

Internet Technology

http://en.wikipedia.org/wiki/Internet_Protocol_Suite



<https://www.coursera.org/course/insidetheinternet>

Coursera

open.michigan

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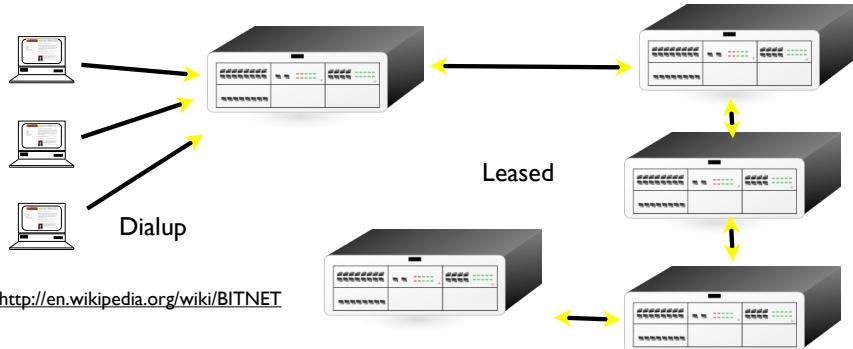
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<http://xkcd.com/742/>

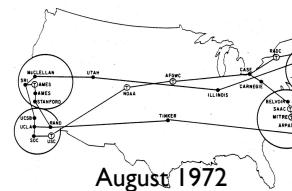
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Store and Forward Networking



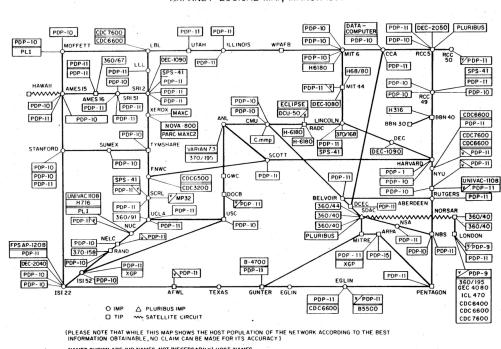
Research Networks 1960-1980's

- How can we avoid having a direct connection between all pairs of computers?
- How to transport messages efficiently?
- How can we dynamically handle outages?



<http://som.csudh.edu/fac/lpress/history/arpamaps/>

ARPANET LOGICAL MAP, MARCH 1977



Heart, F., McKenzie, A., McQuillian, J., and Walden, D., ARPANET Completion Report, Bolt, Beranek and Newman, Burlington, MA, January 4, 1978.
<http://som.csudh.edu/fac/lpress/history/arpamaps/arpnetmar77.jpg>

Efficient Message Transmission: Packet Switching

- Challenge: in a simple approach, like store-and-forward, large messages block small ones
- Break each message into packets
- Can allow the packets from a single message to travel over different paths, dynamically adjusting for use
- Use special-purpose computers, called routers, for the traffic control

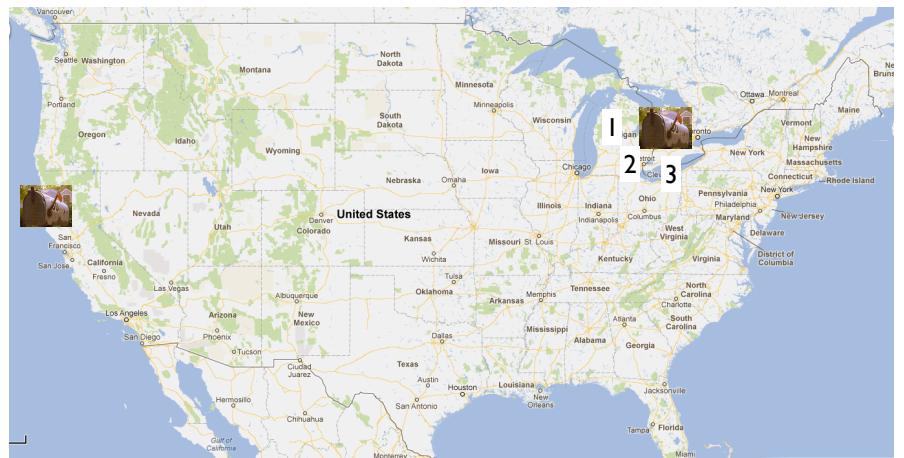
Hello there, have a nice day.

Packet Switching - Postcards

Hello ther (1, csev, daphne)

e, have a (2, csev, daphne)

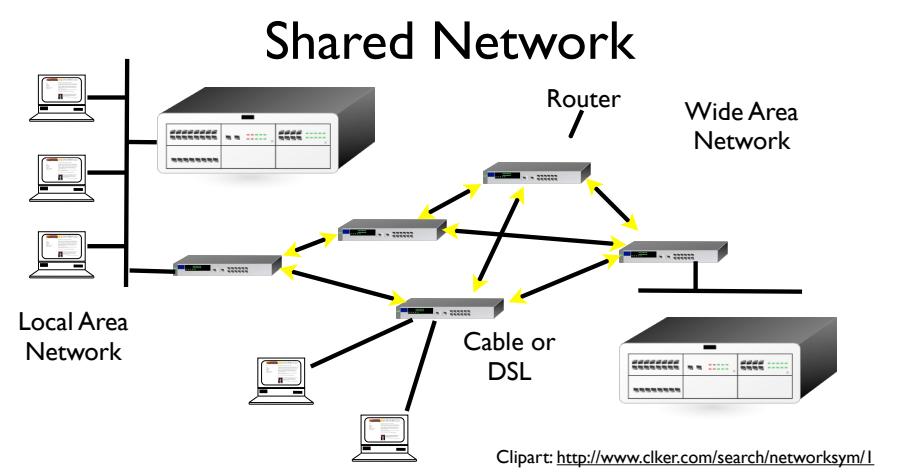
nice day. (3, csev, daphne)



Packet Switching - Postcards



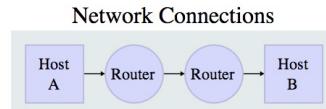
Hello there, have a nice day.



Clipart: <http://www.clerk.com/search/networksym/>

Shared Networks

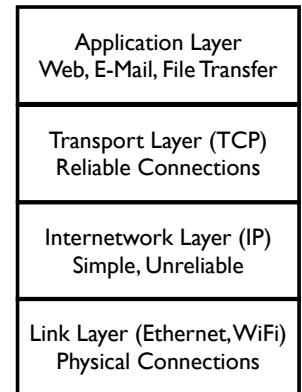
- In order to keep cost low and the connections short geographically - data would be forwarded through several routers.
- Getting across the country usually takes about 10 “hops”
- Network designers continually add and remove links to “tune” their networks



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Layered Network Model

- A layered approach allows the problem of designing a network to be broken into more manageable sub problems
- Best-known model: TCP/IP—the “Internet Protocol Suite”
- There was also a 7 layer OSI: Open System Interconnection Model



Internet Standards

- The standards for all of the Internet protocols (inner workings) are developed by an organization
- Internet Engineering Task Force (IETF)
- www.ietf.org
- Standards are called “RFCs” - “Request for Comments”

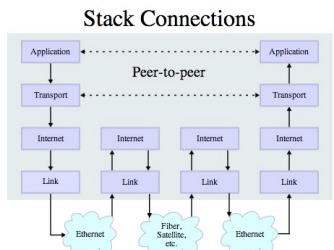
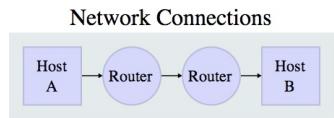
INTERNET PROTOCOL
DARPA INTERNET PROGRAM
PROTOCOL SPECIFICATION
September 1981

The internet protocol treats each internet datagram as an independent entity unrelated to any other internet datagram. There are no connections or logical circuits (virtual or otherwise).
The internet protocol uses four key mechanisms in providing its services: Type of Service, Time to Live, Options, and Header Checksum.

Source: <http://tools.ietf.org/html/rfc791>

Layered Architecture

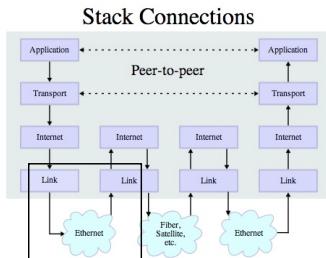
- The Physical and Internet Layers are like trucks and trains - they haul stuff and get it to the right loading dock - it takes multiple steps
- The Transport layer checks to see if the trucks made it and send the stuff again if necessary



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Link Layer (aka Physical Layer)

- As your data crosses the country may use a different physical medium for each “hop”
- Wire, Wireless, Fiber Optic, etc.
- The link is “one hop” - Is it up or down? Connected or not?
- Very narrow focus - no view at all of the “whole Internet”



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Problems solved by the Link Layer

- Common Link Technologies**
 - Ethernet**
 - WiFi**
 - Cable modem**
 - DSL**
 - Satellite**
 - Optical**
- How does data get pushed onto a link?**
- How is the link shared?**

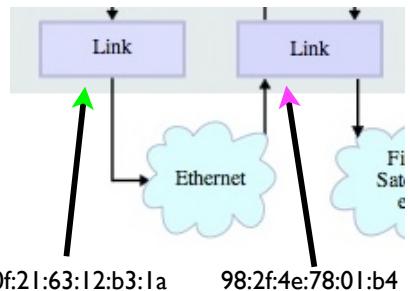
Link Layer Addresses

- Many physical layer devices have addresses built in to them by the manufacturer
 - Ethernet
 - Wireless Ethernet (Wifi)



Link Layer

- Physical addresses are to allow systems to identify themselves on the ends of a single link
- Physical addresses go no farther than one link
- Sometimes links like Wifi and Wired Ethernet are shared with multiple computers



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Sharing Nicely - Avoiding Chaos

- **CSMA/CD Carrier Sense
Multiple Access with
Collision Detection**

- **To avoid garbled messages,
systems must observe
“rules” (Protocols)**

- **Ethernet rules are simple**

- Wait for silence
- Begin Transmitting data
- Listen for your own data
- If you cannot hear your own data clearly, assume a collision, stop and wait before trying again
- Each system waits a different amount of time to avoid “too much politeness”

Ethernet

- Invented at PARC (Xerox)
- The first Local-Area-Network
- Connected PC's to laser printers
- Inspired by an earlier wireless network called Aloha from the University of Hawaii

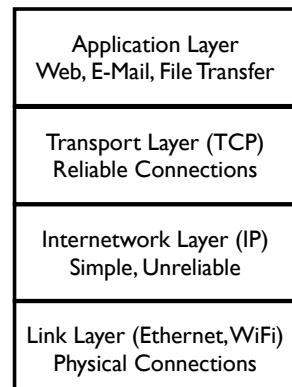


Internetwork Layer (IP)

http://en.wikipedia.org/wiki/Internet_Protocol

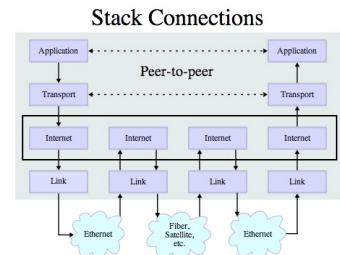
<http://en.wikipedia.org/wiki/Traceroute>

<http://en.wikipedia.org/wiki/Ping>



Internet Protocol Layer

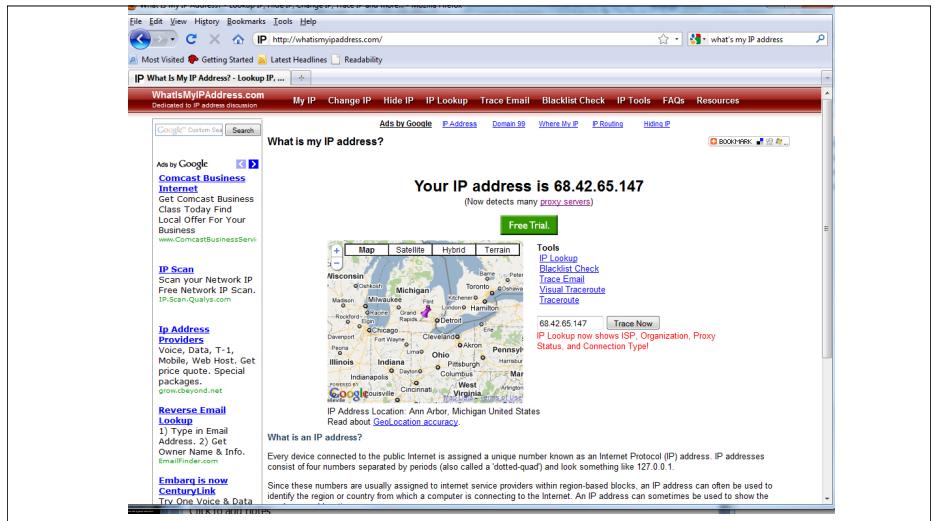
- Goal: Gets your data from this computer to the other computer half way across the world
- Each router knows about nearby routers
- IP Is best effort - it is OK to drop data if things go bad...



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

IP Addresses

- The IP address is the worldwide number which is associated with one particular workstation or server
- Every system which will send packets directly out across the Internet must have a unique IP address
- IP addresses are based on where station is connected
- IP addresses are not controlled by a single organization - address ranges are assigned
- They are like phone numbers – they get reorganized once in a great while



IP Address Format

- Four numbers with dots - each number 1-255 (32 bits)**
- Kind of like phone numbers with an “area code”**
- The prefix of the address is “which network”**
- While the data is traversing the Internet - all that matters is the network number**

(734) 764 1855

Area code

141.211.144.188

Network
Number

141.211.*.*

While in the network, all
that matters is the
Network number.

141.211.144.188

To: 67.149.*.*

67.149.102.75

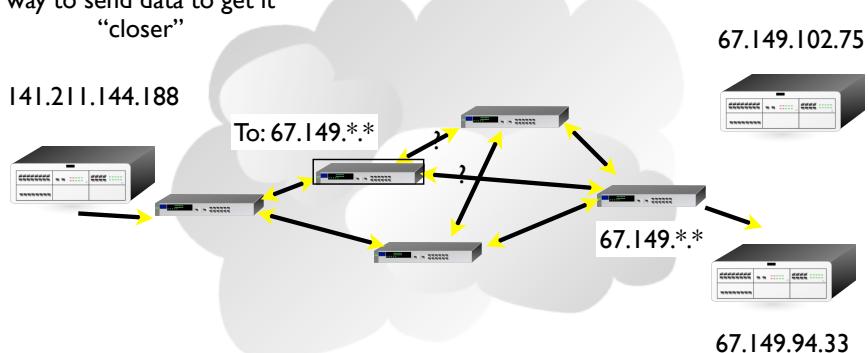
67.149.94.33

To: 67.149.94.33

67.149.94.33

Clipart: <http://www.clker.com/search/networksym/>

No single router knows the whole network - just which way to send data to get it "closer"

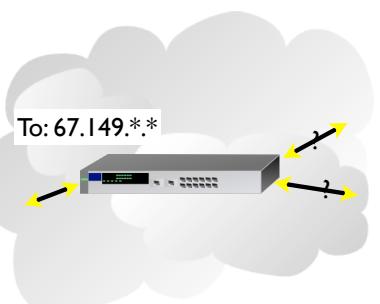


Clipart: <http://www.clker.com/search/networksym/l>

Router Tables

Lists of where to send packets, based on destination network address; bandwidth on adjacent links; traffic on adjacent links; state of neighbor nodes (up or not);
...

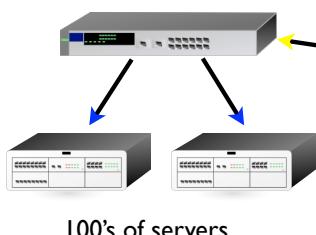
Updated dynamically
Routers "ask each other" for information



Clipart: <http://www.clker.com/search/networksym/l>

IP Is Simple

Local Network



Thousands of network connections.
Billions of bytes of data per seconds.

One "area code" to keep track of inside the Internet.

Clipart: <http://www.clker.com/search/networksym/l>



DHCP = Dynamic Host Configuration Protocol

Hello?



Here I am

What IP Address can I use?

141.26.14.1

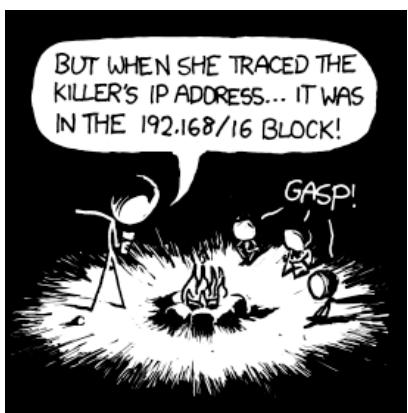
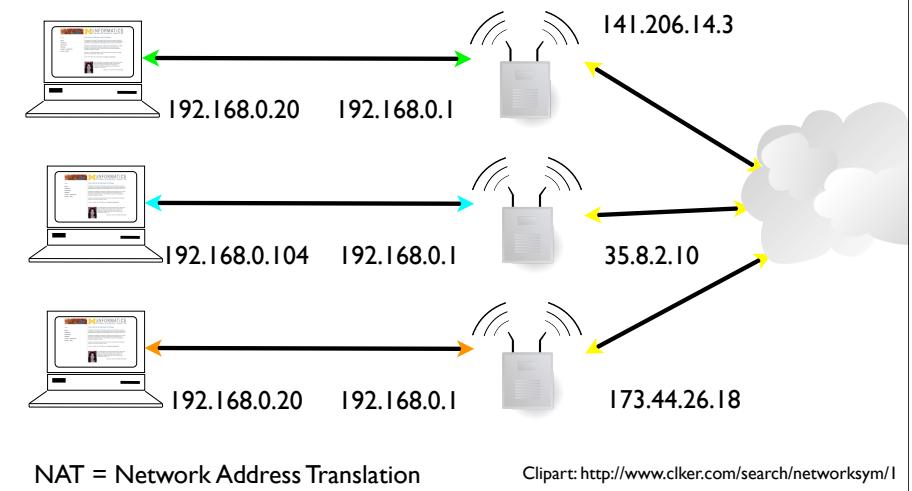


Use 141.26.14.7

Non-Routable Addresses

- A typical home router does Network Address Translation (NAT)
- Your ISP gives your home router a real global routable address
- Your router gives out local addresses in a special range (192.168.*.*)
- The router maps remote addresses for each connection you make from within your home network

http://en.wikipedia.org/wiki/Network_address_translation



<http://xkcd.com/742/>

Peering into the Internet

- Most systems have a command that will reveal the route taken across the internet (traceroute on Mac and tracert on Windows)
- Each IP packet has a field called “Time to Live” - TTL
- The TTL is used to deal with loops in the network - normally if routers got confused and ended up with a loop - the network would clog up rapidly.

Clipart: <http://www.clker.com/search/networksym/>



How Traceroute Works

- Normal packets are sent with a Time to Live (TTL) of 255 hops
 - Trace route sends a packet with TTL=1, TTL=2, ...
 - So each packet gets part-way there and then gets dropped and traceroute gets a notification of where the drop happens
 - This builds a map of the nodes that a packet visits when crossing the Internet.

Traceroute

```
$ traceroute www.stanford.edu
traceroute to www5.stanford.edu (171.67.20.37), 64 hops max, 40 byte packets
 1 141.211.203.252 (141.211.203.252) 1.390 ms 0.534 ms 0.490 ms
 2 v-bin-seb.r-bin-seb.umnet.umich.edu (192.122.183.61) 0.591 ms 0.558 ms 0.570 ms
 3 v-bin-seb-i2-aa.merit-aa2.umnet.umich.edu (192.12.80.33) 6.610 ms 6.545 ms 6.654 ms
 4 192.122.183.30 (192.122.183.30) 7.919 ms 7.209 ms 7.122 ms
 5 so-4-3-0-0.rtr.kans.net.internet2.edu (64.57.28.36) 17.672 ms 17.836 ms 17.673 ms
 6 so-0-1-0-0.rtr.hous.net.internet2.edu (64.57.28.57) 31.800 ms 41.967 ms 31.787 ms
 7 so-3-0-0-0.rtr.losa.net.internet2.edu (64.57.28.44) 63.478 ms 63.704 ms 63.710 ms
 8 hpr-lax-hpr-i2-newnet.cenic.net (137.164.26.132) 63.093 ms 63.026 ms 63.384 ms
 9 svl-hpr-lax-hpr-10ge.cenic.net (137.164.25.13) 71.242 ms 71.542 ms 76.282 ms
10 oak-hpr-svl-hpr-10ge.cenic.net (137.164.25.9) 72.744 ms 72.243 ms 72.556 ms
11 hpr-stan-ge-oak-hpr.cenic.net (137.164.27.158) 73.763 ms 73.396 ms 73.665 ms
12 bbra-rtr.Stanford.EDU (171.64.1.134) 73.577 ms 73.682 ms 73.492 ms
13 ***
14 www5.Stanford.EDU (171.67.20.37) 77.317 ms 77.128 ms 77.648 ms
```

Traceroute

```
$ traceroute www.msu.edu
traceroute to www.msu.edu (35.8.10.30), 64 hops max, 40 byte packets
 1 141.211.203.252 (141.211.203.252) 2.644 ms 0.973 ms 14.162 ms
 2 v-bin-seb.r-bin-seb.umnet.umich.edu (192.122.183.61) 1.847 ms 0.561 ms 0.496 ms
 3 v-bin-seb-i2-aa.merit-aa.2.umnet.umich.edu (192.12.80.33) 6.490 ms 6.499 ms 6.529 ms
 4 lt-0-3-0x1.eq-chi2.mich.net (198.108.23.121) 8.096 ms 8.113 ms 8.103 ms
 5 xe-0-0-0x23.msu6.mich.net (198.108.23.213) 7.831 ms 7.962 ms 7.965 ms
 6 192.122.183.227 (192.122.183.227) 12.953 ms 12.339 ms 10.322 ms
 7 cc-tl-gel-23.net.msu.edu (35.9.101.209) 9.522 ms 9.406 ms 9.817 ms
 8 ***
```

Traceroute

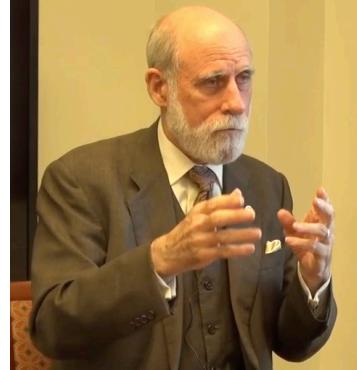
```
$ traceroute www.pku.edu.cn
traceroute: Warning: www.pku.edu.cn has multiple addresses; using 162.105.129.104
traceroute to www.pku.edu.cn (162.105.129.104), 64 hops max, 40 byte packets
  1 141.211.203.252 (141.211.203.252) 1.228 ms 0.584 ms 0.592 ms
  2 v-bin-seb.r-bin-seb.umnet.umich.edu (192.122.183.61) 0.604 ms 0.565 ms 0.466 ms
  3 v-bin-seb-i2-aa.merit-aa2.umnet.umich.edu (192.12.80.33) 7.511 ms 6.641 ms 6.588 ms
  4 192.122.183.30 (192.122.183.30) 12.078 ms 6.989 ms 7.619 ms Michigan
  5 192.31.99.133 (192.31.99.133) 7.666 ms 8.953 ms 17.861 ms Tennessee
  6 192.31.99.170 (192.31.99.170) 59.275 ms 59.273 ms 59.108 ms
  7 134.75.108.209 (134.75.108.209) 173.614 ms 173.552 ms 173.333 ms
  8 134.75.107.10 (134.75.107.10) 256.760 ms 134.75.107.18 (134.75.107.18) 256.574 ms 256.53
  9 202.112.53.17 (202.112.53.17) 256.761 ms 256.801 ms 256.688 ms Seoul
  10 202.112.61.157 (202.112.61.157) 257.416 ms 257.960 ms 257.747 ms
  11 202.112.53.194 (202.112.53.194) 256.827 ms 257.068 ms 256.962 ms
  12 202.112.41.202 (202.112.41.202) 256.800 ms 257.053 ms 256.933 ms Beijing
```

The perfect is the enemy of the good

Le mieux est l'ennemi du bien. –Voltaire

- IP Does: Best effort to get data across bunch of hops from one network to another network
- IP Does Not: Guarantee delivery - if things go bad - the data can vanish
- Best effort to keep track of the good and bad paths for traffic - tries to pick better paths when possible
- This makes it fast and scalable to very large networks - and ultimately “reliable” because it does not try to do too much

Vint Cerf:A Brief History of Packets



- Instrumental in the design and development of the ARPANET
- Vint was a graduate student as the notions of packet-switching were emerging across academia

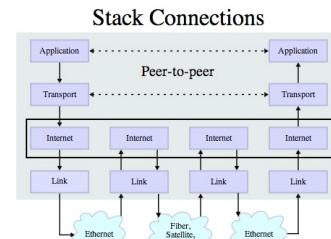
Domain Name System

**The Domain Name System
convert user-friendly
names, like**

www.umich.edu

**to network-friendly IP
addresses, like**

141.211.32.166



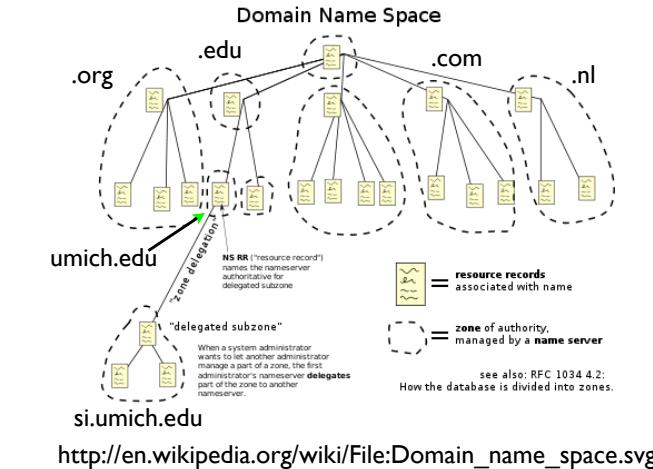
Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Domain Name System

- Numeric addresses like 141.211.63.45 are great for Internet routers but lousy for people
- Each campus ends up with a lot of networks (141.211.*.*, 65.43.21.*)
- Sometimes (rarely) the IP address numbers get reorganized
- When servers physically move they need new IP addresses

DNS: Internet Address Book

- The Domain Name System is a big fast distributed database of Internet names to Internet “phone numbers”
- IP Addresses reflect technical “geography”
 - 141.211.63.44 - read left to right like a phone number
- Domain names reflect organizational structure
 - www.si.umich.edu - read right to left like postal address
 - 2455 North Quad, Ann Arbor, MI, USA, Earth



Internet Layer (IP)

http://en.wikipedia.org/wiki/Internet_Protocol

<http://en.wikipedia.org/wiki/Traceroute>

<http://en.wikipedia.org/wiki/Ping>

Application Layer
Web, E-Mail, File Transfer
Transport Layer (TCP)
Reliable Connections
Internet Layer (IP)
Simple, Scalable, Unreliable
Link Layer (Ethernet, WiFi)
Physical Connections

Transport Layer

http://en.wikipedia.org/wiki/Transmission_Control_Protocol

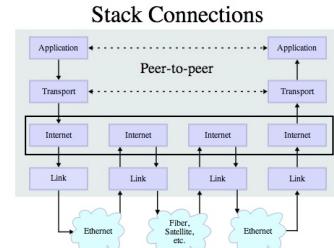
Application Layer
Web, E-Mail, File Transfer
Transport Layer (TCP)
Reliable Connections
Internet Layer (IP)
Simple, Scalable, Unreliable
Link Layer (Ethernet, WiFi)
Physical Connections

Review: The Magic of IP

- What it does - Tries to get one packet across a 5-20 of hops from one network to another network
- Keeps track of the good and bad paths for traffic - tries to pick better paths when possible
- But no guarantee of delivery - if things go bad - the data vanishes
- This makes it fast and scalable - and ultimately "reliable" because it does not try to do too "everything"

Internet Protocol

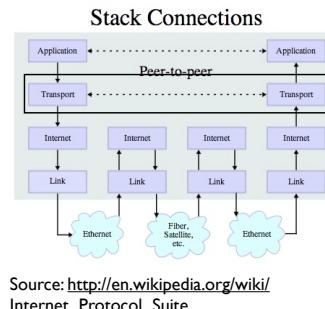
- So many links / hops
- So many routes
- Thinks can change dynamically and IP has to react (links up/down)
- IP can drop packets



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Transmission Protocol (TCP)

- Built on top of IP
- Assumes IP might lose some data
- In case data gets lost - we keep a copy of the data we send until we get an acknowledgement
- If it takes "too long" - just send it again



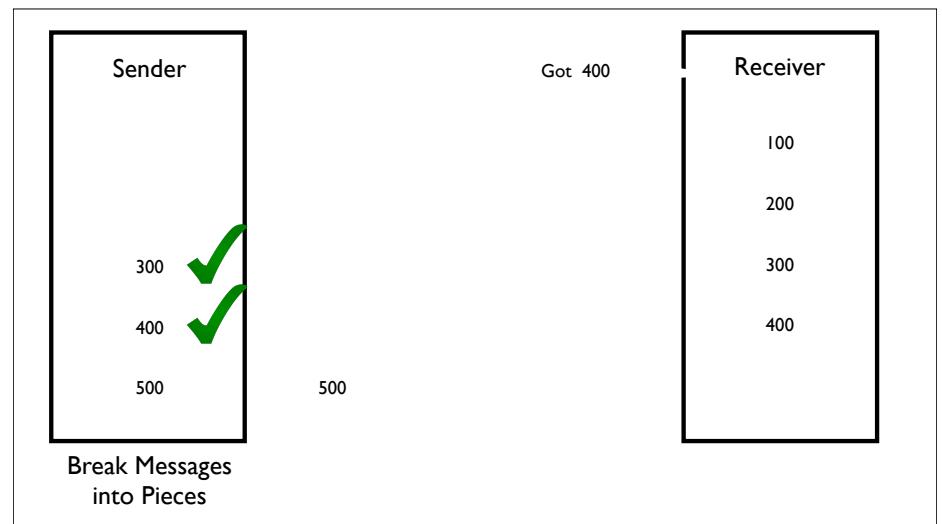
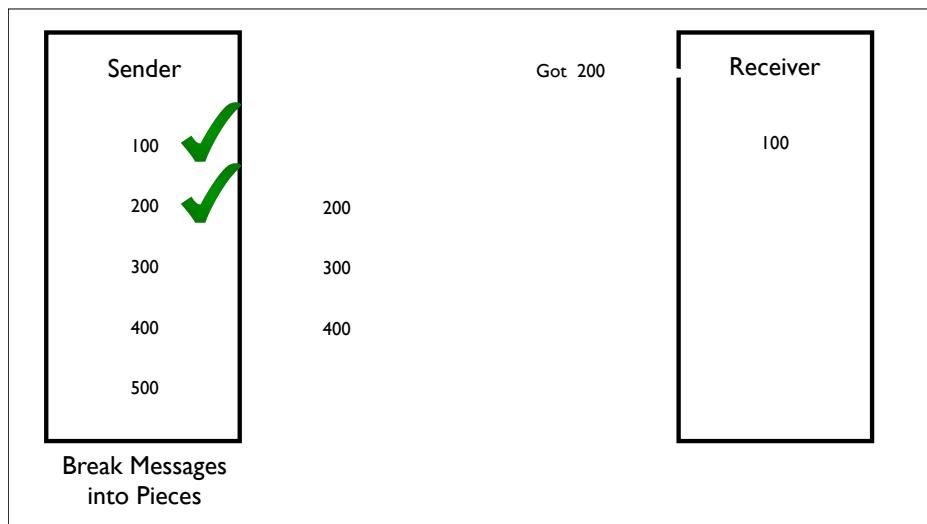
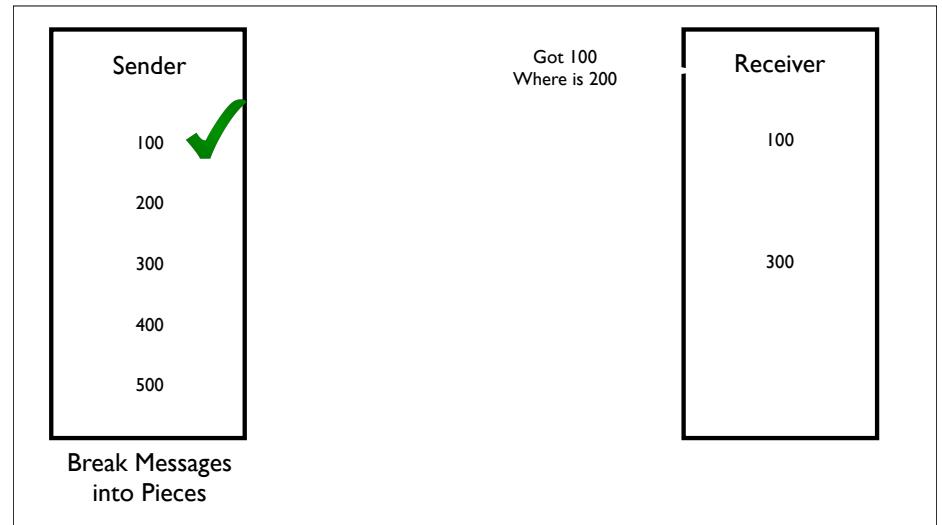
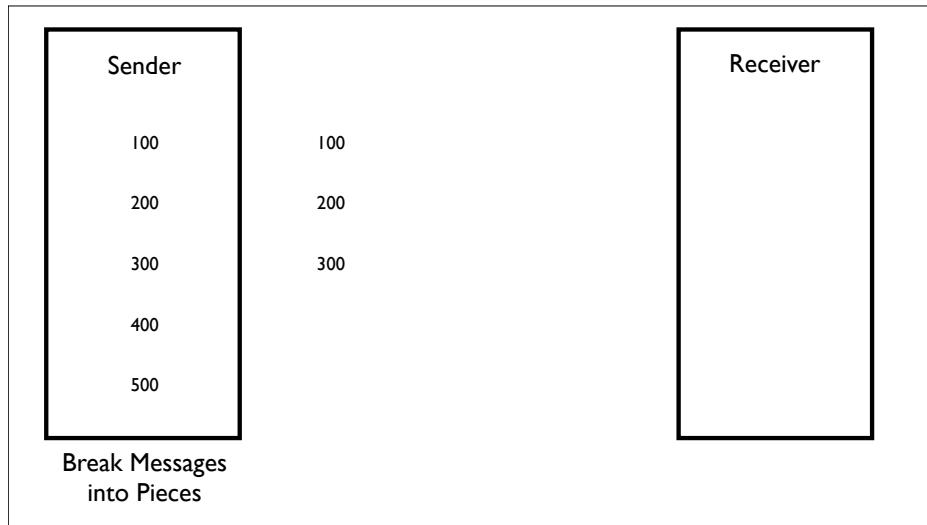
Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

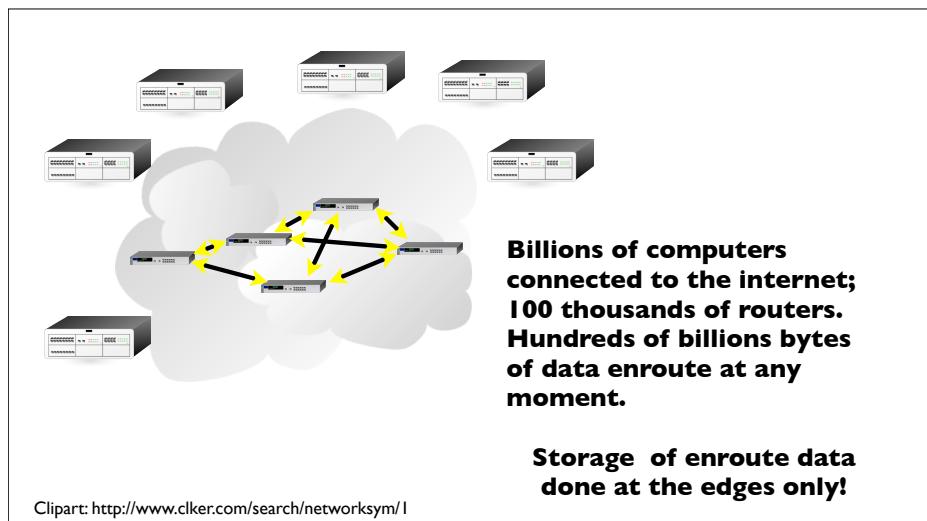
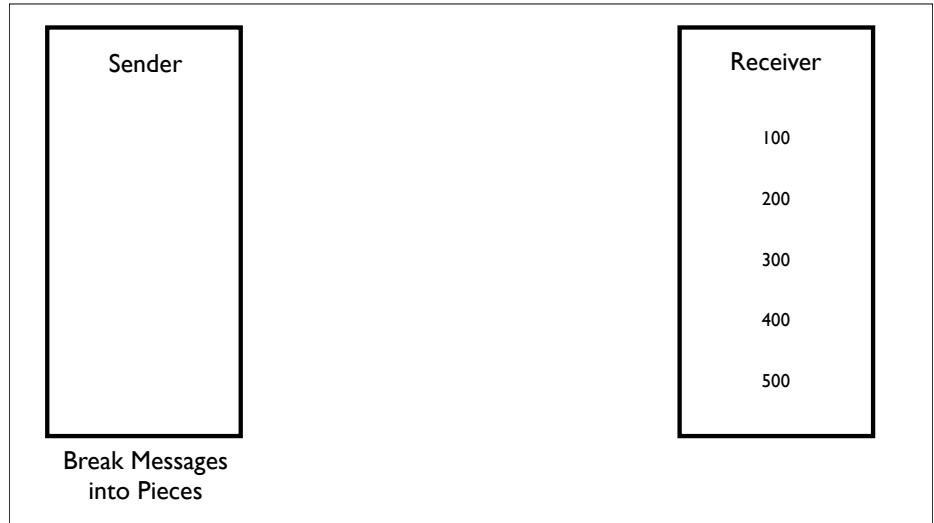
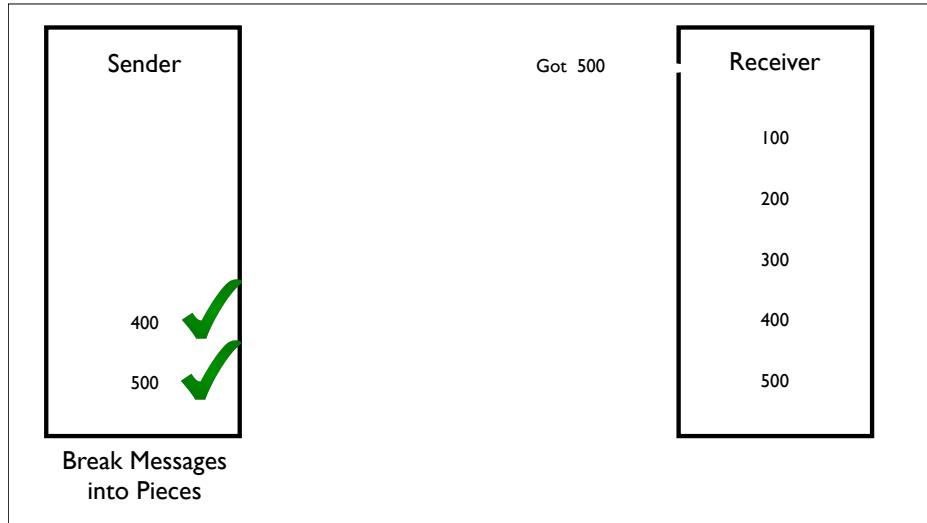
Sender

100
200
300
400
500

Break Messages
into Pieces

Receiver





One (of many) Scary Problem(s)

- In 1987 as local campuses with 10 Mbit networks were connected together using 56Kbit leased lines, things kind of fell apart
- At some point, when there was a little too much traffic, it all fell apart...

<http://www.youtube.com/watch?v=lVgIMeRYmWI>
http://en.wikipedia.org/wiki/Van_Jacobson
http://en.wikipedia.org/wiki/TCP_congestion_avoidance_algorithm

Van Jacobson
Chief Scientist for Packet Design, Xerox PARC

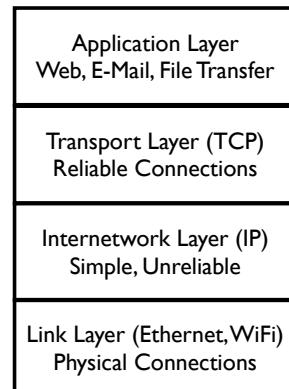
Packets reach high to low bandwidth transition

The image includes a portrait of Van Jacobson and a diagram showing two routers connected by a link with arrows indicating data flow, with the text "Packets reach high to low bandwidth transition" above it.

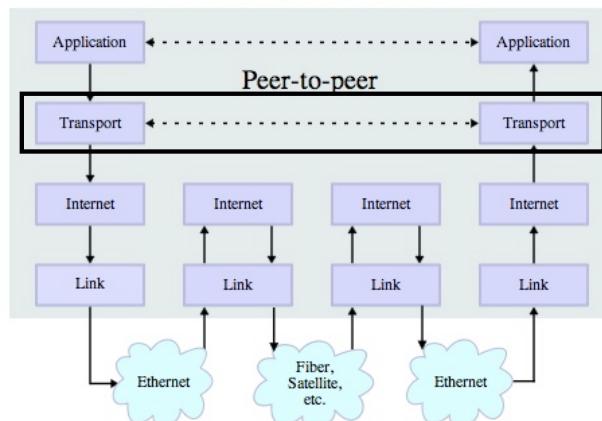
Transmission Protocol (TCP)

- The responsibility of the transport layer is to present a reliable end-to-end pipe to the application
- Data either arrives in the proper order or the connection is closed
- TCP keeps buffers in the sending and destination system to keep data which has arrived out of order or to retransmit if necessary
- TCP provides individual connections between applications

Application Layer

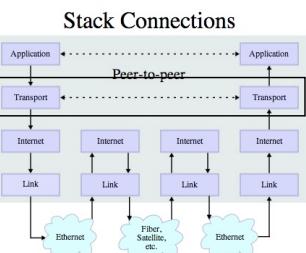


Stack Connections



Quick Review

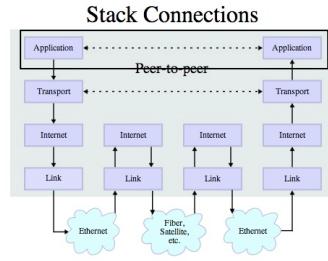
- **Link layer:** gets the data onto the link, and manages collisions on a single hop
- **Internet layer:** moves the data over one hop, trying to get it “closer” to its destination
- **Transport layer:** Assumes that the internet layer may lose data, so request retransmission when needed—provides a nice reliable pipe from source to destination



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Application Protocol

- Since TCP gives us a reliable pipe, what do we want to do with the pipe? What problem do we want to solve?
 - Mail
 - World Wide Web
 - Stream kitty videos



Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

Two Questions for the Application Layer

- Which application gets the data?
 - Ports
- What are the rules for talking with that application?
 - Protocols

http://en.wikipedia.org/wiki/TCP_and_UDP_port

http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

Ports

- Like extensions in a phone number
- The IP address network number (the area code) gets to the LAN
- The IP address host number (the telephone number) gets you to the destination machine
- The port (the extension) gets you to a specific application

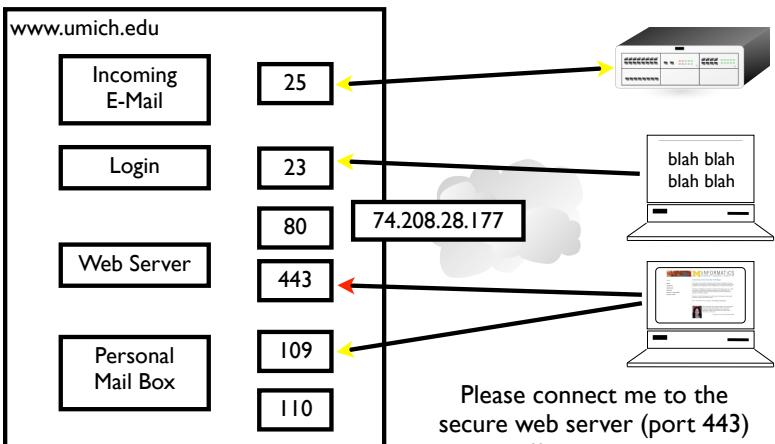
(734) 764 1855 ext. 27

141.211.144.188
Port 25

TCP, Ports, and Connections

http://en.wikipedia.org/wiki/TCP_and_UDP_port

http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers



Application Protocols

<http://en.wikipedia.org/wiki/Http>

<http://en.wikipedia.org/wiki/Pop3>

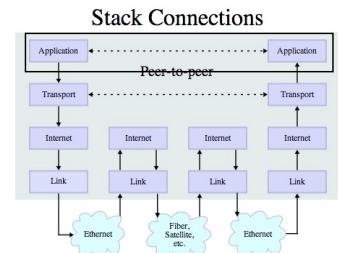
Common TCP Ports

- Telnet (23) - Login
- SSH (22) - Secure Login
- HTTP (80)
- HTTPS (443) - Secure
- SMTP (25) (Mail)
- IMAP (143/220/993) - Mail Retrieval
- POP (109/110) - Mail Retrieval
- DNS (53) - Domain Name
- FTP (21) - File Transfer

http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

Application Protocol

- Since TCP gives us a reliable pipe, what do we want to do with the pipe? What problem do we want to solve?
- Mail
- World Wide Web
- Stream kitty videos



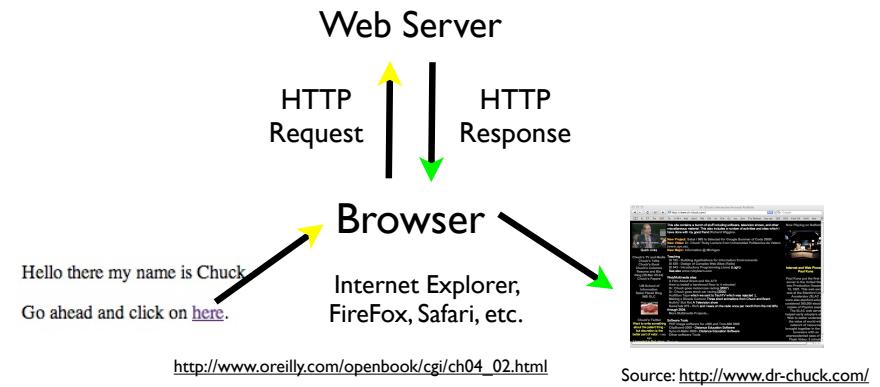
Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

HTTP - Hypertext Transport Protocol

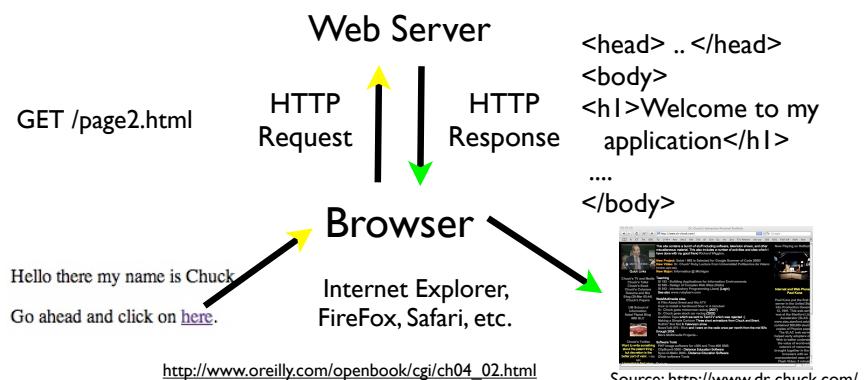
- The dominant Application Layer Protocol on the Internet
- Invented for the Web - to Retrieve HTML, Images, Documents etc
- Extended to be data in addition to documents - RSS, Web Services, etc..
- Basic Concept - Make a Connection - Request a document - Retrieve the Document - Close the Connection

<http://en.wikipedia.org/wiki/Http>

HTTP Request / Response Cycle



HTTP Request / Response Cycle



Internet Standards

- The standards for all of the Internet protocols (inner workings) are developed by an organization
- Internet Engineering Task Force (IETF)
- www.ietf.org
- Standards are called “RFCs” - “Request for Comments”

T. Berners-Lee
NIST/LCS
R. Fielding
UC Irvine
H. Frystyk
NIST/LCS
May 1996

Hypertext Transfer Protocol -- HTTP/1.0

Status of This Memo
This memo provides information for the Internet community. This memo does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

IESG Note:
The IESG has concerns about this protocol, and expects this document to be replaced relatively soon by a standards track document.

Abstract
The Hypertext Transfer Protocol (HTTP) is an application-level protocol with the lightness and speed necessary for distributed, collaborative, hypermedia information systems. It is a generic, stateless, object-oriented protocol which can be used for many tasks, such as name resolution and distributed database access, through extension of its request methods (commands). A feature of HTTP is the typing of data representation, allowing systems to be built independently of the data being transferred.

Source: <http://www.ietf.org/rfc/rfc1945.txt>

5.1.2 Request-URI

The Request-URI is a Uniform Resource Identifier (Section 3.2) and identifies the resource upon which to apply the request.

Request-URI = absoluteURI | abs_path

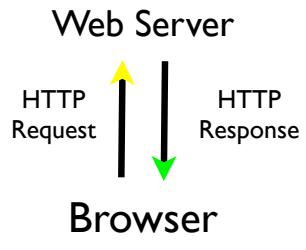
The two options for Request-URI are dependent on the nature of the request.

The absoluteURI form is only allowed when the request is being made to a proxy. The proxy is requested to forward the request and return the response. If the request is GET or HEAD and a prior response is cached, the proxy may use the cached message if it passes any restrictions in the Expires header field. Note that the proxy may forward the request on to another proxy or directly to the server specified by the absoluteURI. In order to avoid request loops, a proxy must be able to recognize all of its server names, including any aliases, local variations, and the numeric IP address. An example Request-Line would be:

GET http://www.w3.org/pub/WWW/TheProject.html HTTP/1.0

“Hacking” HTTP

```
Last login:Wed Oct 10 04:20:19 on ttyp2
si-csev-mpb:~ csev$ telnet www.dr-chuck.com 80
Trying 74.208.28.177...
Connected to www.dr-chuck.com.
Escape character is '^]'.
GET http://www.dr-chuck.com/page1.htm
<h1>The First Page</h1>
<p>
If you like, you can switch to the
<a href="http://www.dr-chuck.com/page2.htm">
Second Page</a>.
</p>
```



Port 80 is the non-encrypted HTTP port

Berners-Lee, et al

Informational

[Page 24]

RFC 1945

HTTP/1.0

May 1996

The most common form of Request-URI is that used to identify a resource on an origin server or gateway. In this case, only the absolute path of the URI is transmitted (see Section 3.2.1, `abs_path`). For example, a client wishing to retrieve the resource above directly from the origin server would create a TCP connection to port 80 of the host "`www.w3.org`" and send the line:

GET /pub/WWW/TheProject.html HTTP/1.0

followed by the remainder of the Full-Request. Note that the absolute path cannot be empty; if none is present in the original URI, it must be given as "/" (the server root).

The Request-URI is transmitted as an encoded string, where some characters may be escaped using the "% HEX HEX" encoding defined by RFC 1738 [4]. The origin server must decode the Request-URI in order to properly interpret the request.

Source: <http://www.ietf.org/rfc/rfc1945.txt>

Accurate Hacking in the Movies



- Matrix Reloaded
 - Bourne Ultimatum
 - Die Hard 4
 - ...

<http://nmap.org/movies.html> (scroll down for video)
Or search YouTube for "Trinity hacking scene"

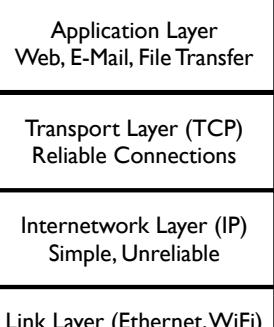
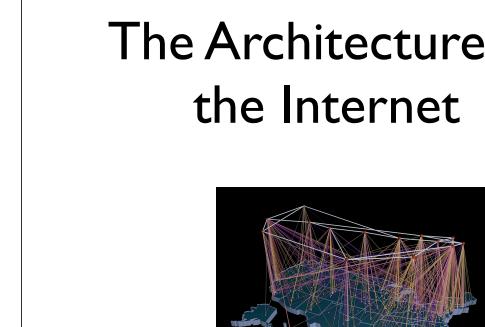
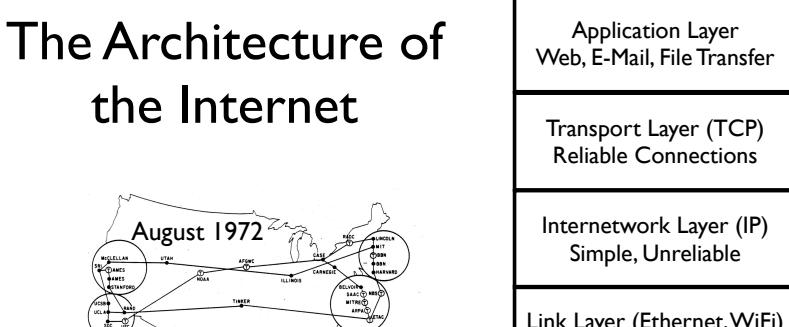
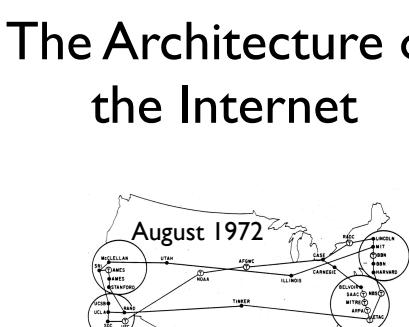


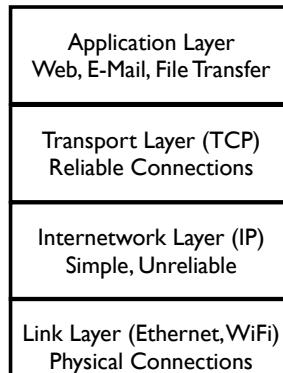
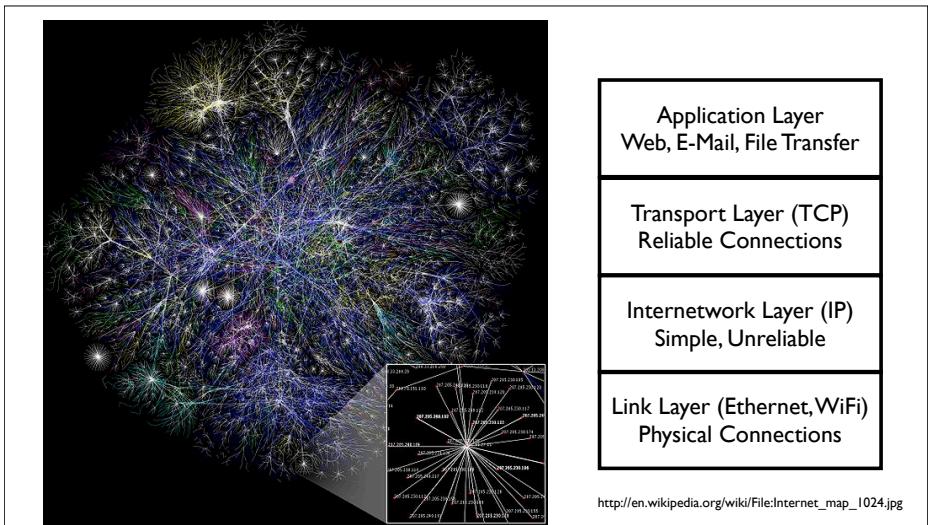
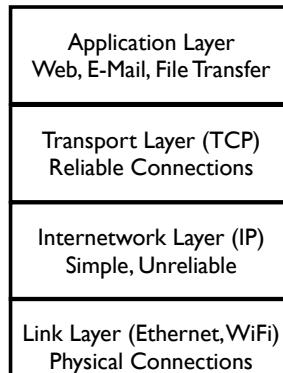
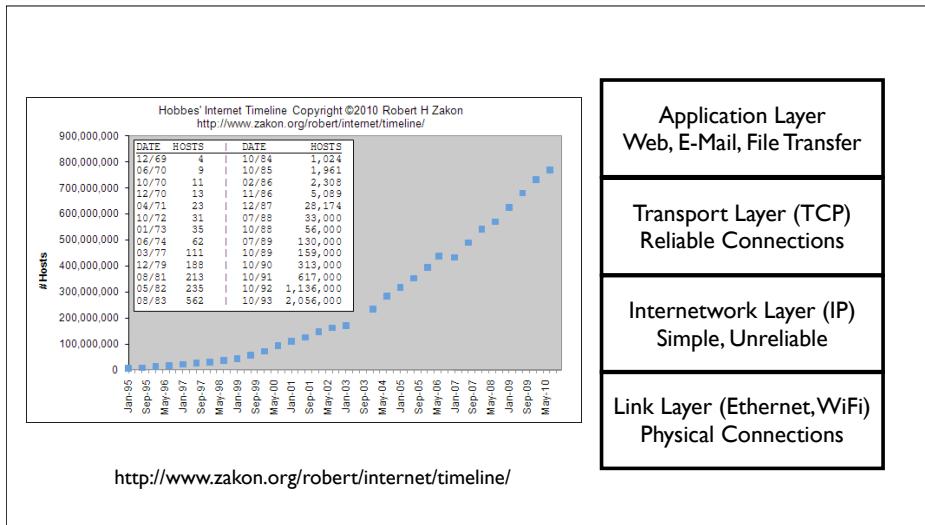
```
80/tcp open http host:9-ec [mobile]
113/tcp open nmap http://host:9-ec [mobile]
115/tcp open nmap U: 2,SANE105
117/tcp open nmap I: 2,SYNCE105
119/tcp open nmap S: 2,SYNCE105
121/tcp open nmap R: 2,SYNCE105
123/tcp open nmap D: 2,SYNCE105
125/tcp open nmap E: 2,SYNCE105
127/tcp open nmap F: 2,SYNCE105
129/tcp open nmap G: 2,SYNCE105
131/tcp open nmap H: 2,SYNCE105
133/tcp open nmap I: 2,SYNCE105
135/tcp open nmap J: 2,SYNCE105
137/tcp open nmap K: 2,SYNCE105
139/tcp open nmap L: 2,SYNCE105
141/tcp open nmap M: 2,SYNCE105
143/tcp open nmap N: 2,SYNCE105
145/tcp open nmap O: 2,SYNCE105
147/tcp open nmap P: 2,SYNCE105
149/tcp open nmap Q: 2,SYNCE105
151/tcp open nmap R: 2,SYNCE105
153/tcp open nmap S: 2,SYNCE105
155/tcp open nmap T: 2,SYNCE105
157/tcp open nmap U: 2,SYNCE105
159/tcp open nmap V: 2,SYNCE105
161/tcp open nmap W: 2,SYNCE105
163/tcp open nmap X: 2,SYNCE105
165/tcp open nmap Y: 2,SYNCE105
167/tcp open nmap Z: 2,SYNCE105
169/tcp open nmap AA: 2,SYNCE105
171/tcp open nmap BB: 2,SYNCE105
173/tcp open nmap CC: 2,SYNCE105
175/tcp open nmap DD: 2,SYNCE105
177/tcp open nmap EE: 2,SYNCE105
179/tcp open nmap FF: 2,SYNCE105
181/tcp open nmap GG: 2,SYNCE105
183/tcp open nmap HH: 2,SYNCE105
185/tcp open nmap II: 2,SYNCE105
187/tcp open nmap JJ: 2,SYNCE105
189/tcp open nmap KK: 2,SYNCE105
191/tcp open nmap LL: 2,SYNCE105
193/tcp open nmap MM: 2,SYNCE105
195/tcp open nmap NN: 2,SYNCE105
197/tcp open nmap OO: 2,SYNCE105
199/tcp open nmap PP: 2,SYNCE105
201/tcp open nmap QQ: 2,SYNCE105
203/tcp open nmap RR: 2,SYNCE105
205/tcp open nmap SS: 2,SYNCE105
207/tcp open nmap TT: 2,SYNCE105
209/tcp open nmap UU: 2,SYNCE105
211/tcp open nmap VV: 2,SYNCE105
213/tcp open nmap WW: 2,SYNCE105
215/tcp open nmap XX: 2,SYNCE105
217/tcp open nmap YY: 2,SYNCE105
219/tcp open nmap ZZ: 2,SYNCE105
221/tcp open nmap AA: 2,SYNCE105
223/tcp open nmap BB: 2,SYNCE105
225/tcp open nmap CC: 2,SYNCE105
227/tcp open nmap DD: 2,SYNCE105
229/tcp open nmap EE: 2,SYNCE105
231/tcp open nmap FF: 2,SYNCE105
233/tcp open nmap GG: 2,SYNCE105
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479/tcp open nmap ZZ: 2,SYNCE105
481/tcp open nmap AA: 2,SYNCE105
483/tcp open nmap BB: 2,SYNCE105
485/tcp open nmap CC: 2,SYNCE105
487/tcp open nmap DD: 2,SYNCE105
489/tcp open nmap EE: 2,SYNCE105
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519/tcp open nmap TT: 2,SYNCE105
521/tcp open nmap UU: 2,SYNCE105
523/tcp open nmap VV: 2,SYNCE105
525/tcp open nmap WW: 2,SYNCE105
527/tcp open nmap XX: 2,SYNCE105
529/tcp open nmap YY: 2,SYNCE105
531/tcp open nmap ZZ: 2,SYNCE105
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627/tcp open nmap VV: 2,SYNCE105
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693/tcp open nmap CC: 2,SYNCE105
695/tcp open nmap DD: 2,SYNCE105
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699/tcp open nmap FF: 2,SYNCE105
701/tcp open nmap GG: 2,SYNCE105
703/tcp open nmap HH: 2,SYNCE105
705/tcp open nmap II: 2,SYNCE105
707/tcp open nmap JJ: 2,SYNCE105
709/tcp open nmap KK: 2,SYNCE105
711/tcp open nmap LL: 2,SYNCE105
713/tcp open nmap MM: 2,SYNCE105
715/tcp open nmap NN: 2,SYNCE105
717/tcp open nmap OO: 2,SYNCE105
719/tcp open nmap PP: 2,SYNCE105
721/tcp open nmap QQ: 2,SYNCE105
723/tcp open nmap RR: 2,SYNCE105
725/tcp open nmap SS: 2,SYNCE105
727/tcp open nmap TT: 2,SYNCE105
729/tcp open nmap UU: 2,SYNCE105
731/tcp open nmap VV: 2,SYNCE105
733/tcp open nmap WW: 2,SYNCE105
735/tcp open nmap XX: 2,SYNCE105
737/tcp open nmap YY: 2,SYNCE105
739/tcp open nmap ZZ: 2,SYNCE105
741/tcp open nmap AA: 2,SYNCE105
743/tcp open nmap BB: 2,SYNCE105
745/tcp open nmap CC: 2,SYNCE105
747/tcp open nmap DD: 2,SYNCE105
749/tcp open nmap EE: 2,SYNCE105
751/tcp open nmap FF: 2,SYNCE105
753/tcp open nmap GG: 2,SYNCE105
755/tcp open nmap HH: 2,SYNCE105
757/tcp open nmap II: 2,SYNCE105
759/tcp open nmap JJ: 2,SYNCE105
761/tcp open nmap KK: 2,SYNCE105
763/tcp open nmap LL: 2,SYNCE105
765/tcp open nmap MM: 2,SYNCE105
767/tcp open nmap NN: 2,SYNCE105
769/tcp open nmap OO: 2,SYNCE105
771/tcp open nmap PP: 2,SYNCE105
773/tcp open nmap QQ: 2,SYNCE105
775/tcp open nmap RR: 2,SYNCE105
777/tcp open nmap SS: 2,SYNCE105
779/tcp open nmap TT: 2,SYNCE105
781/tcp open nmap UU: 2,SYNCE105
783/tcp open nmap VV: 2,SYNCE105
785/tcp open nmap WW: 2,SYNCE105
787/tcp open nmap XX: 2,SYNCE105
789/tcp open nmap YY: 2,SYNCE105
791/tcp open nmap ZZ: 2,SYNCE105
793/tcp open nmap AA: 2,SYNCE105
795/tcp open nmap BB: 2,SYNCE105
797/tcp open nmap CC: 2,SYNCE105
799/tcp open nmap DD: 2,SYNCE105
801/tcp open nmap EE: 2,SYNCE105
803/tcp open nmap FF: 2,SYNCE105
805/tcp open nmap GG: 2,SYNCE105
807/tcp open nmap HH: 2,SYNCE105
809/tcp open nmap II: 2,SYNCE105
811/tcp open nmap JJ: 2,SYNCE105
813/tcp open nmap KK: 2,SYNCE105
815/tcp open nmap LL: 2,SYNCE105
817/tcp open nmap MM: 2,SYNCE105
819/tcp open nmap NN: 2,SYNCE105
821/tcp open nmap OO: 2,SYNCE105
823/tcp open nmap PP: 2,SYNCE105
825/tcp open nmap QQ: 2,SYNCE105
827/tcp open nmap RR: 2,SYNCE105
829/tcp open nmap SS: 2,SYNCE105
831/tcp open nmap TT: 2,SYNCE105
833/tcp open nmap UU: 2,SYNCE105
835/tcp open nmap VV: 2,SYNCE105
837/tcp open nmap WW: 2,SYNCE105
839/tcp open nmap XX: 2,SYNCE105
841/tcp open nmap YY: 2,SYNCE105
843/tcp open nmap ZZ: 2,SYNCE105
845/tcp open nmap AA: 2,SYNCE105
847/tcp open nmap BB: 2,SYNCE105
849/tcp open nmap CC: 2,SYNCE105
851/tcp open nmap DD: 2,SYNCE105
853/tcp open nmap EE: 2,SYNCE105
855/tcp open nmap FF: 2,SYNCE105
857/tcp open nmap GG: 2,SYNCE105
859/tcp open nmap HH: 2,SYNCE105
861/tcp open nmap II: 2,SYNCE105
863/tcp open nmap JJ: 2,SYNCE105
865/tcp open nmap KK: 2,SYNCE105
867/tcp open nmap LL: 2,SYNCE105
869/tcp open nmap MM: 2,SYNCE105
871/tcp open nmap NN: 2,SYNCE105
873/tcp open nmap OO: 2,SYNCE105
875/tcp open nmap PP: 2,SYNCE105
877/tcp open nmap QQ: 2,SYNCE105
879/tcp open nmap RR: 2,SYNCE105
881/tcp open nmap SS: 2,SYNCE105
883/tcp open nmap TT: 2,SYNCE105
885/tcp open nmap UU: 2,SYNCE105
887/tcp open nmap VV: 2,SYNCE105
889/tcp open nmap WW: 2,SYNCE105
891/tcp open nmap XX: 2,SYNCE105
893/tcp open nmap YY: 2,SYNCE105
895/tcp open nmap ZZ: 2,SYNCE105
897/tcp open nmap AA: 2,SYNCE105
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901/tcp open nmap CC: 2,SYNCE105
903/tcp open nmap DD: 2,SYNCE105
905/tcp open nmap EE: 2,SYNCE105
907/tcp open nmap FF: 2,SYNCE105
909/tcp open nmap GG: 2,SYNCE105
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915/tcp open nmap JJ: 2,SYNCE105
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923/tcp open nmap NN: 2,SYNCE105
925/tcp open nmap OO: 2,SYNCE105
927/tcp open nmap PP: 2,SYNCE105
929/tcp open nmap QQ: 2,SYNCE105
931/tcp open nmap RR: 2,SYNCE105
933/tcp open nmap SS: 2,SYNCE105
935/tcp open nmap TT: 2,SYNCE105
937/tcp open nmap UU: 2,SYNCE105
939/tcp open nmap VV: 2,SYNCE105
941/tcp open nmap WW: 2,SYNCE105
943/tcp open nmap XX: 2,SYNCE105
945/tcp open nmap YY: 2,SYNCE105
947/tcp open nmap ZZ: 2,SYNCE105
949/tcp open nmap AA: 2,SYNCE105
951/tcp open nmap BB: 2,SYNCE105
953/tcp open nmap CC: 2,SYNCE105
955/tcp open nmap DD: 2,SYNCE105
957/tcp open nmap EE: 2,SYNCE105
959/tcp open nmap FF: 2,SYNCE105
961/tcp open nmap GG: 2,SYNCE105
963/tcp open nmap HH: 2,SYNCE105
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967/tcp open nmap JJ: 2,SYNCE105
969/tcp open nmap KK: 2,SYNCE105
971/tcp open nmap LL: 2,SYNCE105
973/tcp open nmap MM: 2,SYNCE105
975/tcp open nmap NN: 2,SYNCE105
977/tcp open nmap OO: 2,SYNCE105
979/tcp open nmap PP: 2,SYNCE105
981/tcp open nmap QQ: 2,SYNCE105
983/tcp open nmap RR: 2,SYNCE105
985/tcp open nmap SS: 2,SYNCE105
987/tcp open nmap TT: 2,SYNCE105
989/tcp open nmap UU: 2,SYNCE105
991/tcp open nmap VV: 2,SYNCE105
993/tcp open nmap WW: 2,SYNCE105
995/tcp open nmap XX: 2,SYNCE105
997/tcp open nmap YY: 2,SYNCE105
999/tcp open nmap ZZ: 2,SYNCE105
```

<http://nmap.org/movies.html> (scroll down for video)
Or search YouTube for "Trinity hacking scene"

Application Layer Summary

- We start with a “pipe” abstraction - we can send and receive data on the same “socket”
- We can optionally add a security layer to TCP using SSL - Secure Socket Layer (aka TLS - Transport Layer Security)
- We use well known “port numbers” so that applications can find a particular application *within* a server such as a mail server, web service, etc



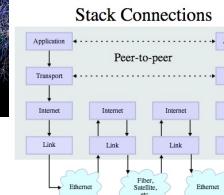
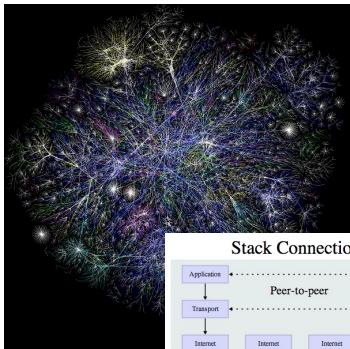
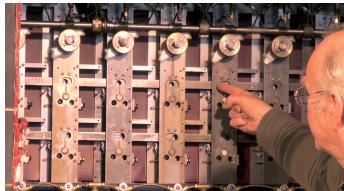


The Internet: An Amazing Design

- Hundreds of millions of computers
- Thousands of routers inside the Internet
- Hundreds of millions of simultaneous connections
- Trillions of bytes of data moved per second around the world
- And it works

The Internet

- It is said that “The Internet is the largest single engineering effort ever created by mankind”
- It was created to work in an organic way - to repair itself and automatically adjust when parts fail
- No one part of the Internet knows all of the Internet (like life)
- It is never 100% up - but it seems up all the time



We are not done experimenting...

- There is still very active exploration on how network technology can be improved
- Content-Centric Networking is only one advanced idea
- Routers in the future can have *lots* of memory - lets try not to send the same piece of data more than once



Van Jacobson
PARC, a Xerox Company

Additional Source Information

- xkcd, <http://xkcd.com/742/>, CC: BY-NC, <http://creativecommons.org/licenses/by-nc/2.5/>
- Internet Protocol Suite Diagrams: Kbrose, Wikimedia Commons, http://upload.wikimedia.org/wikipedia/commons/c/c4/IP_stack_connections.svg, CC:BY-SA, <http://creativecommons.org/licenses/by-sa/3.0/deed.en>
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- Internet Map: The Opte Project, Wikimedia Commons, http://upload.wikimedia.org/wikipedia/commons/d/d2/Internet_map_1024.jpg, CC:BY, <http://creativecommons.org/licenses/by/2.5/deed.en>

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