

Communication Protocols  
and Internet Architectures

Harvard University

Lecture #6

Instructor: Len Evenchik  
[cs40@evenchik.com](mailto:cs40@evenchik.com) or [evenchik@fas.harvard.edu](mailto:evenchik@fas.harvard.edu)

ALIGHLSOD1701

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Lecture Agenda

- Course Logistics
- Q&A and Topics from Last Week
- IP Address Allocation
- Autonomous Systems, Routing and BGP
- IPv6
- One Minute Wrap-Up

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# **Course Logistics**

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## **Course Logistics**

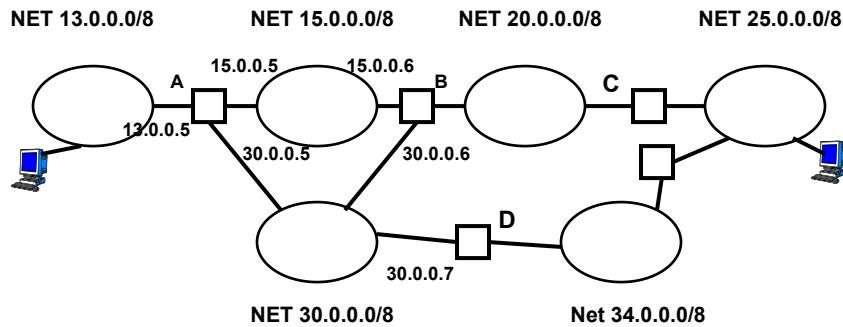
- Homework update
- There will be an online midterm exam and an on-campus or proctored final exam. Students in New England must take the final exam on campus while distance students must arrange to have it proctored.
- Please see the syllabus for the dates of the midterm and the final exam.
- **Please submit a one minute wrap-up each week.  
Thank You!**

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# **Q&A and Some Things from Previous Lectures**

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## **What Does a Router Do?**



**What is in the routing tables of routers A, B, C and D?**

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## **Simplified Router Forwarding Table**

Network #	Distance (or cost)	Outgoing Port #	Next Hop IP Address	Etc.,

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## **Virtual LANs (VLANs) 802.1P & 802.1Q**

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## Virtual LANs (1)

*“Switches are easy, routers are hard.” Given this, how can we separate users via switches? What are the benefits?*

- Virtual LANs assign users to a specific IP network regardless of the ethernet switch, or the port on a particular switch, that the user is physically connected to.
- This means that different users on the same ethernet switch can be members of different networks. In other words, one switch can support multiple IP networks.
- Each network (or subnet) has a different IP network number and therefore provides a separate broadcast domain.
- The switches maintain VLAN configuration information which identifies which switch ports, and/or which users, are members of each VLAN, i.e., individual IP network.

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## Virtual LANs (2)

- The switches maintain VLAN configuration information which identifies which switch ports, and/or which users, are members of each VLAN, i.e., individual IP network.
- By using VLANs, one IP network can span multiple switches and multiple locations.
- Users are assigned to a VLAN by a network administrator, or automatically via a management system. Auto-configuration requires a policy such as, “all users on switch ports 1 to 5 are on the accounting network”
- The term VLAN can be confusing since it mixes together two different things: LAN topology, and assigning users to a particular IP network.
- Given that users on different VLANs are on different IP networks, how do they talk to each other?

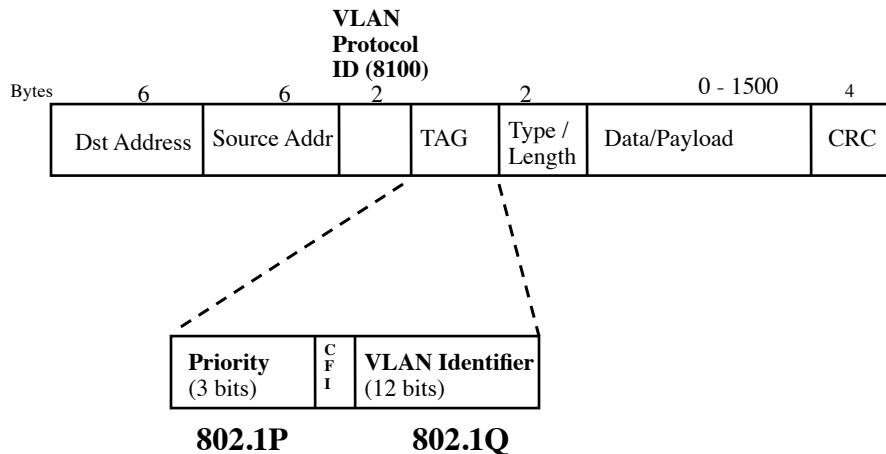
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## Virtual LANs – 802.1q

- VLANs are identified by a 12 bit VLAN Identifier. It is common to talk about VLAN colors, but there are no colors. A VLAN tag is a number.
- Devices connected to a switch are assigned, or put into a specific VLAN, based on one or more of the following:
  - Switch Port – all devices on this port are on a specific VLAN
  - MAC address of the sending station
  - IP address of the device
  - Type of traffic on that port – specific VLAN for wireless traffic
  - Specific user that is currently logged into a device
  - Other IP and/or TCP information
  - Combination of the above
- Ethernet priority and VLANs are distinct concepts, but they are intertwined by the technology.

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## IEEE 802.1 P / Q Frame Format

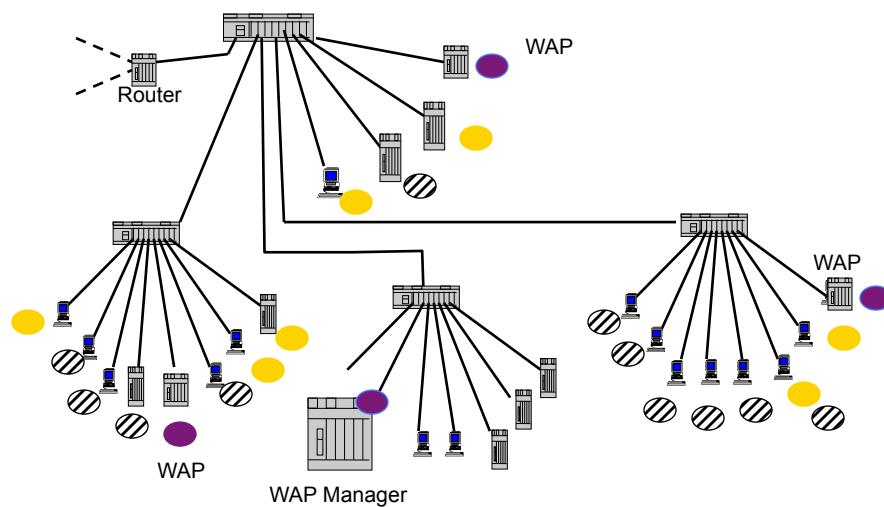


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# Wireless LANs and VLANs

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## Wireless Networks and VLAN Topology



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## **Address Allocation**

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# IANA Address Resources

**iana**  
Internet Assigned Numbers Authority

DOMAINS NUMBERS PROTOCOLS ABOUT IANA

**Number Resources**

- Overview**
- Abuse Issues
- Overview
- Questions and Answers

## Number Resources

IANA is responsible for global coordination of the Internet Protocol addressing systems, as well as the Autonomous System Numbers used for routing Internet traffic.

Currently there are two types of Internet Protocol (IP) addresses in active use: IP version 4 (IPv4) and IP version 6 (IPv6). IPv4 was initially deployed on 1 January 1983 and is still the most commonly used version. IPv4 addresses are 32-bit numbers often expressed as 4 octets in "dotted decimal" notation (for example, 192.0.2.53). Deployment of the IPv6 protocol began in 1999. IPv6 addresses are 128-bit numbers and are conventionally expressed using hexadecimal strings (for example, 2001:0db8:85a3:0000:0000:8a2e:33:29).

Both IPv4 and IPv6 addresses are generally assigned in a hierarchical manner. Users are assigned IP addresses by Internet service providers (ISPs). ISPs obtain allocations of IP addresses from a local Internet registry (LIR) or National Internet Registry (NIR), or from their appropriate Regional Internet Registry (RIR):

Registry	Area Covered
AFRINIC	Africa Region
APNIC	Asia/Pacific Region
ARIN	Canada, USA, and some Caribbean Islands
LACNIC	Latin America and some Caribbean Islands
RIPE NCC	Europe, the Middle East, and Central Asia

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# IPv4 Address Distribution

**Source and copyright:**  
<http://www.icann.org/en/announcements/announcement-29jan10-en.htm>

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## Regional IP Addresses (partial listing)

- 41/8 (41.0.0.0 to 41.255.255.255)  
<http://www.afrinic.net> - Africa Region
- 194/8 and 195/8 (194.0.0.0 to 195.255.255.255)  
<http://www.ripe.net> - Europe, Middle East, and Central Asia
- 198/8 and 199/8 (198.0.0.0 to 199.255.255.255)  
<https://www.arin.net> - North America
- 200/8 and 201/8 (200.0.0.0 to 201.255.255.255)  
<http://www.lacnic.net> - Latin America and Caribbean Region
- 202/8 and 203/8 (202.0.0.0 to 203.255.255.255)  
<http://www.apnic.net/> - Asia and Pacific Regions

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## IPv4 Address Space Registry (1 of 2)

### IANA IPv4 Address Space Registry

#### Last Updated

2017-09-15

#### Registration Procedure(s)

Allocations to RIRs are made in line with the Global Policy published at (<http://www.icann.org/en/resources/policy/global-addressing>).

#### Description

The allocation of Internet Protocol version 4 (IPv4) address space to various registries is listed here. Originally, all the IPv4 address spaces was managed directly by the IANA. Later parts of the address space were allocated to various other registries to manage for particular purposes or regional areas of the world. RFC 1466 [[RFC1466](#)] documents most of these allocations.

#### References

[[RFC249](#)]

#### Available Formats



Prefix	Designation	Date	WHOIS	RDAP	Status	Note
000/8	IANA - Local Identification	1981-09			RESERVED	[2]
001/8	APNIC	2010-01	whois.apnic.net	<a href="https://rdap.apnic.net/">https://rdap.apnic.net/</a>	ALLOCATED	
002/8	RIPE NCC	2009-09	whois.ripe.net	<a href="https://rdap.db.ripe.net/">https://rdap.db.ripe.net/</a>	ALLOCATED	
003/8	General Electric Company	1994-05	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
004/8	Level 3 Communications, Inc.	1992-12	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
005/8	RIPE NCC	2010-11	whois.ripe.net	<a href="https://rdap.db.ripe.net/">https://rdap.db.ripe.net/</a>	ALLOCATED	
006/8	Army Information Systems Center	1994-02	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
007/8	Administered by ARIN	1995-04	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
008/8	Level 3 Communications, Inc.	1992-12	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
009/8	Administered by ARIN	1992-08	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
010/8	IANA - Private Use	1995-06			RESERVED	[3]
011/8	DoD Intel Information Systems	1993-05	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
012/8	AT&T Bell Laboratories	1995-06	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	
013/8	Administered by ARIN	1991-09	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	LEGACY	

## IPv4 Address Space Registry (2 of 2)

CODE	NAME	WHOIS ARIN.NET	LEGACY
033/8	DLA Systems Automation Center	1991-01 whois.arin.net	LEGACY
034/8	Halliburton Company	1993-03 whois.arin.net	LEGACY
035/8	Administered by ARIN	1994-04 whois.arin.net	LEGACY
036/8	APNIC	2010-10 whois.apnic.net	ALLOCATED
037/8	RIPE NCC	2010-11 whois.ripe.net	ALLOCATED
038/8	PSINet, Inc.	1994-09 whois.arin.net	LEGACY
039/8	APNIC	2011-01 whois.apnic.net	ALLOCATED
040/8	Administered by ARIN	1994-06 whois.arin.net	LEGACY
041/8	AFRINIC	2005-04 whois.afrinic.net	ALLOCATED
042/8	APNIC	2010-10 whois.apnic.net	ALLOCATED
043/8	Administered by APNIC	1991-01 whois.apnic.net	LEGACY
044/8	Amateur Radio Digital Communications	1992-07 whois.arin.net	LEGACY
045/8	Administered by ARIN	1995-01 whois.arin.net	LEGACY
046/8	RIPE NCC	2009-09 whois.ripe.net	ALLOCATED
047/8	Administered by ARIN	1991-01 whois.arin.net	LEGACY
048/8	Prudential Securities Inc.	1995-05 whois.arin.net	LEGACY
049/8	APNIC	2010-08 whois.apnic.net	ALLOCATED
050/8	ARIN	2010-02 whois.arin.net	ALLOCATED
051/8	UK Government Department for Work and Pensions	1994-08 whois.ripe.net	LEGACY
052/8	E.I. duPont de Nemours and Co., Inc.	1991-12 whois.arin.net	LEGACY
053/8	Daimler AG	1993-10 whois.ripe.net	LEGACY
054/8	Administered by ARIN	1992-03 whois.arin.net	LEGACY
055/8	DoD Network Information Center	1995-04 whois.arin.net	LEGACY
056/8	US Postal Service	1994-06 whois.arin.net	LEGACY
057/8	Societe Internationale de Telecommunications Aeronautiques S.C.R.L.	1995-05 whois.ripe.net	LEGACY
058/8	APNIC	2004-04 whois.apnic.net	ALLOCATED
059/8	APNIC	2004-04 whois.apnic.net	ALLOCATED
060/8	APNIC	2003-04 whois.apnic.net	ALLOCATED
061/8	APNIC	1997-04 whois.apnic.net	ALLOCATED
062/8	RIPE NCC	1997-04 whois.ripe.net	ALLOCATED
093/8	ARIN	1997-04 whnis.arin.net	ALLOCATED

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## ARIN <https://www.arin.net>

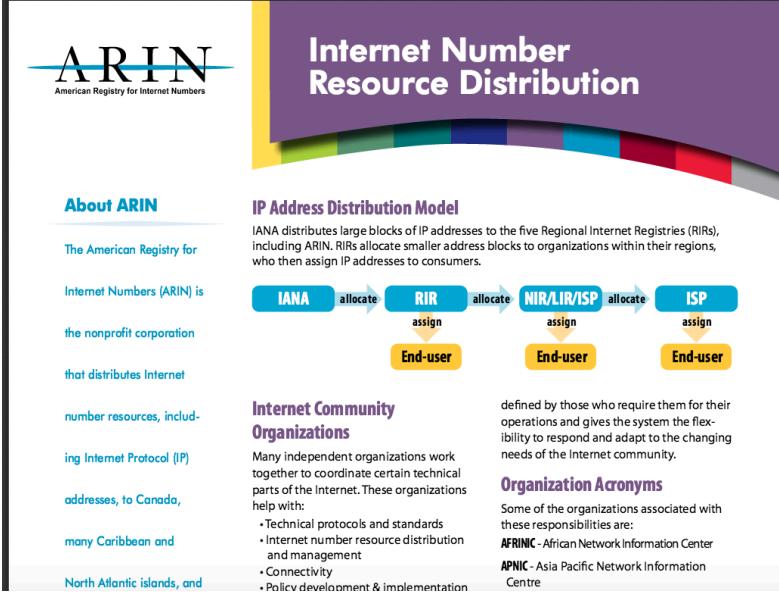
**ARIN WHOIS Lookup**  
<https://whois.arin.net>

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**ARIN WHOIS on 128.103.0.0/16**

Source: <http://whois.arin.net/> (October 2017) © 1998 - 2017 L. Evenchik

## ARIN IP Address Distribution



The American Registry for Internet Numbers (ARIN) is the nonprofit corporation that distributes Internet number resources, including Internet Protocol (IP) addresses, to Canada, many Caribbean and North Atlantic islands, and

**IP Address Distribution Model**

IANA distributes large blocks of IP addresses to the five Regional Internet Registries (RIRs), including ARIN. RIRs allocate smaller address blocks to organizations within their regions, who then assign IP addresses to consumers.

```

graph LR
    IANA[IANA] -- "allocate" --> RIR[RIR]
    RIR -- "assign" --> EndUser1[End-user]
    RIR -- "allocate" --> NIRLIRISP[NIR/LIR/ISP]
    NIRLIRISP -- "assign" --> EndUser2[End-user]
    NIRLIRISP -- "assign" --> ISP[ISP]
    ISP -- "assign" --> EndUser3[End-user]
  
```

**Internet Community Organizations**

Many independent organizations work together to coordinate certain technical parts of the Internet. These organizations help with:

- Technical protocols and standards
- Internet number resource distribution and management
- Connectivity
- Policy development & implementation

defined by those who require them for their operations and gives the system the flexibility to respond and adapt to the changing needs of the Internet community.

**Organization Acronyms**

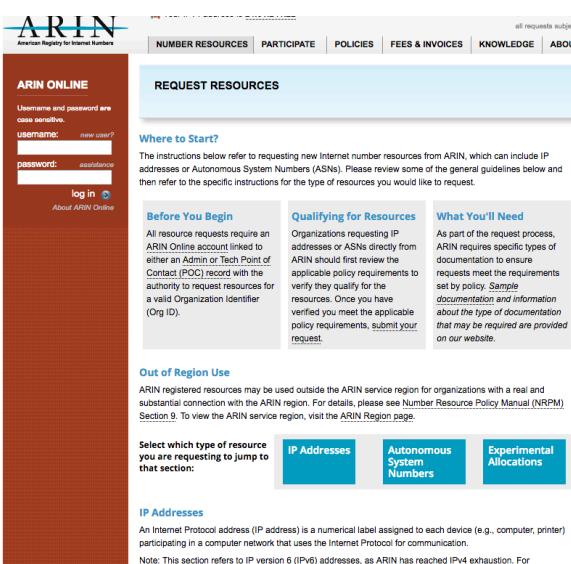
Some of the organizations associated with these responsibilities are:

- AFRINIC - African Network Information Center
- APNIC - Asia Pacific Network Information Centre

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## ARIN IP Address Request

<https://www.arin.net/resources/request.html>



**Before You Begin**

All resource requests require an ARIN Online account linked to either an Admin or Tech Point of Contact (POC) record with the authority to request resources for a valid Organization Identifier (Org ID).

**Qualifying for Resources**

Organizations requesting IP addresses or ASNs directly from ARIN should first review the applicable policy requirements to verify they qualify for the resources. Once you have verified you meet the applicable policy requirements, submit your request.

**What You'll Need**

As part of the request process, ARIN requires specific types of documentation to ensure requests meet the requirements set by policy. Sample documentation and information about the type of documentation that may be required are provided on our website.

**Out of Region Use**

ARIN registered resources may be used outside the ARIN service region for organizations with a real and substantial connection with the ARIN region. For details, please see Number Resource Policy Manual (NRPM) Section 9. To view the ARIN service region, visit the ARIN Region page.

Select which type of resource you are requesting to jump to that section:

- IP Addresses**
- Autonomous System Numbers**
- Experimental Allocations**

**IP Addresses**

An Internet Protocol address (IP address) is a numerical label assigned to each device (e.g., computer, printer) participating in a computer network that uses the Internet Protocol for communication.

Note: This section refers to IP version 6 (IPv6) addresses, as ARIN has reached IPv4 exhaustion. For instructions on how to obtain IPv4 address space, visit the [Request IPv4 Addresses page](#).

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**IPv4 Address Blocks at ARIN  
in October 2014**

REMAINING IPV4 INVENTORY	
Discrete Block Size (CIDR)	Number of Blocks Available
/10	1
/11	1
/12	2
/13	1
/16	6
/17	4
/18	7
/19	4
/20	10
/21	88
/22	93
/23	403
/24	988

Source: <http://whois.arin.net/> (October 2014) © 1998 - 2017 L. Evenchik

**ARIN IPv4 Address Depletion**  
[https://www.arin.net/resources/request/ipv4\\_countdown.html](https://www.arin.net/resources/request/ipv4_countdown.html)

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## ARIN IPv4 Address Depletion

<https://www.arin.net/vault/announcements/2015/20150924.html>



### ARIN IPv4 Free Pool Reaches Zero

Posted: Thursday, 24 September 2015

On 24 September 2015, ARIN issued the final IPv4 addresses in its free pool. ARIN will continue to process and approve requests for IPv4 address blocks. Those approved requests may be fulfilled via the [Wait List for Unmet IPv4 Requests](#), or through the [IPv4 Transfer Market](#).

Exhaustion of the ARIN Free Pool does trigger changes in ARIN's Specified Transfer policy ([NRPM 8.3](#)) and Inter-RIR Transfer policy ([NRPM 8.4](#)). In both cases, these changes impact organizations that have been the source entity in a specified transfer within the last twelve months:

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## Private Address

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# Private IP Addresses

- Defined in RFC 1918. The title of this RFC is “Address Allocation for Private Internets”
  - A better way to think about these addresses is that they are not publicly routable. This means that the public Internet will not route IP packets with these addresses.
- |              |                                |
|--------------|--------------------------------|
| • 10/8       | 10.0.0.0 to 10.255.255.255     |
| • 172.16/12  | 172.16.0.0 to 172.31.255.255   |
| • 169.254/16 | 169.254.0.0 to 169.254.255.255 |
| • 192.168/16 | 192.168.0.0 to 192.168.255.255 |

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## IPv4 RFC 1918

### IANA IPv4 Special-Purpose Address Registry

Created  
2009-08-19  
Last Updated  
2017-07-03  
Available Formats  
 CSV  
 JSON  
 XML  
 HTML  
 Plain text

#### Registry included below

- IANA IPv4 Special-Purpose Address Registry

Address Block	Name	RFC
0.0.0/8	"This host on this network"	[RFC1122], Section 3.2.1.3
10.0.0/8	Private-Use	[RFC1918]
100.64.0.0/10	Shared Address Space	[RFC6598]
127.0.0/8	Loopback	[RFC1122], Section 3.2.1.3
169.254.0.0/16	Link Local	[RFC3927]
172.16.0.0/12	Private-Use	[RFC1918]
192.0.0/24	IETF Protocol Assignments	[RFC6890], Section 2.1
192.0.0/29	IPv4 Service Continuity Prefix	[RFC7335]
192.0.0/32	IPv4 dummy address	[RFC7600]
192.0.0/32	Port Control Protocol Anycast	[RFC7723]
192.0.0/10/32	Traversal Using Relays around NAT Anycast	[RFC8155]
192.0.0.170/32, 192.0.0.171/32	NAT64/DNS64 Discovery	[RFC7050], Section 2.2
192.0.2/24	Documentation (TEST-NET-1)	[RFC6737]
192.31.198.0/24	AS112-v4	[RFC7595]
192.52.193.0/24	AMT	[RFC7490]
192.88.99.0/24	Deprecated (6to4 Relay Anycast)	[RFC7526]
192.168.0.0/16	Private-Use	[RFC1918]
192.175.48.0/24	Direct Delegation AS112 Service	[RFC7534]
198.18.0.0/15	Benchmarking	[RFC2544]
198.51.100.0/24	Documentation (TEST-NET-2)	[RFC5737]
203.0.113.0/24	Documentation (TEST-NET-3)	[RFC5737]
240.0.0.0/4	Reserved	[RFC1112], Section 4
255.255.255.255/32	Limited Broadcast	[RFC8190] [RFC919], Section 7

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## **Autonomous Systems, ASN, and Routing**

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## **Routing Protocol Families**

- Interior gateway protocols (IGP) are used to exchange routing information within an Autonomous System (AS.) In this case, an AS is a network such as one managed by Harvard or an ISP such as RCN.
- RIP and OSPF are examples of IGP.
- Exterior gateway protocols are used to advertise routes between autonomous systems and manage the routing between AS. BGPv4 is the prime example of such a protocol.

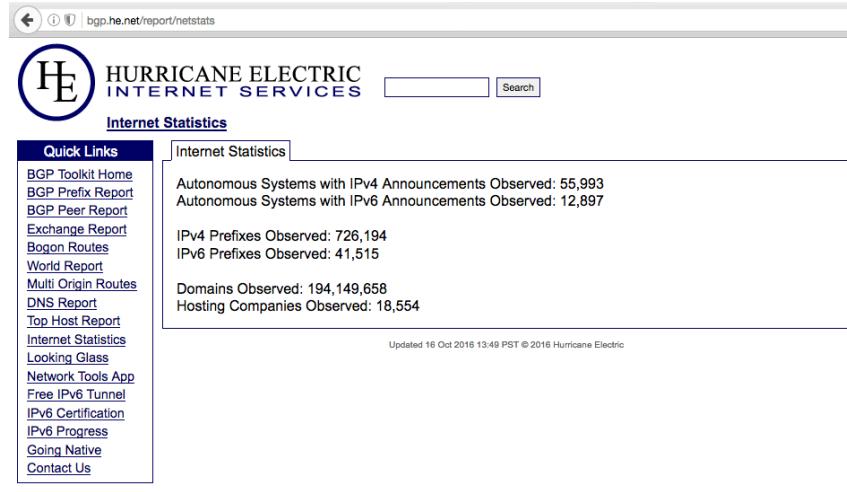
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## **ASN - Autonomous System Number**

- In simple terms, an Autonomous System is a group of routers that are managed by a single organization. An AS can be a large user (corporation or university), an ISP, or another type of network provider.
- An AS is identified by an ASN
- The concept of an Autonomous System provides a way to manage the complexity of the Internet and Internet routing.
- The number of autonomous systems in the Internet is significantly less than the number of networks that comprise the Internet.
- One AS originates and announces multiple network prefixes. It originates fewer than it announces.

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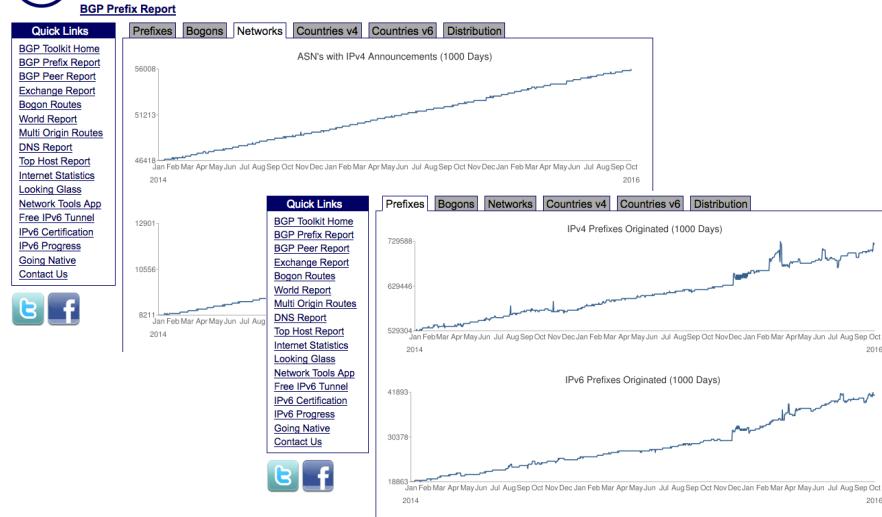
## AS Is Not the Same as an Address Prefix (1)



Source: <http://bgp.he.net/>

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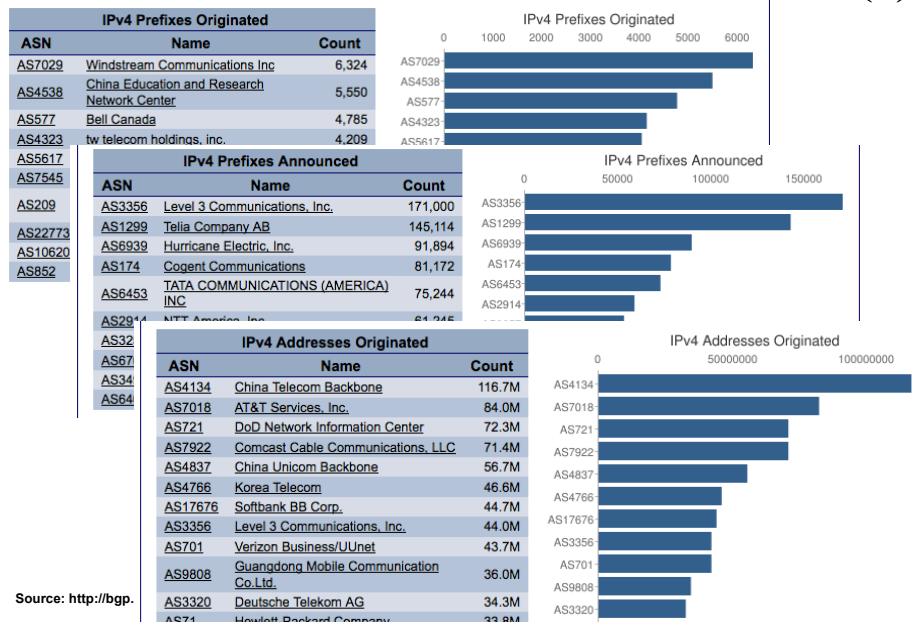
## AS Is Not the Same as an Address Prefix (2)



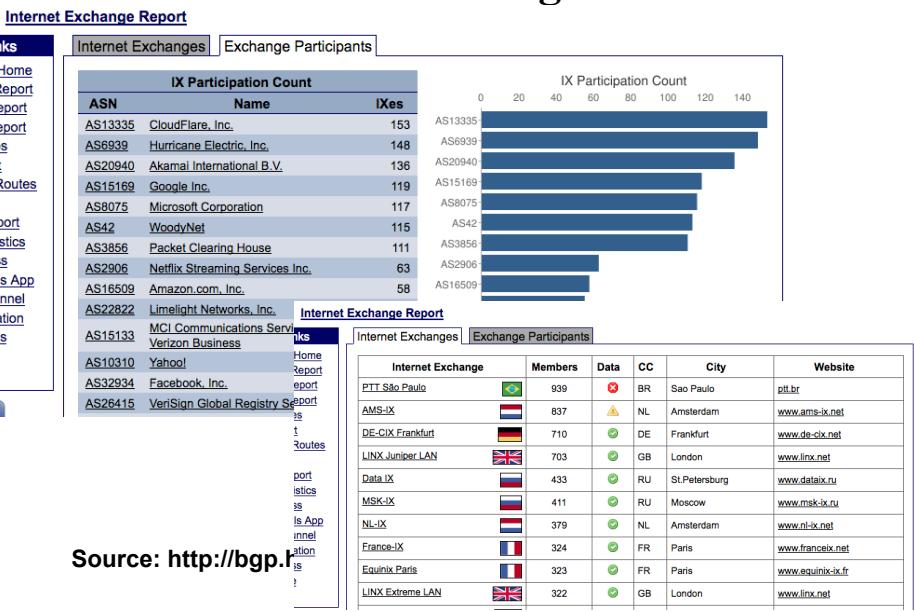
Source: <http://bgp.he.net/>

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## AS Is Not the Same as an Address Prefix (3)



## Internet Exchange Points



## RCN Manages a Number of AS

**HURRICANE ELECTRIC  
INTERNET SERVICES**

Quick Links

- [BGP Toolkit Home](#)
- [BGP Prefix Report](#)
- [BGP Peer Report](#)
- [Bogon Routes](#)
- [World Report](#)
- [Multi Origin Routes](#)
- [DNS Report](#)
- [Top Host Report](#)
- [Internet Statistics](#)
- [Looking Glass](#)
- [Network Tools App](#)
- [Free IPv6 Tunnel](#)
- [IPv6 Certification](#)
- [IPv6 Progress](#)
- [Going Native](#)
- [Contact Us](#)

Search Results

Result	Description
<a href="#">AS7848</a>	RCN
<a href="#">AS6555</a>	RCN
<a href="#">AS6249</a>	RCN
<a href="#">AS6079</a>	RCN
<a href="#">AS5712</a>	RCN
<a href="#">AS4530</a>	RCN
<a href="#">AS4527</a>	RCN
<a href="#">AS3803</a>	RCN
<a href="#">AS3674</a>	RCN
<a href="#">AS10513</a>	RCN
<a href="#">AS10368</a>	RCN

Source: <http://bgp.he.net/>

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## One AS Announces Many IP Address Prefixes

**HURRICANE ELECTRIC  
INTERNET SERVICES**

AS6079 RCN

Quick Links

- [BGP Toolkit Home](#)
- [BGP Prefix Report](#)
- [BGP Peer Report](#)
- [Exchange Report](#)
- [Bogon Routes](#)
- [World Report](#)
- [Multi Origin Routes](#)
- [DNS Report](#)
- [Top Host Report](#)
- [Internet Statistics](#)
- [Looking Glass](#)
- [Network Tools App](#)
- [Free IPv6 Tunnel](#)
- [IPv6 Certification](#)
- [IPv6 Progress](#)
- [Going Native](#)
- [Contact Us](#)

AS Info Graph v4 Graph v6 Prefixes v4 Prefixes v6 Peers v4 Peers v6 Whois IRR IX

Prefix	Description
24.136.0.0/19	RCN
24.136.0.0/20	RCN
24.136.16.0/20	RCN
24.148.0.0/18	RCN
24.148.0.0/19	RCN
24.148.32.0/19	RCN
24.148.64.0/19	RCN
24.148.64.0/20	RCN
24.148.80.0/20	RCN
64.121.0.0/16	RCN
64.121.0.0/17	RCN

Source: <http://bgp.he.net/> (2017)

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## Harvard AS 1742

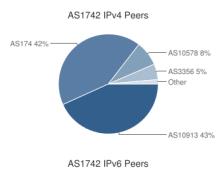
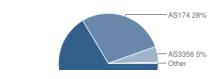
**(HE) HURRICANE ELECTRIC INTERNET SERVICES**

AS1742 Harvard University

**Quick Links**

- [BGP Toolkit Home](#)
- [BGP Prefix Report](#)
- [BGP Peer Report](#)
- [Exchange Report](#)
- [Bogon Routes](#)
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- [Network Tools App](#)
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- [IPv6 Certification](#)
- [IPv6 Progress](#)
- [Going Native](#)
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[!\[\]\(b71737736c94679dc790a0d0ccaa8792\_img.jpg\)](#) [!\[\]\(98e5e019384262c45abb731b7ca6cb22\_img.jpg\)](#)

<p>Country of Origin:</p> <p>United States </p> <p>Prefixes Originated (all): 17 Prefixes Originated (v4): 15 Prefixes Originated (v6): 2</p> <p>BGP Peers Observed (all): 9 BGP Peers Observed (v4): 9 BGP Peers Observed (v6): 4</p> <p>Average AS Path Length (all): 4.419 Average AS Path Length (v4): 4.361 Average AS Path Length (v6): 4.569</p> 	<p>Prefixes Announced (all): 21 Prefixes Announced (v4): 19 Prefixes Announced (v6): 2</p> <p>IPs Originated (v4): 215,808 AS Paths Observed (v4): 707 AS Paths Observed (v6): 276</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>ASN</th> <th>Name</th> </tr> </thead> <tbody> <tr> <td>AS10913</td> <td>Intersea Network Services Corporation</td> </tr> <tr> <td>AS174</td> <td>Cogent Communications</td> </tr> <tr> <td>AS10578</td> <td>Harvard University</td> </tr> <tr> <td>AS3356</td> <td>Level 3 Communications, Inc.</td> </tr> </tbody> </table> <p>AS1742 IPv6 Peers</p>  <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>ASN</th> <th>Name</th> </tr> </thead> <tbody> <tr> <td>AS10578</td> <td>Harvard University</td> </tr> <tr> <td>AS174</td> <td>Cogent Communications</td> </tr> <tr> <td>AS3356</td> <td>Level 3 Communications, Inc.</td> </tr> </tbody> </table>	ASN	Name	AS10913	Intersea Network Services Corporation	AS174	Cogent Communications	AS10578	Harvard University	AS3356	Level 3 Communications, Inc.	ASN	Name	AS10578	Harvard University	AS174	Cogent Communications	AS3356	Level 3 Communications, Inc.
ASN	Name																		
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ASN	Name																		
AS10578	Harvard University																		
AS174	Cogent Communications																		
AS3356	Level 3 Communications, Inc.																		

**Note that Harvard has a more than one AS.**  
Source: <http://bgp.he.net/> (Oct. 2016)

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## Harvard AS 1742 IPv4 Prefixes

**(HE) HURRICANE ELECTRIC INTERNET SERVICES**

AS1742 Harvard University

**Quick Links**

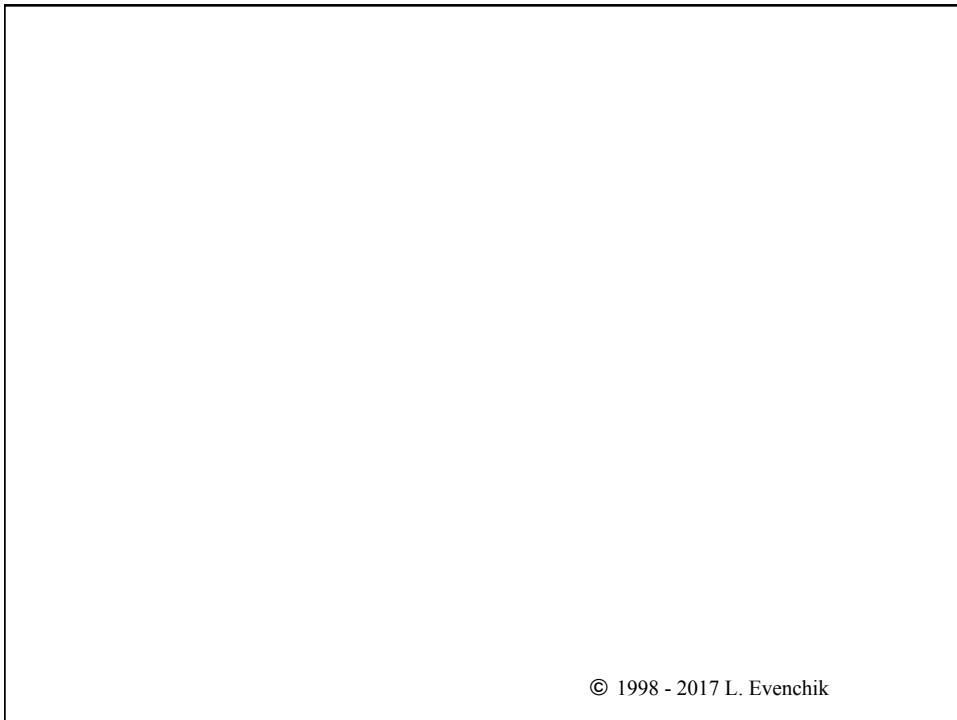
- [BGP Toolkit Home](#)
- [BGP Prefix Report](#)
- [BGP Peer Report](#)
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[!\[\]\(7750f6b14c60f968a2bc65812f3f92db\_img.jpg\)](#) [!\[\]\(e7cf99a695198f48d7c53d4da8381241\_img.jpg\)](#)

Prefix	Description
12.0.48.0/20	AT&T Services, Inc.
12.6.208.0/20	AT&T Services, Inc.
65.112.0.0/20	Harvard University
67.134.204.0/22	QLT HARVARD UNIVERSITY
128.103.0.0/16	Harvard University
131.142.0.0/16	Harvard-Smithsonian Center for Astrophysics
140.247.0.0/16	Harvard University
140.247.111.0/24	Harvard University
140.247.236.0/24	Harvard University
192.5.66.0/24	Harvard University
192.54.223.0/24	Harvard University
192.131.102.0/24	Rowland Institute for Science
199.94.60.0/22	Harvard University
206.191.184.0/21	Private Customer (C06081591)
206.253.200.0/21	Private Customer (C06062813)

**Note that Harvard has multiple AS.**  
Source: <http://bgp.he.net/> (2017)

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## Announcing 512K IPv4 Prefixes Caused a Problem

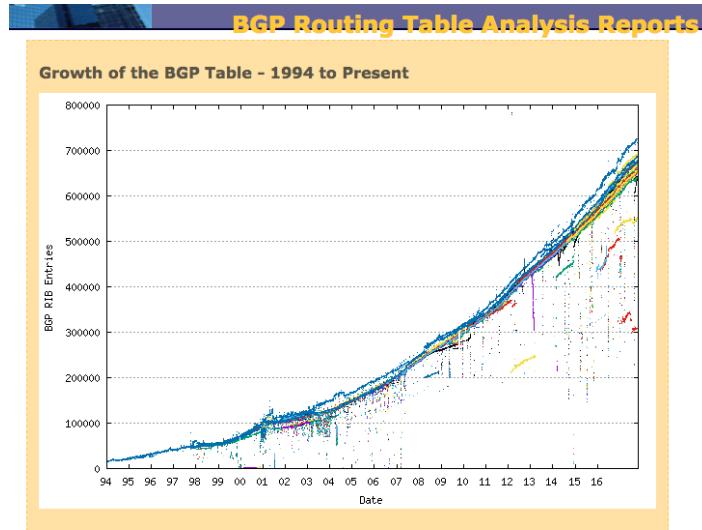
August 12, 2014

The Register logo at the top. Below it is a navigation bar with links: Data Center, Software, Networks, Security, Business, Hardware, Science, Bootnotes, Video, Forums, Weeks, Servers, HPC, Cloud, Storage, Data Networking, Virtualisation, BOFH. A sidebar on the left shows a star icon with the number 176 and the text 'RELATED STORIES'. The main content area starts with the headline 'The internet just BROKE under its own weight – we explain how' and a sub-headline 'Next time, big biz, listen to your network admin'. It includes a byline 'By Trevor Pott, 13 Aug 2014' and a 'Follow' button with 1,530 followers. The text discusses the 512KDay event, mentioning Cisco devices, route limits, and major outages. There are also links for secure remote control and an x86 Cluster market update.

Source: <http://www.theregister.co.uk>

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## Growth of Internet Routing Tables – BGP



Source: <http://bgp.potaroo.net/> (October 2017) © 1998 - 2017 L. Evenchik

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# **Routing – BGP**

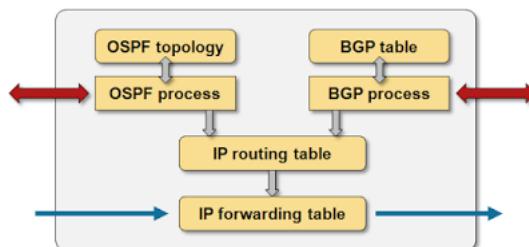
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## **BGP- Border Gateway Protocol**

- BGPv4 is the EGP for the Internet and it manages routing between AS. There are over 70,000 ASN in the Internet and they form an arbitrary interconnected graph.
- BGP can be considered an edge-to-edge protocol that identifies the reachability of a network.
- BGP advertises AS and what networks are within the AS. Networks are identified via their IP prefixes.
- In other words, BGP announces (or withdraws) the reachability of networks.
- BGP runs over TCP, is authenticated, and sends incremental changes to its neighbors
- Note the use of “Gateway”, which is the original name for a router, in the documents

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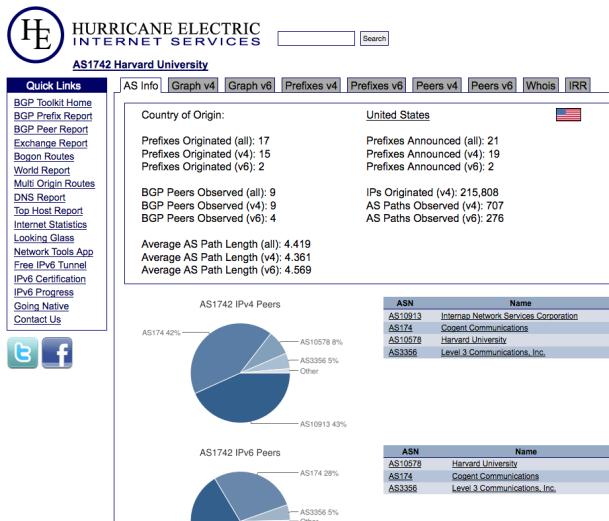
# BGP Routing



Source unknown

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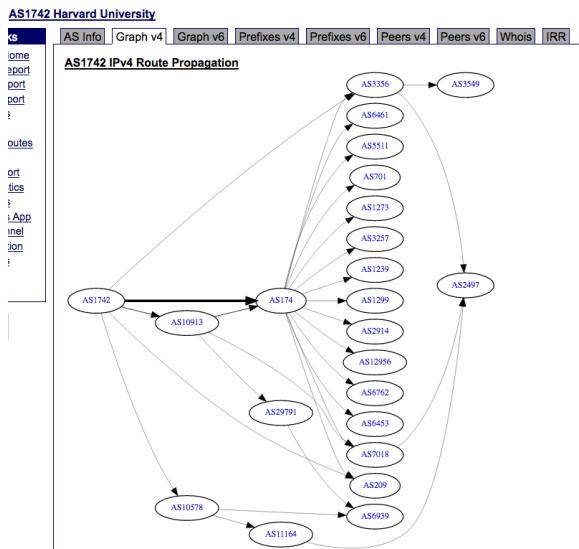
## Harvard AS 1742



Note that Harvard has a more than one AS.  
Source: <http://bgp.he.net/>

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## Harvard AS 1742 Route Propagation (IPv4)



Source: <http://bgp.he.net/> (October 2017)

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## RIPE BGP Tools

The screenshot shows the RIPEstat interface. The top navigation bar includes links for Manage IPs and ASNs, Analyse, Participate, Get Support, Publications, and About Us. The main content area features a search bar for 'Search RIPE stat' and a 'System Statistics' section showing '45,580' requests seen in the last full hour. A sidebar on the left shows 'Your IP address is: 50.136.92.167' and links for RIPEstat Home, About RIPEstat, Documentation, and Use Cases. A small window on the right displays a visualization titled 'Routing visualised! BGPlay.' showing a network graph.

Source: <https://stat.ripe.net>

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## AS1742 Information

Source: <https://stat.ripe.net/as1742#tabId=at-a-glance> (October 2017)

The screenshot shows the 'At a Glance' section for AS1742. It includes:

- AS Overview (AS1742):** Shows the name 'HARVARD-UNIV - Harvard University', RIR 'ARIN', Status 'ASSIGNED', Registration '1992-02-19', and Country 'US'. A button 'Show IANA Registry Information' is present.
- Geoloc (AS1742):** A map of the United States showing network reachability. Labels include '6.83%', '0.11%', and '94.30%'. A note states: 'Data is based on MaxMind's GeoLite City data set and valid for the stated query time (see below)'.
- Whois Matches (AS1742):** Shows ASNumber 1742, ASName HARVARD-UNIV, Ref https://whois.arin.net/rest/asn /AS1742, source ARIN. A note says: 'Showing results for AS1742 as of 2017-10-16 16:51:00 UTC'.
- Routing Status (AS1742):** Shows the first ever seen as origin announcing 12.6.208.0/20 on 2000-08-18 08:00:00 UTC. It lists originated IPv4 prefixes (15), originated IPv6 prefixes (2), observed BGP neighbours (8), address space announced (IPv4) (215808 IPs), and address space announced (IPv6) (equiv. to 65537 /48s).

## AS1742 Information

<https://stat.ripe.net/as1742#tabId=routing>

The screenshot shows the 'Routing Status (AS1742)' section. It includes:

- A note: 'At 2017-10-16 08:00:00 UTC, AS1742 was visible to 100% of 157 IPv4 and 100% of 158 IPv6 RIS full peers.'
- Statistics: First ever seen as origin announcing 12.6.208.0/20, on 2000-08-18 08:00:00 UTC. Originated IPv4 prefixes: 15, Originated IPv6 prefixes: 2, Observed BGP neighbours: 8, Address space announced (IPv4): 215808 IPs, Address space announced (IPv6): equiv. to 65537 /48s.
- A note: 'Results exclude routes with very low visibility (less than 3%)'
- A note: 'Given query time (2017-10-16 08:00:00 UTC) has been chosen, the time there is data available for!'
- BGP Update Activity (AS1742):** A line graph showing announcements per hour from October 4 to 16, 2017. The Y-axis ranges from 0 to 1000. The X-axis shows dates from 4. Oct to 16. Oct. A blue circle marks 'AS1742 (announce)'.

# Which AS are Announcing 128.103.0.0/16

Source: <https://stat.ripe.net/widget/looking-glass> (October 2016)  
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# BOGON Route Announcements

Source: <http://bgp.he.net/> (October 2017)  
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## BOGON Announcements by AS

### Bogon Routes

#### Quick Links

[BGP Toolkit Home](#)  
[BGP Prefix Report](#)  
[BGP Peer Report](#)  
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[Bogons](#) [IPv4 by Origin](#) [IPv6 by Origin](#) [IPv4 by Prefix](#) [IPv6 by Prefix](#)

ASN	Name	Prefixes
AS81	MCNC	192.154.32.0/19 -> unallocated 192.154.64.0/19 -> unallocated
AS112	DNS-OARC	192.31.198.0/24 -> unallocated
AS209	Qwest Communications Company, LLC	209.193.112.0/20 -> unallocated
AS680	Verein zur Foerderung eines Deutschen Forschungsnetzes e.V.	192.124.252.0/22 -> unallocated
AS701	Verizon Business/UUnet	198.168.0.0/16 -> unallocated 208.67.132.0/22 -> unallocated 209.135.171.0/24 -> unallocated 209.135.175.0/24 -> unallocated
AS702	Verizon Business/UUnet Europe	192.101.72.0/24 -> unallocated
AS721	DoD Network Information Center	192.188.208.0/20 -> unallocated 198.97.72.0/21 -> unallocated 198.97.96.0/19 -> unallocated 198.97.240.0/20 -> unallocated 199.121.0.0/16 -> unallocated 199.123.16.0/20 -> unallocated
AS812	Rogers Communications Canada Inc.	198.62.198.0/24 -> unallocated
AS1267	Wind Telecommunicazioni SpA	10.1.8.0/24 -> RFC1918
AS2519	ARTERIA Networks Corporation	103.252.180.0/22 -> unallocated
AS2828	MCI Communications Services, Inc. d/b/a Verizon Business	172.30.102.0/24 -> RFC1918 172.30.103.0/24 -> RFC1918 216.119.192.0/20 -> unallocated

Source: <http://bgp.he.net/> (October 2017)

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## BOGON Announcement



HURRICANE ELECTRIC  
INTERNET SERVICES

209.135.171.0/24

#### Quick Links

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[BGP Prefix Report](#)  
[BGP Peer Report](#)  
[Exchange Report](#)  
[Bogon Routes](#)  
[World Report](#)  
[Multi Origin Routes](#)  
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[Looking Glass](#)  
[Network Tools App](#)

[Network Info](#) [Whois](#) [DNS](#) [IRR](#) [Bogon](#)

209.135.171.0/24 is a bogon prefix (unallocated).

#### Announced By

Origin AS	Announcement	Description
AS701	209.135.171.0/24	American Registry for Internet Numbers

Updated 15 Oct 2017 16:02 PST © 2017 Hurricane Electric

Source: <http://bgp.he.net/> (October 2017)

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# BOGON Announcement

AS701 Verizon Business/UUnet

Quick Links

- BGP Toolkit Home
- BGP Prefix Report
- BGP Peer Report
- Exchange Report
- Bogon Routes
- World Report
- Multi Origin Routes
- DNS Report
- Top Host Report
- Internet Statistics
- Looking Glass
- Network Tools App
- Free IPv6 Tunnel
- IPv6 Certification
- IPv6 Progress
- Going Native
- Contact Us

AS Info | Graph v4 | Graph v6 | Prefixes v4 | Prefixes v6 | Peers v4 | Peers v6 | Whois | IRR | IX

AS701 announces bogons.

Company Website: <http://www.verizonbusiness.com>

Country of Origin: United States 

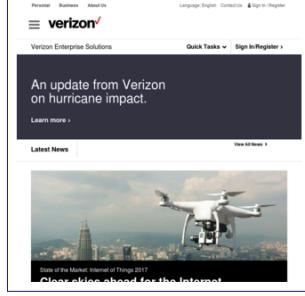
Internet Exchanges: 3

Prefixes Originated (all): 1,872  
Prefixes Originated (v4): 1,852  
Prefixes Originated (v6): 20

Prefixes Announced (all): 21,548  
Prefixes Announced (v4): 20,555  
Prefixes Announced (v6): 993

BGP Peers Observed (all): 1,255  
BGP Peers Observed (v4): 1,248  
BGP Peers Observed (v6): 151

IPs Originated (v4): 43,375,104  
AS Paths Observed (v4): 86,069  
AS Paths Observed (v6): 16,297



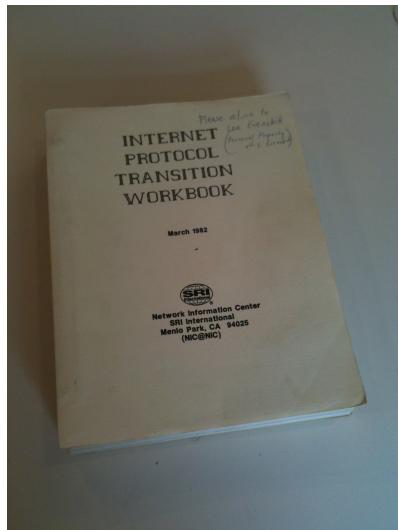
Source: <http://bgp.he.net/> (October 2017) © 1998 - 2017 L. Evenchik

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# IPv6 Fundamentals

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## The First IP Transition

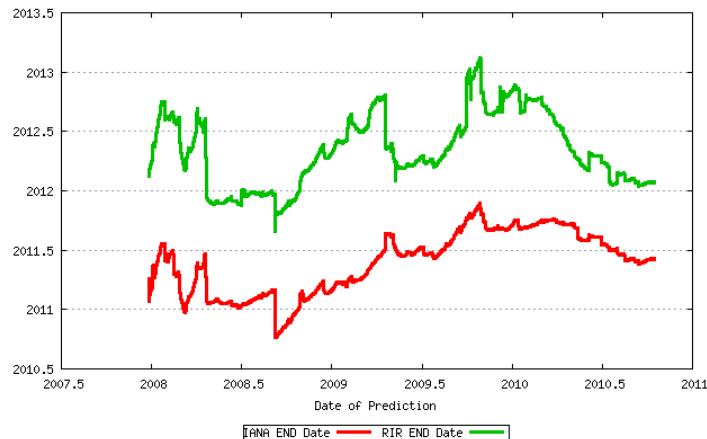


Internet Protocol  
Transition Workbook

March 1982

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## Predicted IP Address Exhaustion Date since early 2008



Source: <http://ipv4.potaroo.net> (2013)

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## ID on IPv4 End of Work

[\[Docs\]](#) [\[txt|pdf|xml|html\]](#) [\[Tracker\]](#) [\[WG\]](#) [\[Email\]](#) [\[Diff1\]](#) [\[Diff2\]](#) [\[Nits\]](#)

Versions: ([draft-howard-ipv4-ietf](#)) 00\_01

Network Working Group L. Howard  
Internet-Draft Retevia  
Intended status: Standards Track September 18, 2017  
Expires: March 22, 2018

**IETF: End Work on IPv4**  
[draft-ietf-sunset4-ipv4-ietf-01](#)

**Abstract**

The IETF will stop working on IPv4, except documented security issues, to facilitate to enable IPv4 decommissioning.

**Status of This Memo**

This Internet-Draft is submitted in full provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also be working on related documents as Internet-Drafts. The current state of this document is available at <https://datatracker.ietf.org>. For the latest published version of this document, please refer to the [IETF](#).

Internet-Drafts are draft documents valid for reference by implementations or as a basis for further discussion. They are subject to change at any time. It is inappropriate to use Internet-Drafts as material or to cite them other than as "works in progress".

This Internet-Draft will expire on March 22, 2018.

**IETF: End Work on IPv4**  
[draft-ietf-sunset4-ipv4-ietf-01](#)

**Status** IESG evaluation record IESG writeups Email expansions History

Versions: 00\_01

[draft-howard-ipv4-ietf](#) 00 [\[diff\]](#)  
[draft-ietf-sunset4-ipv4-ietf](#) 01 [\[diff\]](#)

**Document**

Type Active Internet-Draft (sunset4 WG)  
Last updated 2017-10-02 (latest revision 2017-09-18)  
Replaces [draft-howard-ipv4-ietf](#)  
Stream IETF  
Intended RFC Proposed Standard status  
Formats [\[plain text\]](#) [\[xml\]](#) [\[pdf\]](#) [\[html\]](#) [\[bibxml\]](#)  
Reviews [IETDIR Last Call Review - due: 2017-10-12](#) [GENART Last Call Review - due: 2017-10-12](#)

**Stream**

WG state Submitted to IESG for Publication (wg milestone: Jul 2017 - IPv6 Support Within ...)  
Documents [\[View\]](#)  
Shepherd Marc Blanchet  
Shepherd write-up [\[View\]](#) (last changed 2017-09-19)

**IESG**

IESG state In Last Call (ends 2017-10-12)  
Consensus Yes

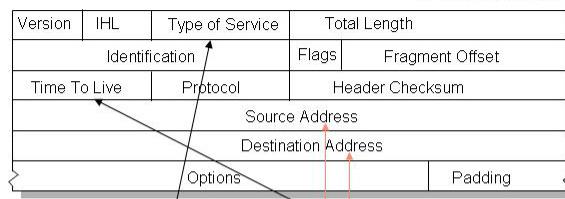
## Primary IPv6 Changes from IPv4 (as described in RFC 2460)

- Expanded Addressing capabilities: addresses are 128 bits long, improved auto-configuration, anycast addresses, etc.
- Simplified Header format
- Better support for Options and Extensions
- Capability for Flow Labeling is added
- Added Authentication and Privacy Capabilities

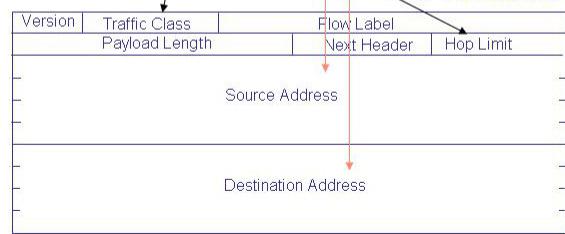
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## IPv4 and IPv6

IPv4 Header



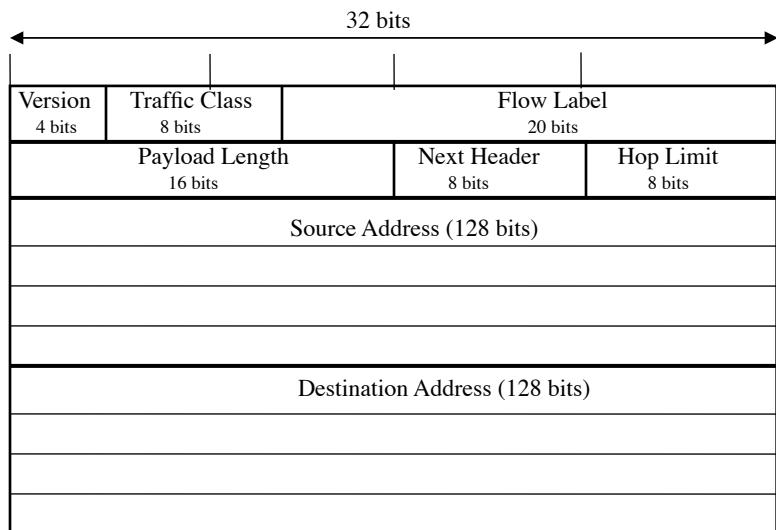
IPv6 Header



Source: <http://ispcolumn.isoc.org/2007-08/fig1.jpg>

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## IPv6 Header Format



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## IPv6 Addresses per RFC 5952

IPv6 addresses are 128 bits long and have the format.  
ABCD:EF01:2345:6789:ABCD:EF01:2345:6789

All of the following are legitimate addresses but  
RFC 5952 recommends a specific representation

2001:db8:0:0:0001:0:00AB:0001  
2001:0db8:0:0:1:0:0AB:1  
2001:db8::0:1:0:AB:1  
2001:0db8::1:0:00ab:1  
2001:DB8::1:0:AB:1 THIS IS THE PREFERRED ONE

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## IPv6 Addressing RFC 4291 (Feb. 2006) but we'll check IANA for the Details,

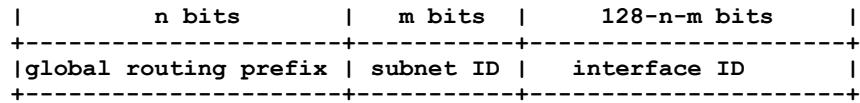
### Section 2.4

The type of an IPv6 address is identified by the high-order bits of the address, as follows:

Address type	Binary prefix	IPv6 notation
Unspecified	00...0 (128 bits)	::/128
Loopback	00...1 (128 bits)	::1/128
Multicast	11111111	FF00::/8
Link-Local unicast	1111111010	FE80::/10
Global Unicast	(everything else)	

### 2.5.4. Global Unicast Addresses

The general format for IPv6 Global Unicast addresses is:



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## IANA IPv6 Address Space Registry

IPv6 Prefix	Allocation	Reference	Notes
0000::/8	Reserved by IETF	[RFC4291]	[1] [2] [3] [4] [5] [6]
0100::/8	Reserved by IETF	[RFC4291]	0100::/64 reserved for Discard-Only Address Block [RFC6666]. Complete registration details are four
0200::/7	Reserved by IETF	[RFC4048]	Deprecated as of December 2004 [RFC4048]. Formerly an OSI NSAP-mapped prefix set [RFC4548].
0400::/6	Reserved by IETF	[RFC4291]	
0800::/5	Reserved by IETF	[RFC4291]	
1000::/4	Reserved by IETF	[RFC4291]	
2000::/3	Global Unicast	[RFC4291]	The IPv6 Unicast space encompasses the entire IPv6 address range with the exception of f000::/8, p, range of 2000::/3. IANA assignments from this block are registered in [IANA registry ipv6-unicast-add].
4000::/3	Reserved by IETF	[RFC4291]	
6000::/3	Reserved by IETF	[RFC4291]	
8000::/3	Reserved by IETF	[RFC4291]	
a000::/3	Reserved by IETF	[RFC4291]	
c000::/3	Reserved by IETF	[RFC4291]	
e000::/4	Reserved by IETF	[RFC4291]	
f000::/5	Reserved by IETF	[RFC4291]	
f800::/6	Reserved by IETF	[RFC4291]	
fc00::/7	Unique Local Unicast	[RFC4193]	For complete registration details, see [IANA registry iana-ipv6-special-registry].
fe00::/9	Reserved by IETF	[RFC4291]	
fe80::/10	Link-Scope Unicast	[RFC4291]	Reserved by protocol. For authoritative registration, see [IANA registry iana-ipv6-special-registry].
fec0::/10	Reserved by IETF	[RFC3879]	Deprecated by [RFC3879] in September 2004. Formerly a Site-Local scoped address prefix.
ff00::/8	Multicast	[RFC4291]	IANA assignments from this block are registered in [IANA registry ipv6-multicast-addresses].

## IANA IPv6 Unicast Address Assignment

Prefix	Designation	Date	WHOIS	RDAP	Status	Note
2001:0000::/23	IANA	1999-07-01	whois.iana.org		ALLOCATED	2001:00 2001:1:: <a href="#">Errata 1</a> for EID: <a href="#">RFC73</a> <a href="#">special-</a>
2001:0200::/23	APNIC	1999-07-01	whois.apnic.net	<a href="https://rdap.apnic.net/">https://rdap.apnic.net/</a>	ALLOCATED	
2001:0400::/23	ARIN	1999-07-01	whois.arin.net	<a href="https://rdap.arin.net/registry">https://rdap.arin.net/registry</a> <a href="http://rdap.arin.net/registry">http://rdap.arin.net/registry</a>	ALLOCATED	
2001:0600::/23	RIPE NCC	1999-07-01	whois.ripe.net	<a href="https://rdap.db.ripe.net/">https://rdap.db.ripe.net/</a>	ALLOCATED	
2001:0800::/23	RIPE NCC	2002-05-02	whois.ripe.net	<a href="https://rdap.db.ripe.net/">https://rdap.db.ripe.net/</a>	ALLOCATED	
2001:0a00::/23	RIPE NCC	2002-11-02	whois.ripe.net	<a href="https://rdap.db.ripe.net/">https://rdap.db.ripe.net/</a>	ALLOCATED	
2001:0c00::/23	APNIC	2002-05-02	whois.apnic.net	<a href="https://rdap.apnic.net/">https://rdap.apnic.net/</a>	ALLOCATED	2001:dt
2001:0e00::/23	APNIC	2003-01-01	whois.apnic.net	<a href="https://rdap.apnic.net/">https://rdap.apnic.net/</a>	ALLOCATED	
2001:1200::/23	LACNIC	2002-11-01	whois.lacnic.net	<a href="https://rdap.lacnic.net/rdap/">https://rdap.lacnic.net/rdap/</a>	ALLOCATED	
2001:1400::/23	RIPE NCC	2003-02-01	whois.ripe.net	<a href="https://rdap.db.ripe.net/">https://rdap.db.ripe.net/</a>	ALLOCATED	

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## Example of IPv6 Address (1)

```
fas% ifconfig

Eth0  Link encap:Ethernet  HWaddr 00:0b:cd:82:57:e7
      inet addr:140.247.34.101  Bcast:140.247.34.111
                  Mask:255.255.255.240
      inet6 addr: fe80::20b:cdff:fe82:57e7/64 Scope:Link
             UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
             RX packets:207116194 errors:0 dropped:0
             TX packets:227671204 errors:0 dropped:0

Eth1  Link encap:Ethernet  HWaddr 00:0b:cd:82:57:c6
      inet addr:140.247.33.101  Bcast:140.247.33.255
                  Mask:255.255.255.0
      inet6 addr: fe80::20b:cdff:fe82:57c6/64 Scope:Link
             UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
             RX packets:1460947464 errors:0 dropped:17
             TX packets:1172961408 errors:0 dropped:0
```

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## Example of IPv6 Address (2)

```
MacMini:~ cs40$ ifconfig

lo0: flags=8049 mtu 16384
      inet6 ::1 prefixlen 128
      inet6 fe80::1 %lo0 prefixlen 64 scopeid 0x1
          inet 127.0.0.1 netmask 0xff000000

en0: flags=8863 mtu 1500
      ether 00:26:b0:de:7a:a0
      inet6 fe80::226:b0ff:fede:7aa%en0
          prefixlen 64 scopeid 0x4
          inet 192.168.11.21 netmask 0xffffffff00
              broadcast 192.168.11.255
              media: autoselect (1000baseT <full-duplex>)
              status: active
```

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## IPv6 RFC 4291 and RFC3581

RFC 4291, 2.5.4. Global Unicast Addresses  
The general format for IPv6 Global Unicast addresses is:

n bits	m bits	128-n-m bits
-----+-----+-----+	-----+-----+-----+	-----+-----+-----+
global routing prefix   subnet ID   interface ID		
-----+-----+-----+	-----+-----+-----+	-----+-----+-----+

### IANA Assigned Unicast

3	45 bits	16 bits	64 bits
-----+-----+-----+-----+	-----+-----+-----+-----+	-----+-----+-----+-----+	-----+-----+-----+-----+
001  global routing   subnet ID   interface ID			
-----+-----+-----+	-----+-----+-----+	-----+-----+-----+	-----+-----+-----+

3 13bits 16bits 16 bits	16 bits	64 bits
-----+-----+-----+-----+	-----+-----+-----+-----+	-----+-----+-----+-----+
001  RIR   AS   Customer   Subnet ID   interface ID		
-----+-----+-----+	-----+-----+-----+	-----+-----+-----+

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**test-ipv6.com**

Test IPv6    FAQ    Mirrors

**Test your IPv6 connectivity.**

Summary    Tests Run    Share Results / Contact

	Your IPv4 address on the public Internet appears to be 24 .... ... !
	Your Internet Service Provider (ISP) appears to be COMCAST-7922 - Comcast Cable Commun
	No IPv6 address detected <a href="#">(more info)</a>
	You appear to be able to browse the IPv4 Internet only. You will not be able to reach IPv6-only :)
	To ensure the best Internet performance and connectivity, ask your ISP about native IPv6. <a href="#">(more)</a>
	Your DNS server (possibly run by your ISP) appears to have IPv6 Internet access.

**Your readiness score**

0/10

for your IPv6 stability and readiness, when publishers are forced to go IPv6 only

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**Public IPv6 Addresses for MIT.EDU**

**DNS Lookups via DIG for AAA records**

```
macmini:~ cs40$ dig www.mit.edu AAAA
; <>> DiG 9.8.3-P1 <>> www.mit.edu AAAA

;; QUESTION SECTION:
;www.mit.edu.    IN      AAAA

;; ANSWER SECTION:
www.mit.edu.        795     IN      CNAME   www.mit.edu.edgekey.net.
www.mit.edu.edgekey.net. 22     IN      CNAME   e9566.dsrb.akamaiedge.net.
e9566.dsrb.akamaiedge.net. 20     IN      AAAA   2001:559:19:885::255e
e9566.dsrb.akamaiedge.net. 20     IN      AAAA   2001:559:19:888::255e

;; SERVER: 75.75.75.75#53(75.75.75.75)
;; WHEN: Mon Oct 17 11:11:50 2016
;; MSG SIZE rcvd: 158
```

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## **Public IPv6 Addresses for IETF.ORG**

### **DNS Lookups via DIG for AAA records**

```
macmini:~ cs40$ dig www.ietf.org AAAA
; <>> DiG 9.8.3-P1 <>> www.ietf.org AAAA

;; QUESTION SECTION:
;www.ietf.org.           IN      AAAA

;; ANSWER SECTION:
www.ietf.org.    14      IN CNAME www.ietf.org.cdn.cloudflare-dnssec.net.
www.ietf.org.cdn.cloudflare-dnssec.net. 300
                           IN AAAA 2400:cb00:2048:1::6814:155
www.ietf.org.cdn.cloudflare-dnssec.net. 300
                           IN AAAA 2400:cb00:2048:1::6814:55
```

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## **Public IPv6 Addresses**

### **DNS Lookups via DIG for AAA records**

```
fas% dig www.harvard.edu AAAA
(THIS WAS IN OCT. 2013)

;; ANSWER SECTION:
www.harvard.edu    9881   IN   A      69.172.200.24
www.harvard.edu    10800  IN   AAAA  2607:fb60:100:210::e6

;; ADDITIONAL SECTION:
internaldns-b1.harvard.edu. 6373   A      128.103.201.105
internaldns-b1.harvard.edu. 312    AAAA  2607:fb60:a:1::d
-----
```

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## WHOIS Lookup of IPv6 Address

```
fas%
fas% whois 2607:fb60:a:1::d

NetRange: 2607:FB60:: - 2607:FB60:FFFF:
          FFFF:FFFF:FFFF:FFFF:FFFF:FFFF
```

CIDR: 2607:FB60::/32  
OriginAS: AS40127, AS1742, AS10578, AS11  
NetName: HARVARD-UNIV-IPV6  
NetHandle: NET6-2607-FB60-1  
Parent: NET6-2600-1  
NetType: Direct Allocation  
RegDate: 2009-07-06

The screenshot shows the ARIN Online WHOIS search interface. The search bar contains the IP address 2607:fb60:a:1::d. The results table includes columns for Network, NetRange, CIDR, Name, Handle, Parent, and Net Type. The results match the information provided in the text above.

Network	NetRange	CIDR	Name	Handle	Parent	Net Type
	2607:FB60:: - 2607:FB60:FFFF: FFFF:FFFF:FFFF:FFFF:FFFF:FFFF	2607:FB60::/32	HARVARD-UNIV-IPV6	NET6-2607-FB60-1	NET6-2600-1 (NET6-2600-1)	Direct Allocation

**Lookup can be done via the ARIN website**

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## IANA IPv6 Multicast Addresses

### IPv6 Multicast Address Scopes

Registration Procedure(s)  
IETF Review

Reference  
[\[RFC7346\]](#)

Note  
The definition of any Realm-Local scope for a particular technology should be published in an RFC. For example, a scope definition would be appropriate for publication in an 'IPv6-over-foo' RFC.

Any RFCs that define a Realm-Local scope will be listed in this registry as an additional reference in the Realm-Local entry. Such RFCs are expected to make an explicit request to IANA for inclusion in this registry.

### Available Formats



CSV

Scope	Name	Reference
0	Reserved	<a href="#">[RFC4291][RFC7346]</a>
1	Interface-Local scope	<a href="#">[RFC4291][RFC7346]</a>
2	Link-Local scope	<a href="#">[RFC4291][RFC7346]</a>
3	Realm-Local scope	<a href="#">[RFC4291][RFC7346]</a>
4	Admin-Local scope	<a href="#">[RFC4291][RFC7346]</a>
5	Site-Local scope	<a href="#">[RFC4291][RFC7346]</a>
6-7	Unassigned	
8	Organization-Local scope	<a href="#">[RFC4291][RFC7346]</a>
9-D	Unassigned	
E	Global scope	<a href="#">[RFC4291][RFC7346]</a>
F	Reserved	<a href="#">[RFC4291][RFC7346]</a>

### Variable Scope Multicast Addresses

Registration Procedure(s)  
IETF Review

Reference  
[\[RFC7346\]](#)

Note  
These permanently assigned multicast addresses are valid over all scope ranges. This is shown by an "x" in the scope field of the address that is present in the first octet.

As defined in [\[RFC4291\]](#), IPv6 multicast addresses which are only different in their scope field represent different groups. Nodes must join each group individually.

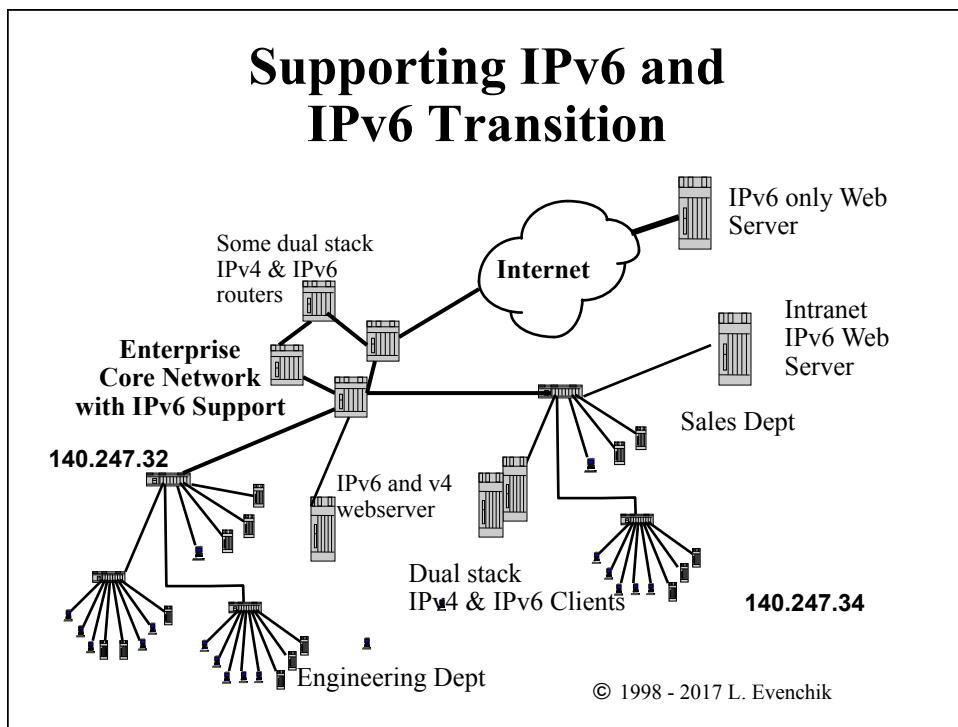
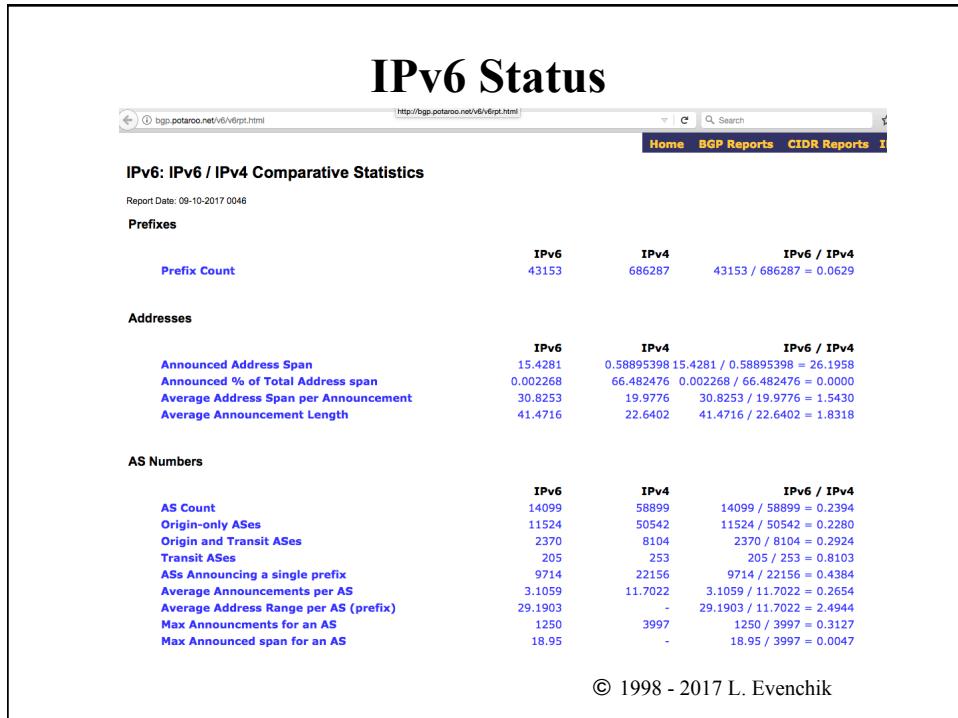
Alternative Format



CSV

Address(s)	Description	Reference	Date Registered	Last Reviewed
FF00:0:0:0:0:0:0:0	Reserved Multicast Address	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:1	Link Local	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>	2006-09-21	
FF00:0:0:0:0:0:0:100	mDNS6	<a href="#">[RFC6773]</a>	2006-10-05	
FF00:0:0:0:0:0:0:101	All Routers	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>	2013-04-10	
FF00:0:0:0:0:0:0:102	All Routers FORWARDERS	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>	2013-04-10	
FF00:0:0:0:0:0:0:103	All CoAP Nodes	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>	2013-07-29	
FF00:0:0:0:0:0:0:104	NSS - Name Service	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:105	All Hosts - Avatar	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:106	NSS - Name Service Server	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:107	AUDIONEWS - Audio News	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:108	SUN NEWS - Information Service	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:109	MLP - Multicast Listener Protocol	<a href="#">[RFC4291]</a> <a href="#">[RFC7346]</a>		
FF00:0:0:0:0:0:0:110	IETF-LOW-AUDIO	<a href="#">[Steve_Carey]</a>		
FF00:0:0:0:0:0:0:111	IETF-1-AUDIO	<a href="#">[Steve_Carey]</a>		
FF00:0:0:0:0:0:0:112	IETF-VIDEO	<a href="#">[Steve_Carey]</a>		
FF00:0:0:0:0:0:0:113	IETF-2-Low-Audio	<a href="#">[Steve_Carey]</a>		

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## IPv6 Ping

The command on Unix is ping6 and on Win7 it is ping -6

---

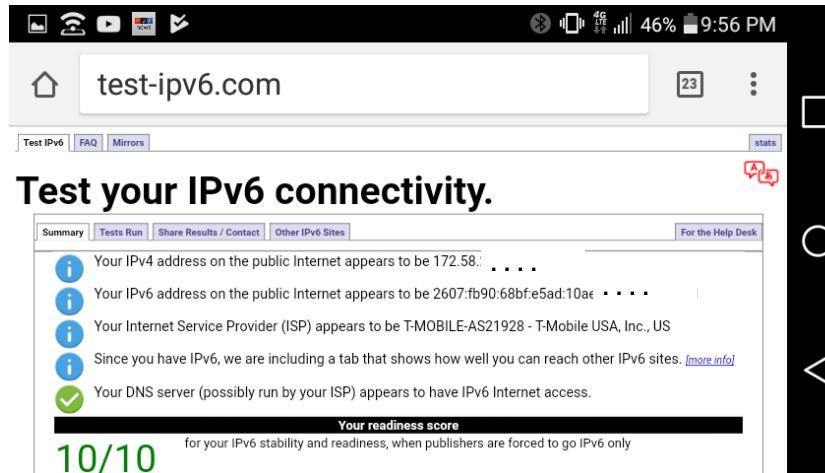
```
fas% ping6 -I eth0 ff02::1
PING ff02::1 from fe80::20b:cdf fe82:57e7 eth0: 56 data bytes

64 bytes from fe80::20b:cdf fe82:57e7: icmp_seq=1 time=0.060 ms
64 bytes from fe80::21e:4fff:fe32:494b: icmp_seq=1 time=0.478 ms
64 bytes from fe80::20b:cdf fe83:a9a: icmp_seq=1 time=0.901 ms
64 bytes from fe80::20b:cdf fe82:4673: icmp_seq=1 time=1.82 ms
64 bytes from fe80::224:e8ff:fe64:e434: icmp_seq=1 time=2.19 ms
64 bytes from fe80::224:e8ff:fe64.... Etc
```

```
fas% ping6 -I eth0 SomeIPv6Host
??
```

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## IPv6 Used Within Cell Phone Networks



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## IPv6 Used Within Cell Phone Networks (2)

A screenshot of a mobile device's screen displaying a table of IPv6 prefixes. The table has columns for Prefix, Country, and ISP. Each row contains a green checkmark icon and a blue information icon. A vertical column on the right side of the table contains a gear icon, a 'mirror' button, and three small icons (square, circle, triangle) at the bottom.

Prefix	Country	ISP			
aa.net.uk	UK	AAISP (UK IPv6 ISP)	✓	i	
bvconline.com.ar	AR	BVNET S.A	✓	i	
campaya.co.uk	UK	Campaya	✓	i	
duplimaster.com	ES	duplimaster.com	✓	i	
eurobilltracker.com	FI	EuroBillTracker	✓	i	
google.com	global	Google	✓	i	
he.net	US (CA)	HE.net	✓	i	
ipv6-test.ch	UK	BSC-Telecom	✓	i	
ipv6-test.pl	PL	Net-Admin	✓	i	♂
jamieweb.net	UK	Jamie Scalfie (JamieOnUbuntu)	✓	i	
nic.br	BR	NIC.br	✓	i	
nex.de	DE	Stephan Fiebrandt (personal)	✓	i	
civita.ct	CT	Dalon Atashoni	✓	i	

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## IPv6 Used Within Cell Phone Networks (3)

A screenshot of the Hurricane Electric BGP Toolkit Home page. The page features a logo with 'HE' and the text 'HURRICANE ELECTRIC INTERNET SERVICES'. It includes a search bar and a 'BGP Toolkit Home' link. On the left, there is a 'Quick Links' sidebar with various reports like BGP Toolkit Home, BGP Prefix Report, BGP Peer Report, Exchange Report, Bogon Routes, World Report, Multi Origin Routes, DNS Report, Top Host Report, and Internet Statistics. The main content area shows a 'Home' link, a welcome message, and information about the visitor's IP address (2607:fb90:68bf:e5ad:10ae:c466). It also displays route announcements and the user's ISP (AS21928, T-Mobile USA, Inc.). A vertical column on the right side contains a square, circle, and triangle icon at the bottom.

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***Thank You!***

ALIGHSOD1701

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## **One Minute Wrap-Up**

- Please do this Wrap-Up at the end of each lecture.
- Please fill out the form on the website.
- The form is anonymous (but you can include your name if you want.)
- Please answer three questions:
  - What is your grand “Aha” for today’s class?
  - What concept did you find most confusing in today’s class?
  - What questions should I address next time
- **Thank you!**

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