



# IPv6 in Internet2

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## General Internet2 Infrastructure

- Internet2 Goals
- Abilene Partners
- Abilene Backbone
- Connectors
- Peers
- Focus

## IPv6 Deployment

- Goals
- History
- Current Status
- Issues
- Applications
- Future

# Internet2 Goals

- ✍ Create a leading edge network capability for the national research community
- ✍ Enable revolutionary Internet applications
- ✍ Ensure the rapid transfer of new network services and applications to the broader Internet community.

# Abilene Network

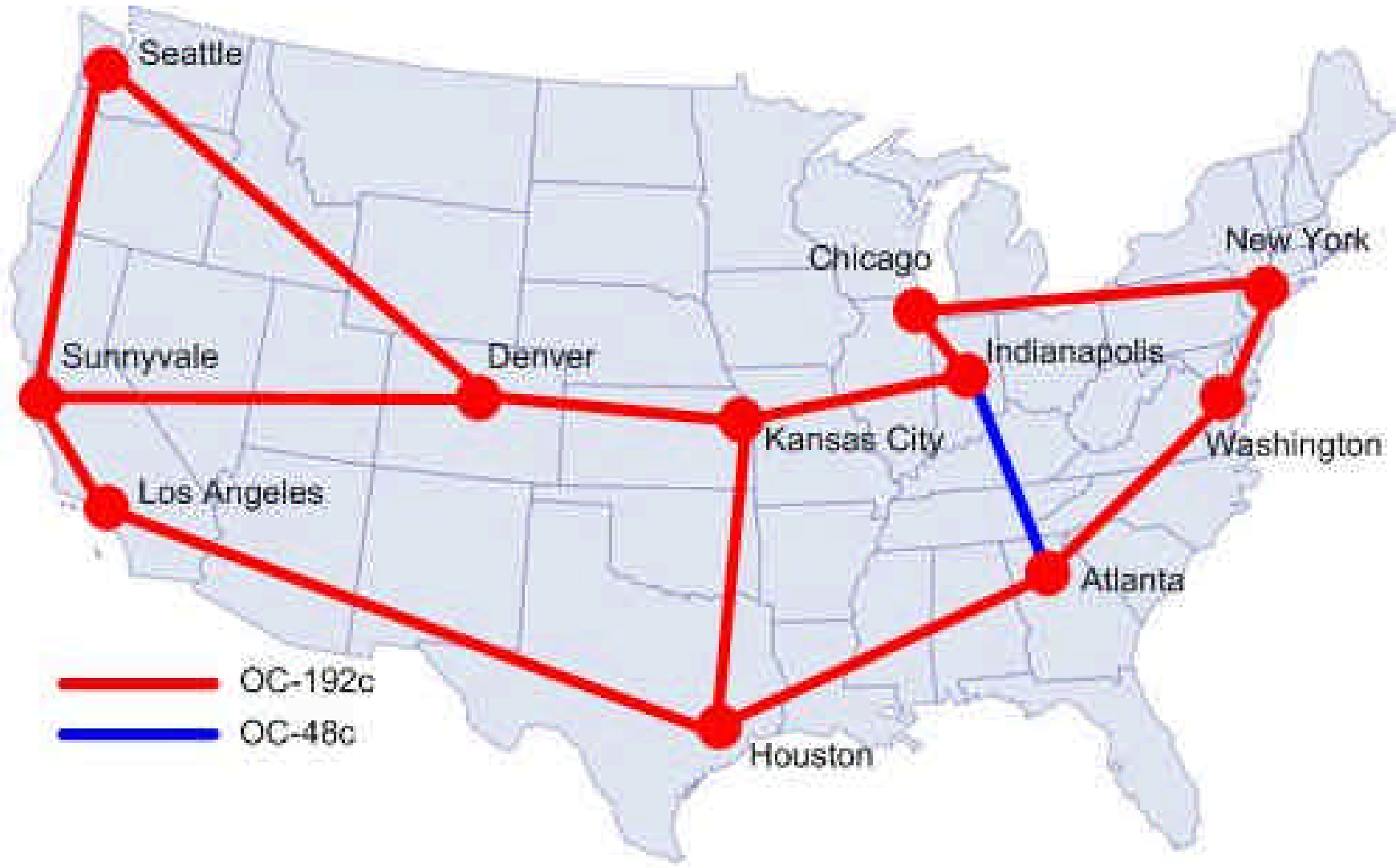
Abilene is a high-performance network developed in partnership with

- Cisco Systems
- Indiana University
- Juniper Networks
- Nortel Networks
- Qwest Communications
- North Carolina, Ohio, San Diego ITECs

# Abilene Backbone

- ✍ Abilene backbone – OC-192c over unprotected DWDM waves with SONET framing
- ✍ Upgrade to OC-192c completed
- ✍ Often easier to deploy advanced services on a backbone network than at the edges
  - Multicast
  - IPv6

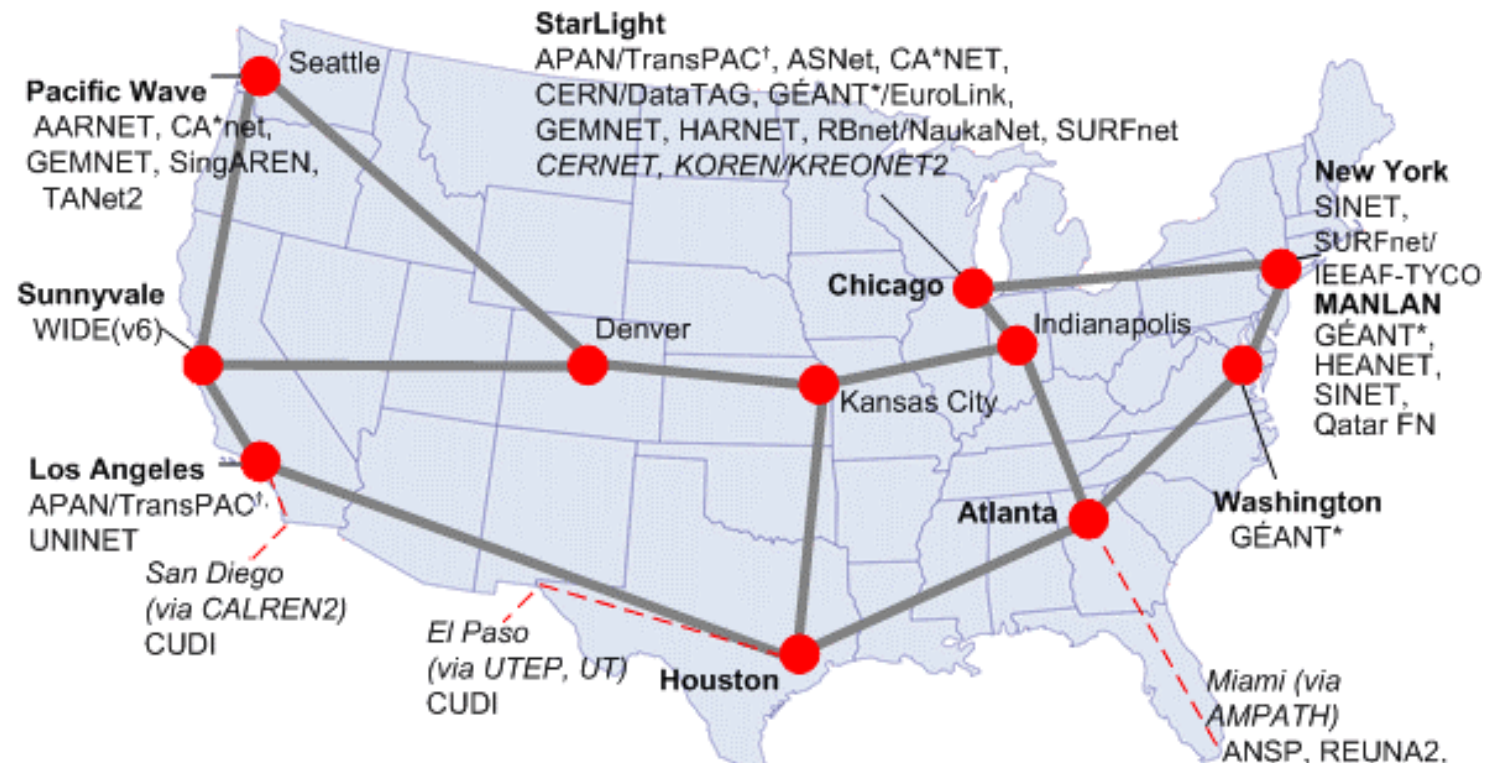
# Abilene Backbone





# Abilene International Peering

## Abilene International Network Peers



<sup>\*</sup> via GEANT: AConet, BELNET, CARNet, CESNET, CYNET, Forskningsnettet, EENet, Funet, Renater, G-WIN, GRNET, HUNGARNET, Rhnet, HEAnet, IUCC, GARR, LANET, LITNET, RESTENA, Univ. Malta, SURFnet, UNINETT, POL34, RCTS2, RoEduNet, RBnet, SANET, ARNES, RedIRIS, SUNET, SWITCH, JANET, ULAKBYM, CERN

<sup>†</sup> via APAN/TransPAC: WIDE/JGN, IMnet, CERNet/CSTnet/NSFCNET, KOREN/KREONET2, PREGINET, SingAREN, TANET2, ThaiSARN



# Abilene Federal/Research Peering

## Abilene Federal/Research Network Peers



# Abilene Scale

February 2004

✍ IP-over-DWDM (OC-192c) and IP-over-SONET  
OC-48c Backbone

✍ 49 Connectors (OC-3c ? 10 GigE)

- 2 10 GigE connections
- 6 OC-48c
- 24 OC-12c or higher

✍ 240 participants – research universities & labs

- All 50 states, District of Columbia, & Puerto Rico
- Aggregation on the rise!

✍ Expanded access

- 92 sponsored participants, expected to increase
- 30 State networks, expected to increase

# Internet2 Infrastructure

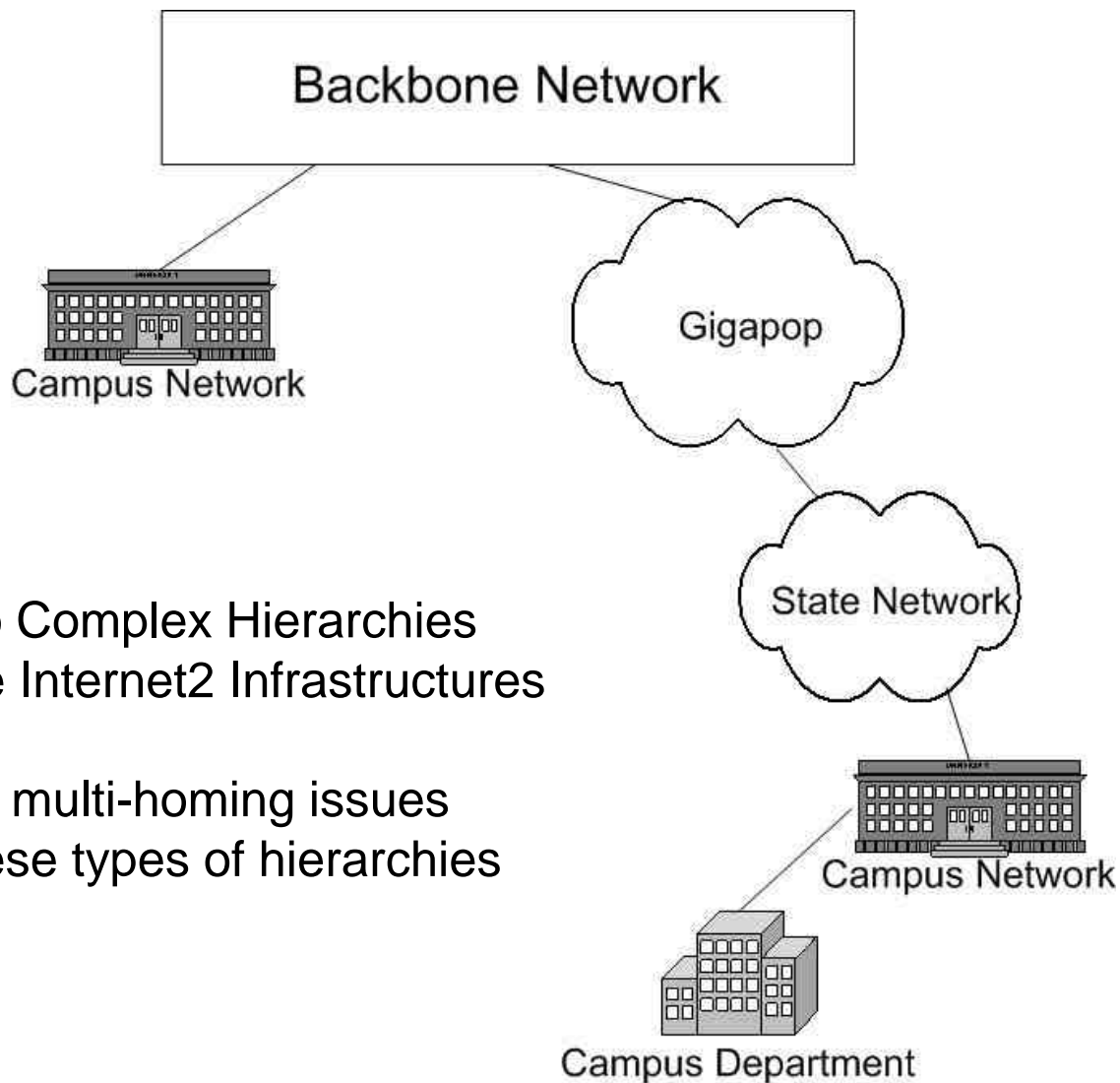
 The full Internet2 infrastructure is diverse and complex

- Backbone is relatively simple
  - Management provided by Indiana Global NOC
  - Testing by Internet2 Test and Evaluation Centers (ITECs)
- Connectors often exhibit a complicated hierarchy
  - Some research institutions connected directly
  - Some are connected through regional networks, state networks, and some have complex campus networks
  - Land Grant institutions often have county extension offices
  - Diversity/Complexity increases as one gets closer to the edges of the network

 Influences the way IPv6 is implemented

- Consider the classic IPv6 addressing/routing plan, with potentially multiple connections, in this diverse infrastructure

# Internet2 Infrastructure



Simple to Complex Hierarchies  
within the Internet2 Infrastructures

DNS and multi-homing issues  
within these types of hierarchies

# Abilene Focus Areas

## Advanced Services

- IPv6 and Multicast (and IPv6 Multicast)
- All the following include both IPv4 and IPv6 – the common bearer service for Abilene is both IPv4 and IPv6

## Facilitating end-to-end performance

## Supporting network research – Abilene Observatory

## Experimenting with MPLS/VPN on backbone

## Supporting large MTUs

## Security and the REN-ISAC

# Internet2 IPv6 Goals

✍ Support and encourage development of advanced applications using IPv6

✍ Create a national infrastructure to support IPv6 for the Research and Education Community

- Implement IPv6 on Abilene Backbone
- Encourage deployment of IPv6 throughout the Internet2 infrastructure
- Support end-2-end transparency for IPv6 advanced applications
  - Important issue for high performance applications
  - High performance applications often have trouble with NATs
  - Provide a more robust infrastructure to provide security

✍ Educating the Internet2 IPv6 user base

✍ Support interconnectivity and transit during the initial stages of IPv6 deployment

- Actively looking for peers – commodity and research and education peers

# Abilene IPv6 History

- ✍ Substantial input from the Internet2 IPv6 working group
- ✍ Tunnel network deployed 2001
  - First IPv6 tutorial at Lincoln, Nebraska joint-techs meeting in May 2001
- ✍ Migration to native, dual stack implementation at end of 2001
  - Before upgrade began
  - Using Cisco GSR routers
  - Began migration of connectors
- ✍ Native dual stack was default for Abilene upgrade
- ✍ Early testing
  - 8 gig tests from Sunnyvale to Washington DC
  - IPv4, IPv6, and mixed IPv4/IPv6
  - No distinguishable difference in performance

# Current IPv6 Status

## Backbone unicast enabled

- Routing – BGP and IS-IS
- Experimenting with IPv6 multicast as standards and technology evolve

## Connectors and Peers

- Significant number of peers and connectors now have connections, almost all native:
  - 26 connectors
  - 19 international peers
  - 4 research/federal peers
- See <http://abilene.internet2.edu/observatory/connection-technologies.html>
- See <http://www.abilene.iu.edu/images/v6.pdf>

# Current Status

## Campus penetration

- More than 24 member campuses with native connections
- More than 10 member campuses with tunneled connections

## One live 6to4 relay, two more coming


## Significant experimentation and support effort

- Abilene Observatory and IPv6
- DNS experiments, IPv6 transport servers
- Tutorials at the GigaPoP or University level

# Current Status

## Addressing Plan

- Currently have /32, originally was a /35
- Allocate a /40 to a GigaPoP or a /48 to a university
  - Some GigaPoPs have 12 member universities and had to allocate their /40 to those universities plus state networks
- Universities immediately felt constrained by this
  - Some universities have locations in potentially 200 counties within a state (i.e. Land Grant Institutions)

 WiscREN and Pittsburgh gigapops have obtained their own space

 Some universities attempting to obtain space

- could satisfy current ARIN guidelines

## Provisioning an IPv6 Measurement Infrastructure

- Attempting to perform measurements using IPv4 and IPv6
- Need implemented MIBs for basic measurements via SNMP
- Types of data collected
  - One way latency tests
  - Throughput measurements
  - Netflow measurements
  - Routing
  - End-2-end performance testing

# Deployment Issues

✍ Some campuses unable to deploy IPv6 due to lack of support for IPv6 in router and switch production software code

- Reluctance to upgrade stable code

✍ Most standard public software now IPv6 enabled

- Examples include sendmail, apache, news, etc.
  - Reluctance to upgrade stable servers to new versions
- For software that is IPv6 enabled, the use of IPv4/IPv6 is almost always transparent. It just works!

✍ Some software is not available yet

- Moonv6 tests are very valuable – what is ready, and what is not.

# Deployment Issues

## Applications

- Many applications currently available
- Some reluctance to deploy for fear of breaking v4 availability – gradually decreasing
  - Need to educate server administrators
- Considering a review process for application deployment. For example,
  - Web servers
  - DNS servers
  - Mail servers
- Many new applications to come
- Ability to run IPv6 only machines

# Deployment Issues

 Many monitoring tools are missing, impacting security

- For example, full support for basic IPv6 mib, limiting ability to monitor usage easily.
- IPv6 flow analysis is missing on Abilene routers
  - It is difficult to debug DoS attacks, for example
- Must encourage vendors to support standard tools

# Deployment Issues


## ✍ Addressing and routing – multi-homing


- Abilene currently has a /32, allocates /40 prefixes to large connectors, /48 prefixes to universities
- The classic model for IPv6 is PA addressing, to contain the size/stability of the global routing table – potentially very large if using PI addressing.
- Recall the complicated hierarchy within our infrastructure
- Within the next 6 months, we expect member institutions to inherit multiple prefixes, potentially from 2 or more research networks and 2 or more commodity networks
- Policy requirements complicate the multi-homing problem

# IPv6 Everywhere by 2006?

 Is it realistic that by 2006, these issues will be resolved?

- We believe the answer is “yes”, and need to encourage support from vendors and research and education networks!

 Note that dual-stack IPv4/IPv6 architectures are likely to endure for a long time after IPv6 deployment

 There is significant activity on the international scene to deploy IPv6 networks, and some may be IPv6 only.

- Deployment will likely continue world wide and reach a point where it is crucial to be IPv6 enabled.

# Internet2 Commitment

- ✍ Internet2 is committed to deploying an IPv6 native dual stack network for the research community.
- ✍ Internet2 is committed to encouraging connectors, peers, and members to fully deploy IPv6 on their networks by 2006.
- ✍ Internet2 will monitor IPv6 penetration in the future to provide guidance to the community.
  - Network penetration.
  - Availability of software and tools
  - Security Issues
  - Create future web page outlining the deployment

# Support for IPv6

## Tutorials

- Two day workshops, hands-on experience
- Descriptions and planning guides
  - <http://ipv6.internet2.edu/workshops/index.shtml>
- Alternate discussion/lecture with hands-on work
- Slides are available and open for use by Internet2 members and affiliated organizations
  - <http://ipv6.internet2.edu/presentations/>
- Very popular events

# Support for IPv6

## Topics

- Addressing
- Allocation Schemes
- Router Configuration
- Basic Functionality
- Multi-homing
- Provider Independent Addressing
- Provider Independent Addressing Lab
- Under the Hood
- Stateless Autoconfiguration
- Neighbor Solicitation
- Transition and Tunnels
- **Multicast IPv6**
- DNS
- Unix Hosts
- Microsoft Windows
- DVTS
- ISIS
- GigaPoP Implementations

# Internet2 IPv6 Deployment Issues

## References

- <http://www.internet2.edu>
- <http://abilene.internet2.edu>
- <http://ipv6.internet2.edu>

## Questions?

- [abilene@internet2.edu](mailto:abilene@internet2.edu)

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