Communication Protocols
and Internet Architectures

Harvard University

Lecture #4

Instructor: Len Evenchik
cs40@evenchik.com or evenchik@fas.harvard.edu

ALIGHLSOD1701

Lecture Agenda

- Course Logistics
- Q&A and Topics from Last Week
- Ethernet Roadmap
- What is the Internet?
- IP Philosophy, Design and Implementation
- IP Addressing
- Address Resolution Protocol (ARP)
- ICMP
- IETF Standards Process
- One Minute Wrap-Up

Course Logistics

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!**

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!**

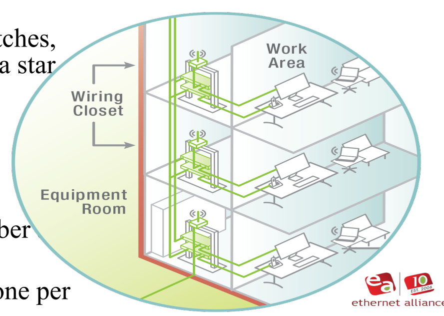
Q&A and Some Things from Previous Lectures

Addressing

- Should addresses have local or global significance?
- How should addresses be structured?
- How many addresses are needed in a packet or frame given addresses can have local or global significance?
- How are addresses assigned?
- Can addresses be private?
- What is the difference between an address, a name, and a route?
- ***How many different types of addresses should a device on a network have? Why?***

LAN Wiring Design and Implementation (2)

- Wiring Topology
  - Devices connected via ethernet switches, but the layout is typically drawn as a star bus
  - Star of stars topology is common implementation in buildings
- Wiring Building Blocks
  - Wiring Components – UTP wire, fiber patch panels, connectors, etc.
  - Horizontal distribution (typically done per floor for larger buildings)
  - Communication closets or wiring closet for the switches on a single floor.
  - Vertical distribution connects together different floors and also connect to main equipment room
  - Connection to WAN called a Demarc



Graphic from Ethernet Alliance

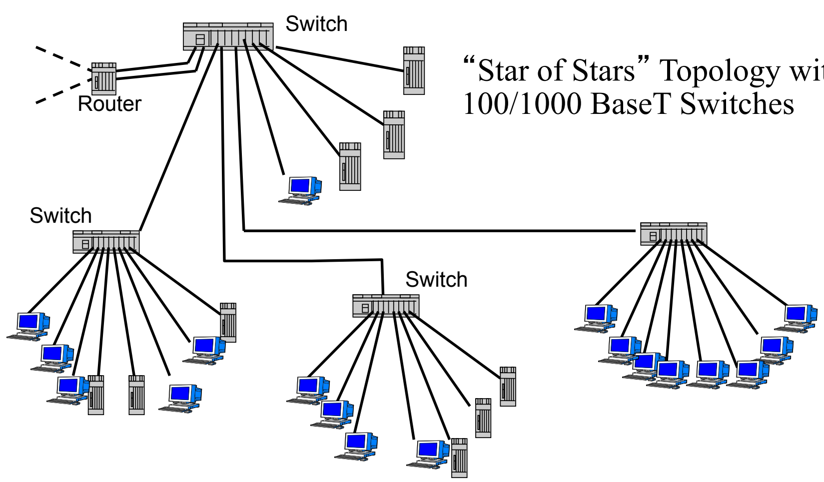
LAN Wiring Design and Implementation (2)

- There are EIA and IEEE standards for ethernet wiring. In addition to these standards, there are important building codes, fire codes, and electrical codes that must be followed. The specific safety and building codes depend on where you live.
- System Administration and Management of all the wires and devices is still a very difficult problem.
- Wireless networks reduce the number of wires, but remember that wireless access points must be connected to the building's equipment room and this is done via UTP or fiber. In other words, wireless networks still require wired connections.

1,000s of Wires in a Typical Building

Channel Allocation for a Shared Multi-Access Channel

Typical Ethernet Topology

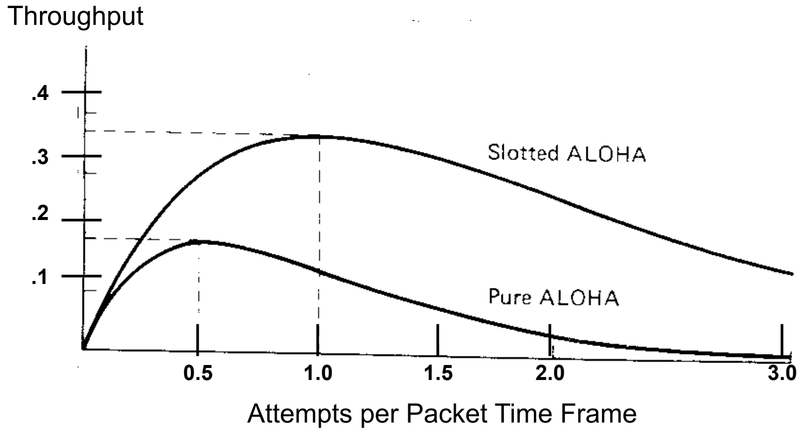


“Star of Stars” Topology with 100/1000 BaseT Switches

The Channel Allocation Problem

- Objective is to share a single multi-access channel in a fair way among multiple stations
- Options include static versus dynamic assignment of channel, and centralized versus distributed management of the channel
- ALOHA protocol and slotted ALOHA are important for both historical and practical reasons. ALOHA was developed in Hawaii 50 years ago and it was the basis for the wired ethernet standard.
- The performance and stability of CSMA/CD and follow-on protocol still used today in wired and wireless ethernet is important to understand since resource sharing continues to be an important problem.

Throughput Versus Offered Traffic ALOHA and Slotted ALOHA



(Source and copyright 2003
Tanenbaum Computer Networks, Fig. 4-3)

Ethernet Medium Access Control

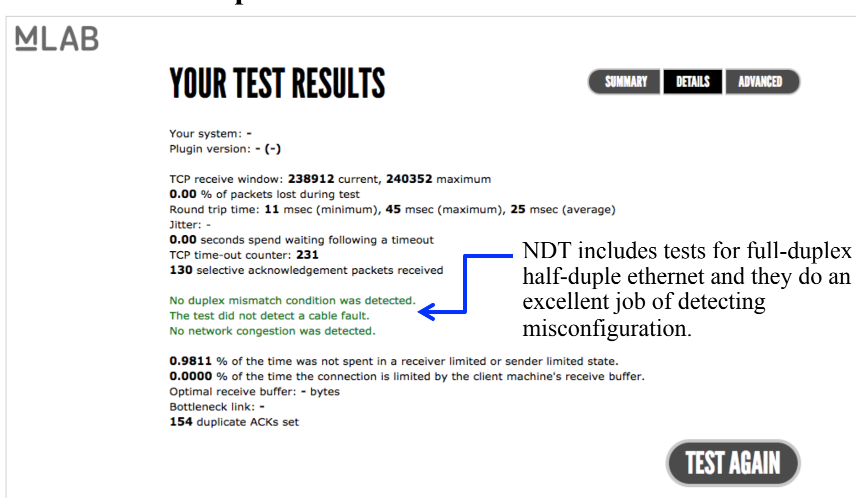
- Classic Ethernet LAN is a broadcast media
- Medium Access Control uses CSMA/CD
  - All stations broadcast on same channel
  - Stations listen for clear channel before sending
  - Sending stations listen for collision
  - Colliding stations back off and wait for a random time before retransmitting, they repeat this a few times
  - Collisions increase as number of active stations increase
- It is still important to understand CSMA/CD even though hubs should never be used today to build LANs since wireless LANs continue to share a single channel. (LANs today use Ethernet switches which have one device per port.)

Is ethernet reliable or unreliable?

Repeater/Hub versus Bridge/Switch versus Router

- Hub/Repeater (Should not be used to build networks)
  - Improved distance
  - End stations see one physical LAN
  - Single broadcast domain, single collision domain
- Switch/Ethernet Switch/ historical name was bridge
  - End stations see one logical LAN
  - Protocol insensitive
  - Single broadcast domain, multiple collision domains
- Router (sometimes called a L3 Switch)
  - Protocol sensitive (at layer 3)
  - Traffic isolation
  - Multiple broadcast domains, multiple collision domains
  - End stations see multiple networks and of course, multiple LANs

Network Diagnostic Tool (NDT) results from https://www.measurementlab.net/

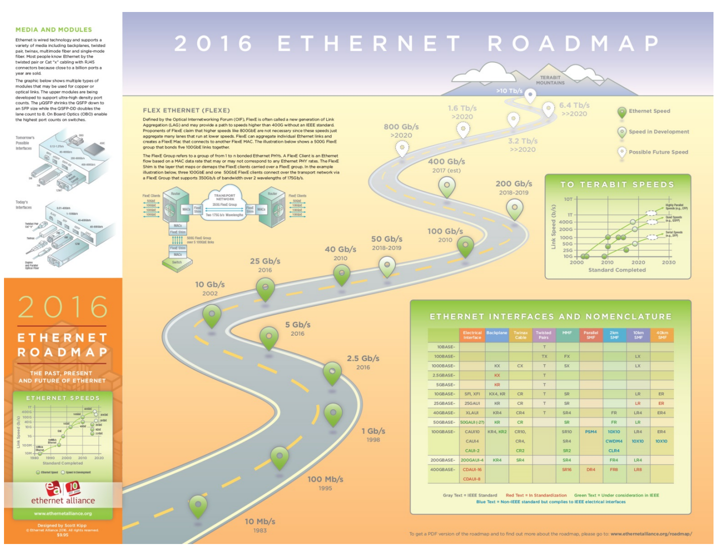


NDT includes tests for full-duplex and half-duple ethernet and they do an excellent job of detecting misconfiguration.

Ethernet Futures

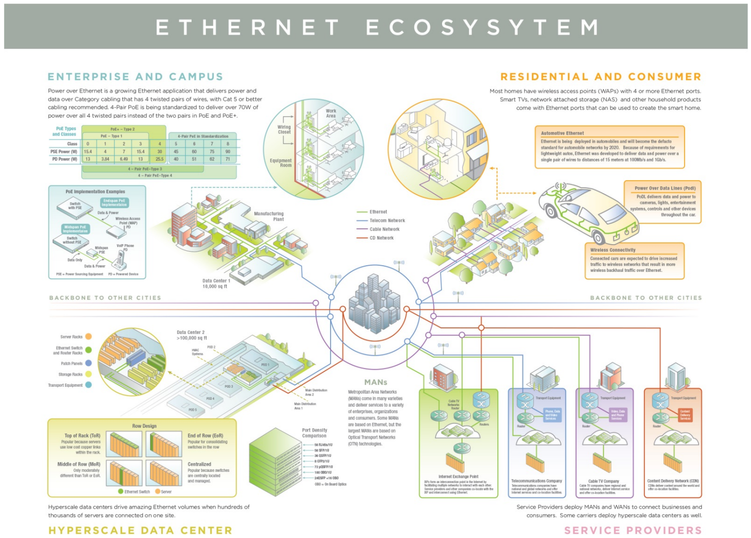
© 1998 - 2017 L. Evenchik

Ethernet Alliance Roadmap (1)
source http://www.ethernetalliance.org/roadmap/



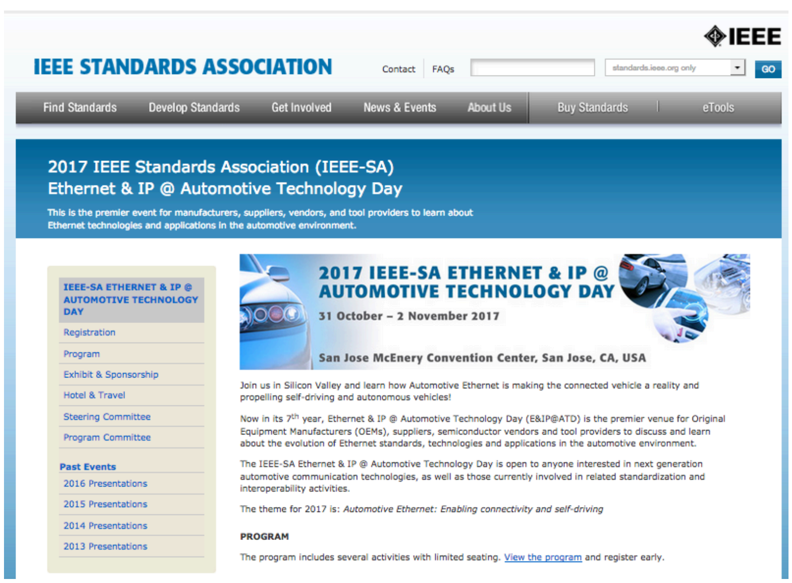
Ethernet Alliance Roadmap (2)

source http://www.ethernetalliance.org/roadmap/



Industry-Specific Ethernet Group

Source https://standards.ieee.org/events/automotive/index.html

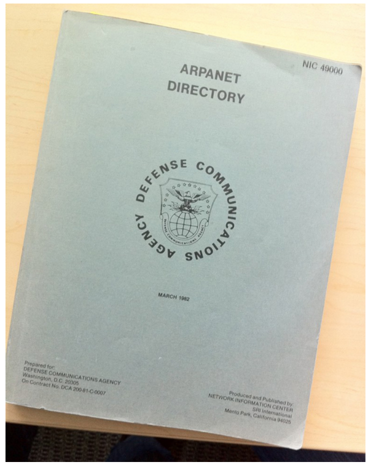


What is the Internet?

An Overly Simplistic Approach to Understanding its Complexity

Internet History
The Internet Directory: March 1982

(400 pages, 20 names per page)



What is the Internet

- A network of networks with a couple billion users
- With large national and international ISPs (Internet Service Providers) as the core networks
- With regional ISPs connected to national ISPs
- With local ISPs connected to national/regional ISPs
- All ISPs exchanging inbound and outbound traffic with other ISPs across public and/or private peering points.
- With billions of users connected to customer networks at the outer edge, that then connect to one or more of the ISPs.
- All using the TCP/IP suite of protocols

What is the Internet

- A network of networks with a couple billion users
- With large national and international ISPs (Internet Service Providers) as the core networks
- With regional ISPs connected to national ISPs
- With local ISPs connected to national/regional ISPs
- All ISPs exchanging inbound and outbound traffic with other ISPs across public and/or private peering points.
- With billions of users connected to customer networks at the outer edge, that then connect to one or more of the ISPs.
- *All using the TCP/IP protocol suite*

Changes in Internet Topology

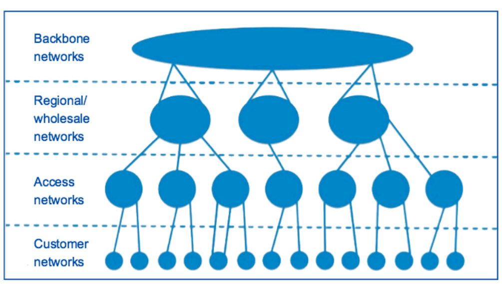


Figure 2 Traditional Internet hierarchical model

Straightforward Hierarchical Topology Early '90s

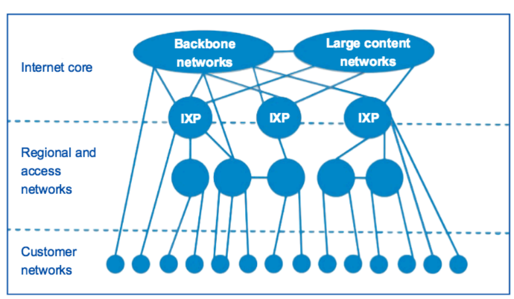
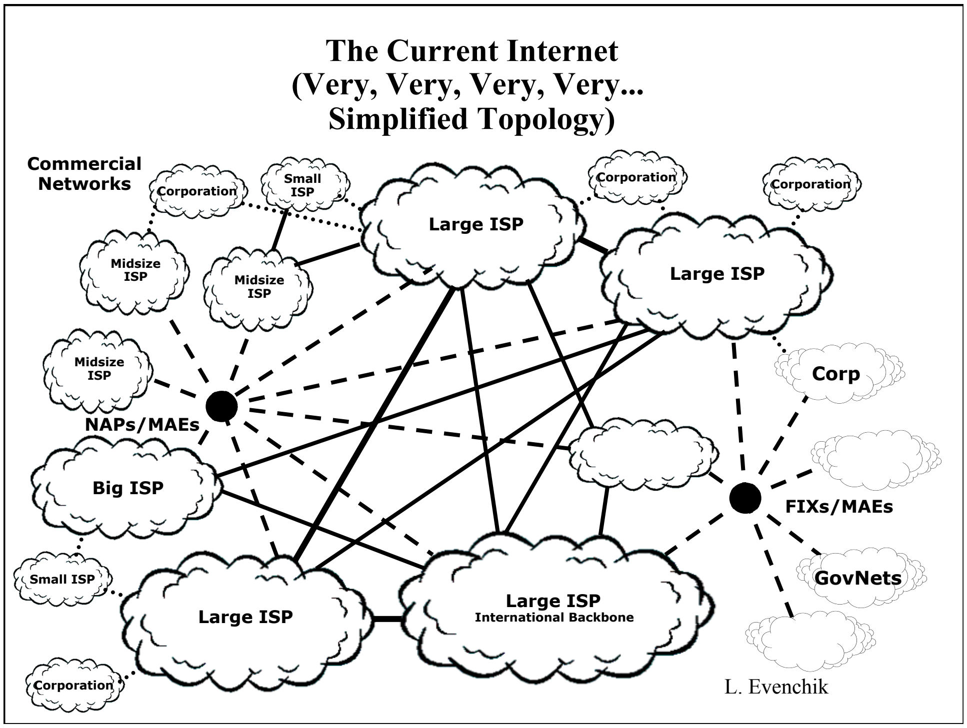


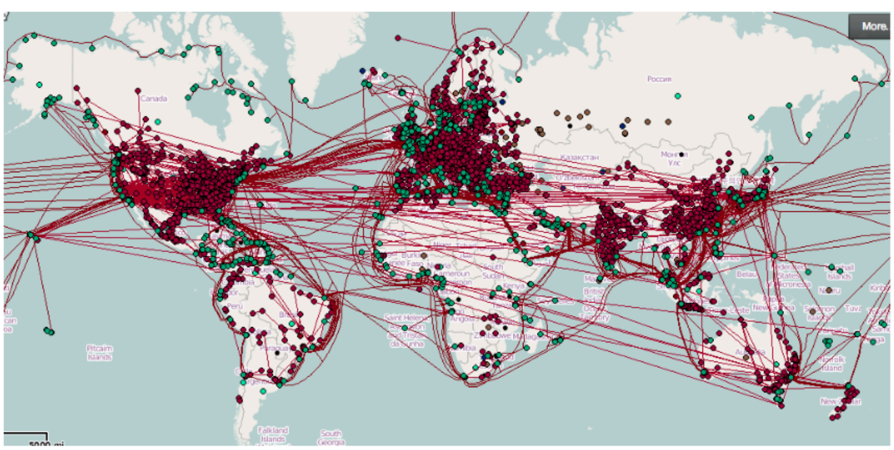
Figure 3 Flatter, more connected model

Mesh or Highly Connected Topology Today, Both ISPs and Others Provide Connectivity as well as Content

Source: ISOC Reports



Internet Topology Diagram



Source: internetatlas.org and Univ of Wisconsin, 2013

Internet Trace from Harvard to MIT

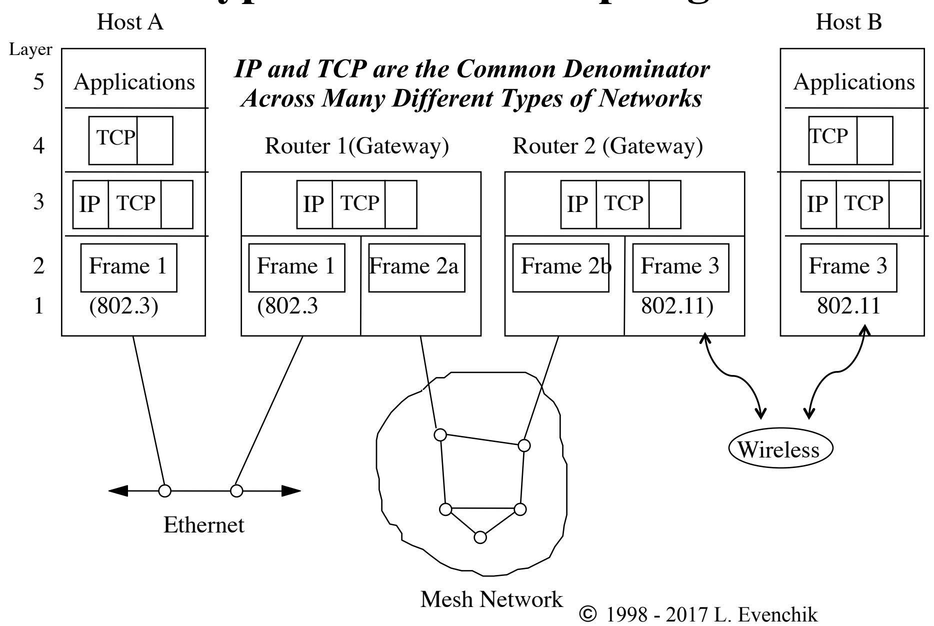
```
fas% traceroute www.mit.edu
traceroute to DANDELION-PATCH.MIT.edu (18.181.0.31),40 byte packets
 1  scmr-gw.fas.harvard.edu (140.247.30.1)  1 ms  1 ms  1 ms
 2  sc-gw.fas.harvard.edu (140.247.6.2)  1 ms  1 ms  0 ms
 3  camgw1-fas.harvard.edu (140.247.20.1)  1 ms  2 ms  1 ms
 4  192.5.66.18 (192.5.66.18)  2 ms  1 ms  1 ms
 5  192.5.66.50 (192.5.66.50)  1 ms  1 ms  1 ms
 6  192.5.66.41 (192.5.66.41)  1 ms  2 ms  1 ms
 7  192.5.66.34 (192.5.66.34)  1 ms  2 ms  1 ms
 8  MIT-MEDIAONE.MIT.EDU (18.95.0.1)  30 ms  2 ms  2 ms
 9  W20-RTR-FDDI.MIT.EDU (18.168.0.8)  3 ms  3 ms  3 ms
10  DANDELION-PATCH.MIT.EDU (18.181.0.31)  2 ms *  4 ms
fas%
```


Internet Trace to Oxford University

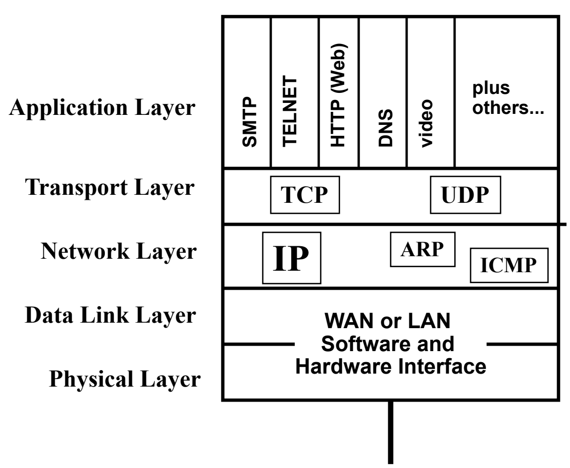
```
fas% traceroute www.oxford.edu
traceroute to www.OXFORD.edu (163.1.0.45), 30 hops max, 40 byte packets
 1  scmr-gw.fas.harvard.edu (140.247.30.1)  1 ms  1 ms  1 ms
 2  sc-gw.fas.harvard.edu (140.247.6.2)  1 ms  1 ms  0 ms
 3  camgw1-fas.harvard.edu (140.247.20.1)  0 ms  0 ms  1 ms
 4  192.5.66.18 (192.5.66.18)  2 ms  1 ms  1 ms
 5  192.5.66.9 (192.5.66.9)  2 ms  2 ms  2 ms
 6  12.127.80.125 (12.127.80.125)  3 ms  3 ms  3 ms
 7  br2-a3110s1.cb1ma.ip.att.net (12.127.5.10)  3 ms  3 ms  3 ms
 8  br3-h20.wswdc.ip.att.net (12.127.15.177)  12 ms  13 ms  11 ms
 9  gr1-a3100s1.wswdc.ip.att.net (192.205.31.185)  13 ms  13 ms  13 ms
10  - 15 …. multiple hops in ALTER.NET, only a few shown in this slide
16  - 21 …. multiple hops in.Teleglobe.net, only a few shown in this slide
22  external-gw.ja.net (128.86.1.40)  145 ms  145 ms  143 ms
23  london-core.ja.net (146.97.251.58)  152 ms  142 ms  145 ms
24  146.97.251.82 (146.97.251.82)  150 ms  148 ms  149 ms
25  noucs2.backbone.ox.ac.uk (192.76.35.2)  152 ms  155 ms  150 ms
26  wwwtest.ox.ac.uk (163.1.0.45)  152 ms  150 ms  152 ms
fas%
```

IP Philosophy and Basic Design

Typical Network Topologies



Simplified TCP/IP Protocol Stack
Remember that we will use this 5 Layer Model in the Course



Internet Protocol (IP)

- IP protocol grew out of the DOD ARPANET need for a network layer protocol that could interconnect computers and networks, and handle the growth and variety of the underlying networks at that time (technology, topology, wiring, administrative details, size, etc.)
- Originally defined in a series of "Requests for Comments" (RFCs).
- Additional protocols were defined in concert with IP to handle reliable packet delivery (TCP), routing, address resolution, network management, etc., etc., etc..
- Many competitive protocols were also developed in the era when the work on IP was being done.
- We will be talking mostly about IPv4 in this lecture and cover IPv6 in detail in the coming weeks.

Services Provided by IP

- Connectionless, datagram service only. No delivery acknowledgment or delivery guarantee is offered. Basic error detection only. IP is not reliable.
- IP is not reliable. Datagram service means unreliable.
- IP does not make many assumptions about the type of network substrate that it runs on top of. See RFC 1149.
- The underlying network substrate can lose, duplicate, or mis-order IP datagrams in transit.
- IP datagram service is usually used in conjunction with a connection-oriented, reliable transport layer protocol such as TCP (given that a reliable service is required.)
- Transport layer protocol (TCP) performs end-to-end sequencing and error detection and correction to compensate for IP's unreliability.

RFC 1149
IP Can Run on Top of Almost Any Network

https://www.ietf.org/rfc/rfc1149.txt

```
Network Working Group                                    D. Waitzman
Request for Comments: 1149                                   BBN STC
                                                        1 April 1990


   A Standard for the Transmission of IP Datagrams on Avian Carriers

Status of this Memo

   This memo describes an experimental method for the encapsulation of
   IP datagrams in avian carriers.  This specification is primarily
   useful in Metropolitan Area Networks.  This is an experimental, not
   recommended standard.  Distribution of this memo is unlimited.

Overview and Rational

   Avian carriers can provide high delay, low throughput, and low
   altitude service.  The connection topology is limited to a single
   point-to-point path for each carrier, used with standard carriers,
   but many carriers can be used without significant interference with
   each other, outside of early spring.  This is because of the 3D ether
```

RFC 2549
Avian Networks with QoS

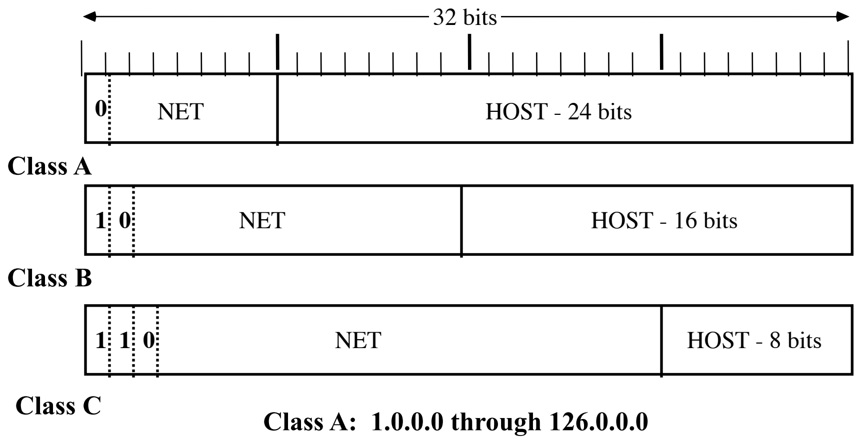
```
[Docs] [txt|pdf] [Errata]

                                                     INFORMATIONAL
                                                      Errata Exist
Network Working Group                                  D. Waitzman
Request for Comments: 2549                       IronBridge Networks
Updates: 1149                                         1 April 1999
Category: Experimental


             IP over Avian Carriers with Quality of Service

Status of this Memo

   This memo defines an Experimental Protocol for the Internet
   community.  It does not specify an Internet standard of any kind.
   Discussion and suggestions for improvement are requested.
   Distribution of this memo is unlimited.

Copyright Notice

   Copyright (C) The Internet Society (1999).  All Rights Reserved.

Abstract

   This memo amends RFC 1149, "A Standard for the Transmission of IP
   Datagrams on Avian Carriers", with Quality of Service information.
   This is an experimental, not recommended standard.
```

IPv4 Addressing

- Internet addresses specify a host's connection(s) to a network. A host may have more than one IP address, and can connect to the same or to multiple networks.
- IPv4 Internet addresses are 32 bits long and include both a network number (network ID) and a host address. Address prefixes are used to delineate between network and host
- IPv4 addresses are written with dotted decimal notation (for example, 128.103.5.3
- Internet routing is based on just the network number.
- "Classic" addresses are of four different forms: classes A, B, C and D. This was the original approach, it is still talked about, but it is out of date.
- Internet addresses must be mapped to physical network addresses, for example, by the Address Resolution Protocol (ARP) for use on LANs

“Classic” Classful IPv4 Address Format

Note that this format is out of date but you will see it in older RFCs



Class A: 1.0.0.0 through 126.0.0.0
Class B: 128.1.0.0 through 191.255.0.0
Class C: 192.0.1.0 through 223.255.255.0
Class D: 224.0.0.0 through 239.255.255.255 (multicast)

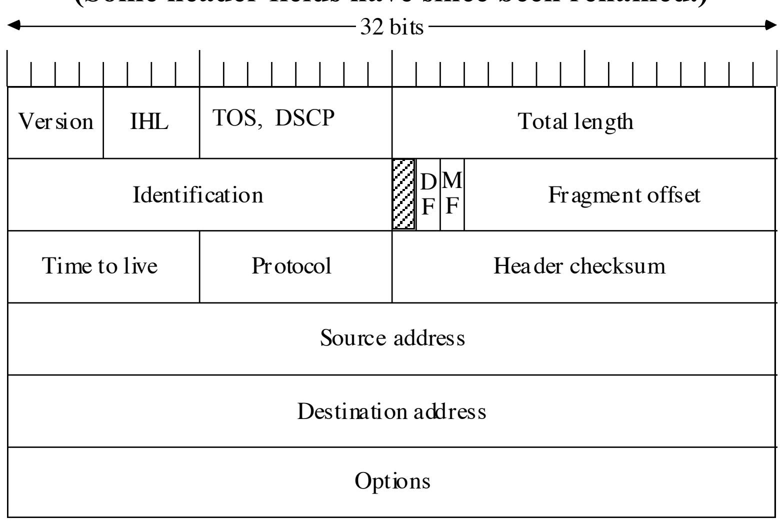
IP Protocol Design

Services Provided by IP

- Connectionless, datagram service only. No delivery acknowledgment or delivery guarantee is offered. Basic error detection only. IP is not reliable.
- IP is not reliable. Datagram service means unreliable.
- IP does not make many assumptions about the type of network substrate that it runs on top of. See RFC 1149.
- The underlying network substrate can lose, duplicate, or mis-order IP datagrams in transit.
- IP datagram service is usually used in conjunction with a connection-oriented, reliable transport layer protocol such as TCP (given that a reliable service is required.)
- Transport layer protocol (TCP) performs end-to-end sequencing and error detection and correction to compensate for IP's unreliability.

Original IP Packet Format

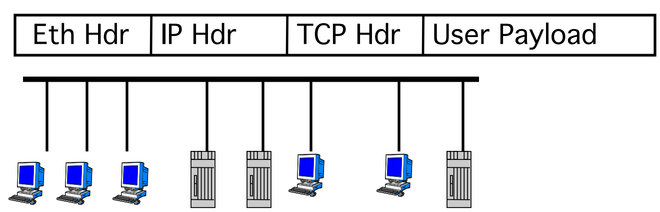
(Some header fields have since been renamed.)



IPv4 Header Packet Trace

```
▷ Frame 54 (62 bytes on wire, 62 bytes captured)
▷ Ethernet II, Src: 00:04:75:f7:cf:bb, Dst: 00:a0:8e:20:f4:90
▽ Internet Protocol, Src Addr: 10.103.0.98 (10.103.0.98), Dst Addr: 140.247.198.100 (140
    Version: 4
    Header length: 20 bytes
  ▷ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 48
    Identification: 0x9000 (36864)
  ▷ Flags: 0x04 (Don't Fragment)
    Fragment offset: 0
    Time to live: 128
    Protocol: TCP (0x06)
    Header checksum: 0x0000 (incorrect, should be 0x0ca3)
    Source: 10.103.0.98 (10.103.0.98)
    Destination: 140.247.198.100 (140.247.198.100)
▷ Transmission Control Protocol, Src Port: 4024 (4024), Dst Port: http (80), Seq: 0, Ack

0000  00 a0 8e 20 f4 90 00 04  75 f7 cf bb 08 00 45 00   ... .... u.....E.
0010  00 30 90 00 40 00 80 06  00 00 0a 67 00 62 8c f7   .0..@... ...g.b..
0020  c6 64 0f b8 00 50 52 bf  28 42 00 00 00 00 70 02   .d...PR. (B....p.
0030  ff ff 99 f1 00 00 02 04  05 b4 01 01 04 02         ........ ......
```


Encapsulation – Ethernet and IP Headers



IPv4 Sequencing, Flow Control, Option Negotiation

- Since IP does not perform sequencing, IP does not guarantee the sequenced arrival of the packets. That's left to a higher layer protocol (if needed.)
- Absence of connections and sequence numbers means no mechanism for flow control. The application layer must rely on the transport layer to provide this function if needed. (Might the link layer ever provide flow control or reliable delivery – why or why not?)
- No connection means no opportunity to negotiate options, but yet IPv4 has Options.
- Options fields in IPv4 header are available to indicate option requests; receiver either accepts or ignores datagram according to its ability to honor option selection

Error Control

- IP makes no assumptions about the error handling in the link layer, and assumes that the higher layers will handle data loss and sequencing errors (if needed.)
- Since there is only datagram service, the error handling method within IP is to discard datagrams that cannot be processed.
- IPv4 header does contain a header checksum field but it is of limited usefulness today. What happened in IPv6?

Fragmentation and Reassembly

- Datagram size is limited by the underlying physical network. It is called the MTU.
- Once a datagram is fragmented it should remain fragmented until it reaches its final destination.
- All IPv4 hosts must be prepared to accept a minimum datagram size of 576 octets. (Size changed in IPv6.)
- IPv4 fields necessary for fragmentation and reassembly are address fields, length fields, ID, MF flag, and fragment offset.
- Some datagrams should not be fragmented since it seriously degrades performance (video and other real time traffic.)
- Is fragmentation important today?

© 1998 - 2017 L. Evenchik

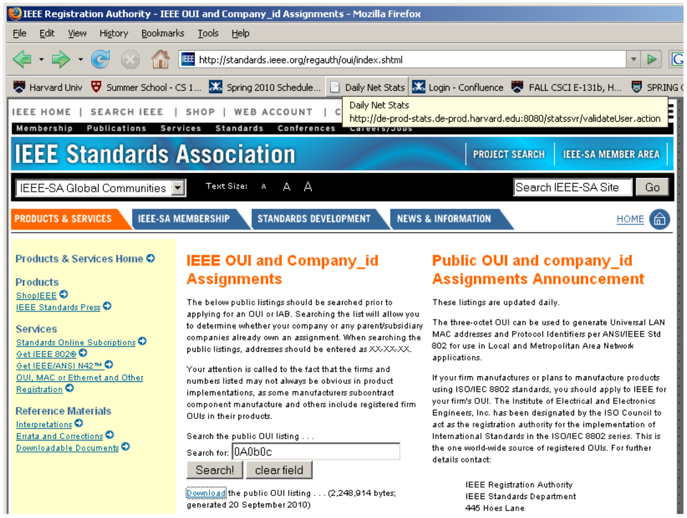
ARP - IP Address Resolution

Mapping an IP Address to a Hardware Ethernet (MAC) Address.

Ethernet 802 Addresses

- Also known as MAC addresses
- Frame contains both source and destination addresses
- Address is 48 bits including Multicast and G/L bits
- 24 bits are OUI (Org. Unique ID)
- Other 24 bits are unique within a given OUI
- Broadcast address is all ones
- There are many different multicast addresses
- Bit ordering issues are nontrivial – historical note, now handled correctly by all the chips
- **Ethernet addresses are flat addresses: no location or routing information is provided by the address. What does this mean and why is it important?**

OUI database at http://standards.ieee.org/



© 1998 - 2017 L. Evenchik

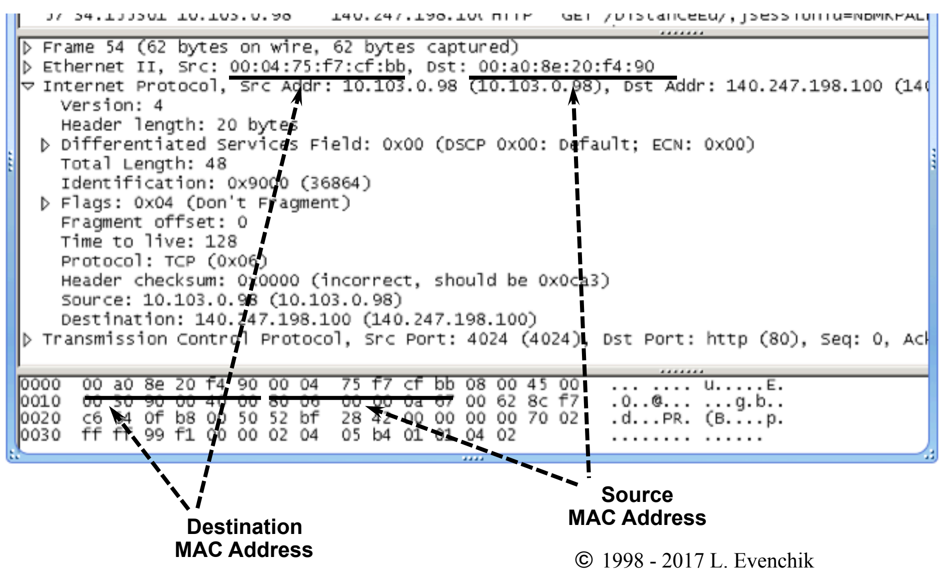
IP Address Resolution

- Devices typically have multiple addresses. Address resolution is the general problem of mapping between a globally unique and routable address, and a second address which has only local significance
- Both static and dynamic address resolution algorithms are used in various networks. (What about cell phones for example?)
- ARP (RFC 826) is a low-level protocol that dynamically maps IP addresses to local physical addresses. ARP requests require network broadcasts.
- An address resolution cache is important to reduce network overhead. Cache entries should be updated by all stations on the network.
- DHCP is used by a host to obtain an IP addresses when one is not manually configured. Does not replace ARP.

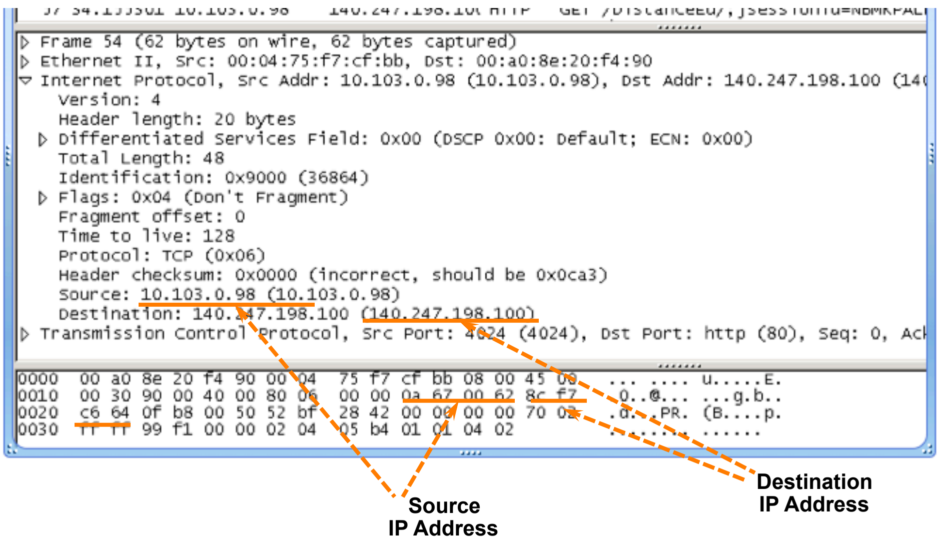
© 1998 - 2017 L. Evenchik

What About Cell Phones?

Ethernet Addresses

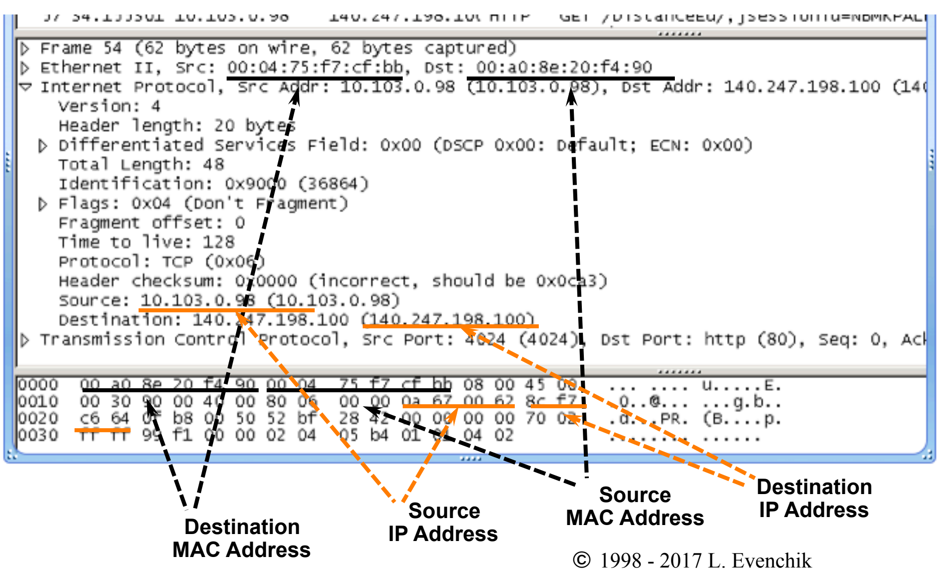


IPv4 Addresses



© 1998 - 2017 L. Evenchik

Ethernet and IPv4 Addresses



© 1998 - 2017 L. Evenchik

ARP Format and Encapsulation

ARP Protocol Format

32 bits

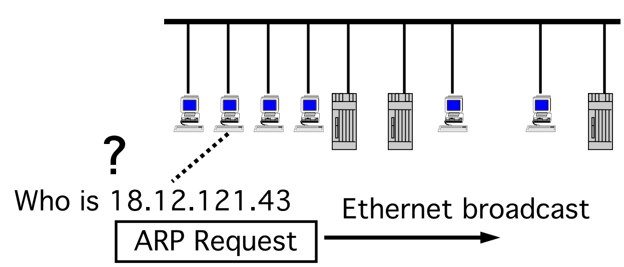
Hardware		Protocol	
HLEN	PLEN	Operation	
Sender HA (octets 0-3)			
Sender HA (octets 4-5)		Sender IA (octets 0-1)	
Sender IA (octets 2-3)		Target HA (octets 0-1)	
Target HA (octets 2-5)			
Target IA (octets 0-4)			

ARP encapsulated in Ethernet frame

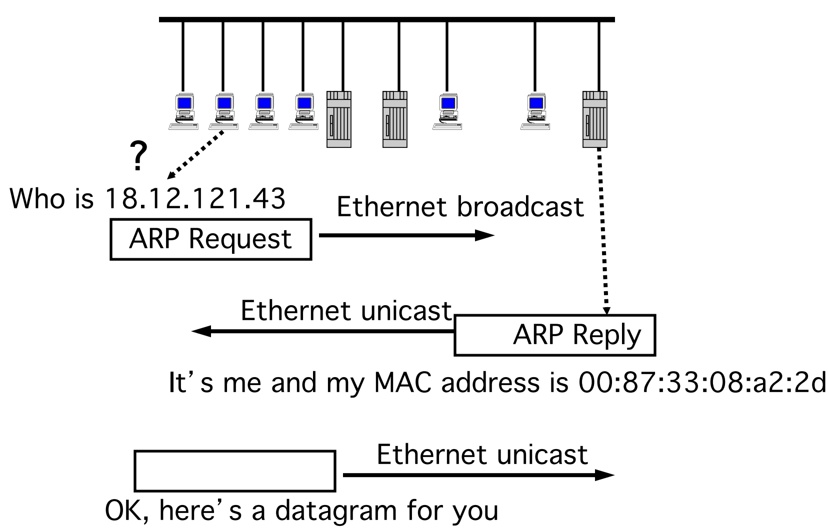
Ethernet Header	Payload - encapsulated ARP message

Source: ARP RFCs

Ethernet ARP Procedure



Ethernet ARP Procedure



ARP Cache Information

fas% **arp -a**

admin.fas.harvard.edu (140.247.30.41) at 00-00-f8-09-24-fe
ns3.fas.harvard.edu (140.247.30.30) at 00-00-f8-03-ba-8a
core4-33.fas.harvard.edu (140.247.33.24) at 00-60-6d-21-11-b1
sc-mr-gw-vl30.fas.harvard.edu (140.247.30.1) at 00-d0-d3-28-f2-58
is01.fas.harvard.edu (140.247.30.101) at 00-00-f8-71-ad-e7
is05.fas.harvard.edu (140.247.30.105) at 00-00-f8-09-24-f6
………. . . . .
(Note that the above is an abridged display of the output from arp -a)

Globally Unique Addresses can have Global or Just Local Significance

- A host on an ethernet has both an IP and a MAC address.
- IP addresses are globally unique and Internet routing is based on the network number. IP addresses have global significance. (Not considering private addresses here.)
- The host also has a MAC or ethernet address at the physical/link layer and these MAC addresses are also globally unique. However, they do not provide routing information and have local significance only. (By local significance we mean that they are only used within a specific network.)
- For example, the host uses the MAC address to quickly answer the question… “is this passing frame for me?”

Globally Unique Addresses can have Global or Just Local Significance

- For example, the host uses the MAC address to quickly answer the question… "is this passing frame for me?"
- To deliver a packet, the IP address must be mapped to the MAC address using the ARP protocol.
- There are other advantages for devices to have both a hardware (local) address and a globally unique address (that provides for routing)
- Another example of the use of global/local addresses: cellular networks use both an ESN and a telephone number and/or IP address.

IPv4 Addressing

CIDR, Network Prefixes, Subnets, etc.

Determining IPv4 Address Information

- UNIX command is ifconfig –a (many options)
- Windows command is ipconfig
- Sample output from command:

  Host Name …….. fas.harvard.edu

  IPv4 Address……….140.247.34.98

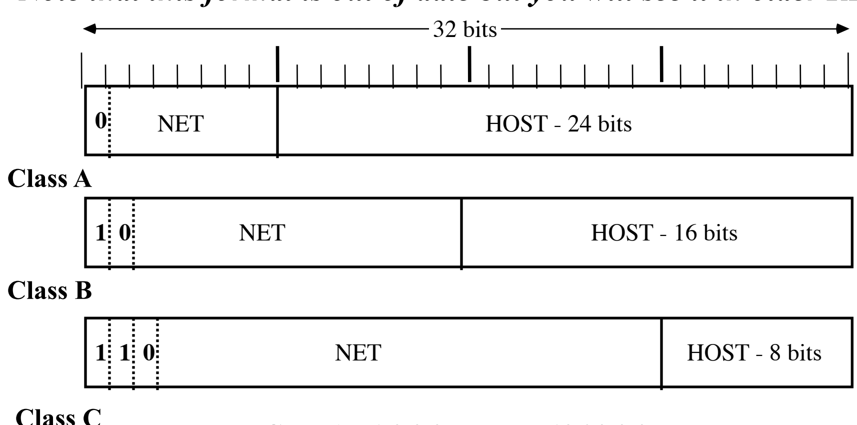
  Subnet Mask……..255.255.255.0

  Default Gateway…140.247.34.1

  MACaddr… 00:0b:cd:82:46:57
- Other fields can be displayed about network performance, IPv6 addresses, DNS and DHCP information, etc.

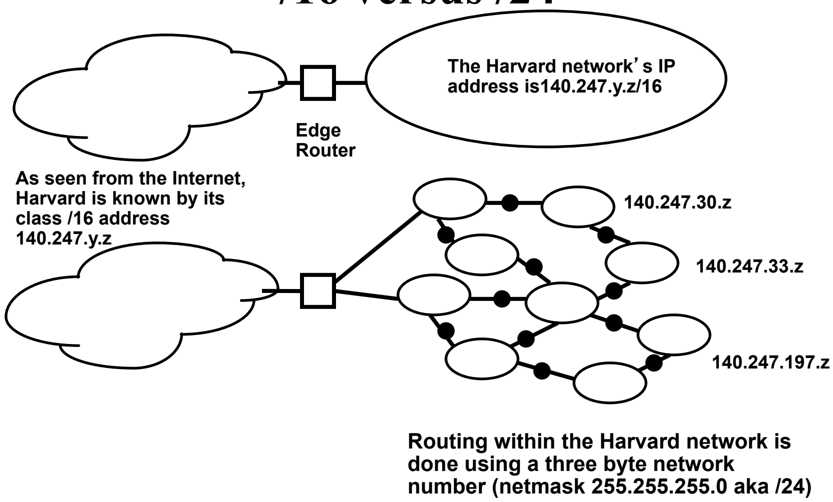
"Classic" Classfull IPv4 Address Format

Note that this format is out of date but you will see it in older RFCs



Class A: 1.0.0.0 through 126.0.0.0
Class B: 128.1.0.0 through 191.255.0.0
Class C: 192.0.1.0 through 223.255.255.0
Class D: 224.0.0.0 through 239.255.255.255 (multicast)

Simplified Subnet Topology /16 versus /24



Subnet Addressing
Developed in the Classfull Address Era

- Original IP address space not optimized for large numbers of small networks
- Subnetting allows a single network, which is used by an organization, to be split into multiple networks for internal use.
- The organization still appears as a single network to the outside world. However, the organization operates with many different internal networks.
- The configuration of subnets typically use subnet masks to distinguish networks, subnets and hosts
- **BUT NOTE, addresses using a network prefix provides the same functionality as a subnet mask, and is the better approach for describing the address.**

Addressing using Network Prefixes

- Address description using the Network Prefix Length format now the norm (but many people still don't know this since they commonly see network masks such as 255.255.255.0 versus /24
- This approach was developed as part of CIDR
- Notation is: address / <prefix length>
  - Class A, networks would be /8 prefix, or 34.2.3.4/8
  - Class B, networks would be /16 prefix, or 140.247.30.33/16
  - Class C, networks would be /24 prefix, or 198.3.4.23/24
- Prefix approach is used for subnetting within an organization.
- Consider 140.247.198/23 as an example

Addressing with Network Prefixes (2)

- Prefix approach is used for subnetting within an organization.
- Consider 140.247.198/23 as an example

© 1998 - 2017 L. Evenchik

CIDR Address Blocks

notation	addresses per block	# blocks	
n.n.n.n/32	1	4294967296	"host route"
n.n.n.x/31	2	2147483648	"pt2pt link"
n.n.n.x/30	4	1073741824	
n.n.n.x/29	8	536870912	
n.n.n.x/28	16	268435456	
n.n.n.x/27	32	134217728	
n.n.n.x/26	64	67108864	
n.n.n.x/25	128	33554432	
n.n.n.0/24	256	16777216	legacy "Class C"
n.n.x.0/23	512	8388608	
n.n.x.0/22	1024	4194304	
n.n.x.0/21	2048	2097152	
n.n.x.0/20	4096	1048576	
n.n.x.0/19	8192	524288	
n.n.x.0/18	16384	262144	
n.n.x.0/17	32768	131072	
n.n.0.0/16	65536	65536	legacy "Class B"
n.x.0.0/15	131072	32768	

CIDR, RFC 4632

- RFC 4632 / BCP 122 (August 2006) obsoletes 1519 (1993)
- The title is very descriptive - Classless Inter-domain Routing (CIDR): The Internet Address Assignment and Aggregation Plan
- CIDR requires the use of network prefixes
- CIDR provides a solution to the "3 bears problem" and the resulting growth of internet routing tables.
- From the abstract of the RFC says … strategy for address assignment of the existing 32-bit IPv4 address space with a view towards conserving the IPv4 address space, and limiting the growth rate of global routing state

CIDR – Classless InterDoman Routing

- CIDR is also known as "Supernetting"
- CIDR provides hierarchical routing and route aggregation via grouping of network addresses. This is used in routers.
- Routers must evaluate longest address match first for proper routing decisions

Special IP Addresses

• 0.0.0.0	this host on this net
• 0.0.0.hostid	specified host on this net
• 127.0.0.1	loopback address
• 255.255.255.255	limited broadcast, this subnet
• *.*.*.255	net directed broadcast

The value 0 typically means this host or this net.

Regional IP Addresses
(more on this in a later lecture)

- 194.000.000.000 to 195.255.255.255
  Europe
- 198.000.000.000 to 199.255.255.255
  North America
- 200.000.000.000 to 201.255.255.255
  Central and South America
- 201.000.000.000 to 203.255.255.255
  Asia and Pacific

Private IP Addresses
(Partial list, more on this in a later lecture)

- RFC 1918 - private network address
- 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

ICMP

ICMP

- ICMP is an integral part of IP.
- ICMP is used to send debugging information and error reports between hosts, routers and other network devices.
- ICMP messages can be lost or discarded. Errors in ICMP messages should not generate additional ICMP messages. Firewalls today typically block ICMP and this is a big problem.
- ICMP provides very limited functionality. Additional protocols are required for routing, management, and control.
- ICMP includes messages for reporting routing errors, host problems, IP parameter errors, MTU size and fragmentation, and network testing (pinging).
- The software PING and Traceroute use the ICMP protocol.
- **ICMP is important and network devices should support it!**

ICMP Ping

```
fas%
fas% ping www.harvard.edu
PING zooey.harvard.edu (128.103.60.55): 56 data bytes
64 bytes from 128.103.60.55: icmp_seq=0 ttl=252 time=1 ms
64 bytes from 128.103.60.55: icmp_seq=1 ttl=252 time=1 ms
64 bytes from 128.103.60.55: icmp_seq=2 ttl=252 time=1 ms
64 bytes from 128.103.60.55: icmp_seq=3 ttl=252 time=1 ms
64 bytes from 128.103.60.55: icmp_seq=4 ttl=252 time=1 ms

----zooey.harvard.edu PING Statistics----
5 packets transmitted, 5 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 1/1/1 ms
fas%
```


Internet Trace from Harvard to MIT

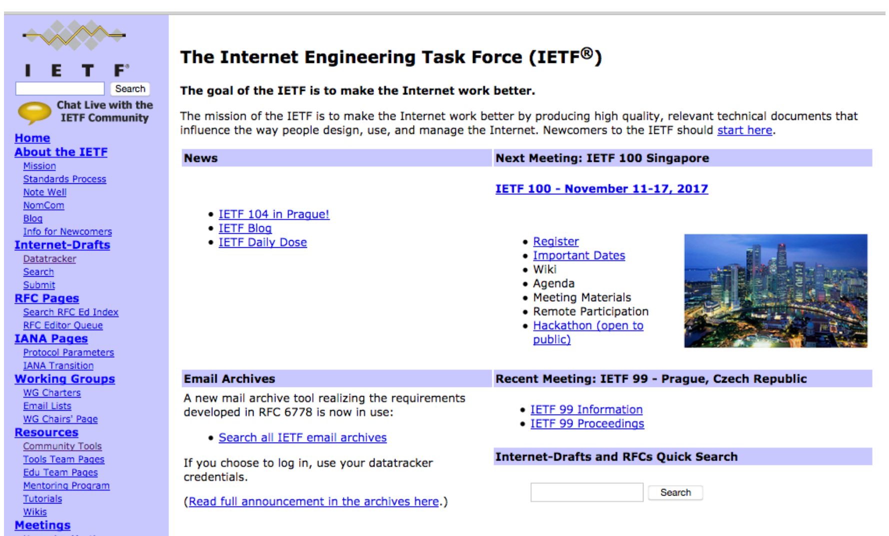
```
fas% traceroute www.mit.edu
traceroute to DANDELION-PATCH.MIT.edu (18.181.0.31),40 byte packets
 1  scmr-gw.fas.harvard.edu (140.247.30.1)  1 ms  1 ms  1 ms
 2  sc-gw.fas.harvard.edu (140.247.6.2)  1 ms  1 ms  0 ms
 3  camgw1-fas.harvard.edu (140.247.20.1)  1 ms  2 ms  1 ms
 4  192.5.66.18 (192.5.66.18)  2 ms  1 ms  1 ms
 5  192.5.66.50 (192.5.66.50)  1 ms  1 ms  1 ms
 6  192.5.66.41 (192.5.66.41)  1 ms  2 ms  1 ms
 7  192.5.66.34 (192.5.66.34)  1 ms  2 ms  1 ms
 8  MIT-MEDIAONE.MIT.EDU (18.95.0.1)  30 ms  2 ms  2 ms
 9  W20-RTR-FDDI.MIT.EDU (18.168.0.8)  3 ms  3 ms  3 ms
10  DANDELION-PATCH.MIT.EDU (18.181.0.31)  2 ms *  4 ms
fas%
```

IETF
History, Philosophy, Standards and Procedures

Who Establishes Protocols and Standards

- Standards bodies and other organizations:
  - IETF, Internet Engineering Task Force, www.ietf.org
  - ISOC, Internet Society, www.internetsociety.org
  - ISO, International Organization for Standardization
  - ITU-T, International Telecommunication Union (was CCITT)
  - NIST, National Institute for Standards and Technology (was NBS)
  - IEEE, Institute of Electrical and Electronics Engineers
  - W3C, World Wide Web Consortium
  - plus ... EIA, ECMA, etc...
- Computer, software and communication companies
- Large users and user groups

www.ietf.org



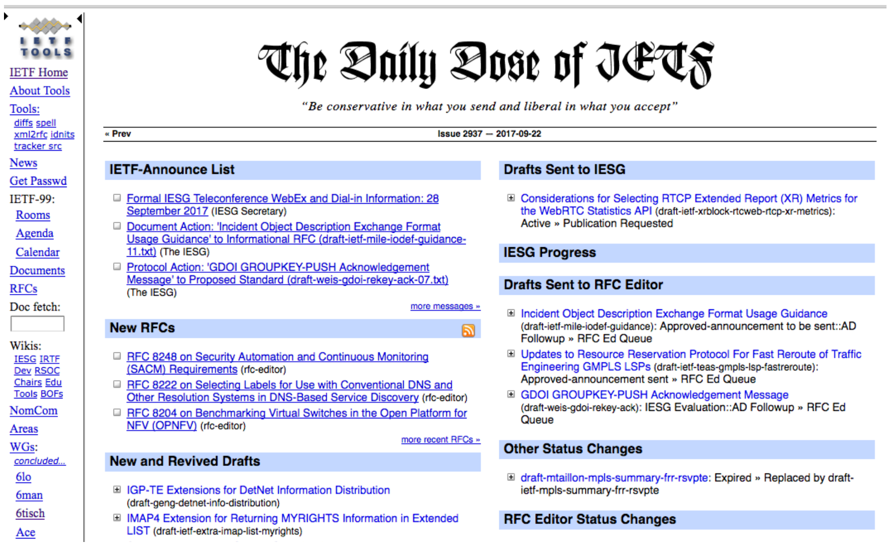
IETF Organization

- The IETF is an engineering and standards organization that has a non-obvious structure, atypical procedures and a very interesting history.
- The IETF is a technical organization, that along with other groups, develops standards for use in the Internet.
- The IETF was formed in 1986 but it has a longer history than that.
- The IETF does not manage or run the Internet or the web
- A very good way to understand the IETF is to read the Tao of the IETF.

IETF Philosophy

- The philosophy of the IETF is "Rough consensus and running code..." attributed to David Clark at MIT over 30 years ago
- Anyone can join the IETF. (Ask me about the secret handshake.)
- Approval of standards and other work is primarily done in the Working Groups via the mailing lists.
- Approval of a proposal at a meeting does not involve counting or require unanimity, rather it is a show of hands or humming
- All documents are publicly accessible and do not cost anything to download. This has been very important to developing the standards the Internet uses.
- Working out all the Intellectual Property (IP) issues is a very important ongoing issue. This is not what we normally mean when we say IP in this course.

IETF News



The Daily Dose of IETF

"Be conservative in what you send and liberal in what you accept"

« Prev — Issue 2937 — 2017-09-22

IETF Home
About Tools
Tools:
diffs spell
xml2rfc idnits
tracker src
News
Get Passwd
IETF-99:
Rooms
Agenda
Calendar
Documents
RFCs
Doc fetch:
Wikis:
IESG IRTF
Dev RSOC
Chairs Edu
Tools BOFs
NomCom
Areas
WGs:
concluded...
6lo
6man
6tisch
Ace

IETF-Announce List

- Formal IESG Teleconference WebEx and Dial-in Information: 28 September 2017 (IESG Secretary)
- Document Action: 'Incident Object Description Exchange Format Usage Guidance' to Informational RFC (draft-ietf-mile-iodef-guidance-11.txt) (The IESG)
- Protocol Action: 'GDOI GROUPKEY-PUSH Acknowledgement Message' to Proposed Standard (draft-weis-gdoi-rekey-ack-07.txt) (The IESG)

more messages »

New RFCs

- RFC 8248 on Security Automation and Continuous Monitoring (SACM) Requirements (rfc-editor)
- RFC 8222 on Selecting Labels for Use with Conventional DNS and Other Resolution Systems in DNS-Based Service Discovery (rfc-editor)
- RFC 8204 on Benchmarking Virtual Switches in the Open Platform for NFV (OPNFV) (rfc-editor)

more recent RFCs »

New and Revived Drafts

- IGP-TE Extensions for DetNet Information Distribution (draft-geng-detnet-info-distribution)
- IMAP4 Extension for Returning MYRIGHTS Information in Extended LIST (draft-ietf-extra-imap-list-myrights)

Drafts Sent to IESG

- Considerations for Selecting RTCP Extended Report (XR) Metrics for the WebRTC Statistics API (draft-ietf-xrblock-rtcweb-rtcp-xr-metrics): Active » Publication Requested

IESG Progress

Drafts Sent to RFC Editor

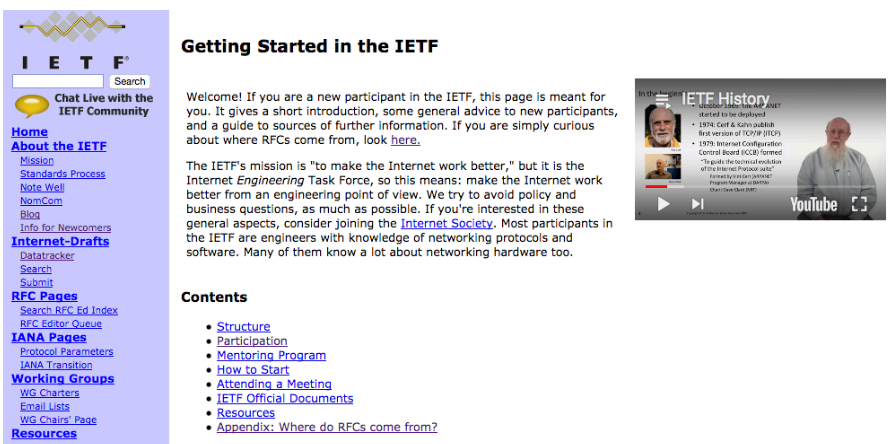
- Incident Object Description Exchange Format Usage Guidance (draft-ietf-mile-iodef-guidance): Approved-announcement to be sent::AD Followup » RFC Ed Queue
- Updates to Resource Reservation Protocol For Fast Reroute of Traffic Engineering GMPLS LSPs (draft-ietf-teas-gmpls-lsp-fastreroute): Approved-announcement sent » RFC Ed Queue
- GDOI GROUPKEY-PUSH Acknowledgement Message (draft-weis-gdoi-rekey-ack): IESG Evaluation::AD Followup » RFC Ed Queue

Other Status Changes

- draft-mtaillon-mpls-summary-frr-rsvpte: Expired » Replaced by draft-ietf-mpls-summary-frr-rsvpte

RFC Editor Status Changes

Joining the IETF



I E T F®

Search

Chat Live with the IETF Community

Home
About the IETF
Mission
Standards Process
Note Well
NomCom
Blog
Info for Newcomers
Internet-Drafts
Datatracker
Search
Submit
RFC Pages
Search RFC Ed Index
RFC Editor Queue
IANA Pages
Protocol Parameters
IANA Transition
Working Groups
WG Charters
Email Lists
WG Chairs' Page
Resources

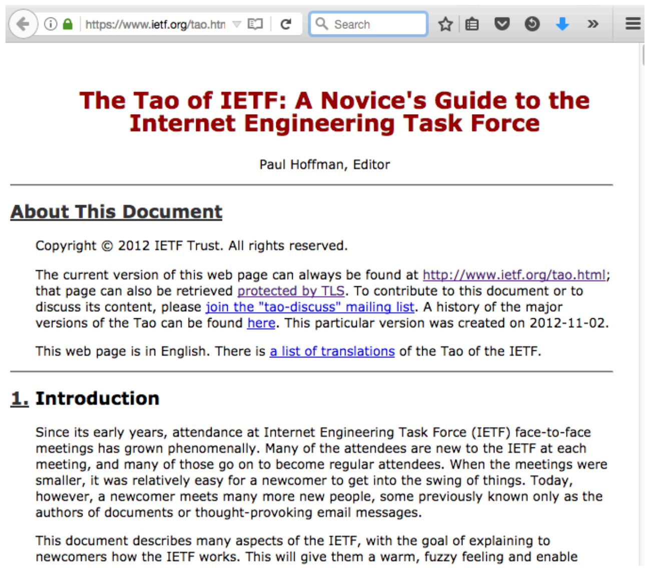
Getting Started in the IETF

Welcome! If you are a new participant in the IETF, this page is meant for you. It gives a short introduction, some general advice to new participants, and a guide to sources of further information. If you are simply curious about where RFCs come from, look here.

The IETF's mission is "to make the Internet work better," but it is the Internet *Engineering* Task Force, so this means: make the Internet work better from an engineering point of view. We try to avoid policy and business questions, as much as possible. If you're interested in these general aspects, consider joining the Internet Society. Most participants in the IETF are engineers with knowledge of networking protocols and software. Many of them know a lot about networking hardware too.

Contents

The Tao of the IETF



The Tao of IETF: A Novice's Guide to the Internet Engineering Task Force

Paul Hoffman, Editor

About This Document

The current version of this web page can always be found at http://www.ietf.org/tao.html; that page can also be retrieved protected by TLS. To contribute to this document or to discuss its content, please join the "tao-discuss" mailing list. A history of the major versions of the Tao can be found here. This particular version was created on 2012-11-02.

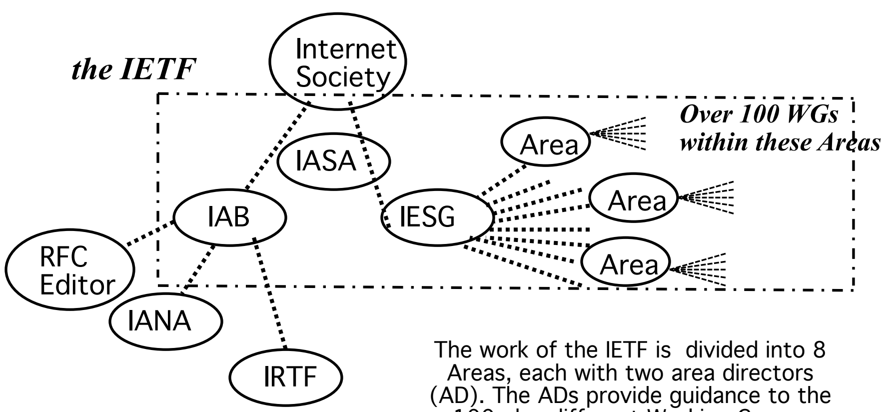
This web page is in English. There is a list of translations of the Tao of the IETF.

1. Introduction

Since its early years, attendance at Internet Engineering Task Force (IETF) face-to-face meetings has grown phenomenally. Many of the attendees are new to the IETF at each meeting, and many of those go on to become regular attendees. When the meetings were smaller, it was relatively easy for a newcomer to get into the swing of things. Today, however, a newcomer meets many more new people, some previously known only as the authors of documents or thought-provoking email messages.

This document describes many aspects of the IETF, with the goal of explaining to newcomers how the IETF works. This will give them a warm, fuzzy feeling and enable

High Level Organizational View



The work of the IETF is divided into 8 Areas, each with two area directors (AD). The ADs provide guidance to the 100 plus different Working Groups.

Source is IETF newcomers presentation.

The IETF and other Standards Groups Work Together
(IETF blog post on Sept. 16, 2016)

IETF®

Search

Chat Live with the IETF Community

- Home
- About the IETF
  - Mission
  - Standards Process
  - Note Well
  - NomCom
  - Info for Newcomers
- Internet-Drafts
  - Datatracker
  - Search
  - Submit
- RFC Pages
  - Search RFC Ed Index
  - RFC Editor Queue
- IANA Pages
  - Protocol Parameters
- Working Groups
  - WG Charters
  - Email Lists
  - WG Chairs' Page
- Resources
  - Community Tools
  - Tools Team Pages
  - Edu Team Pages
  - Tutorials
  - Wikis
- Meetings
  - Upcoming Meetings
  - Past Meetings
  - Interim Meetings
  - Important Dates
  - Proceedings
- Mailing Lists
  - Announcement Lists
  - Discussion Lists
  - Non-WG Lists
- IESG
  - Announcements
  - Statements
  - Members
  - Minutes

Working with the IEEE 802

Standards organisations have their areas of work, but for many topics efforts affect multiple organisations, or even span across multiple organisations. Take the IETF and the IEEE for instance, as our efforts often interact. From the IETF perspective, the most relevant IEEE standards group is the IEEE 802 LAN/MAN Standards Committee. It develops and maintains networking standards and recommended practices for local, metropolitan, and other area networks.

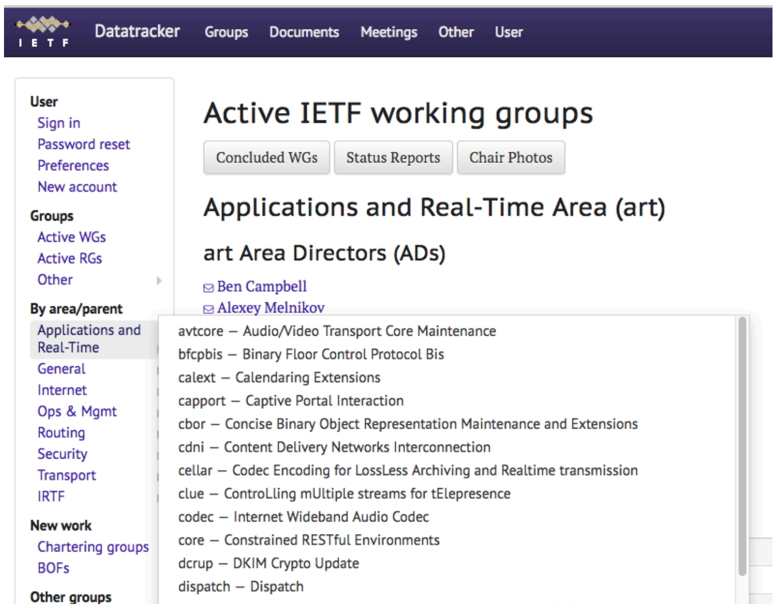
IETF and IEEE 802 leadership and liaison managers are in contact regularly, and every couple of years we also meet in person to better understand what work is happening on the other side, and make sure we stay coordinated. Last week, we held our fourth such meeting, continuing our tradition of meeting in outskirts of large airports in nondescript hotels 🙂 this time outside Charles-de-Gaulle airport in Paris.

Source https://www.ietf.org/blog/2016/09/working-with-the-ieee/

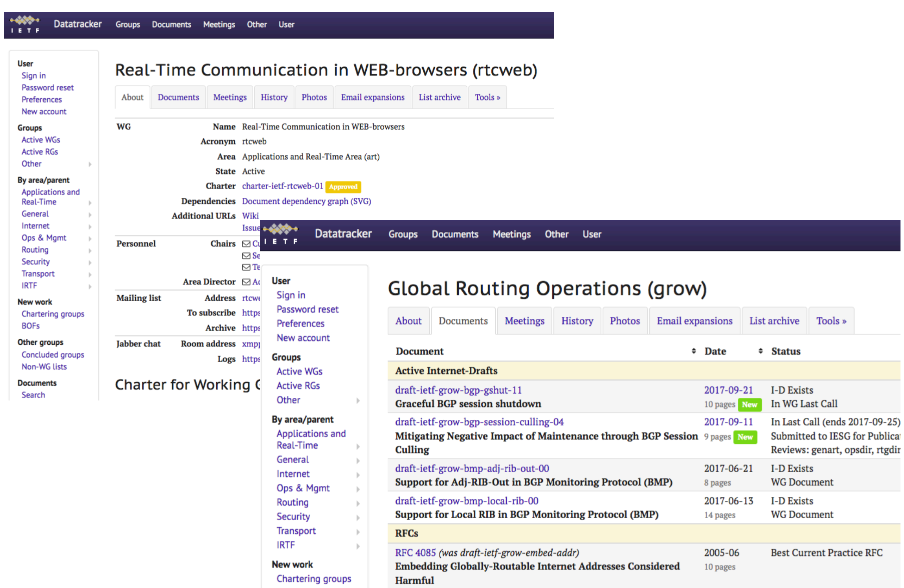
IETF Working Groups

- The working groups are where the technical work in the IETF actually gets done
- The majority of the work is done on the mailing list but the working groups do meet at IETF meetings
- There are 8 Areas and over 100 WGs
- WGs close when the work is done.
- Anyone can join a working group. Everyone in class should join one or more WGs.

IETF WG Areas and Working Groups



IETF Working Groups



SIPCORE WG Mailing List Activity

It is important to actively participate to understand what is going on.

Date: Wed, 13 June 2011 20:58:09 +0200
From: Hans xxxx
To: "John xxxx
Cc: SIPCORE <sipcore@ietf.org>
Subject: Re: [sipcore] Inconsistency in RFC 3325?

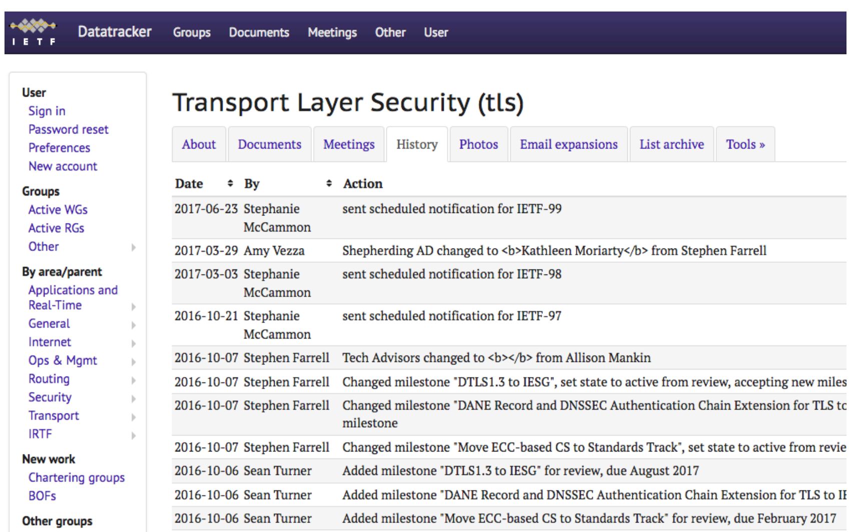
Hi John,

If you cite the complete paragraph: "6. Hints for Multiple Identities

If a P-Preferred-Identity header field is present in the message that a proxy receives from an entity that it does not trust, the proxy MAY use this information as a hint suggesting which of multiple valid identities for the authenticated user should be asserted. If such a hint does not correspond to any valid identity known to the proxy for that user, the proxy can add a P-Asserted-Identity header of its own construction, or it can reject the request (for example, with a 403 Forbidden). The proxy MUST remove the user-provided P-Preferred-Identity header from any message it forwards."

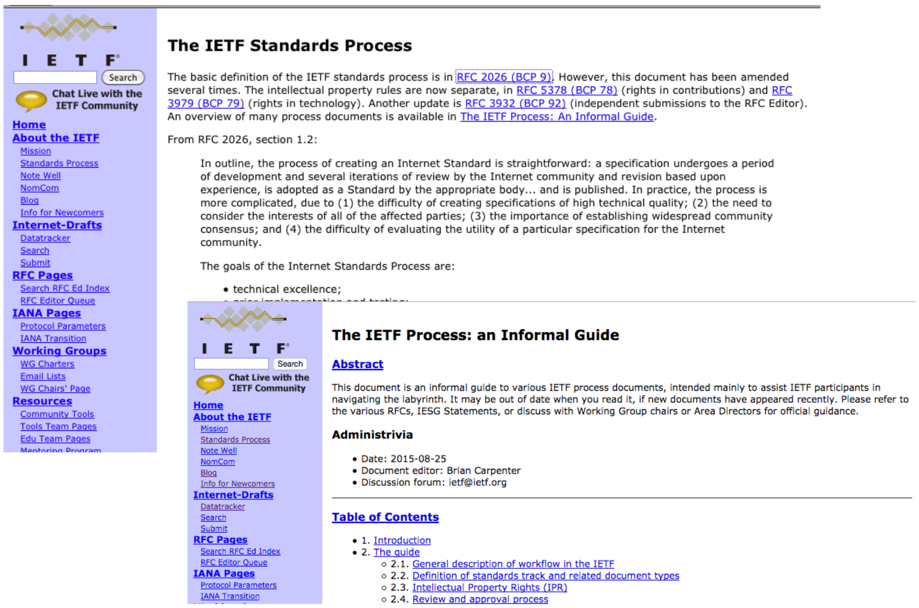
then it is clear that "The proxy" is not just any proxy, but ...

tls Working Group



Date	By	Action
2017-06-23	Stephanie McCammon	sent scheduled notification for IETF-99
2017-03-29	Amy Vezza	Shepherding AD changed to Kathleen Moriarty from Stephen Farrell
2017-03-03	Stephanie McCammon	sent scheduled notification for IETF-98
2016-10-21	Stephanie McCammon	sent scheduled notification for IETF-97
2016-10-07	Stephen Farrell	Tech Advisors changed to from Allison Mankin
2016-10-07	Stephen Farrell	Changed milestone "DTLS1.3 to IESG", set state to active from review, accepting new miles
2016-10-07	Stephen Farrell	Changed milestone "DANE Record and DNSSEC Authentication Chain Extension for TLS tc milestone
2016-10-07	Stephen Farrell	Changed milestone "Move ECC-based CS to Standards Track", set state to active from revie
2016-10-06	Sean Turner	Added milestone "DTLS1.3 to IESG" for review, due August 2017
2016-10-06	Sean Turner	Added milestone "DANE Record and DNSSEC Authentication Chain Extension for TLS to IE
2016-10-06	Sean Turner	Added milestone "Move ECC-based CS to Standards Track" for review, due February 2017

IETF Standards Process



The IETF Standards Process

The basic definition of the IETF standards process is in RFC 2026 (BCP 9). However, this document has been amended several times. The intellectual property rules are now separate, in RFC 5378 (BCP 78) (rights in contributions) and RFC 3979 (BCP 79) (rights in technology). Another update is RFC 3932 (BCP 92) (independent submissions to the RFC Editor). An overview of many process documents is available in The IETF Process: An Informal Guide.

From RFC 2026, section 1.2:

> In outline, the process of creating an Internet Standard is straightforward: a specification undergoes a period of development and several iterations of review by the Internet community and revision based upon experience, is adopted as a Standard by the appropriate body... and is published. In practice, the process is more complicated, due to (1) the difficulty of creating specifications of high technical quality; (2) the need to consider the interests of all of the affected parties; (3) the importance of establishing widespread community consensus; and (4) the difficulty of evaluating the utility of a particular specification for the Internet community.
>
> The goals of the Internet Standards Process are:
>
> - technical excellence;

The IETF Process: an Informal Guide

Abstract

This document is an informal guide to various IETF process documents, intended mainly to assist IETF participants in navigating the labyrinth. It may be out of date when you read it, if new documents have appeared recently. Please refer to the various RFCs, IESG Statements, or discuss with Working Group chairs or Area Directors for official guidance.

Administrivia

- Date: 2015-08-25
- Document editor: Brian Carpenter
- Discussion forum: ietf@ietf.org

Table of Contents

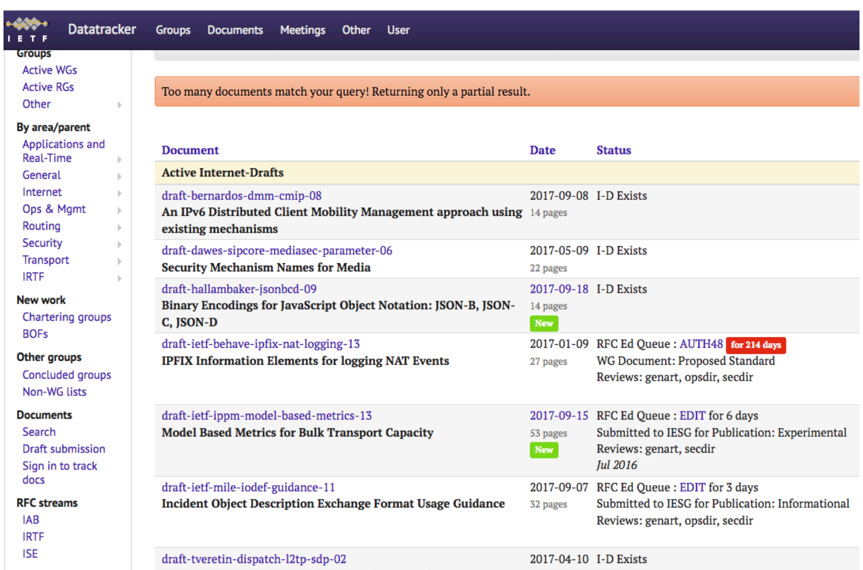
RFCs

- RFC first meant Request for Comments, it is now just a form of publication within the IETF
- The first RFC was in 1969 (RFC#1, Host Software)
- Today, there are many different types of RFCs, many that you would not expect to see
- It is important to understand that not all RFCs are standards
- Now over 5,000 RFCs and counting
- Technical standards track RFCs start out as Internet Drafts (ID.) An ID is not a standard.

Internet-Drafts (IDs)

- IETF working documents are called Internet-Drafts
- There is limited review for documents that are submitted as IDs
- IDs have a stated lifetime of 6 months (but the web means you can always find out-of-date copies.)
- RFCs start out as IDs, but the majority of IDs do not move beyond the ID stage.

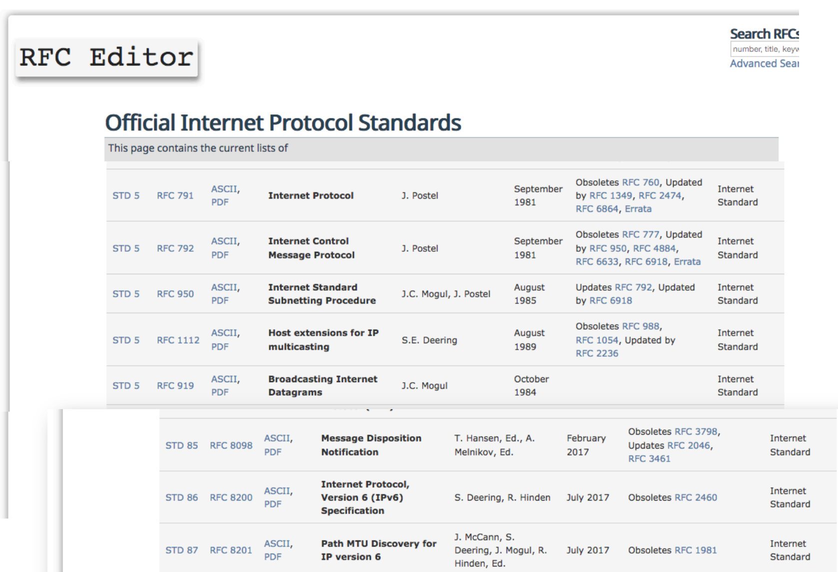
There are 1,000s of active Internet-Drafts (IDs)



IETF Standards Process
(Revised by RFC 6410 in 2011)

- Technical documents follow a defined process before they become IETF Standards
- Proposal for a future standard is first published as an ID. It is then refined and updated within a working group.
- Today there is a two step process for an RFC to become an IETF standard. (see RFC 6410)
- First level of the process is called the Proposed Standard
- The second and final level is the Internet Standard
  - As described in RFC 2026: An Internet Standard is characterized by a high degree of technical maturity and by a generally held belief that the specified protocol or service provides significant benefit to the Internet community.

Internet Standards



STD 5	RFC 791	ASCII, PDF	**Internet Protocol**	J. Postel	September 1981	Obsoletes RFC 760, Updated by RFC 1349, RFC 2474, RFC 6864, Errata	Internet Standard
STD 5	RFC 792	ASCII, PDF	**Internet Control Message Protocol**	J. Postel	September 1981	Obsoletes RFC 777, Updated by RFC 950, RFC 4884, RFC 6633, RFC 6918, Errata	Internet Standard
STD 5	RFC 950	ASCII, PDF	**Internet Standard Subnetting Procedure**	J.C. Mogul, J. Postel	August 1985	Updates RFC 792, Updated by RFC 6918	Internet Standard
STD 5	RFC 1112	ASCII, PDF	**Host extensions for IP multicasting**	S.E. Deering	August 1989	Obsoletes RFC 988, RFC 1054, Updated by RFC 2236	Internet Standard
STD 5	RFC 919	ASCII, PDF	**Broadcasting Internet Datagrams**	J.C. Mogul	October 1984		Internet Standard
STD 85	RFC 8098	ASCII, PDF	**Message Disposition Notification**	T. Hansen, Ed., A. Melnikov, Ed.	February 2017	Obsoletes RFC 3798, Updates RFC 2046, RFC 3461	Internet Standard
STD 86	RFC 8200	ASCII, PDF	**Internet Protocol, Version 6 (IPv6) Specification**	S. Deering, R. Hinden	July 2017	Obsoletes RFC 2460	Internet Standard
STD 87	RFC 8201	ASCII, PDF	**Path MTU Discovery for IP version 6**	J. McCann, S. Deering, J. Mogul, R. Hinden, Ed.	July 2017	Obsoletes RFC 1981	Internet Standard

Thank You!

ALIGHLSOD1701

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!**