

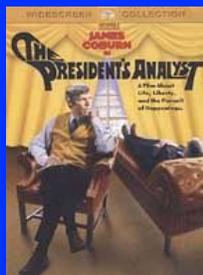
Internet-101

Scott Bradner
Harvard University
8 April 2011

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Back to the Start - What was there?

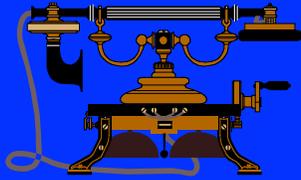


The Phone Network
from The Phone Company - AT&T
circuit-based
statically **predictable** calling patterns
predictable growth rates
assumed absolute requirement for QoS
assumption of being carrier-provided
a regulated **monopoly**
the **largest** corporation in the world
most of the \$ from **communications**
not from other services

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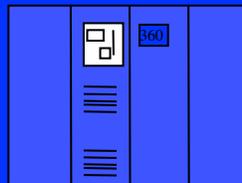
Circuits



pre setup paths through a network
e.g., for a phone call
predetermined capacity
set up as part of calling process
torn down (removed) when call done
and capacity released
can not establish new circuits if not enough
capacity
get “fast busy” signal in phone system
if circuits full

Packets, Not Circuits

Dest Addr	Src Addr	payload
-----------	----------	---------



self contained packets
multiple unrelated efforts
packet switching theory: (Kleinrock) 1961
showed packet switching to be a more
efficient switching method than
circuits
day dreaming: (Licklider's Galactic
Network) 1962
survivable infrastructure for voice and
data: (Baron) 1964
make use of remote expensive computers:
(Roberts) 1964
but **Roberts had the money**

Packets!



self contained
 handled independently of preceding or following packets
 contains destination and source **internetwork** addresses
may contain processing hints
 e.g. QoS tag
no delivery guarantees
 net may drop, duplicate, & deliver out of order
 reliability (where needed) must be done by ends

Common Bearer Service

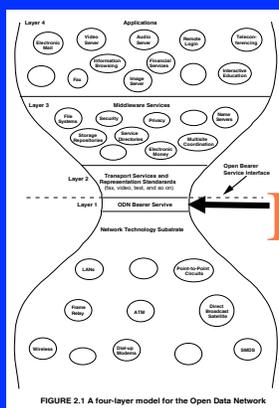


FIGURE 2.1 A four-layer model for the Open Data Network

Realizing the Information Future

use existing networks
 not have to build new infrastructure
 not tied to one network technology
 thus, required a **Common Bearer Service** (IP) & treat networks as generic IP **very** simple
 just transport packet to destination
ends are responsible for security & reliability

Unreliability can be Important

**IP/TCP
not
IPTCP**

original plan was to only have a reliable service - problems:

not good for **voice** & video

data has to be delivered in time - retransmission for reliability causes too great a delay

i.e., not the right answer for all applications

e.g. a debugger has to work in lossy environment

retransmission algorithm may vary with application

thus: **split** IP & TCP and add UDP

now reliability is an option, not an assumption

host can decide what is best

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Transmission Control Protocol (TCP)



a reliable data stream for applications runs on top of IP

adjusts information transfer speed to capacity of end systems

end systems are in charge

adjusts information transfer speed to capacity of network path

uses **lost packets** as an indication of path congestion - & **slows down** retransmits lost packets for reliability

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User Datagram Protocol (UDP)



a packet-data transfer mechanism for applications

runs on top of IP

same characteristics as IP

used for streaming voice and video

does not react to network conditions

End-to-End Argument



initially a 1981 paper

Saltzer, Reed, & Clark

end systems know what they can do

e.g., performance

end systems know what they are doing

e.g., what application

end systems know they want

e.g., reliability, security, etc.

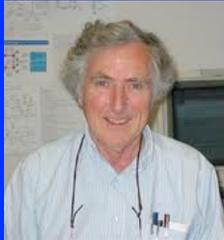
network cannot reliably know

without being told by end system

some networks try by using deep packet

inspection (**DPI**)

A Quote



“the lesson of the Internet is that efficiency is not the primary consideration. Ability to grow and adapt to changing requirements is the primary consideration. This makes simplicity and uniformity very precious indeed.”

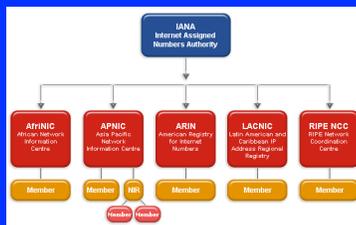
Bob Braden IETF mailing list 2-Feb-2001

I.e., not build network to be “best” for any particular application
cannot know what application will come next

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IP Addresses



IPv4: 32-bits

4,294,967,296 (4.3 B) addresses

IPv6: 128-bits

340,282,366,920,938,463,463,374,607,431,768,211,456

allocated by IANA to regional IP registries (RIRs)

allocated by RIRs to ISPs

allocated by ISPs to customers

RIR contract specifies that IP addresses are **loaned not owned**

IANA ran out of IPv4 addresses in Feb.



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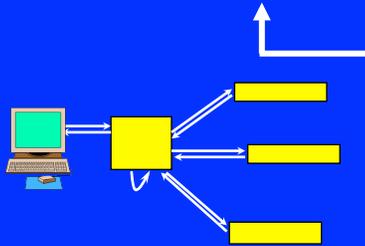
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Domain Name System (DNS)

www.cnn.com

www.bbc.co.uk

www.mit.edu



translate human-friendly alphanumeric names into IP addresses

uses distributed set of database servers (DNS servers) run by different organizations

(I run my own, Harvard runs its own) top level domains (TLDs) assigned by IANA

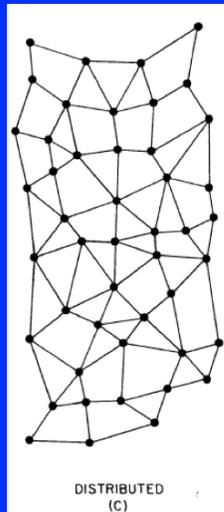
about to assign (sell) many more approved .xxx March 2011

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Ripe NCC

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Network Architecture



from Paul Baran (1964)

redundant paths in network

routers at link interconnections dynamic routing protocol to determine current network topology

topology changes if a link breaks may chose a new path for the next packet if topology changes

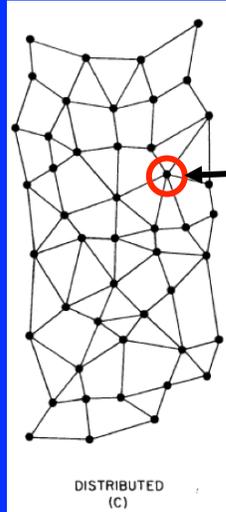
automatic reroute on network failure most of Internet is redundant

except for “**tail circuits**” to homes, businesses & (sometimes) to countries

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Routing



sub parts of the network are connected together by computers that forward packets toward destination

these computers are called **“routers”**

routers use the destination address in packet to make forwarding decisions

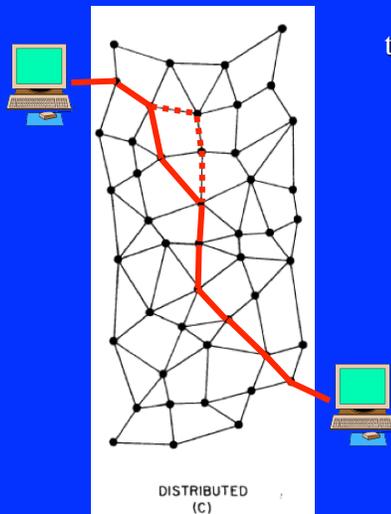
routers exchange reachability information with other routers to build tables of “next hops” toward specific local networks

reachability information says where sets of destination networks are

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From Me to You



to send a message from me to you

- 1/ I break message into chunks
- 2/ I determine your IP address
e.g. look up your Domain Name Address
- 3/ I build a series of packets with your address in destination address fields & chunks of the data
- 4/ I send packets to local router
- 5/ router forwards packets to next router (etc.) then to the destination (your computer)
can take different paths, can arrive out of order
- 6/ your computer reassembles the data chunks from the packets into the message

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The Commercial Internet



GENUITY



at&t

Verizon FIOS

Comcast

preceded by ARPANET (1969-1989)
started in late 1980s

US funding out of the picture by 1995
multiple Internet service providers (ISPs)
ISPs **interconnect** to provide the "Internet"
at peak - ~ 6,500 ISPs
most big independent ISPs now gone
at least for residential service
telephone & cable **carriers** have
taken over
little serious competition

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What Did Teleco think of the Internet?



by definition

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The Irrelevant Internet



IBM



AT&T



common wisdom:

no guarantees, security, QoS, etc.

Internet useless for real work

cannot build a corporate data network

with TCP/IP - IBM about 1992

no 'formal' standards process

no governments involved

IETF does not exist

cannot create 'standards'



Netheads vs. Bellheads **WIRED** 1996

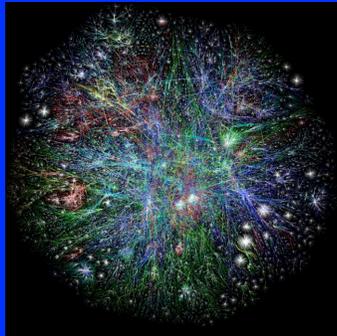
Internet **ignored** by regulators (in the US),
formal SDOs, big business, carriers, etc.

until late 1990s

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Today's Internet



The Internet
Jan 16, 2009
Lumeta Corp.

the Internet matters

1.8 B people

700 M hosts

200 M web sites

\$3.7 T e-commerce (in U.S.)

replacing all of old telecommunications
infrastructure

but carriers do not think they are
making much money

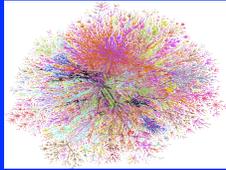
regulatory mixed bag

mostly wiretapping requirements

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More Today's Internet



confuses citizens
has **no security**
for user, little security for infrastructure
redirect You **Tube**

& 37K prefixes to China April 8



has **no privacy**
Google knows all (not government)

3rd party advertisers know more
bypasses taxed telephone carriers
bankrupts businesses

newspapers, music publishers
frustrates governments
e.g., .iq TLD



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Internet Economics



lots of money made **using** the Internet
Google, **amazon.com**, iTunes, porn
much less money made **providing**
the wired Internet
Verizon FIOS, **Comcast**,  **at&t**
carriers claim a need for increased revenue
to keep investors happy
to pay for new infrastructure
at a time of flattening customer growth
carriers claim need to **manage** networks
wireless carriers doing better
carriers looking to content for revenue
but must be 'in the loop' to benefit

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Internet Governance



what is the court for the Internet?
a state court in Kentucky?



no one in charge

internationally or domestically in
many countries

U.S. has some control through ICANN
ICANN does technical coordination
protocol values, DNS & addresses

power vacuum?

some governments think so
want the ITU to fill the perceived vacuum
government-based decision process
e.g., International settlements

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ICANN



Internet Corporation for Assigned Names
and Numbers

setup by US government in 1998

has contract for the **IANA** function

Internet Assigned Numbers Authority

remit includes

DNS TLDs

root name servers

IP Address pool

protocol identifiers (for IETF)

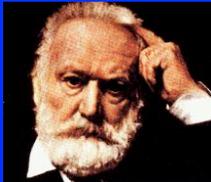
notice of inquiry from US government on

IANA contract - just concluded

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What Did the Internet Give Us?



Internet is **generative**
enable innovation by others
no permission required
unrestrained communication
bypass controls
unrestrained innovation
disrupt old business models
enable new ones

e.g., newspapers

chaos, for lack of a better word, is good?

AR&D

the Internet is a “**parent revolution**”



Network Neutrality



invisible network - common carriage
just transport the bits to the destination
support any application
as well as it can with best effort service
connect to any service provider
transport any content
no handing differences based on source,
destination, application or content



Ted Stevens

paying more for a bigger pipe is OK
as long as anyone can do so
marking packets for “better” service is OK
even if that costs extra
as long as anyone can do so

Network Neutrality: Carrier View



*"How do you think they're going to get customers? Through a broadband pipe. Cable companies have them. We have them. Now what they would like to do is use my pipes for **free**, but I ain't going to let them do that because we have spent this capital and we have to have a **return** on it."*

SBC (now AT&T) CEO Edward Withacre 11/7/05

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El Dorado of the Net



myth

"content revenue could dwarf the revenue generated by voice and the Internet"

columnist Thomas Nolle

net neutrality *"is about streaming movies"*

Jim Cicconi AT&T

reality (2008 numbers)

US telecommunications revenue \$297B

world wide Hollywood revenue \$10B

US porn industry (estimate) \$8B

"content is not king" Andrew Odlyzko

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Communications



the real money is in communications
me **talking** to you

almost all of the \$297B in 2008
telecommunications \$ was voice or IM
both **very low** bandwidth applications

carriers do not accept that
they see the Internet as a way to access
content not as a communications
mechanism

Rorschach test
is **You Tube** one or two way?



Questions?