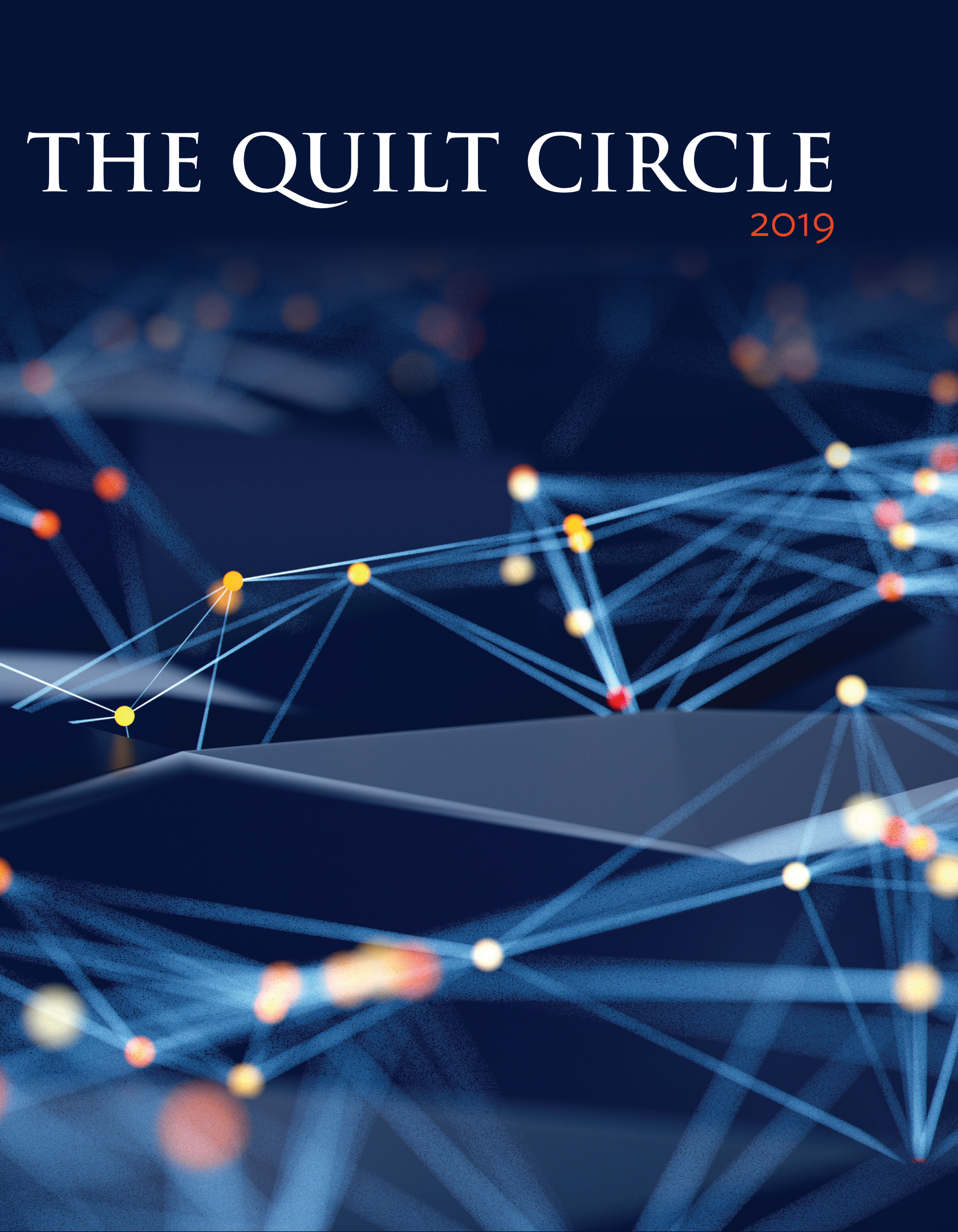
THE QUILT CIRCLE

2019



A Letter From the President

Welcome to the 2019 edition of *The Quilt Circle*. You are in for a treat to learn more about the impressive work of our country's Research and Education (R&E) Networks. As you turn each page, you'll discover our Quilt members' networks in action furthering scientific discovery, advancing the academic enterprise, and positively impacting the communities connected to these networks. Like The Quilt itself, we believe that this single collection of examples of our Quilt member missions in action, is more powerful than the sum of its parts.

The Quilt is a national collaboration of 40 R&E networks throughout the United States. Our collective mission focuses on investing and operating resilient, secure, high-capacity, high-performance network infrastructure that is purpose-built to further scientific discovery and advance our country's academic enterprise. *The Quilt Circle* is an annual compilation showcasing the positive impacts that R&E networks have on the institutions they serve. This publication offers insight into the depth and breadth of projects, partnerships, and outcomes enabled across the country by the work of these non-profit, publicly missioned organizations.

Woven throughout these pages is a spirit of collaboration with which these organizations approach their work. You'll find evidence of the progress we are collectively making toward two of our Quilt strategic visions - to be the forum for sharing, collaboration, and continuous learning for membership as well as to promote the development, deployment, and operation of advanced cyberinfrastructure for research and education. For those unfamiliar with the term cyberinfrastructure, our R&E networking community uses this term when referring to the research environments that support advanced data acquisition, data movement, data storage, data management, data integration, data visualization, and other computing and information processing services distributed across resource providers.

This year's edition of *The Quilt Circle* brings to light several examples of the key role of regional networks in both providing and facilitating the use of a fabric of interoperable research cyberinfrastructure termed 'research platforms'. You'll also enjoy learning about an NSF-funded project called The Engagement and Performance Outreach Center which supports collaborative science allowing researchers to make the most effective use of shared data, computing, and storage resources to accelerate the discovery process. This edition also showcases how R&E networks leverage their unique positions in their respective broadband landscapes to find solutions to bridge rural broadband gaps. Lastly, you will see the direct impact these organizations have within their member communities by providing support for disaster preparedness and recovery, local elections, digital courtrooms, virtual technology to support military families and so much more.

The collaborative spirit of our members is the driving force behind the creation of The Quilt almost 20 years ago and the success of the organization today. Our work together this year is a valuable reminder of the key roles all of our members play in the success of one another's organizations and in building the national fabric of regional network community that we call "The Quilt".

Jen Leasure
President and CEO

Acknowledgements

The Quilt wishes to recognize and thank Carol Farnham for her contributions to this publication.
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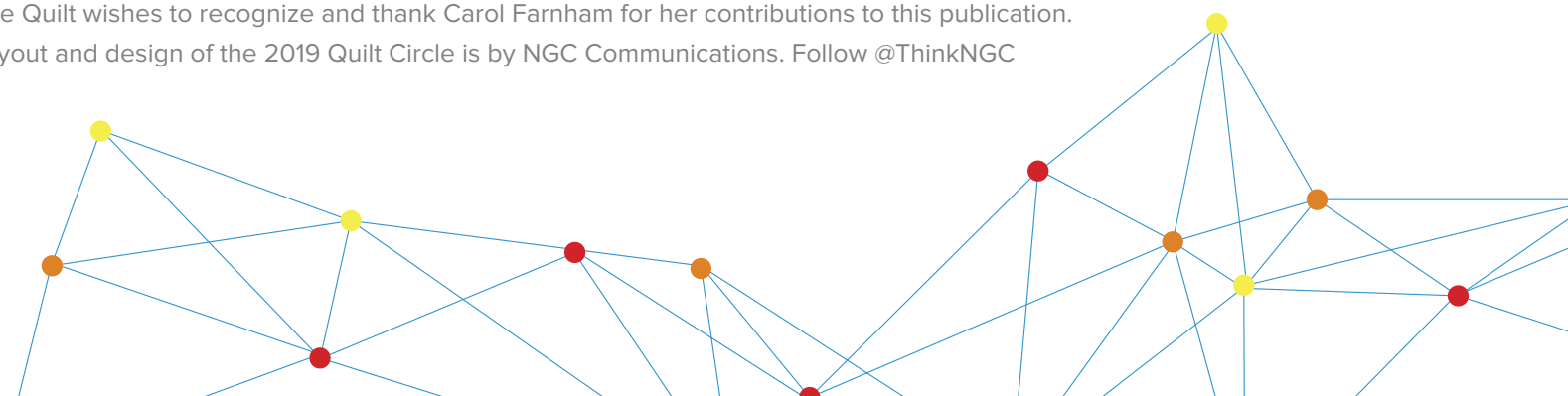

The Quilt

About Us

The Quilt is the national coalition of non-profit U.S. regional research and education networks representing 40 networks across the country. Participants in The Quilt provide advanced network services and applications to over 900 universities and tens of thousands of other educational and community anchor institutions. With the goal of promoting consistent, reliable, inter-operable and efficient advanced networking services that extend to the broadest possible community; and to represent common interests in the development and delivery of advanced cyberinfrastructure that enables innovation through our education and research mission.

Our Mission

Through The Quilt, non-profit regional research and education networks collaborate to develop, deploy and operate advanced cyberinfrastructure that enables innovation in research and education.

Our Name

Just like the various fabric patches of a quilt highlight different colors, patterns and textures, each regional network reflects the diversity and the unique qualities found in different parts of the country and the different institutions that particular network serves. Yet all regional patches must be stitched together seamlessly, coherently and interoperably to serve a larger purpose and community.

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Merit Network and the Michigan Moonshot

Like many states, much of Michigan lacks access to broadband Internet. Research and Education Networks like Merit are uniquely positioned to catalyze unserved communities toward connectivity. Merit, in partnership with M-Lab and the Quello Center at Michigan State University, has developed a phased plan to address the digital divide within our state. Dubbed the "Michigan Moonshot," Merit's approach includes access and availability data collection, investigation and community education in regard to infrastructure investment and societal impact studies along the way.

Access to, and use of, the Internet has become an integral component of everyday life in the 21st century. Digital information has reshaped how individuals participate in nearly every dimension of society. It is imperative for communities to leverage broadband network access to eliminate the homework gap and for the benefit of education, telemedicine, public safety, and workforce development to maintain the quality of life.

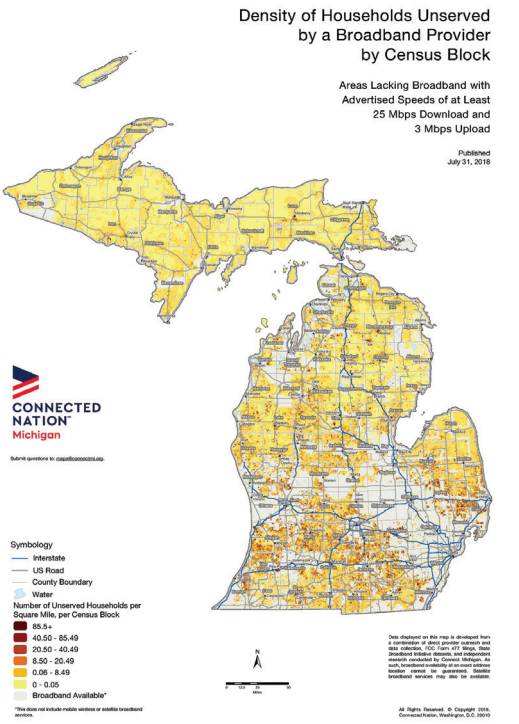
According to the Wireless Innovation for Last Mile Access (WILMA) report, nearly 40% of rural America lacks access to broadband. Connectivity, even via wireless networks, requires access to a fiber optic network backbone. Low population densities make economic return on investment problematic for commercial providers. Some rural areas of Michigan house as few as 2-20 individuals per square mile. Often, a for-profit organization cannot earn enough revenue to justify the costs of building a fiber connection to rural communities.

A consistent challenge nationally is understanding where broadband is available. Current Federal Communications Commission (FCC) data collection methodology does not provide enough granularity for accurate measurement, and over-reliance on ISP providers' information may present reporting challenges. For example, current FCC measurements are aggregated to the census block level (or higher), which could misrepresent the availability of broadband. These information gaps can be overcome by collecting on-the-ground consumer sourced data.

We propose a new approach for data collection that builds on collaborative network organizations (CNOs), often used in citizen science, to uniquely leverage (1) networks of stakeholders (i.e., Merit and other participating Research and Education Networks) to manage the sourcing of data from users across the nation; (2) a partnership with academic researchers that allows for data quality control (identifying and correcting problematic data) and sophisticated analyses using multiple sources and forms of data; and (3) data collection through a user-friendly app. This will allow the flexible collection of data from multiple devices, fixed or mobile. This project will collect both speed test data and user provided household broadband access and availability data.

Merit is currently in the development and deployment stage of this data collection process. With accurate access and availability information, we can advance the ability of policymakers and academics to empirically analyze and influence effective policy to address pressing issues such as the homework gap and other problems associated with underserved populations.

Armed with an accurate picture of Michigan's connectivity, barriers to broadband network deployment in rural communities could be reduced through a combination of techniques. Efforts to secure one-time funds to supplement network construction costs, the creation of community connectivity task force teams, the deployment of municipal network education initiatives, and seeking planning grants, could present viable next steps to address the lack of connectivity in Michigan. To learn more visit Merit.edu/Moonshot.



Density of Households Unserved by Broadband Providers, attribution is to Connected Nation Michigan

Merit Network is the nation's longest-running research and education network. Merit owns and operates 4,000 miles of fiber optic infrastructure throughout Michigan. We offer networking, security and community services to nonprofits. For more information, visit: www.merit.edu.

EdgeDiscovery: A Platform for Scientific Research

Inspired by the vision for a national research platform and with the realization that regionalization and collaboration are prerequisites to attracting grants from preeminent research funding entities, NJEdge has now strategically advanced its capacity and capability to support and advance research in New Jersey and beyond with a research as a service (RaaS) solution called *EdgeDiscovery*.

NJEdge has been fortunate to partner with Rutgers University and the Rutgers Office of Academic Research Computing (OARC), which has redefined the paradigm for research support toward a model that relies upon optimized, federated, regionalized, and shared services approaches. Convinced that the model is extensible, Rutgers has worked collaboratively with research institutions, Internet2, and other Research and Education Networks (RENs) to spearhead the Eastern Research Network proof of concept (ERN-POC) and demonstrate the viability of the new construct.

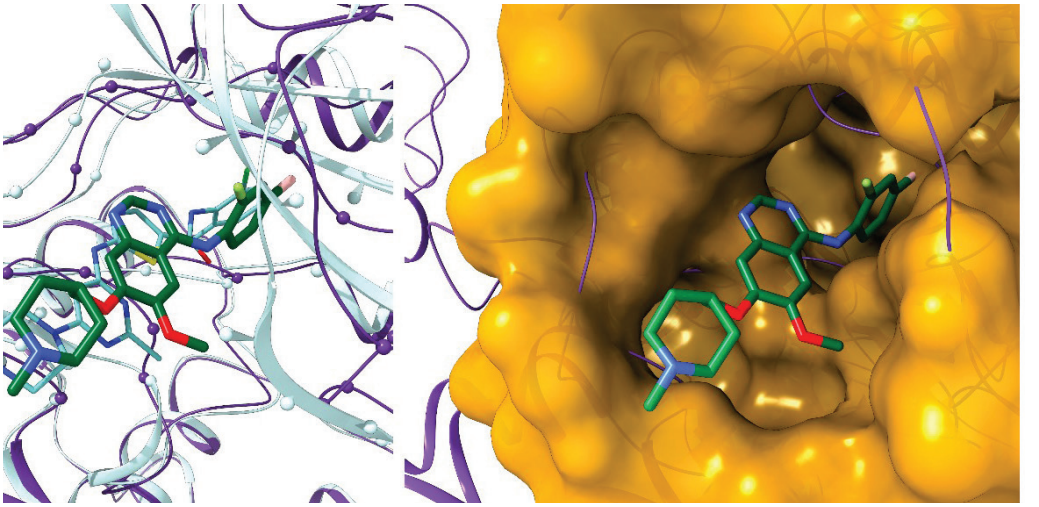
Recognizing the new model's potential to democratize access to research capacity and capability for less well-resourced institutions, NJEdge regards these developments as an opportunity to bring value to the community with *EdgeDiscovery*. *EdgeDiscovery* combines an NJEdge research network DMZ with an optimized technology stack residing on our backbone, and is outfitted with hardware and software components which enable researchers accessing it to streamline their research projects, schedule compute cycles, and access applications, analytics tools, and storage resources. NJEdge's new research network paradigm is accomplished on a common, federated platform that will interoperate with the many research support constructs currently evolving in conjunction with the quest for a standards-based national research platform.

The *EdgeDiscovery* prototype was developed in conjunction with the ERN-POC program recipe and is intended to serve as an on-demand research platform available to researchers in under resourced organizations otherwise unable to invest in next generation research infrastructure. Those accessing *EdgeDiscovery* will receive a clear set of instructions to provision HPC clusters with a set of software tools that are thoroughly tested and easy to implement. *EdgeDiscovery* will serve as their staging area for connecting to the ERN and similar projects under development as the quest for a national research platform continues. This solution will provide access to compute nodes hosted in on-premise datacenters or in cloud environments. The *EdgeDiscovery* solution saves the researcher valuable time by allowing them to focus on research data rather than technology tools. Relying upon automation and best practices for HPC, the *EdgeDiscovery* RaaS model will evolve in concert with the hardware and software landscape, ensuring the latest relevant tools are incorporated into the solution.

With the addition of *EdgeDiscovery*, NJEdge will enable access to the cyber-infrastructures and e-infrastructure resources required for full participation in the new research paradigm via our high-performance network. NJEdge resides at the geographic and technical crossroads in the pursuit of innovation through advancements in next generation networking and research computing. In seizing opportunities to advance our footprint regionally, NJEdge will continue to instantiate and evolve a United States northeast regional research ecology involving services in support of scientific discovery, a thriving data economy, research infrastructures as thematic service providers, and sustainable, configurable research environments.

NJEdge is a non-profit provider of high performance optical networking, Internet, digital asset management solutions and IT products and services. NJEdge provides these solutions to colleges and universities, K-12 school districts, government entities, hospital networks and businesses as part of a membership-based consortium. NJEdge's membership spans Maryland, Michigan, New Jersey, New York, Pennsylvania and Virginia. The company's mission is to empower members with affordable, reliable and leading internet-based technologies and services. For more information, visit: www.njedge.net.

LONI Provides Computing Resources to Help Find Treatments for Rare Diseases



About 7,000 rare diseases currently affect more than 350 million people worldwide. Although these conditions collectively pose significant health care problems, commercial drug discovery for orphan diseases is financially complicated due to the limits of individual markets. Developing new treatments for diseases that fall into this category often requires financial incentives from governments, special research grants, and private philanthropy. To circumvent the economic hurdles, researchers have found drug repositioning to be a cheaper and faster alternative to traditional drug discovery. This method extends the purpose of a drug beyond its intended disease by identifying other conditions it can be effective against and significantly reducing research costs.

Although drug repositioning is time effective, economically advantageous, and has great potential in the development of treatments for rare conditions, each repositioning application possibility comes with its own set of challenges. In order to mete out the complexities of these challenges, rational and effective computational methods to develop solutions for existing therapeutics are being explored. These pioneering computer simulations systematically evaluate possible links between currently FDA-approved drugs and potential therapeutic targets for rare diseases, allowing the most promising candidates for repositioning to be tested in the lab.

The Computational Systems Biology Group (CSBG) led by Dr. Michal Brylinski at Louisiana State University has developed a collection of tools for drug repositioning computer simulations. CSBG researchers used this promising methodology to match 715 known drugs against 922 potential drug targets implicated in rare diseases. Their results revealed as many as 18,145 candidates for repurposing, unveiling a number of opportunities to combat rare diseases with existing drugs. The team conducted their simulations on Louisiana Optical Network Infrastructure's (LONI) Queen Bee 2 (QB2) supercomputer. Equipped with more than 10,000 CPU cores and more than 1,000 General Purpose Graphic Processing Units (GPGPUs), QB2 provides an ideal platform for researchers working on large-scale problems, such as computer-aided drug discovery and repositioning.

Since its inception more than a decade ago, LONI has provided cyberinfrastructure that is vital for researchers like CSBG to fulfill their missions and make noteworthy contributions to scientific research in the State of Louisiana. In 2018, QB2 supported a total of 168 research projects, representing a wide variety of scientific disciplines not limited to engineering, material sciences, chemistry, and biological sciences. During the year, 226 researchers from 12 institutions ran 132,848 jobs on QB2, consuming more than 50 million CPU-hours.

LONI offers its participants a world-class network and high-performance computing environment with the strategic integration of highly available and scalable bandwidth, computational, storage, and personnel resources.

LONI is a state-of-the-art, fiber optics network that runs throughout Louisiana, and connects Louisiana research universities to one another as well as Internet2. The resources provided by LONI enables greater collaboration on research that produces results faster and with greater accuracy. For more information, visit: www.loni.org.

Grow Food, Grow Jobs: How Broadband Can Boost Farming in California

The Central Valley of California is an enormous economic force, producing over one-third of the nation's vegetables, two-thirds of its fruit and nuts, and contributing billions of dollars annually to the California economy. Unfortunately, many of California's farming communities still lack reliable broadband Internet access. This lack prevents farmers from using cutting-edge technologies and real-time data inputs that would improve agricultural production, and severely hampers educational opportunities that support farming and growth.

Robert Tse, the California rural broadband development coordinator for the USDA and longtime organizer for California's agricultural community, imagines what farmers can accomplish with greater connectivity. "When moisture sensors are deployed in fields," Tse said, "agricultural economists have found that farmers can realize a 10 to 20% decrease in water use as well as a significant increase in field output." In a state plagued by drought, using less water to grow more food is a major improvement. But, without broadband connectivity, such tools remain out of reach for many farmers.

Expanding connectivity also enables the dissemination of real-time information, like weather predictions and experimental approaches to crop management. One of the main missions of the University of California Division of Agriculture and Natural Resources (UC ANR) is to provide farmers with up-to-date science and information. Gabriel Youtsey, UC ANR's chief innovation officer, emphasized how improved connectivity would further UC ANR's mission: "To fulfill our education mission, research centers host local farmers at meetings and field days. With connectivity, those that live too far away to travel will be able to receive real-time video streams." Several of UC ANR's facilities now have broadband after being connected to the CENIC fiber backbone.

Yet extending access to these rural areas is often neglected, due to last-mile and middle-mile challenges. Laying fiber cable in the ground is not feasible in many places that remain disconnected. That's where CEO Skyler Ditchfield and his company GeoLinks come in. GeoLinks is trailblazing the use of fixed wireless technologies to expand access with approaches that require less time and less infrastructure. "It can be difficult to meet the broadband needs of rural California with fiber connections alone," said Ditchfield. "Fixed wireless broadband can meet the data needs, fiscal demands, and timeline to deploy these critical technologies across California." GeoLinks uses solar and wind technologies to power carefully sited wireless towers that form a grid of connectivity across a community.

Now that wireless extension approaches have evolved enough to provide quality, reliable broadband to rural areas, the challenge is organizing community partners for widespread implementation. CENIC is partnering with organizations — as it has done with UC ANR, GeoLinks, and others — to develop plans for better connectivity, find funding to extend a wireless mesh into the unlinked reaches of the state, and ultimately help more farmers grow food and jobs. As Gabe Youtsey noted, "California communities must take control of their broadband future to ensure that everyone can participate in our digital economy by partnering to create new technologies and business models."

CENIC connects California to the world — advancing education and research statewide by providing the world-class network essential for innovation, collaboration, and economic growth. This nonprofit organization operates the California Research & Education Network (CalREN), a high-capacity network designed to meet the unique requirements of over 20 million users, including the vast majority of K-20 students together with educators, researchers, and others at vital public-serving institutions. For more information, visit: www.cenic.org.

MCNC Delivers During Historic Hurricane Season

The 2018 hurricane season was the most active on record. It was particularly unforgiving for many coastal communities – especially in the Carolinas. In September 2018, Hurricane Florence impacted much of North Carolina. As forecasted, the storm made landfall on Sept. 13 just south of Wilmington, with high winds and record amounts of rain. Throughout the historic weather event MCNC was ready.

MCNC operational teams worked in coordination with senior management and constituents to gain a clear understanding of which locations planned to turn off equipment in advance of the storm. Additionally, fiber and facilities teams conducted site inspections to make sure those facilities in the path of Florence were properly prepped. During the peak of the storm, there were 148 outages reported for NCREN endpoints. As with Hurricane Matthew two years prior, all MCNC hut locations east of I-95 at one point in time were operating via on-site emergency power generators due to facility power being unavailable. Generators ran for extended periods at MCNC's hut in Wilmington, as well as in Fayetteville, New Bern, Morehead City, Pembroke, Whiteville, and Bolivia. The NCREN core optical and IP infrastructure did not experience an outage.

"Once again, another major hurricane impacted our state and the core of NCREN worked just as designed."

Tommy Jacobson,
MCNC Chief Operations Officer

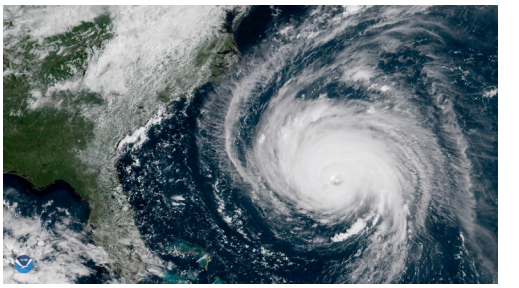
"Once again, another major hurricane impacted our state and the core of NCREN worked just as designed." Stated Tommy Jacobson, MCNC chief operations officer.

The MCNC Business Continuity/Disaster Recovery (BCDR) Team also was activated to alert constituents to the current status of NCREN as the storm worked its way out of the state and operations returned to normal. MCNC was effective in providing real-time network advisories on their website and on social media.

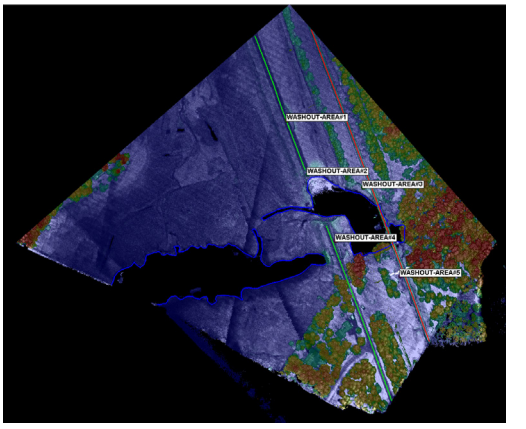
Everette Teal, director of technology for Public Schools of Robeson County, N.C., said he didn't think lightning could strike twice with two major storms in a two-year period – both of which destroyed central technology operations for the school district, forcing them to move their core data structure to a new, non-flood zone in order to get their system back online.

"MCNC came through immediately with a plan of action to move and restore Internet to our district in a very timely manner," added Teal. "Our service was back in operation in less than three business days with minimal loss of information and in full operation throughout the district. We would like to give all the credit to the MCNC team for bringing some type of normalcy back to our staff and students."

The Federal Emergency Management Agency (FEMA) called upon MIT Lincoln Laboratory to use their state-of-the-art lidar (light detection and ranging) system to image the destruction in the region. And, MCNC was ready to help. MCNC provisioned a 10-gigabit IP connection



Satellite Image of Hurricane Florence courtesy of the NOAA.



Lidar Scan Image courtesy of MIT Lincoln Laboratory

from NCREN to Internet2 and made it possible for FEMA to process and share terabytes of satellite data faster than ever before during a recovery effort.

Even though at impact Hurricane Florence had been reduced to a Category 1 storm, Florence produced record-breaking rainfall, with more than 30 inches measured in some locations. At least 53 deaths were attributed to the storm and property damage and economic loss estimates have reached almost $24 billion, which is higher than the costs from 2016's Hurricane Matthew and Hurricane Floyd in 1999 combined. Hurricane Florence remains a weather event that many in North Carolina will not forget for years to come. MCNC continues to fine-tune its process and procedures during emergencies and weather-related events, and will once again be ready to deliver, not if something happens again – but *when*.

MCNC is a non-profit, client-focused organization. Founded in 1980, MCNC owns and operates the North Carolina Research and Education Network (NCREN), one of America's longest-running regional research and education networks. With over 35 years of innovation, MCNC continues to provide high-performance technology services for education, research, libraries, health care, public safety, and other community anchor institutions throughout North Carolina. For more information, visit: www.mcnc.org.

UETN Rural Fiber Project Brings Broadband to Remote Communities

Laying fiber-optic conduit in soft ground is one thing. Cutting through solid rock to facilitate fiber is another. The Utah Education and Telehealth Network (UETN) and its telecom and tribal partners are doing both to bring robust broadband infrastructure to isolated communities in the west.

"Utah students and educators, patients and physicians should have access to the best technology no matter where they live," says UETN CEO Ray Timothy. "Broadband is a necessity to promote growth in communities, business, tourism, education, and healthcare."

In Daggett county, contractors use specialized rigs to cut four-foot deep conduit trenches through solid rock ridges in the rugged Uintah Mountains. San Juan and Daggett currently rely on limited digital microwave technology with a maximum bandwidth of just 200 Mbps. Fiber will increase capacity five-fold to a minimum of 1 Gbps.

Collaboration is key to the project. UETN is partnering with the Ute Mountain Ute and Navajo tribes, the Utah Department of Transportation, the Federal Communications Commission, Emery Telecom in San Juan, and Strata Networks in Daggett. Construction in Daggett started in June of 2018 and will take up to two years to complete.

The Universal Service Administrative Company (USAC) of the FCC recently approved stage one of the San Juan project. It will extend fiber optic infrastructure from Blanding to the Ute Mountain Ute Tribe's White Mesa Library; Bluff Elementary School in Bluff, Utah; and White Horse High and Montezuma Creek Elementary schools in the Navajo community of Montezuma Creek.

Both education and heath care will benefit. Residents and tourists visiting San Juan's iconic Monument Valley and surrounding National Parks will have greater bandwidth at Blanding's Blue Mountain Hospital and Community Health Centers, as will visitors to Daggett's Flaming Gorge National Recreation Area who require the services of the Flaming Gorge Medical Center or the Manila Clinic.

"The Daggett school district is among the last two districts in the state not fully connected to fiber for its schools in Manila and Dutch John," says UETN associate director Jeff Egly. "We are also focused on bringing fiber to remote San Juan county. That includes schools within the Utah portion of the Navajo Nation. All of these projects are complex, time consuming and cost intensive."

The good financial news is that both locations qualify for matching funds from the E-Rate program of the Federal Communications Commission. The funding enables UETN to leverage state dollars with other sources including telecom providers, the Utah Department of Transportation, and tribal funding. E-Rate means that the San Juan's project's $12 million price tag will require less than $2 million in funding from the Utah State Legislature.

While not exactly moving mountains, UETN's rural fiber project is definitely boring through parts of them to facilitate statewide fiber infrastructure.

Whether it's a teacher in Tooele or a physician in Fillmore, a patient in Parowan or a student in St. George, the Utah Education and Telehealth Network provides robust infrastructure, applications and support for education and healthcare. UETN connects all Utah school districts, schools, and higher education institutions and serves hospitals, clinics and health departments in urban, suburban and rural areas of the state. For more information, visit: www.uetn.org.

Connecting Families Across the Globe

For most parents, their child's high school graduation is an event not to be missed. Some, however, cannot be there due to circumstances beyond their control. Donna Ortiz is one of those parents. She is a command sergeant major (CSM) in the U.S. Army Reserves and is currently stationed overseas. Ms. Ortiz knew she would not be home to see her daughter Alejandra graduate, so she reached out to Pilgrim High School and asked if there were any options to stream it online.

Warwick School District IT director, Doug Alexander, was aware of OSHEAN's video platform, Video Commons 2.0. Video Commons would provide the online streaming service Ortiz needed. "It was a relatively simple process and I knew this was the solution we were looking for," said Alexander. The groundwork was now laid.

As the date for the ceremony got closer, Alexander reached out to OSHEAN, CCRI (the event venue), and Studio 107 - the district's audio/visual studio out of Pilgrim High School - to put the project together. It was a collaborative effort – OSHEAN supplied the server, Studio 107 provided the camera, and CCRI supplied the sound and technical support. Set up and testing went without a hitch.

Toll Gate High School hosted their own graduation the night before Pilgrim High School. This provided a great opportunity to test *Video Commons 2.0* live. The video experience was executed as expected and the district achieved its highest number of viewers ever for a streamed event! When the Pilgrim

Graduation was held the following night, halfway across the globe Ms. Ortiz, was able to watch her daughter, in real-time, graduate high school. The Ortiz family and the Warwick School District were extremely pleased.

All in all, the event was a huge success. So much so that the story was picked up by local media. After the ceremony, OSHEAN set up a Warwick School District page where links to both graduation streams can be accessed. With the success of these two events, the district is now looking to use the Video Commons service platform for other events such as assemblies, concerts and meetings allowing students to work and manage the equipment and technology. A video streaming and capture plan has the potential to be incorporated into the curriculum pending budgetary and management logistics.

There are times when technology operates in the background and can even be taken for granted. There are other times, however, when the application of technology is felt. Bringing presence to a military family for an event like a daughter's graduation is one of those wonderful, meaningful examples.

OSHEAN Inc., is a 501c3 non-profit consortium of member organizations that was formed to foster the development of a communications infrastructure for Rhode Island's research, educational, health care, and public service community. OSHEAN is committed to developing network expertise among its member organizations and to creating an environment that encourages collaboration through shared resources, information and expertise. For more information, visit: www.oshean.org.

Going the Extra Mile to Build the World's Fastest Temporary Network

Supercomputing 2018 (SC18), the international conference for high-performance computing, networking, storage, and analysis, was held in Dallas, Texas, in November 2018. The event also results in the high-intensity installation of a dedicated high-capacity network infrastructure: SCinet. Designed and built by volunteer experts from industry, academia, and government, SCinet, for the duration of the conference, is the fastest and most powerful network in the world. As the local leaders of the SCinet effort, LEARN's staff had a critical role to play.

Pankaj Shah, president and CEO of LEARN said, "LEARN dedicated its entire team to assist in architecture and building of SC18 infrastructure. This is a year-long effort. SC is one of the most fertile grounds for engineers to experience state-of-the-art, bleeding-edge technologies, while making lifetime peer relationships from across the world."

Setting up SCinet required 225 volunteers from 85 Institutions, $52 million in contributed networking gear, 14 racks of hardware weighing 4.25 tons, and nearly 70 miles of fiber optic cables.

"My team has been participating for several years," Akbar Kara, LEARN's CTO said. "You end up working with peers who bring a fresh perspective. That's part of growing as a professional and you become on a first name basis with really smart engineers in the academic and vendor community. When companies send eight to ten million dollars' worth of hardware, they also send smart people to make sure stuff works. The insights you learn and the relationships you develop are invaluable."

But none of this would have mattered if the LEARN team hadn't first found a way to get high-speed access to the convention center in the first place. LEARN was fortunate that one of the major aggregation points of the network on many backbones happens to be less than one mile away from the convention center. This is where Internet2, ESnet, LEARN and Century Link —research and education networks as well as carriers — terminate their capability, their networks, and their fibers.

But making the connection from the aggregation point to the convention center meant identifying a path through the bowels of City Hall to allow them to install the fiber. The fiber is the nervous system for the show. Every booth requires some level of connectivity to support the demonstrations and some of these demonstrations required up to 1.6 Tb or 1,600 gigabits-per-second of bandwidth that was plumbed between the network operations center to the booth to support science.

"We couldn't have done it without LEARN," Jason Zurawski, the 2018 SCinet chair said. "They were able to move mountains on their end to make sure their local infrastructure was capable of meeting SCinet's needs."

This effort netted the collaborators, LEARN, Ciena, Energy Sciences Network (ESnet), Internet2, and Utah Education and Telehealth Network (UETN), the inaugural "Spirit of Innovation Award" from the conference for embracing "the spirit of collaboration and cooperation that showcases the best there is to offer in demonstrating, implementing, and operating leading-edge solutions to challenging problems," according to Zurawski.

The Lonestar Education and Research Network (LEARN) is a consortium of 41 organizations throughout Texas that includes public and private institutions of higher education, community colleges, the National Weather Service, and K–12 public schools. The consortium, organized as a 501(c)(3) non-profit organization, connects its members and over 600 affiliated organizations through high performance optical and IP network services to support their research, education, healthcare and public service missions. LEARN is also a leading member of a national community of advanced research networks, providing Texas connectivity to national and international research and education networks, enabling cutting-edge research that is increasingly dependent upon sharing large volumes of electronic data. For more information, visit: www.tx-learn.org.

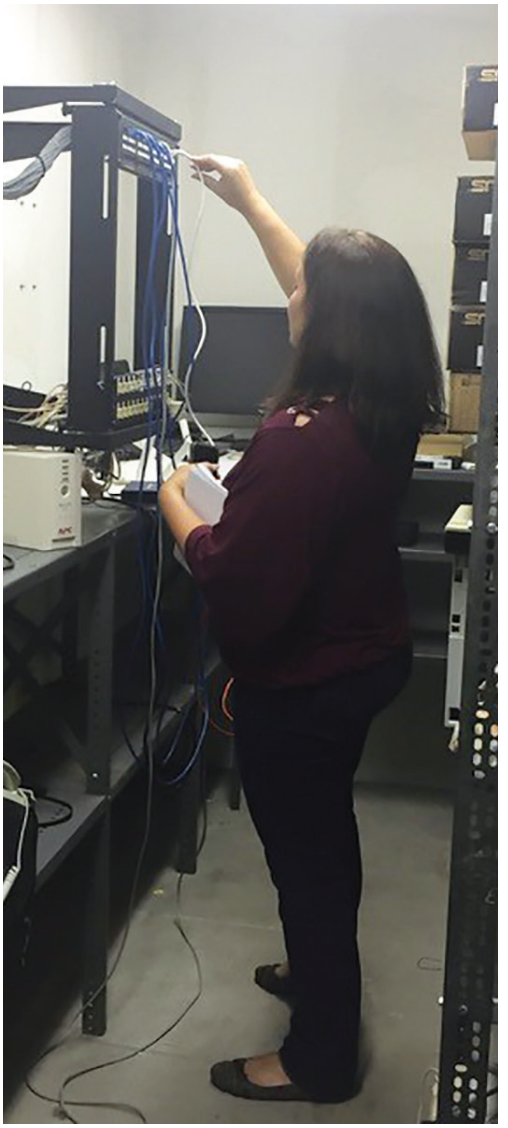
Helping Public Libraries Improve Broadband Services

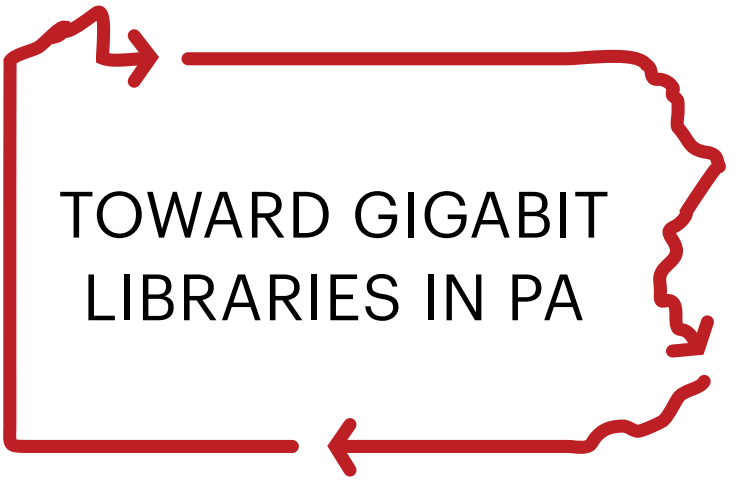
The Keystone Initiative for Network Based Education and Research (KINBER) has been working with public libraries and library systems in Pennsylvania for several years but with new funding and support, KINBER will be increasing its efforts and helping even more libraries to improve their broadband services. This increase was made possible through a Library Services and Technology Act (LSTA) statewide library assistance grant administered by the Pennsylvania Department of Education's Office of Commonwealth Libraries.

In January 2019, KINBER was awarded the LSTA statewide library assistance grant for the *Toward Gigabit Libraries in Pennsylvania* project which aims to support libraries across the commonwealth in their acquisition, use, and understanding of broadband networking and IT infrastructure technologies.

This project builds upon a 2016-2018 Institute for Museum and Library Services grant to Internet2, a nonprofit computer networking consortium. Internet2's program helps public and tribal librarians across the country learn about their current broadband infrastructure and internal information technology environment. KINBER was one of several research and education network partners that worked on this national project and was involved as a pilot participant. KINBER's Toward Gigabit Libraries in Pennsylvania grant will leverage the freely available Broadband Toolkit and Broadband Improvement Plan template created as part of the Internet2 program. Project activities expand on the success of the Internet2 program and continue the work started in Pennsylvania to support and develop library practitioners' understanding of their library's broadband connection and related IT infrastructures.

As part of the project, KINBER will conduct a survey of Pennsylvania's libraries on their broadband capabilities and awareness and provide training and education through in-person workshops, virtual events, and library site visits by KINBER on the use of the Library Broadband Toolkit and Broadband Improvement Plan template. KINBER is also leveraging and scaling the work it has done in providing library network assessments to public libraries in Pennsylvania as part of its ongoing efforts in serving public libraries.





The Keystone Initiative for Network Based Education and Research (KINBER) is Pennsylvania's statewide research, education and community network. The non-profit organization is a trusted technology partner that provides a strategic and competitive advantage to 100+ Pennsylvania-based organizations through high-speed broadband connectivity, collaboration, and innovative use of digital technologies. KINBER is committed to delivering equitable, reliable and affordable digital infrastructure and tools to inspire tomorrow's scientific discoveries, enable the exchange of ideas and culture among diverse populations, educate the next generation of citizens, and revitalize Pennsylvania's economy. For more information, visit: www.kinber.org.

Snapshot: Scaling a National Research Platform

Based on community input and on ESnet's Science DMZ concept, the National Science Foundation (NSF) has funded over 100 campuses to deploy Science DMZs to build local big-data freeways starting in 2011. The Science DMZ is a portion of the network, built at or near the campus or laboratory's local network perimeter that is designed such that the equipment, configuration, and security policies are optimized for high-performance scientific applications rather than for general-purpose business systems or "enterprise" computing.

In 2015, NSF awarded a five-year, $5 million grant to fund the creation of a regional, end-to-end, science driven, big-data, highway system, called the Pacific Research Platform (PRP). Led by researchers at UC San Diego and UC Berkeley, PRP is a partnership of more than 50 institutions that includes all 10 University of California campuses, the National Science Foundation, Department of Energy, and multiple research universities in the U.S. and around the world. The PRP's data-sharing architecture utilizes FIONAs (Flash I/O Network Appliance): clustered Data Transfer Nodes (DTNs) carefully optimized for storing, forwarding, or using large amounts of data (10s to 100s of terabytes) on 10, 40, or 100 gigabit per second networks. This regional, big-data, superhighway system enables researchers to move data between labs and collaborators' sites, supercomputer centers, or data repositories without performance degradation.

Inspired by the PRP project activities and goals, multi-partner collaborations across the U.S. are underway to provide new and transformative capabilities for high-performance science applications. Collectively, these efforts are serving as pilot testbeds to push toward a National Research Platform or NRP. The NRP's primary purpose is to accelerate scientific research and discovery through building networks of campus Science DMZs that scale across geographies to create an end-to-end, science-driven, big-data, superhighway system through partnerships in science engagement and technology adoption. The vision of the NRP goes beyond simply unifying the nation's high-speed research networks. It aspires to serve as a cloud-like, distributed supercomputer for the nation and beyond.

Leveraging their positions as trusted collaborators as well as regional network aggregators for their community institutions, Quilt members are actively involved in efforts to scale to a national research platform. Here's a snapshot of several of these efforts.

Full-length articles for Great Plains Network, NJEdge, and Florida LambdaRail about their research platform initiatives are featured in this *Quilt Circle*.

Lonestar Education and Research Network (LEARN) - Texas

The PRP has connected universities and labs in California, Oregon, and Washington, and, more recently spread eastward to Chicago and Colorado and westward to Hawaii and the Pacific Rim. The NRP continues the network's march south and east across the U.S.

"The PRP worked with Texas, Oklahoma and the Great Plains Networks to extend a really fast backbone link further east," said Akbar Kara, LEARN's CTO. "Together we received additional funds from NSF to bring in a 100-gigabit facility that came into Houston and Dallas, where we have points of presence. LEARN connected to both Dallas and Houston, so researchers can tap into resources connected to new Pacific Research Network facilities." LEARN is directly connected to Pacific Wave via a 200 Gbps network that can carry traffic internationally to enable greater collaboration across borders. LEARN plays an important role as a major regional testbed. It will help the NRP develop and test use cases for difficult data transfer needs with hardware like the LEARN-routed FIONA, located at the Texas Advanced Computing Center (TACC), which began operations in February 2019. New collaborations that were previously difficult will emerge because of the improved ability to collaborate, share, and access computing and scientific datasets instruments. Learn more at www.tx-learn.net.

Eastern Regional Network - CAAREN, Connecticut Education Network, KINBER, NetworkMaine, OARnet, OSHEAN, NJEdge, and NYSERNet

Through a partnership of eight Quilt member regional network providers, numerous higher education institutions, research facilities, and Internet2, the Eastern Regional Network (ERN) provides layered and transparent access to shared data and computing facilities for research projects located at and between partner sites. The resulting regional research and education platform will support a diverse set of science drivers and emergent educational opportunities and offer the educational research community access to a broad range of collaborative multi-institutional resources that are not available on any one campus alone. The goal of this multi-institution, multi-state collaboration is to create a prototype for a policy-based federation of research resources that span participating campuses and commercial cloud resources. The prototype provides the ability to reserve network slices and launch containerized jobs as well as traditional HPC jobs, from any site to any other site,

including commercial cloud, via Simple Linux Utility for Resource Management (SLURM) schedule. Learn more at https://github.com/rutgers-oarc/ern-poc.

New York State Education and Research Network (NYSERNet)

NYSERNet is participating in a pilot to scale the PRP into a national testbed (NRP). The technology consists of Data Transfer Nodes (DTNs), Compute Nodes, and a distributed Ceph storage environment acting in concert to enable inter-institutional, high-speed, research data transfers on a federated computing platform offering Intel and GPU processing capacity. Not designed to compete with multi-million core Supercomputers, this is an environment based on federated access into Kubernetes Linux containers providing a temporary virtual compute and storage environment suitable for smaller research workloads. Thus far, NYSERNet has deployed the DTN component of the NRP Pilot in both its Syracuse Data Center and at Stony Brook University. NYSERNet, in collaboration with Stony Brook, is implementing a Science DMZ network and supporting research needs such as improving data transfers to XSEDE via the DTN. NYSERNet has also started collaborating with the American Museum of Natural History on an NSF-funded project to design a Science DMZ which supports NRP Pilot activities including facilitating an astrophysicist's data transfers with the Palomar Observatory and providing a compute platform. Learn more at www.nysernet.org.

Florida LamdaRail

Florida LambdaRail's (FLR) Regional Science DMZ is the basis for the Atlantic Research Platform (ARP), a science-driven, high-capacity data exchange and transport facility that links campuses to other regional, national, and global science DMZs. The FLR Regional Science DMZ and ARP provide participants the ability to extend and interconnect campus research, high-performance computing, and instructional technology environments to the global research and education networking fabric. Utilizing the capabilities of the Internet2 Advanced Layer 2 Services Network, the FLR Science DMZ now peers with the PRP thereby extending the Science DMZ concept from coast to coast. For more on Florida LambdaRail's Regional DMZ, see pg. 22.

Nighttime long exposure of the open Hale Telescope dome. (Palomar/Caltech)

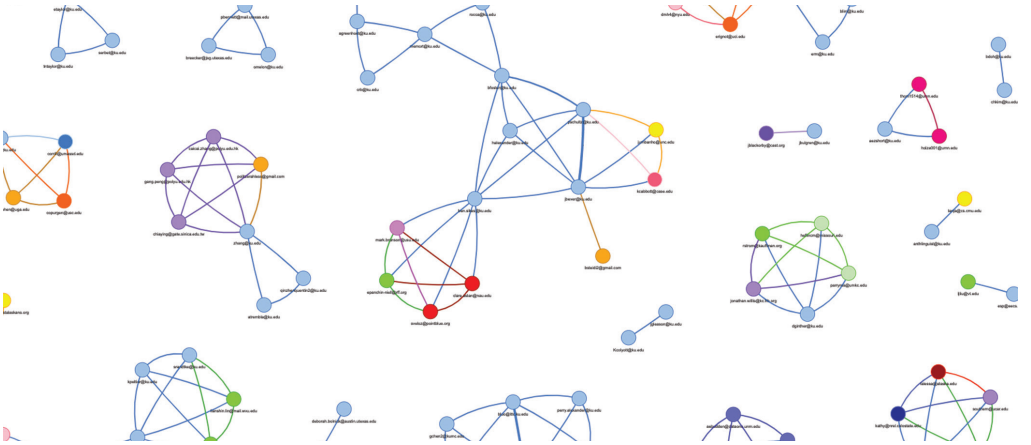
Great Plains Network Research Platform

The Great Plains Network Research Platform (GPN RP) began with a goal to draw together different groups of people to create a seamless research platform that encourages collaboration on a broad range of data-intensive fields and projects. GPN is accomplishing this by closing the gap between a number of communities including scientific equipment, high-performance computing (HPC), storage, and the networks that connect them. This ultimately increases access to the research cyberinfrastructure across the region. For more on the GPN RP, see pg. 13.

NJEdge – New Jersey

NJEdge has strategically advanced its capacity and capability to support and advance research in New Jersey and beyond with a research as a service (RaaS) solution called *EdgeDiscovery*. NJEdge has been fortunate to partner with Rutgers University and the Rutgers Office of Academic Research Computing (OARC), which has worked collaboratively with other institutions, organizations, and networks in the region to spearhead the Eastern Research Network proof of concept and demonstrate the viability of the new construct. Recognizing the new model's potential to democratize access to research capacity and capability for less well-resourced institutions, NJEdge regards these developments as an opportunity to bring value to the community with *EdgeDiscovery*. *EdgeDiscovery* combines an NJEdge research network DMZ with an optimized technology stack residing on our backbone, and is outfitted with hardware and software components which enable researchers accessing it to streamline their research projects, schedule compute cycles, and access applications, analytics tools, and storage resources. For more on NJEdge's *EdgeDiscovery* see pg. 3.

Advancing the Research Platform across the Plains



How do you draw together different groups of people to create a seamless research platform that encourages collaboration on a broad range of data-intensive fields and projects? Hold a Monday morning meeting?

The Great Plains Network Research Platform (GPN RP) began and is succeeding with that exact strategy. The end goal, like the Pacific Research Platform and other regional efforts, is to create a seamless research platform that encourages collaboration on a broad range of data-intensive fields and projects. GPN is accomplishing this by closing the gap between a number of communities including scientific equipment, high performance computing (HPC), storage, and the networks that connect them. This ultimately increases access to the research cyberinfrastructure across the region.

The first GPN RP meeting was Monday, February 19, 2018, and HPC directors, system administrators, research computing facilitators, and network engineers from GPN member universities and their state networks have been meeting most Mondays ever since. These groups of people often don't get a chance to interact outside of collaborative groups like these.

GPN purchased Flash I/O Network Appliance (FIONA) boxes for seven members. Several other universities and state networks purchased their own, demonstrating their commitment to the project. The boxes were based on the specifications the Pacific Research Platform developed and GPN members refined. The first two months of GPN RP meetings coordinated the configuration, ordering, and delivery of the FIONAs.

Over the course of the first year, the GPN RP has deployed a Kubernetes cluster - geographically separate computers that function collaboratively as one orchestrated computing platform. The goal of GPN RP and its Kubernetes cluster is to "drop the clutch on science," says George Robb III of the University of Missouri.

Two groups who typically do not have a history of interaction, system administrators at universities and the state network engineers, have the opportunity to ask each other questions and let each other know about upcoming projects that will affect network use.

Improvements in research data flow have already occurred. In one situation, a meteorologist mentioned during a meeting with a Campus Champion that data from the National Oceanic and Atmospheric Administration (NOAA) took too long to reach him. NOAA data traveled from Colorado across various networks before finally reaching the meteorologist's Extreme Science and Engineering Discovery Environment (XSEDE) computing resource in Texas. Thanks to the GPN RP meetings, the Campus Champion knew how to escalate and diagnose the issue. Within days the meteorologist was happy because his research data workflow was once again completing successfully.

The collaboration within the region inspired GPN to develop a visualization tool to identify these great collaborators. Initially focused on the awarded grants within the National Science Foundation, the tool creates a social network graph, a "constellation", reflecting the "stars" - the PIs and co-PIs of awards - with the lines detailing the awarded grants. Using the tool has proved invaluable in engagement at the campus, state and national level - both for general outreach but also to help communicate the value of research cyberinfrastructure. Within the GPN region it's been used to identify centers that needed assistance in improving throughput to the cloud as well as to communicate with state legislature about the need for continued research network support. The tool with its rough edges can be found here: https://www.greatplains.net/nsfanalysis.

The Great Plains Network (GPN) is a non-profit consortium aggregating networks through GigaPoP connections while advocating research on behalf of universities and community innovators across the Midwest and Great Plains who seek collaboration, cyberinfrastructure and support for big data and big ideas, at the speed of the modern Internet. For more information, visit: www.greatplains.net.

The Engagement and Performance Operations Center (EPOC)

Over the last decade, the scientific community has experienced an unprecedented shift in the way research is performed and how discoveries are made. Highly sophisticated experimental instruments create massive datasets for diverse scientific communities and hold the potential for new insights that will have long-lasting impacts. However, scientists cannot make effective use of this data if they are unable to move, store, and analyze it.

The Engagement and Performance Operations Center (EPOC) is a production platform for operations, applied training, monitoring, and research and education support jointly led by Indiana University (IU) and the Energy Sciences Network (ESnet). EPOC provides researchers with a holistic set of tools and services needed to address the growing demands of scientific innovation by helping to assist with expectations related to performance issues, reliable and robust data transfers, and understanding scientific workflow. By considering the full end-to-end data movement pipeline, EPOC is uniquely able to support collaborative science, allowing researchers to make the most effective use of shared data, computing, and storage resources to accelerate the discovery process.

EPOC supports five main activities: 1) "Roadside Assistance" via a coordinated Operations Center to resolve network performance problems with end-to-end data transfers reactively; 2) application Deep Dives to work more closely with application communities to understand full workflows for diverse research teams in order to evaluate bottlenecks and potential capacity issues; 3) network analysis enabled by the NetSage monitoring suite to proactively discover and resolve performance issues; 4) encapsulated Network Services (aka "Services-in-a-Box") that provide managed data services via support through the IU GlobalNOC and our Regional Network Partners; and 5) coordinated training to ensure effective use of network tools and science support.

EPOC can not only deliver appropriate end-to-end user support and engineering solutions but is a central community hub that provides personal expertise and assistance on an ongoing basis. Through targeted partnerships, this Center has the potential to benefit nearly all of US science, research, and education on a far broader scale than any one organization can accomplish alone.

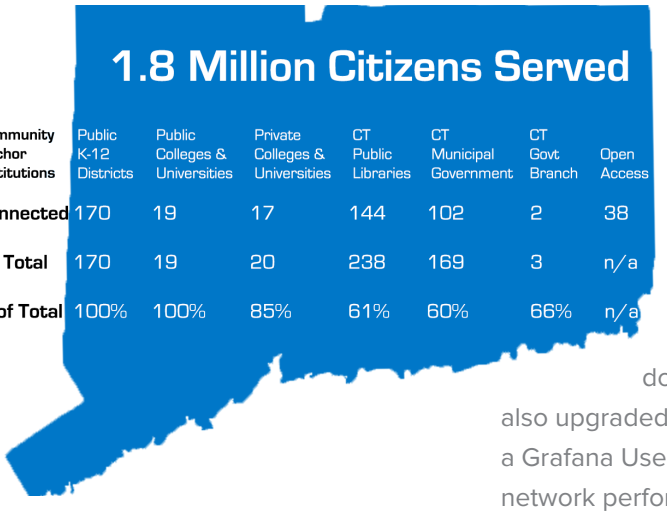
By providing not only a depth of understanding to achieve better data transfers but also the human expertise needed to make the most of research collaborations, EPOC will be transformational to science and education. For further information, visit http://epoc.global.

EPOC
Engagement and Performance Operations Center

The Energy Sciences Network (ESnet) is a high-performance, unclassified network built to support scientific research. Funded by the U.S. Department of Energy's Office of Science (SC) and managed by Lawrence Berkeley National Laboratory, ESnet provides services to more than 50 DOE research sites, including the entire National Laboratory system, its supercomputing facilities, and its major scientific instruments. ESnet also connects to 140+ research and commercial networks, enabling DOE-funded scientists to productively collaborate with partners around the world. For more information, visit: www.es.net.

Founded in 1820, Indiana University is one of the world's foremost public institutions. With nearly 100,000 students and more than 20,000 employees statewide, IU continues to pursue its core missions of education and research while building a foundation for the university's enduring strengths in teaching and learning, world-class scholarship, innovation, creative activity, community engagement and academic freedom. Bloomington is the flagship campus of the university, and each one of IU's seven campuses is an accredited, four-year degree-granting institution. For more information, visit: www.iu.edu.

Making Great Strides Connecting Connecticut's Communities



Community Anchor Institutions	Public K-12 Districts	Public Colleges & Universities	Private Colleges & Universities	CT Public Libraries	CT Municipal Government	CT Govt Branch	Open Access
Connected	170	19	17	144	102	2	38
CT Total	170	19	20	238	169	3	n/a
% of Total	100%	100%	85%	61%	60%	66%	n/a

One of Connecticut Education Network's (CEN) proudest accomplishments is the degree to which they support Connecticut's public sector, in particular, public K-12, public libraries, and municipal governments. In October, Education Super Highway's "State of the States" report announced that CEN provides access to the Internet at 100 Kbps/per student or faster in 100% of Connecticut's K-12 school districts. In addition, CEN has entered the third year of a project to move libraries to high-speed fiber connections. With this project CEN has connected 54 libraries through the first three phases with an additional 22 libraries committed to connect by the end of phase four and five. Eligible libraries who choose to pursue grant funding provided by the Connecticut State Library, like their predecessors, will transition from DSL or cable Internet connections (3 – 12 Mbps) to CEN's fiber optic network supporting speeds of 1 Gbps initially and providing ample capacity for growth to 10 – 40 Gbps. CEN also added 20 municipalities and 7 private nonprofit organizations across the State to the existing connected community in 2018.

To ensure the network is ready to serve a growing member base and bandwidth demands, CEN completed a series of network upgrades adding 200 Gbps connectivity to each of the three core routers, more than doubling their capacity. CEN also upgraded the monitoring portal with a Grafana User Interface (UI), enhancing network performance monitoring and improving capacity management, and implemented Ansible to help automate network software updates. CEN launched a new website in March giving members quick and easy access to the tools they need to maximize their connections.

In addition, CEN became Mutually Agreed Norms for Routing Security (MANRS) certified, the global initiative supported by the Internet Society that increases overall network security and provides crucial fixes to reduce the most common routing threats including filtering, anti-spoofing, coordination and global validation.

CEN also established three new advisory councils with focus on: Service Management, Technical Advancement, and Engagement and Professional Development. All councils are co-chaired by members with administrative support from CEN team members. The three councils provide CEN with guidance and recommendations for service development, network applications and tools, training and outreach. CEN hosted a number of strategy workshops throughout the state with member participation completing S.W.O.T. analyses and using the results to develop a comprehensive five-year strategic plan.

CEN completed its second year without any general fund support from the state, and as a Universal Service Administration Company (USAC) E-Rate Service Provider, helped most K-12 schools and many libraries take advantage of federal E-Rate subsidies. USAC's Schools and Libraries (E-rate) Program provides discounts to keep students and library patrons connected to broadband and voice services.

Lastly, CEN's continued membership growth and operational efficiency has allowed for bandwidth tier price stability for the fiscal year beginning July 1, 2019. This included a price reduction in the 50 Mbps tier to help those members transitioning up from 25 Mbps. CEN's bandwidth tier pricing includes multiple value-added services: DDoS detection and mitigation, CIPA compliant web filtering, on-demand burst ability, DNS hosting, private ethernet circuits, and access to Internet2 and multiple backbone Internet providers. The net result for the CEN membership is an ISP offering that provides them unmatched performance, reliability, and an annual cost savings of over $20M when compared to alternative providers.

CEN will continue to be the trusted partner through which Connecticut's digital and human networks, connect, collaborate, and share resources to realize the full potential of a robust statewide network.

Connecticut Education Network (CEN), the nation's first all-optical research and education network, delivers reliable, high-speed internet access, data transport, and value-added services to its members drawn from K-12, higher education, libraries and municipalities throughout Connecticut. CEN's statewide fiber optic network connects more than 1.8 million students, educators, researchers, state and municipal employees, and citizens in support of Connecticut's workforce and economic development. For more information, visit: www.ctedunet.net.

A Unique Partnership to Meet the Growing Need for Public Broadband in Oregon

Broadband access is an essential utility for any community to fully engage in the global digital economy. While Oregon cities generally boast above-average internet speeds, many rural parts of the state don't fare nearly as well. Oregon's research universities and state government now are working together to address connectivity challenges through an emerging non-profit organization, the Oregon Fiber Partnership, operating as Link Oregon.

Link Oregon brings together Oregon's Office of the State Chief Information Officer (OSCIO), Oregon State University (OSU), the University of Oregon (UO), Oregon Health & Science University (OHSU) and Portland State University (PSU). The partnership leverages the capabilities of its partners, building particularly on the extensive experience within the Network for Research and Education in Oregon (NERO) based at UO.

"This is a unique collaboration between Oregon research universities and state government to develop a truly statewide shared backbone network," said Steve Corbató, Link Oregon executive director. "Faster, more robust networks like this are vital for our universities to stay at the cutting edge of research and innovation, and a broad reach is critical to fulfill our partners' extensive statewide missions around research, education, healthcare and public service." As a public sector partner, Link Oregon seeks to creatively address the geographic and economic challenges to sustainable, affordable rural broadband service in Oregon. It has forged relationships with local telecommunications carriers and municipal broadband initiatives to leverage existing dark and lit fiber infrastructure for middle and last mile connections.

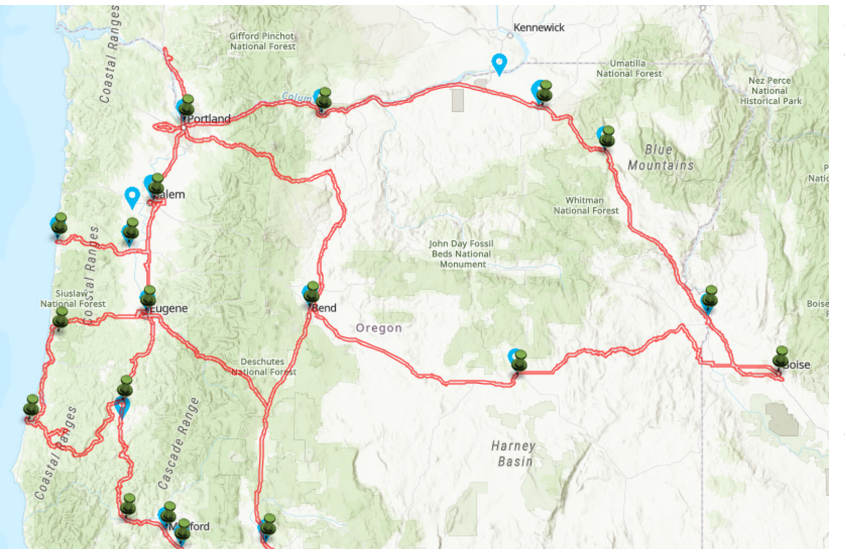
Link Oregon has already acquired more than 2,300 route miles of optical fiber from multiple vendors, including CenturyLink, LS Networks, and Zayo. PEAK Internet has provided fiber optic cable for a new direct connection between OSU's main campus in Corvallis and its Hatfield Marine Science Center in coastal Newport. This pilot network segment supports critical research such as seismic risk mitigation and offshore wave energy trials.

Collaboration between research universities, medical centers, and rural clinics can help address urgent population health issues, including the rural opioid epidemic and unmet needs for mental health services. Robust connectivity means better, faster service delivery for local government agencies, K-12 schools, libraries, Native American Tribes, and healthcare organizations. It can boost techniques and best practices for digital agriculture and forestry, improve rural STEM education, and help develop new, sustainable avenues for local economic development.

Link Oregon is working already with small municipalities—including Independence, Lakeview, and John Day—and with Oregon's Tribes to understand their unique social, economic, environmental, governance and research connectivity needs. The Klamath Tribes, for instance, are researching ways to preserve two endangered species of sucker fish that traditionally inhabited the Upper Klamath Lake watershed.

Link Oregon will maintain connections to the national Internet2 network as well as CENIC's California Research and Education Network and focus on meeting the advanced requirements for partners' cybersecurity, disaster recovery and overall resiliency planning needs.

The first phase of the network is expected to be operational in the second half of 2019, with additional critical milestones to follow in early 2020. Link Oregon also has the potential to house future state IT collaborations in areas such as cybersecurity, trust and identity, and research computing.



The initial footprint of Link Oregon's fiber optic backbone covers the state. For the first time, Link Oregon will provide extensive connectivity to public sector entities on the Oregon coast and in the eastern part of the state as well as in the more populous Willamette Valley.

Link Oregon is a unique not-for-profit partnership that brings together Oregon's Office of the State Chief Information Officer, the Oregon Department of Transportation and several other state agencies as well as Oregon's four public research universities to develop and operate a statewide, high-speed optical network. For more information, visit: www.linkoregon.org.

Election Security – ICN Chosen as a Trusted Partner of the Illinois Cyber Navigator Program

The Illinois Century Network (ICN) is playing a key role to ensure Illinois election security. To help protect the integrity of the nation's election processes, and in light of growing vulnerability concerns and prior documented attacks, the President signed the Help America Vote Act into law on March 23, 2018. The statute authorized $380 million in federal grants to states resulting in $13.2M being awarded to Illinois, which, together with a state match totals $13.89M to "improve the administration of elections of Federal office, and to enhance election security technology and improve systems, equipment, and process used in federal elections."

Following the receipt of this grant, to increase security for Illinois elections, Illinois signed into law the Cyber Navigator Program which consists of the following three initiatives: 1) ICN Upgrade and Expansion; 2) Cybersecurity Information Sharing; and 3) Cyber Navigators.

The first initiative, ICN upgrade and expansion, will result in several services being provided to election offices. This includes a separate and private dedicated network enabled by Multi-Protocol Label Switching (MPLS) technology and a centrally managed firewall providing broad protection against known malicious IP addresses and a central "choke point" for attacks against Illinois elections infrastructure.

In addition, Distributed Denial of Service (DDOS) Mitigation will keep election office websites, databases and other applications accessible in the event of a DDOS attack. Each election office will be able to automatically forward firewall logs to DoIT's 24/7 Security Operations Center for monitoring and analysis. Election traffic on the ICN will also pass through the Department of Homeland Security's (DHS) "Albert" sensor Intrusion Detection device. This device provides further 24/7 monitoring by DHS staff.

The ICN will provide cleaner, safer Internet access, automatically blocking known malicious sites and IP addresses through IP filtering, Geo filtering, etc. Traffic between State Board of Elections and each election office will never be exposed to the Internet – the traffic will stay entirely within the ICN and its firewalls and other protective services.

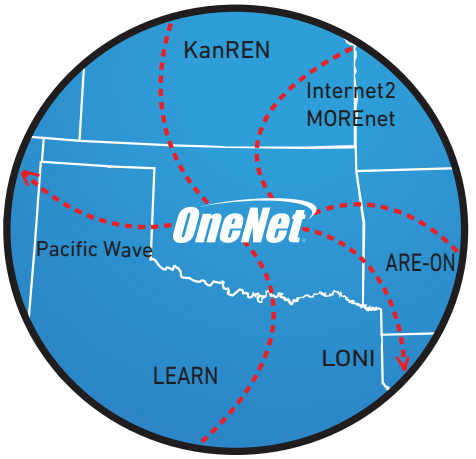
For the second initiative, Cybersecurity Information Sharing, a program manager has been recruited and serves as the coordinator for outreach and information sharing with election authorities statewide. The program manager also offers election officials security awareness training, educational webinars and conferences, updates on cybersecurity best practices, as well as mitigation and recovery if a cyberattack should occur.

Finally, for the third initiative, the state hired nine "Cyber Navigators" to provide "boots on the ground" support for the state's election authorities. Cyber Navigators provide comprehensive risk assessment services by evaluating security controls and assessing the likelihood and magnitude of potential harms. They also analyze system and network documentation for accuracy, recommend software security patches, system updates, and other enhancements, while assisting with security controls. All 108 election offices are expected to participate in the Cyber Navigator program. The ICN provides the connectivity from each election office to the State Board of Elections database.

The Illinois Cyber Navigator Program is an excellent example of the collaboration between State Board of Elections, Illinois Department of Innovation & Technology and the Illinois State Police's State Terrorism Intelligence Center. The role of Illinois Century Network shows the critical and significant role filled by managed state networks. ICN is perfectly situated to partner in this effort to help provide a more reliable, robust and secure voting process for the State of Illinois.

The Illinois Century Network (ICN) began in 1997 with the recommendation from the Higher Education Technology Task Force to create a single, statewide educational network. The ICN became reality in May of 1999 with the signing of legislation called the Illinois Century Network Act. The ICN has evolved significantly since 1999 and is now a 2000 mile state wide high speed broadband network serving K12 and Higher Education, Public Libraries and Museums, State and Local Government and Commercial service providers. The ICN is managed and operated by the Illinois Department of Innovation and Technology. For more information, visit: www2.illinois.gov/icn.

Expanding Partnerships to Boost Local and Regional Connectivity



OneNet is building on regional partnerships to boost connectivity in the state of Oklahoma and throughout the south central region. OneNet's geographic location as a crossroads uniquely positions the network to expand high-speed services across the region.

"Historically, some have classified Oklahoma as a 'fly-over' state," said Vonley Royal, OneNet's executive director. "Now we are a participant in facilitating high-bandwidth connections for the entire region."

OneNet, along with Oklahoma data centers and telecommunications providers, has created a new partnership, the Oklahoma City Internet Exchange or OKCIX. This partnership formalizes OneNet's content delivery network (CDN) project and provides a safe, collaborative place for Oklahoma-based telecommunications and content providers to connect with each other.

OneNet is facilitating the new fiber connections into Oklahoma City area data centers, where participants connect with OneNet's network. Through this connection, participants can access OneNet's CDN services, which include content providers such as Netflix, Facebook, Alkami, Microsoft, Amazon, Google and Valve. OKCIX partners can reduce costs through CDN services and by peering with other participants.

A new technology, node slicing, will also reduce costs for both local and regional partners. Node slicing is the ability to virtualize multiple router instances inside a single physical router. OneNet is deploying node slicing to enable multiple organizations to utilize equipment more efficiently. This new technology will reduce the cost of colocation in participating data centers and provide virtual resources for public/private partners.

OneNet's current partnerships with Great Plains Network and Western Regional Network have provided regional connectivity for the South Central states and connections to the West Coast. Through these partnerships, OneNet is connected to Internet2 and the Pacific Wave International Exchange, which support advanced research and scientific discovery.

OneNet's leadership identified the need to build on these partnerships and establish more direct connections within Oklahoma and among surrounding states. These new connections support regional research and education networks, content providers and telecommunications partners.

Multiple regional networks have formed the Dallas Consortium with the goals of increasing connectivity, lowering costs and bringing more content to member states. The consortium includes OneNet in Oklahoma, ARE-ON in Arkansas, KanRen in Kansas, LEARN in Texas, LONI in Louisiana and MOREnet in Missouri.

Consortium members are provisioning fiber and wave services across state lines to deploy more direct connections for the research networks.

These direct fiber connections improve access to resources for member networks and the organizations they serve, such as higher education institutions and health care providers. These connections generate cost savings and enable organizations on the network to communicate more effectively across the region.

"OneNet plans to build on these new partnerships to deliver world-class connectivity to Oklahoma and its neighboring states," said Royal. "These partnerships are a key strategy for fulfilling our mission of advancing technology across Oklahoma and offering better services and improved quality of life in Oklahoma and throughout the South Central region." Organizations interested in participating in these partnerships can contact OneNet at info@onenet.net.

As a division of the Oklahoma State Regents for Higher Education, OneNet's mission is to advance technology across Oklahoma. OneNet serves colleges and universities, research centers and laboratories, public and private schools, libraries, tribal organizations, hospitals and clinics, nonprofit organizations and local, state and federal governments. For more information, visit: www.onenet.net.

Expanding Fast and Safe Access for Research and Education

The Northern Crossroads (NoX), with an expanded footprint, faster backbone, and top-rated security, has kept pace with the growing needs of research and education in the Northeast. The NoX has grown beyond its original colocation facilities in Boston and Cambridge with the establishment of strategic peering points in four additional sites, including the Massachusetts Green High Performance Computing Center (MGHPCC) in Holyoke, two sites in New York City, and one in Albany.

With this expansion into New York, the NoX is establishing direct peering with Apple, Google, Akamai, Netflix, and Facebook. Links to Connecticut Education Network (CEN), the Mid-Atlantic GigaPOP in Philadelphia for Internet2 (MAGPI), New York State Education and Research Network (NYSERNet), and the Ocean State Higher Education Economic Development and Administrative Network (OSHEAN) put the foundations in place to provide seamless access to the Eastern Region Network (ERN) and other regional and national research initiatives. And with an upgraded backbone, the network can provide support for 100GE connectivity.

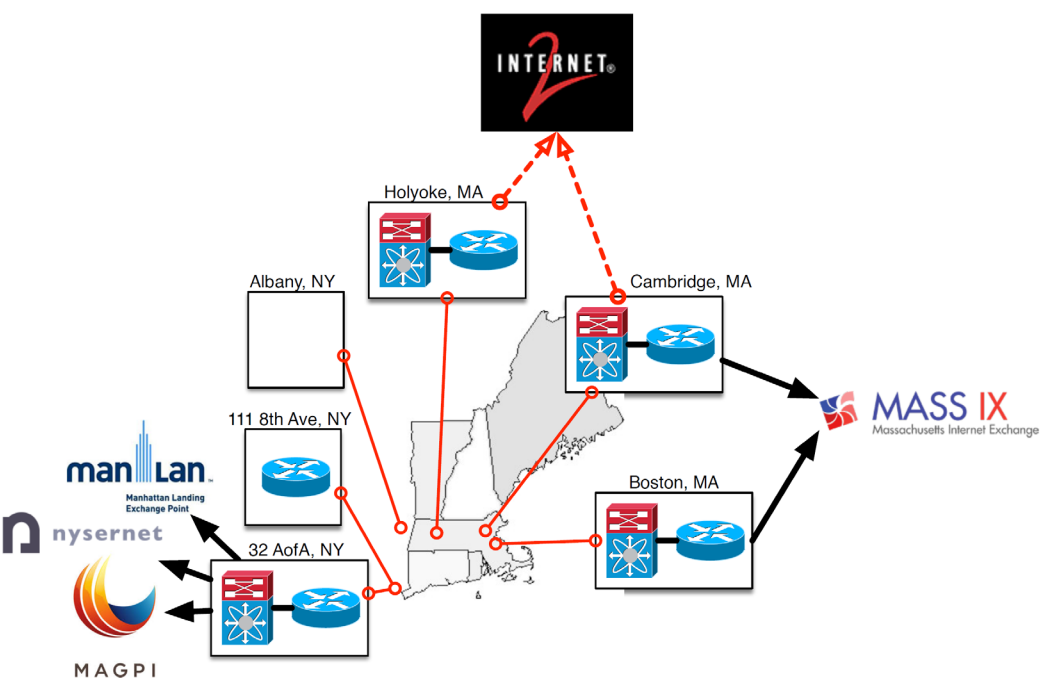
Beyond strategic peering and connectivity, the NoX also offers its entire community Akamai's highly valued Prolexic DDoS protection service. Attacks of up to several hundred Gb/s are mitigated and scrubbed, allowing clients to focus on their work undisrupted.

NoX also supports a myriad of research activities across its New England membership. Examples include the Mass Open Cloud (MOC), the Northeast Storage Exchange (NESE), and the ATLAS experiment.

MOC is a shared cloud and collaboration platform operated in the Massachusetts Green High Performance Computing Center (MGHPCC) by Boston University, Harvard University, Massachusetts Institute of Technology, Northeastern University, and the University of Massachusetts. Its Infrastructure as a Service offering, based on OpenStack, lets users stand up virtual machines, use object storage, and create on-demand Hadoop Distributed File System (HDFS) environments (with Hadoop, SPARK, PIG, etc.).

NESE is a shared regional storage collaboration funded by the National Science Foundation and operated as a long-term partnership between the five flagship universities at the MGHPCC and RedHat. NESE's main goals are to meet the storage needs of the data revolution for science, engineering, education and technology, particularly for researchers in the northeastern part of the U.S.

The ATLAS experiment is a large detector system developed by physicists from around the world; the system tracks very-high-energy proton-proton interactions at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) laboratory for high-energy physics near Geneva, Switzerland. This experiment will probe the origins of electroweak symmetry breaking and the particles associated with the new physics (such as the hypothetical Higgs Boson). A 100GE pipe to the MGHPCC feeds the Tier-2 ATLAS cluster operated by Boston University and Harvard University. NoX has established an Advanced Layer 2 Service connection across its framework to the LHC Open Network Environment (LHCone) at New York, supporting the large-scale data transfers to the cluster.



The Northern Crossroads (NoX) facilitates advanced networking among research institutions in New England. Participants include institutions of higher education and partner organizations that support research, education, and economic development. For more information, visit: www.nox.org.

WVNET and the "Courtroom of the Future"

In the late 1990s, the State of West Virginia decided to replace its 55 local jails located as part of the courthouse complexes in the county seats, with 10 Regional Jails each serving 5-6 counties. This created a challenge for judges and lawyers to do their jobs when the defendants were at a distant location. The West Virginia Supreme Court asked Judge Dan O'Hanlon, head of the Judicial Technology Commission, to research and propose a videoconferencing solution.

Judge O'Hanlon found that other states transmitting video on Integrated Services Digital Networks (ISDN) were having video/voice sync problems and frequent dropping of calls. At that time the West Virginia Network for Educational Telecomputing (WVNET) had received a grant to become the first all-ATM (Asynchronous Transfer Mode) switched network in the country, and O'Hanlon knew that ATM was the perfect network to carry video conferencing. He teamed up with Allen Daugherty, telecommunications manager at WVNET, and they received a grant from the state to do a pilot project. Within a year, they connected three counties and two regional jails. Now an arrested person could appear before a judge from a room in a jail, saving money along with bringing faster due process for the individual.

"The system worked beautifully and I came to admire the incredible talent at WVNET!" says Judge O'Hanlon.

A few years and several grants later, WVNET connected every jail, prison, juvenile facility, and courthouse in the state along with the state capitol building, creating the largest ATM-based public video conferencing system in the world! It saved the state millions of dollars in guard and transportation costs because prisoners did not have to be transported between jails and courthouses, and it eliminated the risk involved in doing that.

The "Courthouse of the Future" project gained national attention, winning the Governor's Technology Award, getting recognition for demonstrated Internet business leadership in Cisco's iQ Magazine, and being reported in Forbes magazine, Fortune magazine, and the Wall Street Journal.

WVNET later moved from ATM to an IP-based fiber optic network. Upgrades were made to the video network, including the addition of newer Cisco and Polycom equipment, to significantly improve security for calls both in and outside of West Virginia. WVNET handles the scheduling for all calls with out-of-state sites. They also work with the court technical staff to troubleshoot and replace faulty video equipment, and help to migrate from older to more modern systems.

Judge O'Hanlon adds, "Perhaps the greatest part of the story is that for 20 years WVNET has run the network with almost no glitches or problems. Hundreds of video calls go out across the network, continuing to save time and money. Many people from other states and countries visit WVNET to see how they manage to do that."

WVNET's video network continues to find new users, including corrections, federal judges and prisons, witnesses, law firms, language interpreters, the West Virginia Department of Health and Human Resources (DHHR), and healthcare agencies and hospitals. Combined with WVNET's Distance Learning resources, the West Virginia Supreme Court uses the system for professional development and training. WVNET employees use it to meet with colleagues throughout the state. These are some of the many ways that WVNET provides essential cost-effective services to the state of West Virginia.

West Virginia Network for Educational Telecomputing (WVNET) is a dynamic service organization providing telecommunications and computing services within West Virginia. Administered by the Higher Education Policy Commission (HEPC) and focused on state colleges and universities, WVNET also provides significant services to state and county government, K-12, public libraries and non-profit organizations. As a centralized state resource, WVNET reacts to customer needs in providing efficient and cost-effective deployment of technology, training and support. For more information, visit: www.wvnet.edu.

Industry Leaders Power Fastest Network Ever Built for Research and Education

Indiana GigaPOP network engineers collaborated with Ciena, Internet2, and U.S. Department of Energy Science Network (ESnet) to power the fastest network ever built for research and education. The new 400-gigabits-per-second 'Monon400' debuted in November 2018 at the International Conference for High Performance Computing, Networking, Storage, and Analysis (SC18) in Dallas, Texas.

Called the Monon400 because it operates over 400G channels, the 800-gigabits-per-second capacity high-speed network can transfer a 4K-resolution movie in about one second. The network can be upgraded to a maximum capacity of 25.6 terabits-per-second, or roughly 32 times its current speed.

For scientists and researchers, Monon400 enables high-speed sharing of massive amounts of data created by modern digital instruments like gene sequencers, powerful microscopes, and the Large Hadron Collider. The Monon400 runs from Indianapolis to Chicago, linking the Indiana GigaPOP with Internet2, Big Ten Academic Alliance, and national research and education networks.

For the SC18 Network Research Exhibition (NRE) demo, the Monon400 ran over a dedicated 100G circuit provided by the ESnet and three shared 100G circuits, two from Internet2 and one from CenturyLink, to complete the 400G capacity.

"The SC18 demonstration is just the first example of what the Monon400 will enable through the high-speed, low-latency network connectivity we have built in Indiana," said Marianne Chitwood, director of I-Light, Indiana's statewide higher education optical fiber network, and the Indiana GigaPOP. "Researchers will be able to do high-performance data transfers at much higher speeds than before—all because Monon400 has been built with the research community and its requirements in mind."

For the Monon400, Indiana GigaPOP worked with Ciena to deploy the company's Waveserver® Ai 400G stackable interconnect platform and Blue Planet® Manage, Control and Plan (MCP) domain controller with Liquid Spectrum™ analytics applications. It is the first research network deployment of Blue Planet MCP and Waveserver® Ai. The resulting programmable infrastructure will enable the use of 400G channels connecting Indianapolis to Chicago with full visibility into network efficiencies.

High performing networks that have the ability to scale are imperative in the research and education networking community. The current platform and software enable Indiana University to deliver high-capacity 400G wavelengths and greater flexibility in the network to facilitate more efficient collaboration between scientists and easier access to data intensive resources.

I-Light, a unique collaboration among Indiana colleges and universities, state government, and private sector broadband providers, is a high-speed fiber optic network that connects Indiana member sites to state, national, and international research and education communities. For more information, visit: www.ilight.net.

The Indiana GigaPOP, a partnership of Indiana University and Purdue University, serves as the network hub for the state's colleges and universities.

Florida LambdaRail Expands Reach of Regional Science DMZ

Florida LambdaRail's (FLR) Regional Science DMZ is the basis for The Atlantic Research Platform (ARP), a science-driven, high-capacity data exchange and transport facility that links campuses to other regional, national and global science DMZs. The ARP integrates campus Science DMZs (following a model developed by ESnet) and links together many of the Campus Cyberinfrastructure initiatives (e.g., CC-NIE, CC-IIE, CC-DNI) that have been funded by the National Science Foundation in recent years.

FLR
Florida LambdaRail
Florida's 100 Gigabit Research and Education Network

First developed by ESnet, the Science DMZ concept features a network architecture designed specifically for the support of data-intensive scientific and research applications outside and away from standard Internet traffic. The FLR Regional Science DMZ and ARP provide participants the ability to extend and interconnect campus research, high-performance computing, and instructional technology environments to the global research and education networking fabric. The FLR Regional Science DMZ was established utilizing internal funding from its member institutions to support and enable institutional research initiatives via high-speed networking. It was first operationalized in 2015 upon the completion of a network upgrade to 100G.

Since that time, FLR partner institutions have worked to improve their campus networking environments where today four Florida universities – The University of Florida, Florida State University, the University of Miami, and the University of South Florida – have connected to the FLR Science DMZ. Four additional institutions – Florida Atlantic University, Nova Southeastern University, Florida Institute of Technology and The University of North Florida – are pursuing campus network upgrades and are expected to connect soon.

Utilizing the capabilities of the Internet2 Advanced Layer 2 Services Network, the FLR Science DMZ now peers with the West Coast Regional Science DMZ called the 'Pacific Research Platform (PRP)' thereby extending the Science DMZ concept from coast to coast. The Pacific Research Platform is a National Science Foundation funded initiative to support high speed science traffic on a large regional scale throughout the West. This connection to the PRP provides optimal low latency national connectivity between sites engaged in research.

Conversations over the past two years have taken place among interested institutions regarding the need to establish a National Research Platform combining and extending regional research platforms such as the PRP and the FLR Regional Science DMZ to establish a true national standard. FLR's connectivity with the PRP is just one example of innovative institutions making advancements on behalf of their partners in furtherance of national networking goals for research and education.

Florida LambdaRail (FLR) is Florida's Research and Education Network. With its 100 Gbps 1,540 mile dark fiber network, FLR provides a cost effective, ultra-high speed, inter-connected, broadband service delivery network that enables Florida's higher education institutions and partners to collaborate, connect, utilize, and develop new innovative broadband applications and services in support of their scientific research, education, and 21st century economy initiatives. For more information, visit: www.flrnet.org.

User-Friendly Web Portal Helps Connect the Value for MOREnet's Members

While our member institutions were busy serving their communities in academia and the public sector, MOREnet continued to improve its user portal, with the goal of helping members visualize the value of their participation in the MOREnet consortium.

Although for several years, we've had a self-service portal for members to monitor fees and bandwidth usage, we've made a concentrated effort over the last 12 months to enhance the information available making it even more valuable for our members. Our primary goal was to improve the user experience of the portal to draw more users and broaden the local understanding of MOREnet service availability, usage, and relevance for their institution. The secondary goal was to show a more complete story of the value they receive from the services they subscribe to, including our Member Service Package, which includes a bundling of our most popular and essential technical services. We also populate the portal with tools that highlight the competency of the broadband connection into our local research and education network. Since our connectivity is unlike what most providers deliver, we want our members to see the difference and understand what sets it apart.

Members connected to our network can see their current circuit capacity, including both ordered and provisioned bandwidth, the expiration date of the circuit, and the hostname as well as the interface. Users can review IP addresses assigned to their organization. New graphics show utilization as well as maximum utilization over the most recent 24-hour period to help members understand if capacity meets demand. There is also an option to drill down with Netflow reporting to better understand traffic patterns for analysis and planning future bandwidth needs. Finally, members can set up alerts for their circuits.

MOREnet's Membership Service Package includes online resources such as EBSCO, EBSCO eBooks, HeritageQuest, and LearningExpress. In MyMOREnet, our members-only portal, members can see monthly usage statistics including searches and full-text downloads. In the Document section, we share downloadable documents that may be of interest to members. And under the Service Utilization drop down menu, members can see the professional development that faculty and staff from their organization have attended through MOREnet-offered training workshops, conferences or online training.

In the Subscriptions section, all members are able to see all active service subscriptions which provides a real-time fee estimate based on current service rates. To assist with budget planning, members have the ability to print a PDF of their current subscriptions and the associated fees to share and reference as needed. Members can create or view a help desk case in real time; the table shows users the status of each case (open or closed) as well as a quick case description and its identification number. Administrators are now able to manage their contacts in MyMOREnet. This is an easy way to designate who MOREnet staff should contact for particular areas--billing, technical issues, E-rate, online resources or cyber security.

We are pleased with the positive comments we have received on this new interface for MyMOREnet. This new platform gives us greater flexibility to continue to enhance the experience for users and expand the adoption and value of this tool.

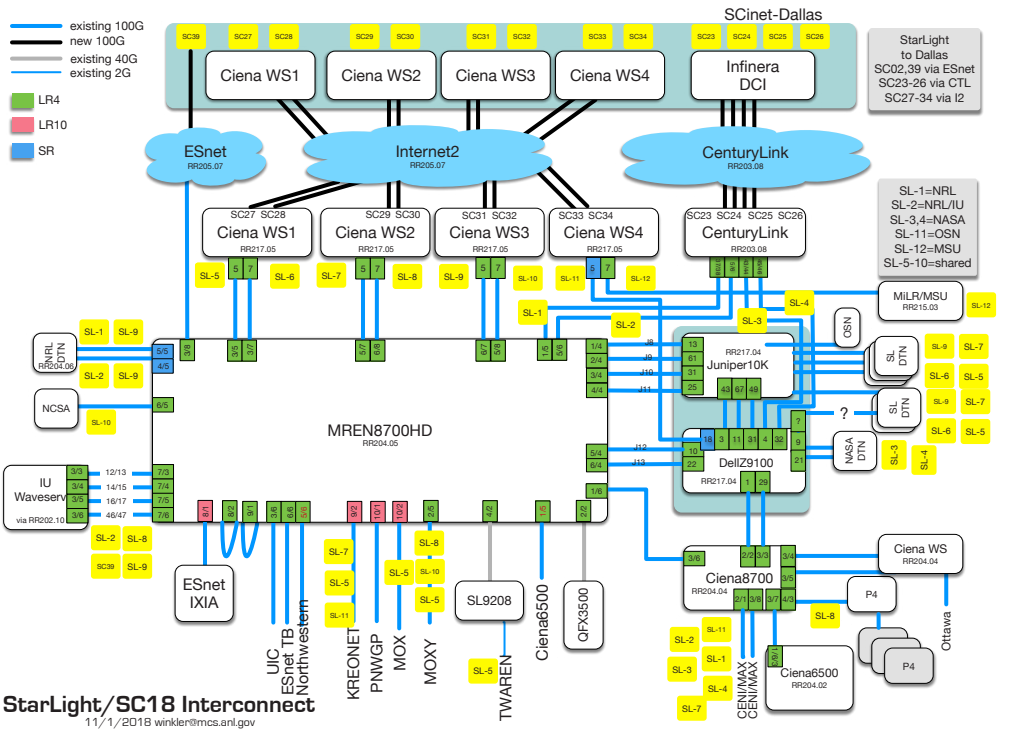
The Missouri Research and Education Network (MOREnet) is a member-driven consortium providing Internet connectivity, access to Internet2, technical services, resources and support, as well as technical training to Missouri's public sector entities, including K-12 schools, colleges and universities, public libraries, health care, government and other affiliated organizations. MOREnet serves more than 700 members across Missouri. For more information, visit: www.more.net.

Creating Advanced Networking Services for Data Intensive Science

The Metropolitan Research and Education Network (MREN) was established specifically to meet the requirements of data-intensive science. The key data movement challenges of data-intensive science that are being addressed by MREN are two-fold. The first is the need to support large-scale capacity. This means not only addressing increasing numbers of 100 Gbps paths, but also preparing for the capacity to support 400 Gbps and Tbps paths using bonded lightpaths provisioned over superchannels. The second is the need for network programmability such as the use of software-defined networking (SDN) to optimize that large scale capacity. Recently, network programming using SDN has become more sophisticated, and it now includes techniques for integration with network programming languages, such as P4.

To showcase these innovative services and technologies, MREN collaborates with its community partners to stage demonstrations at major international and national technology workshops, conferences, and special forums. One major venue for these demonstrations is the SC supercomputing conference. In 2018, the 30th annual ACM international Supercomputing Conference for High-Performing Computing, Networking, Storage, and Analysis International Conference (SC18) took place in Dallas, Texas. For this conference, MREN, the SCinet Wide Area Network (WAN) team, the StarLight consortium, and multiple national and international research partners, designed and successfully implemented several demonstrations. These included creating a 13*100 Gbps network path from the StarLight Facility to the conference venue in Dallas, creating a 6*100 Gbps path from Washington, D.C., to the venue and also creating 2*100 Gbps from Washington, D.C., to the StarLight Facility.

The SCinet WAN was used to stage 35 sets of national and international 100 Gbps demonstrations of emerging advanced networking services, architecture, and technology. Demonstrations included a showcase of the capabilities for supporting Petascale science with the StarLight International Software-Defined Exchange (SDX) and for programmable WAN networking with the NSF Global Environment for Network Innovations SDX. Also supported were demonstrations of advanced services for the High Energy Physics research communities, with a focus on the Large Hadron Collider Open Network Environment. Another MREN supported project showcased a prototype service for the Large Synoptic Survey Telescope which is being developed on a mountain in Chile. When operational, this telescope will send hundreds of gigabits of space exploration data from Chile to Sao Paulo, Brazil, to Miami, Florida, to the StarLight Facility to the National Center for Supercomputing Applications at the University of Illinois Urbana Champaign, where the data will be shaped into science products and then distributed to research science communities world-wide. In addition, MREN supported multiple Data-Trans Node (DTN) demonstrations, including international DTN meshes and a partnership with SCinet that implemented a DTN-as-a-Service prototype.



The Metropolitan Research and Education Network (MREN) is an advanced, high-performance, regional network supporting organizations in seven states in the upper Midwest. MREN's primary focus is on providing advanced digital communications for leading-edge research and educational applications, primarily communication services for data intensive science. MREN is a founding member of the Pacific Research Platform initiative (PRP), which is an NSF support project, developing a regional Science DMZ that extends from the west coast to the StarLight facility. Recently, MREN has been involved in the PRP efforts to support a National Research Platform (NRP) pilot project. For more information, visit: www.mren.org.

Homemade DDoS Mitigation Solution Identified by MDREN Members as "Strength"

In a recent membership meeting, member institutions of MDREN, Maryland's State-Wide Research and Education Network, identified Distributed Denial of Service (DDoS) Mitigation as one of the network's strengths. According to Norwin Malmberg, chief network technology officer, "The fast, 30-second time to detect and mitigate is a substantial factor in preventing institutions from even noticing that an attack took place."

According to Michael Gemeny, senior network engineer, "The system has been fully automatic for over two years now, and has successfully identified and mitigated over 75 DDoS attacks. By the time we see the page, the mitigation has already kicked in."

The scrubbing engines are based on Juniper routers running a static BGP-Flowspec rule set which rate limits every known DDoS amplification vector. This effectively discards the attack traffic while passing the legitimate traffic to the IP address under attack.

"We originally were using an old Juniper M20 recovered from the scrap pile as our scrubber, but recently we upgraded to a pair of Juniper MX104 routers. This allows us 20 to 40 Gig of dirty traffic scrubbing capacity on net," Gemeny said. While the original configuration was based on equipment which was essentially free, the upgraded configuration was a one-time investment of $56,000.

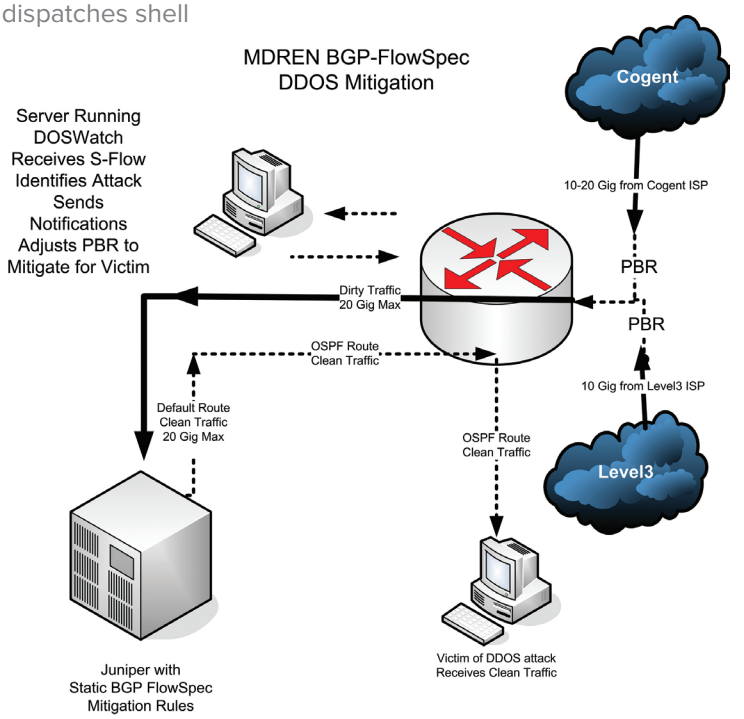
The core routers (facing upstream ISPs) are Brocade routers, and do not support BGP-Flowspec, so the Juniper routers, used as scrubbers, are applied as a companion "appliance" to the ingress routers.

When a DDoS attack is detected, Policy Based Routing (PBR) in the Brocades are adjusted, routing the victim IPs ingress traffic through the scrubber. Once scrubbed, the clean traffic is returned to the same core router. However, this time it is not coming in from an ISP connection. As such, it is not subject to the PBR and is routed to its destination with normal Open Shortest Path First (OSPF) routes.

The DDoS detection software was written in house and is a mixture of C and Perl running on a standard UNIX NOC server. This software monitors S-Flow data from the ingress routers, and dispatches shell scripts to adjust the PBRs and send pages when attacks are identified.

"It takes 5 seconds to identify an attack, 5 more seconds to quantify the attack, then 10 seconds to adjust the PBRs, and an additional 10 seconds for the routers to actually do what they have been told to do. That adds up to 30 seconds," said Gemeny.

Malmberg added that, "We do subscribe to Internet2's ZenEdge DDoS mitigation service for peace of mind, but we've never had to use it. The on-net mitigation is faster and only affects the single IP address under attack, which reduces the chance of inadvertent side effects. The potential magnitude of DDoS attacks seem to be unbounded, so it's nice to have yet another option besides just a 'Black Hole'."



The Maryland Research and Education Network (MDREN), provides advanced network services to education, research, and public service institutions throughout the State of Maryland and connections to regional and national resources. MDREN provides its members connections to the Internet and the national research network Internet2, as well as access to teleconferencing and distance learning facilities, over facilities ranging from 1 to 100 Gigabit Ethernet using MDREN's own fiber core infrastructure. MDREN leverages aggregation and partnership opportunities to provide services that would be unaffordable otherwise. For more information, visit: www.mdren.net.

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National Regional Networks Consortium

Advanced regional networking in support of research and education