to networking.

Network Planning

When planning how to incorporate SDN technologies into an existing network, one helpful approach is to create a cyberinfrastructure plan as defined by NSF. The upgrade and

refresh plans for the campus network can also provide an opportunity to assess the potential opportunities for adopting SDN and 100 Gigabit Ethernet connectivity to external networks. And as an initial SDN project, a Science DMZ infrastructure can yield a good planning blueprint for implementing SDN technologies elsewhere in the campus network.

Budget Allocations and Funding Sources

In 2012, NSF awarded 39 Campus Cyberinfrastructure-Network Infrastructure and Engineering (CC-NIE) program grants totaling \$21 million for an institution's implementation of advanced network and collaboration infrastructures. Additional grant funding for SDN deployments may be available in the future (see resources at end of paper).

Clemson's Schmiedt indicates this is the time for universities to consider allocations of their established IT budgets for network refreshes and upgrades. "I'm looking to spend real budget money on SDN because I expect it to produce significant cost savings for our planned upgrades through more efficient networking and the need for fewer specialized appliances," he says.

Deployment

To understand the differences brought about by SDN before making a full deployment, the University of Houston's Gurkan recommends obtaining an OpenFlow-capable network switch and connecting a controller to it, then writing a controller module that will dynamically change the traffic flows. "This experiment will help you see the potential of your network in a very different way," she says.

If the budget allows, she further recommends creating an overlay of OpenFlow-compliant devices on the production network in order to obtain more extensive learning and experience on SDN technology before deploying it in the institution's production network.

An initial SDN deployment will also allow IT staff or researchers to develop and test applications that take

advantage of the flexible SDN infrastructure. At the end of this pilot project, identify the lessons learned and prioritize the next projects for implementation.

Conclusion: SDN is Ready for Your Consideration

With any new technology, it can be hard to know whether it has moved beyond the visioning stage to readiness for adoption in real networks that serve real users. For SDN, that readiness stage is arriving soon as evidenced by these activities:

- Standards bodies are defining protocols and other essential standards for SDN technologies.
- Industry vendors are developing and enhancing SDN-compatible products.
- Universities are implementing initial SDN projects to validate the new network designs, technologies and applications as well as to assess the potential benefits for broader SDN deployment.

"I can't stress enough how exciting SDN is," says Schmiedt of Clemson University. "The cool thing about SDN is that you can wish it into what you want it to be, and now is the time to get involved in the decisions to shape it into something that will truly change the face of networking."

Resources

- ESnet FAQ for a Science DMZ:
<http://fasterdata.es.net/science-dmz/frequently-asked-questions/>
- Internet2 SDN Working Group:
www.internet2.edu/
- National Science Foundation Office of Cyberinfrastructure:
www.nsf.gov/dir/index.jsp?org=OCI
- Open Networking Foundation:
www.opennetworking.org/index.php

Endnotes

1. CDE interview with Deniz Gurkan, December 12, 2012
2. Adapted from "Spotlight on software-defined networks," *IT World*, www.itworld.com/networking/323240/spotlight-software-defined-networks
3. Internet2 network description, www.internet2.edu/network/
4. Adapted from the Brocade white paper, "The business case for software defined networking," www.brocade.com
5. CDE interview with Eric Boyd, December 10, 2012
6. Adapted from Science DMZ description, ESnet, <http://fasterdata.es.net/science-dmz>
7. CDE interview with Dan Schmiedt, December 12, 2012



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