TransPAC4
Award #1450904
Year 3 Quarter 4 and
Year 3 Annual Report
1 Dec 2016 through 30 Nov 2017

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Summary
The TransPAC project supports circuits and services for the use of 100G networks between the US and Asia with a focus on measurement and end user support. During Year 3, highlights included migration of JGN services from Los Angeles to Seattle, support for multiple demos by our partners at University of Tokyo, multiple MOU signings, and Edward Moynihan joining our team first as a science engagement consultant then as a full time employee. During Year 4, we will focus on deploying additional capacity, increasing the reach of our engagement efforts, and expanding the scope and usefulness of the training we offer.

1. TransPAC4 Overview
The TransPAC project supports circuits and network services between the US West coast and Asia. During Year 3, these circuits included:

- The TransPAC-Pacific Wave 100G Circuit: a 100Gbps link between Seattle, Washington, and Tokyo, Japan. This circuit has been in production since February 2016 and is the primary project circuit for production traffic for TransPAC4. This link is fully supported by NSF and is managed in cooperation with PacWave and Pacific Northwest GigaPop (PNWGP).
- The JGN-X Circuit: a 10Gbps layer-2 circuit that was largely used for experiments and Software Defined Networking (SDN) trials. This circuit was part of the Japan Gigabit Network Extension (JGN-X) project, a testbed funded by the Japanese National Institute of Information and Communications Technology (NICT) (http://www.nict.go.jp/en). This link was not supported by NSF funds. A backup routed peering connection between TransPAC and APAN also ran across this link. This link was decommissioned March 29, 2017. This did not affect any production traffic as the link was being used for research purposes only. All of JGN's networking equipment was moved to Seattle in July. The ongoing support of the experiments using that equipment has been shifted over to the TransPAC-Pacific Wave 100G circuit.

These circuits are used to support a wide variety of science applications and demonstrations of advanced networking technologies. In addition, the TransPAC award supports science engagement, SDN experimental work, measurement deployments, and security activities.

2. Staffing

At the end of Year 2, project staff consisted of:

- Jennifer Schopf, IN@IU Director
- Andrew Lee, International Networks Architect
- Hans Addleman, Primary TransPAC Network Engineer
- Predrag Radulovic, Science Engagement Specialist
- Edward Moynihan, Science Engagement Consultant - part time contractor
- Scott Chevalier, perfSONAR Specialist

On June 1, Edward Moynihan shifted from a part time consultant to full time employee at Indiana University as a Science Engagement Specialist. Moynihan on the project means that we will have an extended reach into application groups in Asia. On June 6, Radulovic left the group to pursue other opportunities. Most of Radulovic's responsibilities had shifted to Moynihan prior to this. In addition, in October, we hired Heather Hubbard as a project coordinator who is assisting with project planning and events.

The most important staffing change during Year 3 was that co-PI Lee took over the bulk of the day-to-day operations for the overall project. He is now responsible for strategic planning, coordination with our Asian partners, and setting the team direction.

At the end of Year 3, project staff included:

- Jennifer Schopf, IN@IU Director
- Andrew Lee, TransPAC Lead, International Networks Architect
- Hans Addleman, Primary TransPAC Network Engineer
- Edward Moynihan, Science Engagement Specialist
- Scott Chevalier, perfSONAR Specialist
- Heather Hubbard, Project support

In Year 4 we will be hiring two positions for the remaining two years of the project. One will work jointly with the IRNC NetSage project with a focus on the analysis of the TransPAC network traffic. This will enable us to better understand the use of the networks and to verify that end users are achieving effective performance over the circuit. The other will help with the research aspects of the project, including work with Distributed Denial of Service (DDoS) and Data Transfer Nodes (DTN). This staff member will also enable us to expand our training program.

3. Travel and Training

TransPAC staff participated in various meetings to support their role in collaborations in Asia. Some of these trips were funded by sources other than TransPAC. Travel during Project Quarters 1, 2 and 3 are detailed in those quarterly reports and included:

- Addleman attended a Security Leadership SANS course on November 28-December 2, 2016.
- Schopf and Radulovic attended the Winter ESIP meeting in Bethesda, MD, on January 11-13 http://meetings.esipfed.org/winter-meeting-2017
- Schopf and Lee attended the Trans Pacific Research and Education Networking Workshop and Pacific Telecommunications Council meeting in Honolulu, HI, on January 15-18 https://www.ptc.org/ptc17.
- Schopf and Radulovic, along with members of the ESNet Science Engagement Team, spent January 23 with Camille Crittenden (PRP) at UC Berkeley.
- Schopf and Radulovic attended the Quilt Regional Networking Winter Meeting in San Diego, CA, on February 7-9 http://www.thequilt.net/public-event/2017-winter-member-meeting-february-7-9-2017-la-jolla-ca/.
- Addleman and Lee attended APAN 43 in New Delhi, India, on February 12-16 http://apan43.in/.
- Addleman, Dahlmann, and Lee ran an Operating Innovative Networks (OIN)-style workshop in Manila, Philippines on March 8-10.
- Schopf and Radulovic attended the CENIC Annual meeting at the University of California San Diego on March 19-23 http://www.cvent.com/events/the-right-connection-cenic-2-0/archived-fc937869fad34c9baccb10ffc904d910.aspx.
- Radulovic attended the LHCOPN-LHCONE meeting at Brookhaven National Lab, NY, on April 4-5 https://indico.cern.ch/event/581520/.
- Lee attended the GlobusWorld annual meeting in Chicago, IL, on April 11 https://www.globus.org/events/globusworld-2017.
- Radulovic attended the PRAGMA 32 meeting in Miami, FL, on April 12-15 http://www.pragma-grid.net/pragma32/.
- Schopf and Moynihan attended the Internet2 Global Summit in Washington, DC, on April 23-27 https://meetings.internet2.edu/2017-global-summit/.
- Schopf, Lee, and Moynihan attended TNC in Linz, Austria, on May 29-June 1 https://tnc17.geant.org/core/poster/1.
- Chevalier attended perfSONAR meeting at University of Michigan in Ann Arbor, MI, on June 7-10.
- Chevalier traveled to Boulder, CO, funded by TransPAC, to participate in the Code Sprint setup for SC17, on June 13-16
- Schopf attended PEARC17 in New Orleans, LA, on July 9-13 https://www.pearc17.pearc.org/.
- Schopf, Lee, and Moynihan attended Earth Science Information Partners (ESIP) Summer Meeting 2017 in Bloomington, IN, on July 25-28

http://www.esipfed.org/meetings/upcoming-meetings/esip-summer-meeting-2017.

- Schopf attended National Research Platform Workshop in Bozeman, MT, on August 7-8 http://prp.ucsd.edu/events/the-first-national-research-platform-workshop.
- Addleman, Lee, and Moynihan attended the APAN 44 conference in Dalian, China, on August 26-September 1 http://www.apan44.edu.cn/dct/page/1.

In Project Quarter 4, travel included:

- Lee attended GLIF in Sydney, Australia, on September 25-27 https://www.glif.is/meetings/2017/. He presented on the Open Exchange Point attribute work jointly with Jeronimo Bezerra and Alexander van den Hil. Lee also had productive conversations regarding the NEAAR, TransPAC, and NetSage projects, GLIF governance, monitoring techniques and other topics.
- Lee attended the Australia and New Zealand Software Defined Networking (ANZSDN) Workshop held at the University of New South Wales on September 28 http://www.anzsdn.net/index.php/event/sdn-workshop-2017/. He presented on SciPass and SDN work under way at IU.
- Lee attended the LHC Asia Tier Center Forum (ATCF) in Daejeon, Korea, on October 11-15. He met with engineers from Asian LHC Tier 1 and 2 centers and other NREN engineers to discuss issues specific to the Asian LHC environment including how to improve network connectivity.
- Lee attended the HePiX/LHCONE meeting in Tokyo, Japan, on October 16-18. He presented on the TransPAC and NetSage projects and met with other participants in the LHCONE to discuss networking issues.
- Addleman went to the SuperComputing SCinet Staging event in Denver on October 19-27. He participated as part of the Wide Area Network Team that delivered over 30 100G circuits to the SuperComputing show floor from many international and national destinations. During Staging they started to bring up and test the equipment that landed these circuits and circuits themselves.
- Schopf, Addleman, Lee, and Chevalier attended SuperComputing 2017 on November 5-18 https://sc17.supercomputing.org/. They participated in an IRNC PI Meeting jointly hosted by the IRNC NOC and NetSage projects. They also briefed NSF program officers on the TransPAC project and progress. They met with colleagues from NICT and the Singapore Advanced Research and Education Network (SingAREN) to discuss issues involving LHCONE and MOU signing. Addleman and Chevalier were volunteers with SCinet.
- Lee traveled to Singapore to attend the Asia Pacific Ring Ceremony on November 27-December 3. He met with colleagues from Singapore's National Supercomputing Center (NSCC), signed the Asia Pacific Ring MOU on behalf of the TransPAC project, and participated in the launching ceremony for the new SingAREN/NICT Tokyo-Hong Kong-Singapore 100G.

4. Additional Collaborations

4.A Collaborations with Asian Partners

We have now established an approved process within IU to sign additional Memorandums of Understanding (MOUs). In Year 3, TransPAC signed MOUs with the Asia Pacific Advanced Network (APAN) and with the Trans-Eurasia Information Network Cooperation Center (TEIN*CC) at the APAN meeting in August. These MOUs are vehicles for formalizing partnerships and for highlighting specific areas of collaboration, including Advanced Networking Infrastructure, User Engagement, and Communication and Interaction. In Year 4, we expect to sign MOUs with the China Education and Research Network (CERNET), the Joint University Computer Centre (JUCC) in Hong Kong, and SingAREN.

In addition to these TransPAC specific MOUs, we also signed an MOU along with Asia Pacific Ring (APR). This collaboration has enabled the first intra-Asia 100G backbone connection that links Tokyo, Hong Kong, and Singapore. That link, together with the TransPAC-Pacific Wave 100G circuit, the Internet2/SingAREN Los Angeles-Singapore 100G circuit, and the Pacific Wave backbone from Los Angeles to Seattle forms a ring around the Asia Pacific region. The MOU creates an environment for greater cooperation among the parties that bring resources to the effort, both in terms of communication and backup/bandwidth sharing that will be leveraged going forward.

We continue to have discussions with the wider community on a possible circuit to Asia via Guam. We expect to release an RFP for capacity between Guam and Hong Kong shortly after the Guam Open Exchange (GOREX) is fully operational, likely early in Year 4.

In October 2017, the Asi@Connect project released a 2nd Call for Proposals to fund collaborations in the TEIN region, especially within Least Developed Countries (LDCs). In November 2017, we submitted two proposals to Work Package 2 - Capacity Development of Developing Country NRENs - for workshops to expand our previous perfSONAR training to new venues and expand the content to cover Data Transfer Node (DTN) concepts. Funding from this program will cover in-region participant travel to the workshops, as well as site costs and a small amount of equipment. One workshop proposal focused on the South Asian region, with the workshop planned to be held at the Indiana University Gateway Office in Delhi, India, with invited participants from India, Afghanistan, Pakistan, Nepal, Bhutan, Bangladesh, and Sri Lanka. The second workshop will be focused on the Lower Mekong region, with the workshop planned to be held at the National University of Laos in Vientiane, Laos, with participants from Laos, Vietnam, Cambodia, Thailand, and Myanmar. Announcements as to which proposals will be funded are expected in

January or February. If approved we plan to conduct the workshops in early 2019, during Year 5.

Within APAN, Lee was appointed the co-chair of both the Network Engineering Workshop and the Backbone Committee. The Network Engineering Workshop focuses on providing a forum for discussion of operational network status as well as network research endeavors within the APAN community. The Backbone Committee provides a forum for NRENs to discuss acquisition of capacity, high level policy, and emerging network paradigms (such as the proposed US National Research Platform (NRP)). This participation allows us to make sure that the interests of US researchers will be represented in the APAN community going forward, as well as providing leadership to the community as a whole.

4.B Networking Experiments

As mentioned in previous quarterly reports, after JGN disconnected their 10G circuit from Los Angeles to Tokyo that had been used for experimentation, the equipment that was supported by the circuit was also disconnected. In July, JGN engineers re-installed that equipment in Seattle and connected to both the Pacific Wave switch and the TransPAC router at 10G. Connectivity for the JGN POP in Seattle is now provided by the TransPAC-Pacific Wave 100G circuit through the Pacific Wave switch. The connection to the TransPAC router is reserved for future experimental use.

Conferences such as TNC and SuperComputing are a prime venue for network-oriented demonstrations as they combine a highly technical audience with a large amount of bandwidth provisioned for the purposes of experimentation. Addleman was a member of the SuperComputing 2017 SCinet WAN team, which is responsible for provisioning and monitoring all of the external connectivity used by the conference for experiments and demos. This allowed the TransPAC project to better support our partners in being successful with their experiments. At the end of SC17 he was asked to return to SC18 as the deputy chair of the WAN team.

During TNC in May, TransPAC, along with several other networks including NEAAR, supported the latest iteration of demonstrations by Dr. Kenjiro Yamanaka, Japanese National Institute of Informatics, for the Massively Multi-connected File Transfer Protocol (MMCFTP). During the demonstration, Yamanaka was able to sustain a 150 Gbps transfer rate from Tokyo to London. The demonstration was also part of the poster session of the conference: https://tnc17.geant.org/core/poster/1.

During the SuperComputing Conference 2017 (SC17), TransPAC supported several network bandwidth demonstrations. The largest of these was performed by Dr. Yamanaka. He used his MMCFTP protocol across 3 trans-Pacific 100G links including TransPAC. His goal was to achieve 240 Gbps total sustained bandwidth between Tokyo and the SC17 venue. Figures 1 and 2 show that the experiment was able to achieve maximum throughputs close to 100G on the TransPAC link. We will continue to provide a high level of support for demonstrations in Year 4.

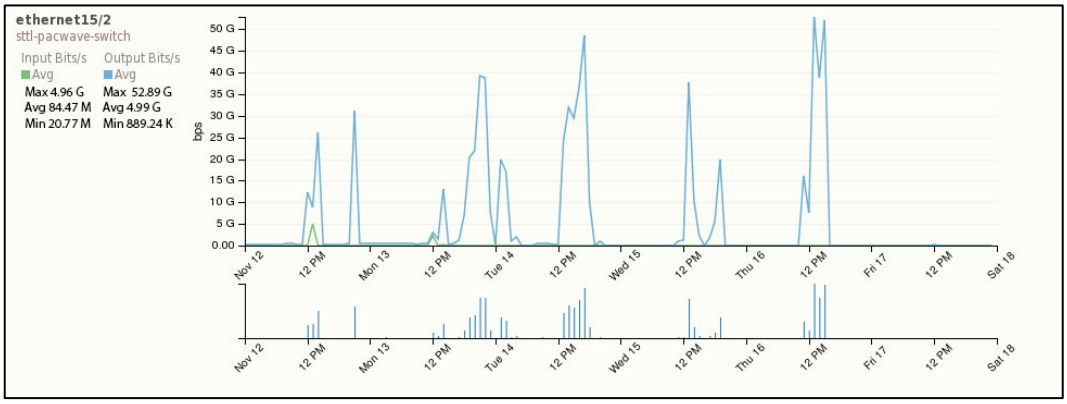

Figure 1: TransPAC-PacWave Seattle-Tokyo 100G Circuit (NSF-funded) traffic during SC'17 using smoothed daily averages.

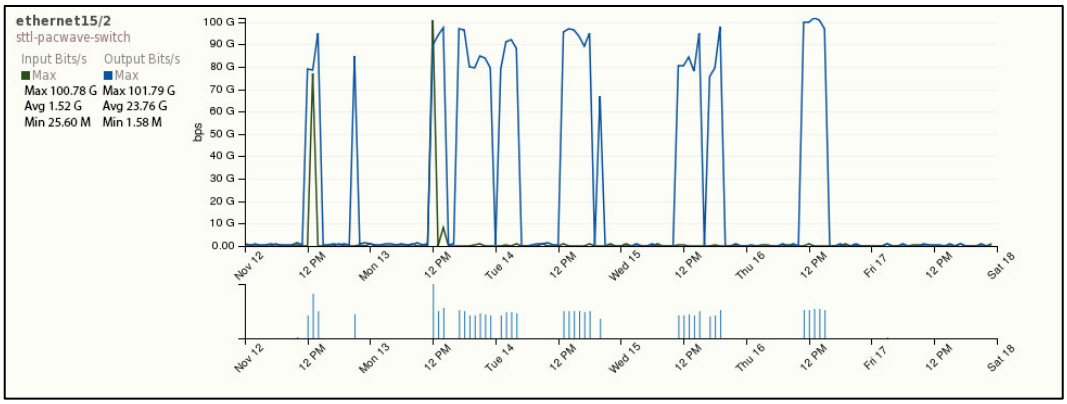

Figure 2: TransPAC-PacWave Seattle-Tokyo 100G Circuit (NSF-funded) traffic during SC'17 using maximum daily averages.

4.C Science Engagement

After a visit in Quarter 3 to the Centre for Bioinformatics (CBI) at Peking University in Beijing, follow-up video meetings were held in Quarter 4 to help bring together researchers and IT staff from Peking University with colleagues from CERNET to begin addressing performance issues between sites in China and sites in the US. We also continued to assess interest within the Bioinformatics community in a Cross Connect workshop in China. However, for a number of converging reasons, including changes with IU staff, difficulty getting researcher commitment, and concerns with travel and visas we have postponed the workshop until later in the project. In the meantime, we are continuing to work with CERNET on wider engagement and have begun the MOU process with them. We expect to sign that MOU during the first half of Year 4 to formalize these efforts.

We continued working with JUCC and members of the Hong Kong Academic and Research NETwork (HARNET) to discuss user engagement practices and to identify collaborative research projects. JUCC has committed to working with TransPAC to actively support US-Hong Kong collaborative projects and to focus on increasing network utilization. We also began working with SingAREN to address performance

issues and to develop a strategy for supporting US researchers collaborating with researchers in Singapore. We expect to sign MOUs with CERNET, JUCC, and SingAREN in early 2018 to formalize these efforts.

The Large Hadron Collider continues to be a significant global science driver. We continued our participation in the Large Hadron Collider Open Network Environment (LHCONE) community in order to determine ways that the TransPAC project can be of use. At the LHCONE meeting in Japan in October, Lee supported a proposal ask the Worldwide LHC Computing Grid (WLCG) board to adjust the LHCONE AUP to allow Belle-II traffic. The proposal will be forwarded and we expect a decision at the next WLCG meeting that will occur in December. Discussions have pointed to a gap in the network in the area of connectivity between the Asia LHC community as represented by the Asia Tier Center Forum (ATCF) and the US. We have been working closely with NICT, TEIN, and the Academia Sinica Grid Computing Centre (ASGC) to create a new peering between the LHCONE networking instance in Hong Kong and ESNet in response to this to improve network connectivity between US researchers and institutions in Southeast Asia for high energy physics. We hope to have this completed in the first half of Year 4.

Our participation in the Federation of Earth Science Information Partners (ESIP) continued in Year 3. Our collaborative activities included: presenting a poster at the Winter ESIP meeting, helping host the Summer ESIP meeting in Bloomington, IN, and contributing a session presentation on our Science Engagement efforts at the Summer meeting. These activities helped us build and maintain relationships with the US geoscience community and led to ongoing conversations on how TransPAC can support researchers with large data transfer needs. For example, we began working with NASA representatives to better understand data transfer and network performance between NASA repositories around the world. We also began discussions with NASA to understand networking requirements for future data intensive projects, including the SWOT mission (https://swot.jpl.nasa.gov/). These collaborations and our participation in ESIP will continue in Year 4.

In Quarter 4, we sent outreach emails to over 20 NSF Partnerships for International Research and Education (PIRE) awardees. These outreach emails were designed to provide more information about the TransPAC project, to assess if these projects have international data transfer needs, and to offer assistance where necessary. From this outreach in Quarter 4, we began discussions with Michael Steckler from Columbia University who has a NSF EAR IES grant (NSF Award # 1714892) to deploy seismometers and GPS in Bangladesh. Due to poor connectivity in Bangladesh, Dr. Steckler currently relies on collecting hard drives but is now working with our team to connect to the Bangladesh Research and Education Network (BdREN) and to incorporate R&E connectivity into future project plans.

During Year 3, we documented the extent of US branch campuses in Asia and started discussions with NREN partners on how we could best support these campuses' international data transfers. However, our initial outreach to US branch campuses in

Asia did not yield a useful response. During Year 4, we will reevaluate our tactics to counteract the lack of response from branch campuses, continue to work with NRENs to gather better data, and reach out to the branch campuses to find a way to proceed. If unsuccessful, we must conclude that such support is not desired and will no longer pursue this.

We also continue to participate in several international science engagement and coordination projects. Moynihan is on the Steering Committee of GEANT's Task Force for Researcher Engagement Development (TF-RED) and participates in the Special Interest Group for Transnational Education. Schopf is a member of the Internet2 External Advisory Group for Research and Engagement (EAG), as well as the CaRC Consortium, the follow on to ACI-REF. We also collaborate and share best practices with the Pacific Research Platform, PRAGMA, the perfSONAR consortium, and the JET.

In Year 4, our science engagement strategy will focus on leveraging existing and new MOU partnerships to identify, engage, and support scientific research and educational projects in the Asia-Pacific region. We will also look to expand our partnerships with least developed countries (LDCs) and work with them to emphasize the need for and value of active end user engagement.

With additional staffing, we will also expand out outreach work to include contacting groups that are identified through the analysis of flow data. For example, the Pakistan Education and Research Network (PERN) is listed as a top 10 source or destination in Year 3's analysis of flow data, indicating large flows. In addition, we have identified groups at University of Hawaii in Astronomy that we plan to engage with that are trying to make improve their data transfer performance using our link.

4.D Collaborations with IRNC Partners

Collaboration with the IRNC AMIS awardee, NetSage, is moving forward successfully, with TransPAC able to be a guinea pig for deployments of several measurement sources. NetSage is currently capturing ongoing Tstat, NetFlow, SNMP, and perfSONAR data for TransPAC. Live network statistics from TransPAC can be viewed on the NetSage portal at https://portal.netsage.global/grafana/dashboard/db/bandwidth-dashboard?refresh=1d&orgId=2. We will also ensure any new capacity has the necessary monitoring equipment installed as part of the deployment in order to fully participate with NetSage. We will continue to share data with NetSage in Year 4, as well as investigate ways to make more use of the Tstat and NetFlow data within the scope of the TransPAC project.

Moynihan also worked with the NetSage project to begin developing and populating the Science Registry that will allow flows to be tagged and identified by science domain, project, location, and educational institution endpoints, starting with the Top Talkers data from TransPAC. In Year 4, we will continue to engage and assist with the development and population of the Science Registry.

Through meetings such as the Trans-Pacific Research & Education Networking (TPREN) workshop hosted at the University of Hawaii, we continue to collaborate with PIREN in areas such as GOREX, wider Trans Pacific network connectivity, and engagement in the Pacific Islands. We will rely on this relationship to identify relevant Pacific Island-Asia research and stay informed on wider community needs including network connectivity and training opportunities.

We continue to work very closely with Pacific Wave in many areas. In addition to the circuit itself, we have bi-weekly calls to coordinate and focus efforts in order to avoid deploying duplicate services and resources. This collaboration in part has also led to additional engagement between our group and the Pacific Research Platform (PRP) and ESNet in areas such as deployment of DTNs in a backbone environment. We will be adapting the PRP DTN training material for use with our Asian partners. Also in Year 4, part of this collaboration will include the deployment of a Data Transfer Node (DTN) in Seattle.

The IRNC NOC continues to provide Tier 1 support services including monitoring the state of the trans-Pacific circuit and the installed equipment in Seattle. TransPAC continued its contract with the IU GlobalNOC to supply Tier 2 and Tier 3 services.

5. Circuit Status and Performance

The TransPAC-Pacific Wave 100G circuit runs between Seattle, Washington, and Tokyo, Japan. We currently collect sampled flow data, Tstat, SNMP data, and perfSONAR data for this circuit.

5.A Traffic Graphs

Figures 3 and 4 show the traffic on the TransPAC-PacWave 100G Circuit during the period of December 1, 2016 through February 28, 2017. The traffic spikes seen in February were caused by network testing conducted by WIDE engineers. The spikes at the end of May and in November were due to the network experiments of Yamanaka during TNC and SC respectively, described in Section 4.B. During the year, traffic increased by approximately 500mbps during outages on the Internet2/SingAREN 100G circuit, which can be seen in more detail in the Quarter 2 and Quarter 3 reports.

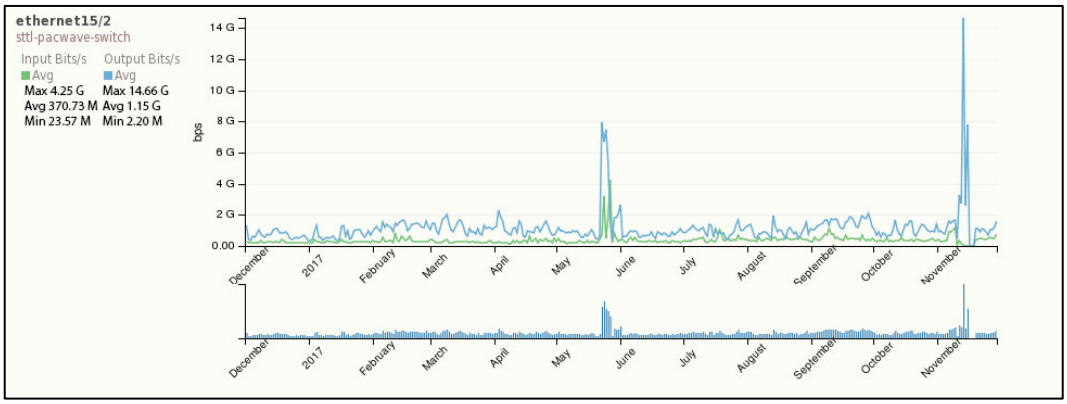

Figure 3: TransPAC-PacWave Seattle-Tokyo 100G Circuit (NSF-funded) traffic using smoothed daily averages.

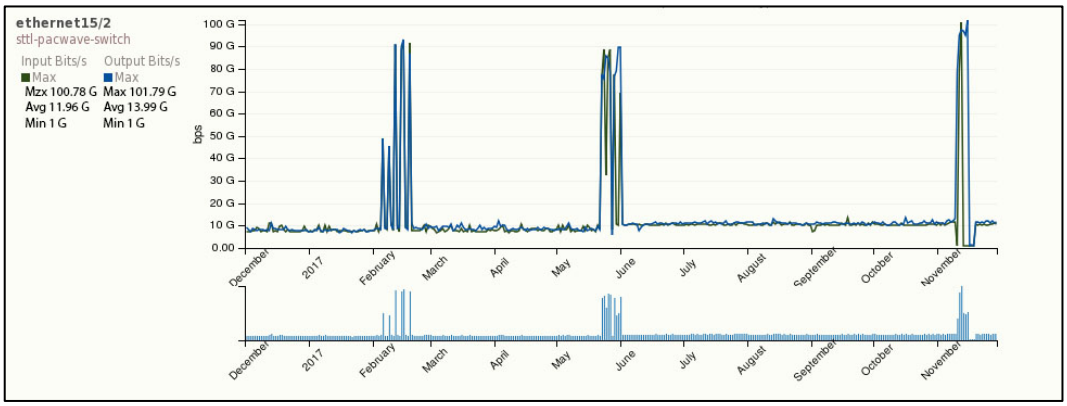

Figure 4: TransPAC-PacWave Seattle-Tokyo 100G Circuit (NSF-funded) traffic using maximum daily averages.

Table 1 shows full volume of traffic transferred over the TransPAC-PacWave link during the Quarter 4. Over 1.7 Petabytes of traffic has been transferred over the link during the 3 months. Table 2 shows full volume of traffic transferred over the TransPAC-PacWave link during Year 3. Over 7.6 Petabytes of traffic has been transferred over the link during the 12 months. As seen in Figures 3 and 4, the larger volume of traffic in Quarters 2 and 4 were likely caused by TNC 2018 in May and SC 2018 in November.

Table 1: Traffic in terabytes transferred over TransPAC-PacWave link, Sep 1, 2017 through Nov 30, 2017.

	Sep	Oct	Nov	Total
Tokyo-Seattle	166.83	123.97	128.93	419.72
Seattle-Tokyo	372.60	338.15	602.64	1,313.39
Total	539.43	462.12	731.57	1,733.11

Table 2: Traffic in terabytes transferred over TransPAC-PacWave link, Dec 1, 2016 through Nov 30, 2017.

	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Total
Tokyo-Seattle	876.7	381.8	385.20	419.72	2,483.14
Seattle-Tokyo	278.21	1,337.04	904.09	1,313.39	5,146.12
Total	1,154.91	1,718.84	1,289.29	1,733.11	7,629.26

5.B Flow Data

The TransPAC-Pacific Wave 100G circuit collects sampled flow data and unsampled Tstat data. De-identified versions of this data are also shared with the IRNC NetSage project. We are also investigating ways to utilize this data within the TransPAC project regarding in-depth analysis, including understanding poor performance of flows, network performance problems, and identifying potential engagement partners.

Figures 5 and 6 display the Top 10 Talkers for inbound to the United States flows by autonomous system sources and destinations. Figures 7 and 8 display the Top 10 Talkers for outbound to Asia flows by autonomous systems sources and destinations.

Inbound sources in Asia included sites in Japan and Taiwan, as has been common over Years 2 and 3. Over the course of Year 3 we have seen an increase in data from Pakistan Education and Research Network (PERN). This appears to be High Energy Physics related data going to the US. During Year 4, we will engage with PERN to see if we can help improve their transfers and discuss what type of data and research they are doing.

Inbound destinations in the United States are steady and correlate with High Energy Physics and Climate research. We continue to pass traffic from Asia to destinations in Europe. As the network connections between Asia and Europe mature we will discuss routing with parties in both regions to make sure the routing is efficient.

As shown by the outbound source graph (Figure 5), The University of Hawaii has been pushing traffic to Asian destinations over this year. Based on a more detailed examination of the flow data, much of this is a mix of climate and astronomy data. We are engaged with them and currently working on increasing the transfer rates for Astronomy data sets. This year we have also brought online peerings with Australia across the 100Gb/s link between Pacific Wave and Australia. We are still their best path to Asia. This should change in the next year as more circuits in the Pacific region come online.

During the year we have stayed engaged with our partners in China, Hong Kong, and Taiwan. 7As the outbound destination graph shows, they are major destinations for

traffic sourced from the United States with Chinese institutions the destination for 18.5% of the overall traffic, Hong Kong institutions as the destination for 22.2% of the traffic, and Taiwanese institutions the destination for 10.4% of the traffic. In addition, PERN also shows up as a Top 10 destination over the year and fuels the need to engage with their engineers.

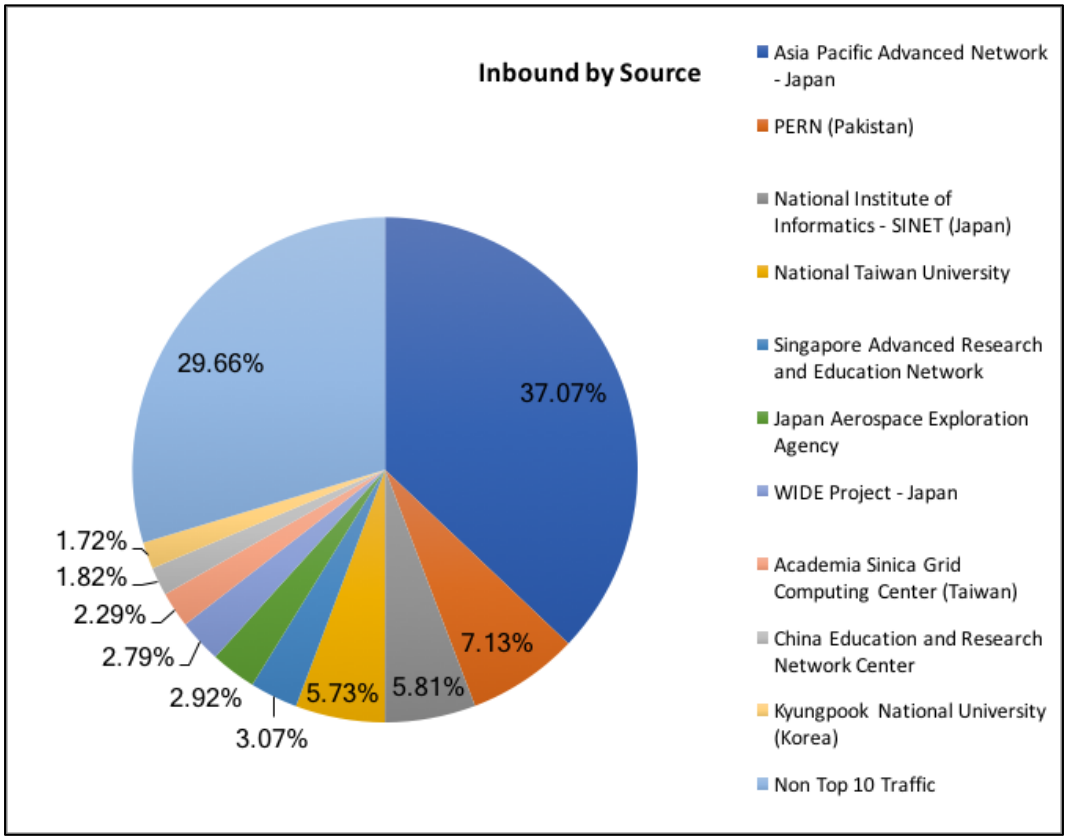

Figure 5: Top 10 Talkers by autonomous system source, inbound to the US for the year.

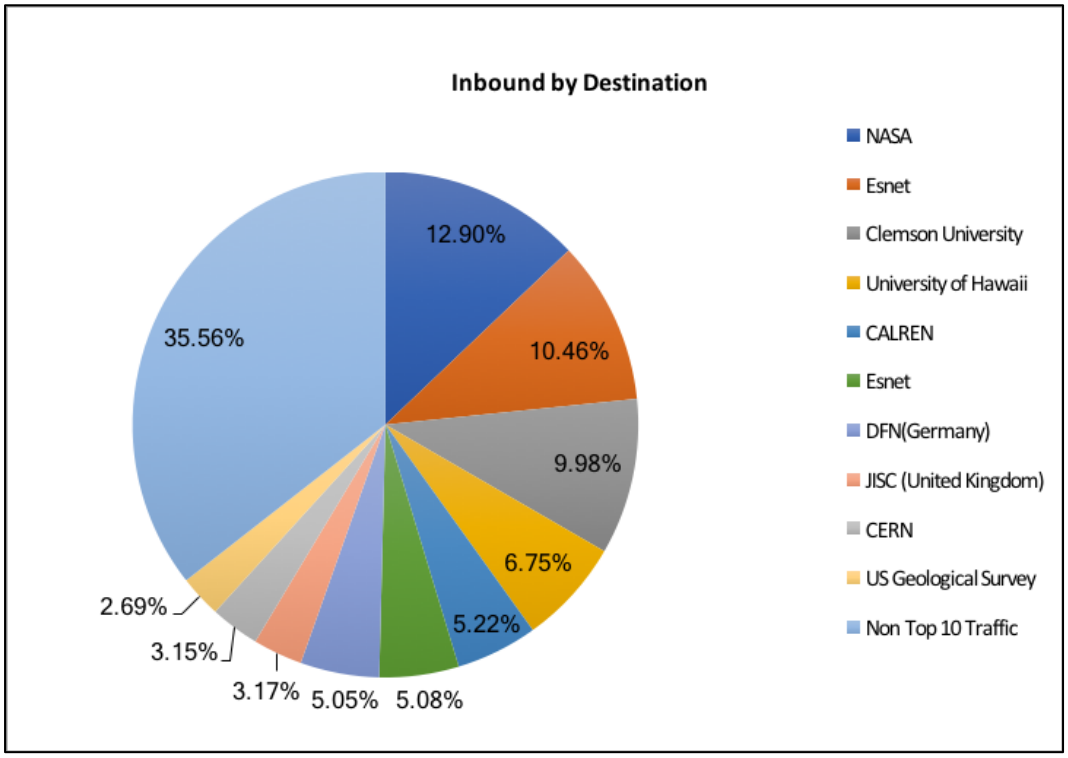

Figure 6: Top 10 Talkers by autonomous system destination, inbound to the US for the year.

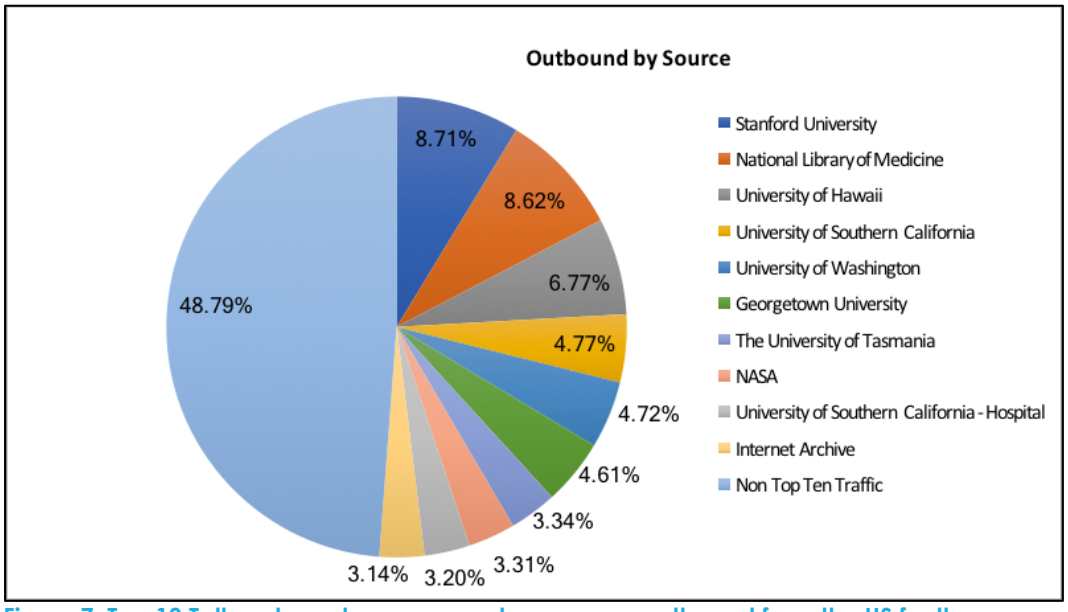

Figure 7: Top 10 Talkers by autonomous system source, outbound from the US for the year.

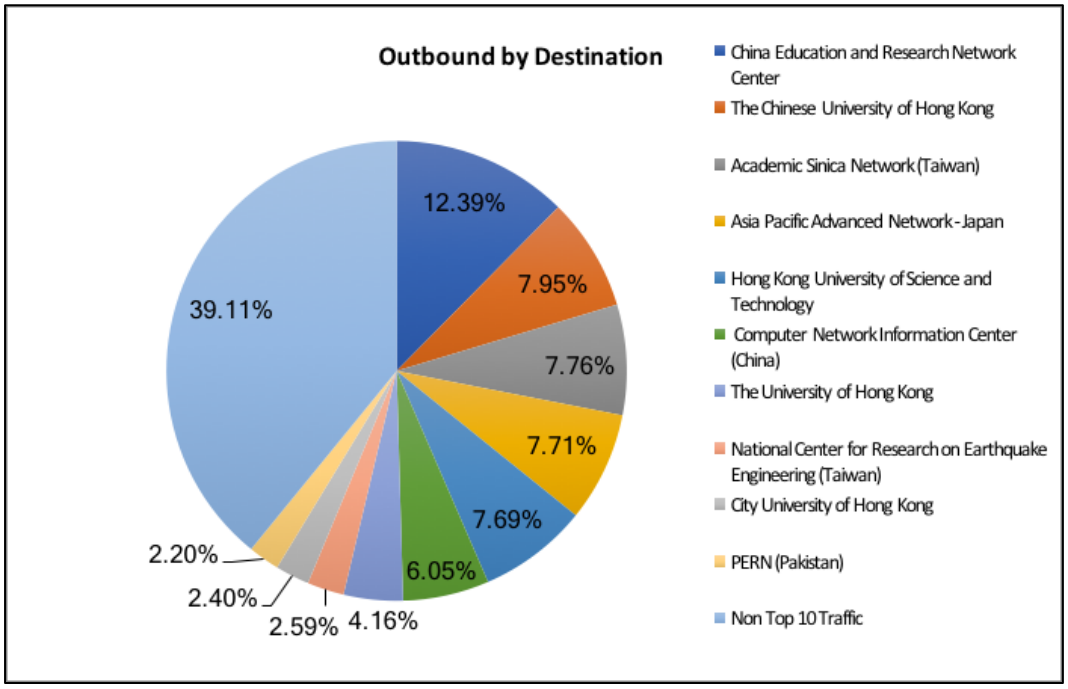

Figure 8: Top 10 Talkers by autonomous system destination, outbound from the US for the year.

5.C PerfSONAR

The TransPAC project supports a perfSONAR deployment in Seattle that provides periodic testing between several US and Asian sites. TransPAC participates in the IRNC mesh available at http://data.ctc.transpac.org/maddash-webui/index.cgi?dashboard=IRNC%20Mesh. We also participate in the APAN testing matrix at http://ps2.jp.apan.net/maddash-webui/.

At APAN 43 in Delhi, India, and at APAN 44 in Dalian, China, our team presented one day workshops on perfSONAR deployment and troubleshooting techniques. Both workshops were well attended and participants were engaged and inquisitive.

TransPAC staff participate as part of the perfSONAR Consortium. Schopf is a member of the Leads group and Chevalier oversees the Training activities. During Year 3, the perfSONAR core development team added functionality to enable the collection of traceroute data as part of its normal operation. During Year 4, we will to determine if our development efforts to address traceroute data are still needed or if the new capabilities of perfSONAR have made the work unnecessary.

Additional perfSONAR effort took place at SC'17, where Chevalier was a member of the SC'17 SCinet DevOps team. He helped plan and deploy a perfSONAR mesh to allow better monitoring within the SCinet network and to measure the performance of the many circuits that feed the sophisticated network demonstrations that take place as part of the conference.

5.D Trouble Tickets

During Year 3, there were fourteen unscheduled outages and ten scheduled maintenances, as seen in Tables 3 and 4.

Table 3: Unscheduled outages for TransPAC equipment and circuits for Year 4.

Ticket Number	Customer Impact	Network Impact	*Title*	Outage Type	Source Of Impact	*Start Time (UTC)*	*End Time (UTC)*
1837	2-High	2-High	Outage Resolved - TransPAC Backbone SEAT-TOKY	Unannounced Maintenance	Vendor	05/05/2017 1:00 PM	05/05/2017 1:12 PM
1856	2-High	2-High	Outage Resolved- TransPAC Backbone SEAT-TOKY	Circuit - Damaged Fiber	Vendor	06/27/2017 3:03 PM	06/27/2017 7:39 PM
1859	2-High	2-High	Outage Resolved - TransPAC Backbone SEAT-TOKY	Undetermined	Vendor	07/11/2017 6:22 PM	07/11/2017 7:37 PM
1863	4-Normal	2-High	Brief Outage - TransPAC Backbone SEAT-TOKY	Undetermined	Vendor	07/29/2017 3:05 PM	07/29/2017 3:06 PM
						07/29/2017 6:48 PM	07/29/2017 6:49 PM
1866	4-Normal	2-High	Brief Outage Resolved - TransPAC Backbone SEAT-TOKY	Hardware	Vendor	08/23/2017 9:28 AM	08/23/2017 9:29 AM
1867	4-Normal	2-High	Brief Outage - TransPAC Backbone SEAT-TOKY	Hardware	Vendor	08/24/2017 6:51 PM	08/24/2017 7:12 PM
1869	4-Normal	2-High	Brief Outage Resolved - TransPAC Backbone SEAT-TOKY	Unannounced Maintenance	Vendor	08/25/2017 5:14 PM	08/25/2017 5:22 PM
1878	2-High	2-High	Outage Resolved - TransPAC Backbone SEAT-TOKY	Hardware	Vendor	09/10/2017 6:49 AM	09/10/2017 8:48 AM
1882	4-Normal	2-High	Brief Outage - TransPAC Backbone SEAT-SEAT	Unannounced Maintenance	Vendor	09/20/2017 7:28 AM	09/20/2017 7:35 AM
1884	4-Normal	2-High	Brief Outage - TransPAC Backbone SEAT-TOKY	Undetermined	Vendor	09/23/2017 2:03 AM	09/23/2017 2:07 AM
1895	4-Normal	2-High	Brief Outage Resolved - TransPAC Backbone SEAT-TOKY	Unannounced Maintenance	Vendor	11/02/2017 6:04 AM	11/02/2017 6:05 AM
1896	2-High	2-High	Outage Resolved - TransPAC Backbone SEAT-TOKY	Power	Vendor	11/03/2017 7:24 AM	11/03/2017 7:26 AM

						11/03/2017 7:31 AM	11/03/2017 9:21 AM
						11/03/2017 10:04 AM	11/03/2017 10:06 AM
1898	4-Normal	2-High	Brief Outage Resolved - TransPAC Backbone SEAT-TOKY	Hardware	Vendor	11/06/2017 4:32 PM	11/06/2017 4:34 PM
1899	4-Normal	2-High	Brief Outage Resolved - TransPAC Backbone SEAT-TOKY	Hardware	Vendor	11/06/2017 9:13 PM	11/06/2017 9:27 PM

Table 4: Scheduled maintenance for TransPAC equipment and circuits for Year 4.

Ticket Number	**Customer Impact**	**Network Impact**	***Title***	**Outage Type**	**Source Of Impact**	***Start Time (UTC)***	***End Time (UTC)***
1793	3-Elevated	2-High	Maintenance Completed - TransPAC Backbone SEAT-TOKY	Software	Vendor	12/30/2016 1:30 PM	12/30/2016 1:31 PM
1806	3-Elevated	2-High	Maintenance 1 of 2 Completed - TransPAC Backbone SEAT-TOKY	Circuit	Vendor	03/10/2017 10:09 AM	03/10/2017 3:33 PM
1818	3-Elevated	2-High	Maintenance 1 of 2 Completed - TransPAC Backbone SEAT-TOKY	Circuit	Vendor	04/12/2017 4:16 PM	04/12/2017 5:04 PM
1840	3-Elevated	2-High	Maintenance Completed - TransPAC Backbone SEAT-TOKY	Circuit	Vendor	05/12/2017 3:00 PM	05/12/2017 3:10 PM
1845	3-Elevated	2-High	Maintenance Completed - TransPAC Backbone SEAT-TOKY	Circuit	Vendor	05/17/2017 6:01 PM	05/17/2017 6:14 PM
1870	3-Elevated	2-High	Maintenance Completed - TransPAC Backbone SEAT-TOKY	Circuit	Vendor	09/07/2017 4:07 PM	09/07/2017 6:22 PM
1881	3-Elevated	2-High	Maintenance Completed - TransPAC Interconnect Backbone SEAT-SEAT	Circuit	Vendor	09/20/2017 1:37 PM	09/20/2017 3:07 PM
1891	3-Elevated	2-High	Maintenance Completed - TransPAC	Software	Vendor	10/31/2017 12:03 PM	10/31/2017 12:37 PM

			Backbones SEAT-SEAT & SEAT-TOKY				
1894	3-Elevated	2-High	Maintenance Completed - TransPAC Backbone SEAT-TOKY	Software	Vendor	11/01/2017 9:00 PM	11/01/2017 9:01 PM
1900	3-Elevated	2-High	Emergency Maintenance Completed - TransPAC Backbone SEAT-TOKY	Circuit	Vendor	11/09/2017 6:11 PM	11/09/2017 6:16 PM

5.E Downtime and Availability

Table 5 shows the reported downtime for core nodes on the project. Table 6 lists the downtime for the projects circuits. Overall, the TransPAC-PacWave 100G circuit has been extremely reliable. In contrast, the Internet2-SingAREN 100G circuit between Los Angeles and Singapore experienced a greater than 40% downtime for calendar year 2017.

Table 5: Downtime and availability for TransPAC core nodes.

TransPAC Core Nodes	**Down Time**	**Reporting Period Availability**	**52 Week Availability**
TransPAC MX480 - LA	0 hr 0 min	100%	100%
Brocade MLXe4	0 hr 0 min	100%	100%
3410 Ethernet Switch	1 hr 15 min	99%	99%
OOB Router	0 hr 0 min	100%	100%
Aggregate TransPAC Core Nodes	1 hr 15 min	99%	99%

Table 6: Downtime and availability for TransPAC circuits.

TransPAC Backbone Circuits	**Down Time**	**Reporting Period Availability**	**52 Week Availability**
TP-LOSA-TOKY-10GE-1	0 hr 0 min	100%	100%
TP2-LOSA-LOSA-100GE-01521	0 hr 0 min	100%	100%
TP2-LOSA-LOSA-10GE-01520	0 hr 0 min	100%	100%
TP2-SEAT-TP-SEAT-TP-100GE-01523	2 hr 11 min	99%	99%
TP2-SEAT-TP-TOKY-100GE-01522	20 hr 17 min	99%	99%
Aggregate All TransPAC Backbone Circuits	22 hr 28 min	99%	99%

6. Software and Systems Work

No new tools were needed to be developed, and all tools continued to be supported.

During Year 3, we collected traceroute information using the perfSONAR nodes in the APAN MaDDash. During Year 4, we will work on methods to use this data to detect path changes that may impact network performance.

During Year 3 Addleman spent time working with partners in the GlobalNOC to deploy SciPass in the lab for experimentation. Addleman also continued work with FastNetMon to identify DDOS traffic in the lab. FastNetMon (https://fastnetmon.com/) is a program that can look at many different traffic sources including SFlow, NetFlow, or the output from a span or mirror port. It analyzes the traffic and can identify DDOS attacks in less than 2 seconds. In Year 4, Addleman plans to glue FastNetMon and SciPass together and build an automated SDN-based DDOS mitigation tool. SciPass will mirror traffic with OpenFlow to a FastNetMon instance that will inspect the traffic and then signal SciPass if it detects DDOS traffic. SciPass will then have the ability to report and block that traffic with a NetFlow rule. This is a much more efficient solution to DDOS mitigation than the current approach of black holing entire subnets. This project is ongoing as software development continues.

7. Security Events and Activities

Basic security measures are being maintained and there were no security incidents to report for this quarter.

Addleman finished working with CACR to complete the security documents in Quarter 4. The security documents were reviewed by both the International Networks team and a representative from the CACR team, Andrew K. Adams. The documents are currently stored on Box and the public documents will be made available on our website early in Year 4.

8. Milestones and Progress

1. Planning / Coordination

1.2.1 Evaluate circuit capacity and community needs. Negotiate with vendors and partners for new circuits as capacity demands grow. Phase 2 planning.

- ONGOING. The TransPAC project has discussed with the community at length and determined that a Hong Kong to Guam circuit would be the most useful. Early in Year 4 we will release an RFP for such a circuit

1.2.2 Finish partner MOU process - Contact partners and start the process of signing Memorandum of Understandings with each.

- ONGOING: During Year 3, we signed MOUs with of NII, APAN, APR, and TEIN*CC. In Year 4 we plan on signing MOUs with JUCC, CERNET, and SingAREN.

1.3.1 Evolve network architecture - New network designs over the evolution of the 5 year award. This will include 100G circuit speeds, software defined networking / exchanges, possible new peering points, and greater then 10G flows.

- ONGOING - We expect to release an RFP for capacity between Guam and Hong Kong shortly after the Guam Open Exchange (GOREX) is fully operational, likely early in Year 4.

1.3.2 Coordinate with IRNC:NOC winner - Coordinate with the IRNC:NOC awardee to ensure they have a sufficient and appropriate level of access to all of the TransPAC4 equipment supporting international activities. This includes appropriate logs, SNMP access, portal or login access to obtain data not available via SNMP, etc.

- ONGOING: The TransPAC project continues close coordination with the IRNC NOC since took over responsibility for TransPAC in January 2016

1.3.3 Coordinate with IRNC:AMI winner - Coordinate with the IRNC:AMI awardee for the appropriate distribution of flow data, per our own security and data policies, SNMP and other access as appropriate.

- ONGOING TransPAC was the first backbone to share measurement data, specifically SNMP and perfSONAR data, with NetSage. TransPAC continues to work closely with NetSage in areas such as Tstat analysis and the Science Registry.

1.3.4 Overall Management of the project

- ONGOING Meetings continue almost quarterly with project partners at conferences such as APAN, TNC, and Internet2's Global Summit and TechX.

1.3.5 Project Reporting - Report generation for the life of the project

- ONGOING - Reporting infrastructure in place for more up to date quarterly reporting; WBS update as part of this report.

1.3.6 Documentation and dissemination

- ONGOING - Both private and public facing documentation continues to be updated as the project continues.

1.3.7 Security plan for project

- COMPLETED – Addleman met with CACR throughout the year and finished working with CACR to complete the security documents in Quarter 4.

2. Outreach

2.2.1 Analyze usage data developed during TransPAC3 to identify geoscience/bioinformatics researchers. Leverage our TransPAC4 partners to provide support and if possible connectivity for these researchers.

- ONGOING - Altered from original from genomics to include bioinformatics, in part in support of the cross connect with ESNet. In Year 4, we will include outreach to the Astronomy community as well.

2.3.1 Coordinate with network partners to extend SDN/SDX to 100G circuits

- DELAYED - SDN work will continue to be conducted in the lab for the time being until it is deemed production ready.

2.3.2 Analyze current Geoscience network traffic and reach out to possible new network users

- ONGOING - We will continue working with our collaborators with ESIP and NASA to ensure rapid dissemination geoscience data such as climate and weather data continues and does not hamper researchers.

2.3.3 Evangelize Path Hinting

- DELAYED - Path hinting deployment is delayed due to postponement of path hinting research.

2.6.1 Attend domestic and international conferences for application identification and relationship maintenance

- COMPLETED:
    - Trans Pacific Research and Education Networking Workshop (TPREN), Hawaii, January, 2017
    - Pacific Telecommunications Conference (PTC), Hawaii, January 2017
    - APAN 43 Delhi, India, February 2017
    - Quilt Meeting, San Diego, February 2017
    - CENIC Annual meeting, San Diego, March 2017
    - LHCONE, BNL April 2017
    - GlobusWorld, Chicago, April 2017
    - PRAGMA 32, Miami, April 2017
    - Internet2 Global Summit, Washington, DC, April 2017
    - TNC, Linz, Austria, May 2017
    - PEARC17, New Orleans, July 2017
    - ESIP Summer Meeting, Bloomington, IN, July 2017
    - National Research Platform Workshop, Bozeman, MT, August 2017
    - APAN44, Dalian, China, August 2017
    - GLIF, Sydney, Australia, September 2017
    - LHC ATCF, Daejeon, Korea, October 2017
    - HePiX/LHCONE, Tokyo, Japan, October 2017
    - SuperComputing '17, Denver, November 2017
    - Asia Pacific Ring Launch, Singapore, November 2017
- ONGOING: We will continue to participate in similar activities in Year 4.

2.6.2 Coordinate connectivity with existing and new TransPAC Partners

- ONGOING – We will continue to hold meetings at APAN, TNC, and Internet2 Conferences with our partners.

2.6.3 Ensure connectivity in support of the Large Hadron Collider

- ONGOING - We will continue our support of the Large Hadron Collider through our efforts in the LHCONE community.

2.6.4 Ensure connectivity in support of Belle-II

- ONGOING - Belle-II hopes to be accepted as a participant in LHCONE by the WLCG, and we will continue to work with the project within that venue.

2.6.5 Coordinate with network partners and researchers to support large flows

- ONGOING – We will continue to develop new flow analysis tools that will assist us in identifying appropriate researchers.

2.6.6 Explore additional application communities

- ONGOING – We continue to look through flow data and discuss with our partners what application communities would most benefit from more intentional engagement.

2.6.7 Identify and contact US branch campuses in Asia-Pacific region

- DELAYED - Lack of engagement on the part of those campuses has pushed this into Year 4.

3. Operations

3.1.1 Analyze TransPAC Flow data in support of research and operations. Develop policy and plan for anonymizing and storing data. Provide data to researchers as requested.

- COMPLETED - Infrastructure is in place; analysis is being performed jointly with NetSage.

3.2.1 Integrate TransPAC3 SDN Controller - Work with systems engineers to transition the TransPAC3 SDN controller into the TransPAC4 network.

- DELAYED - The utility of SDN as a primary function in our current network architecture is still under investigation and may be determined to be undesirable.

3.2.2 Deploy SDN DDOS Solution Deploy the SDN based DDOS mitigation solution developed in TransPAC3.

- DELAYED - This mechanism is still under research in a lab environment to determine the most effective path for deployment, if any.

3.2.3 Evaluate and update existing POPs and equipment Evaluate and install new points of presence and equipment as community demands expands and changes.

- ONGOING - See discussions in Section 5 for additional circuits and OXP.

3.2.4 Deploy Path Hinting service into the TransPAC4 routers and work with partners, connectors, and peers to adopt the service.

- DELAYED - Path hinting deployment is delayed due to postponement of path hinting research.

3.3.1 Evaluate and deploy new circuits

- DELAYED; In original proposal, 100G circuit would be deployed in Year 3, but this is already present. Additional capacity from Guam to Hong Kong is planned based on community feedback.

3.5.1 Refine network measurement and monitoring data Refine and make network telemetry useful to researchers and the IRNC:NOC. This will include creating public web pages and repositories that provide easy access to data.

- ONGOING - We have been and will continue to work with IRNC NOC.

3.5.2 Tune and support large flows Monitor large flows across the network and work with researchers to fine tune the end points and entire path. Work with researchers to ensure performance is as expected.

- ONGOING - We continue to work closely with network researchers to support both large scale demos and day to day activities to ensure optimal network performance.

3.5.3 Deploy support and telemetry for large flows. Work with partners to configure and allow for large flows across the TransPAC4 network. Work with systems to deploy monitoring solutions for large flows.

- ONGOING - The tools we have developed support collection of data for large flows and we will continue to improve them as well as work with our partners to ensure effective network performance.

3.5.4 Operate Infrastructure; Pay for circuit, port, maintenance, and hardware costs.

- ONGOING

4. Research / Experimentation

4.1.1 SDN for DDOS mitigation - Research the feasibility of using SDN technologies for detection and mitigation of DDOS attacks on the TransPAC network.

- ONGOING - Research is continuing in the lab and will continue in Year 4.

4.2.1 Test larger than 10G flows Test network equipment, configuration, and support for greater than 10G flows.

- DELAYED - Delayed until network experimenters express a concerted interest in such activity.

4.2.2 Path Hinting deployment for testing, experimentation, and running community demonstrations.

- DELAYED - Path hinting deployment is delayed due to postponement of path hinting research.

4.3.1 SDN at 100G

- DELAYED - SDN deployment in our production environment is under still under research in the lab.

4.3.2 Evaluate SDN in an Internet Exchange environment

- ONGOING - Research is continuing in the lab and will continue in Year 4.

9. Summary of Year 4 Plans

The objectives for the TransPAC project span across four areas: network infrastructure, outreach and collaboration, measurement and analysis, and research.

9.1 Network Infrastructure

GOREX and additional connectivity (Milestones 1.3.1, 3.2.3) - TransPAC has long been a proponent of open exchange points, as well as a support of the Universities of Guam and Hawaii deploying one on Guam (GOREX). A community need had been expressed for additional capacity to add redundancy between the US and Asia to compliment Guam-Hawaii-Los Angeles 100G link. As of the end of Year 3, however, the GOREX exchange point in Guam was not yet operational and the connectivity was not yet in place. It is expected that GOREX be completed and operational during Year 4 Quarter 1. We plan on releasing an RFP for capacity shortly after by very early in Quarter 2. (See Sections 4.A, 4.D.)

DTN (Milestones 1.3.1, 3.5.3) - The utility of a deployment of a Data Transfer Node (DTN) within the structure of a research and education backbone is a topic that has

received a lot of discussion of late. During Year 3, we worked closely with our colleagues at ESNet and the Pacific Research Platform (PRP) to better understand the role of these devices in the edge case to see how DTNs might be deployed on a backbone. We plan in deploying a DTN in Seattle in the first half of Year 4. (See Section 4.D.)

9.2 Outreach and Collaboration

Branch campus support (Milestone 2.6.7) - During Year 3, we documented the extent of US branch campuses in Asia and started discussions with NREN partners on how we could best support these campuses' international data transfers. However, our initial outreach to US branch campuses in Asia did not yield a useful response. During Year 4, we will reevaluate our tactics to counteract the lack of response from branch campuses, continue to work with NRENs to gather better data, and reach out to the branch campuses to find a way to proceed. If unsuccessful, we must conclude that such support is not desired and will no longer pursue this. (See Section 4.C.)

MOUs (Milestone 1.2.2) - Part of the strength of the TransPAC project is our close cooperation with our partners. We are using Memorandums of Understanding (MOUs) to provide a better framework to encourage collaboration in not just infrastructure but communicating and sharing data on engagement endeavors. During Year 3, we signed MOUs with NII, APAN, TEIN, and the Asia Pacific Ring (APR) collaboration. During the first half of Year 4 we plan on signing MOUs with CERNET, SingAREN, and JUCC. (See Section 4.A.)

LHC Open Networking Environment (Milestone 2.6.3, 2.6.4) - During Year 3, TransPAC engineers had regular discussions with participants in the LHCONE community as well as NRENs to address the need for more efficient routing and additional capacity to support high energy physics. In Year 4, we will facilitate a peering between NICT's Hong Kong router and ESNet that will improve the exchange of data for researchers in the US with the south east Asian high energy physics community. (See Section 4.C.)

Tutorials (Milestone 2.6.1) - In Year 3, we conducted trainings at APAN 43 and 44, as well as a stand alone training adjacent to the PHNOG conference in Manila that was well received. For Year 4, we will expand our training team by hiring an additional staff member to assist. The existing training materials will be updated to include DTN related topics through close collaboration with PRP/NRP and ESNet trainers. We plan to hold workshops concurrent with APAN 45 and 46. We will also work with the community on any requests for workshops outside those venues. If the Asi@Connect workshops submissions are approved, we will plan the material and logistics for holding those, with the expectation they will occur early in Year 5. (See Sections 2, 3, 4.A and 4.D.)

Engagement (Milestone 2.6.7) - We will build on some of our initial successes with engagement during Year 3 with organizations such as JUCC in Hong Kong,

SingAREN, and the University of Peking in China. In Year 4, we will leverage the MOUs we have signed or will have signed with NRENs to locate further opportunities to reach out to the science user community. We will continue our ongoing outreach efforts to US science communities to help identify and support researchers working and collaborating in the Asia-Pacific region. We will also increase our analysis of flow data to identify additional end user communities to contact. (See Sections 4.A, 4.C, and 5.B.)

9.3 Measurement and Analysis

Tstat (Milestone 3.5.3) – In Year 3, we deployed a Tstat collector to the Seattle POP with a splitter attached to the TransPAC/Pacific Wave 100G circuit. Currently this data is ingested by a NetSage flow collector, following the NetSage policies for collecting such data. In Year 4, we will continue to make TransPAC Tstat data available as well as investigating ways to make it more useful for our engineers. We plan to include Tstat deployment and data collection as part of any additional capacity we obtain. (See Section 4.D.)

Dashboards and flow data analysis for large flows (Milestone 3.5.3) - In Year 3, the only flow analysis we did was to identify the top talkers on a quarterly basis, primarily for reporting purposes. In Year 4, we will be hiring on additional staff to enable us to extend the analysis that we perform on flow data, including an analysis of the effectiveness of the data transfer rates experienced by TransPACs largest users. (See Sections 2, 4.C, and 5.B.)

Science registry (Milestone 1.3.3) - Attribution of flows in the network to science domains or even specific scientific endeavors is becoming an important component of how we will shape big science research networks in the future. TransPAC engineers are working closely with NetSage during the development of the Science Registry tools as well as contributing data to provide an initial seeding of the registry itself. In Year 4, we will continue to engage and assist with the development and population of the Science Registry. (See Section 4.D.)

9.4 Research

Traceroute research (Milestone 3.5.1) - During Year 3, the perfSONAR core development team added functionality to enable the collection of traceroute data as part of its normal operation. During Year 4, we will to determine if our development efforts to address traceroute data are still needed or if the new capabilities of perfSONAR have made the work unnecessary. We will also put in place some basic analysis of traceroute data. (See Sections 5.C and 6.)

SDN and DDOS mitigation (Milestones 3.2.1, 3.2.2, 4.1.1) - During Year 3, we have investigated several approaches to DDOS mitigation using SDN tools such as SciPass and other tools such as FastNetMon in the lab. These techniques are suitable for production deployment on our equipment in Seattle, so we will continue to investigate avenues of DDOS mitigation during Year 4. (See Section 6.)

10. Response to EAB Review

We thank the External Advisory Board for their thorough review of the TransPAC project. We appreciate their comments on the strengths of the project and the team.

The panel had two recommendations for focus or improvement of the project.

1) *The panel was concerned about the increasing impact of restrictions on international travel resulting from changes to internal university policy. The ongoing success and future competitiveness of this project are tied to the ability for the PI and co-PIs to travel frequently to a wide set of countries to achieve project deliverables and to maintain reciprocal collaborative relationships with the growing set of international partners.*

Respectfully, the IN@IU team travels all over the world and works closely with many different countries and regions. During calendar year 2017, the IN@IU team traveled over 325,000 miles visiting 13 countries on five continents.
The TransPAC-PacWave 100G circuit supports transfers from 163 countries, which is 84% of all countries in the world. To say that the team may not be competitive in this space in the future is simply untrue.

The Indiana University restrictions on travel to foreign countries involve only a handful of locations with significant and severe safety or health concerns associated with them. These minor restrictions have had no prior impact to the project, nor do we foresee it having an effect in the future. That said, if a country is determined through reasonable measures to be unsafe, the IN@IU team WILL NOT travel there, and any expectation otherwise would be grounds for a staff member to bring legal proceedings against the team and the university.

2) This project is encouraged to continue its collaboration with the PIREN IRNC project to develop the strategic international research exchange point in Guam.

The IN@IU team has been part of the coordination process for the Guam Open Exchange (GOREX) since discussions began and we are in close contact with members of the GOREX staff on a regular basis. The planned second circuit will land on GOREX once the exchange is operational. None of this represents any change from what has been planned for the last two years.