IPv6 Networking

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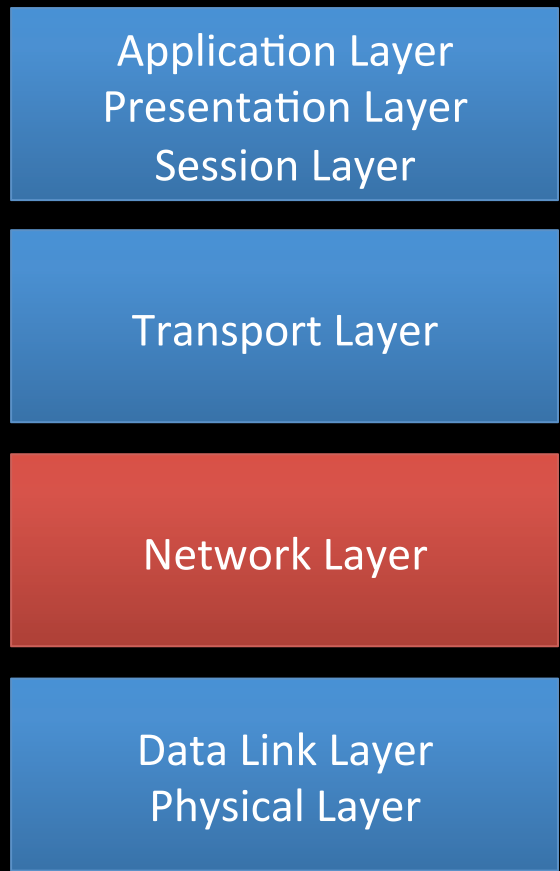
Today’s Outline

- IPv4 and its limitation
- Introduction to IPv6
- Deployment scenario and issues
- IPv6 situation in India till now
- Why IPv6?

Internet Protocol

- Protocol in Network Layer
  - Identifying a network interface card (NIC) or a host in the Internet
  - Addressing and subnetting
  - Routing and loop mitigation
  - Control & error handling mechanism
  - Quality of Service
  - And some more options
- Two versions
  - IPv4 (RFC791, 1981)
  - IPv6 (RFC2460, 1998)



IPv4 Address (1/3)

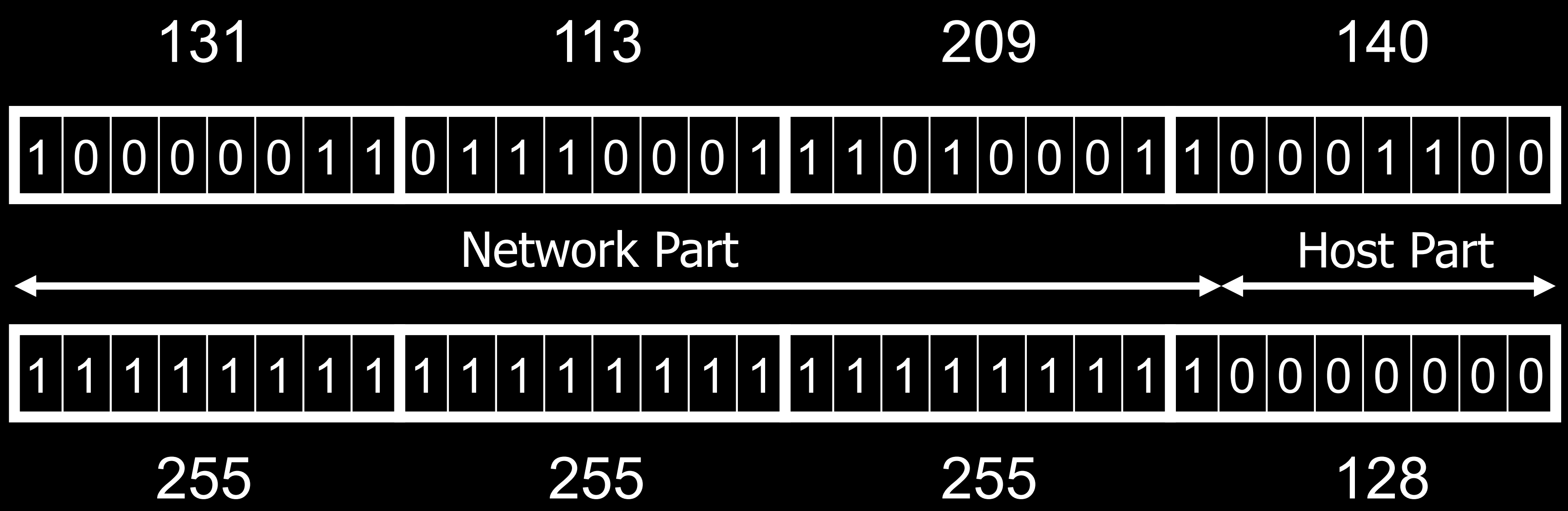
- 32 bits = Apprx. 4 Billion Patterns
- Can be expressed by 4 groups of number
- Separated by dots

1 0 0 0 0 0 1 1	0 1 1 1 0 0 0 1	1 1 0 1 0 0 0 1	1 0 0 0 1 1 0 0

131 . 113 . 209 . 140

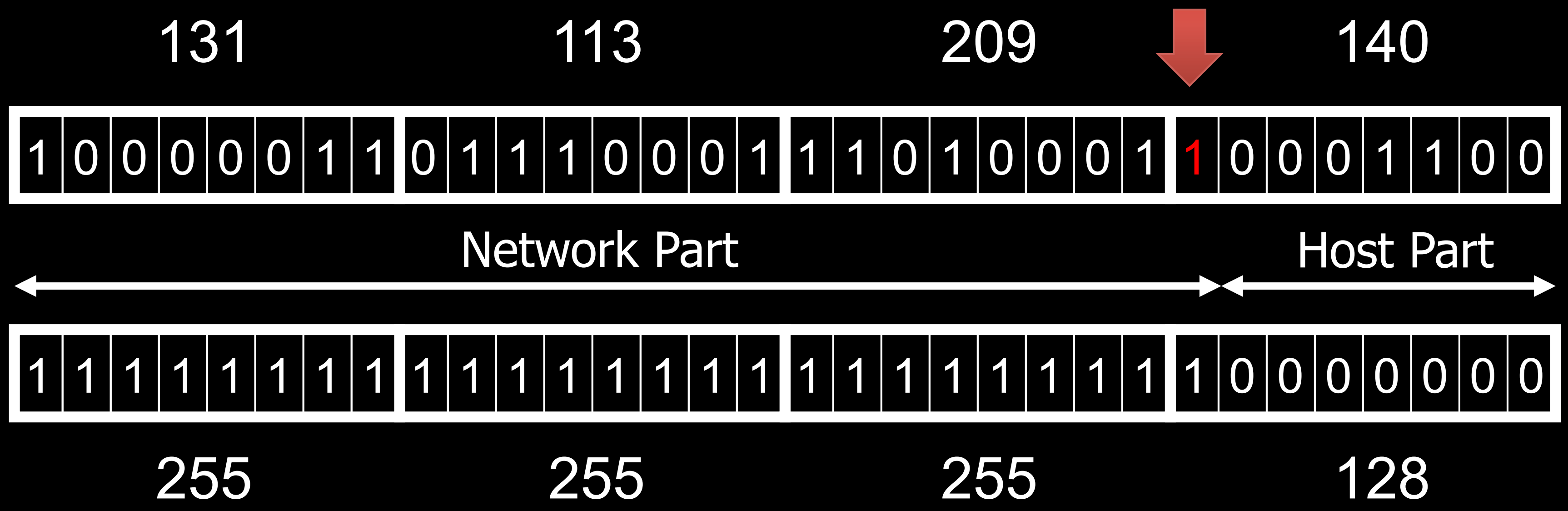
IPv4 Address (2/3)

- Structure of IPv4 Address
  - Network part: Common among hosts in the same subnet
  - Host part: Unique for each of hosts in the subnet
- Example
  - 131.113.209.140/25
  - 131.113.209.140 netmask 255.255.255.128



IPv4 Address (3/3)

- Network Address
  - Host part is all zero: 131.113.209.128
- Broadcast Address
  - Host part is all one: 131.113.209.255



Subnet Mask and Size of Subnet

/24
(256)

Subnet Mask and Size of Subnet

/23
(512)

Subnet Mask and Size of Subnet

/22
(1024)

Subnet Mask and Size of Subnet

/21
(2048)

Subnet Mask and Size of Subnet

/20
(2048)

Subnet Mask and Size of Subnet

/19
(4096)

Subnet Mask and Size of Subnet

/24
(256)

Subnet Mask and Size of Subnet

/25
(128)

Subnet Mask and Size of Subnet

/25
(128)

Subnet Mask and Size of Subnet

/26
(64)

Subnet Mask and Size of Subnet

- /27
  (32)

Modes of Communication and Types of Address in IPv4

- Unicast
  - One-to-one communication
  - WWW, Mail, Skype, etc…
- Broadcast
  - One-to-all communication
  - Limited Broadcast
    - 255.255.255.255
  - Directed Broadcast
    - 1 for all bits in host part
    - Ex: 131.113.209.255
- Multicast
  - One-to-many communication
  - Membership management
  - Video streaming
  - 224.0.0.0/4

- Global
  - Reachable in the Internet
  - Globally unique (no duplication)
- Private
  - Normally used in LAN (home/school/enterprise)
  - No reachability from the Internet
  - 10.0.0.0/8
  - 172.16.0.0/12
  - 192.168.0.0/16

Network Configuration for a Host

- Configuring Network Interface Card
  – IP Address and Subnet Mask
  – Default Gateway
  – Hostname
  – DNS Server

- Approaches
  – Manual (CLI or Configuration Files)
  – Dynamic Configuration

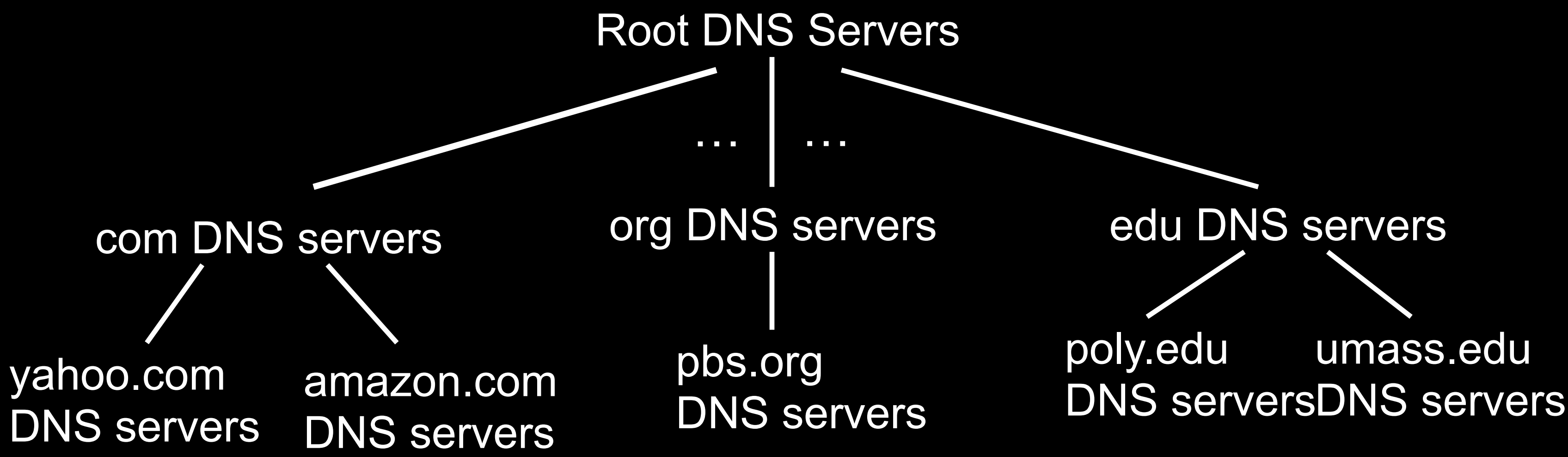
Dynamic Host Configuration Protocol

- Dynamically obtain IP address and other network configuration from a server when a host joins network
  - Server leases an IP address and maintain the state
  - Server allows reuse of addresses if available (remember which MAC address took which IP address)

- Behavior of DHCP
  - A host (Client) broadcasts “DHCP Discover” message
  - Server responds with “DHCP Offer” message
  - Client requests IP address: “DHCP Request” message
  - Server sends address: “DHCP Acknowledgement” message

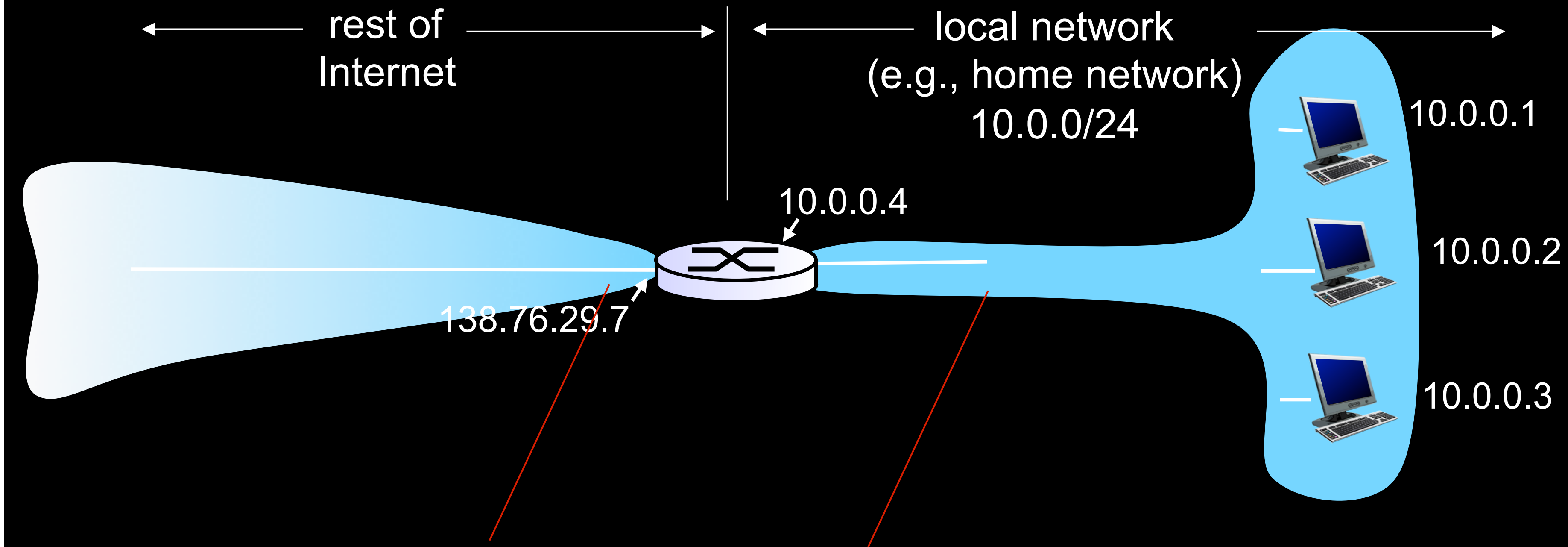
Domain Name System (DNS)

- Hostname / Address Translation
  - Distributed database implemented in hierarchy of many name servers
  - Canonical, alias names
  - Mail server aliasing (MX Record)



Slide Source: Jim Kurose and Keith Ross, *"Computer Networking: A Top Down Approach"*, 6th edition, Addison-Wesley, March 2012

NAT: network address translation



all datagrams *leaving* local network have *same* single source NAT IP address: 138.76.29.7,different source port numbers

datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

Slide Source: Jim Kurose and Keith Ross, *"Computer Networking: A Top Down Approach"*, 6th edition, Addison-Wesley, March 2012

NAT: network address translation

motivation: local network uses just one IP address as far as outside world is concerned:

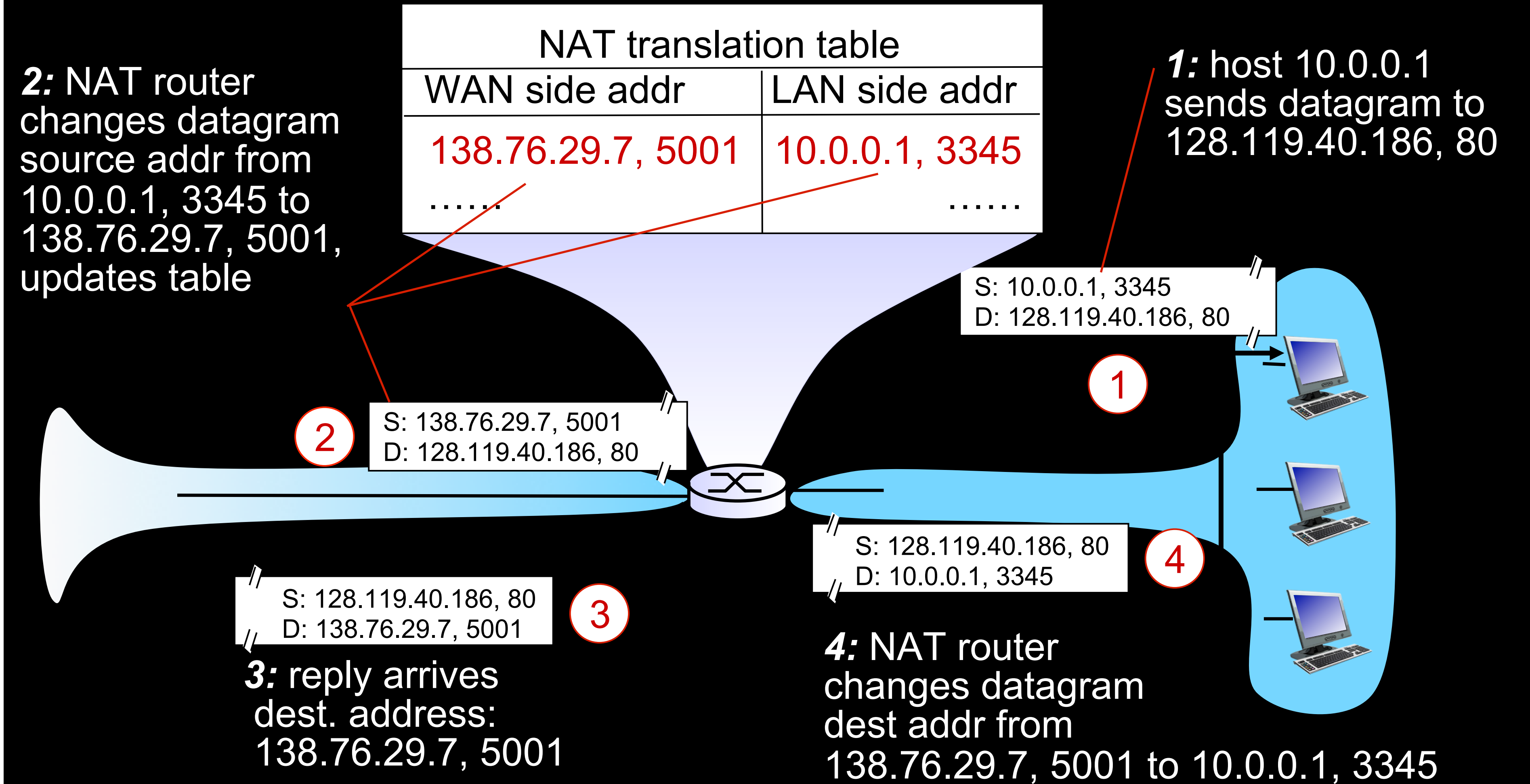
- range of addresses not needed from ISP: just one IP address for all devices
- can change addresses of devices in local network without notifying outside world
- can change ISP without changing addresses of devices in local network
- devices inside local net not explicitly addressable, visible by outside world (a security plus)

NAT: network address translation

implementation: NAT router must:

- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)
  - . . . remote clients/servers will respond using (NAT IP address, new port #) as destination addr
- *remember (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair
- *incoming datagrams: replace* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

Network Address Translation (NAT)



Slide Source: Jim Kurose and Keith Ross, *"Computer Networking: A Top Down Approach"*, 6th edition, Addison-Wesley, March 2012

Limitation of NAT

- NAT Traversal Problems
  – Breaking the concept of End-to-End
    - Server does not know who is actually talking to it
  – Anonymisng malicious host behind NAT
  – Servers can not initiate communication
  – Static NAT needs big amount of effort to maintain the matching between internal host and exposed IP address and port number
  – Port number is only 65K (16 bits). No scalability

- Myth: NAT is a good firewall. Let's put unsecure host behind NAT. -> NO WAY!!

IP Address Shortage

- Proliferation of Internet devices:
  - 405M mobile phones sold in 2000
  - 1B+ by 2005
- New emerging populations:
  - China, Korea, Japan, India, Russia
- Solution = IPv6

Why IPv6?

- Huge Address Space
- Address Renumbering/Hierarchy/Mobility
- Multicast/Anycast
- Security (IPsec, Source Route)
- Flow Labels
- High Performance Design
- Jumbograms (packets > 64 KB)

IPv6 Overview

- Network Layer Protocol for Indentifying Computers on the Internet
  - Not “Next Generation” now…
  - Huge address space
  - Address Auto Configuration
  - Security
- Migration from IPv4 to IPv6
  - Dual Stack
  - Tunneling
  - Translator

IPv6 Background

- IPv4 Addressing
  - Early 90s
    - Address Classes: A (/8), B (/16) and C (/24)
    - Inefficient Addressing
  - CIDR since 1993
    - Classless Addressing
    - Better Flexibility
- Shortage of Address Space
  - Only 4.2 billion addresses
  - Strict Assessment of IPv4 Address Application
  - Insufficient number of global IPv4 address for end users

- Network Layer Protocol with Larger Address Space

IPv6 Advantages

- Huge Address Space
  - 128bit Address
  - Global IP address for everyone
  - Internet of Things
- Improved Performance
  - Simplified header reduces processing load in routers
  - No fragmentation on routers
- New technologies
  - Address Auto-configuration (Plug and Play)
  - Mobility, Security, Scalability and etc…

IPv6 Address

- Address Length: 128bits
- 8 groups of 4 hexadecimal digits (16bits per each)
- Separated by colons

2001:200:0:8803:222:19ff:fe6a:3b70

- “”0s (zeros)” at the beginning of 16bits can be omitted
- Continuous “ALL 0s” between colons can be omitted only once

2001:d30:100:0000:0000:0000:0000:1

= 2001:d30:100::1

IPv6 Addressing

00101010000100100011010001011100
00000000000000000000000000000000
00000000011110000000100110101011
00001100000011011110000011110000

IPv6 Address Notation

2A12:3456:0:0:78:9AB:C0D:E0F0

IPv6 Address Notation

Eight blocks of 16 bits in hexadecimal separated by colons (:)

2A12:3456:0:0:78:9AB:C0D:E0F0

00101010000100100011010001011100
00000000000000000000000000000000
00000000011110000000100110101011
00001100000011011111000011110000

IPv6 Address Notation

2A12:3456:0:0:78:9AB:C0D:E0F0

00101010000100100011010001011100
00000000000000000000000000000000
00000000011110000000100110101011
00001100000011011110000011110000

IPv6 Address Notation

2A12:3456:0:0:78:9AB:C0D:E0F0

00101010000100100011010001011100

00000000000000000000000000000000

00000000011110000000100110101011

00001100000011011110000011110000

IPv6 Address Notation

2A12:3456:0:0:78:9AB:C0D:E0F0

00101010000100100011010001011100
00000000000000000000000000000000
00000000011110000000100110101011
00001100000011011110000011110000

IPv6 Address Notation

- Blocks of 0s may be shortened with double colon (::), and only one double colon is allowed

1234:5678:90AB::5678:0:CDEF

1234:5678:90AB:0:0:5678::CDEF

1234:5678:90AB::5678::CDEF 

IPv6 Address Space Notation

<prefix>/<prefix-length>

1234:5678::/48

1234:5678:9ABC:DEF::/64

Address Scopes

- Global: Globally unique
- Link-local: Unique on the link
  - Effective only on the directly connected link
  - No forwarding by router
- Site-local: obsolete..

Address Types

- Unicast
  - An identifier for a single interface
  - A packet sent to a unicast address is delivered to the interface identified by that address
- Anycast
  - An identifier for a set of interfaces (typically belonging to different nodes)
  - A packet sent to an anycast address is delivered to one of the interfaces identified by that address (the "nearest" one, according to the routing protocol measure of distance)
- Multicast
  - An identifier for as a set of interfaces (typically belonging to different nodes)
  - A packet sent to a multicast address is delivered to all interfaces identified by that address
- No "Broadcast"

Global Address Architecture (OLD)

- RFC2374: Obsolete, was valid up to Year 2003
- Hierarchical aggregation based on network topology

FP	TLA ID	Sub TLA ID	RE	NLA ID	SLA ID	Interface ID
3	13	13	6	13	16	64

FP Format Prefix

RE Reserved

TLA ID Top-Level Aggregation Identifier (Back Bone)

SubTLA ID Sub Top-Level Aggregation Identifier (RIR Spool)

NLA ID Next-Level Aggregation Identifier (ISP Network)

SLA ID Site-Level Aggregation Identifier (HOME Network)

Global Address Architecture (NOW)

- RFC 3587 “IPv6 Global Unicast Address Format”
  - Simplified architecture with more flexibility
  - Interface to be 64 bits (EUI-64)

n bits	(64 – n) bits	64 bits
Global Routing Prefix	Subnet ID	Interface ID

- How big address space should assigned to end sites (homes)? /64 seems to be sufficient?

- RFC 6177 “IP Address Assignment to End Sites”
  - /56, for example, considering future deployment
  - Smaller than /48, bigger than /64

Link-Local Address Architecture

- Starting with “fe80::”
- No Forwarding of datagram that has Link-Local Address

10 bits	54 bits	64 bits
1111111010	ALL 0	Interface ID

- Typical Usage
  - Address Auto-configuration
  - Neighbor Discovery Protocol
  - On-link communication under network failure

EUI-64 for Interface ID

- Current MAC address (EUI-48: 48 bits) will be extended to EUI-64: 64 bits
  - OUI (Vendor Code) will remain as 24 bits
- Converting EUI-48 to EUI-64
  - Insert "FF:FE" after 24th bit of EUI-48

EUI-48 2e:0:18:98:936d

EUI-64 2e:0:18: ff:fe :98:93:6d

IPv6 Example (1/2-1)

kotaro — ssh — 89×18

```
[sfc-cpu:2:42] ifconfig bge0
bge0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> metric 0 mtu 1500
        options=8009b<RXCSUM,TXCSUM,VLAN_MTU,VLAN_HWTAGGING,VLAN_HWCSUM,LI
        ether 00:30:48:88:11:d2
        inet 202.249.25.10 netmask 0xffffffe0 broadcast 202.249.25.31
        inet6 fe80::230:48ff:fe88:11d2%bge0 prefixlen 64 scopeid 0x2
        inet6 2001:d30:101:1::10 prefixlen 64
        nd6 options=1<PERFORMNUD>
        media: Ethernet autoselect (1000baseT <full-duplex>)
        status: active
[sfc-cpu:2:42]
```

IPv6 Example (2/2-1)

kotaro — ssh — 89×20

Internet6:

Destination	Gateway	Flags	Netif	Expire
::/96	::1	UGRS	lo0	=>
default	2001:d30:101:1::1	UGS	bge0	
::1	link#10	UH	lo0	
::ffff:0.0.0.0/96	::1	UGRS	lo0	
2001:d30::1	link#10	UHS	lo0	
2001:d30:101:1::/64	link#2	U	bge0	
2001:d30:101:1::10	link#2	UHS	lo0	
2001:d30:101:2::/64	link#12	U	vlan1	
2001:d30:101:2::130	link#12	UHS	lo0	
2001:d30:101:3::/64	link#11	U	vlan0	
2001:d30:101:3::1	link#11	UHS	lo0	
fe80::/10	::1	UGRS	lo0	
fe80::%bge0/64	link#2	U	bge0	
fe80::230:48ff:fe88:11d2%bge0	link#2	UHS	lo0	
fe80::%bge1/64	link#3	U	bge1	
fe80::230:48ff:fe88:11d3%bge1	link#3	UHS	lo0	
fe80::%lo0/64	link#10	U	lo0	
fe80::1%lo0	link#10	UHS	lo0	

IPv6 Example (1/2-2)

kotaro — ssh — 80×14

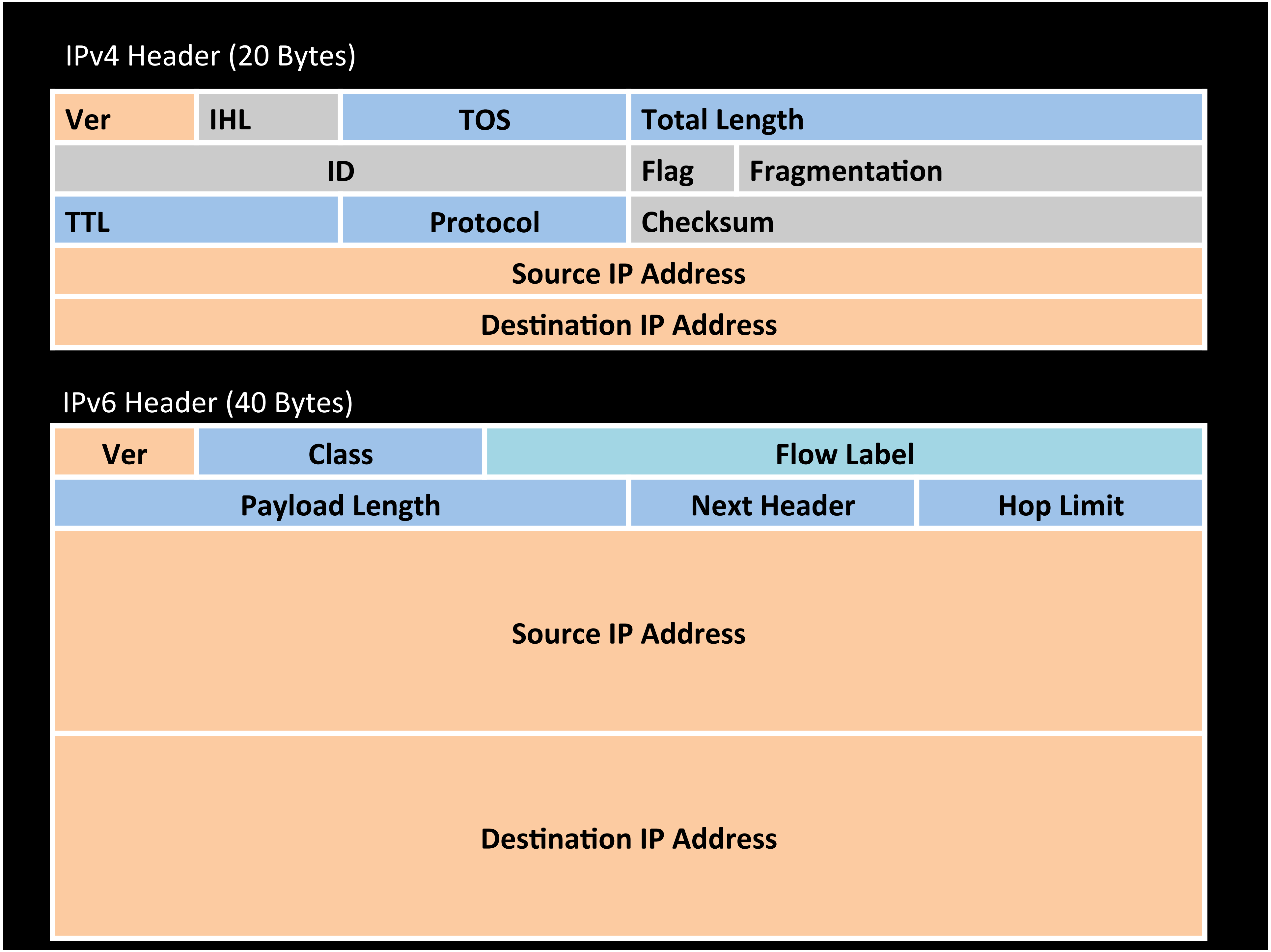
```
[cpu:1:49]ifconfig eth0
eth0      Link encap:Ethernet  HWaddr 00:22:19:6a:3b:70
          inet addr:203.178.142.142  Bcast:203.178.142.159  Mask:255.255.255.224
          inet6 addr: 2001:200:0:8803:222:19ff:fe6a:3b70/64 Scope:Global
          inet6 addr: fe80::222:19ff:fe6a:3b70/64 Scope:Link
          inet6 addr: 2001:200:0:8803:203:178:142:142/64 Scope:Global
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:847667563 errors:0 dropped:0 overruns:0 frame:0
          TX packets:253771659 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1147950377009 (1.0 TiB)  TX bytes:45001568964 (41.9 GiB)
          Interrupt:36 Memory:d6000000-d6012800

[cpu:1:49]
```

IPv6 Example (2/2-2)

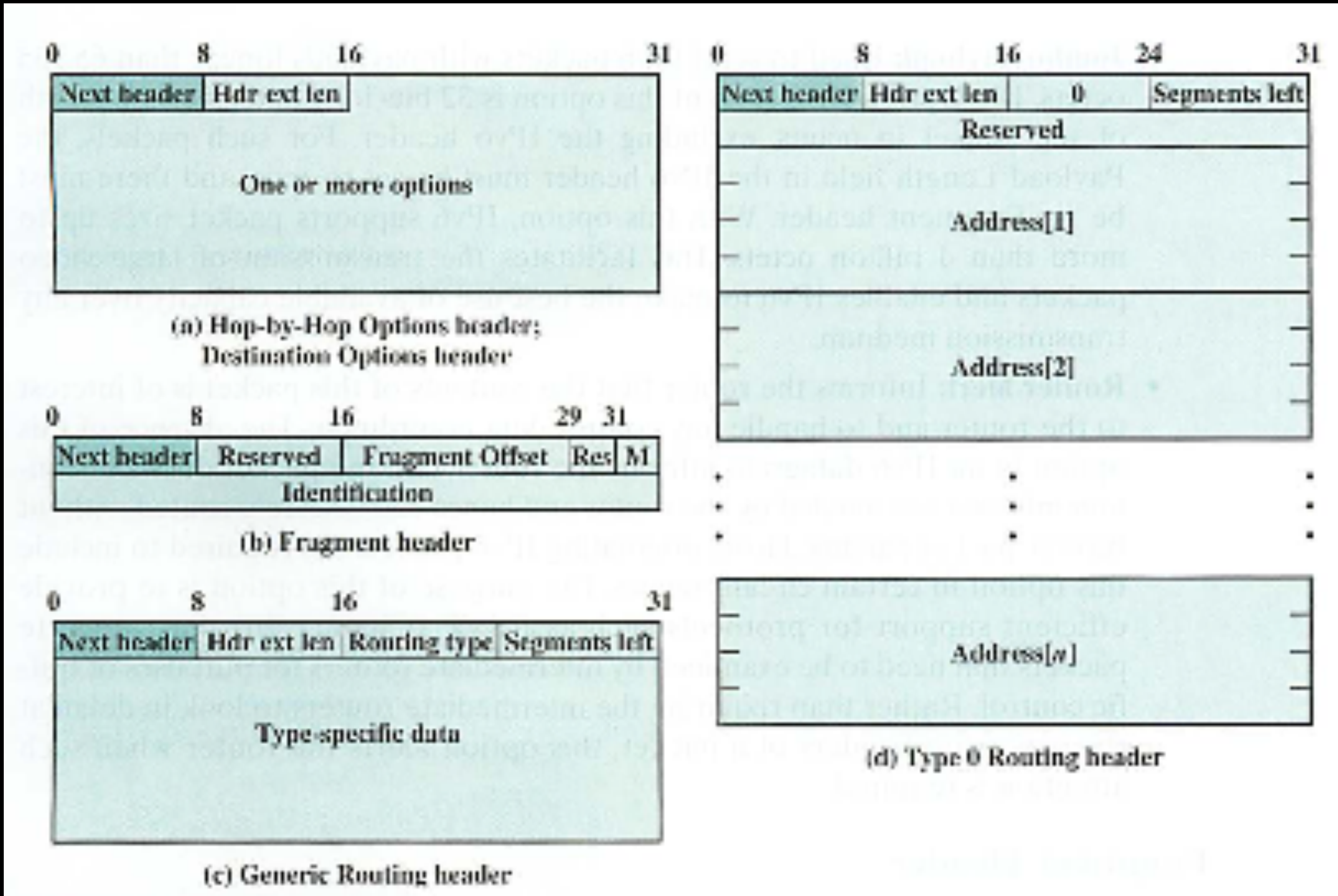
kotaro — ssh — 89×18

```
[cpu:2:25]netstat -rn -6
Kernel IPv6 routing table
Destination                    Next Hop                   Flag Met Ref Use If
2001:200:0:8803::/64           ::                         Ue   256 0  8357 eth0
fe80::/64                      ::                         U    256 0     0 eth0
fe80::/64                      ::                         U    256 0     0 eth1
::/0                           2001:200:0:8803::2         UG   1   1312885 eth0
::/0                           fe80::2ac0:daff:fe89:aa10  UGDAe 1024 0     0 eth0
::/0                           ::                         !n   -1  1427523 lo
::1/128                        ::                         Un   0   1166520 lo
2001:200:0:8803:203:178:142:142/128 ::                         Un   0   162868984 lo
2001:200:0:8803:222:19ff:fe6a:3b70/128 ::                         Un   0   127916669 lo
fe80::222:19ff:fe6a:3b70/128   ::                         Un   0   1109822 lo
fe80::222:19ff:fe6a:3b72/128   ::                         Un   0   1     0 lo
ff00::/8                       ::                         U    256 0     0 eth0
ff00::/8                       ::                         U    256 0     0 eth1
::/0                           ::                         !n   -1  1427523 lo
[cpu:2:26]
```

Protocol Behavior


IPv4 Header (20 Bytes)
Ver
IHL
TOS
Total Length
ID
Flag
Fragmentation
TTL
Protocol
Checksum
Source IP Address
Destination IP Address
IPv6 Header (40 Bytes)
Ver
Class
Flow Label
Payload Length
Next Header
Hop Limit
Source IP Address
Destination IP Address

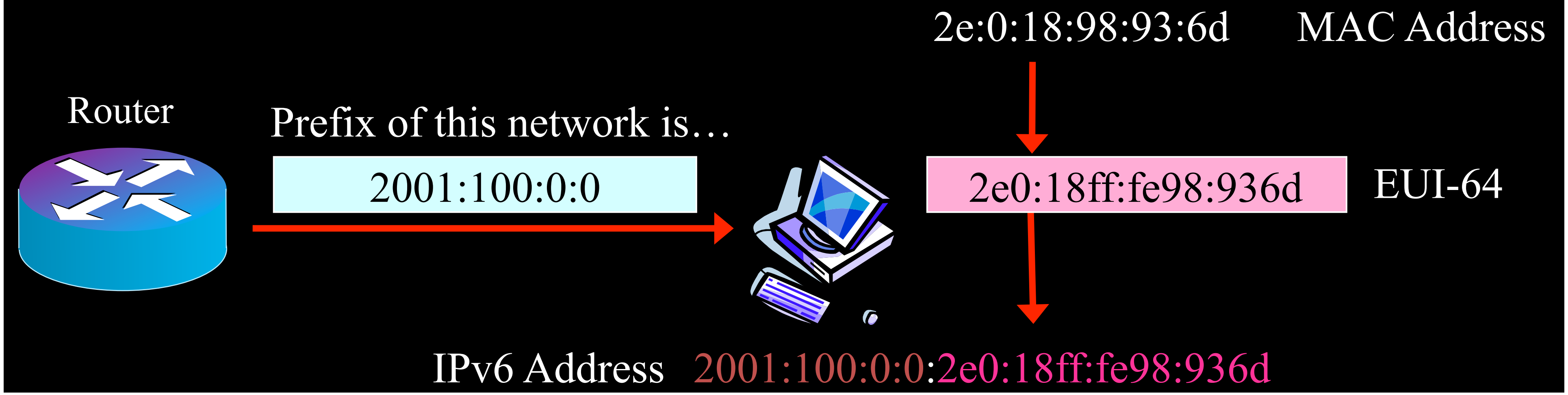
IPv6 Option Headers



Slide Source: William Stallings, *"Data and Computer Communications"*, 9th edition, Pearson Education, 2010

Address Auto-Configuration

- Router Advertisement (RA)
  - Router advertises network information
    Network Prefix, Router's Interface Address (to be default gateway), DNS servers
  - Multicasted to ALL-NODE Multicast Address (ff02::1)
- Host configures its network interface according to RAs
  - May actively solicits RA to routers by Router Solicitation (RS)
  - What if "wrong" RA is received?



Duplicate Address Detection and Neighbor Discovery Protocol

- Neighbor Solicitation (NS)
  - Solicits a node that uses a specific IP address to detect duplicate address
  - Solicits a mac address of a neighbor host (like ARP Request in IPv4)
- Neighbor Advertisement (NA)
  - Answers to a source of NS if the address duplicates
  - Answers to a source to inform the mac address

Manual Configuration

- Address Auto-Configuration
  - Address will be changed if NIC is replaced
- Manual Configuration
  - Static address even after replacing NIC for routers and servers
  - Simplified notation or putting semantic in address

IPv6	2001:200:0:1::5	Manual
IPv6	2001:200:0:1:203:178:143:1	Manual with IPv4 Embedded
IPv6	2001:200:0:1:1122:33ff:fe44:5566	Automatic
IPv4	203.178.143.1	
MAC	11:22:33:44:55:66	

Link-Local Address

- As a protocol behavior
  - Duplicated Address Detection
  - Neighbor Discovery Protocol
  - Address Auto-Configuration
  - Forwarding on routers
- Operational purpose
  - Hosts not exposed to global network
  - Global address was erased by mistake..

Finding A Host on Link

- Ping6 to ALL-Nodes Multicast Address

```
bonito% ping6 -w ff02::1%ed0
PING6(72=40+8+24 bytes) fe80::290:ccff:fea0:f6f7%ed0 --> ff02::1%ed0
37 bytes from fe80::290:ccff:fea0:f6f7%ed0: bonito.paina.jp.
45 bytes from fe80::202:b3ff:feec:6cd4%ed0: rg-gate1.sfc.wide.ad.jp.
45 bytes from fe80::202:b3ff:feec:6cb5%ed0: rg-gate2.sfc.wide.ad.jp.
42 bytes from fe80::20f:1fff:fee8:86ea%ed0: amber.sfc.wide.ad.jp.
44 bytes from fe80::20f:1fff:fe95:5408%ed0: mimicry.sfc.wide.ad.jp.
37 bytes from fe80::290:ccff:fe08:1802%ed0: saurel.paina.jp.
```

- Link-local Multicast Address
  – All-Nodes Multicast (ff02::1)
  – All-Routers Multicast (ff02::2)
  – and more..

Routing Table Example (1/2)

Destination	Gateway	Interface
2001:200:0:402::/64	fe80::201:64ff:fea3:ec55%fxp0	fxp0
2001:200:0:403::/64	fe80::201:64ff:fea3:ec55%fxp0	fxp0
2001:200:0:800::/56	fe80::201:64ff:fea3:ec55%fxp0	fxp0
2001:200:0:802::/64	fe80::201:64ff:fea3:ec55%fxp0	fxp0
2001:200:0:1000::6667	fe80::201:64ff:fea3:ec55%fxp0	fxp0
2001:200:0:1001::/64	link#1	fxp0
2001:200:0:1001::6	00:90:27:cc:df:73	lo0
2001:200:0:1001::9	00:03:47:df:74:df	fxp0
2001:200:0:1001:201:64ff:fea3:ec55	00:01:64:a3:ec:55	fxp0
2001:200:0:1001:203:88ff:fe00:29cb	00:03:88:00:29:cb	fxp0

Routing Table Example (2/2)

kotaro — ssh — 89×20

```
Internet6:
Destination                     Gateway                     Flags      Netif Expire
::/96                           ::1                         UGRS        lo0 =>
default                         2001:d30:101:1::1           UGS        bge0
::1                             link#10                     UH          lo0
::ffff:0.0.0.0/96               ::1                         UGRS        lo0
2001:d30::1                     link#10                     UHS         lo0
2001:d30:101:1::/64             link#2                      U          bge0
2001:d30:101:1::10              link#2                      UHS         lo0
2001:d30:101:2::/64             link#12                     U         vlan1
2001:d30:101:2::130             link#12                     UHS         lo0
2001:d30:101:3::/64             link#11                     U         vlan0
2001:d30:101:3::1               link#11                     UHS         lo0
fe80::/10                       ::1                         UGRS        lo0
fe80::%bge0/64                  link#2                      U          bge0
fe80::230:48ff:fe88:11d2%bge0   link#2                      UHS         lo0
fe80::%bge1/64                  link#3                      U          bge1
fe80::230:48ff:fe88:11d3%bge1   link#3                      UHS         lo0
fe80::%lo0/64                   link#10                     U           lo0
fe80::1%lo0                     link#10                     UHS         lo0
```

Issues on Migrating from IPv4 to IPv6

- No backward compatibility to IPv4
- Implementation of Application Software
  - Embedded IPv4 address in Data Segment

- Existing Solutions
  - Tunneling
  - Translation
  - Application Layer Gateway

IPv4/IPv6 Migration Technologies

- Approaches
  - Dual Stack, Tunneling, Translation
  - Stateless vs. Stateful
- What is a good choice, Pros and Cons?
  - Dual Stack first, then see what happens

Client	ISPs	Server	Solution
IPv4	IPv4	IPv4	CGN
IPv4	IPv6	IPv4	MAP, DS-Lite, 464XLAT
IPv6	IPv4	**IPv6**	6rd
IPv6	*	IPv4	NAT64

Table Source: Yuka Kawakami, *"Technical Trend of IPv4/IPv6 Transition and Coexistence"*, URL *http://pt.slideshare.net/yuyarin*

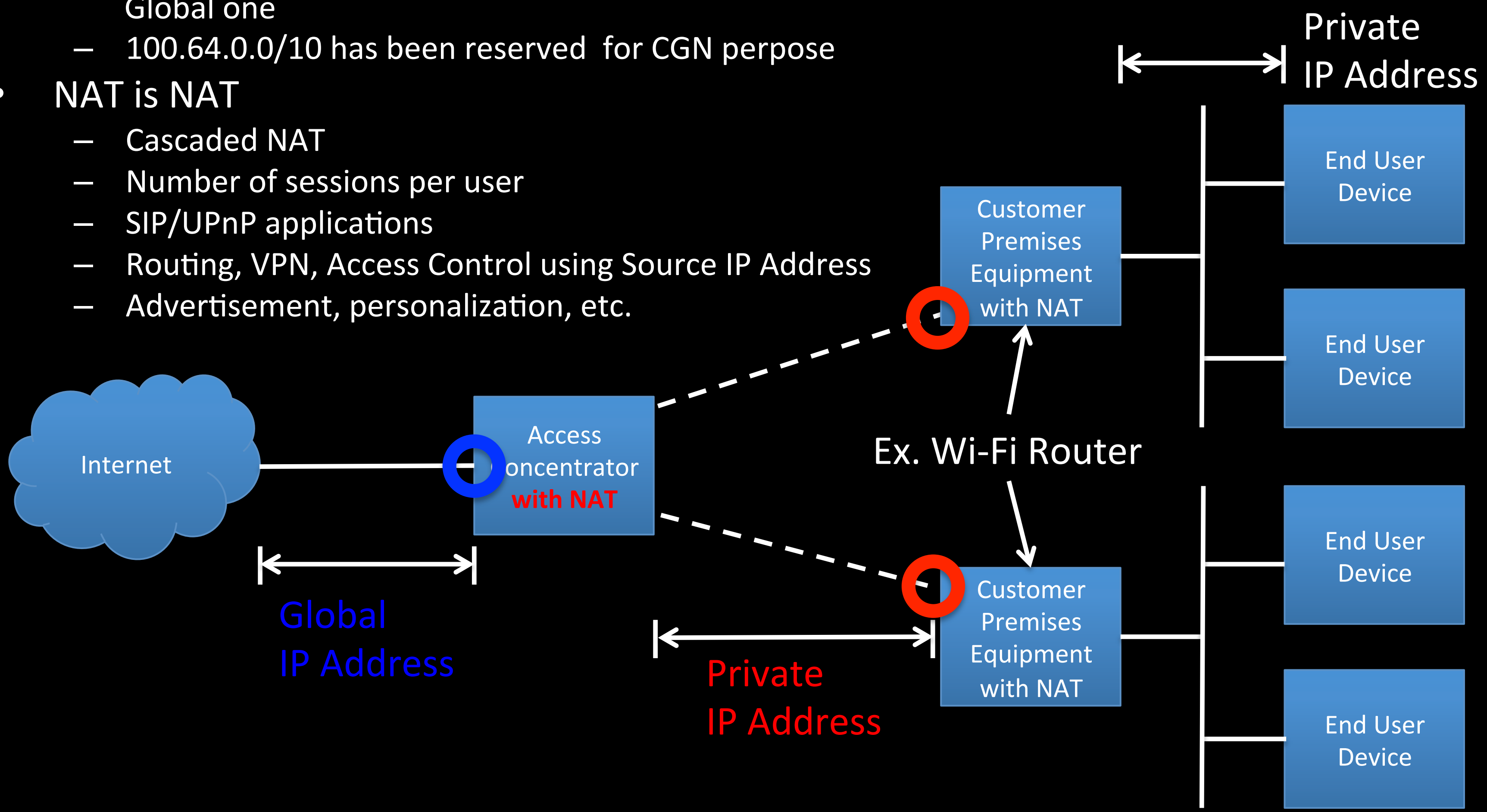
Common Problems

- MTU (Maximum Transfer Unit)
  - Encapsulation and Translation make packets bigger
  - Fragmentation: IPv4 routers can fragment packets, but what about IPv6?
  - How to handle UDP? MSS is not supported
- Port Translation
  - What happens if packets don't include port number? ICMP, L2TP, IPSec?
- Still active
  - New technologies come up, merged, and again new ones come up

Table Source: Yuka Kawakami, *"Technical Trend of IPv4/IPv6 Transition and Coexistence", URL http://pt.slideshare.net/yuyarin*

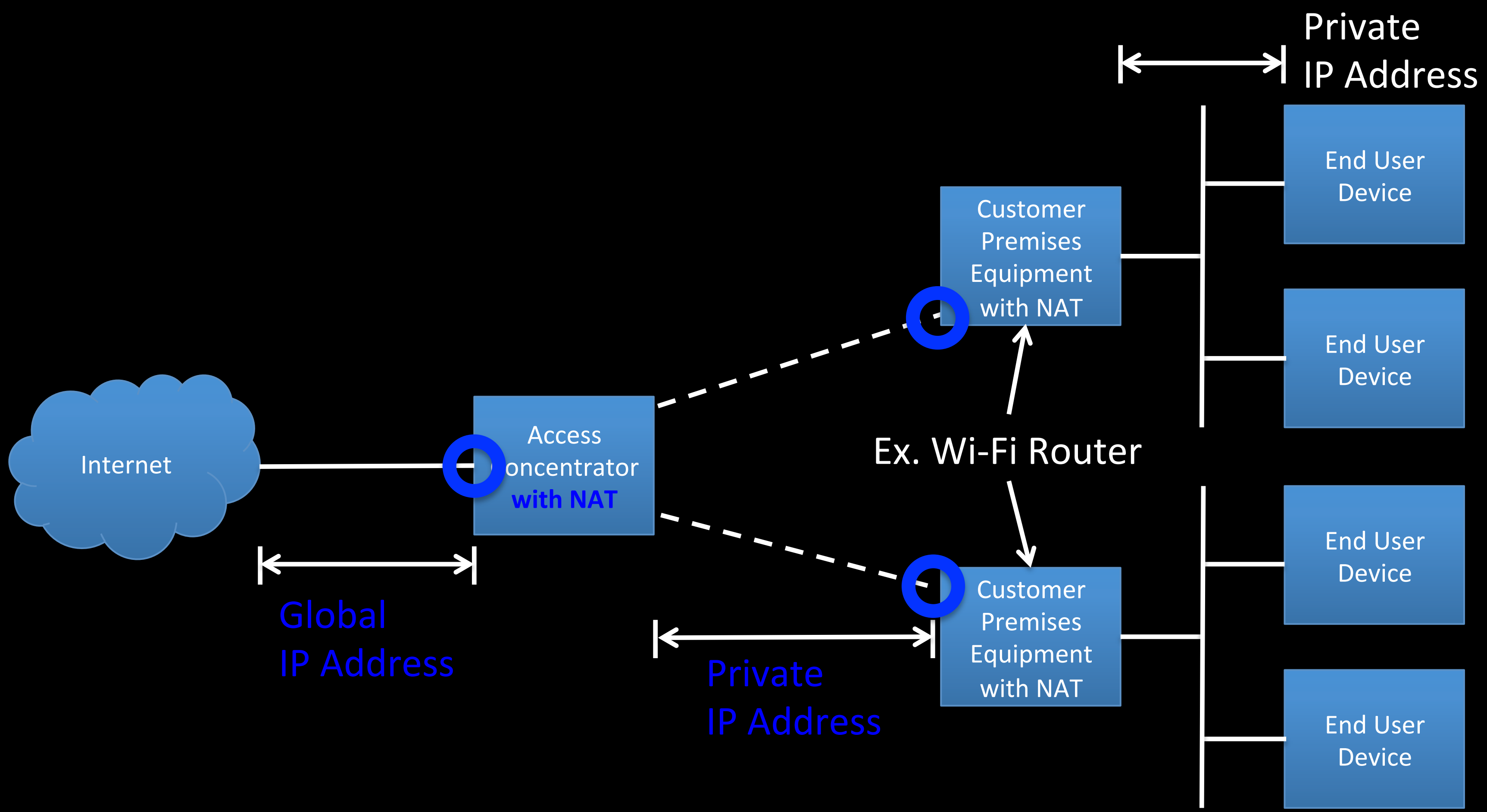
Carrier Grade NAT (CGN) (1/2)

- Reducing the use of Global IPv4 address by enabling NAT in ISP network
  - End user will have Private IP address at Internet side of device (ex. Home router) instead of Global one
  - 100.64.0.0/10 has been reserved for CGN perpose
- NAT is NAT
  - Cascaded NAT
  - Number of sessions per user
  - SIP/UPnP applications
  - Routing, VPN, Access Control using Source IP Address
  - Advertisement, personalization, etc.



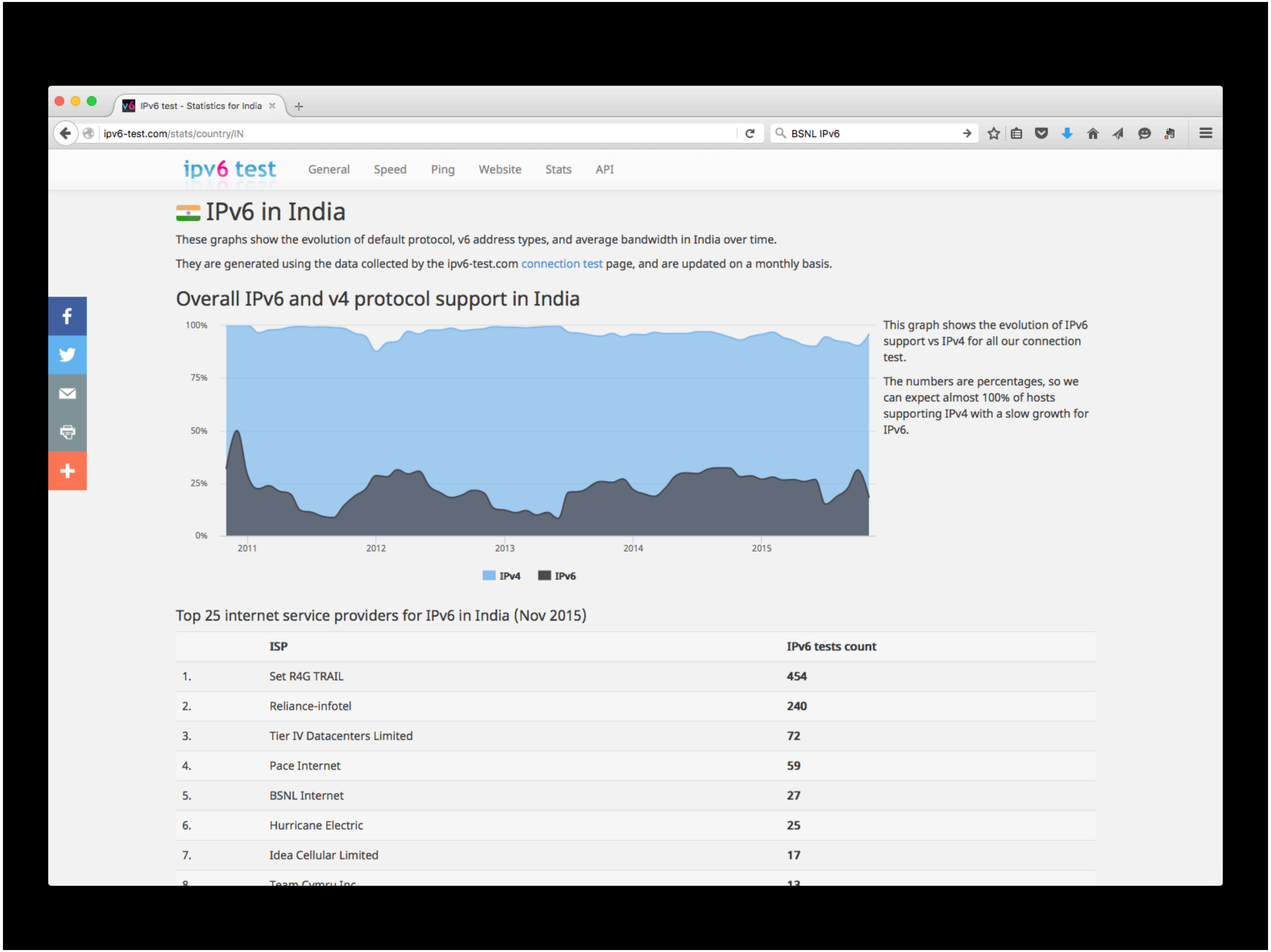
Carrier Grade NAT (CGN) (2/2)

- How does an ISP without CGN look like?



Why migrating to IPv6?

- Let's discuss after some evidences



IPv6 test - Statistics for India

ipv6-test.com/stats/country/IN

ipv6 test General Speed Ping Website Stats API

IPv6 in India

These graphs show the evolution of default protocol, v6 address types, and average bandwidth in India over time.

They are generated using the data collected by the ipv6-test.com connection test page, and are updated on a monthly basis.

Overall IPv6 and v4 protocol support in India

This graph shows the evolution of IPv6 support vs IPv4 for all our connection test.

The numbers are percentages, so we can expect almost 100% of hosts supporting IPv4 with a slow growth for IPv6.

Top 25 internet service providers for IPv6 in India (Nov 2015)

	ISP	IPv6 tests count
1.	Set R4G TRAIL	**454**
2.	Reliance-infotel	**240**
3.	Tier IV Datacenters Limited	**72**
4.	Pace Internet	**59**
5.	BSNL Internet	**27**
6.	Hurricane Electric	**25**
7.	Idea Cellular Limited	**17**
8.	Team Cymru Inc	**13**

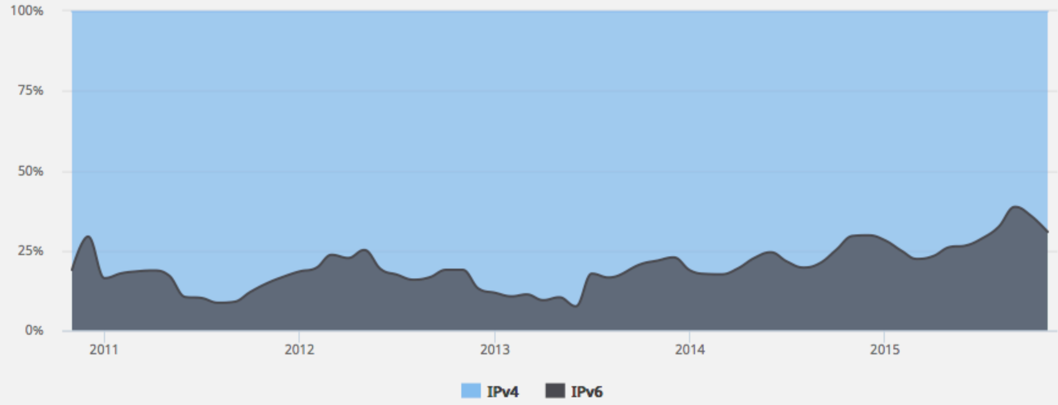
IPv6 test - Statistics for India

ipv6-test.com/stats/country/IN

BSNL IPv6

ipv6 test General Speed Ping Website Stats API

IPv6 and v4 protocol support in India (unique addresses)

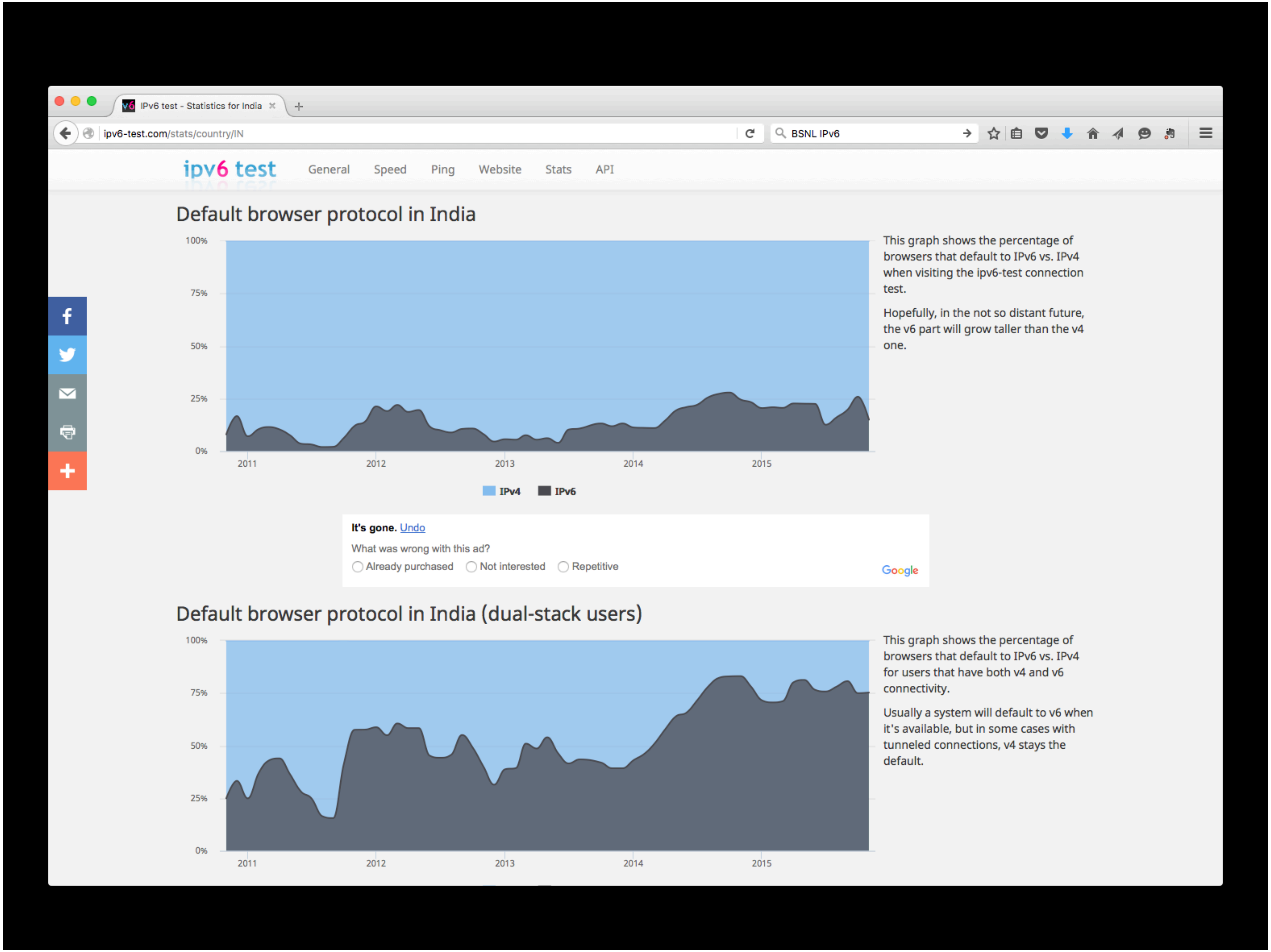


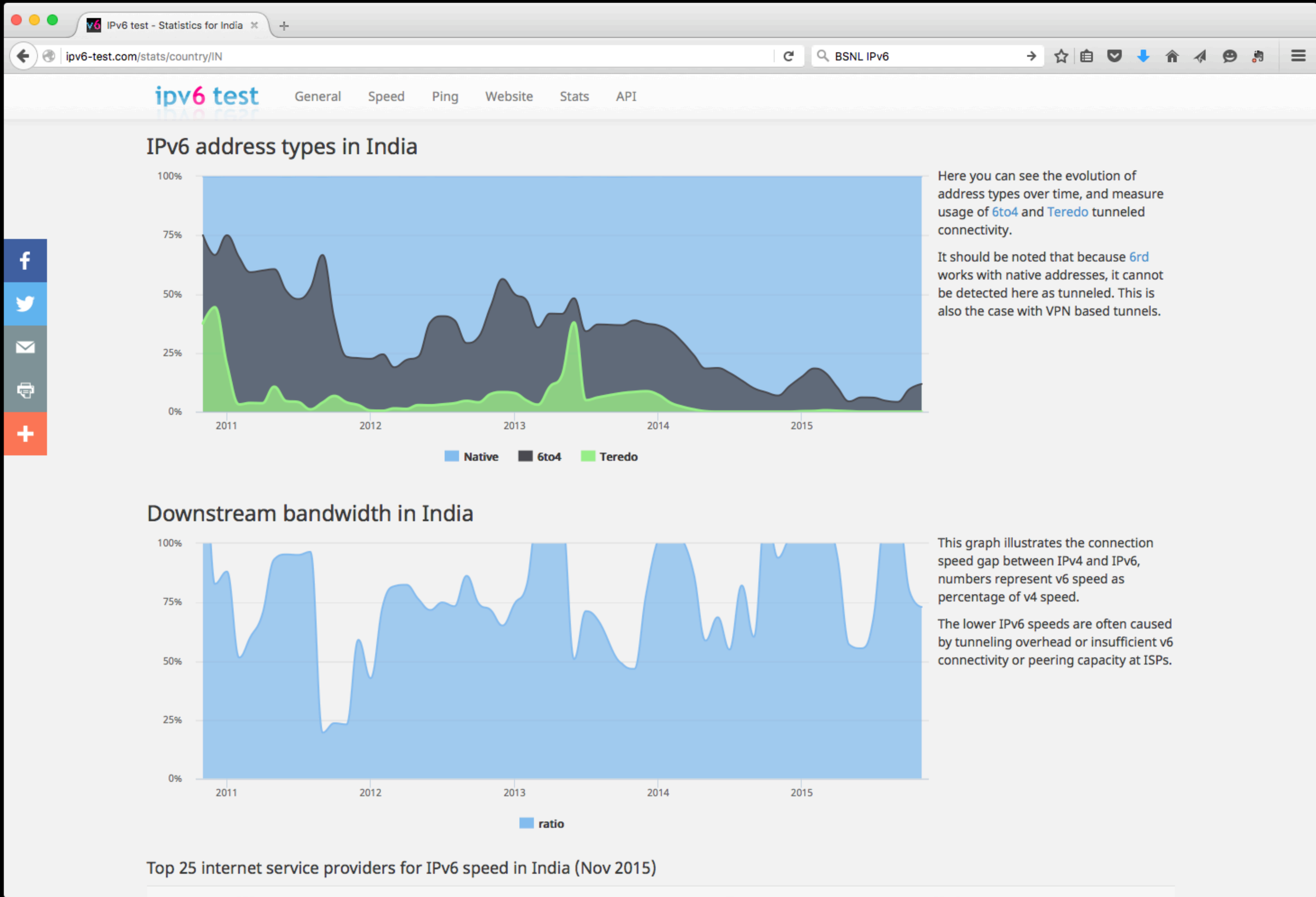
This graph shows the evolution of IPv6 support vs IPv4 for unique users of our connection test.

The numbers are percentages, so we can expect a slow growth towards 50% v4 / 50% v6.

Top 25 internet service providers for IPv6 in India (unique addresses, Nov 2015)

	ISP	Unique IPv6 addresses
1.	Set R4G TRAIL	**366**
2.	Reliance-infotel	**196**
3.	Pace Internet	**41**
4.	Hurricane Electric	**22**
5.	Idea Cellular Limited	**17**
6.	BSNL Internet	**15**
7.	Mts	**10**
8.	Ttl Cisco	**6**
9.	National Knowledge Network	**6**
10.	Bharti	**5**
11.	Asianet	**5**


IPv6 test - Statistics for India
ipv6-test.com/stats/country/IN
BSNL IPv6
ipv6 test
General
Speed
Ping
Website
Stats
API
Default browser protocol in India
100%
75%
50%
25%
0%
2011
2012
2013
2014
2015
IPv4
IPv6
This graph shows the percentage of browsers that default to IPv6 vs. IPv4 when visiting the ipv6-test connection test.
Hopefully, in the not so distant future, the v6 part will grow taller than the v4 one.
It's gone. Undo
What was wrong with this ad?
Already purchased
Not interested
Repetitive
Google
Default browser protocol in India (dual-stack users)
100%
75%
50%
25%
0%
2011
2012
2013
2014
2015
This graph shows the percentage of browsers that default to IPv6 vs. IPv4 for users that have both v4 and v6 connectivity.
Usually a system will default to v6 when it's available, but in some cases with tunneled connections, v4 stays the default.


IPv6 test - Statistics for India
ipv6-test.com/stats/country/IN
BSNL IPv6
ipv6 test
General
Speed
Ping
Website
Stats
API
IPv6 address types in India
100%
75%
50%
25%
0%
2011
2012
2013
2014
2015
Native
6to4
Teredo
Here you can see the evolution of address types over time, and measure usage of 6to4 and Teredo tunneled connectivity.
It should be noted that because 6rd works with native addresses, it cannot be detected here as tunneled. This is also the case with VPN based tunnels.
Downstream bandwidth in India
100%
75%
50%
25%
0%
2011
2012
2013
2014
2015
ratio
This graph illustrates the connection speed gap between IPv4 and IPv6, numbers represent v6 speed as percentage of v4 speed.
The lower IPv6 speeds are often caused by tunneling overhead or insufficient v6 connectivity or peering capacity at ISPs.
Top 25 internet service providers for IPv6 speed in India (Nov 2015)

IPv6 test - Statistics for India

ipv6-test.com/stats/country/IN

BSNL IPv6

ipv6 test General Speed Ping Website Stats API

Top 25 internet service providers for IPv6 speed in India (Nov 2015)

	ISP	Test count	IPv6 average
1.	National Knowledge Network	13	**28.1** Mbps
2.	Hurricane Electric	25	**27.2** Mbps
3.	Reliance-infotel	240	**8.5** Mbps
4.	Set R4G TRAIL	454	**4.9** Mbps
5.	Pace Internet	59	**3.0** Mbps
6.	Bharti	6	**1.7** Mbps
7.	Asianet	8	**0.9** Mbps
8.	Mts	12	**0.6** Mbps
9.	BSNL Internet	27	**0.4** Mbps
10.	Tatacomm	5	**0.2** Mbps
11.	Ttl Cisco	7	**0.0** Mbps
12.	gogo6 Inc.	5	**0.0** Mbps
13.	Team Cymru Inc.	13	**0.0** Mbps
14.	Idea Cellular Limited	17	**0.0** Mbps
15.	Nicnet	5	**0.0** Mbps
16.	Tier IV Datacenters Limited	72	**0.0** Mbps

Why IPv6?

- Reason 1: Response Speed means Quality of Online Banking
  - “IPv6 by default” is increasing
  - Falling back to IPv4 increases response speed of service
- Reason 2: IoT will mean IPv6
  - Online Banking can be triggered by end user’s devices and context
  - What about Ads to various smaller and smart devices?
- Reason 3: Anyway, Internet doesn’t wait for legacy (IPv4-only) services!!

Suggestions

- Make your software Protocol Independent
  - Support both IPv4 and IPv6 using the same source code
  - Use getaddrinfo() instead of gethostbyname(), etc.
- Enable Dual Stack operation in your network and services
- Give pressure to your ISP to natively support IPv6 if not yet

Thank you. Q&A?