

Defense Research and Engineering Network Implementation Details

– 2003 to 2008 –

IPv6-team

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Preparation for IPv6 deployment

(The local implementation – how each enclave will do it)

Introductory remarks–

- In the slides that follow, replace the phrase “DREN IPv6 Pilot” with “Corporate planning team” or “Enterprise implementation group” or “Company deployment committee”, as appropriate to your situation
- In the slides that follow, the term enclave/site may not directly apply to your situation. Substitute the term branch, office, division, or other organizational unit, as appropriate to your situation
- The deployment process is described 3 times: as a 2-slide synopsis, as a 5-slide overview, and the full details





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9 steps in conducting a successful IPv6 deployment:

1. Learn the terminology and technology*
2. Establish the Change Team
3. Describe Desired State
4. Baseline Current State
5. Analyze the Gap
6. Develop the Solution(s)
7. Trial the Solution(s) (on a local test bed)
8. Roll Out the Solution(s) and then build on prior successes
 - Start small with one subnet (but with external connectivity)
 - Test and verify IPv6 deployment
 - Expand scope to next logical increment
 - Repeat until deployment completed
9. Analyze Lessons Learned

“Technology makes change possible, or even necessary, but people make it happen”
– David S. McIntosh,
CBI Network

*Shown in gray since not in the SEI steps

Source the Carnegie-Mellon Software Engineering Institute (SEI), see <http://www.sei.cmu.edu/pub/documents/98.reports/pdf/98tr004.pdf>

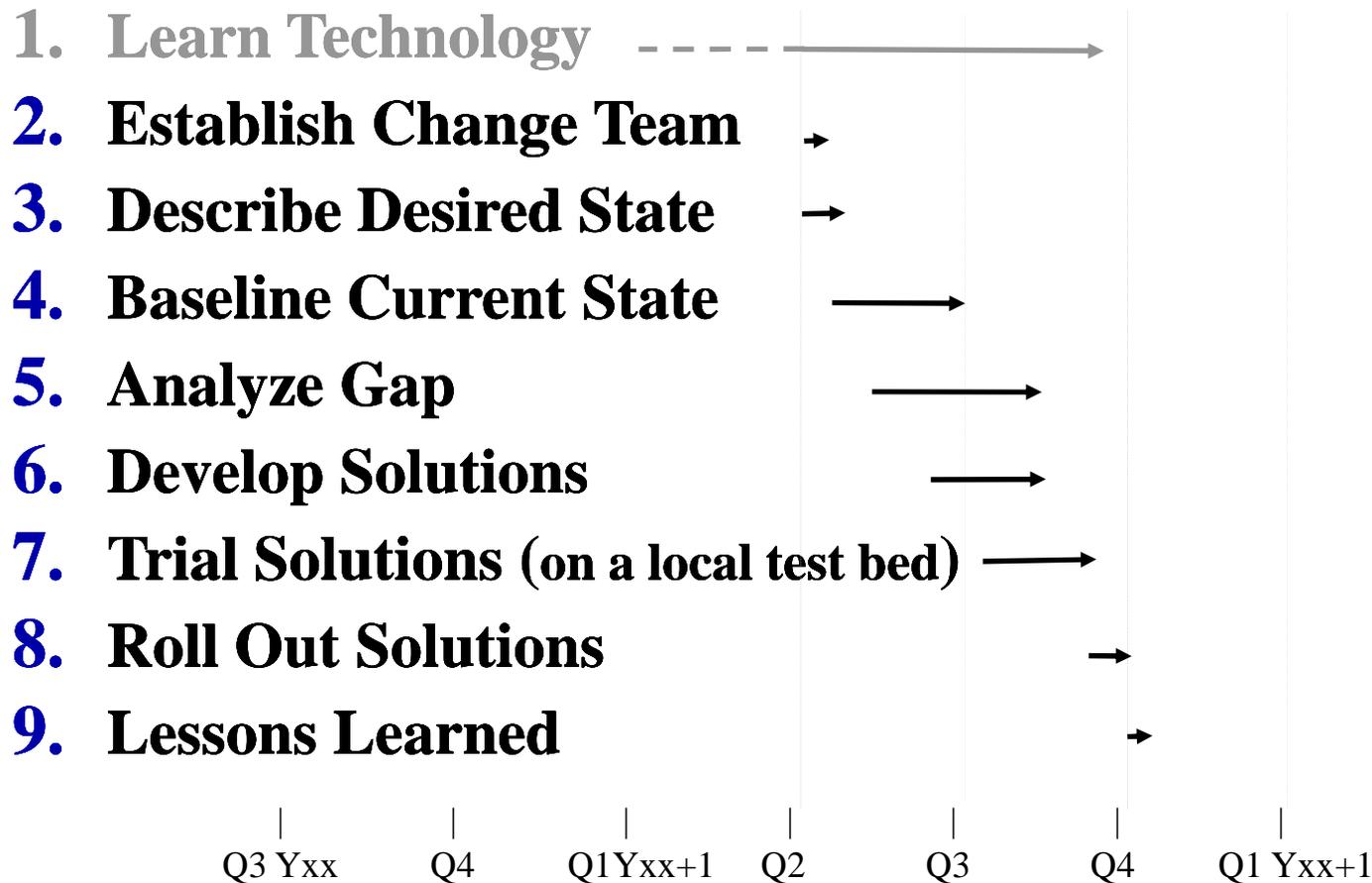




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9 steps in a successful IPv6 deployment: notional timeframe





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9 steps in a successful technology deployment (continued):

Reference Model

1. Learn the terminology and technology*

*Shown in gray since not in the SEI steps

DREN IPv6 Pilot

Most team leaders already knew IPv4, and that helped. Some already knew IPv6; others learned it during the early stages.

At your site

Someone at your site has to know (or learn) IPv4, and then IPv6. All of your team members can be learning IPv6 as they go through steps 2 through 6 of the deployment process. Don't wait to get started until after learning IPv6!





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9 steps in a successful technology deployment (continued):

<u>Reference Model</u>	<u>DREN IPv6 Pilot</u>	<u>At your site</u>
2. Establish the Change Team	These are the team leaders for the pilot Functional Areas (FA).	An early action for your site is to identify the site deployment team leader and member(s)
3. Describe Desired State	This is the result to be achieved across the DREN IPv6 Pilot infra-structure at at each local site	As part of the IPv6 deployment, your site will build a dual stack IPv4/IPv6 environment (on...?)

(These 2 steps often are done together.)





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9 steps in a successful technology deployment (continued):

<u>Reference Model</u>	<u>DREN IPv6 Pilot</u>	<u>At your site</u>
4. Baseline Current State	The FA team serves as the focal point for collating information about the existing infrastructure	You need to locally identify all the IT resources that are or will be present at your site during the deployment
5. Analyze the Gap	The FA team has talked with vendors and developers, and started the process of discovering and documenting needed changes on the web site	Using the IPv6 knowledge base web site, review the IT resources at your site to see what will need to be updated/substituted/remediated





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9 steps in a successful technology deployment (continued):

<u>Reference Model</u>	<u>DREN IPv6 Pilot</u>	<u>At your site</u>
6. Develop the Solution(s)	The pilot team will collate any known solutions available for enabling IPv6 on the knowledge base web site	Draw on the knowledge base web site to collect or develop the updates needed for the IT resources at your site
7. Trial the Solution(s) (on a local test bed)	The FA team will collate previous outcomes from the FA team, vendors, and other pilot sites on the knowledge base web site	This step may have already been done for you by another site, or you may be able to assist later sites in deploying IPv6



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9 steps in a successful technology deployment (continued):

<u>Reference Model</u>	<u>DREN IPv6 Pilot</u>	<u>At your site</u>
8. Roll Out the Solution(s)	The DREN IPv6 pilot implementation plan lays out the overall schedule for getting sites involved in the IPv6 pilot program	This is the challenge for your site: to prepare a logical schedule of the changes to be made at your site
9. Analyze Lessons Learned	As each site goes through their local IPv6 deployment, the pilot team will update the info and plans on the knowledge base web site	Provide feedback early and often to the IPv6 pilot team on what works and what doesn't, to enable us to assist others





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1. Learn the terminology and technology
 - **HPCMP talks and tutorials (slides available on knowledge base)**
 - IPv6 Training and Learning article
 - DREN 2004 and 2009 (IPv6 tutorial by Ron Broersma)
 - sd.wareonearth.com/woe/Briefings/ipv6.ppt
 - Networkers 2000 (IPv6 introduction by Phil Dykstra)
 - **Other sites**
 - Many links given in file linked at IPv6 Training and Learning article
 - **Industry sites**
 - www.ipv6tf.org, <http://www.ipv6forum.org/> - IPv6 world-wide
 - gogonet.gogo6.com/, www.ipv6news.info - industry news and links



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1. Learn the terminology and technology (continued):
 - **Internet2/Abilene talks and workshops**
 - ipv6.internet2.edu/workshops/index.shtml
 - Hands-on 2-day workshops on various IPv6 topics
 - (presentations no longer freely available – must attend workshop)
 - An early workshop slide set from 2002 is still available at <http://ipv6.internet2.edu/workshops/index.shtml>
 - **Commercial sources**
 - www.native6.com/ (a variety of IPv6 courses)
 - www.tonex.com (2-day workshop IPv6 Fundamentals)
 - www.sunsetlearning.com (2-day workshop Cisco based)
 - **Web search “IPv6 tutorial” returns hundreds of hits**
 - Quality, timeliness, information content vary widely
 - A few good ones in file in IPv6 Training and Learning article



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1. Learn the terminology and technology (continued):
 - Reference sources
 - Books (there are dozens, these are worth looking at)
 - Understanding IPv6 by Joseph Davies, published by Microsoft Press ISBN 0-7356-1245-5
 - IPv6 Essentials by Silvia Hagen, published by O'Reilly & Associates ISBN 0-5960-0125-8
 - IPv6: Theory, Protocol, and Practice, 2nd edition by Peter Loshin, published by Morgan Kaufmann Publishers ISBN 1-5586-0810-9
 - On-line
 - RFC pages and Internet-Drafts
 - » <http://www.ietf.org/> and <http://www.faqs.org/faqs/>
 - Various documents and presentations
 - » <http://www.ipv6forum.org> - worth searching presentations
 - » <http://playground.sun.com/pub/ipng/html/> - older but useful
 - IPv6 Working Group (and other working groups)
 - » <http://www.internet2.edu/wg/index.html>



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2. Establish the Change Team

- **An early step for your site is to identify the site deployment team leader and member(s).**
 - **A team leader (any member of the team)**
 - **At least one network administrator (depending on the complexity of the networks where IPv6 is to be deployed)**
 - **At least one system administrator (for each class of systems where IPv6 is to be deployed)**
 - **Application support manager(s), if you have many applications to be IPv6 enabled**
 - **A representative from each local network monitoring organization (internal or external organization)**
 - **Also representatives from security, customer support, data center, operations, major users or user group representatives, et cetera.**

These are all part time positions, not full time. It is important for success that no area be left out that will be affected by the deployment.



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3. Describe Desired State

- As part of the IPv6 deployment, your site will establish a dual stack IPv4/IPv6 environment (on...?)
- Some of the available goal setting approaches include:
 1. The whole enclave. An initial goal only if you have a small enclave or are very courageous. This is your ultimate goal
 2. A logically or physically segregated subnet. An initial goal might be to route IPv6 packets to that subnet *only*. IT resources migrate to this subnet in stages
 3. An integrated subnet. An initial goal might be to have a few IPv6 enabled IT resources. Other IT resources will ignore the IPv6 packets, which aren't addressed to them anyway. Add additional IT resources in stages
 4. Use some small combination of (2) and (3) to get started, ultimately expanding to the whole enclave





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4. Baseline Current System

- You need to identify the IT resources that are or will be installed at your site during the IPv6 deployment period:
 - Suggestion: start at the bottom of the network and work up:
 - Layer 2&3 networking infrastructure, including routers, switches, gateways, dial-up modem server banks, and the like
 - Networking services software, such as DNS, NTP, SMTP, SNMP, and the like.
 - Security infrastructure, including firewalls, proxy servers, IDS, VPN servers, PKI, KDC, Active Directory domain controllers, and the security software on/accessing this infrastructure
 - Computers (HPC, visualization, mass storage, file, mail, and web servers, desktop systems, and others)
 - Anything else with an IPv4 address may need an IPv6 address (printers, scanners, FAX machines, and the like)





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4. Baseline Current System (continued)

- On computers and other IT resources with an operating system or software that can be changed, identify:
 - Operating system version
 - System level utilities and libraries versions
 - Terminal emulation, file transfer, web, mail, and other communications applications versions
 - Application programs, including
 - » Infrastructure applications such as Kerberos
 - » Third-party user applications (COTS and GOTS programs)
 - » User-developed applications (suggested by involved/interested program/project users)



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5. Analyze the Gap

- **Using the knowledge base web site as a starting point, review the IT resources at your site to see what will need to be upgraded/substituted/remediated.**
- **One possible approach:**
 - **Quick baseline of candidate networking and computing environment, per step 3 (Baseline Current System)**
 - **Check to see which of your IT resources are already present on the knowledge base web site**
 - **In parallel:**
 - **For items on the web site, make plans using available info**
 - **Refine and complete baseline of your environment to fill in blanks, and repeat this step until baseline is completed**



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5. Analyze the Gap (continued)

- **What about IT resources that can't be IPv6 enabled?**
 - **Example: Model XYZ doesn't support IPv6 until 2015 timeframe**
 - » **One Solution: Front-end/bastion host to allow remote IPv6 access. Continue to allow IPv4 access to local file servers**
 - **Example: Old router that can't do IPv6?**
 - » **One Solution: Replace with later equipment**
 - » **Another Solution: Move outside of enclave where IPv4 equipment is still useful**
 - **Example: Parent organization's DNS will not support IPv6 in FY09**
 - » **One Solution: Identify alternative source of name service**
 - » **Another Solution: Work with parent organization to accelerate schedule for technology upgrade of DNS (policy, after all)**



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5. Analyze the Gap (continued)

– What about IT resources that can't be IPv6 enabled?(continued)

- Example: IPv6 equipment on IPv4 network
 - » One solution: Move to an IPv6 subnet
 - » Another solution: 6over4 tunnel

– Consider a tunnel broker

- IPv6 tunnels on demand through IPv4 networks using Gogo6 appliance
<http://gogoware.gogo6.com> (also a 6to4 gateway)

– Status:

- Operational, tested on XP, Vista, Linux, and Mac OS X, so far





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6. Develop the Solution(s)

- Using the knowledge base web site as a resource, collect the necessary updates and tests for the IT resources at your site
 - Identify any purchases needed (likely few, mostly S/W), and initiate procurement
 - Identify any patches, and contact vendors to obtain. (If maintenance has lapsed, initiate corrective action.)
 - Identify any configuration changes necessary for the hardware and software you will be using to deploy IPv6
 - Determine if useful scripts for any changes are already on the knowledge base web site. If not, develop and give back to be placed on knowledge base web site



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6. Develop the Solution(s) (continued)

- Using the knowledge base web site as a resource, collect the necessary updates and tests for the IT resources at your site (continued)
 - For testing, identify and get or develop any data sets or software needed for post-deployment tests.
 - Testing tips:
 - Need an external IPv6-only address? ipv6.google.com
 - Need an external point to test your local IPv6 access?
 - » Give www.ipv6tools.org a try. It shows your IP address and allows you to ping, trace, and query DNS via IPv6
 - » Use the gogoCLIENT from gogoware.gogo6.com and the authenticated.freenet6.net server in Montreal, CA to get tunnel broker accounts for testing IPv6 before your local infrastructure is IPv6-enabled (registration required)



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7. Trial the Solution(s)

- **This step may already been done for you. All deployment results and testing experience as reported by sites are collated on the knowledge base web site. It is a living collection of lessons learned reported by and for the benefit of the whole IPv6 community.**
- **For any scripts, data sets, or software you must develop locally, try to get assistance from a vendor or from another site that may have deployed IPv6 on similar IT resources**
 - **In the ideal case, what you need for your local IPv6 deployment will have been tried out by someone else before, but this can't always be the case. Someone must always take the first step**



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8. Roll out the Solution(s)

- **This is the challenge for your site: to prepare a logical schedule of the changes to be made at your site**
 - **As part of preparing the deployment schedule, arrange for on-site or remote assistance during deployment at your site (if you feel it is necessary)**
 - **Have everything you need for a change on hand before you make any changes (S/W, documentation, IP addresses, DNS entries, responsible individuals, and the like)**
 - **Review the reversion process for a change just before making that change**
 - **Resist spur-of-the-moment improvisations and short-cuts**



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8. Roll out the Solution(s) (continued)

- **This is the challenge for your site: to prepare a logical schedule of the changes to be made at your site**
 - **Consider the following in preparing a schedule for your site:**
 1. **What the IPv6 addressing plan for your site will look like**
 2. **What order you will enable the IT resources at your site**
 3. **How you will assign IPv6 addresses to them**
 4. **What domain names will be associated with them**
 5. **What security protections need to be applied to them**
 6. **How and when to involve various other organizations**
 7. **Where will new IPv6 addresses and domain names appear**
 8. **Where else might old IPv4 addresses need to be updated**
 9. **Where else might utilities need to be updated/changed**
 - **Each of these decisions can have long-term impact**



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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:

1. What the IPv6 addressing plan for your site will look like

- » Your goal should be a plan that can endure growth and change without having to be re-address everything
- » Get your IPv6 prefix from your organizations designated source
- » Think big. You have 65,536 subnets to allocate!

← Network → Site

2001	xxxx	sssn	subnet	Interface ID
------	------	------	--------	--------------

- » Seriously rethink continued use of Network Address Translation





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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:
 - 2. What order you will enable the IT resources at your site
 - i. Begin with your border router:
 - Contact the network NOC and schedule a time to configure IPv6 on the local subnet
 - Verify with the NOC your IPv6 prefix you were assigned, so your border router can statically route it
 - Start enabling IPv6 on your infrastructure
 - A border router connected to you ISP will be the first IT resource. Configure its interface to the network with the IPv6 address the NOC gives you
 - Verify you can ping an external IPv6 address



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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:
 - 2. What order you will enable the IT resources at your site
 - i. Begin with your border router (continued):
 - Configure a static default route (::/0) pointing at the your ISP connection point
 - Enable IPv6 on your border router's interfaces in the order you want to bring up IPv6 on your LANs. Assign IPv6 addresses to those interfaces following your IPv6 address plan
 - Enable IPv6 on the layer 2&3 devices on those LANs. Manually assign IPv6 addresses to any routers on those LANs, and configure the address policy you want enforced on that LAN segment
 - Verify that hosts on those LANs that are already IPv6 enabled auto-configure when powered up after the change





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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:
 - 2. What order you will enable the IT resources at your site
 - ii. Follow the order you identified in step 4 – Baseline Current System – to enable additional IT resources
 - iii. Here are some additional suggestions for ordering:
 - The security requirements of the IT resources (start with those having fewer requirements, for example, servers in your DMZ)
 - The homogeneity of the IT resources (start with those having common features, like the same make and model, or the same operating system) – Keep It Simple
 - The criticality of the IT resources (start with non-mission essential resources)
 - The age of the IT resources (newest first)





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8. Roll out the Solution(s) (continued)

– Consider the following in preparing a schedule for your site:

3. How will you assign IPv6 addresses to them?

» A single device will have multiple IPv6 addresses assigned

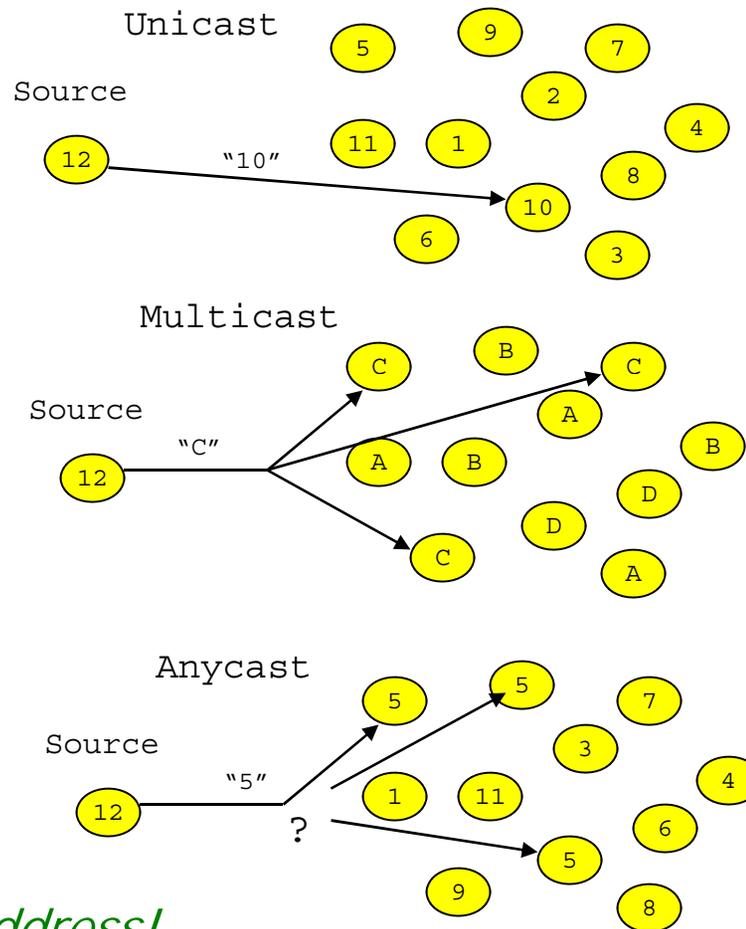
- A link-local address, automatically configured
- A traditional unicast global address (see next page)
- Several multicast address(es) (more if the device is a router)
- Possibly anycast address(es) (used today mostly for routers)



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- **Unicast:** Destination address specifies exactly one target.
- **Multicast:** Destination address specifies a group that includes multiple targets
- **Anycast:** Destination address specifies just one (the closest) of multiple targets



No Broadcast address!



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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:

3. How will you assign IPv6 addresses to them (continued)?

- » A single device can be assigned a unicast address in one of several ways:

- Remember, IPv6 devices will learn the correct link-local prefix from the local router
- Option 1: The traditional manual configuration method (laborious, but possibly necessary given your corporate or local security requirements)
- ✓ Remember, the ultimate goal is to assign both the IPv4 (A record) and IPv6 (AAAA record) records to a single domain name. However, because of flaws in many client programs and IP stacks, giving separate domain names to the IPv4 and IPv6 addresses is not currently recommended. The flaw is as follows: the client requests the AAAA record when it exists, even when there is no IPv6 path to the remote host. Consequently, a noticeable delay occurs while waiting for the attempt to use IPv6 to





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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site: (continued)

3. How will you assign IPv6 addresses to them (continued)?

- » A single device can be assigned a unicast address in one of several ways: (continued)

(continued) access the remote host, a time out occurs, and the client falls back to using IPv4. Most Linux/UNIX implementations have this flaw.

- ✓ Windows XP SP3 and later Windows versions usually do not behave in this way, so an enclave that only plans to support access by Windows systems won't need assign separate domain names for user convenience (though it is still very useful for testing).
- ✓ This delay annoys the end user, and can be avoided as follows: For now, consider assigning separate domain names to the IPv4 and IPv6 addresses. The new IPv6 domain name might be of the form host-v6.domain or host.v6.domain or ipv6.host.domain, as examples. These separate domain names should only be temporary and will be used primarily by the group supporting IPv6 deployment. When IPv6 deployment is complete, such names should be removed from DNS.





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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site: (continued)

3. How will you assign IPv6 addresses to them (continued)?

- » A single device can be assigned a unicast address in one of several ways: (continued)
 - ✓ Be careful with Windows clients: By default, they assign random public IPv6 addresses rather than using the IETF standard method of generating IPv6 addresses based on the MAC address of the network interface. See the [Enabling IPv6 in Microsoft Windows legacy versions](#) article or the [Enabling IPv6 in Windows Vista and Server 2008](#) article for guidance on how to disable random address generation.
 - ✓ Also be careful with Vista and Windows 7 clients: By default, they will attempt to store the client IPv6 address in the Active Directory controlled DNS, prior to any planned deployment of IPv6 by your organization. As part of deployment, check to see if any AAAA records were created by such clients and found their way into DNS – you may want to remove them if you plan to use IETF standard IPv6 address generation.



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8. Roll out the Solution(s) (continued)

– Consider the following in preparing a schedule for your site: (continued)

3. How will you assign IPv6 addresses to them (continued)?

» A single device can be assigned a unicast address in one of several ways: (continued)

- **Option 2: Stateless autoconfiguration – Preferred.**
 - ✓ Typically prior manual DNS entry will be necessary. AAAv6 could do this for you (but it is not ready for prime time)
- **Option 3: Stateful autoconfiguration – DHCPv6.**
 - ✓ Getting DHCPv6 and DHCPv4 to work together in a dual-stack environment is hard. Windows XP SP3 and Macintosh OS X don't support DHCPv6. The v4 and v6 DHCP servers usually won't coordinate their data base updates.
- **See “IPv6 and DNS” knowledge base article for more on this topic**



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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site: (continued)

4. What domain names will be associated with them

» With all the new IPv6 addresses, you will probably want to add new AAAA records to your favorite DNS server(s). May we suggest:

- Each canonical host name having an “A” resource record gets an “AAAA” record. **CAUTION: do this only after the host is reachable via IPv6 and any services on the host are listening for both IPv4 and IPv6 service requests, otherwise resolvers and clients will timeout or get confused**
- How IPv6 addresses are assigned (see 8.3) influences the ways that new host names get entered in DNS, and when they should be
- PTR records in IP6.ARPA and INADDR.ARPA DNS domains should eventually both point to the same host name record, usually the domain name previously associated with the IPv4 address.





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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:

5. What security protections need to be applied to them
 - » IPv6 ports and protocols filtering is like IPv4 (the ports and protocols are the same)
 - » IPv6 is different (the syntax to implement filters on firewalls and routers will vary, and is probably unlike IPv4)
6. How and when to involve various other organizations
 - » Make your help desk/customer service personnel aware
 - » What will your local and corporate security offices think of all this?
 - » What will happen during the next local security review (and until then)?
 - » Who will update your accreditation package(s)



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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:

7. Where will new IPv6 addresses and domain names appear

- » Network monitoring logs and databases
- » Procedure manuals and scripts for operations
- » What web pages need to be updated, when, and by whom?
- » When, how, and by whom will AAAA and IP6.ARPA records be entered into the DNS hierarchy?
- » Whitelists – opt-in to receive AAAA records
- » Do DNS servers and resolvers have IPv6 access? (This is not required but will make life simpler)
- » How will servers (like mail or web) accept requests from clients that do not have IP6.ARPA records?



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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:

8. Where else might old IPv4 addresses need to be updated/replaced with new IPv6 addresses
 - » Names resolved to IP addresses in local/remote firewalls
 - » Hard-coded IP subnet configurations/ACLs in routers
 - » Web .htaccess IP literals (instead of domain names) and remote access controls, including new IPv6 address ranges corresponding to existing IPv4 ranges
 - » TCP wrapper files
 - » DNS resolv.conf files
 - » BIND knobs – no AAAA response unless request received via IPv6 transport
 - » NIS/ypbind via hosts files and security masks
 - » Unix portmap security masks
 - » Et cetera ...





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8. Roll out the Solution(s) (continued)

- Consider the following in preparing a schedule for your site:

9. Where else might utilities need to be updated/changed

- » Apache `.Listen` directive hardcoded IP addresses
- » Samba configuration files
- » PERL scripts in MRLG, MRTG, Net::LDAP, and similar
- » Java source code may need `java.io` and `java.net` updates
- » COTS Java applications may need to have defaults set correctly in their scripts
 - Djava.net.preferIPv6Addresses=false
 - Djava.net.preferIPv4Addresses=false
- » Et cetera ...



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9. Analyze Lessons Learned

- Provide feedback early and often to the IPv6 pilot team on what works and what doesn't, to enable us to assist others
- If you are deploying IPv6 in stages, as suggested in step 2 (Describe Desired State), each time you complete a stage you will have additional feedback to provide



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10. Step 10?? I don't remember any step 10!?!
(The key is found in the phrase in stages in step 3)
 - If you have not yet deployed IPv6 on all IT resources in your enclave:
 - Go back to step 3 (Describe Desired State), and establish a new intermediate goal including more of the IT resources at your site
 - Repeat steps 4 through 9 for this more inclusive goal
 - Repeat in stages until all IT resources for your enclave (or all the ones that your site Change Team is willing/able to deploy IPv6 on) are IPv4/IPv6 dual-stack capable
11. Declare success and celebrate a job well done!

