

Internet-101

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Harvard University
14 January 2014

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In the Beginning - What was there?

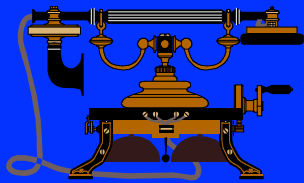


The Phone Network
in the U.S. - AT&T
circuit-based
statically **predictable** calling patterns
predictable growth rates
assumed absolute requirement for QoS
assumption of being carrier-provided
a regulated **monopoly**
the **largest** corporation in the world
most of the \$ from **communications**
not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

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Circuits



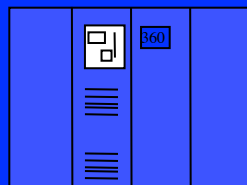
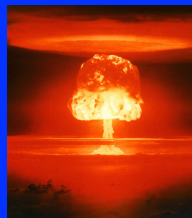
pre setup paths through a network
e.g., for a phone call
predetermined capacity
set up as part of calling process
torn down (removed) when call done
and capacity released
can not establish new circuits if not enough
capacity
get “fast busy” signal in phone system
if circuits full

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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**

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Packets!



self contained chunk of data
 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

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Common Bearer Service

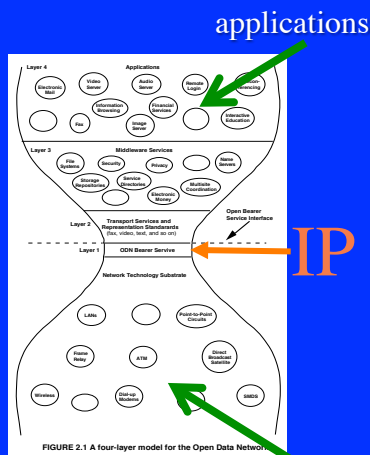


FIGURE 2.1 A four-layer model for the Open Data Network

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The Rise of the Stupid Network



phone network technology: self-named
“Intelligent Network” (IN)

many network-based services

admission control, number translation, ...

Isenberg’s *Rise of the Stupid Network*
compared phone network’s “Intelligent
Network” to Internet

Isenberg’s basic messages:

network-based services slow to change

voice is not all there is

carrier gets in the way

just “deliver the bits” works

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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

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End-to-End Argument

e2e

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**)

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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

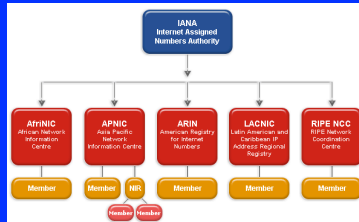
i.e., not build network to be “**best**” for any particular application

cannot know what application will come next

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IP Addresses



IPv4: 32-bits

4,294,967,296 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 Jan 2011.

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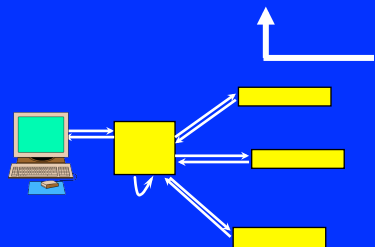
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Domain Name System (DNS)

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

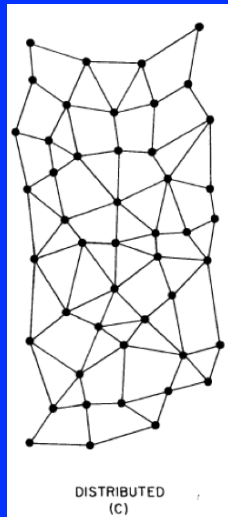
in process of selling many more

Ripe NCC

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Mesh Design



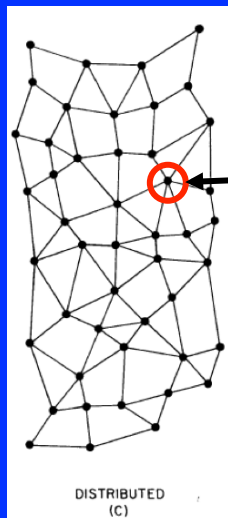
from Paul Baran (1964)

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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

Routing

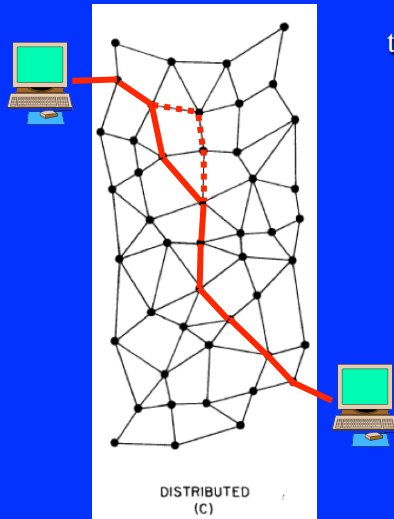


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sub parts of the network are connected
together by computers that forward
packets toward destination
these computers are called “**routers**”
routers use the destination address in
packet to make forwarding decisions
routers exchange reachability information
with other routers to build tables of
“next hops” toward specific local
networks
reachability information says where
sets of destination networks are

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 IP address in destination address fields & chunks of the data
- 4/ I send packets to my 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

preceeded 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?

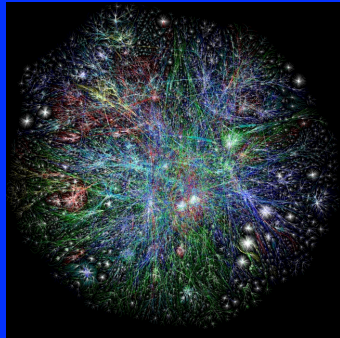


by definition

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Today's Internet



The Internet
Jan 16, 2009
Lumeta Corp.

the Internet matters
2.4 B people
1 B hosts
640 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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The Irrelevant Internet



IBM



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

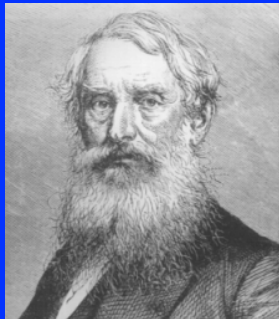
Internet **ignored** by regulators (in the US),
formal SDOs, big business, carriers, etc.

until late 1990s

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Telecommunications Regulation



WHAT HATH GOD WROUGHT

it started with the telegraph

1844 - Samuel Morse

1875 - 650 K miles of telegraph lines

state-owned or licensed providers

confined to a state

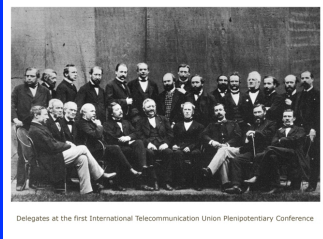
approved services

revenue source for state

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International Telegraph Convention



Delegates at the first International Telecommunication Union Plenipotentiary Conference

governance by
governments

20 European governments met in 1865

adopted convention (ITC) regulating
international telegraph traffic and business:

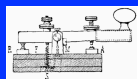
tariffs & settlements, technical standards
retention requirement, complaint process
aims included protecting state & morality

requirement to be able to stop messages
that “may appear *dangerous to the safety
of the State* or which would be contrary to
the laws of the country, *public order* or
morality”

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International Telegraph Union



established by 1865 ITC

became International Telecommunications
Union in 1934

came under UN in 1949

traditional regulator and standards body for
telephone world



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Telephone System Architecture 1950s



Westphalian ideal?

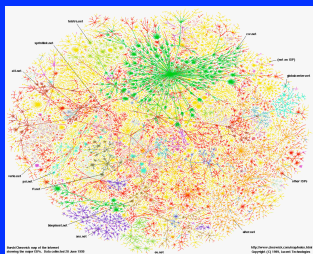
- state-owned or licensed providers
- confined to a state
- approved services
- revenue source for state
- decade long planning cycles
- circuit-based “intelligent network”
- QoS & security guaranteed
- interconnection under ITU rules

divestment, competition and cross border providers since then

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Internet Architecture



- private-owned & unlicensed providers
- not confined to a state
- over the top services
- poor revenue source for state
- no planning cycles
- packet-based “stupid network”
- no QoS or security guarantees
- business-driven interconnection without rules

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Internet Regulation



what Internet regulation?

no need - the Internet is a toy

telephone companies ignored the Internet

so did the regulators

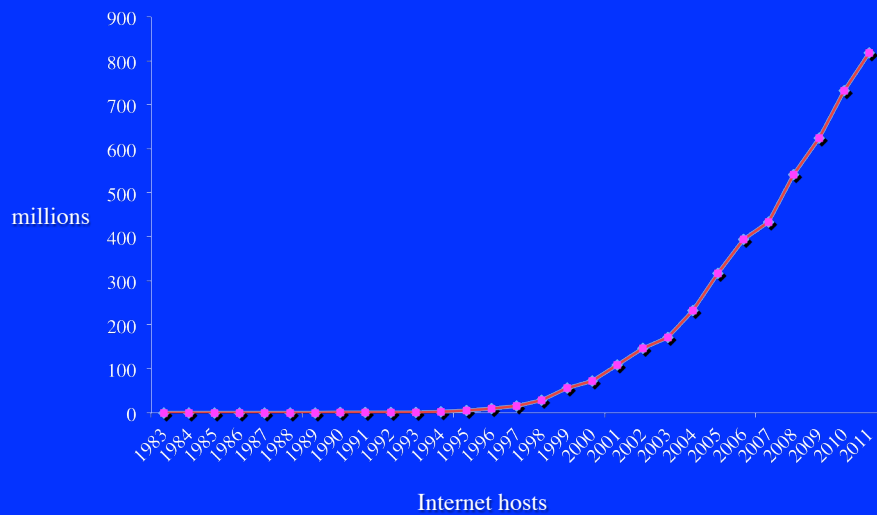
experts: Internet does not/cannot work



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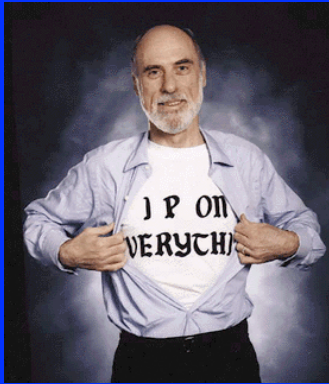
The Internet Does Not Work?



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What Happened?



and vice versa

Internet is now very big business
about 5% of global GDP

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Telephone Standards



countries & companies
countries have final say

results open
process closed except to members

voluntary (sort of)

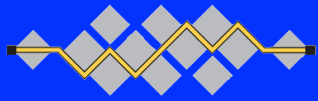
some regulations



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Internet Standards



I E T F[®]



IP & Internet

people

open

voluntary

rough consensus

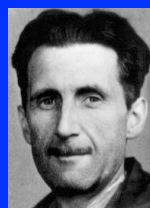
no formal government role

no regulations

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More Today's Internet



confuses citizens

has **no security**

for user, little security for infrastructure

redirect You 

& 37K prefixes to China April 8

has **no privacy**

 & NSA know all

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)

- new effort to restructure IANA management under way
 - meeting in Brazil in April 2014

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Reversal of Fortune



The Guardian



US has been the Internet top-of-pyramid since the start

- first paying for & running ARPANET
- then paying for & running NSFnet
- all along paying for IANA (Jon Postel)
- then empowering ICANN

Fought off rest of the world at ITU, WSIS & WCIT

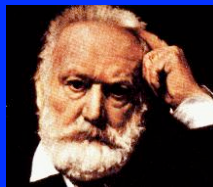
- World Summit on Information Society
- World Conference on International Telecommunications

Then along came Edward Snowden

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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

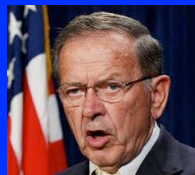
the Internet is a “**parent revolution**”



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Network Neutrality



Ted Stevens

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

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

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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

Verizon v FCC – waiting for decision

Verizon says FCC does not have the authority to require carriers to treat their customers fairly

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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 (2013 numbers)

US telecommunications revenue \$1.2T

US movie industry \$13B

"content is not king" Andrew Odlyzko

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Communications



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

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



Rorschach test
is YouTube one or two way?

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Questions?

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