Asia Pacific Network Information Centre

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APNIC Training

IPv6 Tutorial

20 July 2009 – Chennai, India

In conjunction with

Introduction

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Overview

- IPv6 Architecture
- IPv6 Addressing
- IPv6 Subnetting
- Host configuration
- Case study – IXP
- Transition to IPv6 – Tunneling
- IPv6 and DNS
- IPv6 Policies and Procedures
- How to request for IPv6 addresses
- Summary

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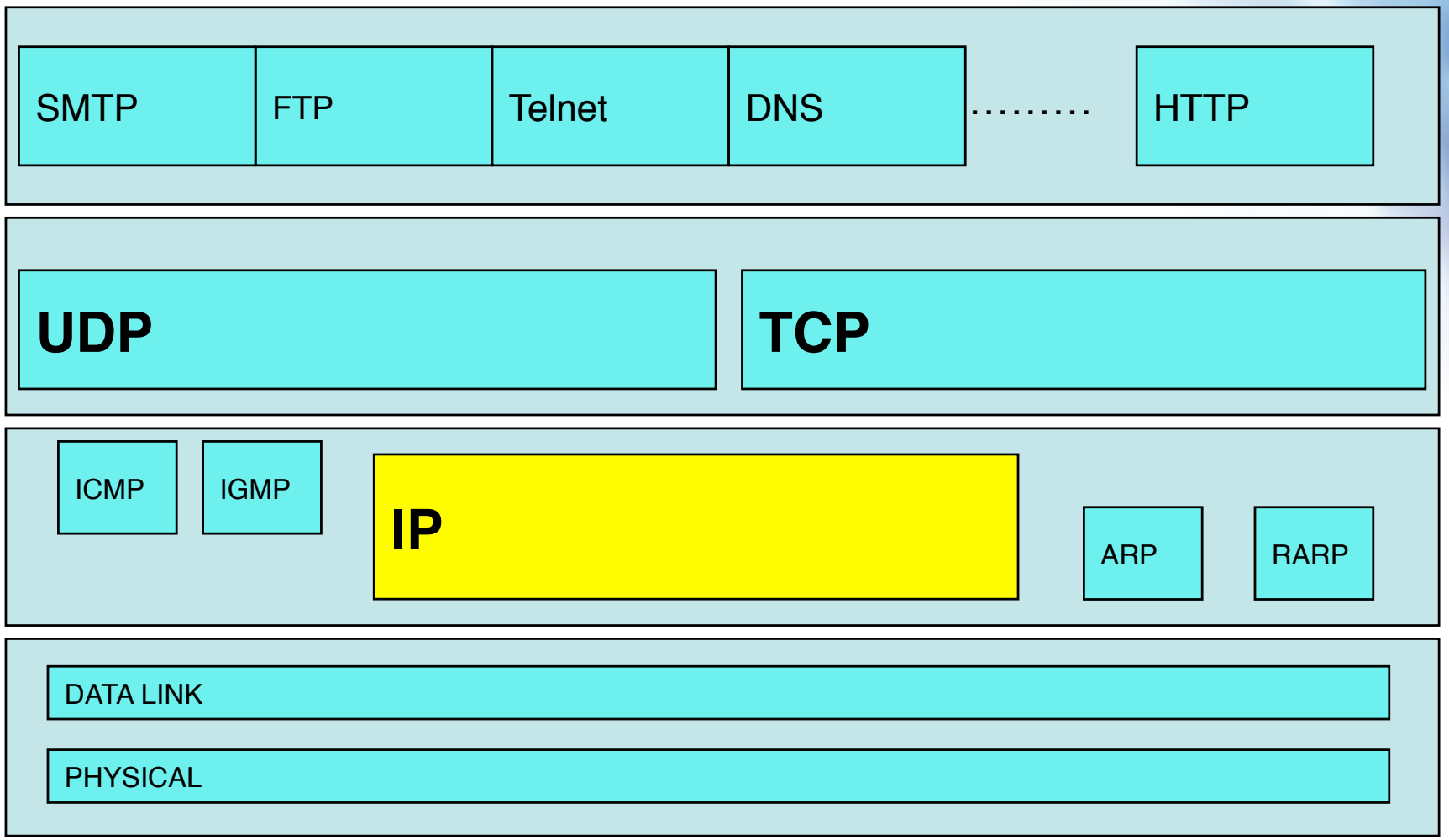
Introduction - IPv6 Architecture Overview

What exactly is the Internet Protocol (IP) ?

- That protocol layer in the TCP/IP protocol stack responsible for the delivery of data to a target destination

TCP/IP protocol structure



IP datagram format

- Datagrams
  - That part of a packet containing the IP headers and the data from the higher layers passed to the IP layer
- IP specifies the header information for the data it requires for its tasks
  - Information needed for routing and delivery
  - E.g. source and destination IP addresses
- It has nothing to do with higher layer headers or data and can transport arbitrary data

So, what is IPv6?

Rationale

- Address depletion concerns
  - Squeeze on available addresses space
    - Probably will never run out, but will be harder to obtain
  - End to end connectivity no longer visible
    - Widespread use of NAT

- IPv6 provides much larger IP address space than IPv4

Main IPv6 benefits

- Expanded addressing capabilities
- Server-less autoconfiguration (“plug-n-play”) and reconfiguration
- More efficient and robust mobility mechanisms
- Built-in, strong IP-layer encryption and authentication
- Streamlined header format and flow identification
- Improved support for options / extensions

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IPv6 Addressing and Subnetting

Size of the IPv6 address space

- An IPv6 address is 16 octets (128 bits)
- This would allow every person on the planet to have their own internet as large as the current Internet
- It is difficult to foresee running out of IPv6 addresses

IPv6 addressing

- 128 bits of address space
- Hexadecimal values of eight 16 bit fields
  - X:X:X:X:X:X:X:X (X=16 bit number, ex: A2FE)
  - 16 bit number is converted to a 4 digit hexadecimal number
- Example:
  - FE38:DCE3:124C:C1A2:BA03:6735:EF1C:683D

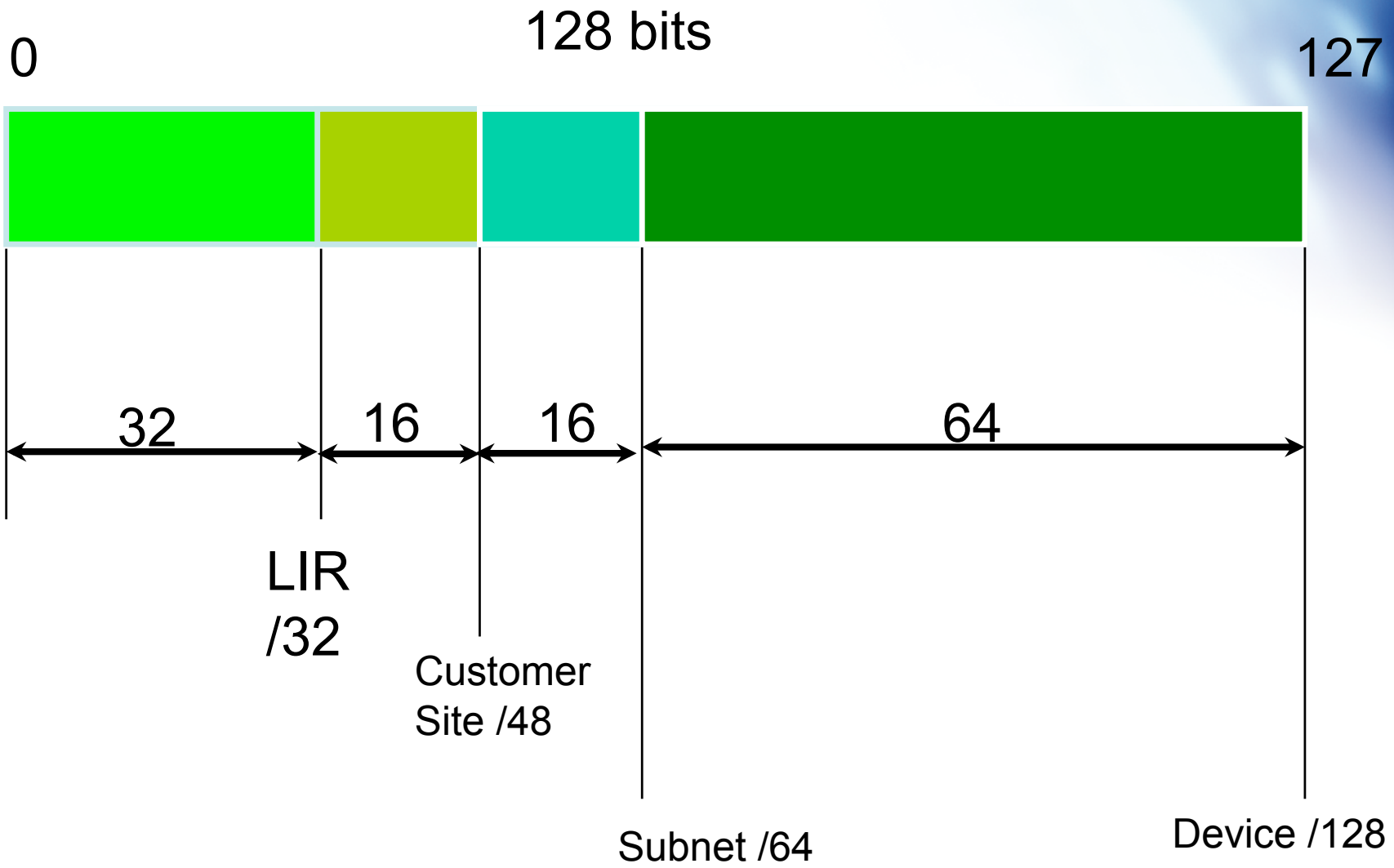
  – Abbreviated form of address
  - 4EED:0023:0000:0000:0000:036E:1250:2B00

  →4EED:23:0:0:0:36E:1250:2B00

  →4EED:23::36E:1250:2B00

  (Null value can be used only once)

IPv6 addressing structure



Exercise 1: IPv6 subnetting

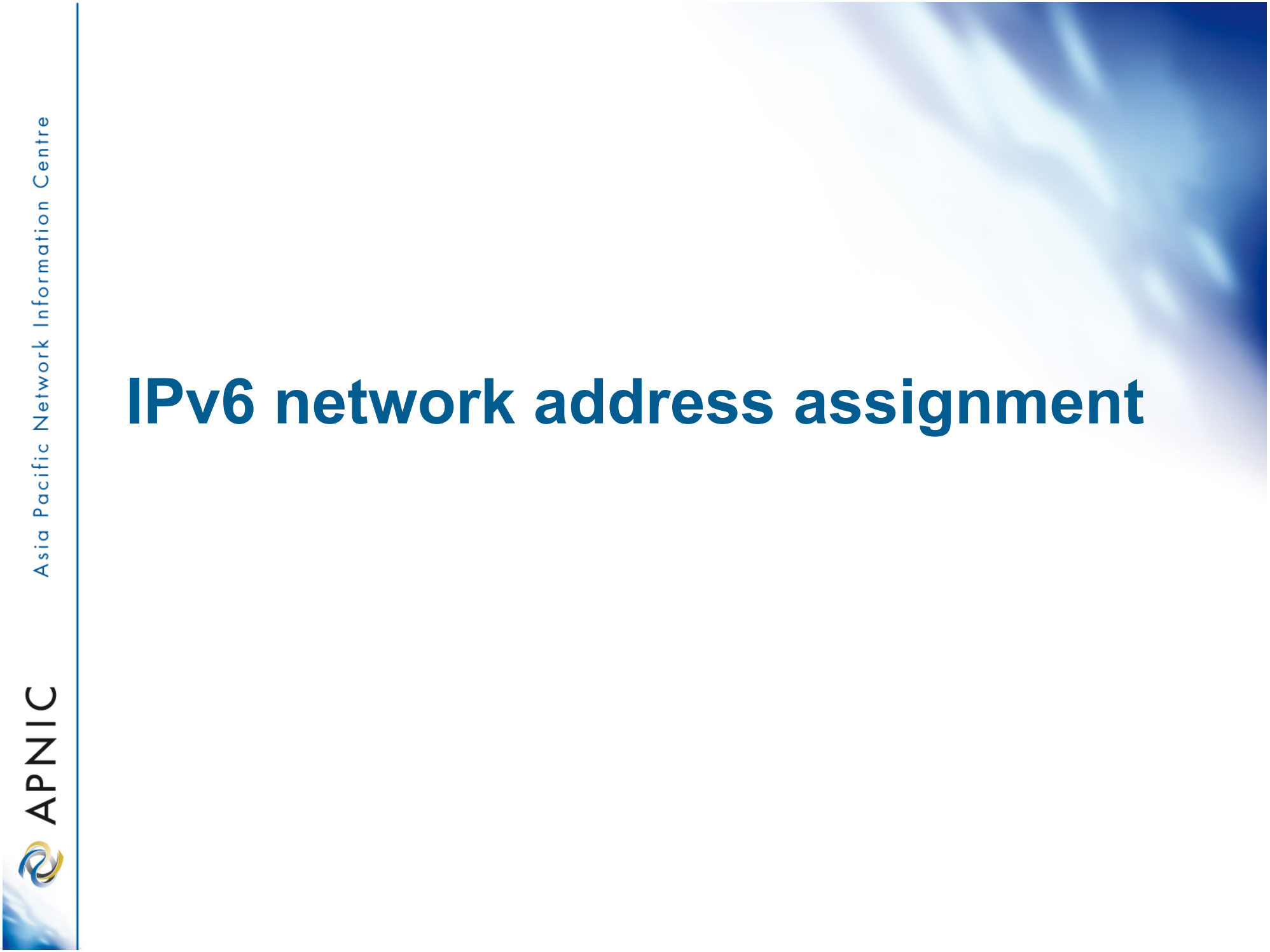
1. Identify the first four /64 address blocks out of 2001:AA:2000::/48
    1. _____
    2. _____
    3. _____
    4. _____

Exercise 2: IPv6 subnetting

1. Identify the fist four /36 address blocks out of 2001:ABC::/32
    1. _____
    2. _____
    3. _____
    4. _____

Exercise 3: IPv6 subnetting

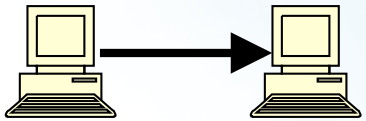
3. Identify the first six /37 address blocks out of 2001:AA::/32
    1. _____
    2. _____
    3. _____
    4. _____
    5. _____
    6. _____

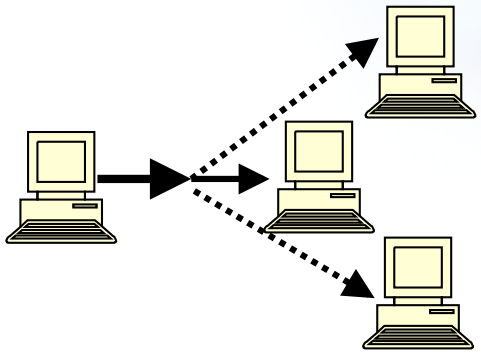


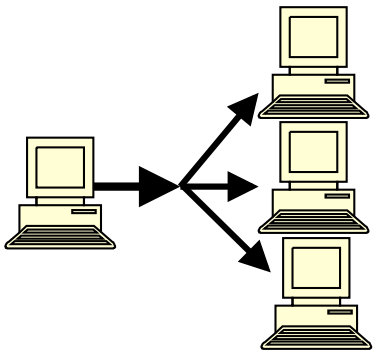
IPv6 network address assignment

IPv6 addressing model

- **IPv6 Address type**
  - Unicast
    - An identifier for a single interface
  - Anycast
    - An identifier for a set of interfaces
  - Multicast
    - An identifier for a group of nodes

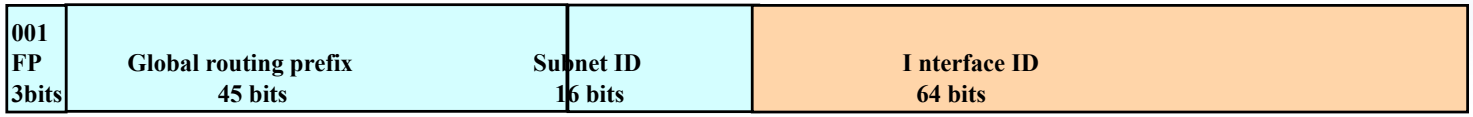




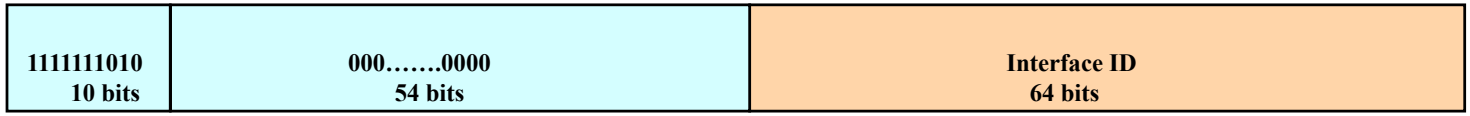


Unicast address

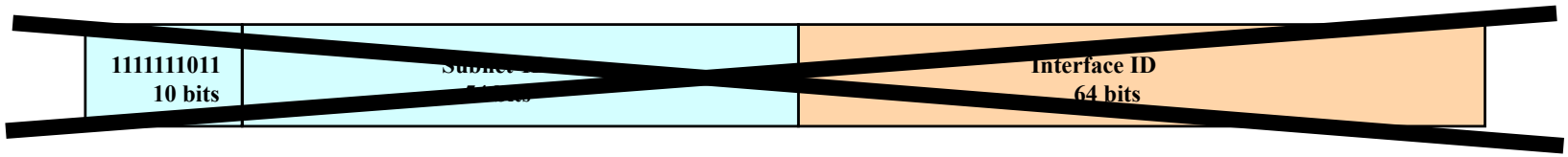
- Address given to interface for communication between host and router
  - Global unicast address currently delegated by IANA



  - Local use unicast address
    - Link-local address (starting with FE80::)



    - Site-local address (starting with FEC0::)



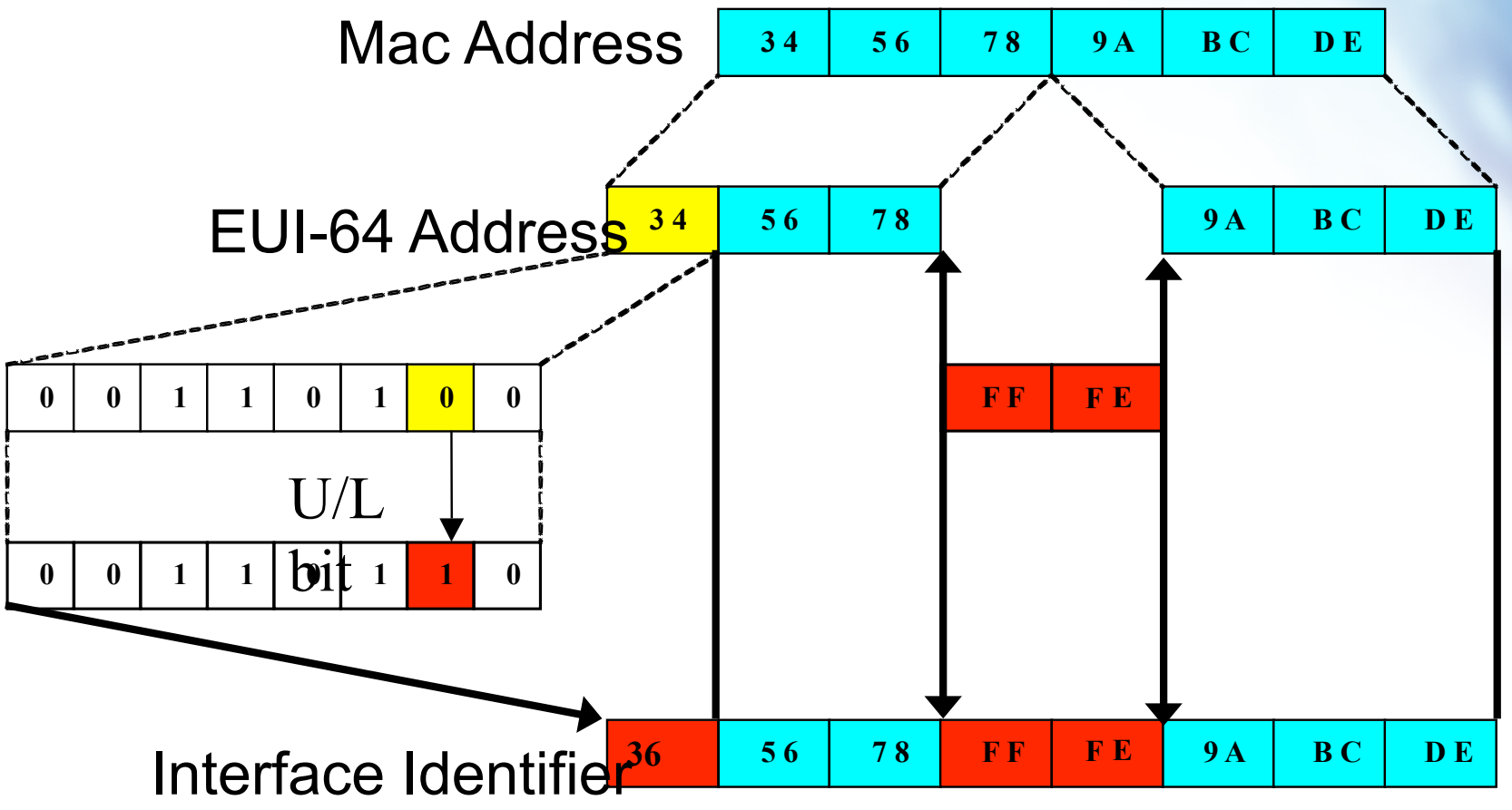
Special addresses

- The unspecified address
  - A value of 0:0:0:0:0:0:0:0 (::)
  - It is comparable to 0.0.0.0 in IPv4
- The loopback address
  - It is represented as 0:0:0:0:0:0:0:1 (::1)
  - Similar to 127.0.0.1 in IPv4

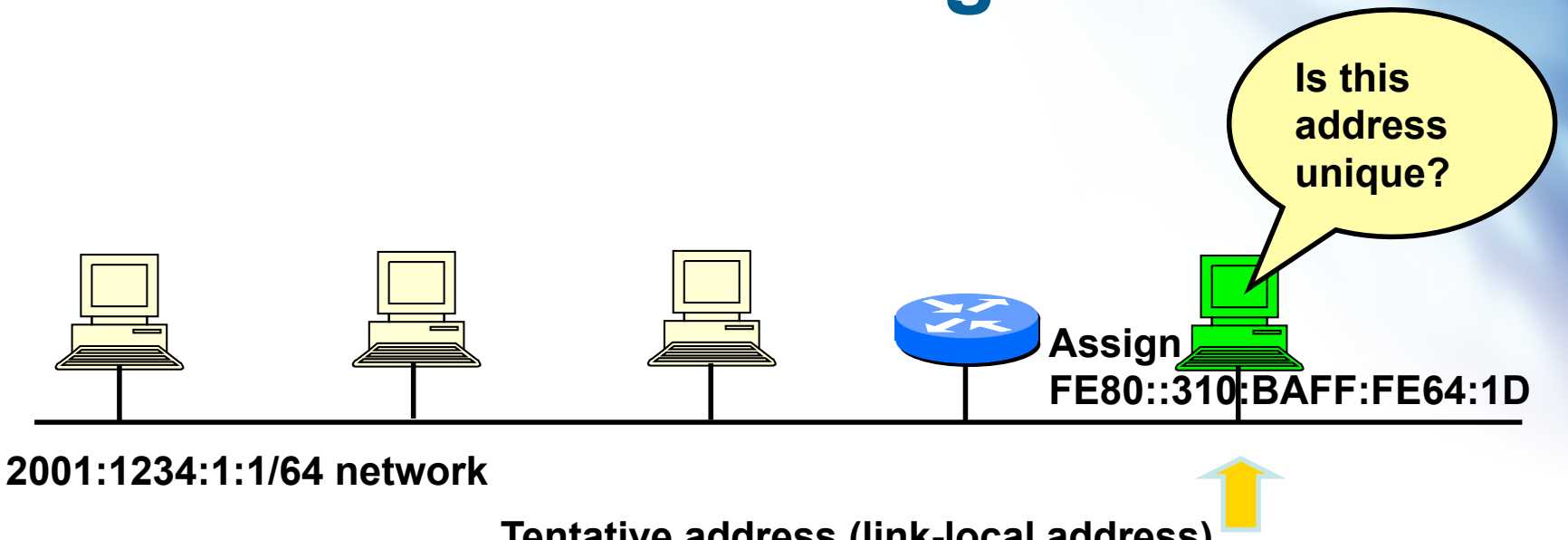
Interface ID

- The lowest-order 64-bit field addresses may be assigned in several different ways:
  - auto-configured from a 48-bit MAC address expanded into a 64-bit EUI-64
  - assigned via DHCP
  - manually configured
  - auto-generated pseudo-random number
  - possibly other methods in the future

EUI-64

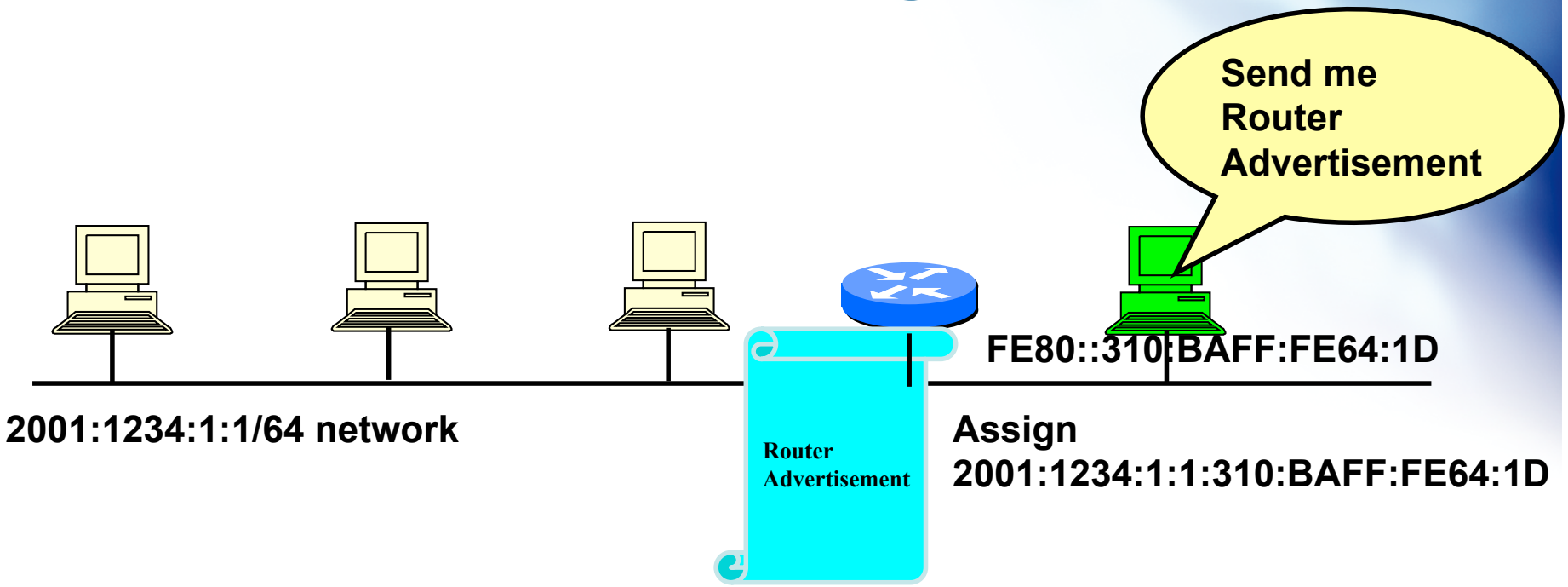


IPv6 autoconfiguration



1. A new host is turned on.
2. Tentative address will be assigned to the new host.
3. Duplicate Address Detection (DAD) is performed. First the host transmit a Neighbor Solicitation (NS) message to all-nodes multicast address (FF02::1)
5. If no Neighbor Advertisement (NA) message comes back then the address is unique.
6. FE80::310:BAFF:FE64:1D will be assigned to the new host.

IPv6 autoconfiguration



1. The new host will send Router Solicitation (RS) request to the all-routers multicast group (FE02::2).
2. The router will reply Routing Advertisement (RA).
3. The new host will learn the network prefix. E.g, 2001:1234:1:1/64
4. The new host will assigned a new address Network prefix+Interface ID E.g, 2001:1234:1:1:310:BAFF:FE64:1D

Exercise

Host configuration

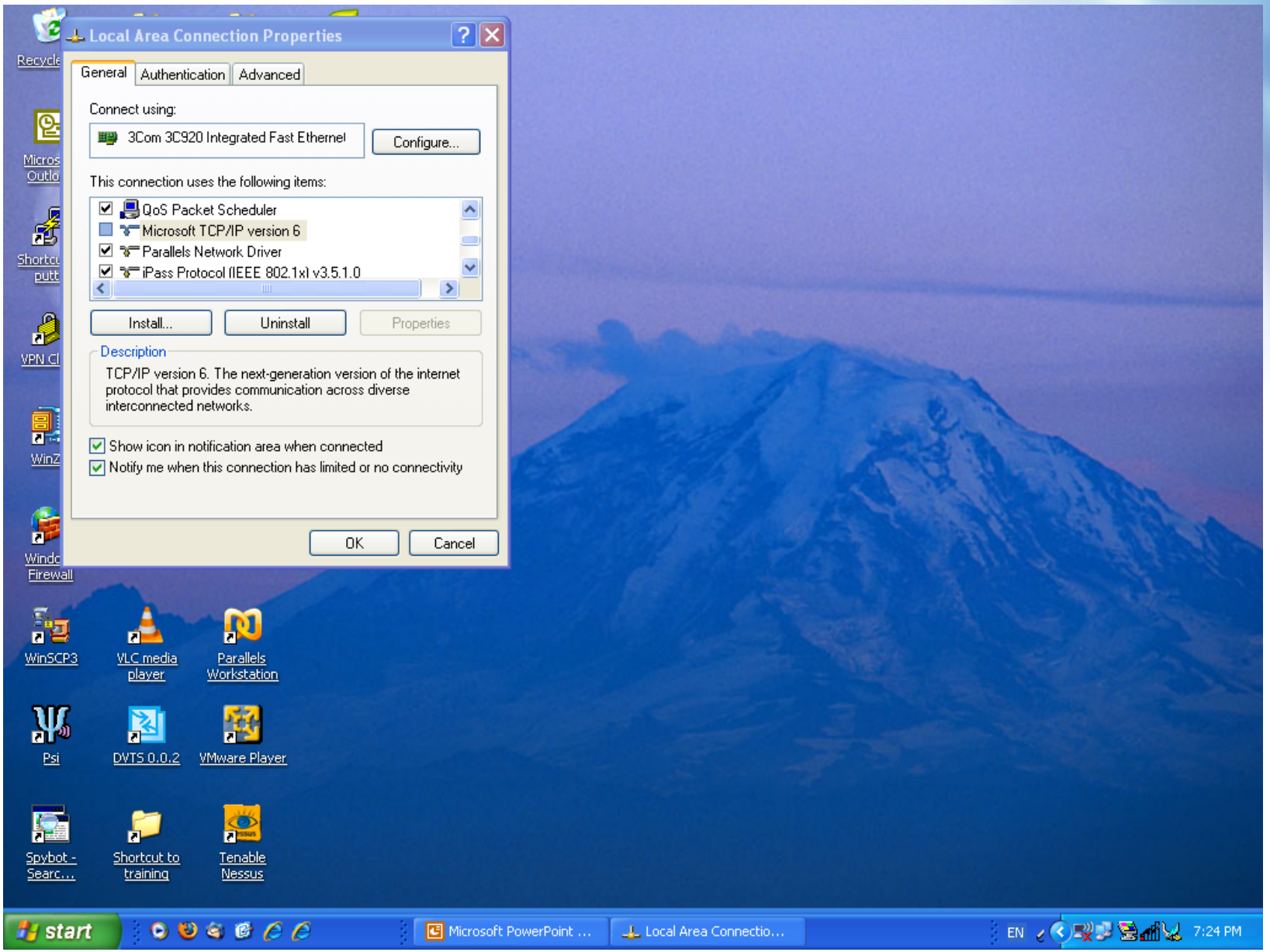
Enabling IPv6 on XP

1. Log on to the computer with a user account that has privileges to change the network configuration.
2. Click **Start**, click **Control Panel**, and then double-click **Network Connections**.
3. Right-click any local area connection, and then click **Properties**.
4. Click **Install**.
5. In the **Select Network Component Type** dialog box, click **Protocol**, and then click **Add**.
6. In the **Select Network Protocol** dialog box, click **Microsoft TCP/IP version 6**, and then click **OK**.
7. Click **Close** to save changes to your network connection.

- Alternately, from the Windows XP desktop, click **Start**, point to **Programs**, point to **Accessories**, and then click **Command Prompt**. At the command prompt
  - Type **netsh interface ipv6 install**

http://www.microsoft.com/technet/network/ipv6/ipv6faq.mspx#EBE

Enabling IPv6 on XP



IPv6 on XP

- XP is not able to operate in an IPv6-only environment
  - XP supports IPv6 in dual stack operation with IPv4
  - In reality, given the current Internet, an office network should become an IPv4/IPv6 dual network, not IPv6-only

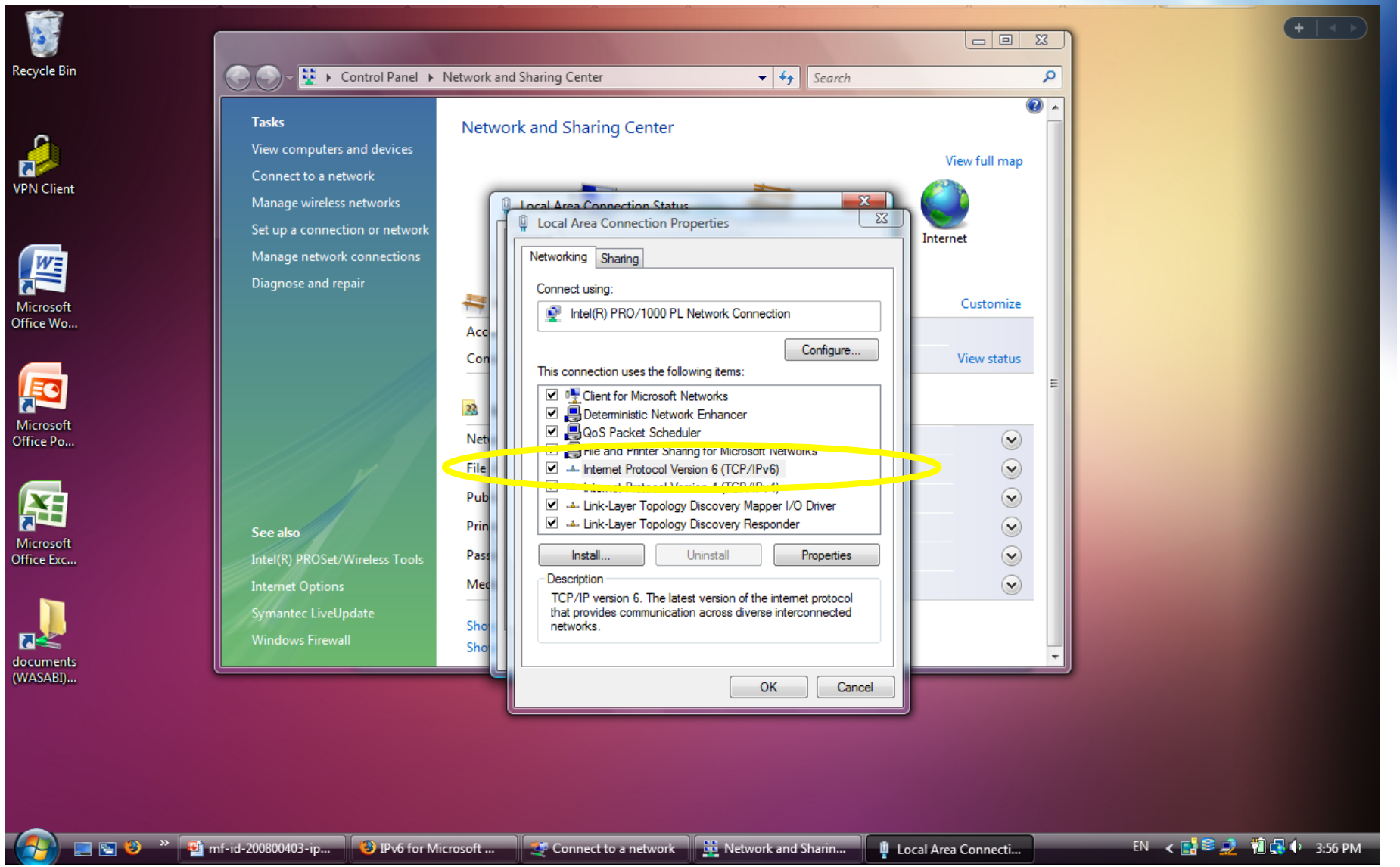
http://www.ipv6style.jp/en/20070115/vista_lifehack1.html

Vista and IPv6

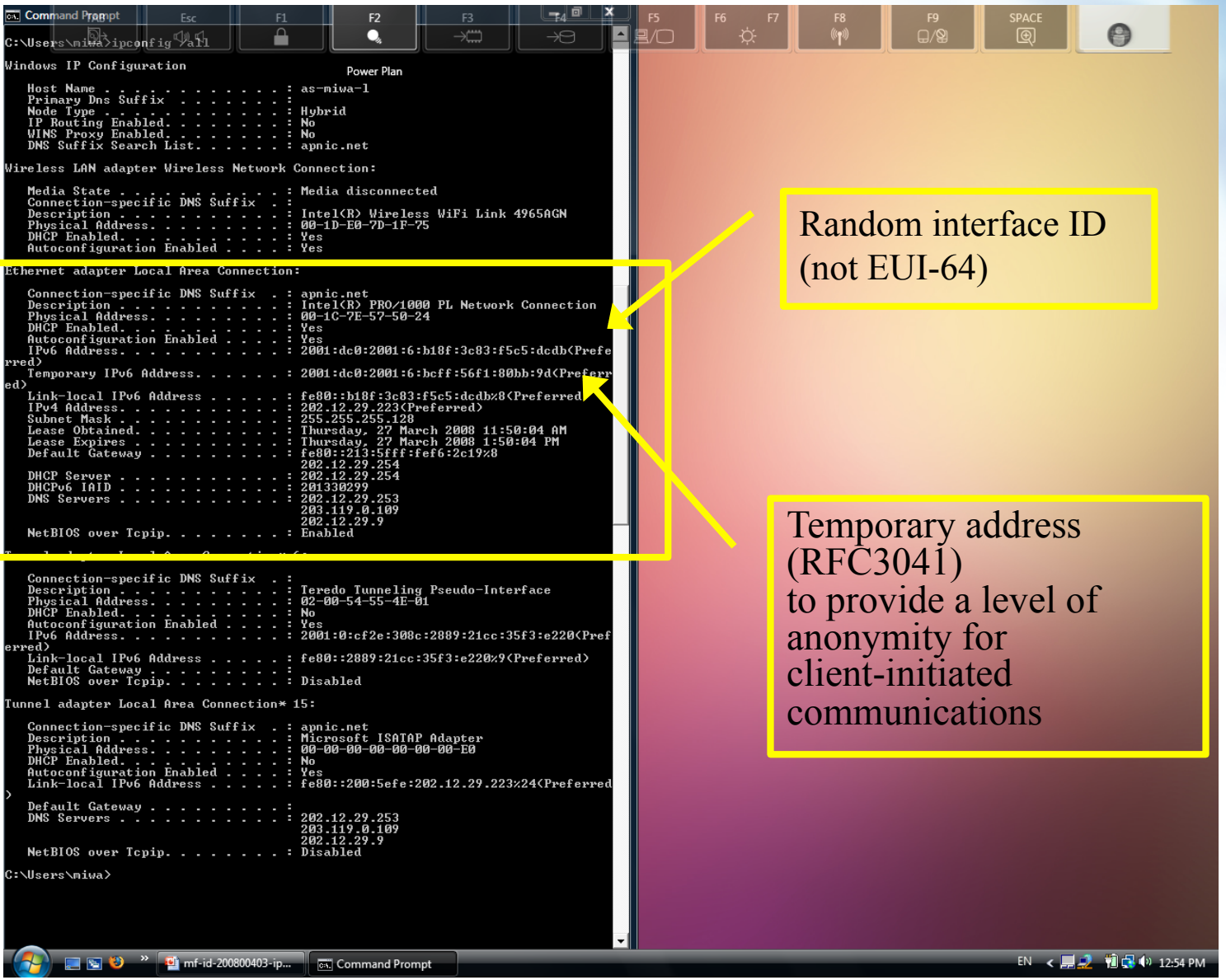
- The IPv6 protocol for Windows Vista and Windows Server 2008 is installed and enabled by default.
- It appears as the **Internet Protocol Version 6 (TCP/IP)** component on the **Networking** tab when you obtain the properties of a connection (via “View Status”)
  - Available from the **Network and Sharing Center**

http://www.microsoft.com/technet/network/ipv6/ipv6faq.mspx#EBE

Vista and IPv6



Vista interface information



http://technet.microsoft.com/en-us/magazine/cc137983.aspx

Vista interface information

IPv6 disabled

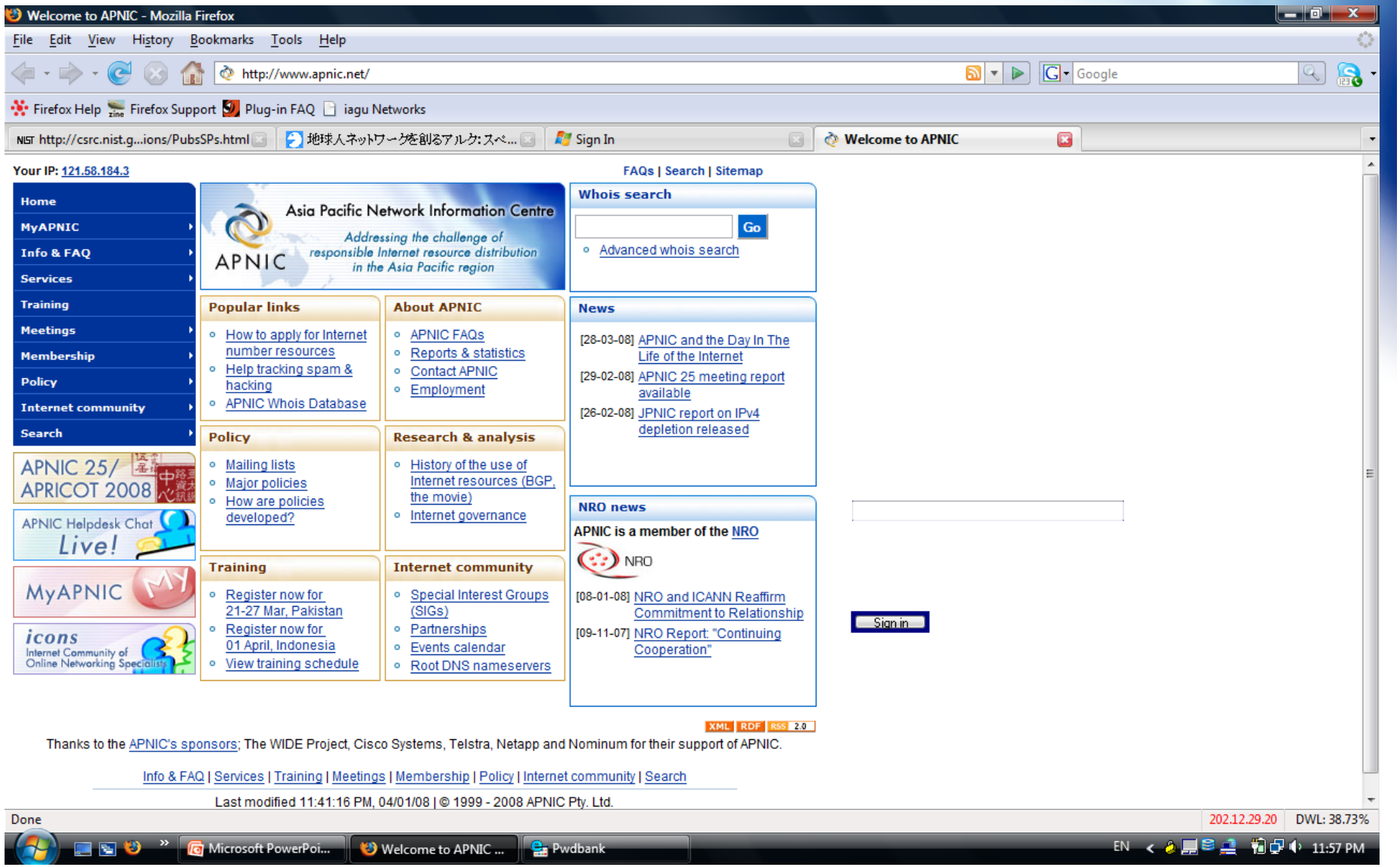
Q.How do I disable IPv6 in Windows Vista and Windows Server 2008?

A.Unlike Windows XP and Windows Server 2003, IPv6 in Windows Vista and Windows Server 2008 cannot be uninstalled. However, you can disable IPv6 in Windows Vista and Windows Server 2008 by doing one of the following:

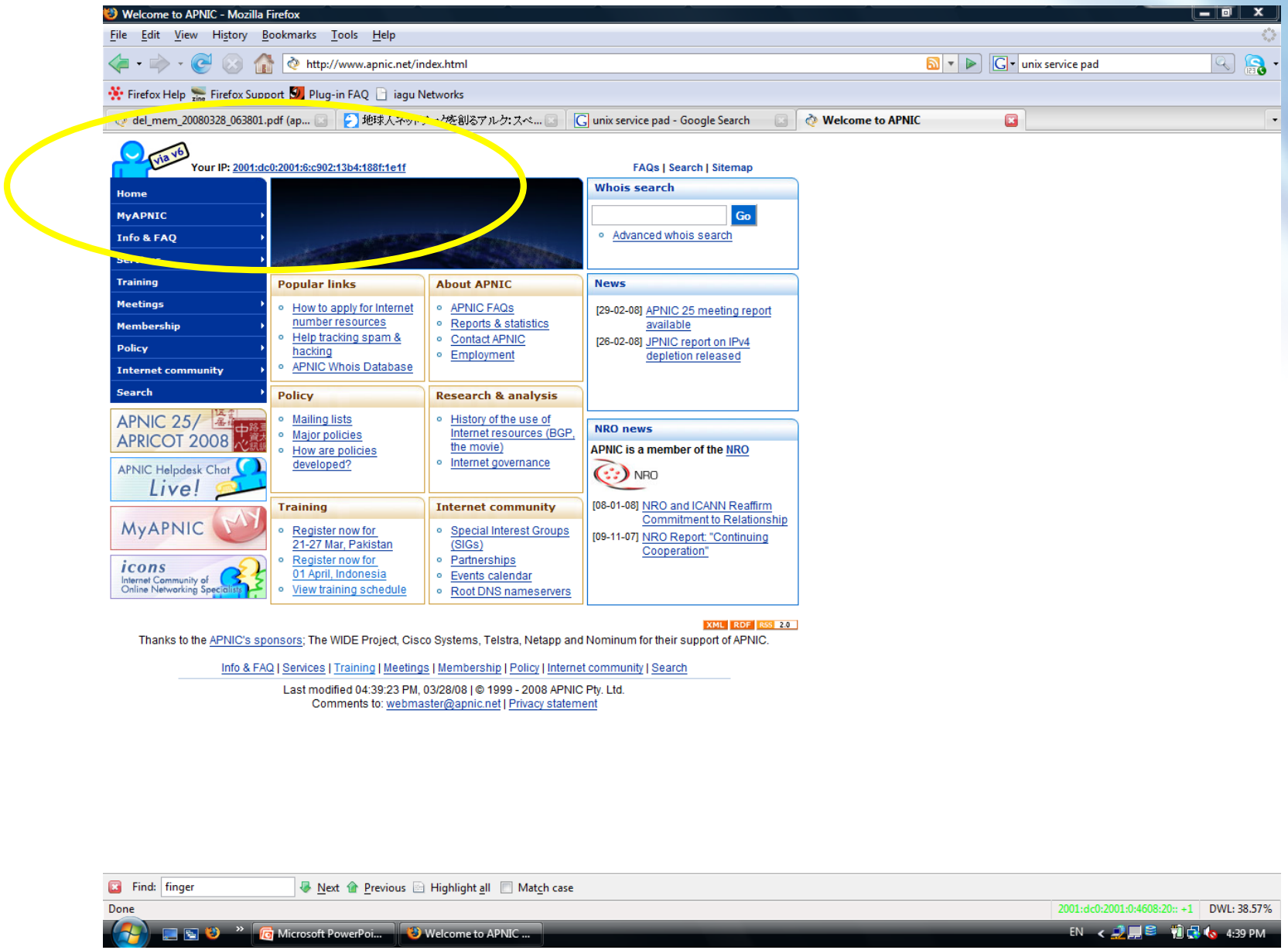
- In the Network Connections folder, obtain properties on all of your connections and adapters and clear the check box next to the **Internet Protocol version 6 (TCP/IPv6)** component in the list under **This connection uses the following items**.
- This method disables IPv6 on your LAN interfaces and connections, but does not disable IPv6 on tunnel interfaces or the IPv6 loopback interface.

http://www.microsoft.com/technet/network/ipv6/ipv6faq.mspx

If your host is IPv6 enabled then…



If your host is IPv6 enabled then…



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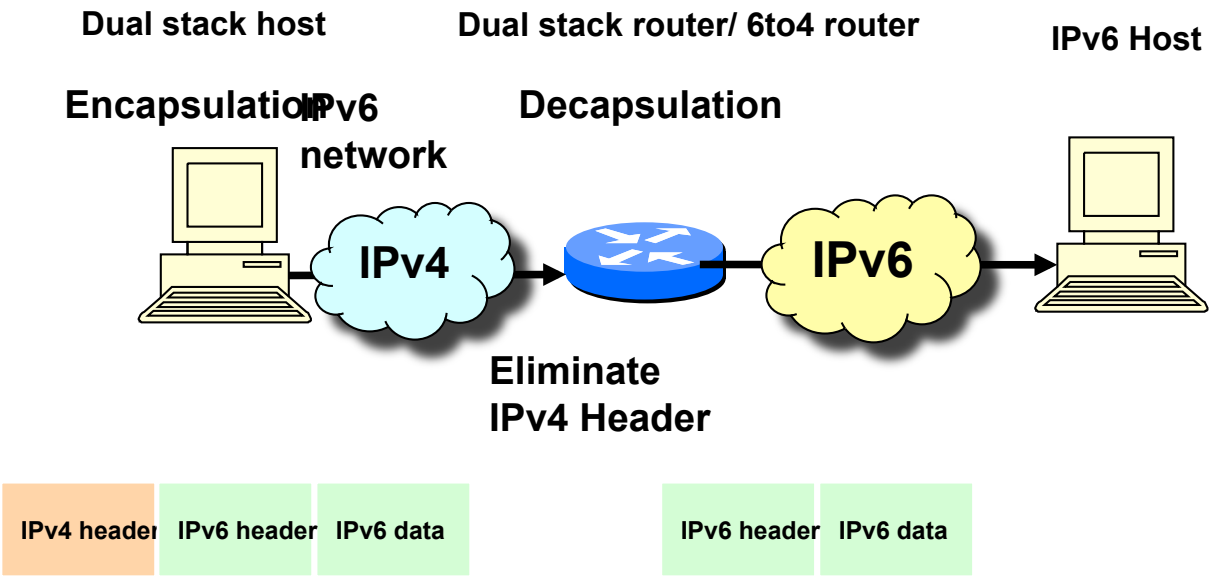
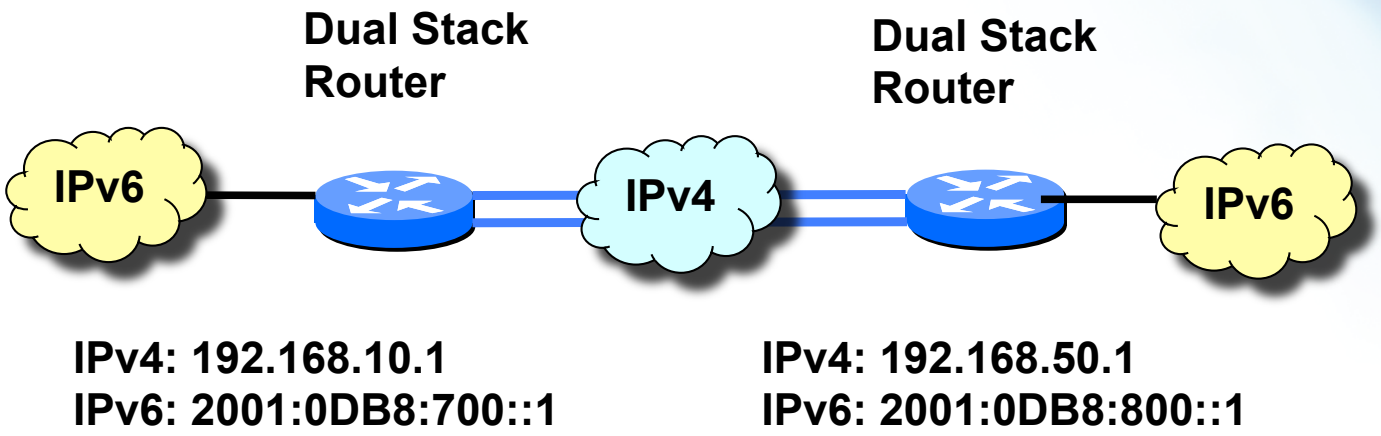
IPv6 Configuration – Building an IPv6 Tunnel

Tunneling – general concept

- Tunneling can be used by routers and hosts
  - IPv6-over-IPv4 tunneling



Manual configuration



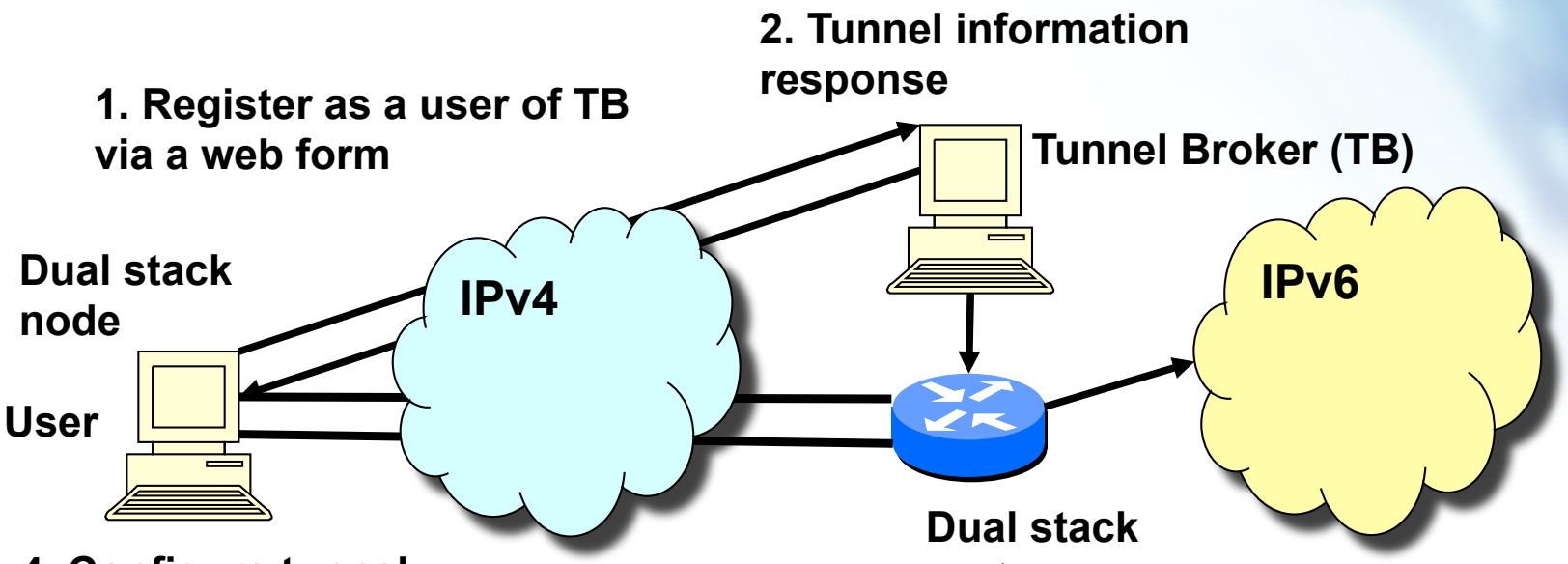
Manually configured tunnels require:

- Dual stack end points
- Explicit configuration with both IPv4 and IPv6 addresses at each end

Concept is borrowed from Cisco, Training material "Ipv6 Seminar" delivered at South Asian IPv6 Summit, Jan 2004

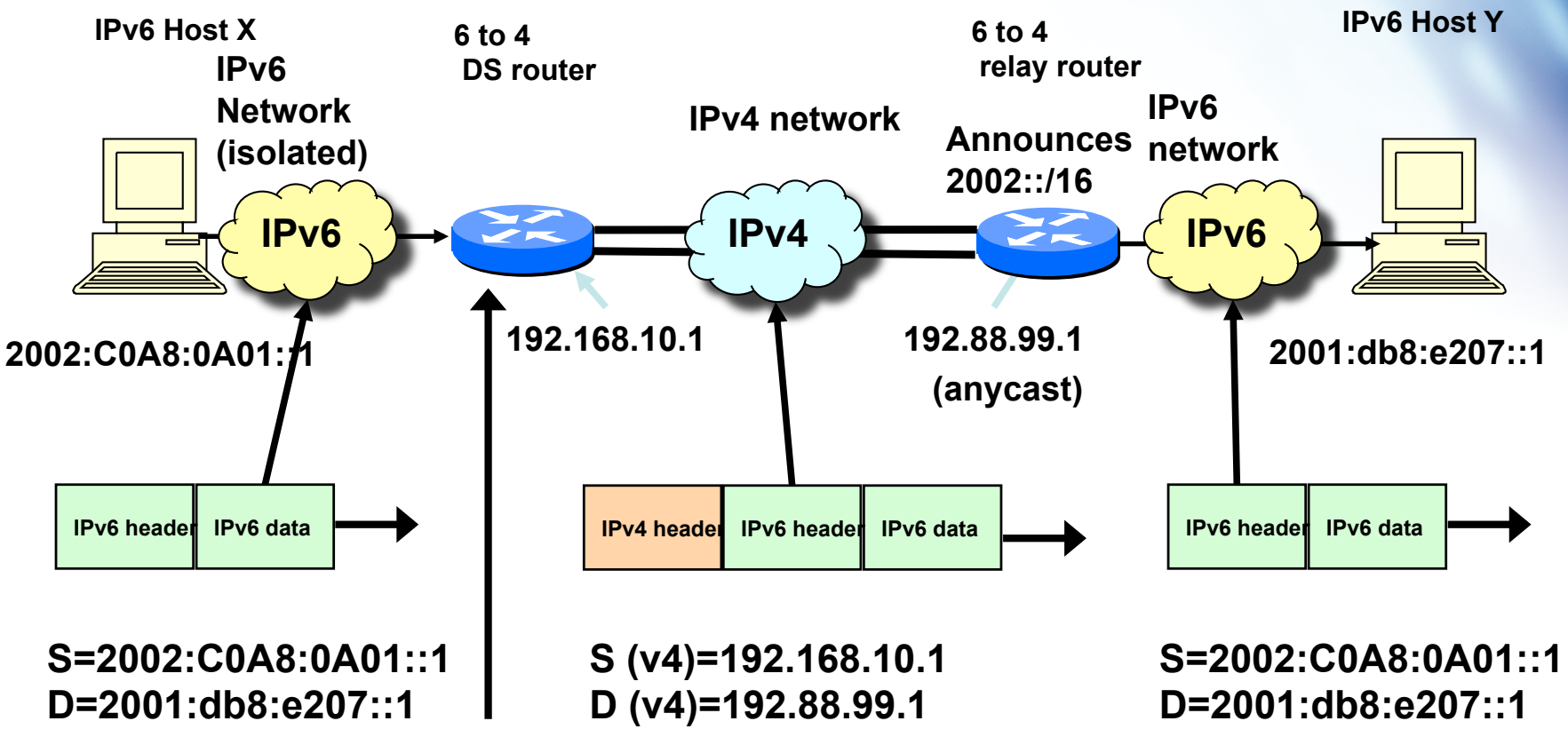
Tunnel broker

RFC 3053



Automatic tunneling – 6to4

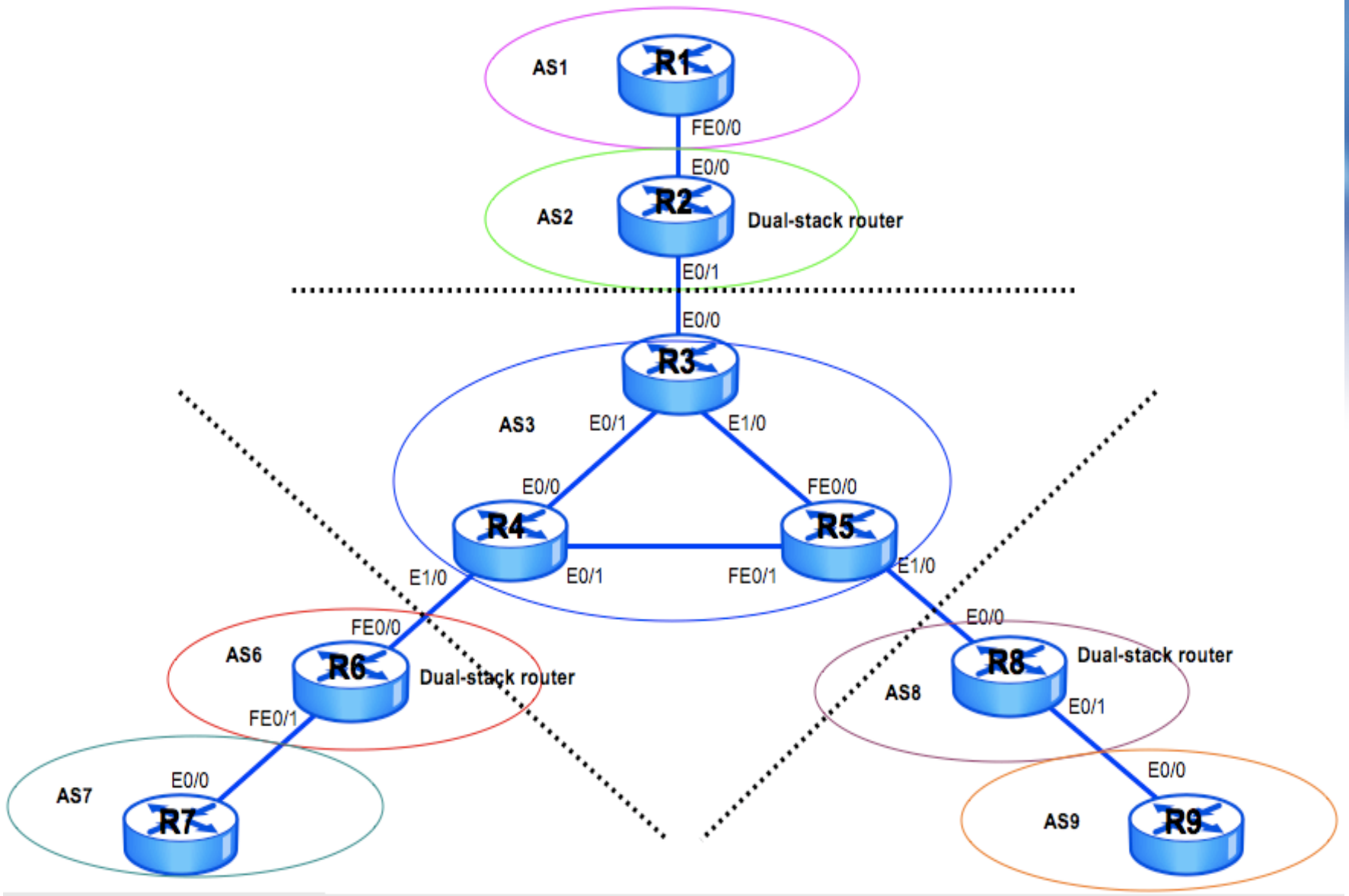
RFC 3056 RFC 3068



Default IPv6 route is 2002:co58:6301::

A destination route to a 2002::/ prefix is encapsulated in IPv4 and bits 17 – 48 used as the next hop. Ie 192.88.99.1 anycast

Configuring a manual tunnel


AS1
R1
FE0/0
E0/0
AS2
R2
Dual-stack router
E0/1
E0/0
R3
AS3
E0/1
E1/0
E0/0
FE0/0
R4
R5
E1/0
E0/1
FE0/1
E1/0
E0/0
FE0/0
AS6
R6
Dual-stack router
FE0/1
AS8
R8
Dual-stack router
E0/1
E0/0
AS7
R7
E0/0
AS9
R9

- Create the appropriate interface for the the tunnel.

Router # configure terminal
Router(config)# interface tunnel [tunnel interface number]

- *Example (for router 2):*

- *Router2* ***# configure terminal***
- *Router2(config) #* ***interface tunnel 1***

- Configure the IPv6 address of the interface created “tunnel 1” with a /64 subnet.

Router(config-if)# ipv6 address ipv6 address/prefix size in CIDR

  - Example for Router 2:

  - *Router(config-if) #* ***ipv6 address 2001:2:1::1/64***

- NOTE: The other side of the tunnel should be in the same subnet
  - Eg. 2001:2:1::2/64

- Enable IPv6 on the tunnel interface.
  - Example for Tunnel1:
  - ***Router2(config-if) # ipv6 enable***

- Configure the interface with “tunnel source interface” or the “tunnel source IP address”.
  - Example for Router 2:

Router2(config-if) # tunnel source 192.168.0.2

- Configure the interface with tunnel destination IP address.
  - Example for Router2 tunnel with Router8:

Router2(config-if) # tunnel destination 192.168.0.8

- Configure the tunnel interface mode (determining how the packet will be transferred to the other dual-stack router)

- ***Router2(config-if) # tunnel mode ipv6ip*** *(for manual tunnel)*

- Create a static route to a the destination IPv6 network, Define the whole /48 subnet

- ***Router2(config)*ipv6 route destination network/prefix <outbound interface or next hop IP address>**
- Example for Router 2: (To reach Router8 customer network via tunnel interface 1)
  - ***Router2(config)#ipv6 route 2001:8::/48 tunnel 1*** *(outbound interface)*
- ***Or***
  - ***Router(config)#ipv6 route 2001:8::/48 2001:2:1::2*** *(next-hop IP- the other end of the tunnel)*

Deploying IPv6 – configuring DNS for IPv6

IPv6 representation in the DNS

- Forward lookup support: Multiple RR records for name to number
  - AAAA (Similar to A RR for IPv4)
- Reverse lookup support:
  - Reverse nibble format for zone ip6.arpa

IPv6 forward lookups

- Multiple addresses possible for any given name
  - Ex: in a multi-homed situation
- Can assign A records and AAAA records to a given name/domain
- Can also assign separate domains for IPv6 and IPv4

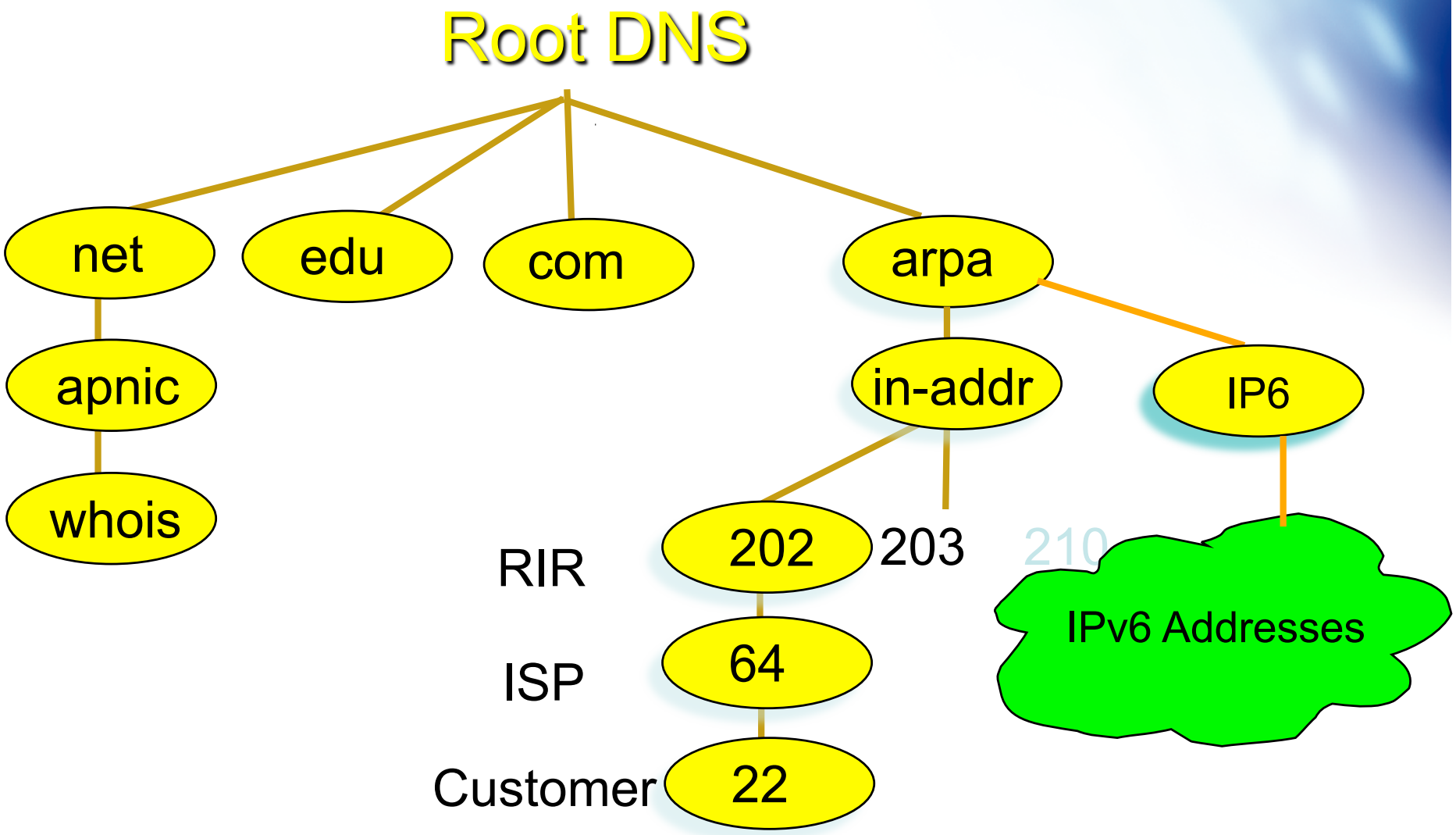
Sample forward lookup file

```
;; domain.edu
$TTL            1d
@     IN        SOA     ns1.domain.edu. root.domain.edu. (
                2009041400    ; serial - YYYYMMDDXX
                6h            ; refresh - 6 hours
                20m           ; retry - 20 minutes
                3600000       ; expire - long time
                1d)           ; negative cache - 24 hours
;; Nameservers
                IN     NS     ns1.domain.edu.
                IN     NS     ns2.domain.edu.

;; Hosts with just A records
host1           IN     A      1.0.0.1

;; Hosts with both A and AAAA records
host2           IN     A      1.0.0.2
                IN     AAAA   2001:468:100::2
```

The reverse DNS tree – with IPv6



IPv6 reverse lookups - PTR records

- Similar to the in-addr.arpa

```
b.a.9.8.7.6.5.0.4.0.0.0.3.0.0.0.2.0.0.0.1.0.0.0.0.0.0.0.1.2.3.4.ip6.arpa.
        IN    PTR       test.ip6.example.com.
```

- Example: reverse name lookup for a host with address 3ffe:8050:201:1860:42::1

```
$ORIGIN 0.6.8.1.1.0.2.0.0.5.0.8.e.f.f.3.ip6.arpa.

1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.2.4.0.0   14400   IN PTR host.example.com.
```

Sample reverse lookup file

```
;; 0.0.0.0.0.0.1.0.8.6.4.0.1.0.0.2.rev
;; These are reverses for 2001:468:100::/64)
$TTL            1d
@     IN       SOA      ns1.domain.edu. root.domain.edu. (
                            2009041400        ; serial - YYYYMMDDXX
                            6h                ; refresh - 6 hours
                            20m               ; retry - 20 minutes
                            3600000           ; expire - long time
                            1d)               ; negative cache - 24 hours
;; Nameservers
                    IN       NS       ns1.domain.edu.
                    IN       NS       ns2.domain.edu.
1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0    IN       PTR      host1.ip6.domain.edu
2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0    IN       PTR      host2.domain.edu
;;
;; Can delegate to other nameservers in the usual way
;;
```

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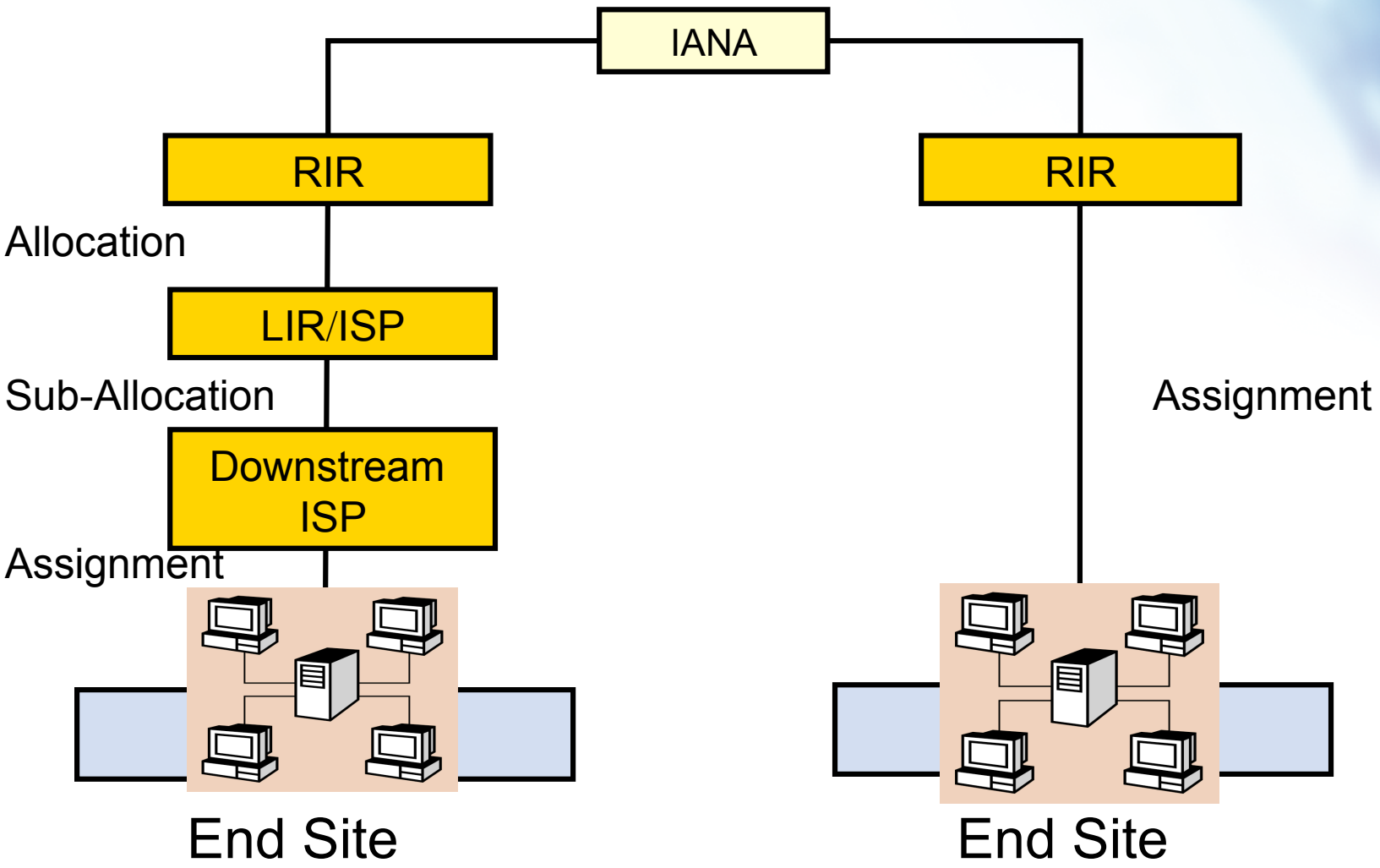
IPv6 –
current facts, figures and policies

IPv6 address management hierarchy



IPv6 address policy goals

- Efficient address usage
  - Avoid wasteful practices
- Aggregation
  - Hierarchical distribution
  - Aggregation of routing information
  - Limiting number of routing entries advertised
- Minimise overhead
  - Associated with obtaining address space
- Registration, Uniqueness, Fairness & consistency

IPv6 initial allocation

- To qualify for an initial allocation of IPv6 address space, an organization must:
  - 1. Be an LIR
  - 2. Not be an end site
  - 3. Plan to provide IPv6 connectivity to organizations to which it will make assignments, by advertising that connectivity through its single aggregated address allocation
  - 4. Meet one of the two following criteria:
    - Have a plan for making at least 200 assignments to other organizations within two years OR
    - Be an existing LIR with IPv4 allocations from an APNIC or an NIR, which will make IPv6 assignments or sub-allocations to other organizations and announce the allocation in the inter-domain routing system within two years

IPv6 initial allocation

- Private networks (those not connected to the public Internet) may also be eligible for an IPv6 address space allocation provided they meet equivalent criteria to those listed above.

- Initial allocation size is /32
  - Default allocation (“slow start”)

IPv6 initial allocation

- Initial allocations larger than /32 may be justified if:
  - 1. The organization provides comprehensive documentation of planned IPv6 infrastructure which would require a larger allocation; or
  - 2. The organization provides comprehensive documentation of all of the following:
    - its existing IPv4 infrastructure and customer base,
    - its intention to provide its existing IPv4 services via IPv6, and
    - its intention to move some of its existing IPv4 customers to IPv6 within two years.

End site assignment policy for IPv6

- Any size longer than /48
  - Decision is up to LIRs or ISPs
    - Implication: any size between /64 - /48
  - Global coordination is required
  - Assuming the HD ratio changes to a larger value
    - HD ratio measurement unit: /48 => /56
      - Implication: Register all assignments shorter than /56?
    - HD ratio: 0.8 => 0.94

IPv6 utilisation

- Utilisation determined from end site assignments
  - LIR responsible for registration of all /48 assignments
  - Intermediate allocation hierarchy not considered
- Utilisation of IPv6 address space is measured differently from IPv4
  - Use HD ratio to measure
- Subsequent allocation may be requested when IPv6 utilisation requirement is met

Amend IPv6 assignment and utilisation requirement

- IPv6 assignment and utilisation requirement policy
  - HD ratio: 0.8 => 0.94
  - Measurement unit: /48 => /56
- The HD ratio threshold is
  - HD=log(/56 units assigned) / log (16,777,216)
  - 0.94 = 6,183,533 x /56 units
- Calculation of the HD ratio
  - Convert the assignment size into equivalent /56 units
    - Each /48 end site = 256 x /56 units
    - Each /52 end site = 16 x /56 units
    - Each /56 end site = 1 x /56 units
    - Each /60 end site = 1/16 x /56 units
    - Each /64 end site = 1/256 x /56 units

IPv6 utilisation (HD = 0.94)

- Percentage utilisation calculation

IPv6 Prefix	Site Address Bits	Total site address in /56s	Threshold (HD ratio 0.94)	Utilisation %
/42	14	16,384	9,153	55.9%
/36	20	1,048,576	456,419	43.5%
/35	21	2,097,152	875,653	41.8 %
/32	24	16,777,216	6,185,533	36.9%
/29	27	134,217,728	43,665,787	32.5 %
/24	32	4,294,967,296	1,134,964,479	26.4 %
/16	40	1,099,511,627,776	208,318,498,661	18.9 %

RFC 3194

"In a hierarchical address plan, as the size of the allocation increases, the density of assignments will decrease."

Subsequent allocation

- Must meet HD = 0.94 utilisation requirement of previous allocation (subject to change)
- Other criteria to be met
  - Correct registrations (all /48s registered)
  - Correct assignment practices etc
- Subsequent allocation results in a doubling of the address space allocated to it
  - Resulting in total IPv6 prefix is 1 bit shorter
  - Or sufficient for 2 years requirement

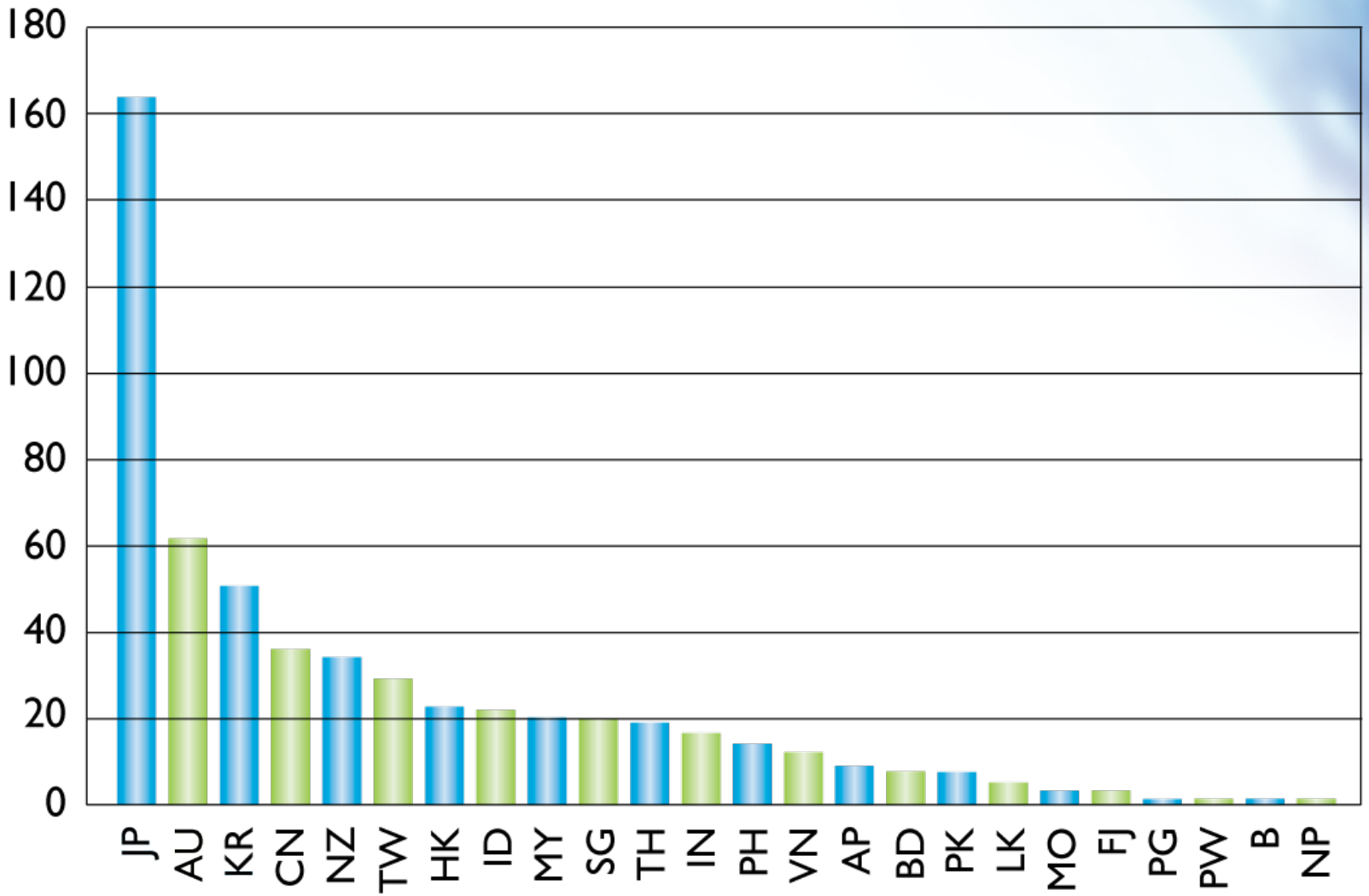
IXP IPv6 assignment policy

- Criteria
  - Demonstrate ‘open peering policy’
  - 3 or more peers
- Portable assignment size: /48
  - All other needs should be met through normal processes
  - /64 holders can “upgrade” to /48
    - Through NIRs/ APNIC
    - Need to return /64

IPv6 portable assignment for multihoming

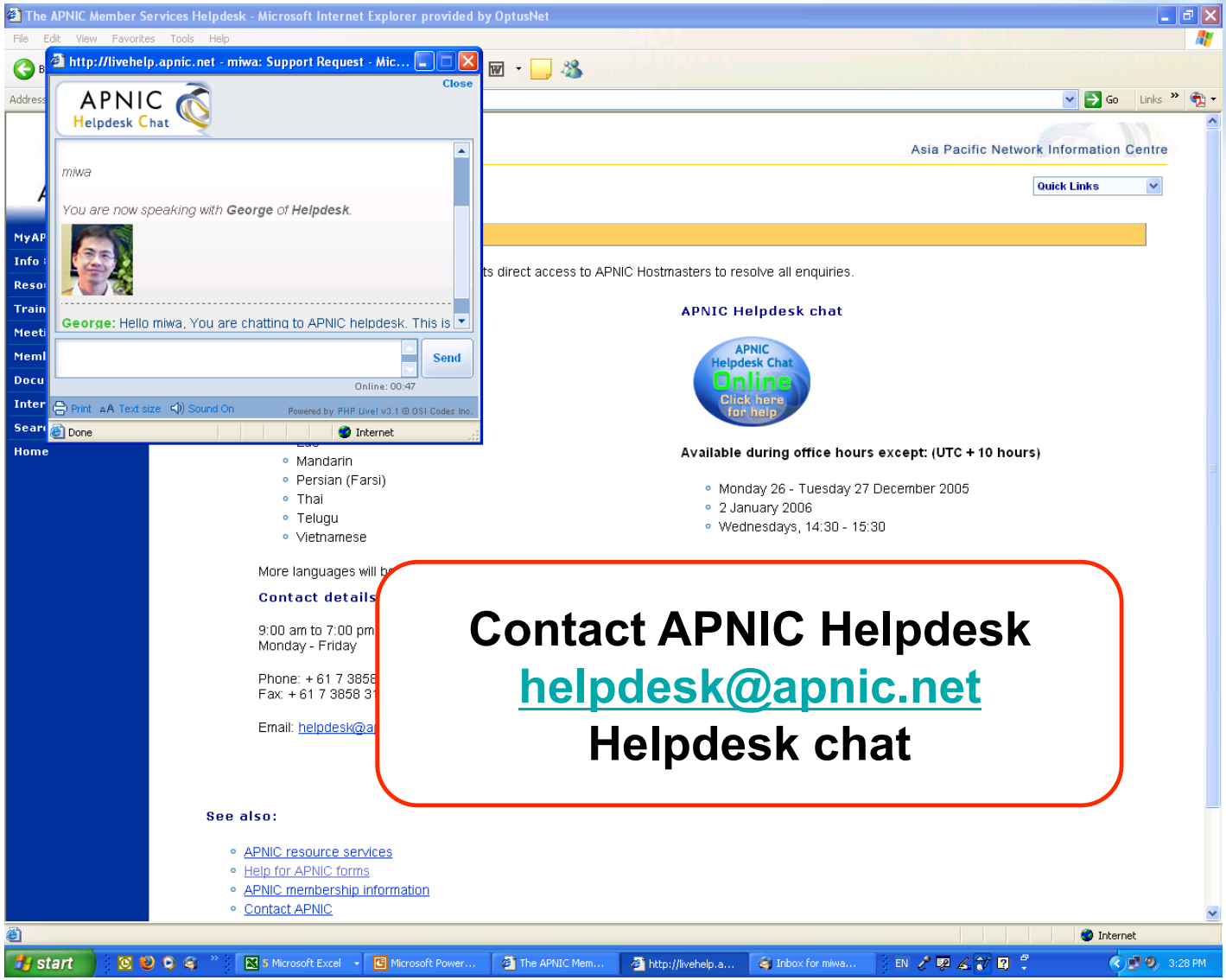
- The current policy did not allow IPv6 portable assignment to end-sites
  - Obstructs setting redundancy connectivity for stable network operation
  - Size: /48, or a shorter prefix if the end site can justify it
  - To be multihomed within 3 months
  - Assignment from a specified block separately from portable allocations address space

APNIC IPv6 delegation by economy



http://www.apnic.net/stats/o3/ as of 26/03/2009

Need IPv6 addresses?



How do I apply for IPv6 addresses?

Check your eligibility for IPv6 addresses

Read IPv6 policies

http://www.apnic.net/docs/policy/ipv6-address-policy.html

Read IPv6 guideline

http://www.apnic.net/docs/policy/ipv6-guidelines.html

Do you have an APNIC account?

If not, become an APNIC member or open a non-member account

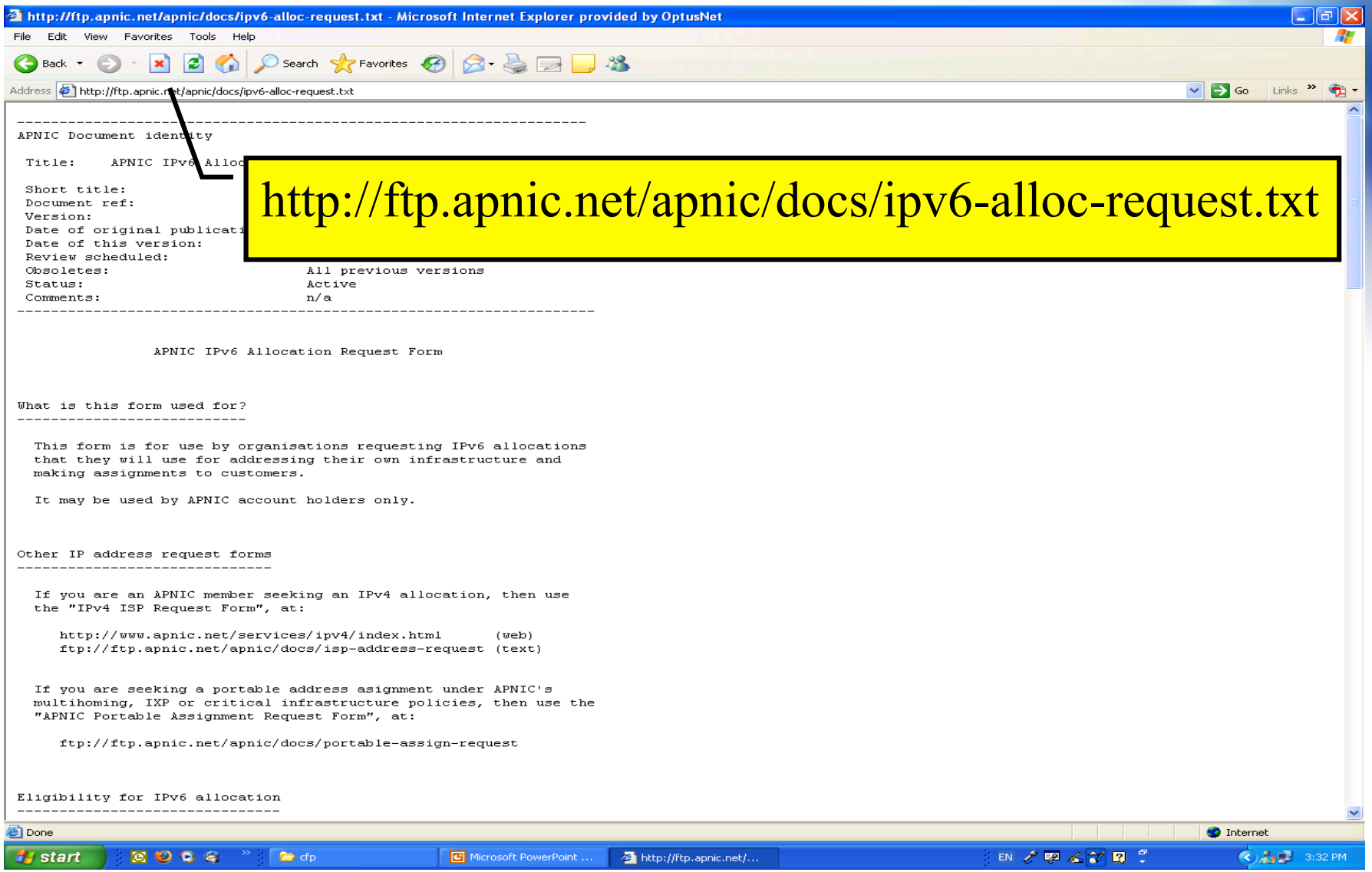
Complete an IPv6 address request form

Submit the form hostmaster@apnic.net

Questions:
email: helpdesk@apnic.net

Helpdesk chat: http://www.apnic.net/helpdesk

IPv6 address request form



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IPv6 address request form

- Requester template
  - Name, email, acct-name, org-relationship:
- Network template
  - Netname, descr, country, admin-c, tech-c, remarks, changed, mnt-lower
- IPv6 usage template
  - Services, cust-types, cust-network, infrastructure, network-plan
- Additional information

Sample form

#[REQUESTOR TEMPLATE]#

name: Ahmad Rahman

email: ar@skynet.net.in

acct-name: SKYNET-IN

org-relationship: Manager

Sample form

#[NETWORK TEMPLATE]#
netname: SKYNET-IN
descr: SKYNET LIMITED
descr: Internet Service Provider
country: IN
admin-c: AR100-AP
tech-c: AR100-AP
remarks: IPv6 Network of SKYNET
changed: ar@skynet.net.in
mnt-lower: MAINT-SKYNET-IN

Sample form

#[IPV6 USAGE TEMPLATE]#

services: ADSL services, VPN and Application Hosting

cust-types: Residential, SOHO, Enterprise, ISPs

infrastructure: /48 /64,/64,/48 20 Mail server segments

infrastructure: /48 /64,/64,/48 20 Web server segments

infrastructure: /48 /64,/64,/48 10 DNS server segments

network plan: /48 /54,/54,/48 100 Corp Head Office LAN New Delhi (customer support, marketing and back-office)

network-plan: /48 /54,/54,/48 50 Bangkok branch LAN (customer support)

network-plan: /48 /54,/54,/48 30 Chennai Office LAN (customer support and R&D)

Sample form

#[ADDITIONAL INFORMATION]#

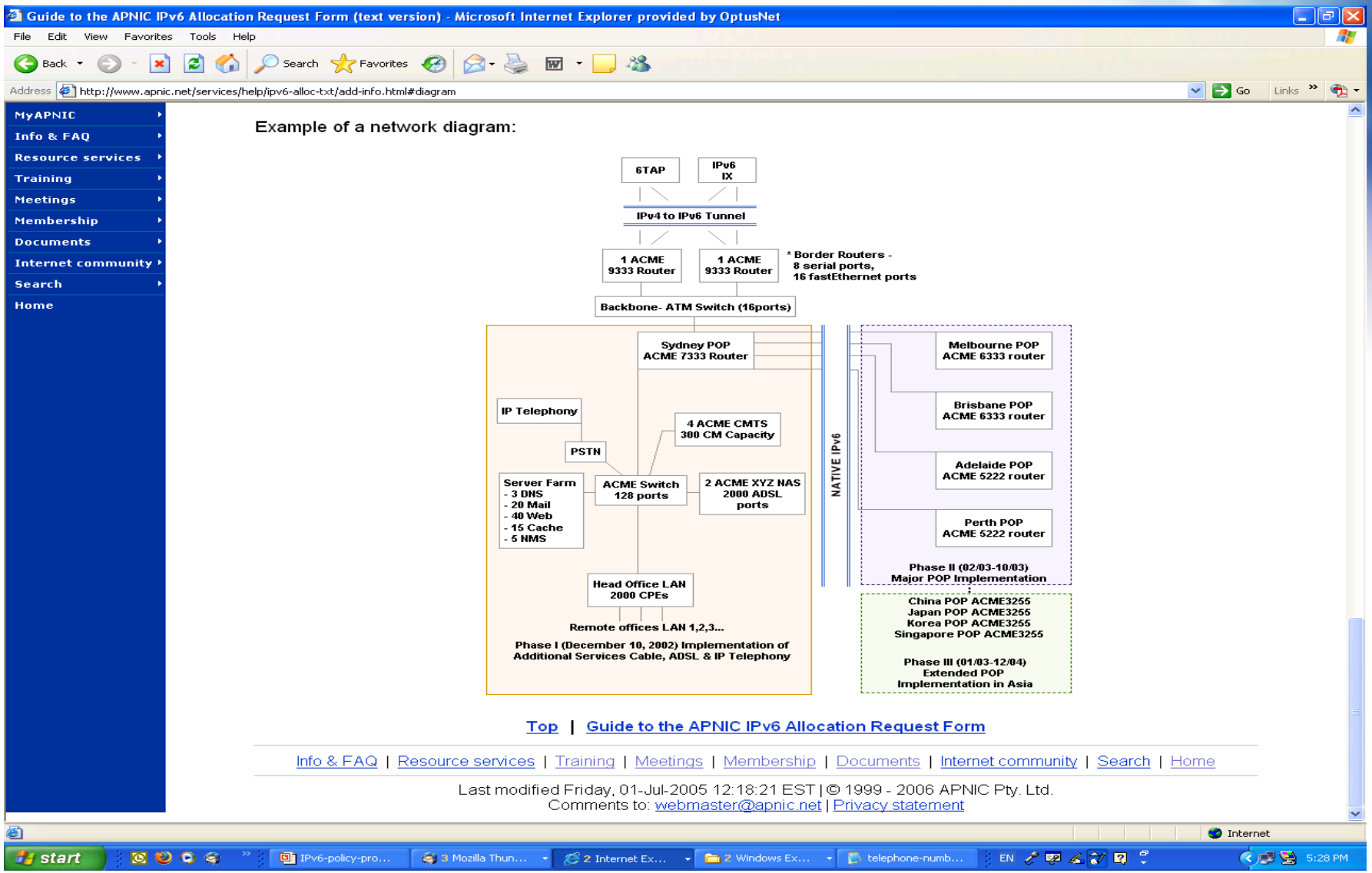
1. Your proposed IPv6 deployment plan
    - Deployment schedule
    - Implementation plan
        - What transition method do you use?
        - Who are the upstream ISP you will connect?
        - What equipment are you using?
        - What services are you planning to provide?

Sample form

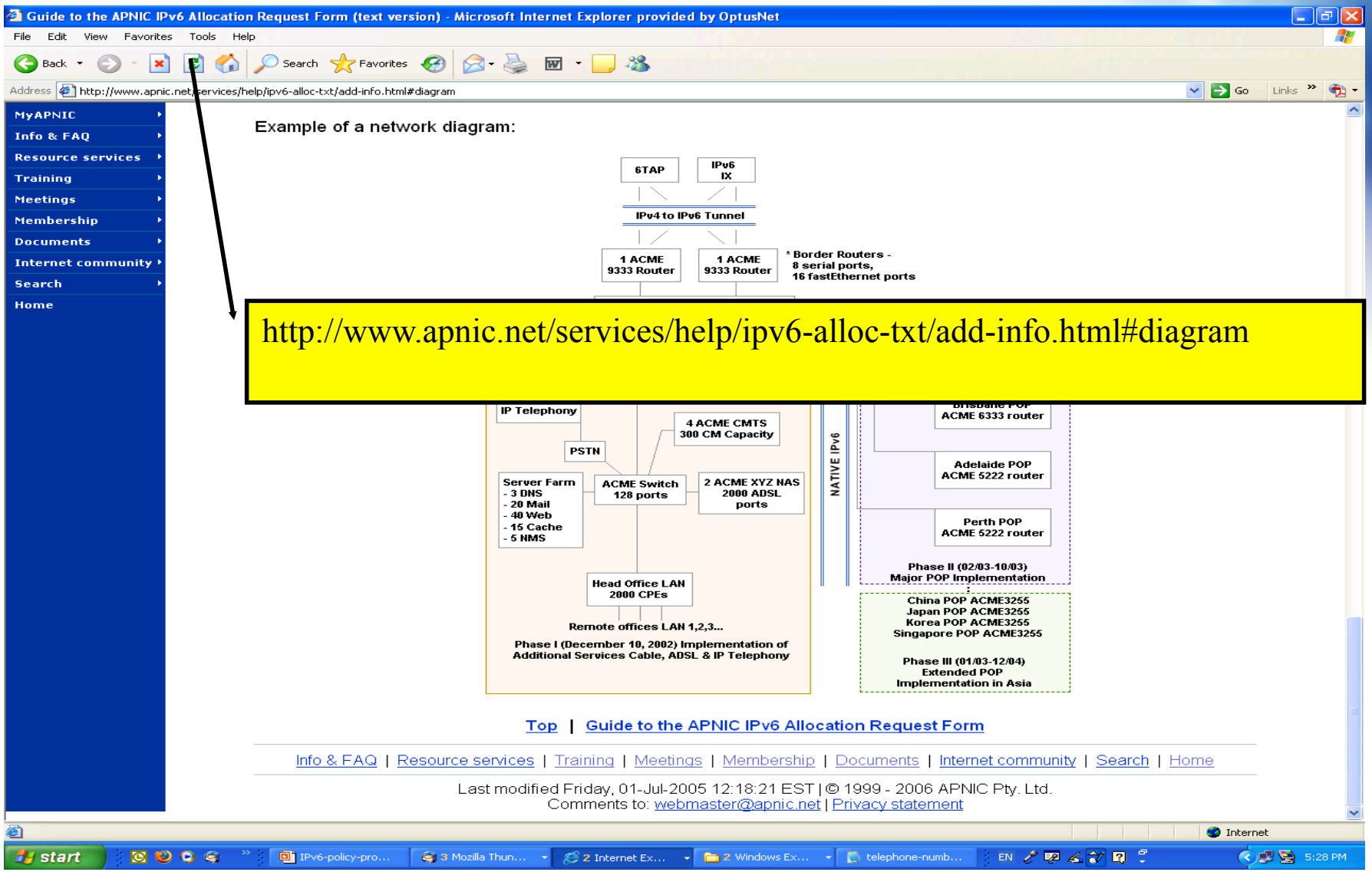
#[ADDITIONAL INFORMATION]#

2. Network diagram showing your planned IPv6 network
3. If requesting more than /32, provide details of your existing IPv4 network
4. Additional comments

Sample form



Sample form



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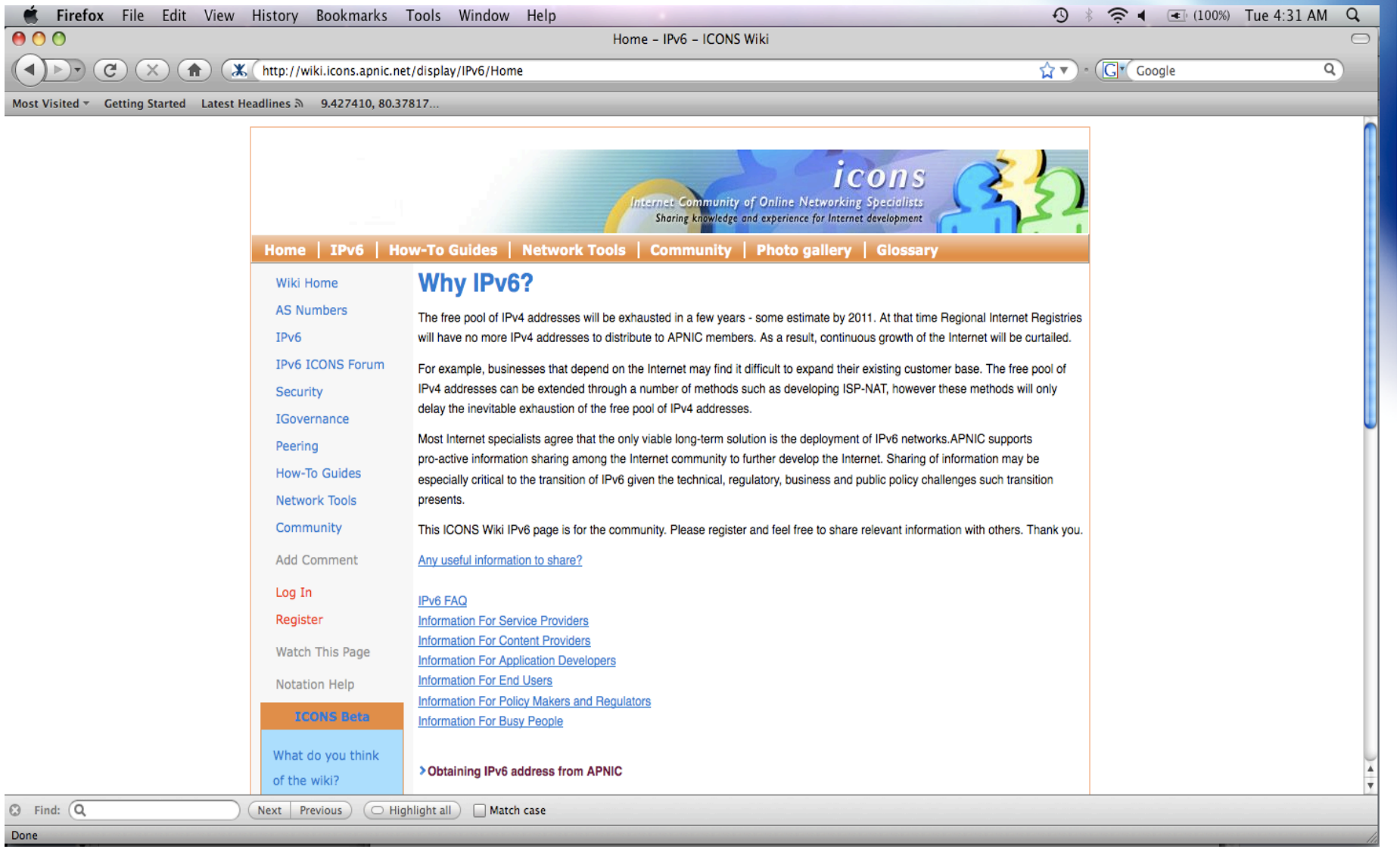
Discuss IPv6 Transition – IPv6 Wiki



IPv6 policy – have your say!

- Limited experience of policy in action
  - Your feedback very important
  - Policy always subject to change and refinement
- Open discussion list
  - global-v6@lists.apnic.net (all regions)
  - SIG Policy mailing list (APNIC region)
- Documentation
  - FAQ information and more!
    - http://www.apnic.net/services/ipv6_guide.html
  - Guidelines document under development
    - To assist new requestors with policy

APNIC 28 – 24-28 August 2009

Questions?

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Thank you! ☺