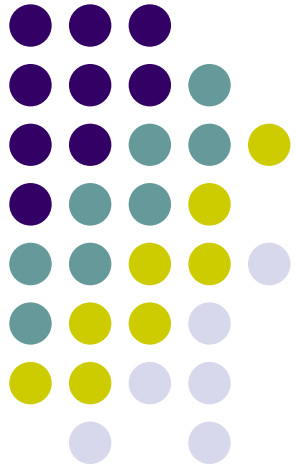
IPv6: A campus experience



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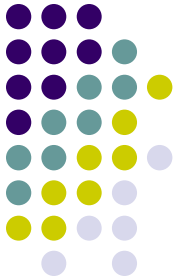
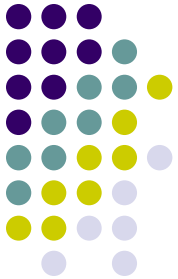
European IPv6 Task Force

Deployment steps



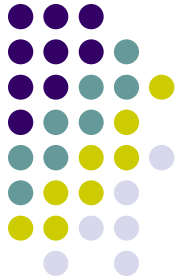
- These are likely to include:
  - Understanding your rationale for deployment
  - Obtaining connectivity
  - Obtaining IPv6 address space
  - Deploying basic services, with basic security
  - Deploying IPv6 widely intra-site
  - Enabling other services and applications
  - Supporting remote IPv6 access
  - Offering new IPv6-specific services

Also contributing to IETF



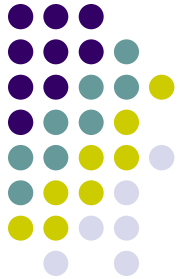
- Specific transition work for enterprise:
  - draft-ietf-v6ops-ent-scenarios-05
  - draft-ietf-v6ops-ent-analysis-00
  - draft-chown-v6ops-campus-transition-01
  - draft-chown-v6ops-vlan-usage-02
- And some issues arising as we deploy:
  - draft-ietf-dhc-dual-stack-02
  - draft-ietf-dhc-stateless-dhcpv6-renumbering-02
  - draft-ietf-dhc-lifetime-02
  - draft-chown-v6ops-renumber-thinkabout-00
  - draft-vandevelde-v6ops-nap-00

Deployment philosophy



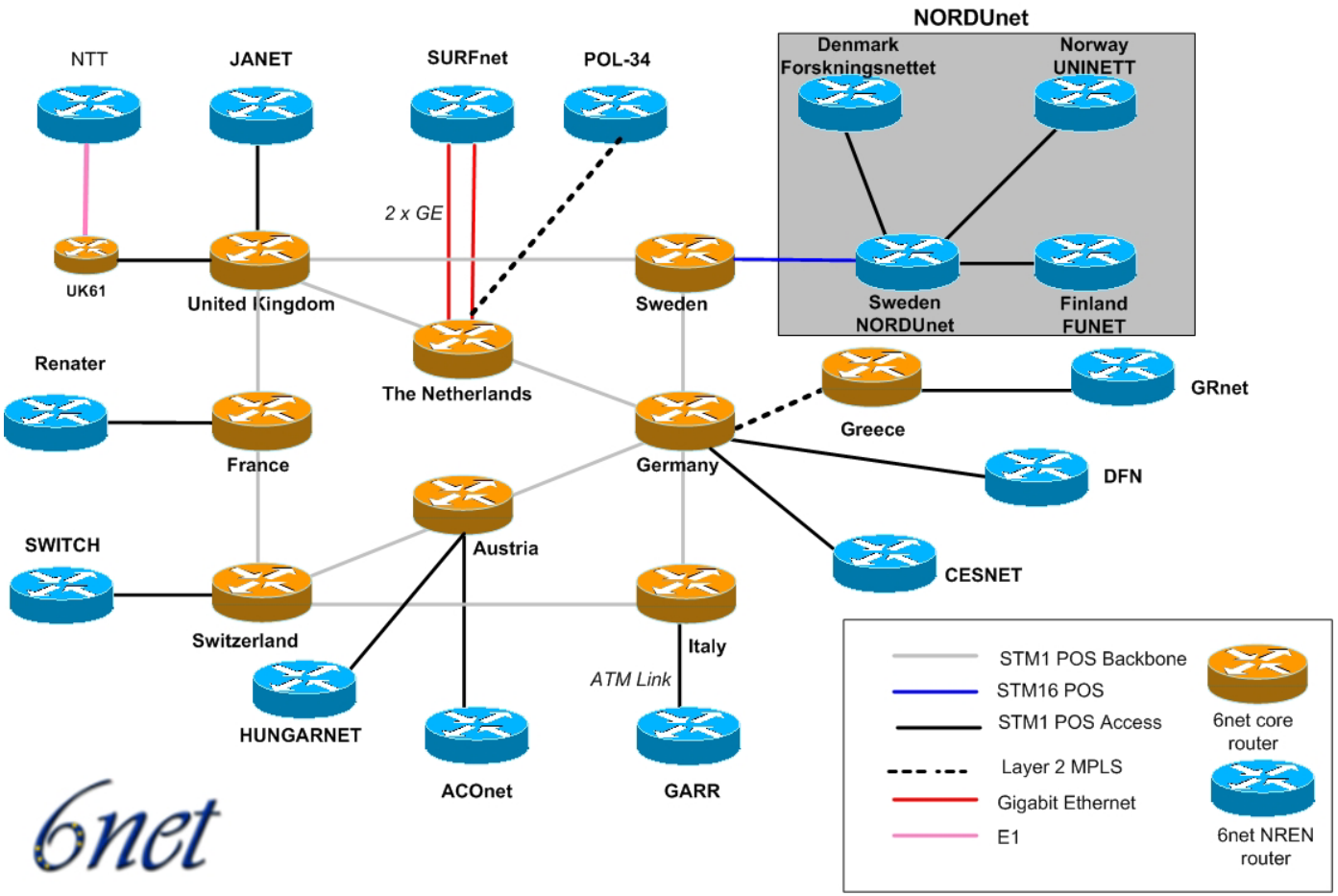
- Our deployment is one (the largest) department on campus
  - Over 1,000 active nodes, 1,500 users
  - IPv4 subnets from /28 to /23 in size (a problem in itself)
- Goal is to enable IPv6 services
  - For teaching, research and production use
  - Support dual-stack operation pervasively
  - Mixed IPv4-IPv6 environment for many years
  - Enable IPv6-only nodes to be deployed early
  - Enable IPv6-only links to be deployed early
  - Support new IPv6 services early (MIPv6)

Academic IPv6 networking

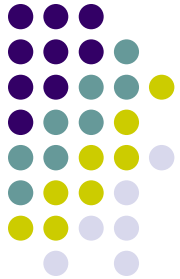


- IPv6 supported dual stack by European NRENs and inter-NREN backbone provider (GEANT)
  - A similar service exists in the US on Abilene
  - See: http://www.global-ipv6.net/
- The UK academic network JANET is dual-stack
  - Regional networks are beginning to migrate
  - For topology info see: http://www.ja.net/topology/
  - Our regional network (LeNSE) has deployed (Cisco) 6PE
  - IPv6 presented to us natively on campus as GigE
- Challenge is now deployment into campuses

6NET


NORDUnet
NTT
JANET
SURFnet
POL-34
Denmark
Forskningsnettet
Norway
UNINETT
2 x GE
UK61
United Kingdom
Sweden
Sweden
NORDUnet
Finland
FUNET
Renater
The Netherlands
GRnet
Greece
France
Germany
DFN
Austria
SWITCH
CESNET
Switzerland
Italy
ATM Link
HUNGARNET
ACOnet
GARR
6net
STM1 POS Backbone
STM16 POS
STM1 POS Access
Layer 2 MPLS
Gigabit Ethernet
E1
6net core router
6net NREN router

Reliable IPv6 connectivity



- Need a reliable IPv6 infrastructure worldwide that performs as good as IPv4 does today
  - Otherwise people will not use IPv6 applications, if they respond more slowly, or IPv6 times out completely
- Overall:
  - Picture is good in the academic networking scope
  - Less good in the “commercial” area
  - Not enough native IPv6 transit providers (yet)
  - Part of the problem is the old 6bone Gordian Knot of tunnels
  - 6bone being deprecated by 06/06/06

IPv4 vs IPv6, .ac.uk - here

$ traceroute login.ecs.soton.ac.uk

```
traceroute to login.ecs.soton.ac.uk (152.78.68.162), 30 hops max, 40 byte packets
 1  10.10.20.1 (10.10.20.1)  58.699 ms  13.793 ms  6.003 ms
 2  129.174.224.1 (129.174.224.1)  46.866 ms *  5.096 ms
 3  129.174.248.217 (129.174.248.217)  5.444 ms  5.834 ms  5.605 ms
 4  129.174.248.65 (129.174.248.65)  8.128 ms  6.132 ms  5.427 ms
 5  10.174.248.69 (10.174.248.69)  5.283 ms  9.029 ms  5.39 ms
 6  206.197.101.66 (206.197.101.66)  12.046 ms  8.711 ms  8.748 ms
 7  192.70.138.22 (192.70.138.22)  9.714 ms  9.198 ms  7.643 ms
 8  abilene-rtr.maxgigapop.net (206.196.177.2)  9.393 ms  43.669 ms  8.384 ms
 9  abilene.de2.de.geant.net (62.40.103.253)  131.139 ms  108.293 ms  138.888 ms
10  * de2-2.de1.de.geant.net (62.40.96.54)  111.632 ms  102.45 ms
11  de.nl1.nl.geant.net (62.40.96.102)  124.947 ms  122.05 ms  124.409 ms
12  nl.uk1.uk.geant.net (62.40.96.182)  101.816 ms  99.08 ms  188.765 ms
13  janet-gw.uk1.uk.geant.net (62.40.103.150)  98.865 ms  104.735 ms  99.951 ms
14  po2-2.lond-scr3.ja.net (146.97.35.137)  98.385 ms  103.225 ms  98.21 ms
15  po1-0.lond-scr.ja.net (146.97.33.29)  98.753 ms  106.053 ms  98.601 ms
16  po2-0.cosh-scr.ja.net (146.97.33.42)  102.5 ms  107.84 ms  100.567 ms
17  po0-0.cosham-bar.ja.net (146.97.35.22)  101.466 ms  107.792 ms  109.236 ms
18  146.97.40.2 (146.97.40.2)  104.141 ms  104.273 ms  100.768 ms
19  * * *
20  * * *
21  212.219.151.122 (212.219.151.122)  131.728 ms  107.749 ms  108.845 ms
22  212.219.151.114 (212.219.151.114)  106.788 ms  106.913 ms  110.138 ms
23  b54hafw1-ga2.net.soton.ac.uk (152.78.0.19)  107.462 ms  105.099 ms  106.095 ms
24  b54gagesw1-fwint.net.soton.ac.uk (152.78.109.14)  107.599 ms  107.324 ms  106.172
        ms
25  b54aagesw1-ga.net.soton.ac.uk (152.78.108.61)  105.462 ms  111.106 ms  106.722 ms
26  login.ecs.soton.ac.uk (152.78.68.162)  106.918 ms  106.67 ms  105.911 ms
```

$ traceroute6 login.ecs.soton.ac.uk (from NAv6TF event to UK)

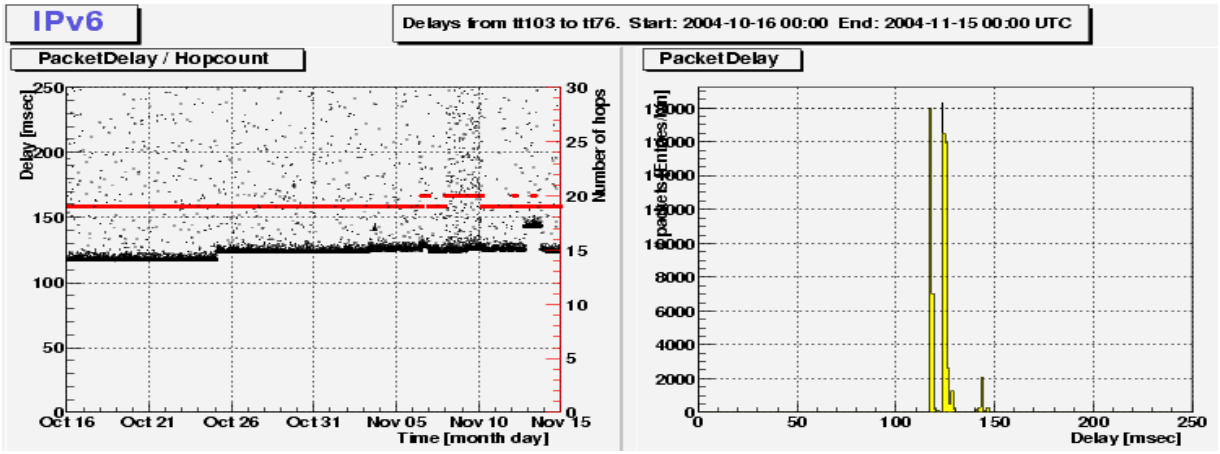
```
traceroute6 to login.ecs.soton.ac.uk (2001:630:d0:115:230:48ff:fe23:58df) from
        2001:418:3ee:2:20a:95ff:fef4:c482, 30 hops max, 12 byte packets
 1  2001:418:3ee:2::45ab  3.197 ms  2.223 ms  2.055 ms
 2  ip-0-2-0-4.r00.asbnva01.us.b6.verio.net  42.459 ms  47.341 ms  71.739 ms
 3  ge-1-1-0-2.r02.asbnva01.us.bb.verio.net  82.51 ms *  67.779 ms
 4  p16-1-0-0.r20.asbnva01.us.bb.verio.net  58.076 ms  63.627 ms p16-0-1-
        2.r21.asbnva01.us.bb.verio.net  61.443 ms
 5  p16-2-0-0.r80.asbnva01.us.bb.verio.net  55.702 ms p16-3-0-
        0.r80.asbnva01.us.bb.verio.net  58.097 ms  64.284 ms
 6  p16-7-1-0.r21.amstnl02.nl.bb.verio.net  150.619 ms  137.768 ms  141.155 ms
 7  p16-7-1-0.r21.londen03.uk.bb.verio.net  154.973 ms xe-6-1-
        0.r20.amstnl02.nl.bb.verio.net  144.494 ms  124.317 ms
 8  xe-6-1-0.r20.londen03.uk.bb.verio.net  131.682 ms  118.022 ms p16-7-1-
        0.r20.londen03.uk.bb.verio.net  120.104 ms
 9  2001:7f8:4::312:1  310.326 ms  373.222 ms  342.303 ms
10  po2-1.lond-scr4.ja.net  343.201 ms  334.975 ms  338.496 ms
11  gi0-2.lond-isr4.ja.net  350.82 ms  345.39 ms  347.91 ms
12  po2-0.cosh-scr.ja.net  331.257 ms  330.518 ms  328.849 ms
13  po0-0.cosham-bar.ja.net  334.36 ms  345.95 ms  336.911 ms
14  lense.site.ja.net  348.169 ms  337.393 ms  334.501 ms
15  * * *
16  2001:630:c1:1::1  347.465 ms  346.381 ms  351.575 ms
17  2001:630:c1:10::2  354.207 ms  343.128 ms  338.038 ms
18  2001:630:c1:100::2  321.959 ms  321.462 ms  329.44 ms
19  internal-router.6core.ecs.soton.ac.uk  323.147 ms  344.415 ms  340.182 ms
20  dent.6core.ecs.soton.ac.uk  332.932 ms  325.366 ms  319.862 ms
21  login.ecs.soton.ac.uk  322.355 ms  323.461 ms *
```

IPv4 vs IPv6, .ac.uk - Internet2

```
$ /usr/sbin/traceroute news.uoregon.edu
traceroute to pith.uoregon.edu (128.223.220.25), 30 hops max, 38 byte packets
 1  servers-router.core.ecs.soton.ac.uk (152.78.68.190)  0.491 ms  0.326 ms  0.315 ms
 2  nokiafw.link (192.168.250.252)  0.743 ms  0.777 ms  0.620 ms
 3  152.78.108.6 (152.78.108.6)  1.232 ms  1.129 ms  1.130 ms
 4  b54gagesw1-aa.net.soton.ac.uk (152.78.108.62)  1.896 ms  1.775 ms  1.403 ms
 5  b54hafw1-ga1.net.soton.ac.uk (152.78.109.9)  2.263 ms  28.542 ms  5.234 ms
 6  b54gagesw2-hafw.net.soton.ac.uk (152.78.0.30)  3.666 ms  2.832 ms  3.117 ms
 7  212.219.151.113 (212.219.151.113)  3.109 ms  3.006 ms  3.200 ms
 8  212.219.151.121 (212.219.151.121)  5.074 ms  3.595 ms  4.670 ms
 9  * * *
10  146.97.40.2 (146.97.40.2)  6.361 ms  6.728 ms  4.656 ms
11  cosham-bar.ja.net (146.97.40.1)  4.830 ms  4.236 ms  4.459 ms
12  po9-0.cosh-scr.ja.net (146.97.35.21)  5.037 ms  4.947 ms  5.840 ms
13  po2-0.lond-scr.ja.net (146.97.33.41)  8.048 ms  7.107 ms  8.266 ms
14  po6-0.lond-scr3.ja.net (146.97.33.30)  8.127 ms  58.828 ms  7.467 ms
15  po2-0.geant-gw3.ja.net (146.97.35.138)  6.190 ms  7.622 ms  7.432 ms
16  janet.uk1.uk.geant.net (62.40.103.149)  6.473 ms  6.672 ms  5.811 ms
17  uk.ny1.ny.geant.net (62.40.96.169)  76.279 ms  82.877 ms  75.657 ms
18  198.32.11.61 (198.32.11.61)  76.891 ms  84.188 ms  90.133 ms
19  chinng-nycmng.abilene.ucaid.edu (198.32.8.82)  105.893 ms  106.342 ms  111.362 ms
20  * iplsng-chinng.abilene.ucaid.edu (198.32.8.77)  335.818 ms  321.100 ms
21  kscyng-iplsng.abilene.ucaid.edu (198.32.8.81)  118.991 ms  181.359 ms  131.587 ms
22  dnvrng-kscyng.abilene.ucaid.edu (198.32.8.13)  132.976 ms  132.671 ms  134.104 ms
23  snvang-dnvrng.abilene.ucaid.edu (198.32.8.1)  155.251 ms  195.379 ms  158.060 ms
24  pos-1-0.core0.eug.oregon-gigapop.net (198.32.163.17)  167.457 ms  166.090 ms
        166.865 ms
25  uo-0.eug.oregon-gigapop.net (198.32.163.147)  187.421 ms  188.076 ms  215.526 ms
26  ge-5-1.uonet1-gw.uoregon.edu (128.223.2.1)  170.776 ms ge-5-1.uonet2-
        gw.uoregon.edu (128.223.2.2)  166.879 ms ge-5-1.uonet1-gw.uoregon.edu
        (128.223.2.1)  167.509 ms
27  pith.uoregon.edu (128.223.220.25)  167.342 ms  167.276 ms  166.636 ms
```

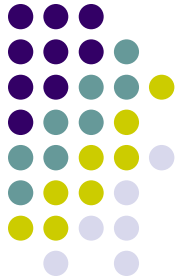
```
traceroute6 news.uoregon.edu
traceroute to pith.uoregon.edu (2001:468:d01:dc::80df:dc19) from
        2001:630:d0:115:230:48ff:fe23:58df, 30 hops max, 16 byte packets
 1  servers-router.6core.ecs.soton.ac.uk (2001:630:d0:115::1)  0.431 ms  0.248 ms  0.243 ms
 2  zaphod.6core.ecs.soton.ac.uk (2001:630:d0:101::1)  0.54 ms  0.644 ms  0.47 ms
 3  ford.6core.ecs.soton.ac.uk (2001:630:d0:100::1)  1.052 ms  0.887 ms  0.81 ms
 4  2001:630:c1:100::1 (2001:630:c1:100::1)  1.215 ms  1.206 ms  0.895 ms
 5  2001:630:c1:10::1 (2001:630:c1:10::1)  1.607 ms  1.826 ms  1.728 ms
 6  * * *
 7  2001:630:c1::1 (2001:630:c1::1)  2.285 ms  2.692 ms  3.004 ms
 8  2001:630:c1::1 (2001:630:c1::1)  3.099 ms  3.123 ms  2.693 ms
 9  po9-0.cosh-scr.ja.net (2001:630:0:10::85)  2.527 ms  1.819 ms  3.185 ms
10  po2-0.lond-scr.ja.net (2001:630:0:10::29)  5.064 ms  4.677 ms  4.168 ms
11  po6-0.lond-scr3.ja.net (2001:630:0:10::36)  4.658 ms  5.03 ms  4.656 ms
12  2001:630:0:10::166 (2001:630:0:10::166)  4.992 ms  4.749 ms  5.475 ms
13  janet.uk1.uk.geant.net (2001:798:2028:10aa::1)  5.892 ms  5.826 ms  4.819 ms
14  uk.ny1.ny.geant.net (2001:798:20cc:1c01:2801::1)  73.718 ms  74.22 ms  74.122 ms
15  nycmng-esnet.abilene.ucaid.edu (2001:468:ff:15c3::1)  77.07 ms  75.443 ms  76.898 ms
16  chinng-nycmng.abilene.ucaid.edu (2001:468:ff:f15::1)  104.282 ms  103.561 ms  104.2 ms
17  * * iplsng-chinng.abilene.ucaid.edu (2001:468:ff:f12::2)  350.199 ms
18  kscyng-iplsng.abilene.ucaid.edu (2001:468:ff:1213::2)  117.603 ms  117.767 ms  120.105 ms
19  dnvrng-kscyng.abilene.ucaid.edu (2001:468:ff:1013::1)  128.359 ms  127.255 ms  144.816
        ms
20  snvang-dnvrng.abilene.ucaid.edu (2001:468:ff:1017::2)  151.471 ms  151.761 ms  153.755
        ms
21  oregon-snvang.abilene.ucaid.edu (2001:468:ff:174d::2)  164.897 ms  164.642 ms  165.2 ms
22  2001:468:d00:a390::3 (2001:468:d00:a390::3)  163.945 ms  164.165 ms  164.502 ms
23  ge-5-1.uonet1-gw.uoregon.edu (2001:468:d01:2::1)  164.259 ms  165.35 ms  165.224 ms
24  pith.ipv6.uoregon.edu (2001:468:d01:dc::80df:dc19)  164.755 ms  164.811 ms  165.215 ms
```

Route stability over time



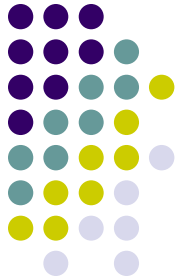
- Various tools are available
- We're using RIPE Test Traffic Measurement servers
  - http://www.ripe.net/ttm/Plots/
  - But only useful to other TTM servers (none in USA…)
  - Keen to measure IPv6 stability to the US/Abilene/Moonv6

Enterprise connectivity



- Different requirements to SOHO environment, thus preferred choice of connectivity methods would probably be:
  - Native IPv6 connectivity
  - Manually configured tunnel
  - Brokered tunnel
  - 6to4 (last resort)
  - Teredo (below last resort!)
- The German 6WiN manages over 300 IPv6 end sites via manually configured tunnels

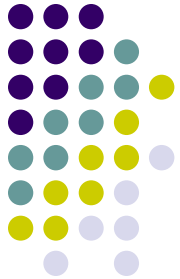
Address space and allocation



- Hierarchical, provider assigned (PA) address space
  - JANET 2001:630::/32
  - SOUTHAMPTON 2001:630:d0::/48
  - SOUTHAMPTON-ECS 2001:630:d0:0::/52
- In moving to IPv6, the university no longer has provider independent (PI) address space

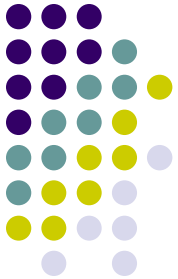
- Need BCP site address allocation plans
- No PI? What about renumbering?
- Use of Unique Local Addresses (ULAs)?

Easy renumbering? Embedded IP addresses…



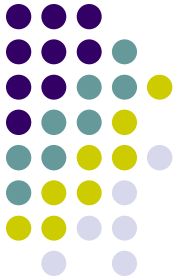
- Provider based prefix(es)
- Names resolved to IP addresses in firewall at startup time
- IP addresses in remote firewalls
- IP-based authentication in remote systems
- IP address of both tunnel end points for IPv6 in IPv4 tunnel
- Hard-coded IP subnet configuration information
- IP addresses for static route targets
- Blocked SMTP server IP list (spam sources)
- Web .htaccess and remote access controls
- Apache .Listen. directive on given IP address
- Configured multicast rendezvous point
- TCP wrapper files
- Samba configuration files
- DNS resolv.conf on Unix
- Nocol/Nagios monitoring tool
- NIS/ypbind via the hosts file
- Some interface configurations
- Unix portmap security masks
- NIS security masks

Address management



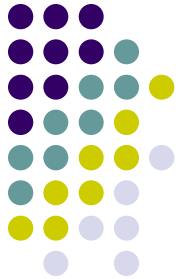
- Various host configuration methods, including:
  - Statelessly autoconfiguring hosts
  - Statefully configured hosts (DHCPv6)
  - Hosts using privacy addresses
  - Hosts using global or unique local addresses
- Stateless autoconfiguration implies dynamic DNS
  - Needs authentication, but so does DHCP…
- Very early DHCPv6 implementations
- Need integrated DHCP and DHCPv6 management

Hooking up



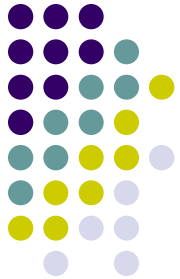
- Connect IPv6 router to upstream provider
  - Initially to test basic connectivity (we use Cisco 7206)
  - We use static routing, have used BGP in past
  - We have separate IPv4 and IPv6 feeds
    - As an interim measure
- Deploy “security” early
  - Border packet filter/firewall, avoid back doors
    - (No evidence of IPv6-based probing/attacks (yet))
- We will move to a unified IPv4 and IPv6 feed
  - Waiting for commercial dual-stack firewall and IDS

Internal transition tools



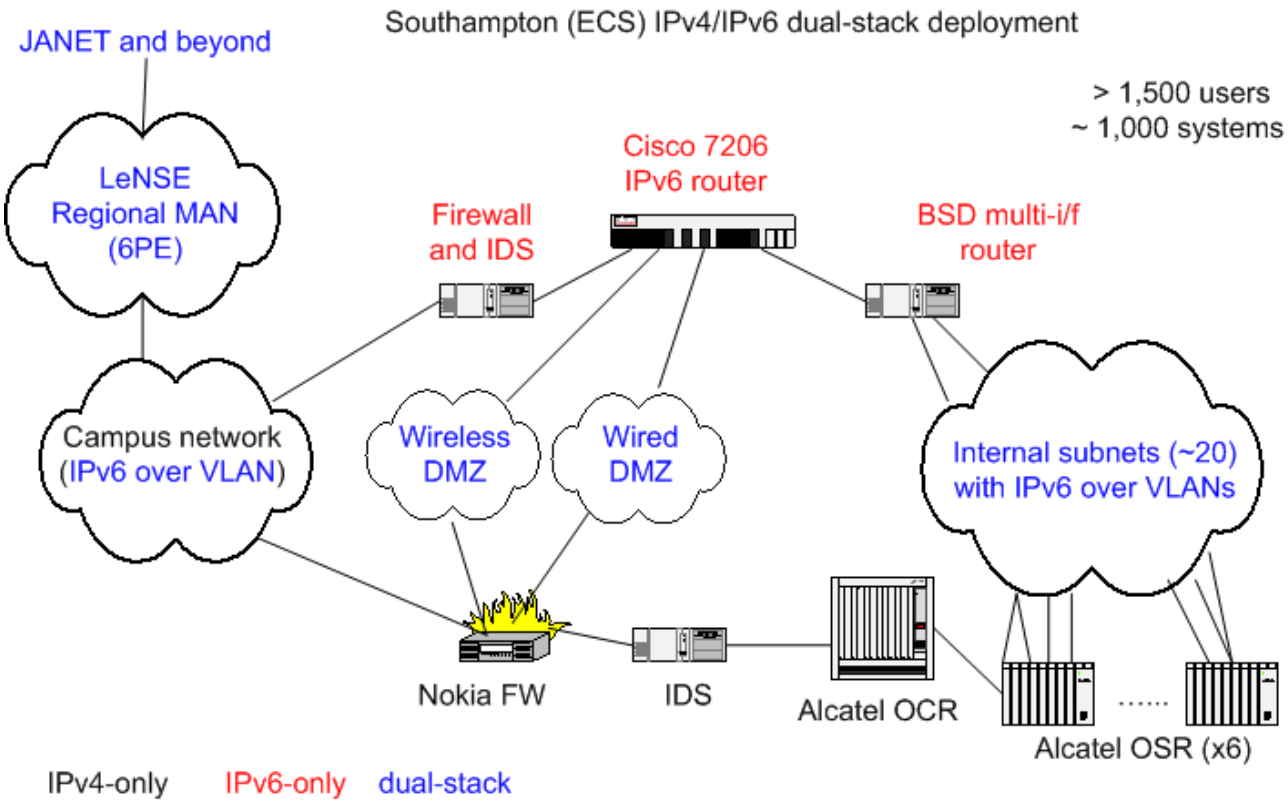
- Many tools could be used on an enterprise Intranet
- Need to decide your philosophy/policy, e.g.
  - Managed or unmanaged?
  - Dense or sparse deployment?
- Can mix and match as required, e.g.
  - Tunnels
  - ISATAP
  - Internal brokering
- Our goal is pervasive, managed deployment
  - So want managed control of deployment, link by link

Parallel routed infrastructure

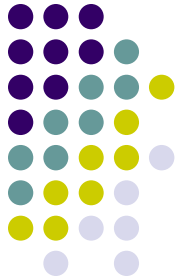


- No routed IPv6 support in existing infrastructure
  - Thus chose to deploy parallel IPv6 infrastructure (using Cisco and BSD) until commercial product available during Summer 2005 procurement
- Use 802.1q VLANs to “inject” IPv6 into network
  - See: draft-chown-v6ops-vlan-usage-02
  - Allows managed intranet IPv6 deployment (unlike ISATAP)
  - Early traffic levels sustainable via BSD platform
  - Can port balance if required
  - Will release a GUI-based front end (for BSD/Linux)
- NB. This is only an interim measure

Parallel IPv6 infrastructure



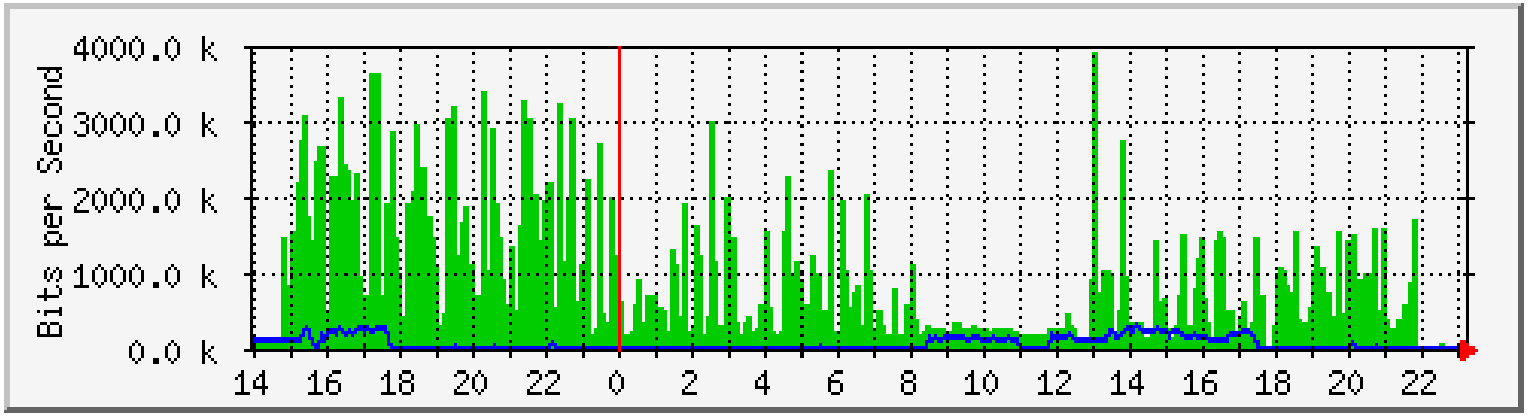
IPv6-enabled services



- Web site(s) (Apache2)
- Login/FTP (ssh, sftp)
- DNS (bind9)
- SMTP (sendmail)
- RADIUS (Radiator)
- NTP (TTM, Meinberg)
- RIPE TTM server
- Nagios
- MRTG
- Snort
- Jabber
- IRC
- Open.H323
- SIP-based VoIP (SER)
- Video streaming
- Radio streaming
- …
- Tunnel broker
- 6to4 relay

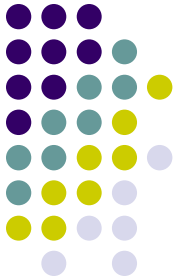
IPv6 external traffic levels

The statistics were last updated **Tuesday, 16 November 2004 at 23:20**, at which time **'Ford'** had been up for **109 days, 7:22:25**



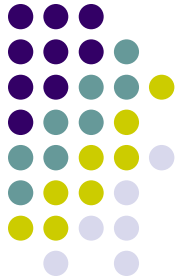
- IPv6 is still less than 5% of our traffic
  - Average ~800Kbit/s, or ~70Gbits throughput/day
  - (The above router is IPv6 only)
- Growing steadily
  - A lot of usage for new applications
  - But works reliably for “legacy” web/ftp/etc

Remote IPv6 access tools



- Want to support IPv6 users in home or other networks without IPv6 support from that ISP
- Have thus deployed:
  - Tunnel broker (in-house)
  - 6to4 relay (manually configured)
  - OpenVPN broker
- Have not deployed
  - ISATAP, Teredo, 6over4, NAT-PT
  - (internally or externally)
  - For IPv6-only links, we expect to deploy ALGs not NAT-PT

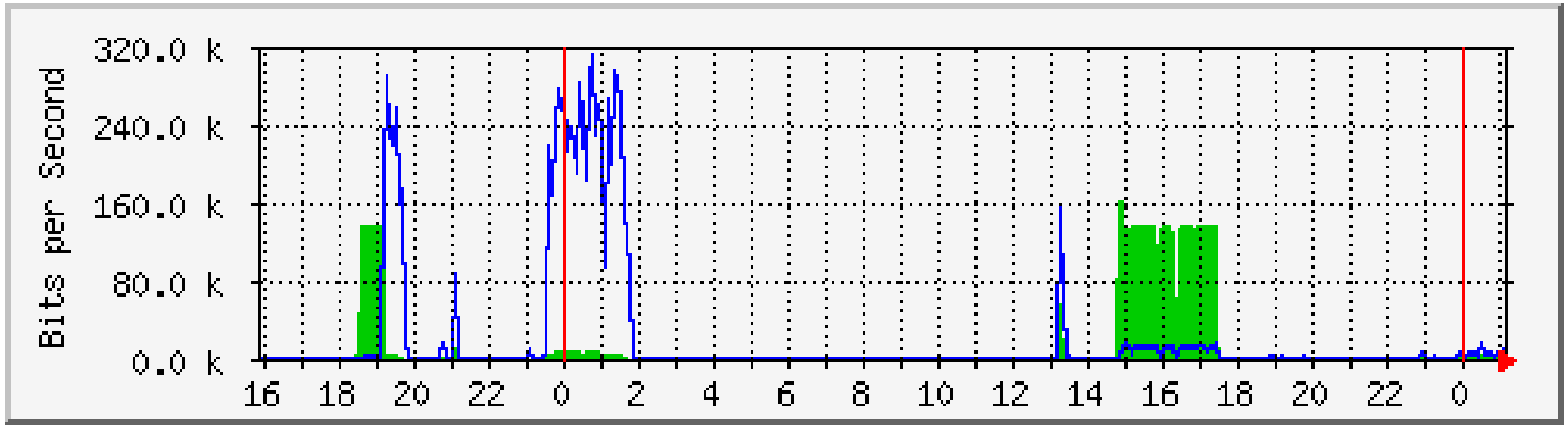
Multicast



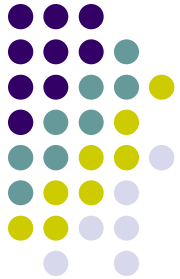
- Not a wild success story in IPv4
- Two thrusts in IPv6:
  - ASM, using embedded-RP for inter-RP communication
  - SSM, simplifying the model, easing deployment
- Running both on site, using BSD and Cisco routers
  - Connectivity to 6NET, m6bone and soon GEANT
- IPv6 SSM applications?
  - Ported Mad-FLUTE to support IPv6 SSM
  - Using for reliable file transfer over multicast
  - Distributing Linux/BSD mirrors, MP3's, IETF documents

Community wireless (SOWN)

- Student-run 802.11-based wireless network
  - External presence in/around campus
  - Complements campus (indoor) WLAN presence
- SOWN has IPv6, currently via 6to4
  - Running MIPv6 between them (e.g. for streaming, ssh)
  - May deploy ULA addresses

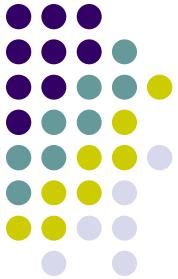


Conclusions



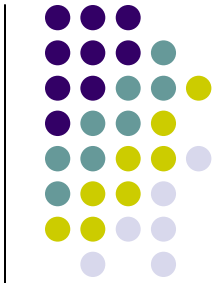
- We can say that in general:
  - IPv6 is deployable in an academic enterprise network
  - The basic services can be IPv6-enabled
  - No significant adverse impact on production IPv4 service
  - Some gaps, mainly in vendor application space
  - (Commercial) network management tools still lacking
  - Interim deployment solutions for early adopters exist, until IPv6 capability is available through procurement
  - Deploying attracts interest from (CS) students, and we are seeing some new services/applications emerging
  - Can utilise new IPv6-capable devices that are now becoming available (e.g. Nokia 9500)

Next Steps



- Always something to do, but include:
  - Layer2/3 enterprise procurement, Summer'05
  - DHCPv6 deployment/trials
  - IPv6 renumbering study
  - Further Source-Specific Multicast development
  - Ongoing application domains: GRID, sensors, …
  - 6NET project work - see http://www.6net.org
- Seeking US collaboration sites for:
  - Interconnectivity testing (including Moonv6)
  - End-to-end network monitoring
  - Application-oriented trials, including multicast

Contact:



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