STRATEGIC TECH FOR INTERNET

NSF OFFICE OF CYBERINFRASTRUCTURE (OCI)

2004–2005 FINAL REPORT

AWARD NO. 0231844

AMPATH

Collaborative Research & Education Operational and Functional Support

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STI: AMPATH Collaborative Research and Education Operational and Functional Support

2002-2005

Final Report

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NSF Program(s) STRATEGIC TECH FOR INTERNET

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1. Introduction

1.1 Background

AMPATH (AMericasPATH) began in March, 2000 at Florida International University (FIU), in Miami. Its principal mission is to provide high-performance research and educational networking in Latin America and the Caribbean in the support of scientific collaboration and education. By August 2001, AMPATH had already developed cooperative agreements with its industrial partners. These agreements included a three-year donation of ten DS3 (45 Mbps) circuits by Global Crossing valued at $25M. Other industrial partners by that time included Cisco Systems, Lucent Technologies, Juniper Networks and Terremark Worldwide. With these assets, AMPATH was able to connect two regional Research & Education Networks (RENs): Chile's REUNA and Brazil's RNP2. By April 2002, AMPATH connected two more RENs: ANSP of Brazil and RETINA of Argentina, as well as the Arecibo Observatory, the University of Puerto Rico, and the Gemini South, NOAO and CTIO observatories in Chip. In August of 2003, the research and education network of Venezuela was connected at the DS-3 level. Panama connected at the DS-3 level in 2004. These achievements are the work of a very small AMPATH staff. The staffing at present includes just seven individuals who amount to less than four FTEs.

1.2 Goals and strategies

AMPATH seeks not only to provide high-speed connectivity between researchers and students throughout North, Central and South America. AMPATH also seeks to foster effective use of such connectivity for scientific and scholastic purposes, especially those of interest to the U.S. With this latter goal in mind, AMPATH has sought to (1) identify connectivity applications of interest to U.S. science and engineering research and education, and (2) foster collaborations between U.S. scientists and their counterparts in the service area.

1.3 Value to U.S. science

Although AMPATH seeks to strengthen science and education in its service area *per se*, it also seeks to enhance U.S. science and to foster closer research and educational ties between the U.S. and the service area. In this sense, AMPATH provides benefits in its service area similar to those already realized by high-speed NSF-sponsored connectivity to Europe and the Asia-Pacific Rim research networks. A number of U.S. science initiatives depend critically upon facilities or environments located in Latin America. One example is observational astronomy. Astronomical observatories located, or to be located, in the Caribbean and South America include Arecibo Observatory, Pierre Auger, the Gemini South, CTIO and NOAO optical telescopes and the Atacama Large Millimeter Array (the latter two in Chile). Another example is the Inter-American Institute for Global Change Research (IAI). This intergovernmental organization coordinates research into environmental and socio-economic change in the Americas, and it counts 17 member countries in the Latin America area as well as the U.S. and Canada. Also, NASA's International Space Station (ISS) project seeks to provide access to the ISS for scientific investigators worldwide, including those in the Latin America. All of these U.S.-led initiatives now depend or will depend crucially upon high-speed connectivity between the U.S. and the Latin America. Several federal agencies currently operate networks in Latin America using point-to-point low-bandwidth circuits. The AMPATH project provides a coordinated and effective approach to these connectivity needs.

2. AMPATH Organization and Management

The AMPATH management team, noted below, is chaired by Julio Ibarra, of FIU, and includes representation from all collaborators. This committee makes policy and application support plans.

Chile	
	REUNA: Florencio Utreras
	Connected June 2001
Argentina	
	RETINA: Carlos Frank
	Connected December, 2001
Brazil	
	RNP2: Nelson Simoes (Rio)
	Connected July 2001
	FAPESP: Luis Lopez (Sao Paulo)
	Connected March 2002
Panama	**Guy Cordoba**
	Connected; June 2004
Venezuela	
	CNTI: Jorge Berrizbeitia
	Connected April 2003

Table 1 AMPATH Management Team

3. Operations

3.1 NETWORK INFRASTRUCTURE

The AMPATH network architecture, as shown in Figure 1, provides access to the wide area network provided over an ATM based Internet Protocol (IP) enabled network. Each national REN connects to AMPATH via this architecture. All AMPATH traffic routed to other international networks flows through the NAP of the Americas located in Miami, Florida. From Miami, the traffic is routed to either Abilene or STARTAP/StarLight. Abilene is the US-based research and education network, and STARTAP/StarLight is the ATM/optical exchange point for international traffic, located in Chicago.

AMPATH offers a variety of <u>network services</u>. Among the major services are:

- ATM and Optical Ethernet peering fabrics
- Intra-regional peering over Layer 2 services, including IP VPNs
- Native IPv6
- Multicast capable

- End-to-end performance measurement and monitoring
- AMPATH Reflector VRVS server for Video over IP
- Flow based and QoS based monitoring using NetFlow tools capabilities
- NOC Services through the Global Research NOC at Indiana University

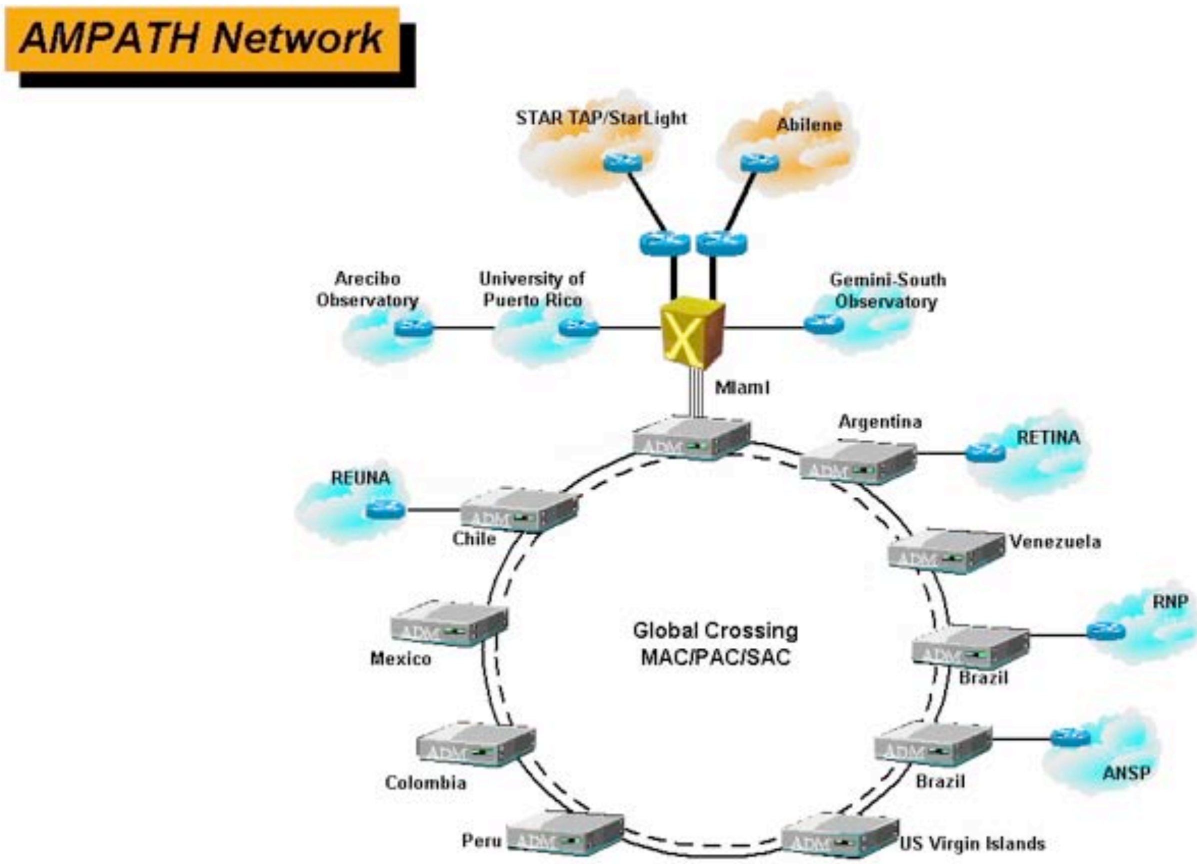

Figure 1 AMPATH Network Architecture and Connectivity

The figure above presents the basic network architecture employed by AMPATH. This architecture is representative of the research and educational networks worldwide. It also depicts the current AMPATH connectivity to the national RENs. As can be seen, the only interface between AMPATH and the rest of the world is through Miami to STARTAP/StarLight and Abilene. Through the STARTAP and Star Light interfaces in Chicago, virtually any location in the world is accessible to the national RENs . This interface is extremely important to the success of AMPATH in that it allows truly international collaboration to be conducted.

3.2 BUDGET

The operations of AMPATH are supported through NSF STI Award 0231844, Florida International University, Global Crossing and contributions from the management team.

Annual Costs:

Abilene Connectivity (622 Mb/s)	$180,000
Local Loops in Miami	$177,000
Network Operations Center (Nap Of the Americas)	$ 24,000
Equipment Maintenance & Replacement	$160,000
Senior and Technical Staff	$185,000
Network Operations Services (Indiana University)	$ 25,000
Administrative Staff	$ 61,000
Travel	$ 120,000
Misc.	$ 28,000
Total:	$960,000
5 DS-3 Circuits	$4,200,000
	Provided by Global Crossing

Cost Sharing:

Chile	$120,000
Argentina	$ 70,000
Brazil	$120,000
Venezuela	$120,000
NSF STI Award	$146,893
Panama	$ 65,000
Florida International University	$329,533

4. Milestones

2000	
April	AMPATH progress report at Brazil's national research networking conference, in Bello Horizonte, Brazil
August	AMPATH status report at the NLANR Joint Techs meeting in Toronto, Canada
Oct	AMPATH status report at Internet2 Member Meeting, Atlanta, Georgia
2001	
June	Chile's Red Universitaria Nacional (REUNA) NREN connects to AMPATH; peer-ing established with Abilene
June	AMPATH status report at the STARTAP Annual Meeting, INET 2001, Stockholm, Sweden
July	Brazil's Rede Nacionale de Pesquisa (RNP) NREN connects to AMPATH; peering established with Abiline

August 15-17	First NSF AMPATH Workshop for Identifying Areas of Scientific Collaboration between the US and the Latin America, ANI-0123388
August	University of Puerto Rico connects to AMPATH
August 23-24	AMPATH Status Report at the HPIIS Workshop on Developing metrics to quantify the use of HPIIS network links, San Diego Supercomputing Center
December	Argentina's Red Teleinformatica Academica (RETINA) connects to AMPATH; peering established with Abilene
2002	
March	Brazil's Academic Network of Sao Paolo (ANSP) connects to AMPATH; peering established with Abilene
April	Gemini South connects to AMPATH; peering established with Abilene
April 12	First NSF International AMPATH Conference in Valdevia, Chile, ANI-0220176
May	AMPATH status report at International Task Force, Internet2 Member Meeting, Arlington, Virginia
May	AMPATH status report at the Global Research Networking Summit, Brussels, Belgium
June	AMPATH establishes presence at the NAP of the Americas
September	AMPATH enables native IPv6 and offers IPv6 peering to members
October	NSF Strategic Technologies for the Internet Award for AMPATH Collaborative Research and Education Operational and Functional Support, ANI-0231844
October	AMPATH status report at International Task Force, Internet2 Member Meeting, Los Angeles, California
December	University of Puerto upgrades to an OC3c its connection to AMPATH
2003	
January	AMPATH upgrades to an OC12c its connection to Abilene.
January	NSF AMPATH Workshop: Fostering Collaborations and Next Generation Infrastructure, ANI-0305876.
January	AMPATH status report at Internet2 Techs/ESCC Workshop in Miami, Florida, hosted at FIU
April	Venezuela's Centro Nacional de Tecnologias de Informacion (CNTI) connects to AMPATH; peering to Abilene established
April	AMPATH status report at International Task Force, Internet2 Member Meeting, Arlington, Virginia
April	AMPATH participates in REUNA's conference on research networking, in Chile
May	AMPATH collaborates with US High-Energy Physics community to submit a proposal to the NSF Experimental Infrastructure Network program (proposal not funded)
May	AMPATH participates in RNP's Brazilian Symposium on Computer Networks, in Natal, Brazil
June	AMPATH status report at the ACURIL conference in Puerto Rico.
June	Plan developed to connect the University of the Virgin Islands and the NRAO radio

	antenna on St. Croix to AMPATH
September	AMPATH member meeting in Buenos Aires, Argentina
September	NSF awards FIU to develop an inter-regional Grid-enabled Center for High-Energy Physics Research Education and Outreach, which includes partial funding for AM-PATH to establish an STM-4 to Rio de Janeiro
October	AMPATH status report at International Task Force, Internet2 Member Meeting, Indianapolis, Indiana
October	Presented a paper on the Digital Divide in Latin America for the Digital Divide Round Table, at the International Center for Theoretical Physics (ICTP), in Trieste Italy
2004	
February	Established formal partnership with CENIC and NLR to provide North-South connectivity in the Western Hemisphere
February	Presented AMPATH STI project at HeGrid workshop in Rio
March	Participated in 1st International Grid Networking Workshop in Geneva
April	Presented at Jet Road Workshop AMPATH measurement activities
May	Participated in REACCIUN 2 seminar in Venezuela
June	Panama connected
July	Presented STI project to NSF at HIPIIS review
August	Begun working with Global Crossing to facilitate CLARA tender
September	Established partnership with CENIC and NLR to collaborate on connectivity between the U.S. and Latin America
October	Held PASI workshop in Argentina
November	Entered into an MOU with CLARA donating remaining AMPATH circuits
December	Begun working with FAPESP to establish long-term connectivitiy goals
2005	
January	RNP's three year circuit expires. Traffic is routed through Europe
March	Chile's three year circuit expires. Chile negotiates extension
April	Venezuela launches new high speed network
May	Sao Paulo transitions from three year DS-3 on Global Crossing to LANautilas
July	Chile's connectivity ends, and is routed through Europe on RedClara
August	RNP upgraded Rio to Sao Paulo connectivity
September	RedCLARA peers with U.S. in California, all other STI supported countries established long-term plan past end of STI support.
October	Project terminates without any countries disconnected. Long-term plans in place or being developed. Options are much better for the entire region than three years ago.

Table 2 AMPATH-STI Milestones

5. Progress Reports

The following sections detail progress against the NSF ANIR STI project milestones. The STI proposal listed milestone activities organized by Infrastructure, e-Science Application Support and Outreach, shown in the proposal, in Appendix D of this report.

5.1 Year 3 Work Plan Progress – July, 2004 through October, 2005

5.1.1 Infrastructure

Ongoing: Develop relationships with more international submarine cable carriers that offer service to other countries not serviced by Global Crossing.

ACTION: Collaborated with Global Crossing to respond to the ALICE EC program for regional networking, offering all current and present assets to assist in the establishment of a regional network.

Ongoing: Connect the remaining NRENs or academic networks in Service Area countries where Global Crossing has a presence.

ACTION Focused on inter-regional connectivity in future activities, and in this period supported the creation of regional, and state sponsored direct connections

ACTION: Established MOU with CLARA and donated 3 unrestricted three year leases of DS-3s for use as they please throughout the region.

Analyze and plan for improved or new AMPATH connectivity to other international connect points such as StarLight

ACTION: Begun collaboration with SURA to start the AtlanticWave.

5.1.2 Outreach

Prepare for the next AMPATH Meeting in Argentina for necessary infrastructure support; video conferences with AMPATH participants and Advisory board member to plan relevant agenda items

ACTION: Conference and working groups meetings held.

Hold a Workshop on leveraging IPV6

ACTION: Participate in the TIDIA meeting in Sao Paulo addressing IPV6 and associated technologies.

A Workshop to promote US-ASIAN-LATIN AMERICAN cooperation

ACTION: Held a CANS conference in Miami

A PASI conference on Grid Computing

ACTION: Held a PASI conference in Argentina

CIARA Application Support Workshops

ACTION: Participating in REN workshops.

5.1.3 Community Building

Organize external advisory committee and identify its purpose; recruit subject matter experts.

ACTION: None taken.

Schedule presentations to US and International agencies, including the Inter-American Development Bank, on the cultural impact of AMPATH, to increase in-country support for NREN's

ACTION: Active in both the Digital Divide initiative and the European Commission's @LIS, working with U.S. State Department and US AID to ensure policies in sync with U.S. government.

AMPATH presence at global networking conferences (such as INET), demonstrating AMPATH's commitment to global collaborations in scientific research and education

ACTION: Participation increased (please reference timeline)

Schedule demonstrations of intercontinental collaborative research and applications at national conferences, such as Internet2 Member Meetings

ACTION: INET presentation. AMPATH has facilitated demonstrations by Brazil at Super Computing, IGrid, and Internet2 Member meeting events.

Develop and publish the AMPATH Annual Report

ACTION: This document.

6. Merit of funded activity and broader impacts.

The proposal's goal was to contribute to the stability of U.S.-Latin American networking, in order to increase the rate of discovery for U.S. scientist. This goal required a predictable infrastructure, support of existing applications and outreach to bring in more collaborators for the benefit of U.S. science. These three topics are addressed separately below.

6.1 INFRASTRUCTURE

The infrastructure program is a very dynamic space. U.S. investigators need both more broad network access (to regions like the Caribbean) and more robust networking to collaborators and instruments in Brazil and Chile. Before the project begun, there was no advanced (greater than e-1) connectivity from Latin America to the U.S. Now there are direct connections and a regional aggregation. Many challenges face the regional aggregations, most significantly the development of domestic networking and last mile challenges. Scientists and broad education use are in Latin America more at odds than elsewhere, as populist agendas often overstep the needs of advancing the state (subsequently out of step with U.S. needs)

6.2 E-SCIENCE APPLICATION SUPPORT

The AMPATH team has reflectively engaged a broad scientific community to determine what is and is not working with application support. For this research came the CIARA project. The CIARA project is a model that FIU, the University of Puerto Rico (UPR), the Universities of Sao Paulo and Venezuela are pursuing to increase the rate of discovery for investigators and improve graduate education. The impact of CIARA is systemic. Participants have institutionalized the initiative, and collaborators from Caracas to Sao Paulo are developing local versions. This model effectively provides a rising tide that has lifted all research effectiveness across the region. The overarching benefit for the U.S. is that collaborators and instruments are more accessible and more effectively used with the technology transfer that the CIARA model provides.

6.3 OUTREACH

The network needs of U.S. investigators are growing rapidly in Latin America. The desire to collaborate on issues such as biodiversity and material science is exceeding the existing partnerships, and the scope of AMPATH. Through this STI grant science and education have been demonstratively advanced through new efforts in Physics, Astronomy, BioDiversity, and Computer Science research. The scope of benefit is specifically manifest in the 7 workshops held and indefinitely augmented with the creation of new communities of practice, with new discovery and new partnerships formed for the advancement of science and education in concert with the NSF's mission.

Appendix A: Papers and Presentations, International Meetings and Conferences

2003, June
AMPATH status report at the ACURIL conference in Puerto Rico.

2003, August
Operational Plan for Upgrading the Internet Connectivity of the United States Virgin Islands (USVI): University of the Virgin Islands (UVI), St. Croix VLBA Radio Astronomy Station and Other Research and Education Facilities

2003, September
AMPATH member meeting in Buenos Aires, Argentina.

2003, August 25
An In-Depth Look at AMPATH StarLight Traffic Accounting and Participant Analysis
A Report for the Strategic Technologies for the Internet (STI): AMPATH Collaborative Research and Education Operational and Functional Support Research Experience for Undergraduates, Award #331112

2003, October
AMPATH status report at International Task Force, Internet2 Member Meeting, Indianapolis, Indiana.

2003, October 23-24
Experiences with the Digital Divide in Latin America
Round Table on Developing Countries Access to Scientific Knowledge, The Abdus Salam ICTP, Trieste, Italy

2003, December 8-9
Role of Science in the Information Society CERN Geneva, Switzerland
2004, February
Participated in the Net@Edu to ensure broad understanding of AMPATH project

2004, February
Demonstrated to HEP community the AMPATH project at teh HeGRID workshop in Rio

2004, March
Participated in 1st International Grid Networking Meeting

2004, May

Engaged Fielding Scholars in CIARA model for AMPATH

2004, June
Presented at the workshop for the Virtual Data Grid Laboratory
2004, July
Presented STI project to the NSF.

2004, September
Internet2 Members meeting

2004 December
RNP Annual meeting presentation
GEMINI IT planning meeting in Miami

2005, March
Digital Divide meeting at CERN

2005, July
Presented at CLARA meeting in Mexico

2005, August
Presented at HEP meeting, DAEGU

Appendix B: AMPATH Projects and Applications

B.1 High Energy Physics

The multi-TeV energy scales needed to advance the study of the nature of matter and its most basic interactions, and to search for new particles and forces, has led to unprecedented challenges in petabyte data access and analysis. This has led in turn to worldwide scientific collaborations where each nation contributes its share to the construction of the experiment, and to the resources needed to analyze the data, while participating in the global process of search and discovery. The Large Hadron Collider (LHC) program at CERN in Geneva, encompasses four major experiments searching for the Higgs particles thought to be responsible for mass, as well as the states of matter and violation of symmetries that existed in the early moments of the universe. The US is a major player in the two largest of these experiments, ATLAS and CMS, with approximately 400 US physicists and engineers (20% of the total) involved in each one.

The CERN/LHC program is a large, but not atypical, example of a collaboration-driven project. The US has expended significant resources in this research area. The principal experimental devices are located in Europe, with major US contributions, and the Computational Data Grids that are being developed will be worldwide. Nevertheless, the program asks questions on such a grand scale that more than 5,000 individual researchers (in four large collaborations) are involved in working with various aspects of the problem. The Parallel and Distributed Processing Group of the Federal University of Rio Grande du Sul, in collaboration with its physics research staff, is an important player in the development of the Grid processing and data handling techniques necessary for the success of the LHC.

This collaboration is possible today in South America because of AMPATH.

B.2 Physical and Organic Chemistry

The University of Utah and the University of Buenos Aires are engaged in collaboration, funded jointly by the NSF and several Argentine agencies, to model chemical shifts in complex organic crystals. The collaboration itself is rooted in special expertise available in Utah and Buenos Aires. One of the objectives of the study is to develop robust techniques to include intermolecular effects in the calculations. Subsequently these techniques will be applied to solve structural problems in biologically active compounds from marine invertebrates from the South Atlantic in collaboration with researchers in the organic chemistry group and Buenos Aires.

B.3 Remote Biological, Marine, and Atmospheric Sensing

Although somewhat influenced by geography, the University of Puerto Rico's remote sensing program represents a collaboration of a different kind □ one across many disciplines. This program acquires large, generally geographically-based, data sets from remote ocean sensing devices, earth-sensing satellites, and a variety of other sources. These data are then applied to problems in oceanography, marine biology, and a variety of related fields.

B.4 Biodiversity

Another broad collaboration dependant on AMPATH, based at the University of Buenos Aires and sponsored by IAI, is examining the role of biodiversity and climate in functioning ecosystems. The group is studying the interrelationships between the atmospheric composition, climate, land use, biodiversity, and the ecosystem as a whole and how that impacts on the provision of human services. This is a global program in terms of the systems studied and it relies on a collaboration between several senior scientists in six South and North American countries. Two of the participating researchers are in the United States, one in Mexico, and several more are in South America.

B.5 Materials Science

The Instituto Balseiro in Argentina is pursuing a program aimed at understanding the thermodynamic, phase stability, and transformation of complex material systems. This effort involves a broad collaboration involving research centers in Florida, France, and Sweden. It includes an important distance-learning component directed at the upper-division and graduate level.

B.6 Unique Facilities and Science Collaborations

Whether sponsored by the NSF, DOE, NASA, or other public or private agencies, today's major US science projects take on economic scales that innately require international participation through partnerships and other forms of collaboration. Thus, for many of these programs the interests of US science and policy are inexorably linked to the international communications infrastructure because the science is being done with internationally shared resources.

Many of the presentations spoke on actual, planned, or desired collaborations to share unique, one-of-a-kind or few-of-a-kind, research tools. There were many examples of in-place programs. The CMS experiment at CERN is a 144-institution partnership across 31 countries, and the ATLAS experiment is a collaboration of similar size and scope. The Gemini observatory is a seven-nation program, managed by the US (NSF), with three South American partners including Chile's CONICYT. The International Space Station is a 15-nation partnership. The UCD program consists of 17 partner nations in the Americas.

A number of other examples of currently active, planned, or desired programs had the same flavor. ALMA is a major international cooperative project involving the US, Canada, Japan, Chile, and the European Southern Observatory which, itself, has nine member countries. FIU has a center for electron microscopy that can be operated remotely from any part of the world and would like to establish a partnership to fund and operate a remotely accessible high-temperature and high-pressure physics laboratory. NASA/Ames would like to establish a similar facility for the analysis of a wide variety of remote ecological, marine, and atmospheric sensor data, as would the University of Puerto Rico with oceanography data.

In many of these cases, the unique facility includes large expensive pieces of equipment, such as telescopes or particle accelerators. In every case, there were one or more remotely accessed shared databases or data archives. AMPATH is the connection to a number of these instruments today.

B.7 Video/Audio Communications

Videoconferencing, both for direct science collaboration and for operations purposes including data gathering, is becoming ubiquitous across AMPATH. Video over IP and Access Grid applications are becoming increasing common. The LHC experiments use the VRVS system for video/IP, including many meetings per day, throughout the year, as an integral part of the collaborations' daily work.

These technologies are especially useful adjuncts to programs involving remote operations or remote users, such as ALMA, Gemini, the University of Utah crystal modeling project with the University of Buenos Aires, and the International Space Station to mention a few. Some programs with multiple sites also mentioned integrating voice over IP into their telephone plants, as a convenience and cost-saving measure.

While some the systems use are already well-advanced, these will be developed into integrated environments for multi-site collaborative work; either on their own or in the context of Data Grids.

B.8 Remote Operations

Users through out the US manipulate and control observational or experimental equipment connected to AMPATH. Some described this as remote operation, and others as virtual operation. In any case, there is a lot of cross coupling between remote data taking, virtual laboratories, and archival data analysis.

The Arecibo and Gemini observatories both make use of observing by scientists at remote sites as an alternative to astronomers having to travel to the telescope. It is intrinsic to Gemini operations, and they plan to expand the capability significantly, to include additional remote observing centers in Arizona, Florida, and Chile. Located at 16,000 feet, the ALMA observatory will have to be operated in this mode.

The NASA/Ames Ecosystem Computer Facility not only is engaged in the analysis of remote sensing data, put has a suite of analysis instrumentation that it plans to enable to allow remote analysis of remotely sensed data.

The Utah/Buenos Aires crystal project, the FIU study of the Andean rivers, and the International Space Station effort all require the remote manipulation of sensor equipment. NASA/Marshall has already developed a remote payload control packed for International Space Station PIs.

B.9 Virtual Laboratories/Observatories

This might be defined as doing remote science from centralized or distributed archives, libraries, and databases, using standardized suites of access and processing tools made for the purpose. One example of such tools is the FIU/NASA Regional Applications Center's Terrafly package that allows the overlay and moving-map visualization of multiple geographically-parsed data sets.

The Caltech/CERN/University of Buenos Aires Large Hadron Collider (LHC) collaboration expects to make extensive use of this approach. ALMA, Gemini, and Arecibo expect to participate in a collaboration called the National Virtual Observatory to permit the mining and analysis of various astronomy data sets with standardized tools.

B.10 Distributed Archives and Libraries

The CERN group will need to transport tens of Petabytes by 2006. The Space Station, ALMA, Gemini, and the Utah/Buenos Aires crystal programs all have multiple international archive sites.

The University of Puerto Rico's Tropical Center for Earth and Space Studies' satellite down-link facility maintains a large digital database of the tropical Western Atlantic Region that is accessed online by NASA and other federal agencies, universities, and the private sector. Ecological programs such as the FIU rivers project and other global change research projects like the Buenos Aires biodiversity and climate study all intimately rely on access to large data sets maintained in many different places.

The IAI global change data and information service project currently has two access nodes (Brazil and Uruguay) and expects to expand to 18 in the near future using AMPATH. This system uses a distributed network of libraries and databases accessed with a Yahoo like search tool that yields relevant metadata and can provide ftp access if required.

B.11 Distributed Processing

The Federal University of the Rio Grande in Brazil has several programs that require distributed processing, including research in that subject itself, biological cell modeling efforts, 3D thermodynamic modeling, and high energy physics problems (with Caltech/CERN).

The Buenos Aires/LHC collaboration will take part in the GriPhyN network-based data-grid program, and will be part of the International Virtual Data Grid Laboratory (iVDGL) being supported by NSF. The FIU rivers project expects to use grid techniques in doing soil and fluids models. The Utah/Buenos Aires project expects to use grid processing in its crystals program. Gemini and ALMA expect that grid approaches will become necessary in the future to handle complex image processing with large data sets.

Appendix C: AMPATH Performance Statistics

For the 2004-2005 timeframe, AMPATH serviced the following NRENs and South Florida GigaPOP members with the following connection speeds. Table 3 shows the networks and their connection characteristics at the start of the final year (July 2004); Table 4 shows the networks and their connections at the conclusion of the year (September 2005).

NREN	Location	Connection Speed
REUNA	Santiago, Chile	DS3 (45 Mbps)
AURA/Gemini	La Serena, Chile	DS3 (45 Mbps)
REACCIUN/CNTI	Caracas, Venezuela	DS3 (45 Mbps)
ANSP	Sao Paulo, Brazil	DS3 (45 Mbps)
RNP	Rio de Janeiro, Brazil	DS3 (45 Mbps)
RETINA	B. A., Argentina	DS3 (45 Mbps)
UPR	San Juan, Puerto Rico	OC3 (155 Mbps)
FIU	Miami, FL	GigE (1000 Mbps)
NWS	Miami, FL	GigE (1000 Mbps)

Table 3 Networks and connections at the start of final year

NREN	Location	Connection Speed
AURA/Gemini	La Serena, Chile	DS3 (45 Mbps)
REACCIUN/CNTI	Caracas, Venezuela	DS3 (45 Mbps)
ANSP	Sao Paulo, Brazil	STM-4 (622 Mbps)
RETINA	B. A., Argentina	DS3 (45 Mbps)
UPR	San Juan, Puerto Rico	OC3 (155 Mbps)
FIU	Miami, FL	GigE (1000 Mbps)
NWS	Miami, FL	GigE (1000 Mbps)

Table 4 Networks and connections at the end of the final year

The first phase of the RedCLARA regional network implementation of the ALICE project, started operation in the last quarter of 2004. Chile's NREN, REUNA, connected to RedCLARA, shortly after. Brazil's NREN, RNP, later in 2004 connected to RedCLARA. When these moves were made from AMPATH to RedCLARA, traffic destined to U.S. R&E networks started being routed to Europe to transit GEANT, then Abilene.

AMPATH during this period also brought into production a new circuit to Abilene's core in Atlanta via FLR's newly established optical network. AMPATH now connects to Abilene via an FLR provided Layer 2 MPLS VPN (compliant with IETF Draft-Martini Layer 2 VPN □ RFC 3031) which terminates in Atlanta at the Abilene collocation space at SoX. This connection replaced the connection AMPATH had to Qwest for connectivity to Abilene. Connected Latin American NRENs and R&E networks are able to continue directly peer with Abilene and the U.S. Federal Networks, with no loss of functionality.

In the period covered by this report AMPATH also established a connection with FLR via a 10 Gigabit Ethermet cross-connect to FLR's collocation space at the NAP of the Americas. This now enables AMPATH's downstream peers to access any State of Florida higher education institution at a significantly faster speed than previously possible; once again enabling collaboration between researchers.

Another significant achievement was the establishment of a 10 Gigabit Ethernet peering with UltraLight; this peering is achieved again through the leveraging of FLR's optical infrastructure; using a dedicated light path through FLR's network which terminates at AMPATH's Ethernet fabric in the form of a 10 GigE port on the Foundry FastIron switch. This newly implemented connectivity will serve as a key step in providing better access to High Energy Physics research projects and again enable collaboration between Physics research scientists which operate in AMPATH's downstream peers.

Connectivity to AMPATH's downstream NRENs and SFGP members was achieved through a mix of Ethernet and ATM circuits supported by AMPATH's core Ethernet fabric in the form of a Foundry FastIron 400 and AMPATH's core ATM fabric in the form of a Lucent CBX 500 ATM switch. The following figure shows the AMPATH network during the 2004 and early 2005 period.

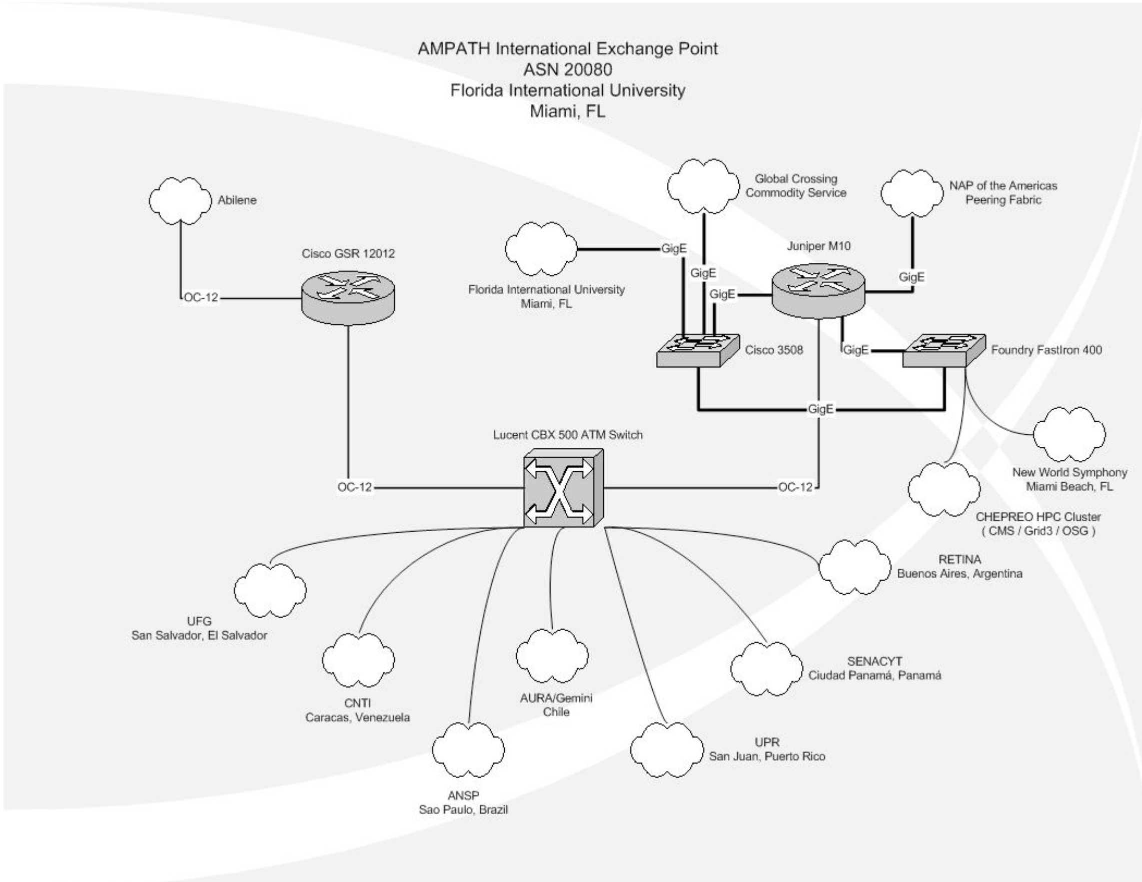

Figure 2 AMPATH in 2004 before ONS 15454 installation

The DS3 link to the Academic Network of Sao Paulo (ANSP) was upgraded to an STM-4 (622Mbps) to support the network and cyberinfrastructure requirements of the NSF Center for High-Energy Physics Research Education and Outreach (CHEPREO) project, award #0312038. During the 2004-2005 period, AMPATH successfully installed and put into production a Cisco ONS 15454 optical switch, collocated at the NAP of the Americas in downtown Miami, FL. The introduction of this new network element allowed for the migration from ATM to SONET/SDH of the ANSP circuit to Sao Paulo, Brazil. This equipment set the stage to leverage resources from other projects to increase bandwidth capacity to Sao Paulo to support U.S. Science and Engineering projects of other NSF activities.

The following figure illustrates the state of AMPATH after the installation of the Cisco ONS 15454 and the ONS's interconnectivity to existing AMPATH network elements:

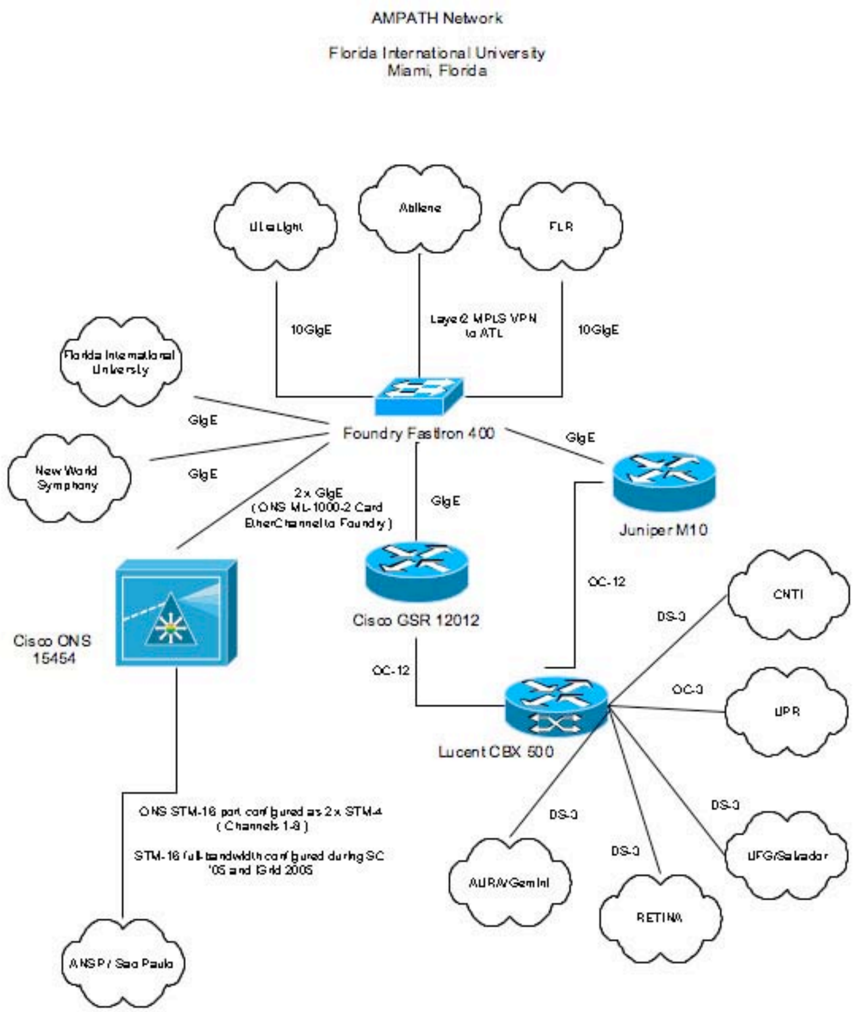

Figure 3 AMPATH network after Cisco ONS 15454 installation

C.1 Real World Demonstrations

In collaboration with the State of Sao Paulo, the CHEPREO project upgraded the link to AMPATH in Miami from a DS3 (45 Mbps) to an STM-4 (622 Mbps). This upgrade was done in time for Brazil and Latin America to participate in the Super Computing 2004 (SC04) event. The upgraded link to Sao Paulo was contracted on STM-16 (2.5 Gbps) ports, giving the CHEPREO project the ability to increase the bandwidth capacity for an event, such as SC04, to the full port capacity. For the first time, Brazil and Latin America, were able to participate in a global demonstration with bandwidth of such magnitude. The SC04 Bandwidth Challenge provided the opportunity to form a global collaboration for a global demonstration powered by high-performance networks.

The CHEPREO link allowed High-energy physicists at the University of Sao Paulo to participate in the SC04 Bandwidth Challenge. For the first time, physicists were not constrained by bandwidth to run events and do very large file transfers to CERN and FermiLab. After the event, the physicists continued to use the link capacity while it remained available. See Figure 2 for a diagram of the network for the SC04 Bandwidth Challenge.

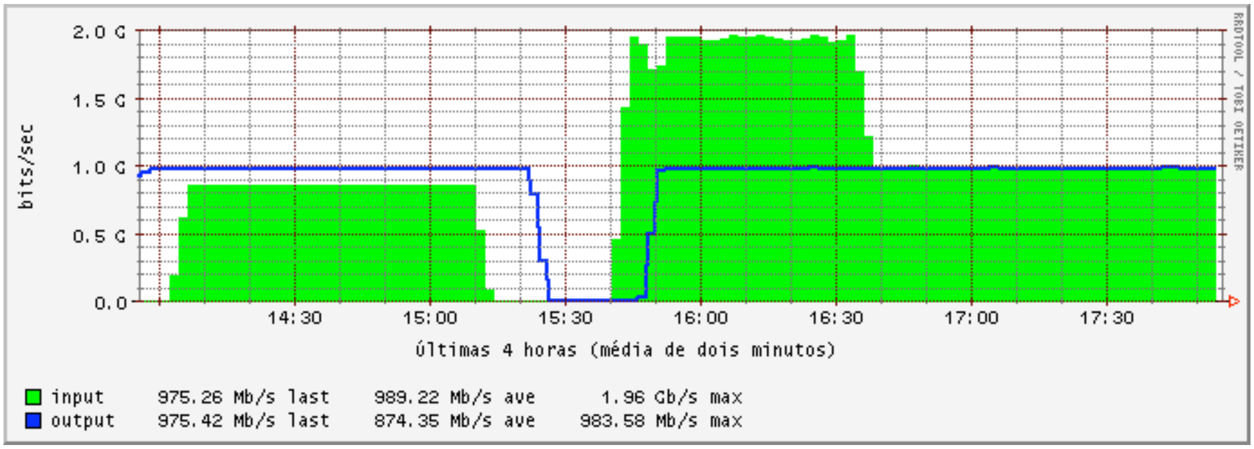

Figure 4 SC04 Bandwidth Challenge - Brazil's participation

During the bandwidth challenge, a new record was set for a Latin American research network with throughputs up to 2.95 Gbps between the conference Center floor in Pittsburgh and the computational clusters in Brazil. The traffic generated on the link between Sao-Paulo and the SC show floor (see Figure 3 below). This was a first big step in enabling physics groups in Sao Paulo, and also Rio de Janeiro (through the use of the GIGA project) to take part fully in the LHC and FNAL physics programs.

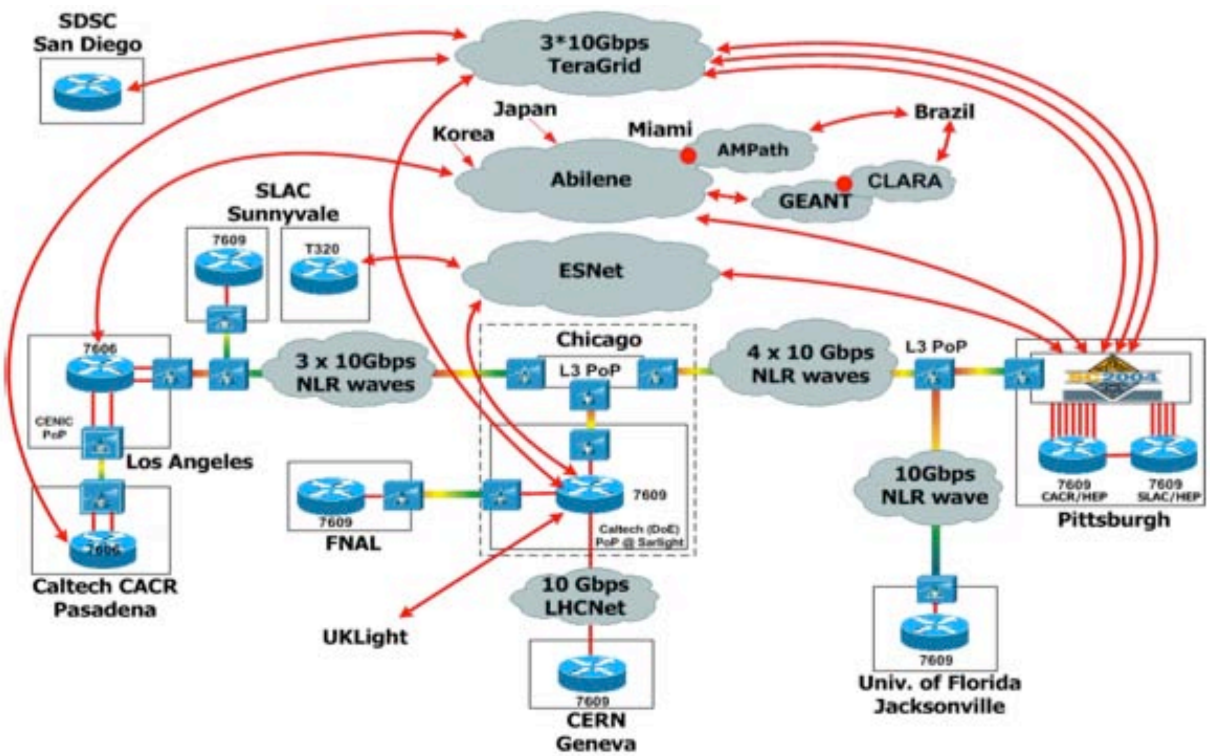

Figure 5 SC04 Bandwidth Challenge network diagram led by Caltech

C.2 Observation of AMPATH Annual Traffic

The following figures of the Multi-Router Traffic Grapher (MRTG) graphs show the average utilization on several of the international links that connect countries participating in AMPATH. The point of reference for the in bound and out bound flows of the MRTG graphs is the AMPATH Cisco GSR 12012 core router.

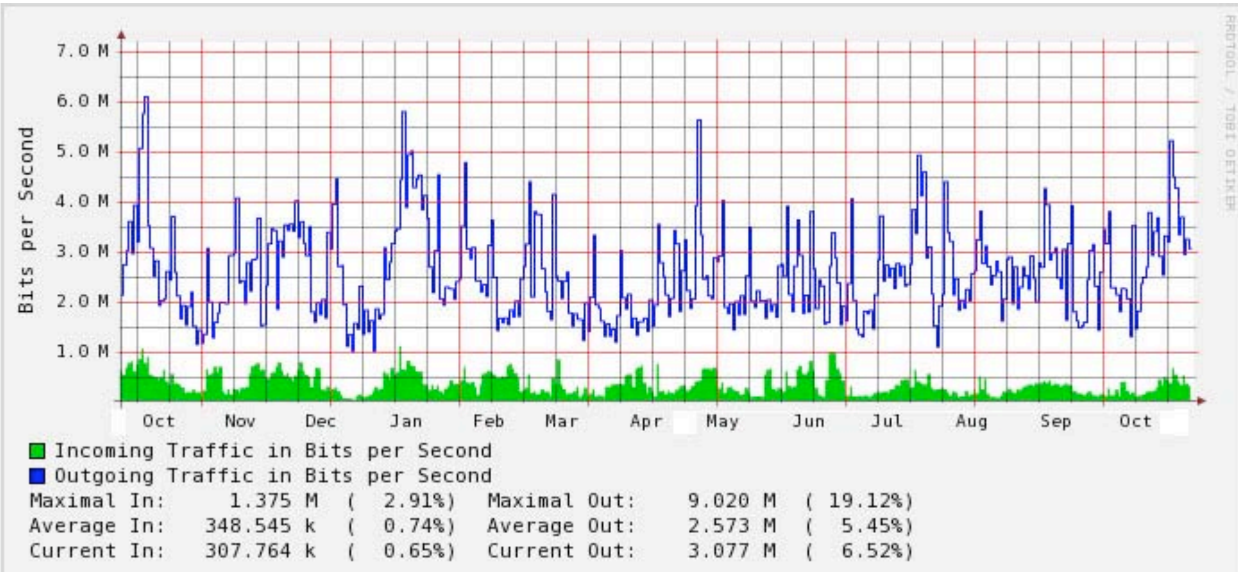

Figure 6 - RETINA Utilization

Figure 6 shows the traffic to and from the NREN of Argentina, RETINA. The Pierre Auger observatory has been using a minimal amount of the bandwidth on the AMPATH connection. Traffic over the AMPATH link has remained about the same for year. Argentina continues to utilize the AMPATH connection to reach the U.S.

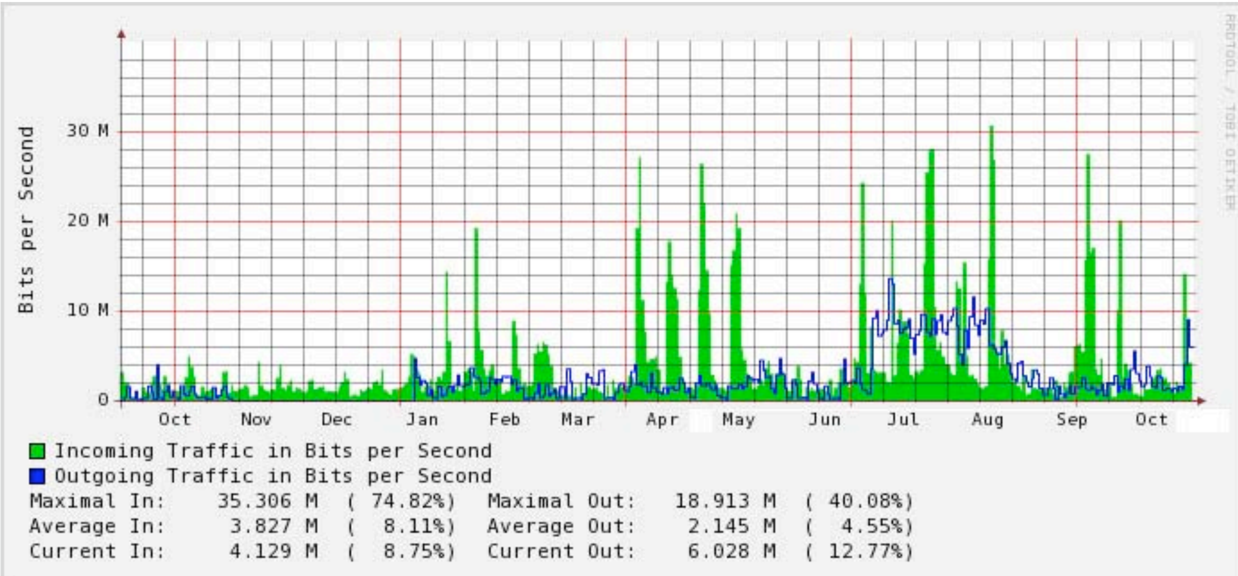

Figure 7 - AURA/Gemini Utilization

Gemini South, CTIO, NOAO and other telescopes in Chile have been increasing their link utilization to Abilene (Figure 7). This is to be expected as the telescopes improve efficiency of observations using queue observing, resulting in faster production of science data products that are transferred to repositories at partner sites.

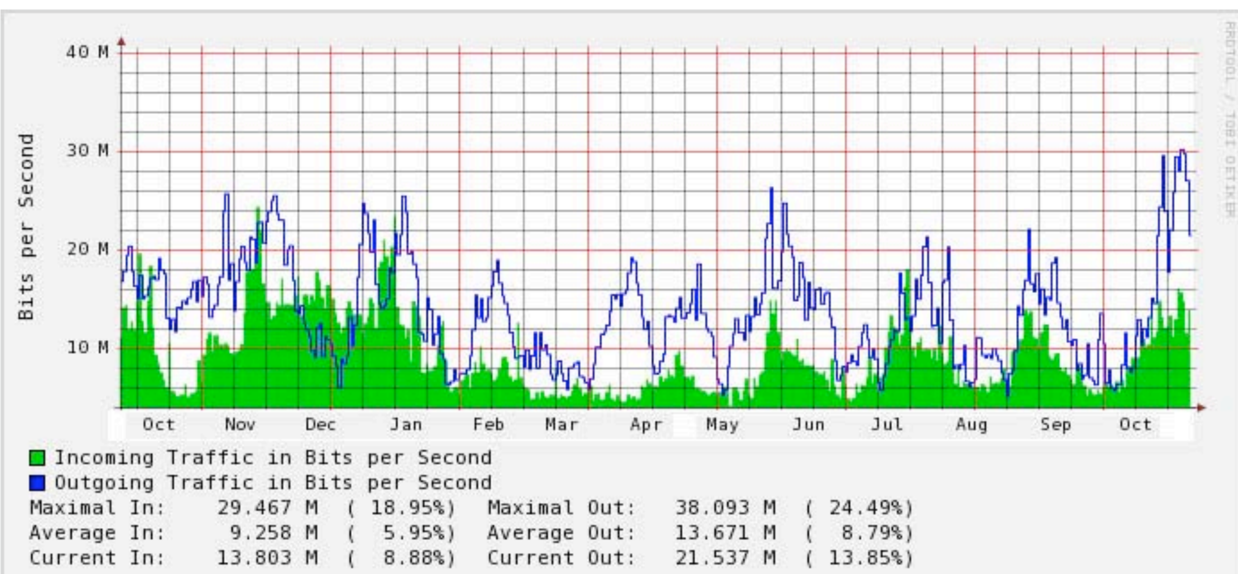

Figure 8 - UPR Utilization

The University of Puerto Rico system and the Arecibo observatory are primary users of this link. Usage on the link (Figure 8) has been steady throughout the year with increases towards the latter months.

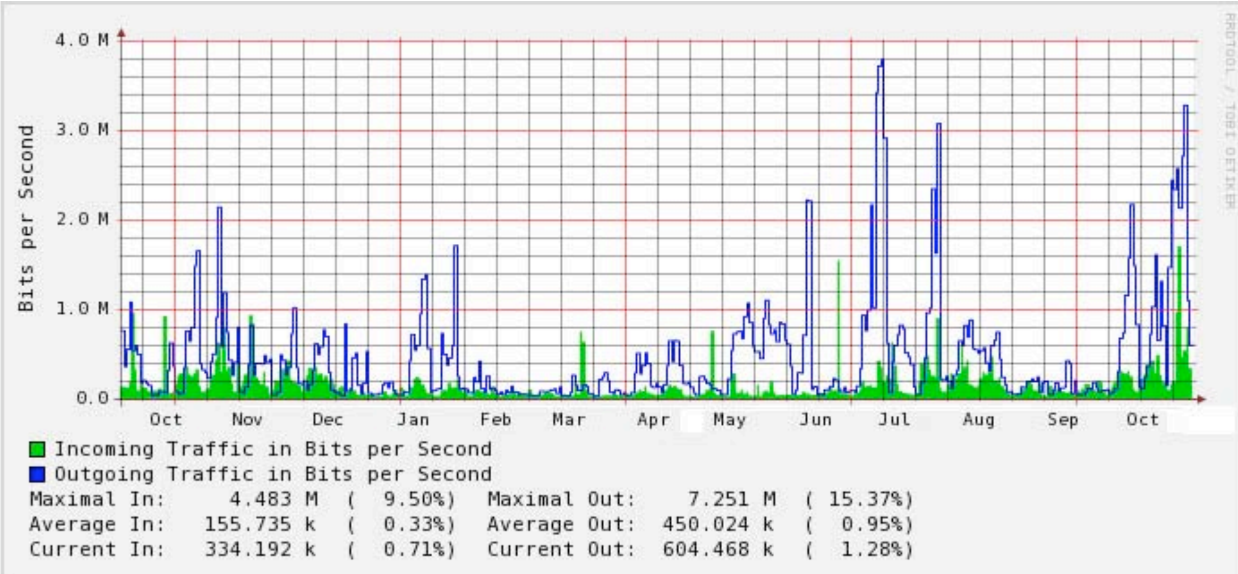

Figure 9 - CNTI Utilization

Venezuela's NREN has been in formation and working to connect universities to the backbone as the goal for the launch of their national Internet2 project. An increase in network usage is evident towards the latter part of the year (Figure 9), as additional universities were connected. Venezuela is also connected to RedCLARA.

Appendix D: AMPATH-STI REU Report: Distributed Network Monitoring

Anatomy of an International Exchange Point: Distributed Network Monitoring Using MonALISA and NetFlow[1]

Jose Fernandez, Ernesto Rubi, Xun Su, Iosif Legrand, Heidi Alvarez, Julio Ibarra[2]

Abstract: In this paper we present a distributed network monitoring system, which exploits MonALISA (Monitoring Agents in A Large Integrated Services Architecture), a distributed web service delivery infrastructure designed to collect and process the network monitoring information. We augment the capability of MonALISA with FlowTools, the popular NetFlow data analysis toolset. We demonstrate how to integrate MonALISA and Flowtools via an UDP-listening agent ApMon, and highlight a case study of AMPATH, an international exchanging point located in Miami and serving a number of South American National Reseach and Education Networks (NRENs). Our experience showcases the elegant design philosophy of a scalable distributed service deployment platform coupled with the open-source traffic analysis tools and its impact on the daily operation of the production networks.

Keywords: NetFlow, MonALISA, Flowtools, Network monitoring.

1. Introduction

As the Internet expands both in its scope, reach and capacity, it becomes evident that there is a strong need to develop a distributed network monitoring infrastructure that can be scaled to support various network topology, traffic granularity and user applications. NetFlow[1] is a widely deployed router-based traffic monitoring mechanism. FlowTools[2] is a open-source NetFlow analysis toolset underlying the data gathering and analysis infrastructure of our project. It is our main motivation to effectively use NetFlow to gain crucial understanding of the traffic characteristics of the networks we operate. In particular, we are interested in understanding how to exploit the key advantages and avoid drawbacks of NetFlow-based traffic analysis by augmenting it with a distributed service-deployment platform. Indeed the focus of our work is to integrate MonALISA[3], a distributed monitoring system based on JINI/JAVA and WSDL/SOAP technologies. MonALISA's flexibility as a framework to gather, store and distribute network data collected was crucial to the success of our investigation and it shall become apparent throughout the course of this paper. The MonALISA framework provides a distributed monitoring service that not only is closely integrated with our monitoring and data distribution philosophy but also acts as a dynamic service system. The goal is to provide the monitoring information from large and distributed systems in a flexible and self-describing way as part of a loosely coupled service architectural model to perform effective resource utilization in large, heterogeneous distributed centers. A salient feature of the MonALISA framework lies in its capability to integrate existing monitoring tools and procedures to collect parameters related to computational nodes, storage devices and network performance. A critical part to the research that we undertook is to integrate the parsed NetFlow data into a MonALISA which would make available the information in a distributed manner through mobile service agents. We will incorporate real-time as well as historical information in our system to improve the understanding of the traffic statistics data from the networks being monitored.

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[1] This work is supported by National Science Foundation's Strategic Technologies for the Internet (STI): Research Experience for Undergraduates Award No. 331112 and a Cisco Systems University Research Program (URP) grant.

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A significant part of the paper is dedicated to the use of our system to analyze network traffic behavior across a real-world production network, AMPATH. The AMericasPATH (AMPATH) network is an FIU project sponsored in part by the US National Science Foundation CISE directorate, in collaboration with Global Crossing and other telecommunications product and service providers. Using Global Crossing's terrestrial and submarine optical-fiber networks, AMPATH is interconnecting the research and education networks in South and Central America and the Caribbean to US and non-US research and education networks via Internet2's Abilene network. The purpose of the AMPATH project is to allow participating countries to contribute to the research and development of applications for the advancement of Internet technologies. The mission of AMPATH is to serve as the pathway for Research and Education networking in the Americas and to the world and to be the International Exchange Point for Latin America and the Caribbean research and education networks. Additionally AMPATH fosters collaboration for educational outreach to underserved populations both in the US and abroad. The AMPATH pathway serves as the bridge between Central and South American National Research Networks (NRENs) and the world's research and education networks. With the multiplicity of complex networked systems and educational activities served by AMPATH's wide-ranging infrastructure a strong demand for high availability and engineering collaboration arises, which is met through the use of various monitoring agents to provide a strong factual foundation to troubleshooting. Likewise, deciphering the everyday activities of our peers is achieved with a distributed approach to data gathering and dissemination.

2. Anatomy of an international exchange point

Figure 1 demonstrates AMPATH's current design, IP addresses as well as Autonomous System Numbers (ASNs) are omitted. We will use simple NREN names to identify our international peers.[3] It is this network that served as the backdrop for our study. Two core routers exist: a Cisco GSR 12012 as well as a Juniper M10, both routers have NetFlow accounting enabled and are designed to export this data to a collection workstation.

[3] For more detailed information please visit http://mrtg.ampath.net.

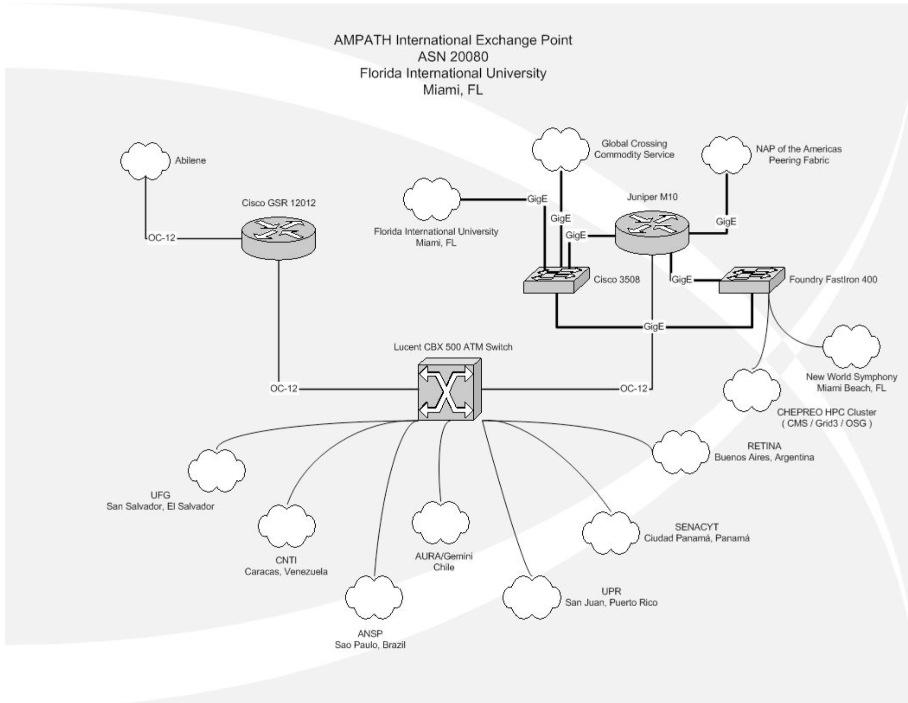

Figure 6: AMPATH schematic architecture.

3. NetFlow and Flowtools

NetFlow was originally developed as a switching path and today it is primarily used for network accounting. Flow records are generated and exported by a router. Each flow record contains information about all packets that are categorized to have the same combination of the following IP header fields:

- Source IP address
- Destination IP address
- Source port
- Destination port
- Layer 3 protocal type
- TOS byte
- Input logical interface

NetFlow records only unidirectional traffic in-bound to any interface on the router. Note however, even though this traffic is unidirectional NetFlow accounts for all traffic going in and out of the router by recording both transit traffic and traffic destined for the router. By storing only the router's flow-level information and neglecting payload it becomes feasible to summarize and "sketch" large amount of data traffic.

A key technical note is the sampling mode at which the router is running. In the GSR's case a 1-100 sampling rate is specified. This means that for every 100 packets processed by the forwarding engine or route processor there will be one packet extracted and reported to the NetFlow process running at the router. This is the lowest allowed sampling rate on our GSR running NetFlow v5 and clearly we can see that this causes limitations on the analysis of network data. It is not uncommon to have short host-to-host sessions where the overall transmission does not exceed 100 packets. It is beyond the scope of this paper to discuss NetFlow sampling algorithms but based on our experience it is likely that if the transmission is 100 packets or less NetFlow will not account for it. This introduces a margin of error to any analysis of data flows but especially to those UDP flows transmitted over our core. With their inherent error correction mechanisms TCP flows are less prone to being ignored by the collection process.

Flow Tools is a collection of programs and libraries used to collect and process NetFlow data. These tools allow users to process stored flow data from a series of command line interfaces. Commands like flow-filter and flow-sort allow the user to filter and sort NetFlow data by IP address, port, AS number and any other parameter present in that data collected. The data is presented on the command line in a table format. However these tools do not provide a dynamic way of dynamically monitoring flow data. Through the use of MonALISA we have used NetFlow data collected and processed by Flow Tools to create a graphical interface by which to view certain characteristics of the Ampath network in a near-real time fashion. For our analysis we implemented flow-tools version 0.66 on a dual Xeon 2.66 GHz system with a copper Gigabit Ethernet network connection to FIU's campus network. The operating system of choice was Fedora Core 2.

Having discussed the data gathering techniques in the following we focus on the data dissemination mechanism. For the rationales that we detail in the next section MonALISA is our platform of choice for this purpose.

4. MonALISA and ApMon

MonALISA (Monitoring Agents in A Large Integrated Services Architecture) is a distributed services architecture to collect, process and act upon real-time monitoring information. While its initial target field of application is networks and Grid systems used by the global high energy and nuclear physics collaborations, MonALISA is broadly applicable to many fields of data intensive science, and to the monitoring and management of major research and education networks. MonALISA is based on a scalable dynamic distributed services Architecture, and is implemented in Java using JINI[21]and WSDL[22] technologies. The scalability of the system derives from the use of a multi-threaded engine to host a variety of loosely coupled self-describing dynamic services, and the ability of each service to register itself and then to be discovered and used by other services or clients that require such information. The framework integrates many existing monitoring tools and procedures to collect parameters describing computational nodes, applications and network performance. Specialized mobile agents are used in the MonALISA framework to perform global optimization tasks or help improve the operation of large distributed system by performing supervising tasks for different applications. MonALISA is currently running around the clock monitoring several Grids and distributed applications on approximately 150 sites.

The core of the MonALISA monitoring service is based on a modular system design used to perform the data collection tasks in parallel, independently. The modules used for collecting different sets of information, or interfacing with other monitoring tools, are dynamically loaded and executed in independent threads. In order to reduce the load on systems running MonALISA, a dynamic pool of threads is created once, and the threads are then reused when a task assigned to a thread is completed. This allows one to run concurrently and independently a large number of monitoring modules, and to dynamically adapt to the load and the response time of the components in the system. If a monitoring task fails or hangs due to I/O errors, the other tasks are not delayed or disrupted, since they are executing in other, independent threads. A dedicated control thread is used to properly stop the threads in case of I/O errors, and to reschedule those tasks that have not been successfully completed. A priority queue is used for the tasks that need to be performed periodically.

A schematic view of this mechanism of collecting data is shown in Figure 2. This approach makes it relatively easy to monitor a large number of heterogeneous nodes with different response times, and at the same time to handle monitored units that are not responding without affecting other measurements. The clients, other services or agents can get any real-time or historical data by using a predicate mechanism for requesting or subscribing to selected measured values. These predicates are based on regular expressions to match the attribute description of the measured values a client is interested in. They may also be used to impose additional conditions or constraints for selecting the values. In case of requests for historical data, the predicates are used to generate SQL queries to the local database. The subscription requests create a dedicated thread, to serve each client. This thread performs a matching test for all the predicates submitted by a client with the measured values in the data flow. The same thread is responsible to send the selected results back to the client as compressed serialized objects. Having an independent thread per client allows sending the information they need, in a fast and reliable way, and it is not affected by communication errors which may be occurring at other clients. In case of communication problems these threads will try to reestablish the connection or to clean up the subscriptions for a client or a service that is no longer active.

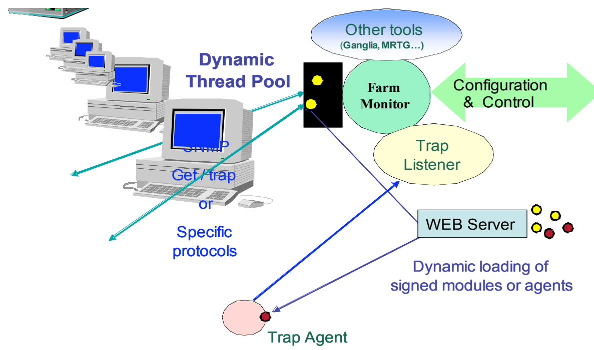

Figure 2: A schematic view of the MonALISA data collection mechanism based on a multi-threaded engine.

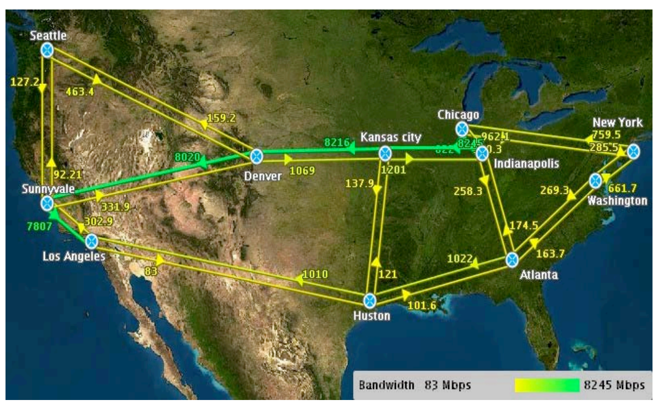

Figure 3: The MonALISA monitoring service for Abilene, shown at a time we injected more than 8 Gigabits/sec.

Figure 3 is a snapshot of the MonALISA monitoring network for Abilene network of the Internet2. It shows all the active nodes running MonALISA services for this particular "farm", discovered automatically by a graphical MonALISA client. The client can display the real time global views and connectivity, as well as the usage and load of the farms. In this particular instance we captured a highly intensive data transfer event on June 19th, 2004 where a group of 12 disk servers in CERN concurrently sent TCP traffic via LHCNet and Abilene to their destinations in Caltech. Note that in this case MonALISA reported a throughput reaching 8.4 Gbps on the Abilene links from Chicago □Kansas City □Denver □Sunnyvale □Los Angeles.

A salient feature of the MonALISA design is its extensibility. It allows user-defined monitoring modules, specific to user-specified system and network information, to be easily implemented and integrated in the MonALISA framework. This facilitates the work reported in this paper, as well as our ongoing project to integrate NLANR PMA[5] real-time packet trace analysis and MonALISA. From a systems point of view, MonALISA provides scalable architectural support for collecting, visualizing and responding to the operating conditions of large-scale distributed systems, and it is especially suited for monitoring and controlling large computing systems and networks used in Grid applications.

ApMon[4] is an Application Programming Interface that facilitates user-specific applications to interact with the MonALISA services. ApMon allows any application to send parameterized monitoring information to MonALISA. The data can be sent as UDP packets to multiple hosts running the MonALISA service.

Through the use of ApMon MonALISA services can receive parameterized data in (name, type, value) tuples. When transmitting a data point to MonALISA the application specifies the name of the parameter about to be sent, the type of the parameter (string, object, integer, double) and the actual value of the parameter. For our implementation we decided to use a 64 bit real number as the type for all of our data transmissions with ApMon. This type is represented in ApMon by the constant `ApMonConst::XDR_REAL64()`. The ApMon module on the MonALISA service will then receive this data and create any needed fields on its database for new parameters or populate existing fields if a particular parameter name already exists.

The resulting data stored in MonALISA is a set of parameters and the values of those parameters over time. MonALISA then provides an interface by which to view one or multiple parameters in a real-time or historical graph.

5. Integrating MonALISA and FlowTools via ApMon

NetFlow allows for the monitoring of a large number of parameters. For this project we decided to limit the parameters monitor to the following:

- UDP/TCP port destination/source traffic
- IP destination/source traffic
- IP protocol traffic
- IP Next Hop traffic
- AS destination/source traffic
- Prefix destination/source traffic

For most of these parameters we will be monitoring that total traffic in octets over a period of time. The initial period of time was 5 minutes. In the flow-capture startup script above the parameter n288 indicates that we want flow-capture to generate 288 files per day which results in a new file generated very 5 minutes.

Our application will use the most recent file to retrieve the desired parameters. This will result in parameterized NetFlow data being retrieved by our application reflecting 5-minute averages for each of the monitored parameters. Hence the value of each parameter will represent the total number of octets associated with that particular parameter over a 5-minute period. We will use flow-stat to collect all of the parameters specified above. Below is a sample output using flow-stat. As we can see for this particular 5-minute interval the HTTP port (80) was most heavily used at 11274635 octets roughly 10.75 MB.

```
$ flow-cat ft-v05.2005-01-19.135207-0500 | flow-stat -f 5 -S 2
#  --- ---- ---- Report Information --- --- ---
#
# Fields:    Total
# Symbols:   Disabled
# Sorting:   Descending Field 2
# Name:      UDP/TCP destination port
#
# Args:      flow-stat -f 5 -S 2
#
#
# port      flows                 octets                 packets
```

```
#
80          42816        11274635      82997
25          2877         3770113       7623
2010        28           2543195       1747
4662        2095         2290946       3770
2009        28           2091493       1413
```

The application written will parse the flow-stat report and generate a name/value pair which will be sent to MonaLISA via ApMON. This name will be one of the following: (1) a port number or name; (2) an IP address; (3) a protocol number or name; (4) an AS number; (5) a Prefix.

The value of the parameter will always be the total number of reported octets for that parameter. This will generate a large number of parameters which is difficult to visualize. ApMon provides the ability to classify the parameters submitted to MonALISA by specifying a cluster and a nodename along with the parameter name/value pairs. A cluster is a group containing a list of nodenames. Each nodename is a group containing a list of parameters. When submitting data to MonALISA we will define each router interface as a cluster and the description of the parameters being measured as a nodename within that cluster. For example the "NWS Internet2" interface in the Juniper router will be consider a cluster (named Juniptер □ NWS Internet2) and it will contain the following nodenames: "Egress Destination IP", "Egress Destination AS", "Egress Source Ports UDP/TCP", etc. Each nodename will contain the actual parameter name/value pairs. In order to give the user the flexibility to specify what values to monitor and how to classify them in MonALISA a configuration files was create for our application. Below is a description of the allowed settings in the configuration file.

Setting Name	Description	Example
cluster_name:	The description of the interface	GSR-StarLight VLAN
node_name:	The description of the parameter being monitored	Ingress Destination Ports
flow_file_directory:	Path to the directory containing the NetFlow files	/home/netflow/flows/gsr/
flow_stat_options:	Options passed directly to flow-stat	-f 5 □S 2 □n
flow_filter_options:	Options passed directly to flow-filter	-i 60
value_param:	The column number from the flow-stat report which will be used as the value for the parameter. Where the first column number is 0.	2
max_params:	The maximum number of name/value pairs which will be processes and transmitted to MonALISA for this nodename.	15
Next	End of the nodename's configuration.	

Our application would parse this information and generate the following report:

```
$flow-cat ft-v05.2005-01-19.224516-0500 | flow-filter -i 60 | flow-stat
-f 5 -S 2 -n
#  --- ---- ---- Report Information --- --- ---
#
# Fields:    Total
# Symbols:   Enabled
# Sorting:   Descending Field 2
# Name:      UDP/TCP destination port
#
# Args:      flow-stat -f 5 -S 2 -n
#
#
```

```
# port      flows        octets       packets
#
57893       1            913876       1106
32808       1            730500       487
6881        52           210301       283
32920       1            151132       101
32918       1            85132        57
1144        3            84854        61
http        39           68171        106
1279        1            67500        45
eDonkey-20  67           64742        107
3113        2            63044        49
33498       3            58552        40
```

The application will parse the generated report and retrieve the parameters name and values as specified in the configuration. For this example the parameter names will be the port numbers and the values will be the octets as specified by the configuration file (value_param:2). The following data would then be sent to MonALISA:

Cluster	Nodename	Parameter Name	Parameter Value
GSR-StartLight VLAN	Ingress Destination Ports	57893	913876
GSR-StartLight VLAN	Ingress Destination Ports	32808	151132
...	...	...	...
GSR-StartLight VLAN	Ingress Destination Ports	http	68171
...	...	...	...

6. Case Study– Monitoring Peer Traffic

In this section we demonstrate the use of our monitoring system in practice. We choose to examine a peer, the NWS Internet2 Gigabit Ethernet link that carries all HPC traffic to and from New World Symphony (NWS), a post-doctorate institution at Miami Beach that has AMPATH be its upstream provider of Internet2 traffic as well as commodity internet.

Once monALISA starts[4] the screen presented in Figure 4 is a global view of all running sites / farms. With a properly established working group under MonALISA we choose a more detailed view from the left menu shown in Figure 5. The "TabPan" view gives detailed information about the monALISA farm but also serves as the starting point to access parameters that are unique to the site.

[4] This requires Java to be installed.

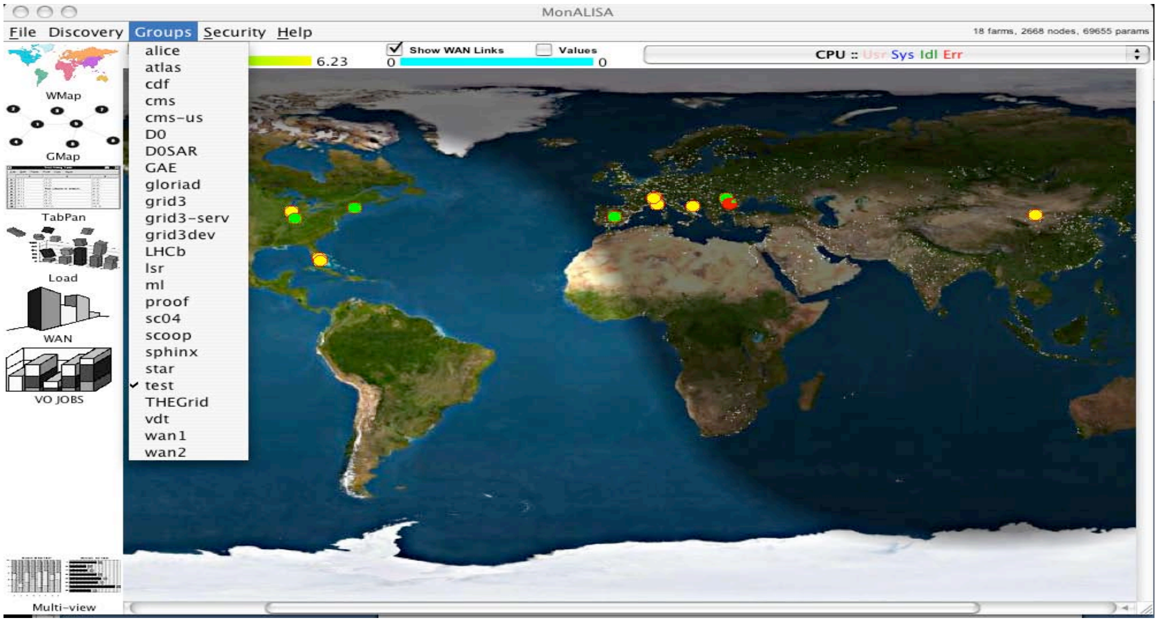

Figure 4 - MonALISA startup screen with 'test' group defined.

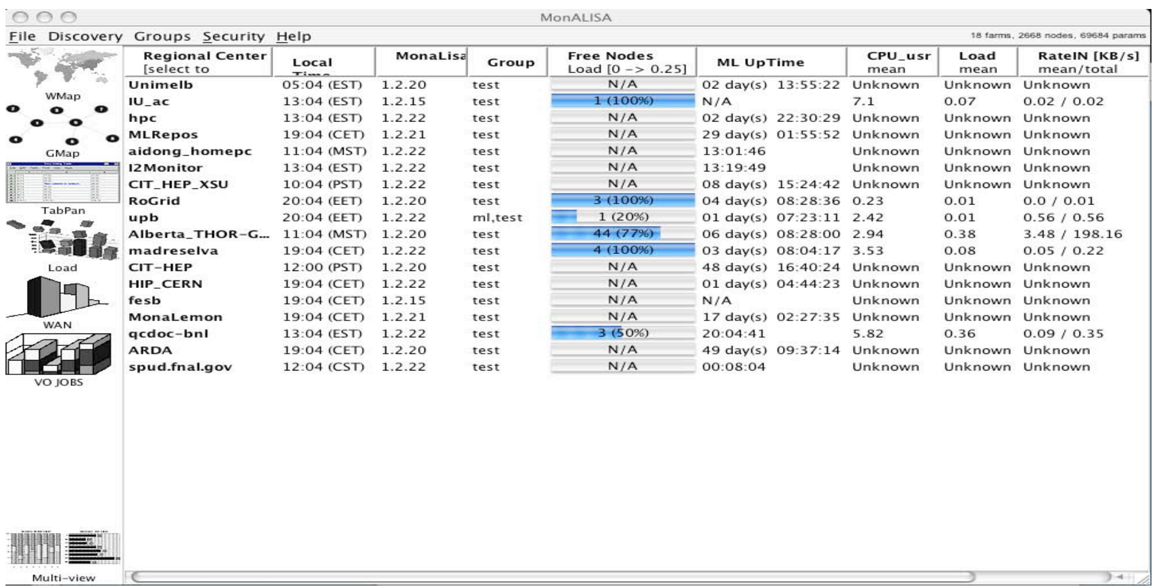

Figure 5 - MonALISA farm overview: note the MonALISA service I2Monitor that we started

In Figure 5 we are presented with a snapshot of the current state of the MonALISA group "test". The MonALISA service that pertains to our particular study is titled I2Monitor. Choosing the I2Monitor farm, we are then presented with the AMPATH specific data which we have chosen to integrate into our analysis, as shown in Figure 6.

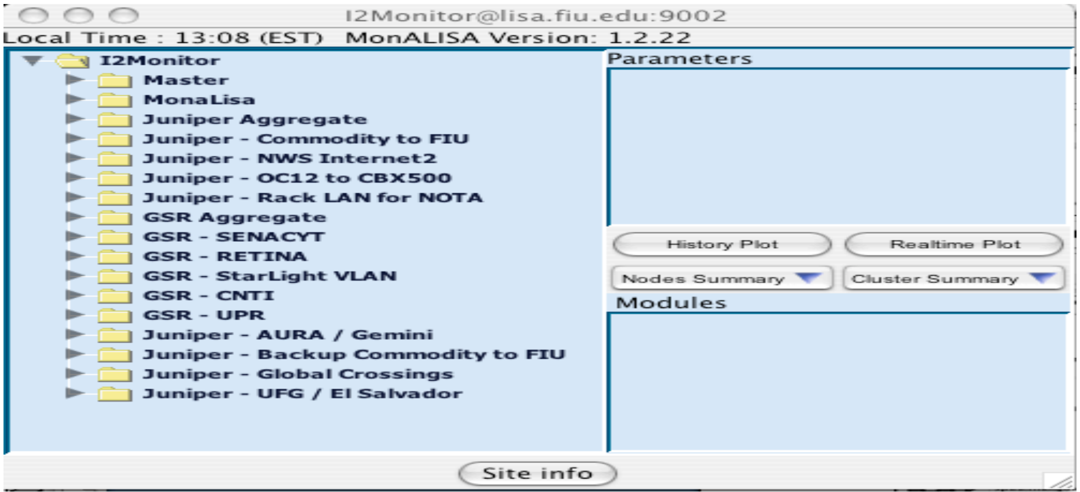

Figure 6 □ AMPATH Farm specific data

It is evident which parameters we have specified to be monitored. Two core routers (a Cisco GSR and a Juniper M10) are monitored. As an example we will analyze the Juniper □ NWS Internet2, as shown in Figure 7.

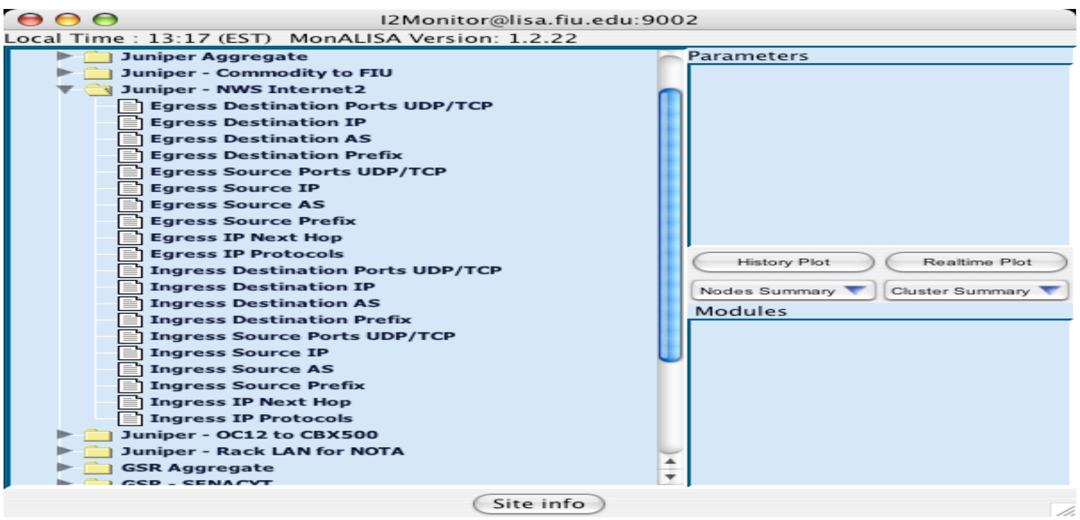

Figure 7 - Traffic parameters studied in this paper

In Figure 8 by choosing Egress Source AS we view the current set of stored AS numbers belonging to flows leaving our Juniper router and destined to the New World Symphony network. With the “Parameters” corresponding to the AS numbers traversing our router destined to NWS we have a clear top-level view of flows of the network, and we can delve deeper into this data by showing a realtime plot or history plot of the AS data gathered. This is given in Figure 9.

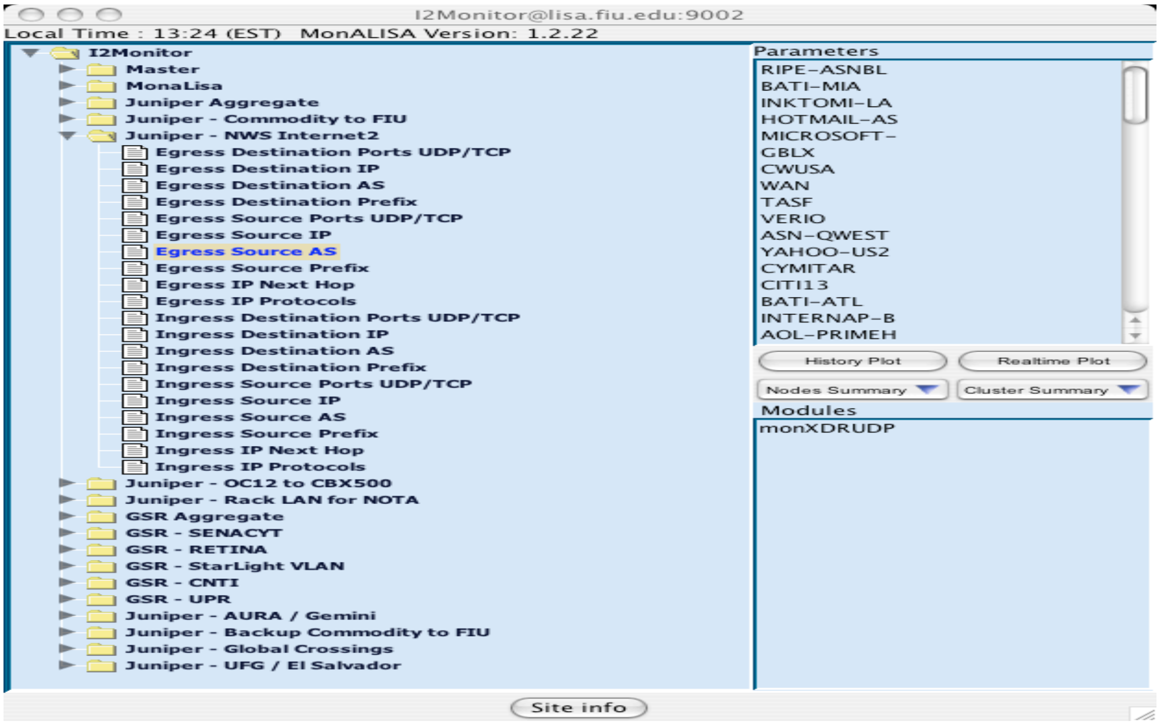

Figure 8 - ASNs traversing AMPATH towards NWS

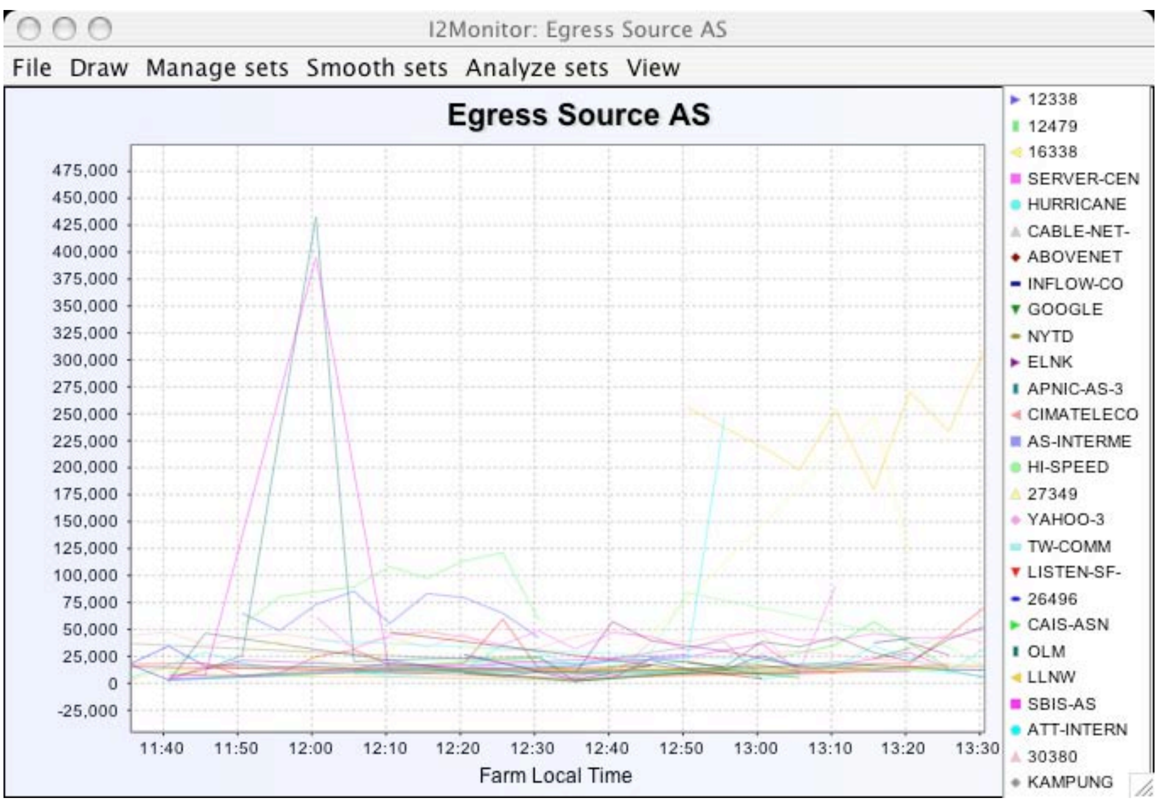

Figure 9 - ASN traffic destined to NWS

In Figure 10 we show the protocols of the traffic traversing the GSR router, the main provider of Internet2 to AMPATH IXP peers. We now drill down through the GSR Aggregate data to show the IP Protocols currently being recorded by the NetFlow process on the router. A historical look can show the recent or long-term utilization of IPv6; and we can visualize it by means of a history plot in Figure 11. We can quickly note that IPv6 data has not been a significant load on AMPATH during the time period specified.

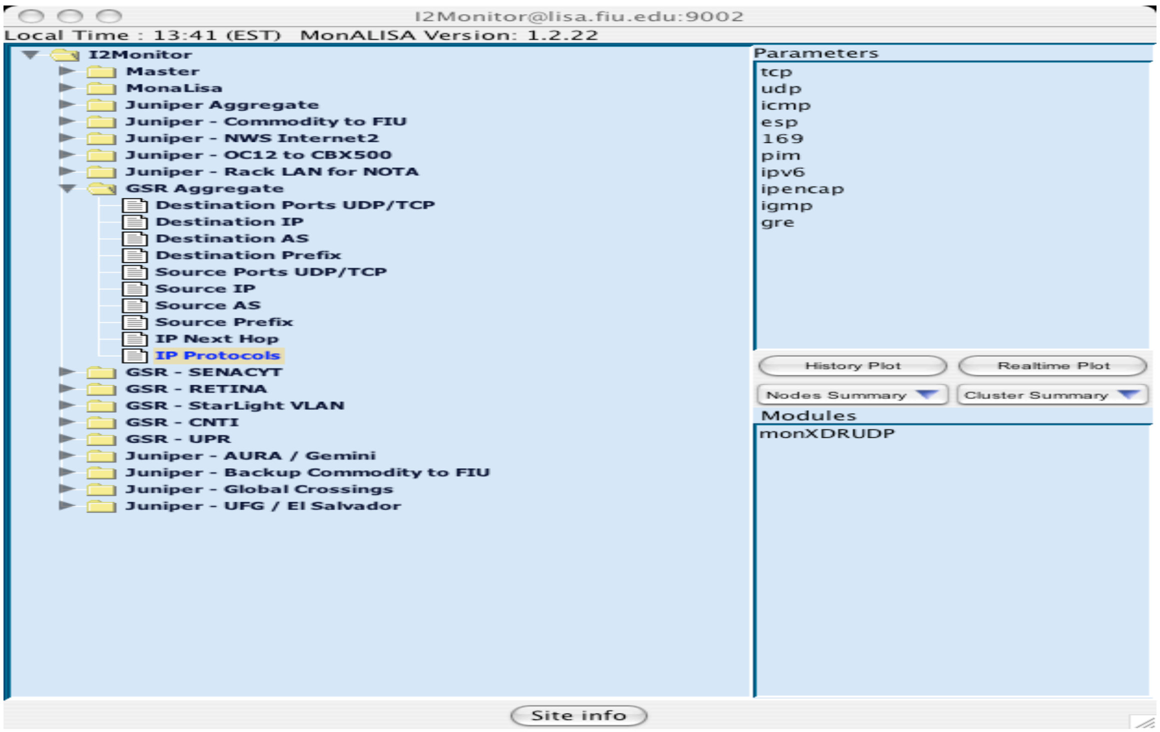

Figure 10 - Router Aggregate NetFlow data

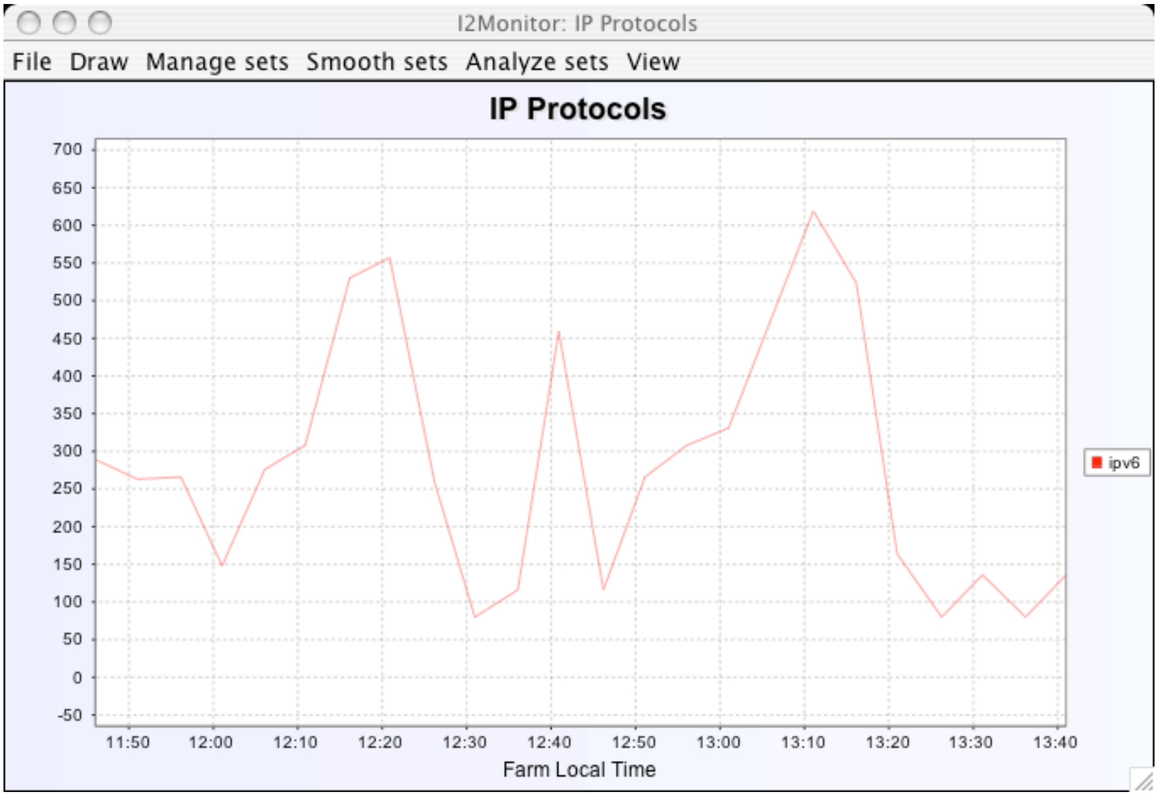

Figure 11 □ Two-hour snapshot of IPv6 data traversing AMPATH

8. Discussions and Future works

NetFlow data contains a rich amount of network information with a multitude of applications. Through the use of the distributed monitoring environment provided by MonALISA and the reporting flexibility embedded in the FlowTools API it is possible to encapsulate and summary this data in visually friendly manner. In doing saw were able to create dynamic and real time views of the AMPATH Internet 2 network traffic and its behaviors. Direct application of this technology could be used to further understand network traffic behavior and trends in complex research networks.

The traffic views generated by MonALISA and the NetFlow application focused on the "top talking" flows. That is MonALISA only received the top x talking flows for a particular period of time. We saw that this technique produced a seemingly random setup of results. Further study should be made to understand this trend and determine its inherent properties.

One further technology that we intended to explore was that of the National Laboratory for Applied Network Research (NLANR) PMA (Passive Monitoring Agent) [5]. There are key differences between PMA data and NetFlow data worthy of serious research effort. With our results we hope to provide a stable platform from which networks of varying degrees can be closely monitored, their traffic patterns clearly identified and the appropriate decisions taken to rectify issues which negatively impact performance or augment those which have a positive impact on the delivery of service to an end user.

References:

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