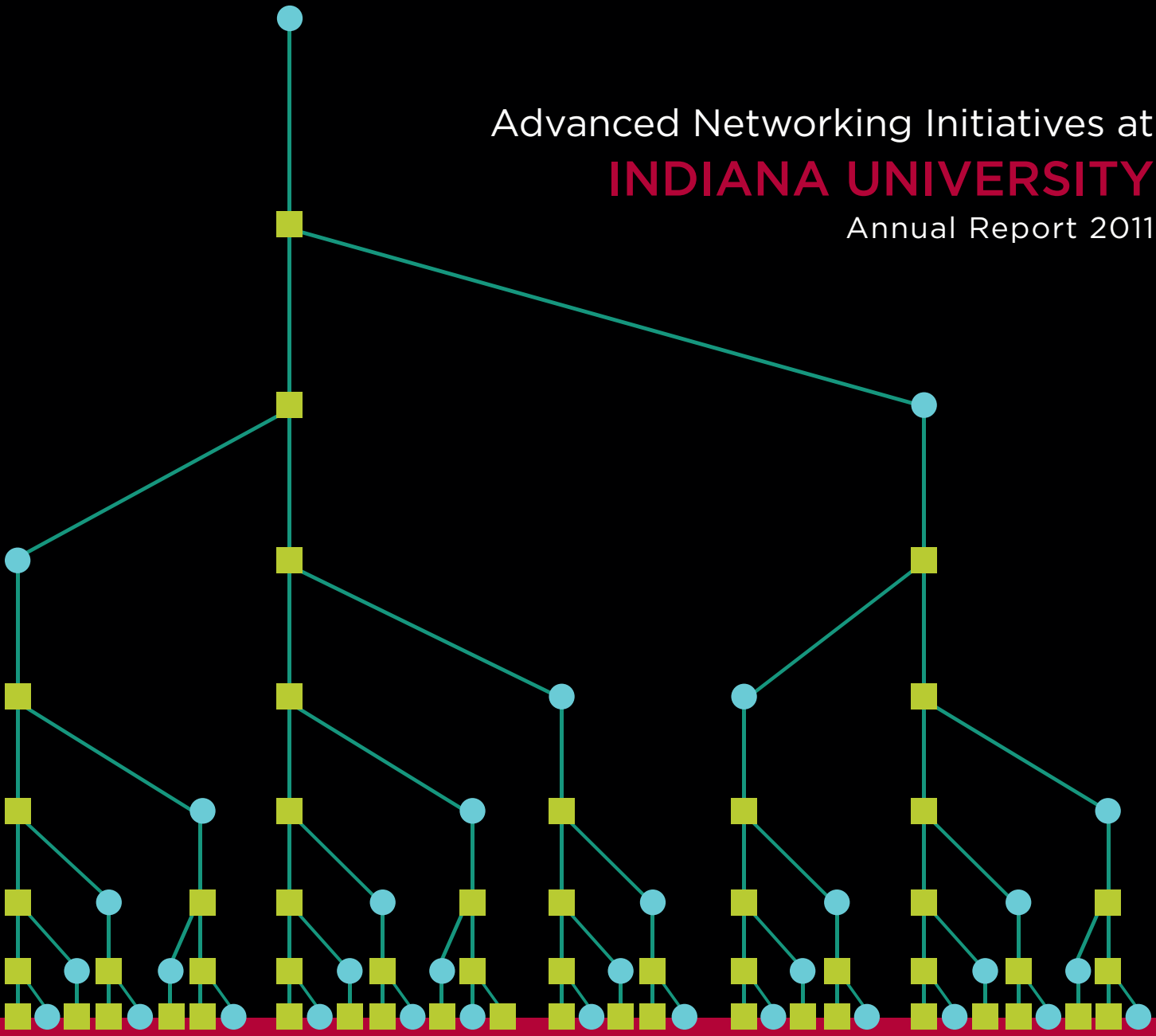
Advanced Networking Initiatives at INDIANA UNIVERSITY

Annual Report 2011



INDIANA UNIVERSITY

INDIANA UNIVERSITY

Fowler Ridge Wind Farm in Benton County, Indiana

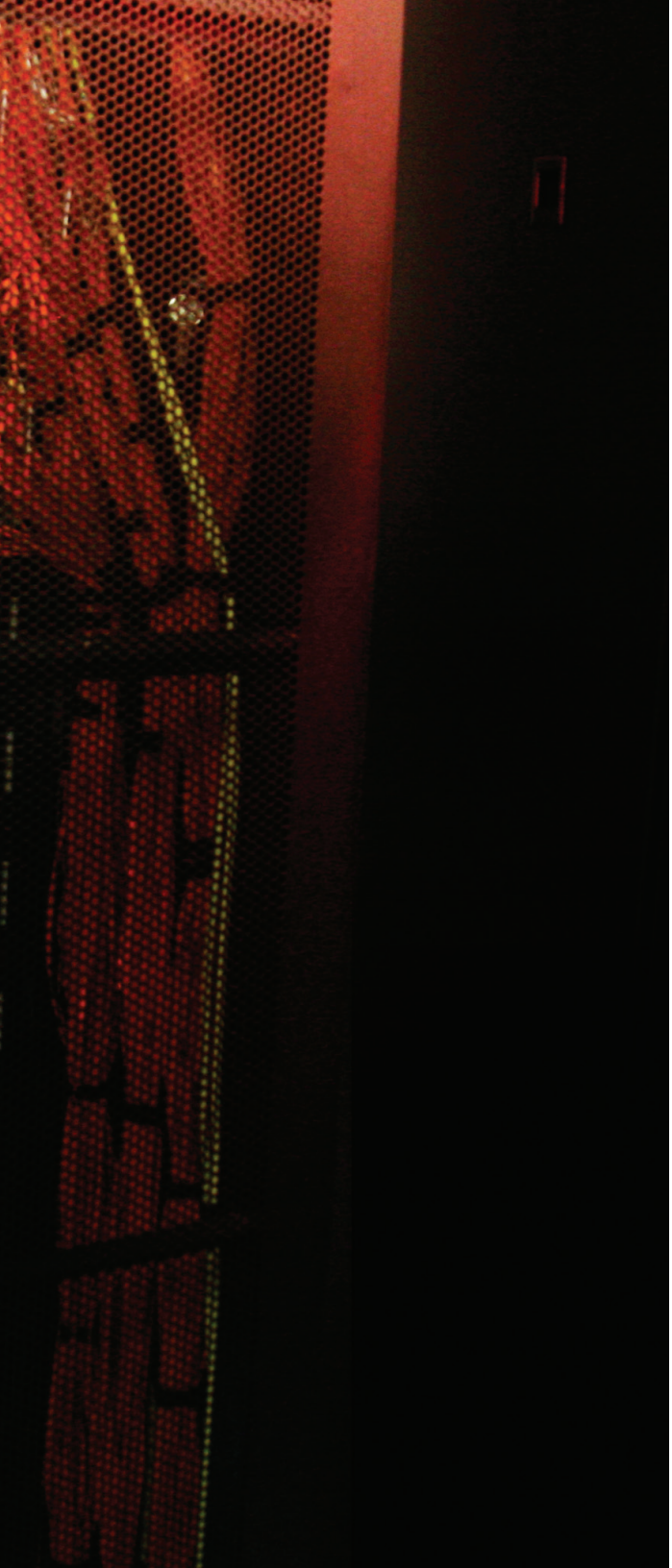
The pulse of global networking comes from THE HEART OF INDIANA

Connecting the supercomputers used by the National Oceanic and Atmospheric Administration. Connecting distant Indiana classrooms with faculty members half a world away through high-quality video streaming. Connecting researchers in Pakistan with researchers in the US to forge scientific diplomacy. Connecting student interns with top networking professionals to prepare them for the high-tech job market. Connections. Connections are what we do as human beings. **Connections are what we need to survive,** thrive, compete, and evolve.

Indiana University has a special vision for making connections. It's called networking. **Networking that supports** the uniquely 21st century way of making very **real human connections**—led from the Indiana heartland. Science. Research. Knowledge. Connections. Indiana.

"Sharing information and knowledge is essential to maintaining the economic vitality of our state and nation... High-speed networks give Indiana's and the nation's scientific and research community a powerful tool in its continuous quest for scientific discovery. Indiana is at the forefront of both network capability and leadership in the United States thanks to the ongoing efforts here at Indiana University in network planning, engineering, and support. **IU's expertise in networks plays a key role in our ability to share knowledge** in a uniquely 21st century way."

Michael A. McRobbie
Indiana University President



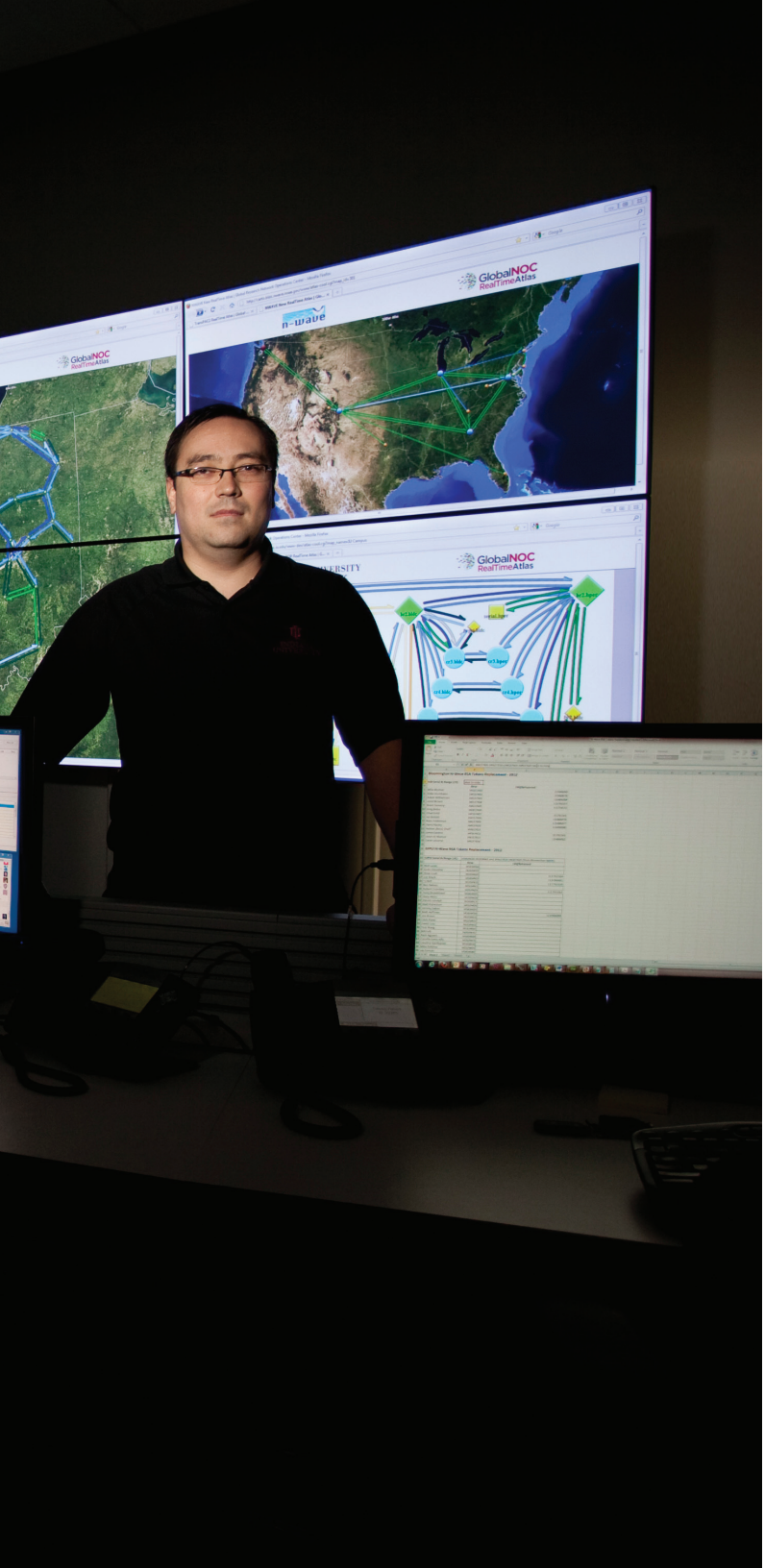
Why networking?
WHY INDIANA?

Why does networking continue to be such a success story for Indiana University? From the very beginning, IU has been able to capitalize on its **unique experience running a complex and diverse networking environment.** This experience has helped drive down costs. It has attracted great engineers. And as these engineers share and apply their expertise to support local, regional, and global networks, it has helped higher education achieve new standards in networking quality.

In short, networking at Indiana University:

- **Keeps premier networks running,** growing, and improving through the GlobalNOC
- **Gives Indiana's colleges a competitive advantage** with the I-Light network
- **Extends Indiana's reach** in the world through international networking initiatives
- **Fosters network innovation** and prepares the next generation of networking professionals through InCNTRE

Advanced Networking Initiatives: **GlobalNOC**



GlobalNOC
Global Research Network Operations Center

Operating and advancing the country's premier RESEARCH NETWORKS

The Global Research Network Operations Center (GlobalNOC) at Indiana University provides **carrier-grade operations, tools, and network expertise** tailored to the unique needs of the research and education (R&E) community.

Formed by IU in 1998 to provide high quality network operations center services for Internet2's Abilene network, GlobalNOC has evolved alongside the community it serves, **growing from a three-person staff to an organization of more than 80 people** who deliver unrivaled service and support for the world's most advanced research and education networks.

The GlobalNOC's Service Desk, Network Engineering, and Software and Systems teams work to ensure the reliability, performance, and advanced capabilities of more than 20 networks and projects.

Highlights for the year

- **New Network Operations Center facility opens in Bloomington**
  The new Network Operations Center (NOC) presence in the Cyberinfrastructure Building (CIB) in Bloomington was completed in fall 2011. Its state-of- the- art equipment allows for seamless monitoring of all GlobalNOC supported networks and continuous scaling of operational services. The new Bloomington NOC stays in constant contact with the IUPUI NOC using a 24/7 video connection.

- **Development of Washington Internet Exchange**
  Internet2 and the Mid-Atlantic Crossroads (MAX) network called on GlobalNOC to build and launch a new international exchange point in Washington, DC, called Washington Internet Exchange (WIX). WIX provides a new meeting point for Internet2, US governmental organizations, and international networks such as America Connects to Europe (ACE).

- **82% growth in GigaPoP traffic**
  The requirements for data-intensive connectivity to collaborators, colleagues, and providers are growing rapidly. In the last three years, network traffic through the Indiana GigaPoP grew more than six-fold, from 9.5Gbps to 58.3Gbps—82% growth each year.

- **Launch of Network Design and Deployment Initiative**
  Software-Defined Networking (SDN) is a revolutionary new approach to networking that allows for greater customization and flexibility than traditional networking. The Network Design and Deployment Initiative (NDDI) began in 2011 as a joint partnership between Internet2, IU, and Stanford to develop the first nationwide SDN infrastructure to support both production and experimental network services.

- **New software for Internet2 Open Science Scholarship and Services Exchange**
  For its first project within NDDI, GlobalNOC developed the new software system to be used for Internet2's Open Science Scholarship and Services Exchange (OS3E). The OS3E will connect Internet2's regional network hubs with key collaborating partners and international exchange points.

> The GlobalNOC has been the single most important factor in the success of N-Wave. NOAA is fortunate to have partners like IU and the GlobalNOC."

Jerry Janssen
N-Wave director, National Oceanic and Atmospheric Administration

> The service with GlobalNOC's Network Management Services can't be stressed enough. Before GlobalNOC, we dealt with long cycle times between feature requests and availability. Now, feature requests are delivered when they are needed most."

James Deaton
chief technology officer, OneNet, Oklahoma's telecommunications network

GlobalNOC partners

- Internet2
- National Oceanic and Atmospheric Administration (NOAA)
- Keystone Initiative for Network Based Education and Research (KINBER)
- National Science Foundation
- State of Indiana
- Connecticut Education Network
- Mid-Atlantic Crossroads
- MCNC (North Carolina's research network)
- OneNet (Oklahoma's telecommunications network)
- Great Plains Network
- Global Environment for Network Innovations (GENI) Program Office
- mpath (Miami, Florida network connection point)

New initiatives in 2011

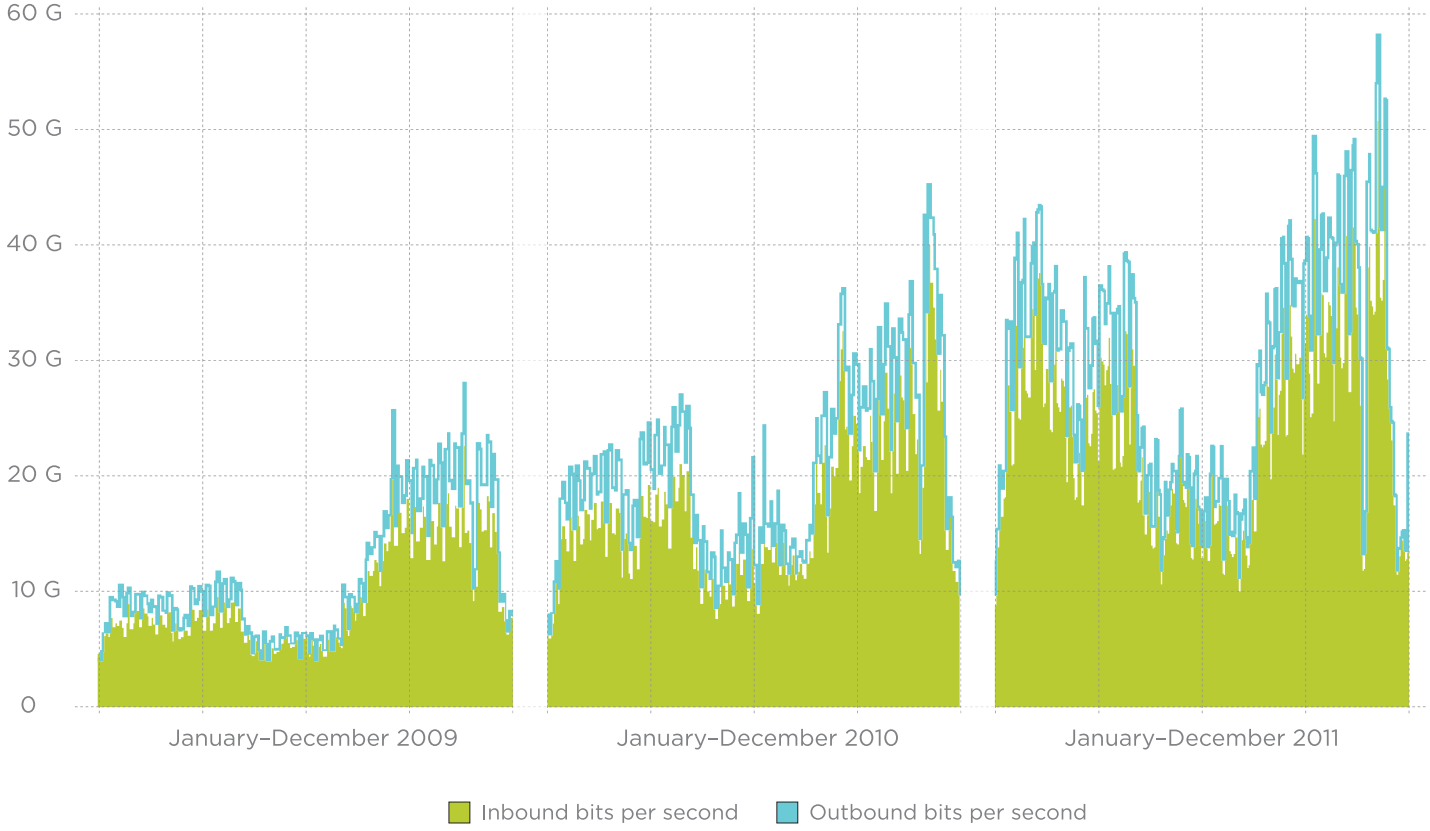
- Global Environment for Network Innovations (GENI) Meta-Operations Service Desk
- GENI Midwest OpenFlow Exchange Initiative (MOXI)
- America Connects Europe (ACE)
- Washington Internet Exchange (WIX)
- GENI Meta-Operations Development
- PennREN (Pennsylvania state research network)
- Network Design and Deployment Initiative (NDDI)
- Internet2 ION (Interoperable On-Demand Network Service)
- Great Plains Network (GPN)

By the numbers

- 43: Network deployment trips
- 83: Days of travel by GlobalNOC engineers
- 200: Different device types supported for monitoring
- 4,500: Devices actively supported
- 260,000: Interfaces monitored

Software highlights

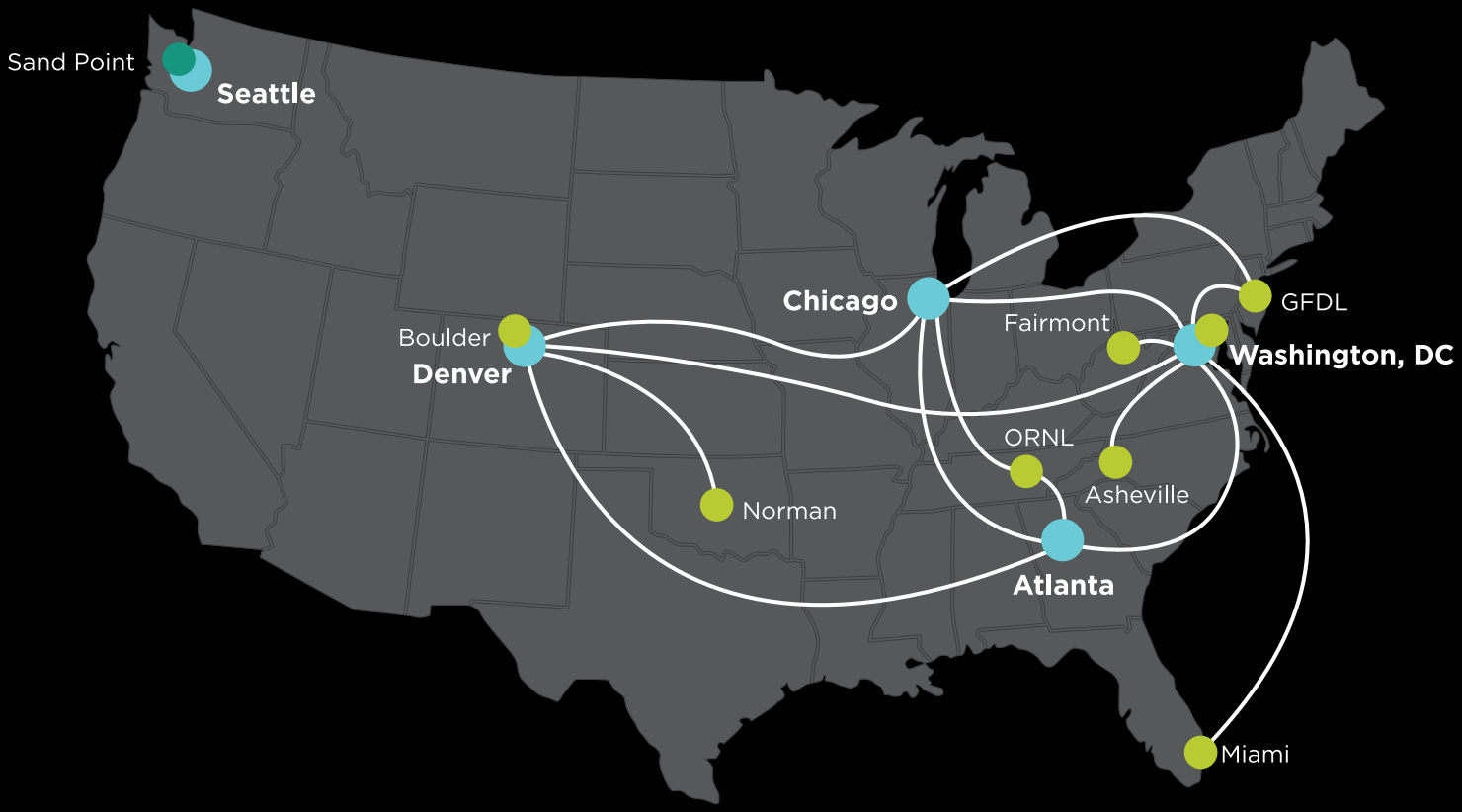
- More than 30 GlobalNOC Network Database software releases
- A new wireless network management system for the IU campus



Meeting growing network demands

The current capabilities of IU's research network, the Indiana GigaPoP, and the IP-Grid-funded optical link between Indianapolis and Chicago are limited to 10Gbps. At the same time, requirements for data-intensive connectivity to collaborators, colleagues, and providers are growing rapidly.

In the last three years, traffic grew more than six-fold from 9.5Gbps to 58.3Gbps, or 82% growth each year. Just as importantly, this high-speed connectivity must now be reachable by a broader set of partners and potential partners outside the university.



GlobalNOC and NOAA: The value of partnership

The mission of the National Oceanic and Atmospheric Administration (NOAA) touches the lives of every American through daily weather forecasts, severe storm warnings, and climate monitoring, as well as fisheries management, coastal restoration, and supporting marine commerce. In December 2010, **NOAA tapped IU's GlobalNOC** as a partner **to design and deploy its next-generation research network,** N-Wave. N-Wave interconnects NOAA's supercomputing facilities located across the US. IU engineers collaborated closely with NOAA to design, build, maintain, and optimize the performance of the communications networks and infrastructure services for N-Wave.

Resulting successes include the High Performance Computing and Satellite Data Archives that are being supported by N-Wave, which are moving over a petabyte of data per month (as of January 2012).

- Network Core Site
- NOAA Customer Site
- Future Customer Site

n-wave
NOAA RESEARCH NETWORK

Advanced Networking Initiatives: **I-Light**

I-LIGHT

Indiana's Optical Network

Giving Indiana's colleges A COMPETITIVE ADVANTAGE

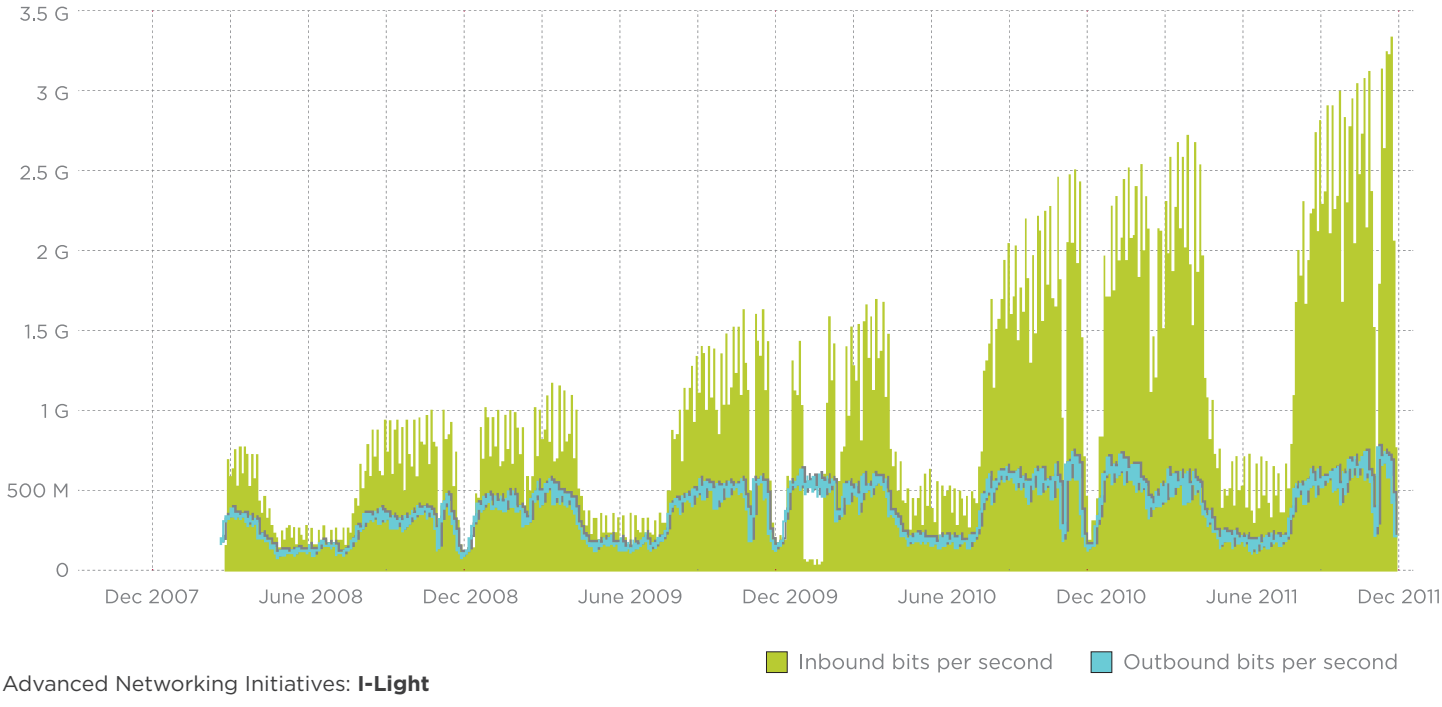
I-Light uses 626 miles of fiber-optic cable to provide high-speed connectivity between 63 Indiana universities and colleges. Winter 2011 marked the completion of fiber connections to Ivy Tech campuses at Warsaw, Monticello, Gary, Elkhart, Evansville, Valparaiso, Fort Wayne, Lafayette, Franklin, Madison, and Lawrenceburg.

In addition to providing more bandwidth than most Indiana colleges and universities could otherwise afford, the network also connects classrooms at distant locations with high-quality video-streaming, **allows researchers at any location to exchange large digital data files,** provides access to supercomputers and scientific data storage facilities, facilitates multi-campus collaborative research projects, and enables the use of high-definition learning tools such as telepresence.

Highlights for the year

- **Launch of next-generation connectivity,** following the retirement of old I-Light Tier 1 network and moving all member sites to significantly higher bandwidth connectivity
- **New fiber connections** to four private post-secondary member sites including Hanover College, Franklin College, Manchester College, and Rose Hulman Institute of Technology
- **Connections to 15 additional Ivy Tech campuses**
- **Cable acquisitions from Vincennes to Evansville,** creating a business case for cable and telecommunication vendors to begin building fiber throughout southern Indiana

Below: Since 2007, I-Light traffic has increased exponentially as more Indiana schools have been added and as bandwidth demand has increased.



Manchester College has benefitted greatly from having I-Light available. We have seen **a rise in collaborative efforts** with other Indiana universities and colleges. For example, we have **shared resources,** improved video conference capabilities, and more. We now have access to Internet2. I-Light also makes communication between our two campuses more feasible.

The I-Light team has done an excellent job of managing the network, engineering solutions, and supporting our initiatives."

Michael Case
Information Technology Services director,
Manchester College

With the expansion of I-Light, rural communities such as Monticello can compete in today's global economy. **Rural access to broadband is as essential to individual and community economic prosperity as electricity,** railroads, and roads once were. Broadband in rural America isn't about creating jobs next week; today broadband is a basic need for our libraries, our schools, our health clinics, and our hospitals. No rural community can survive without broadband."

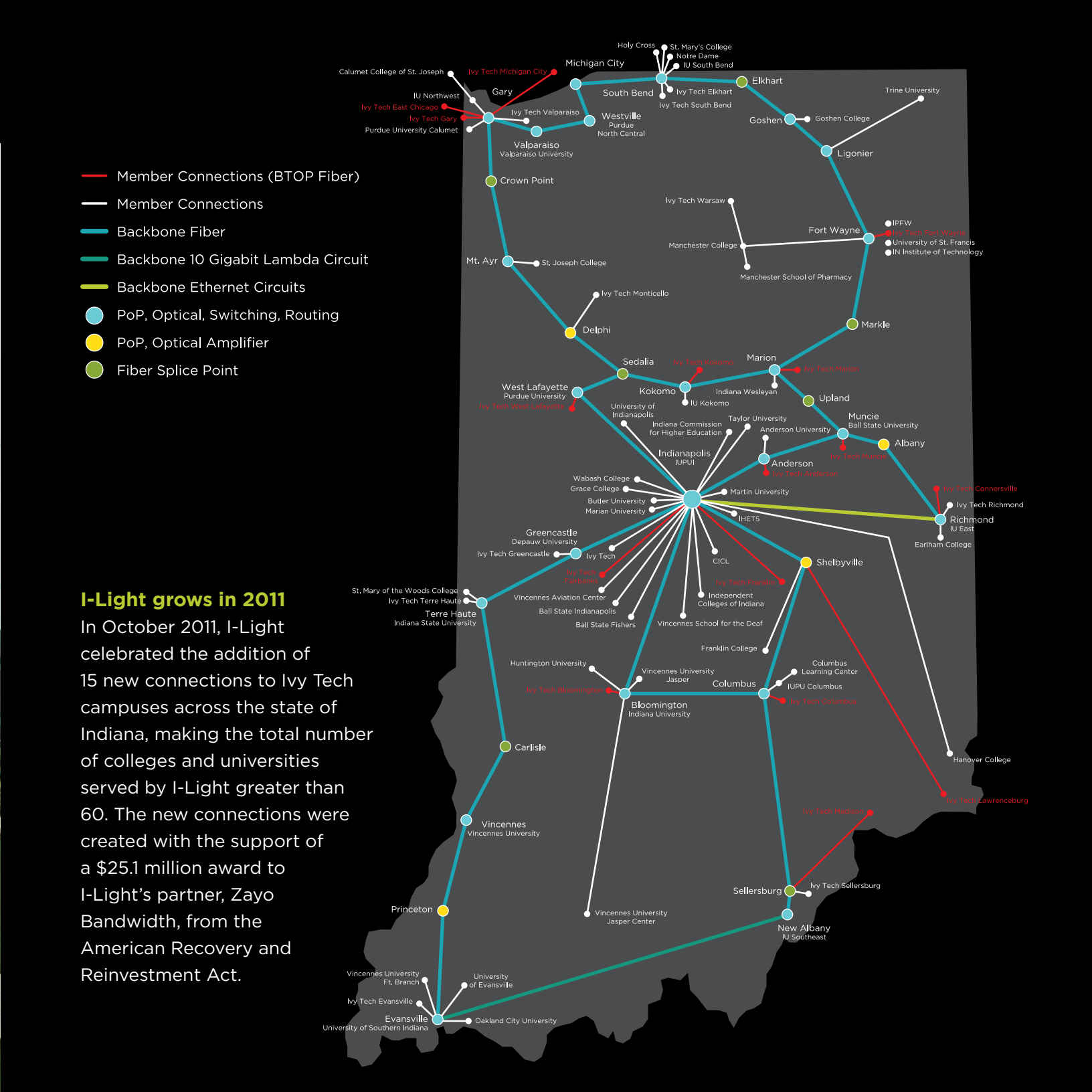
Jason Thompson
former mayor of Monticello, Indiana

I-Light powers research in Indiana

Faculty and students at Valparaiso University are involved in cutting-edge, grant-funded physics and astronomy research directly enabled by I-Light. Students gain hands-on experience running the particle accelerator in the nuclear physics lab, the astronomical telescope, and sophisticated data collection equipment. They learn to operate the Valparaiso University Astronomical Observatory and have full responsibility for open viewing sessions for people from the community and from the campus. And, if they are engaged in astronomical research, they also participate in data collection at the observatory. As a result, students have been awarded competitive research opportunities at facilities such as Los Alamos National Laboratory, Goddard Space Flight Center, and Oak Ridge National Laboratory. I-Light provides the connection that makes this research and education possible.

Reaching underserved communities

I-Light contributed over $1 million towards additional infrastructure in southern Indiana, which has resulted in additional fiber connections **throughout this underserved region.** The added bandwidth has allowed communities to take advantage of such resources as the University of Evansville's Center for Applied Research. The Center works with businesses and organizations throughout the region to help leverage the intellectual capabilities of the University of Southern Indiana, matching faculty, staff, and students with regional businesses and organizations for research, consulting, and other applied projects.



I-Light grows in 2011

In October 2011, I-Light celebrated the addition of 15 new connections to Ivy Tech campuses across the state of Indiana, making the total number of colleges and universities served by I-Light greater than 60. The new connections were created with the support of a $25.1 million award to I-Light's partner, Zayo Bandwidth, from the American Recovery and Reinvestment Act.

INTERNATIONAL NETWORKING
at Indiana University

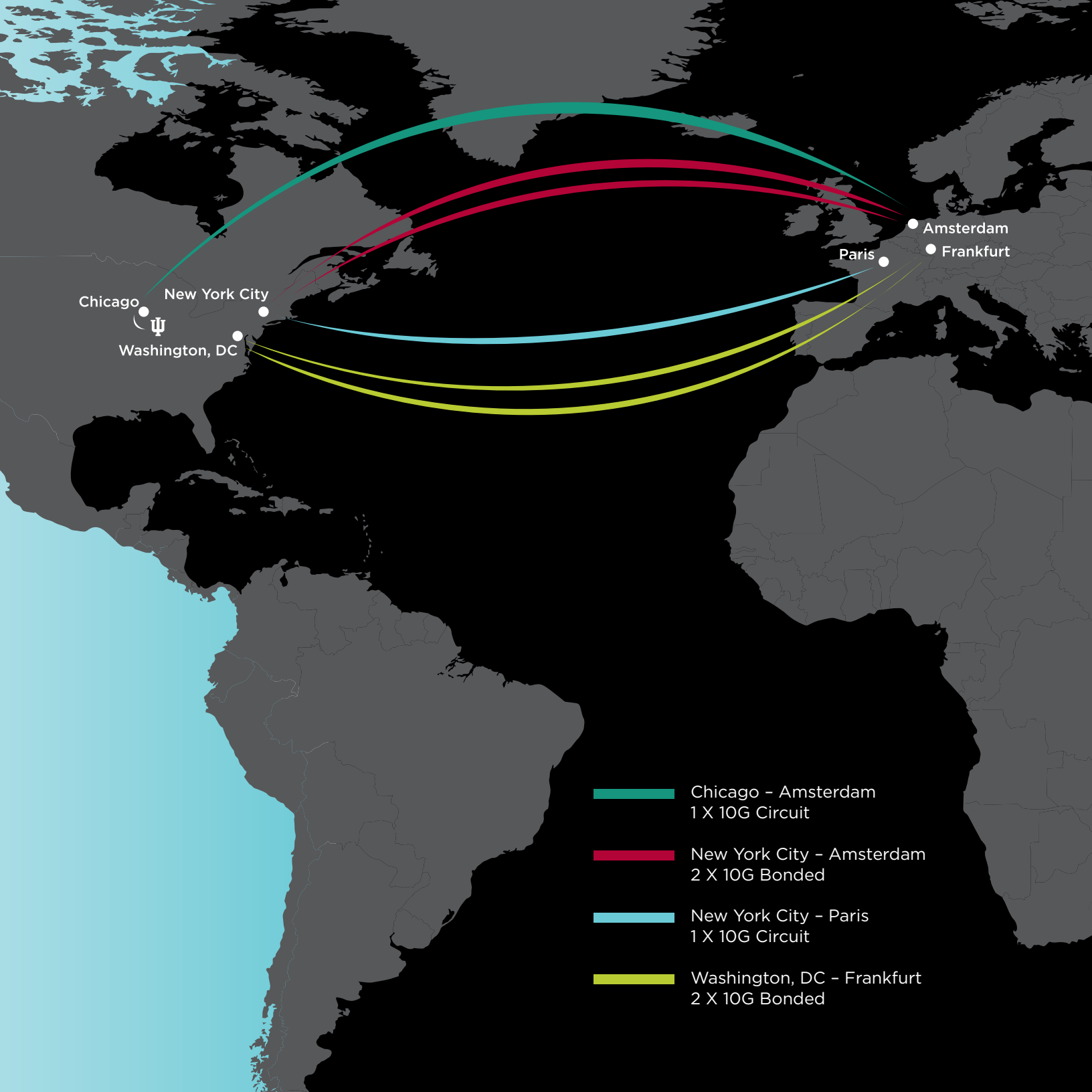
Extending Indiana's REACH IN THE WORLD

International collaboration is essential to high-quality scientific research. Scientists within the US need to access remote instruments, data, and computational resources located across the globe. The National Science Foundation operates the International Research Network Connections (IRNC) initiative to enable these collaborative efforts. International Networking at Indiana University is responsible for **planning, operating, and managing** two NSF-funded IRNC projects: **TransPAC3; and America Connects to Europe (ACE).** TransPAC3 is a 10Gbps network connecting researchers in the US with researchers in Asia and South Asia (Pakistan). ACE is a multiple 10Gbps network connecting researchers in the US to their counterparts in Europe.

International Networking also **develops e-science workshops and guidelines** for international connections to the Global Environment for Network Innovations (GENI), a nationwide experimental network research infrastructure sponsored by the NSF.

ACE
AMERICA CONNECTS TO EUROPE

ACE provides US scientists with network connectivity and services to develop and enhance research and education efforts with their colleagues in Europe. DANTE is the European partner for ACE, making balanced contributions to bandwidth and operations. The partnership is **committed to the support of EU-US science** in all its aspects. The Large Hadron Collider (LHC) activity is but one example. The partnership supplies both best-effort internet protocol services and point-to-point services for use by the LHC scientists.


Amsterdam
Frankfurt
Paris
New York City
Chicago
Washington, DC
Chicago – Amsterdam
1 X 10G Circuit
New York City – Amsterdam
2 X 10G Bonded
New York City – Paris
1 X 10G Circuit
Washington, DC – Frankfurt
2 X 10G Bonded

Highlights for the year

- Additional **60Gbps of network capacity between Europe and the US** over the past 18 months, thanks to the ACE network (supported by the US National Science Foundation) and DANTE (supported by the GÉANT Consortium and the European Commission)
- **New TransPAC3 circuit to Tokyo**
- **New router in Los Angeles** to support TransPAC3
- IU agreement with Chinese collaborators and Internet2 to study the feasibility of a **100Gbps US-China circuit**

US-India Workshop

The US-India Network Enabled Research Collaboration Workshop, held in Delhi and jointly organized by Indiana University in the US and ERNET in India, provided the opportunity for the cyberinfrastructure service providers and the research users from a number of disciplines to come together to jointly develop a way forward that will lead to significantly **enhanced opportunities for collaboration between India and the US.** Here is one example of collaboration catalyzed by the workshop:

Professor Wangikar, an expert in cyanobacteria at the Indian Institute of Technology (IIT) Bombay, will provide data from his laboratory while IUPUI Professor Matthew Palakal's lab will conduct bioinformatics analysis and genome-wide studies for species selection. Robust, high-performing network connectivity between the two sites will be critical to the data sharing and analysis.

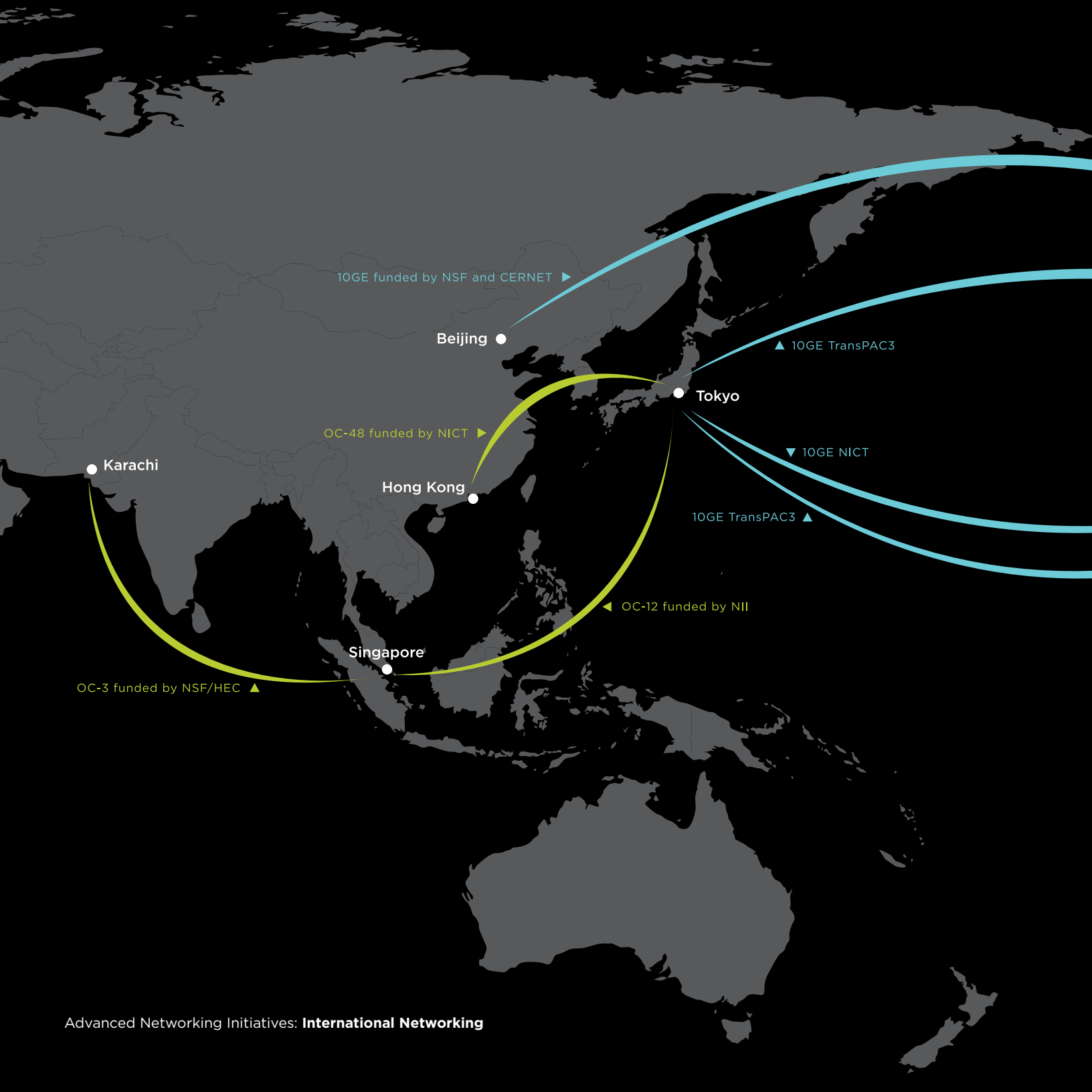
Mr. Fang Maotian, minister counselor for education of the Chinese Embassy, looks on as Indiana University Vice President for IT and CIO Brad Wheeler, Internet2 President Dave Lambert, and Professor and CERNET Director Jianping Wu sign the cooperative partnership agreement.

"Experts from China and the US have been working together for many years on Internet technologies and applications... This is the **first award from both the NSF and the Chinese government** dedicated to support the high-speed direct Internet link to scientific research. This project will certainly and greatly promote the collaborations not only between China and the US, but also globally."

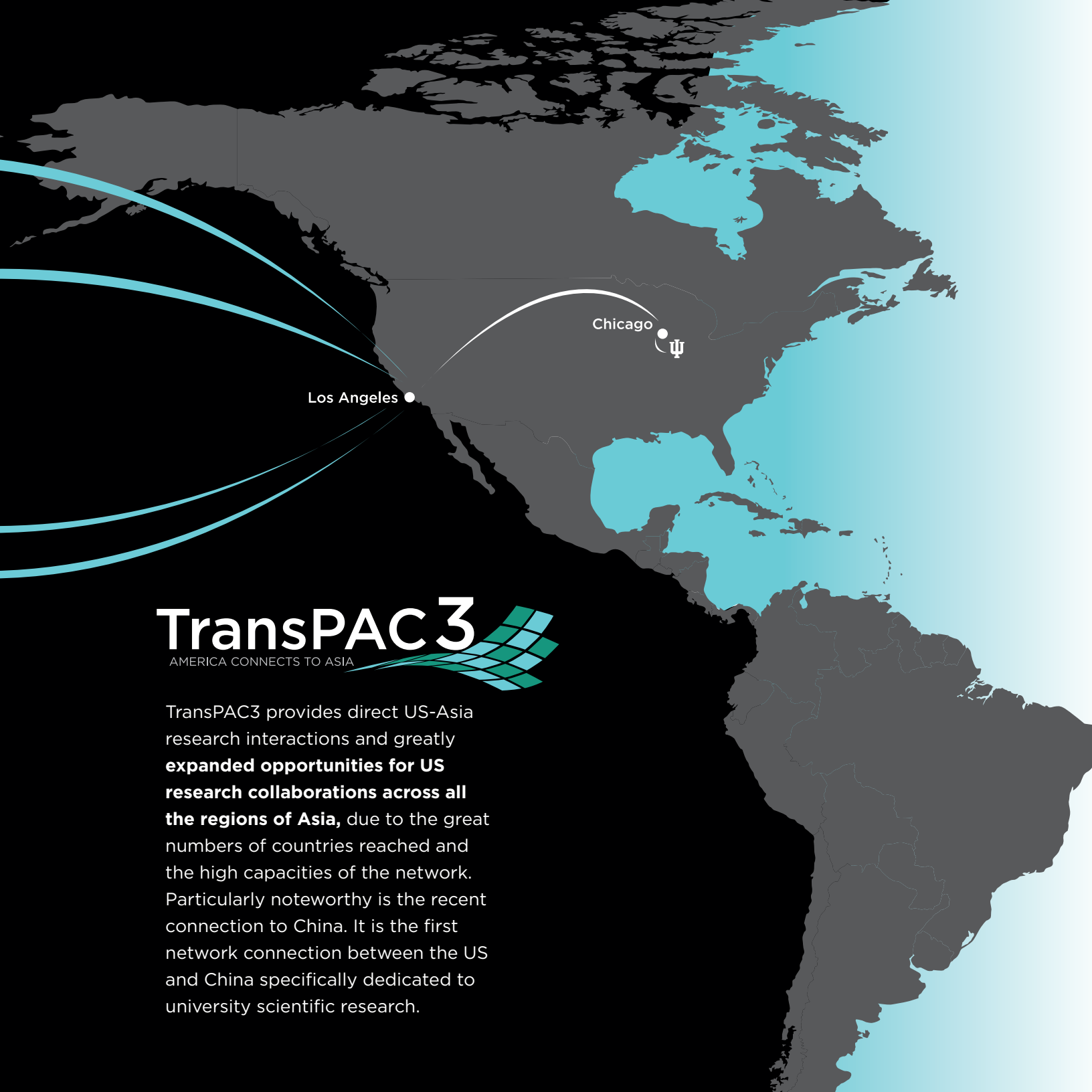
Professor Jianping Wu
director of the China Education and Research Network (CERNET)

"Together, we recognize our valuable partnership and affirm our support of collaborative scientific research between the United States and China. Our current upgrade to the Internet2 network will create the **world's first 100 Gigabit Ethernet production network,** and is key to the future of supporting global scientific research collaboration with China and all of our global partners."

Dave Lambert
president and CEO of Internet2



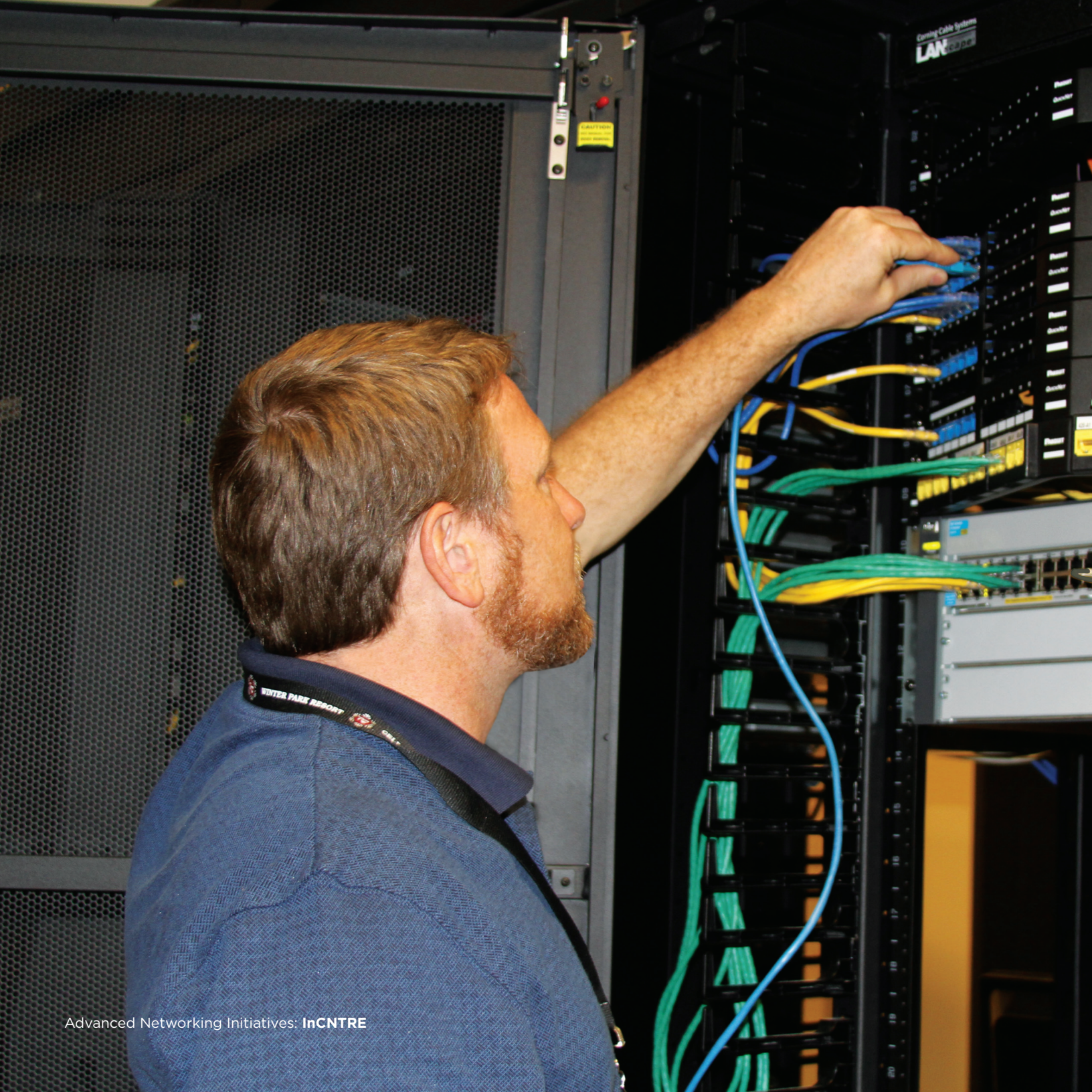
Advanced Networking Initiatives: **International Networking**



TransPAC3

AMERICA CONNECTS TO ASIA

TransPAC3 provides direct US-Asia research interactions and greatly **expanded opportunities for US research collaborations across all the regions of Asia,** due to the great numbers of countries reached and the high capacities of the network. Particularly noteworthy is the recent connection to China. It is the first network connection between the US and China specifically dedicated to university scientific research.



Advanced Networking Initiatives: **InCNTRE**

Indiana Center for Network Translational Research and Education

InCNTRE

Fostering Network INNOVATION

Software-Defined Networking (SDN) is a new approach that is revolutionizing the field of networking by allowing **greater network customization at a much lower cost.** Indiana University created the Indiana Center for Network Translational Research and Education (InCNTRE) to advance the SDN approach to networking, and catalyze researchers, students, and IT staff within the academic community to fully realize the opportunities for innovation enabled by SDN. InCNTRE seeks to advance development, increase knowledge, and encourage adoption of SDN technologies through **educational programs, training, internships, research, and collaboration** among faculty, students, and networking professionals.

Highlights for the year

- **InCNTRE founded** in May 2011
- **$2.4 million total in new external funding** in its first 10 months
- **$1.4 million grant** for GENI Measurement and Instrumentation Infrastructure (GEMINI), **largest award given as part of the GENI project**
- **$300,00 grant** from the National Science Foundation for the **Summer of Networking internship program**
- **$225,000 grant to provide training to universities** on Global Environment for Network Innovation (GENI) and OpenFlow
- **Creation of Software-Defined Networking (SDN) Lab** and membership agreements with HP, NEC, IBM, Brocade, and Big Switch Networks
- **$300,000 in sponsor donations** to SDN Lab
- Summer of Networking **internship program celebrates second year**
- Selection of **nationally recognized networking researcher, Martin Swany,** as director of InCNTRE and an associate professor in the IU Bloomington School of Informatics and Computing
- **Sponsorship of first LEGO® League team** to teach programming skills and teamwork to 9-14 year olds in partnership with the IU School of Informatics and Computing

HP sees **huge promise in the SDN technology**... The thought leadership IU is providing through InCNTRE's SDN Lab will drive industry adoption through improved solution and quality capabilities."

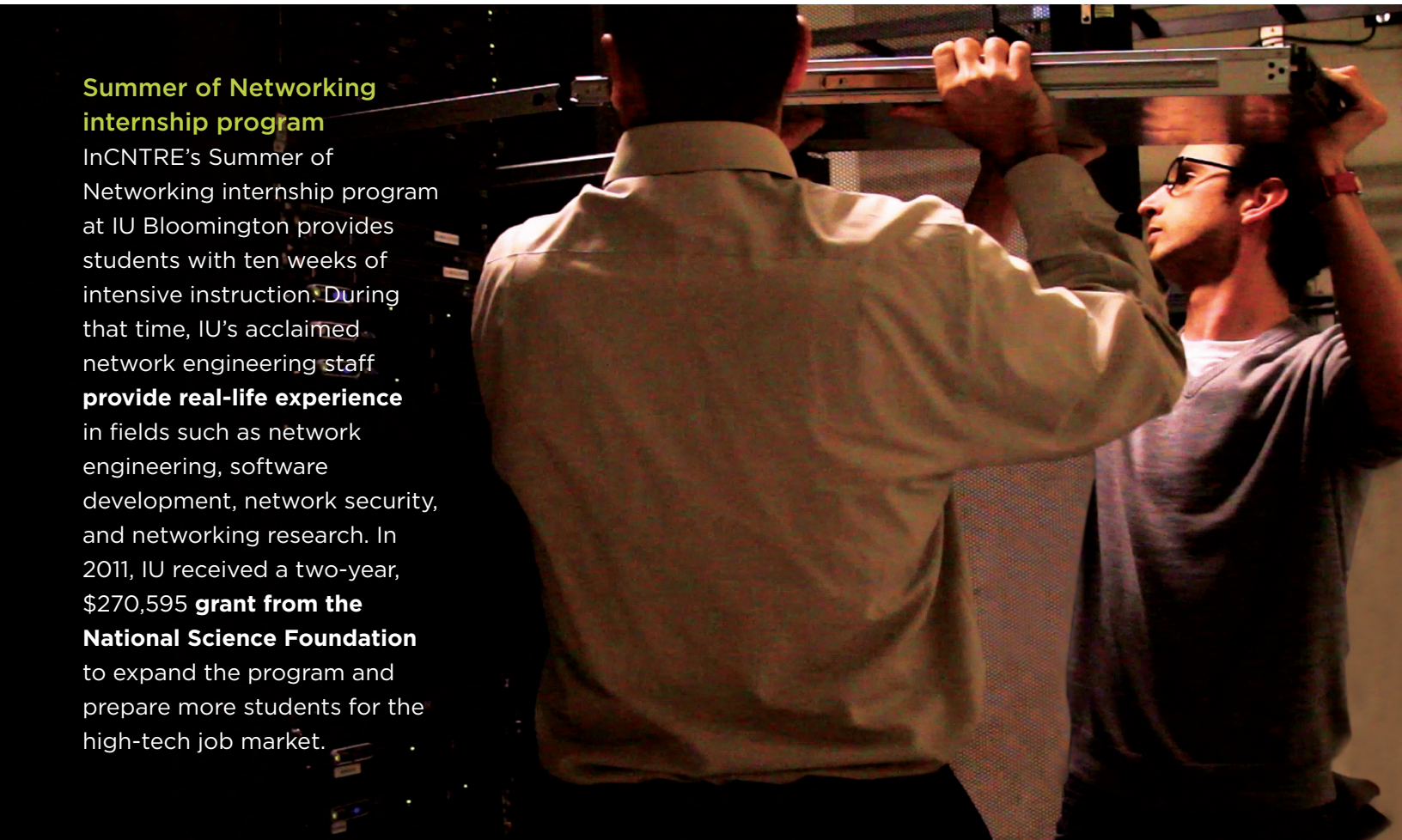
Bill Johnson
director of research and development for Hewlett-Packard ProCurve networking business

You have all the gear. You have all the tools. You can see it in practice. If you want to try something, you have servers that run VMs [virtual machines] and you can set up whatever environment you want to set up. And you can try any configuration you want to try. It's really cool."

John Meylor
2011 InCNTRE Summer of Networking intern

Summer of Networking internship program

InCNTRE's Summer of Networking internship program at IU Bloomington provides students with ten weeks of intensive instruction. During that time, IU's acclaimed network engineering staff **provide real-life experience** in fields such as network engineering, software development, network security, and networking research. In 2011, IU received a two-year, $270,595 **grant from the National Science Foundation** to expand the program and prepare more students for the high-tech job market.



Advanced Networking Initiatives: **InCNTRE**

Bridging the gap

Building the network of the future requires highly trained engineers and researchers with the **conceptual, practical, and theoretical knowledge** to understand network function and solve complex networking problems. **InCNTRE helps to bridge networking knowledge gaps** through its Summer of Networking internship program, SDN Interoperability Lab, training programs, and research partnerships.

- $225,000 award from the NSF's GENI project enables **hands-on OpenFlow training** of network engineers
- Hands-on **Multiprotocol Label Switching training** of network engineers from universities through the state of New York in partnership with NYSERnet
- Significant interest in SDN/OpenFlow training from **universities and the private sector**
- Two workshops hosted in Q1 2012, and six more scheduled for summer 2012 (with more than 130 attendees)
- Training program to grow in scale and breadth over the coming year while engaging public and private sectors

Looking forward to 2012

Because **technology does not stand still,** Indiana University is continually looking forward and helping to define the future of networking, both at home and across the globe.

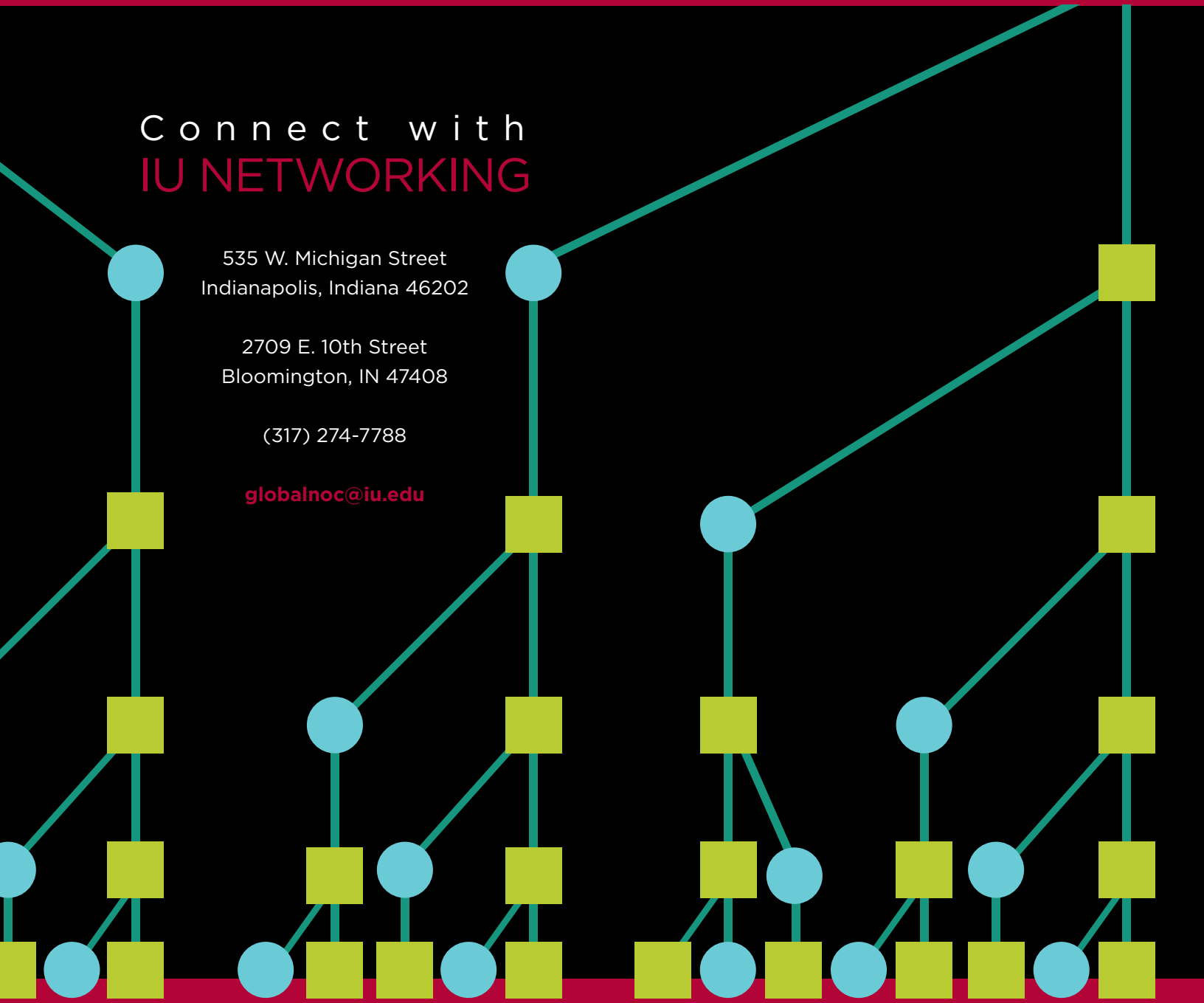
Indiana wind farm along the I-65 corridor

Notable IU-led networking initiatives that will begin in 2012 include:

- Monon100, the **nation's first 100Gbps state network,** between Chicago and Indianapolis
- Planned **expansion of the I-Light network** to approximately 20 new sites
- **First-of-its-kind 10Gbps direct connection between Africa and the US,** and exploration of the possibility of a 100Gbps transatlantic link between America and Europe
- In spring and summer 2012, SDN Lab to announce **several new high-profile corporate partnerships** with potential to significantly accelerate the development of SDN technologies

Fast, reliable, and secure networking is essential to the way we work and learn in the 21st century. At Indiana University, we understand that high quality networking comes from high quality connections. Connections between computers. Connections between ideas. Connections between people.

Science. Research. Knowledge. Connections. **Indiana.**



Connect with IU NETWORKING

535 W. Michigan Street
Indianapolis, Indiana 46202

2709 E. 10th Street
Bloomington, IN 47408

(317) 274-7788

globalnoc@iu.edu

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