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PARADOXES IN INTERNET ARCHITECTURE

S. Keshav
University of Waterloo
Chair, ACM SIGCOMM

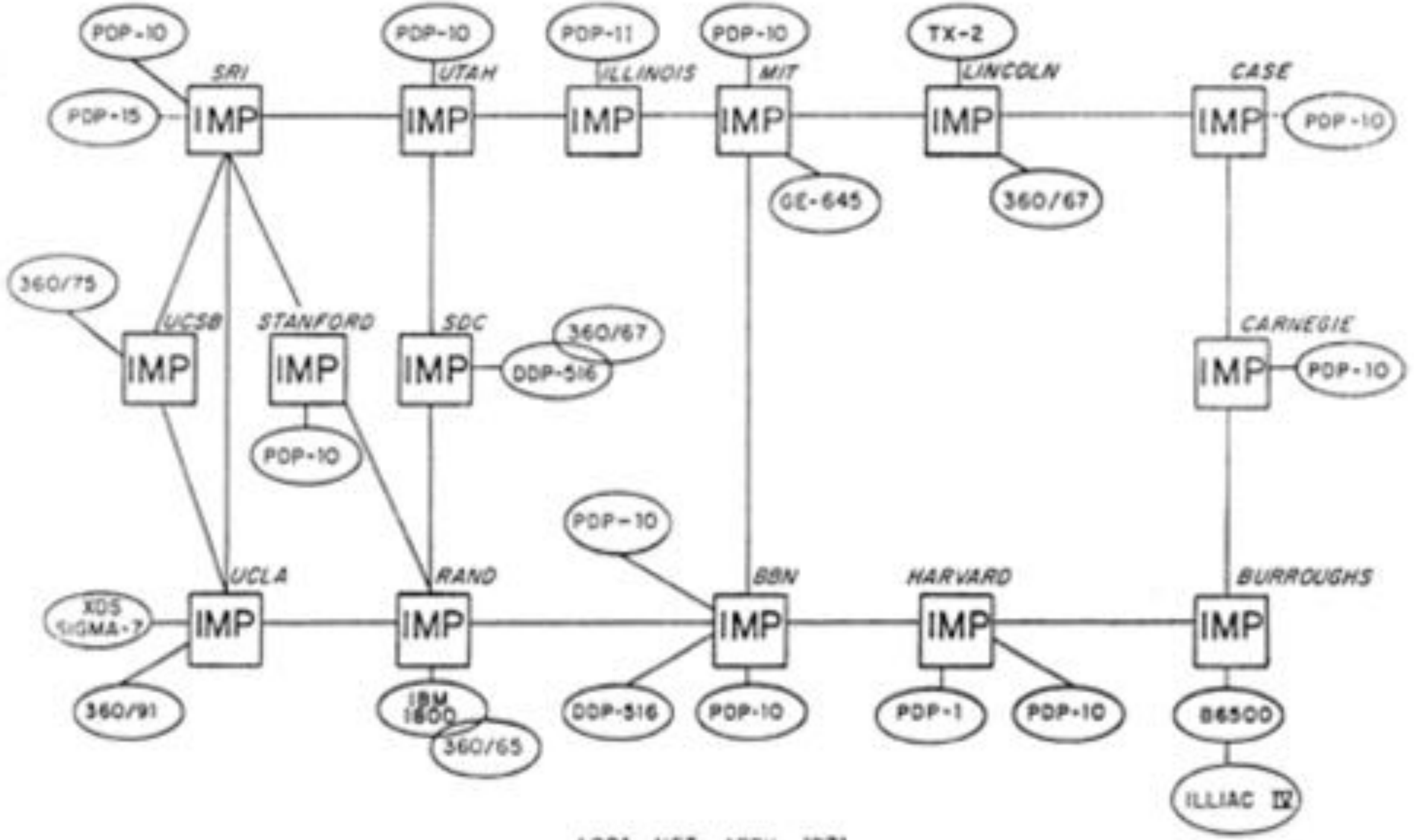

50th
Anniversary

1969

The ARPANET in December 1969

http://www.computerhistory.org/internethistory/1960s/

1971



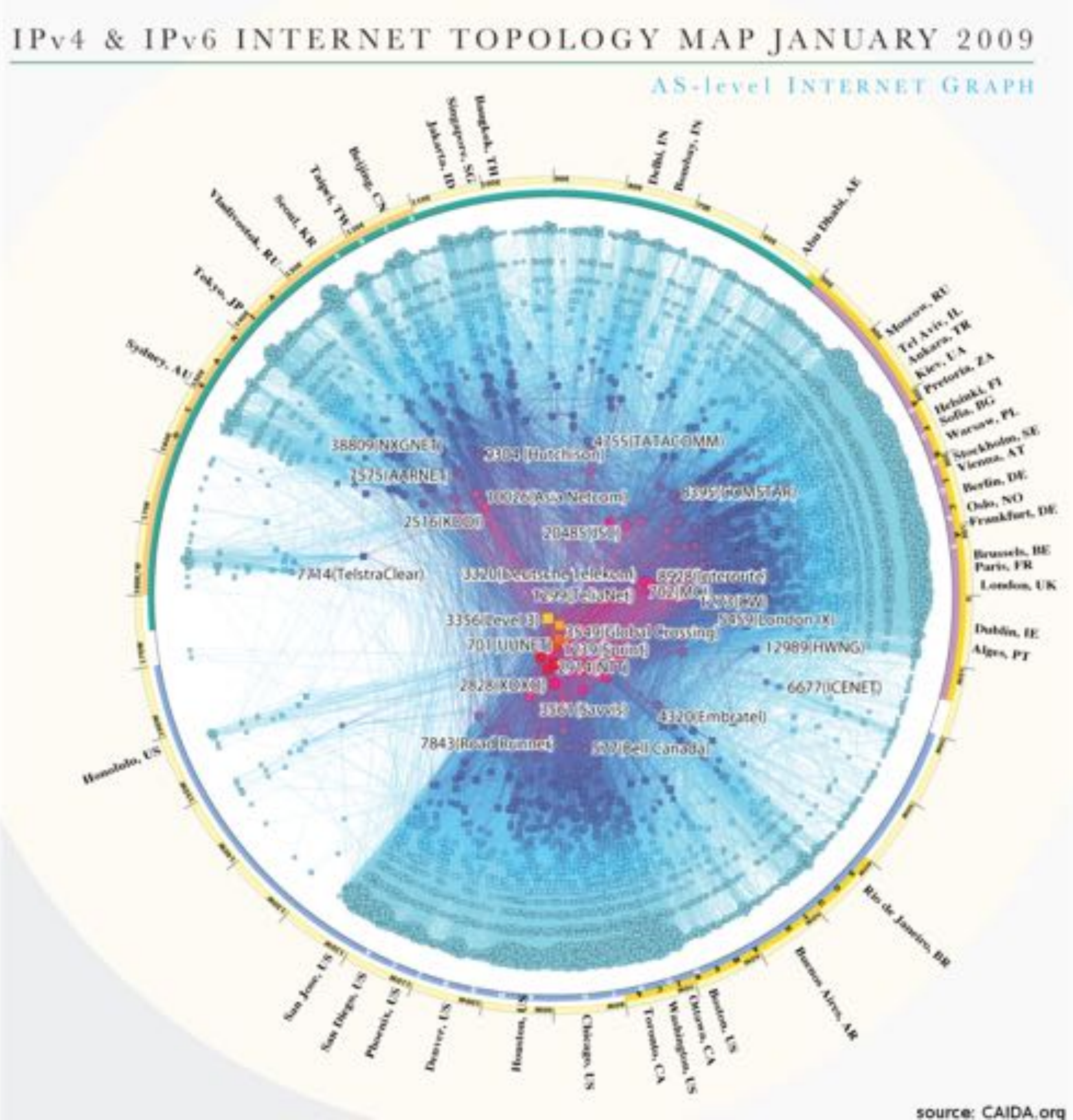
ARPA NET, APRIL 1971

http://www.computerhistory.org/internethistory/1970s/

NSFNET T3 Network 1992

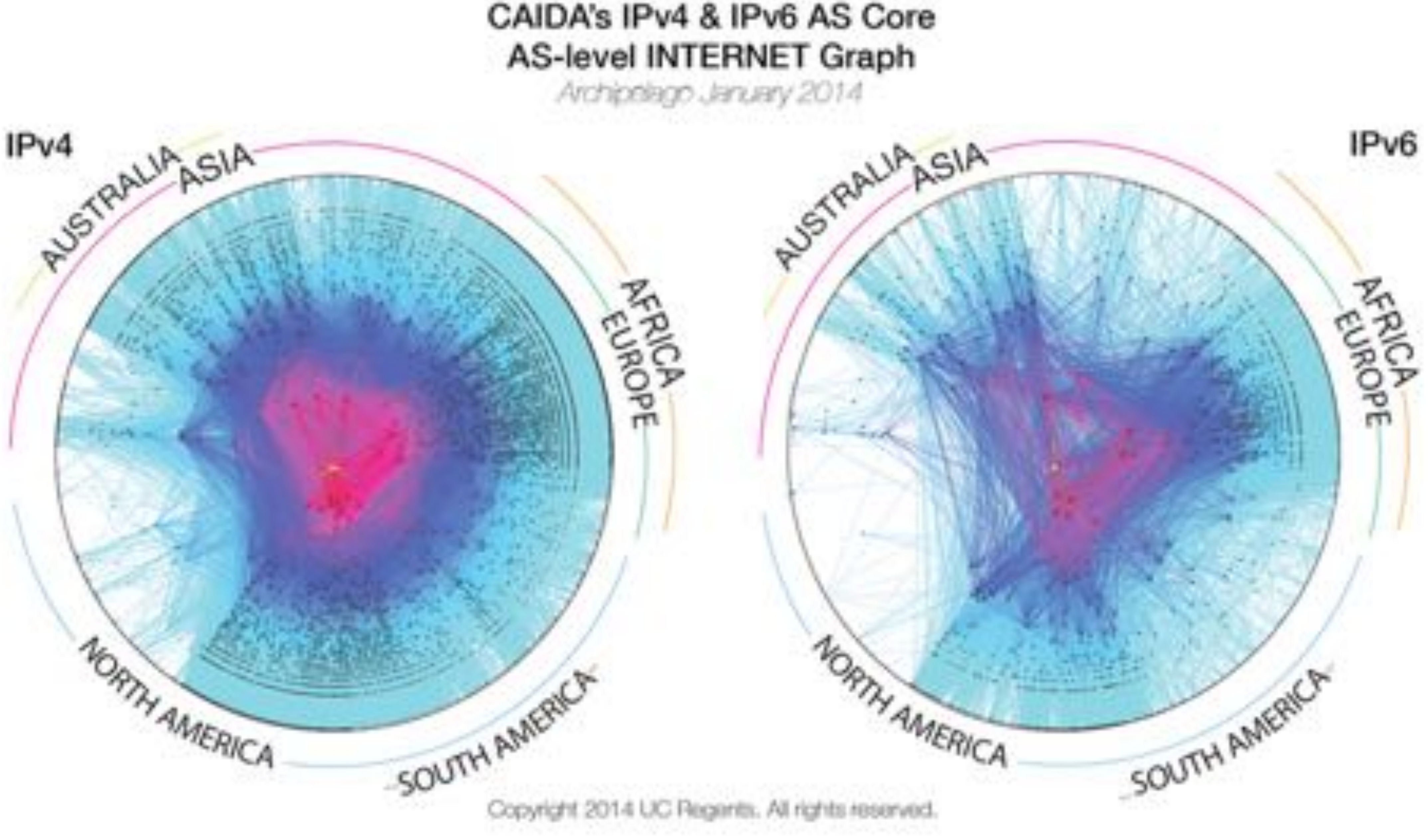
Wikipedia

2009



source: CAIDA.org

2014


CAIDA's IPv4 & IPv6 AS Core
AS-level INTERNET Graph
Archipelago January 2014
IPv4
AUSTRALIA
ASIA
AFRICA
EUROPE
NORTH AMERICA
SOUTH AMERICA
IPv6
AUSTRALIA
ASIA
AFRICA
EUROPE
NORTH AMERICA
SOUTH AMERICA
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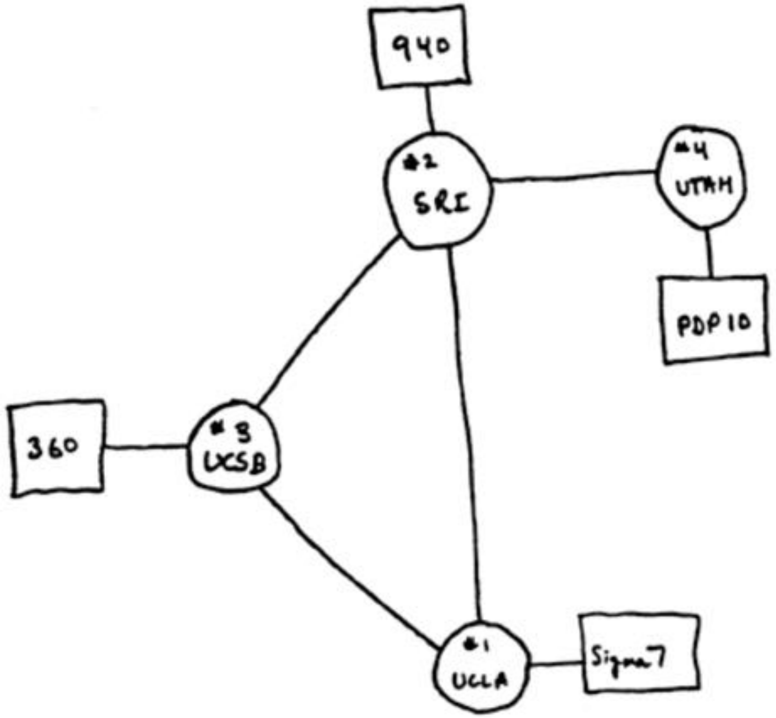
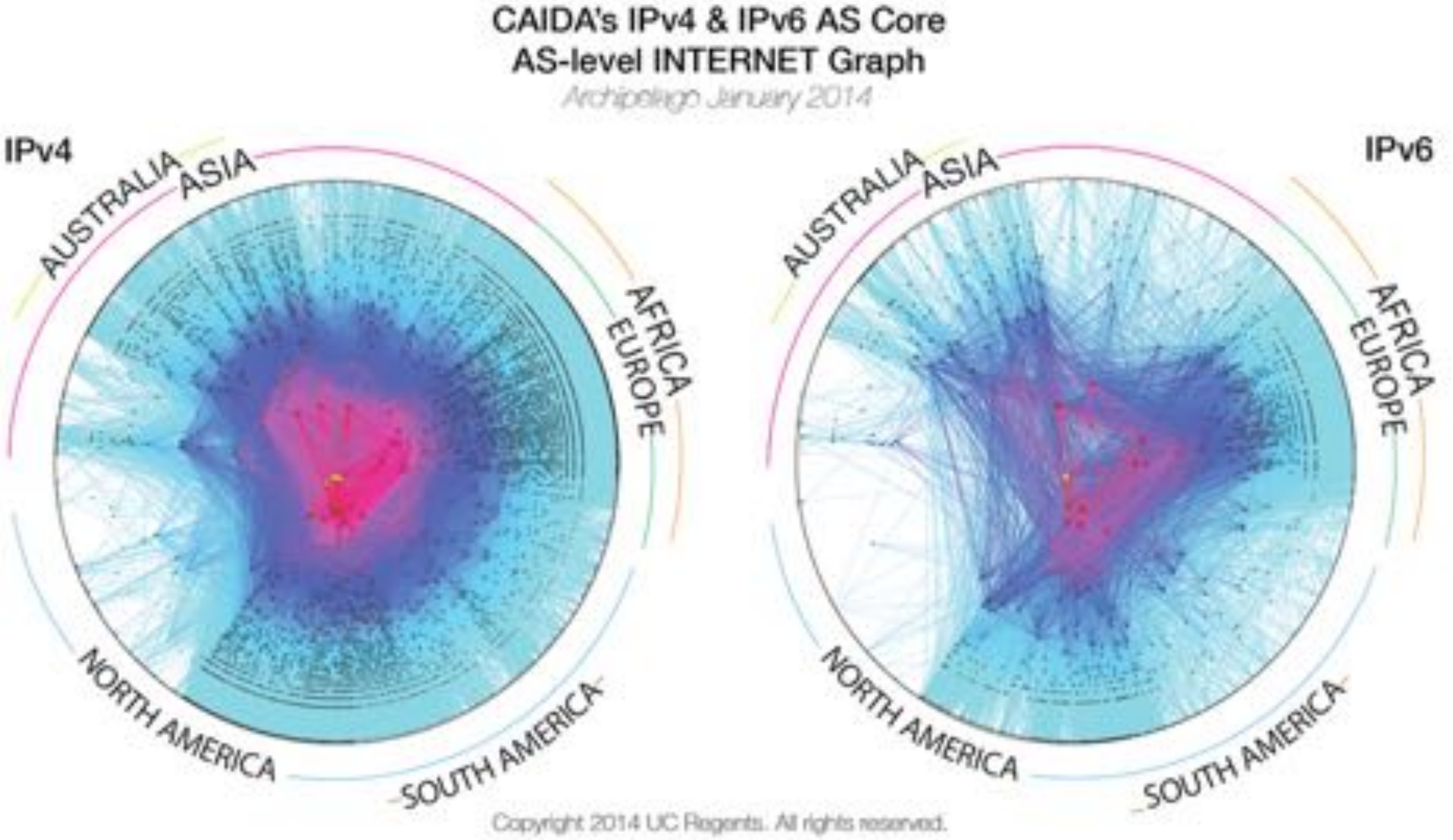
www.topology-zoo.org

1969 vs. 2014


940
#2
SRI
#4
UTAH
PDP10
360
#3
UCSB
#1
UCLA
Sigma7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IPv4
IPv6
AUSTRALIA
ASIA
AFRICA
EUROPE
NORTH AMERICA
SOUTH AMERICA
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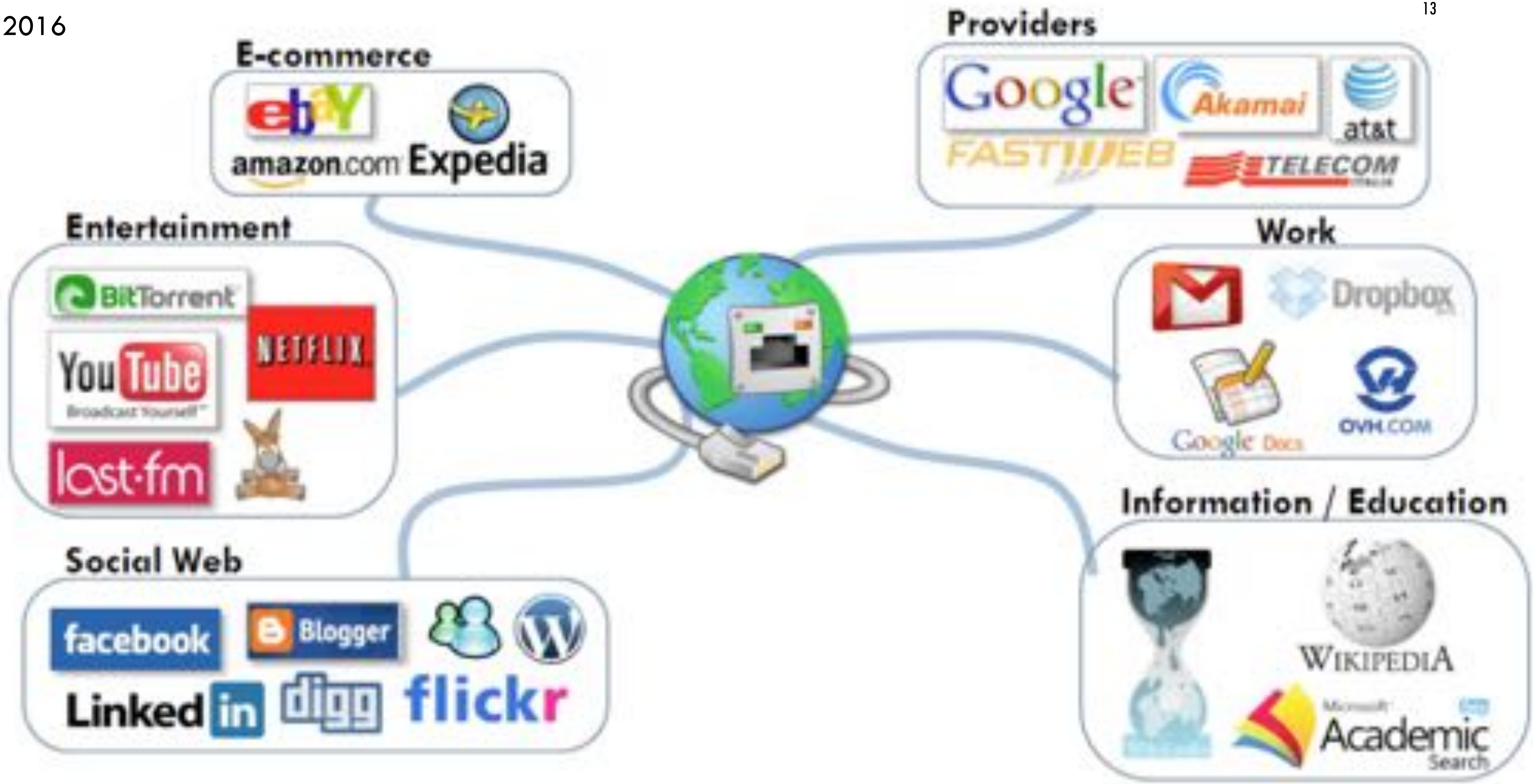
1969 vs. 2014

http://www.computerhistory.org/internethistory/1970s/

1969


5420 - AT&T Teletype
5425 - AT&T Teletype
610 - AT&T Teletype
620 - AT&T Teletype
PC6300PLUS pc6300plus 6300plus
- AT&T PC6300+
unixpc 3b1 pc7300 PC7300 s4
- AT&T UNIX pc
hp2621 - Hewlett-packard
tvi925 - Televideo
vt100 - DEC
<Press RETURN for more instructions>
Some other terminals may work with the Office windows and menus, but not all terminals have been tested.
Most terminals will work with most character-based software on the UNIX PC. If your terminal is "not supported", it will probably work only for simple text and line-by-line data entry. Consult your Remote User's Guide or the Hot Line for more information.
Please type the terminal name, '?' for help, or 'exit' to exit, and press RETURN: vt100_

2016



http://www.ict-mplane.eu/public/about-mplane-intelligent-measurement-plane-future-network-and-application-management

THE VISION FOR COMPUTER NETWORKING

Anytime access to any information by anyone anywhere

ARE WE DONE?

MAYBE NOT...

Images: http://www.cupcakeproject.com/2012/06/homemade-spam-recipe.html

Images: http://www.cupcakeproject.com/2012/06/homemade-spam-recipe.html, 3M

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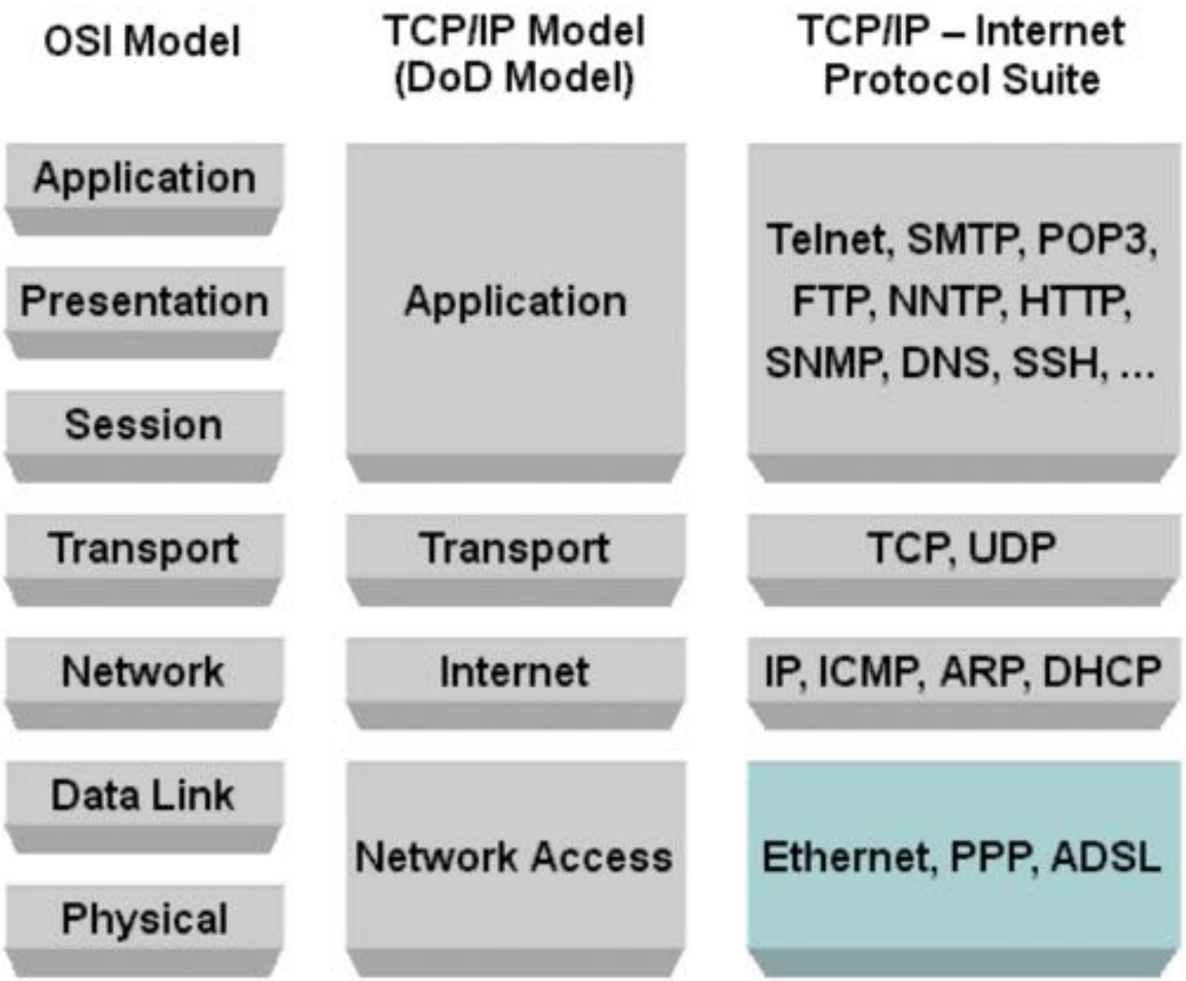
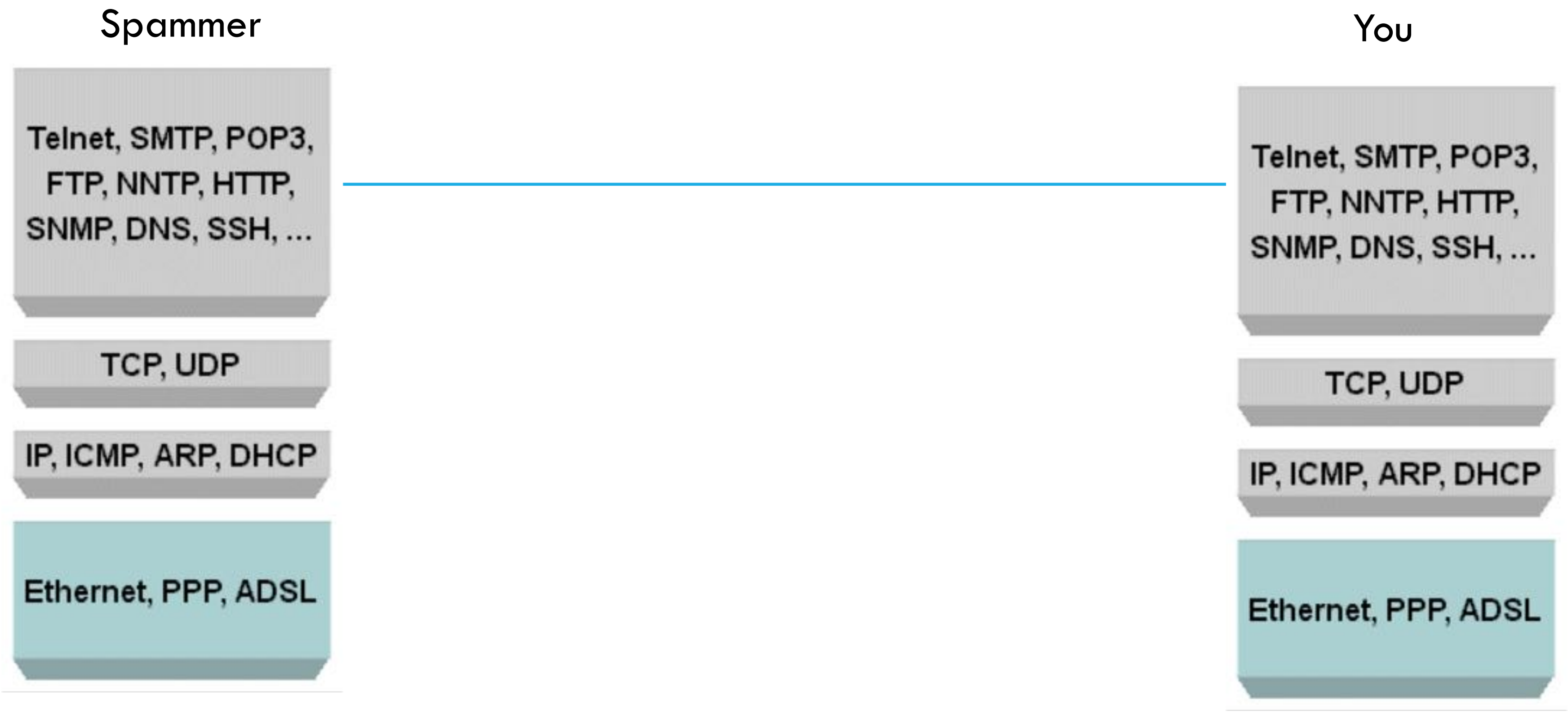
WHY CAN'T WE SIMPLY BLOCK SPAMMERS?

BACK TO BASICS…

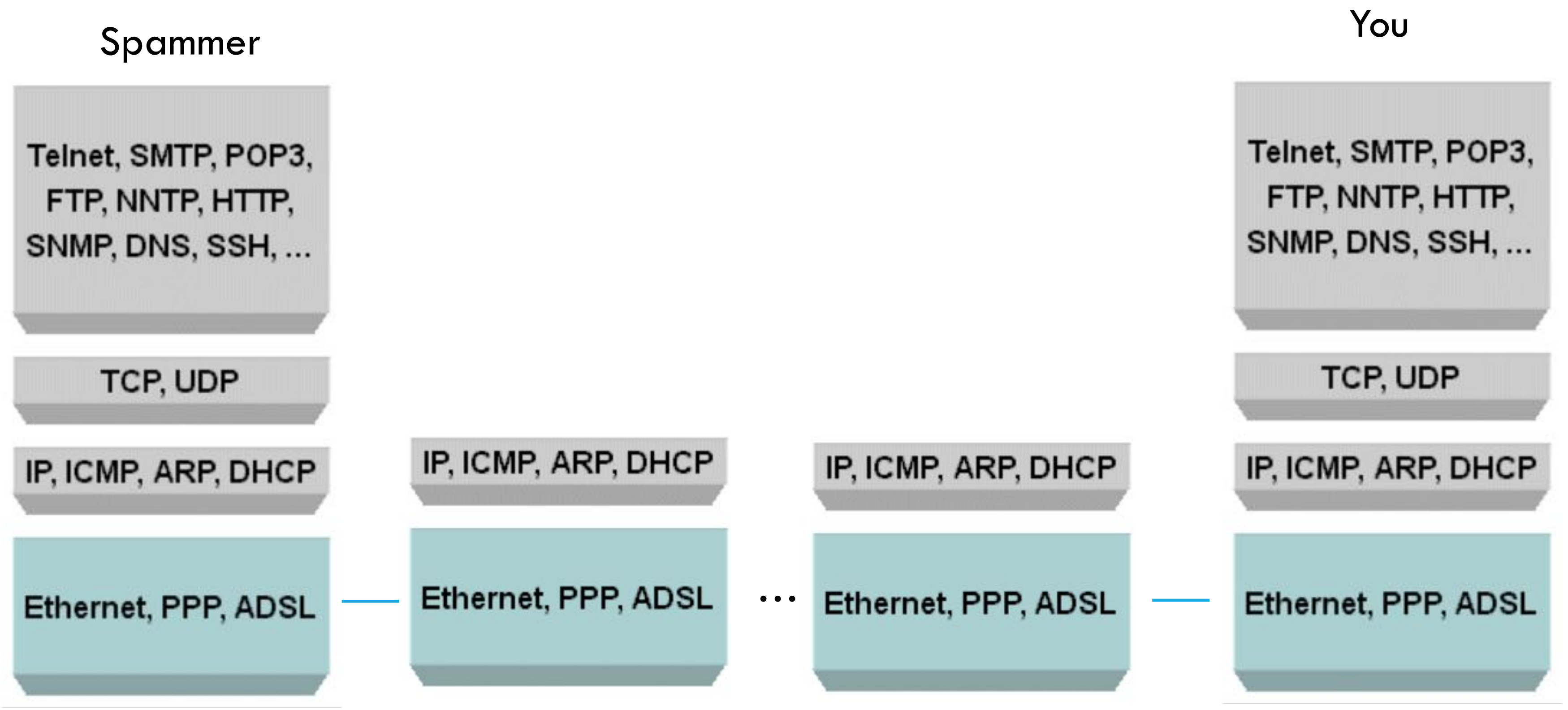


http://bit.kuas.edu.tw/~csshieh/teach/np/tcpip/

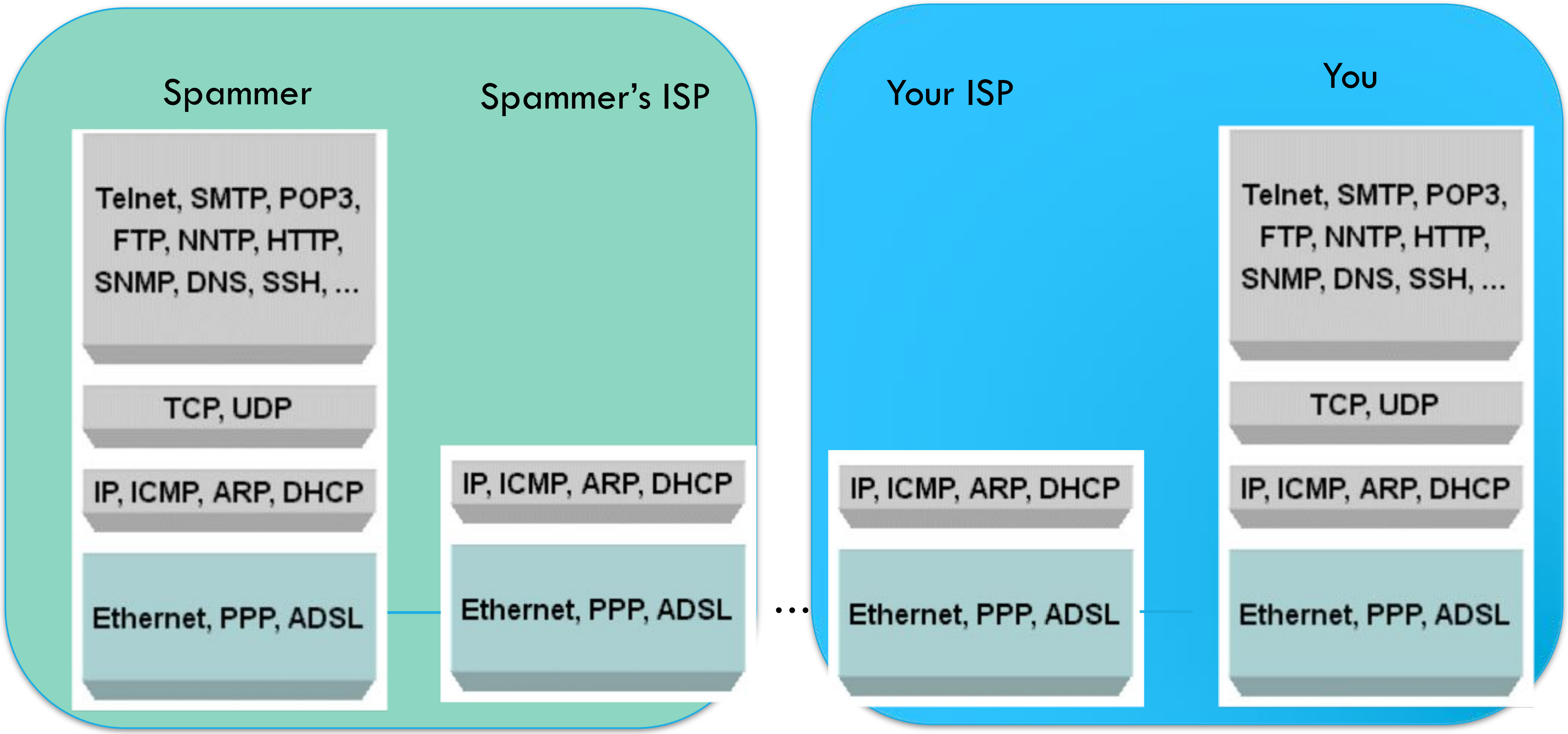
CLIENT SERVER MODEL



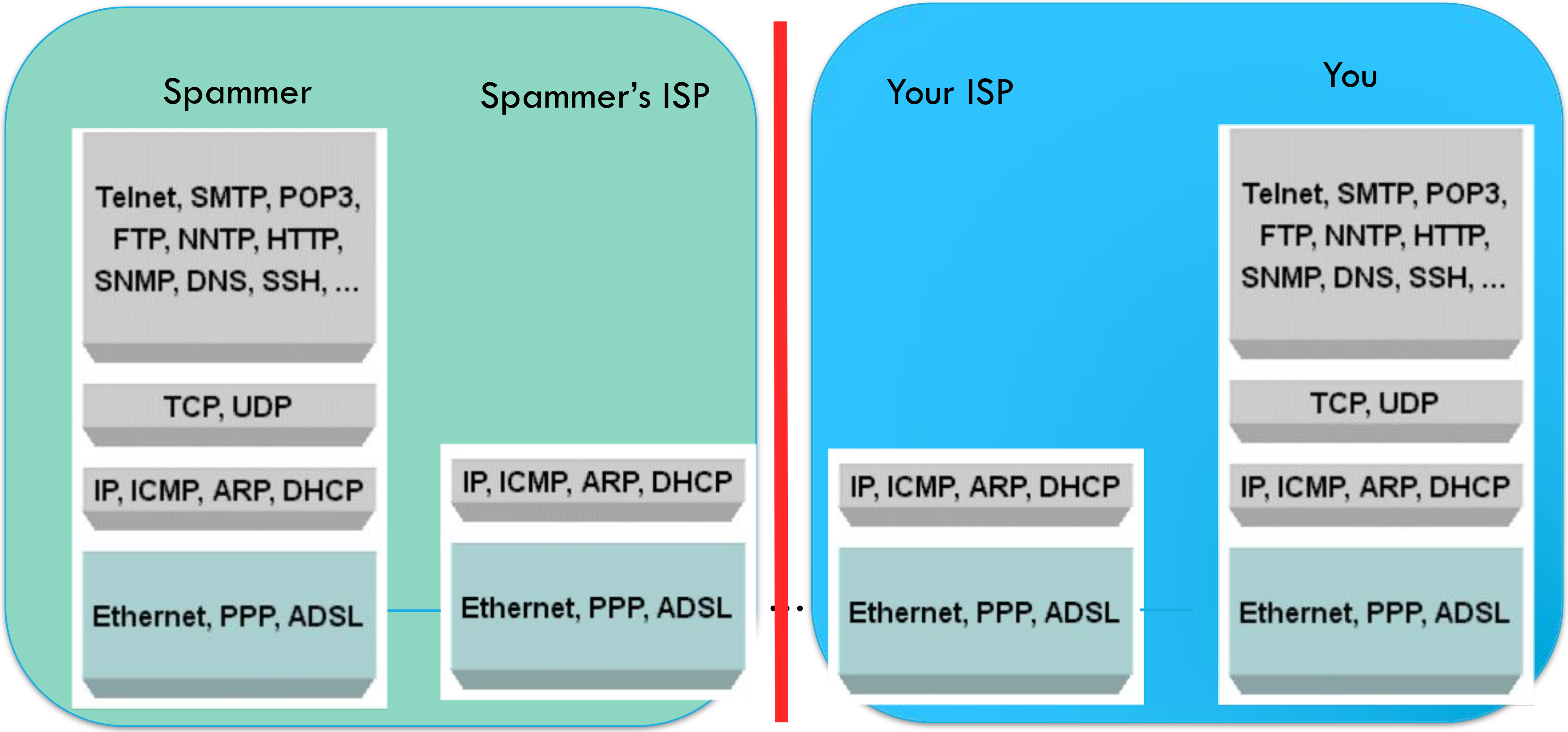
REALITY


Spammer
You
Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...
TCP, UDP
IP, ICMP, ARP, DHCP
Ethernet, PPP, ADSL
IP, ICMP, ARP, DHCP
Ethernet, PPP, ADSL
...
IP, ICMP, ARP, DHCP
Ethernet, PPP, ADSL
Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...
TCP, UDP
IP, ICMP, ARP, DHCP
Ethernet, PPP, ADSL

ISP RELATIONSHIP



INFORMATION HIDING



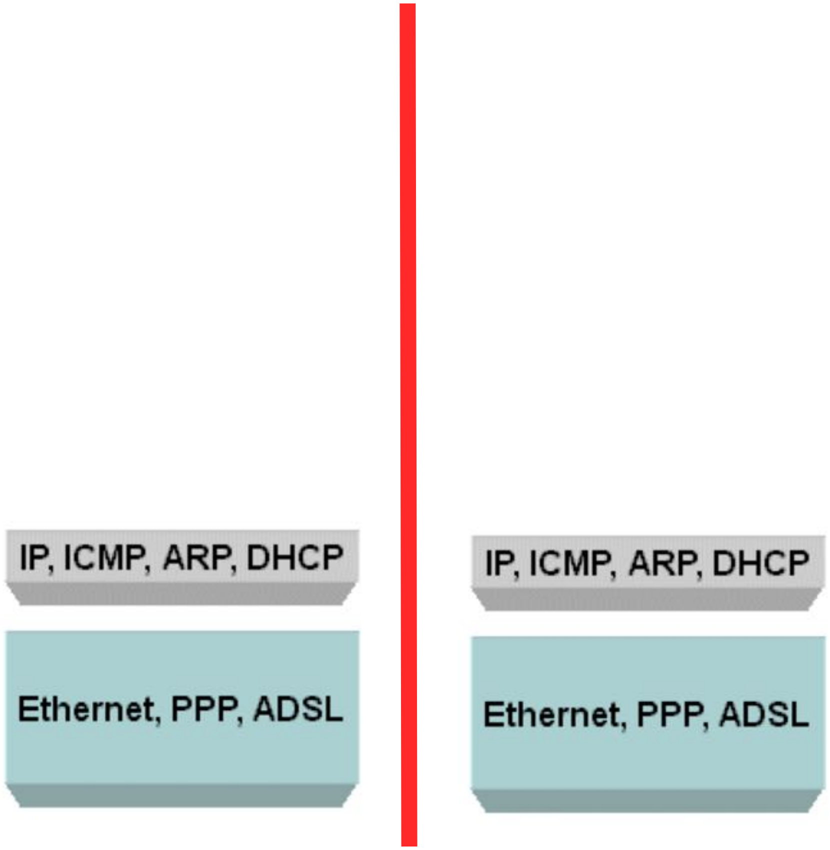
THE REAL PROBLEM

Narrow AS-AS relationship

- Data plane: Packet exchange
- Control plane: Route information exchange

Identities (and QoS) do not traverse AS boundaries

AS behaviour is unregulated beyond packet transfer




BUT WHY?

THESIS

Many of the key problems in the Internet today are due to its origins as an academic research project

The very things that led to its success lie at the heart of its failures

BACK TO THE BEGINNING…

THE DESIGN PHILOSOPHY OF THE DARPA INTERNET PROTOCOLS

David D. Clark

Massachusetts Institute of Technology
Laboratory for Computer Science
Cambridge, Ma. 02139

Clark, David. "The design philosophy of the DARPA Internet protocols." *ACM SIGCOMM Computer Communication Review* 18.4 (1988): 106-114

ORIGINAL DESIGN GOALS

The top level goal for the DARPA Internet Architecture was to develop an effective technique for multiplexed utilization of existing interconnected networks.

1. Internet communication must continue despite loss of networks or gateways.
2. The Internet must support multiple types of communications service.
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VERY SUCCESSFUL!

TELECOMMUNICATIONS

Telecom companies count $386 billion in lost revenue to Skype, WhatsApp, others

Erik Heinrich
Jun 23, 2014

It's been a rough ride for global telecommunications companies in recent years, and it's not because they finally started reading their fan mail. Telcos like China Mobile, Deutsche Telekom, and Telefónica are facing—and struggling to counter—a trend in which the prices of basic voice and data services are declining, like trees falling in a forest.

http://fortune.com/2014/06/23/telecom-companies-count-386-billion-in-lost-revenue-to-skype-whatsapp-others/

HOW TO REDUCE COST?

FACT: Computer communication is inherently bursty

CONSEQUENCE: Allocating a circuit (‘phone call’) to it is expensive

Cheaper to share (‘multiplex’) a circuit among many end-to-end communications

- But this degrades service quality!

QUALITY OF SERVICE

- Four well-known approaches
  - Overprovisioning
  - Admission control
  - Differential service quality: prioritize delay-sensitive flows
  - Drop packets when the queue size grows, expecting sources to respond

QUALITY OF SERVICE

- All approaches have serious problems
  - Overprovisioning
    - Expensive
  - Admission control
    - Requires end-to-end adoption
    - Impossible to allocate costs (more later)
  - Differential service quality: prioritize delay-sensitive flows
    - Requires changes to scheduling disciplines at every multiplexor
  - Drop packets when the queue size grows, expecting sources to respond
    - Requires complex tuning
    - Assumes cooperation

BOTTOM LINE

The primary design goal of the Internet makes it inherently unsuitable for real-time communication

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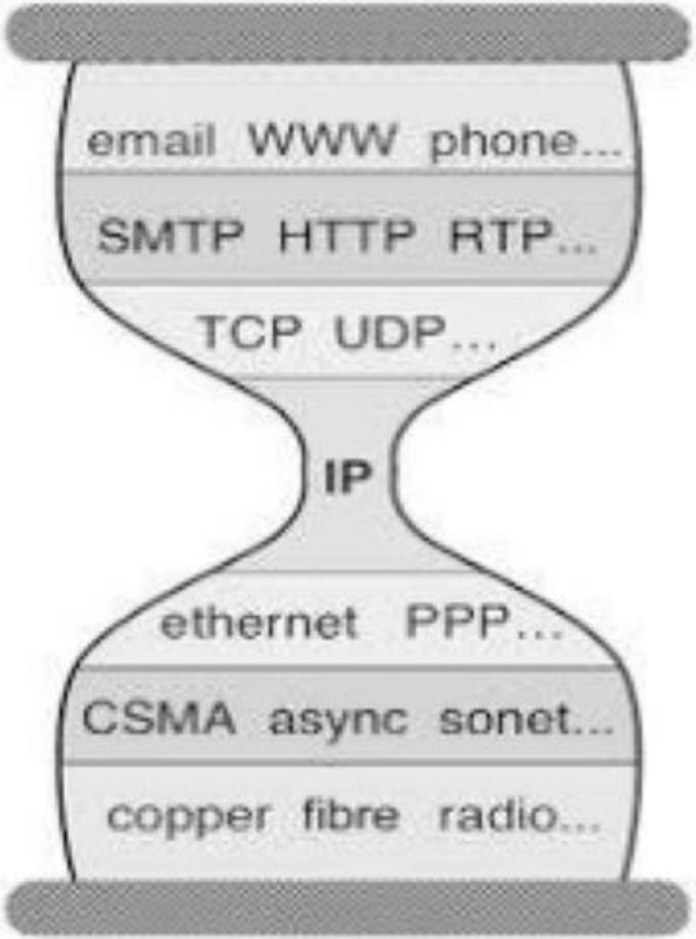
Clark, David. "The design philosophy of the DARPA Internet protocols." *ACM SIGCOMM Computer Communication Review* 18.4 (1988): 106-114.

THE INTERNET IS A NETWORK OF NETWORKS

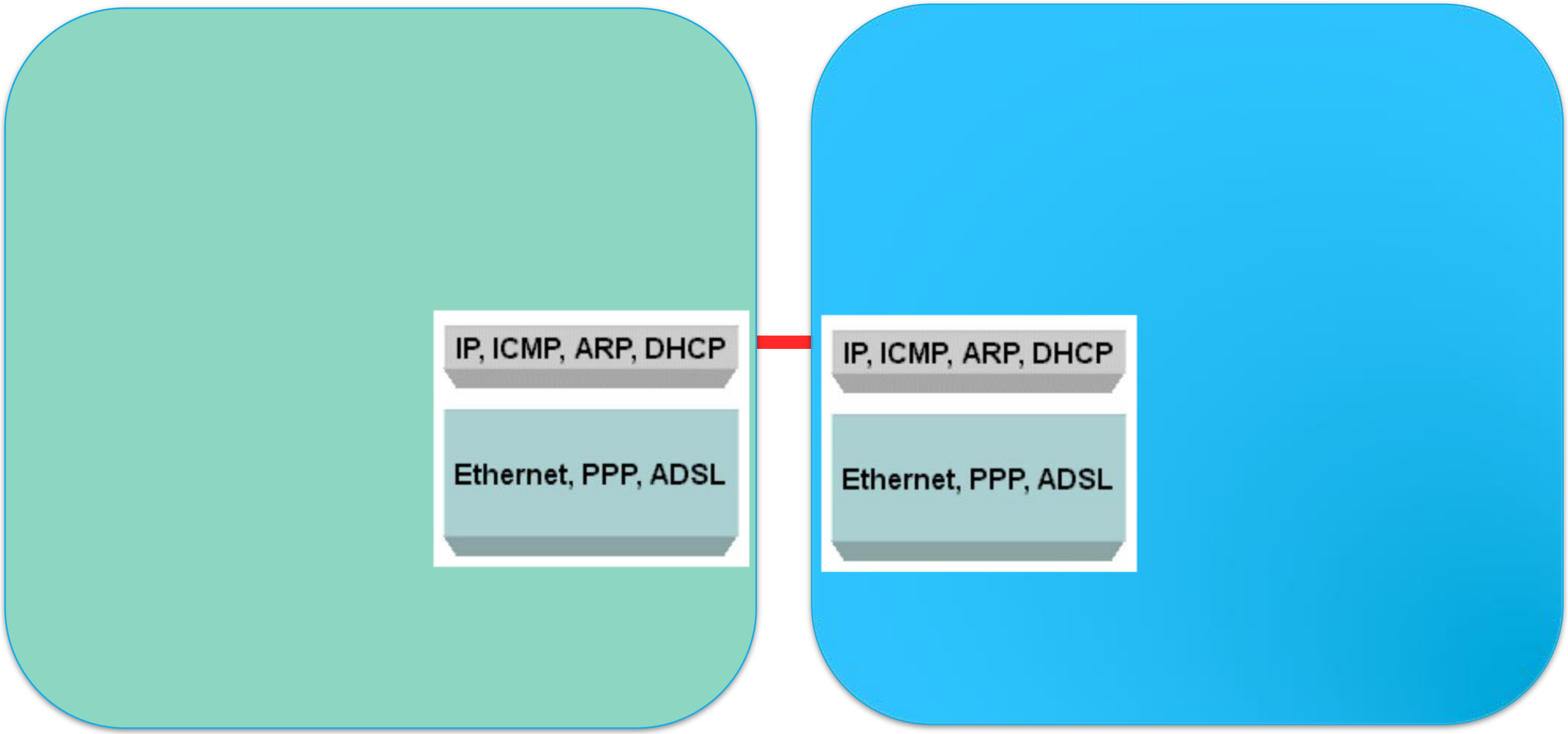
long haul nets (the ARPANET itself and various X.25 networks), local area nets (Ethernet, ringnet, etc.), broadcast satellite nets (the DARPA Atlantic Satellite Network[14, 15] operating at 64 kilobits per second and the DARPA Experimental Wideband Satellite Net,[16] operating within the United States at 3 megabits per second), packet radio networks (the DARPA packet radio network, as well as an experimental British packet radio net and a network developed by amateur radio operators), a variety of serial links, ranging from 1200 bit per second asynchronous connections to T1 links, and a variety of other ad hoc facilities, including intercomputer busses and the transport service provided by the higher layers of other network suites, such as IBM's HASP.

ACCOMMODATING HETEROGENEITY

The Internet architecture achieves this flexibility by making a minimum set of assumptions about the function which the net will provide. The basic assumption is that network can transport a packet or datagram.


email WWW phone...
SMTP HTTP RTP...
TCP UDP...
IP
ethernet PPP...
CSMA async sonet...
copper fibre radio...

NARROW INTERFACE

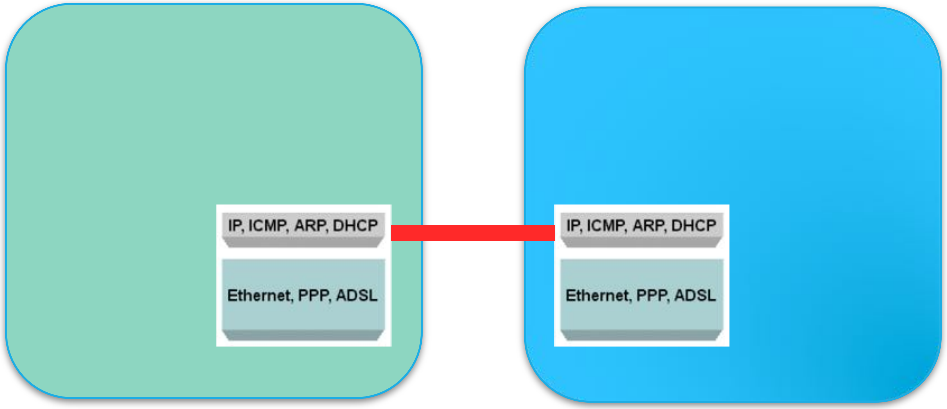


NARROW INTERFACE

Allows interoperability across heterogeneous technologies

Easy to implement

Allows independent evolution



VERY SUCCESSFUL

The architecture has survived the transition of individual ASs

from dialup lines to multi-lambda optical fibers

from text-based interaction to multimedia on wireless devices

while retaining interoperability!

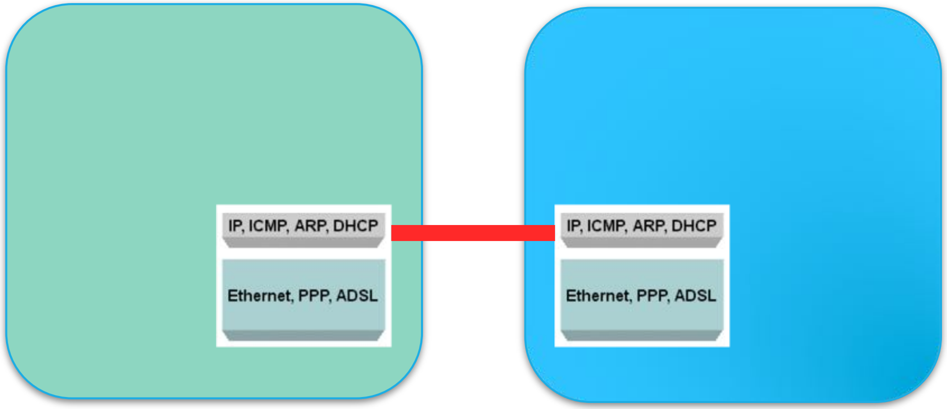
BUT…

Allows interoperability across heterogeneous technologies

Easy to implement

Allows independent evolution

No support for quality of service



AND...

Allows interoperability across heterogeneous technologies

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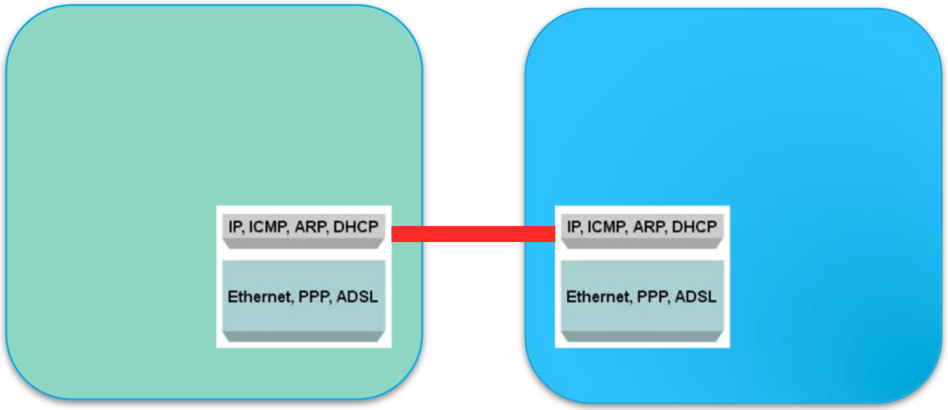
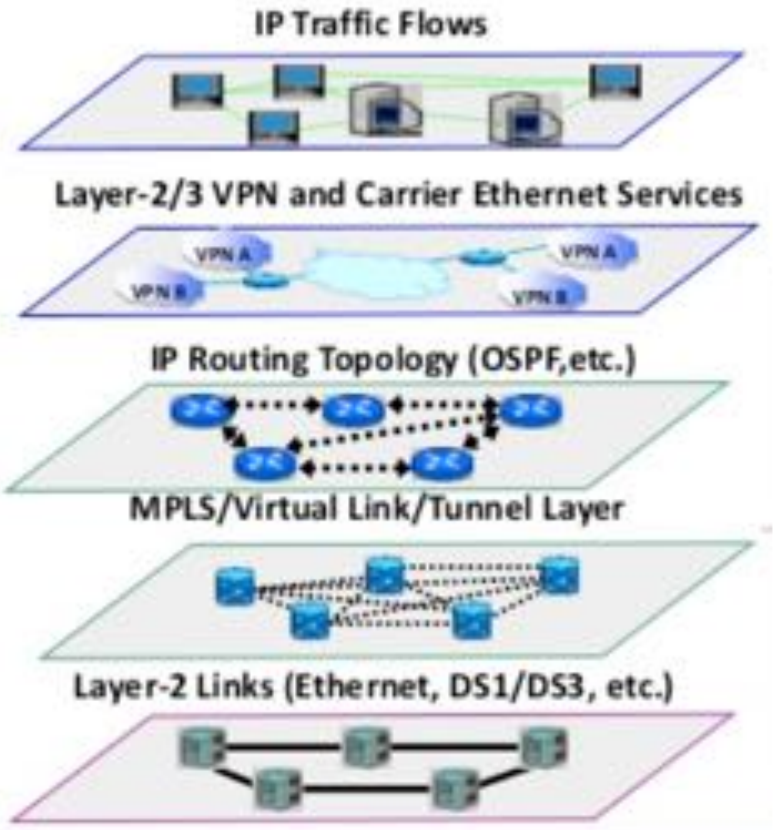


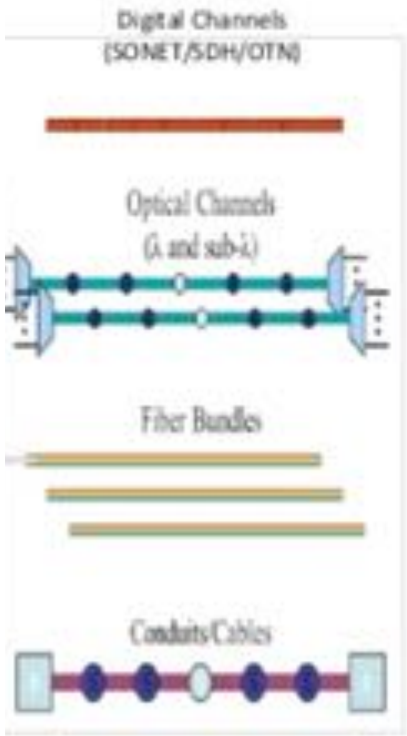
No support for quality of service

Unconstrained implementation

- Arbitrary layering
- Impossible to debug performance

Layers in an IP/Transport Network





Source: Designing Multi-layer Carrier Networks for Capacity and Survivability, OPNETWORK 2012

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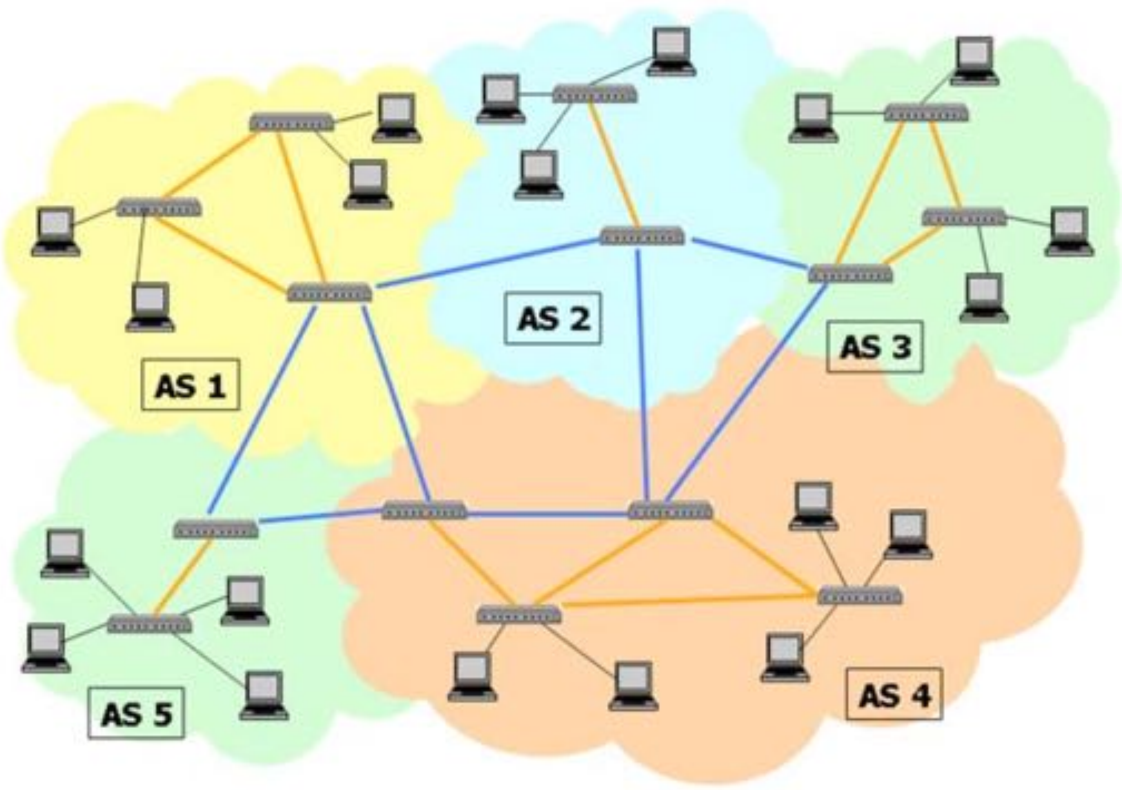
DISTRIBUTED MANAGEMENT

Distributes the task of management using Autonomous Systems



WEAK CENTRALIZATION

ICANN

IANA

Registries

DNS TLDs

DISTRIBUTED MANAGEMENT

Allows rapid deployment

Allows independent evolution

Delegation allows massive scaling

- DNS

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With narrow interfaces, makes quality of service even more challenging

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With narrow interfaces, makes quality of service even more challenging

No network-wide identity

- Security nightmare
- Spam, DDOS, hacking, …

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No single view into the network

- Makes networks unmanageable

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Delegation allows massive scaling

- DNS

With narrow interfaces, makes quality of service even more challenging

No network-wide identity

- Security nightmare
- Spam, DDOS, hacking, …

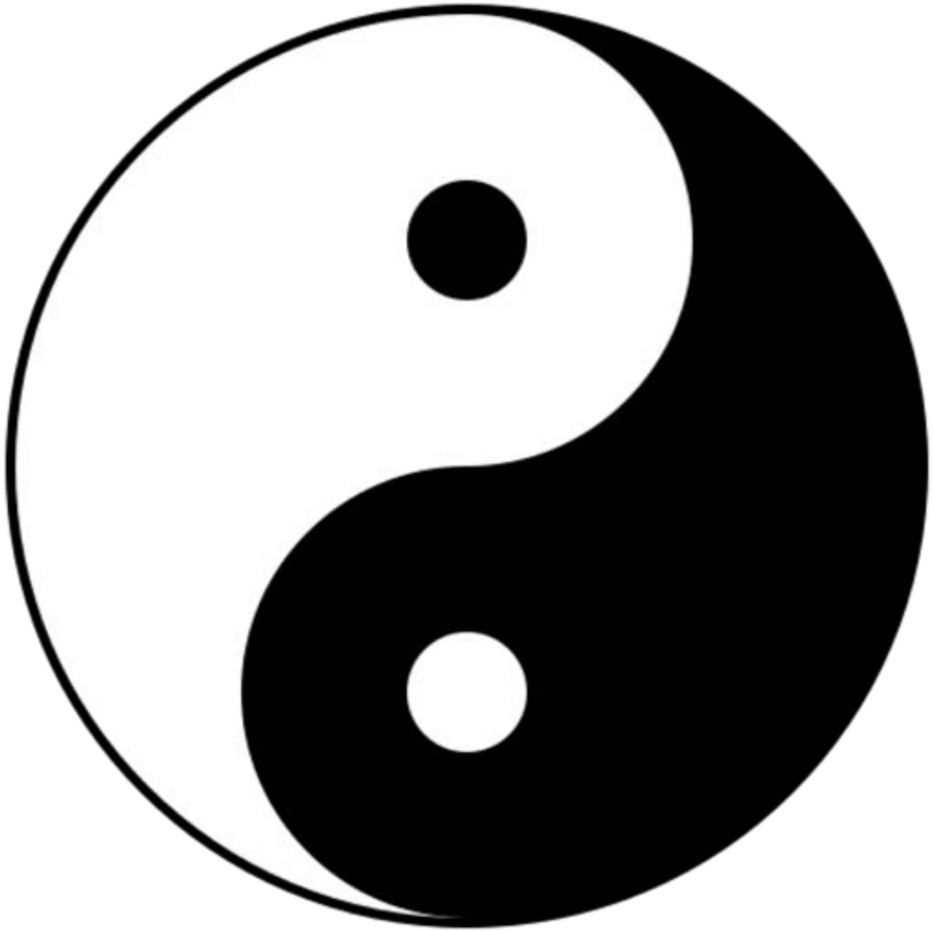
No single view into the network

- Makes networks unmanageable

Autonomous systems

- Can inspect, modify, and drop packets
- No privacy

Images: http://www.cupcakeproject.com/2012/06/homemade-spam-recipe.html, 3M



WHAT TO DO?

LET'S REVISIT ONE OF THE GOALS

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. the intermediate packet switching nodes, or gateways, must not have any essential state information about on-going connections. Instead, they are stateless packet switches

THIS DESIGN APPROACH IS LONG DEAD…

SDN

MPLS for traffic shaping

Middleboxes

- Load balancers
- Firewalls
- Intrusion detectors
- VPN endpoints
- …

THE PATH NOT TAKEN

An alternative to interconnecting existing networks would have been to design a unified system which incorporated a variety of different transmission media, a multi-media network.

TELEPHONE NETWORK

Can we integrate the best aspects of the Internet with the best aspects of the telephone network?

- Prevent spam by allowing identities to be traced
- Require privacy from carriers
- Make the inter-AS interface richer to allow QoS

Keshav, S.. "Why cell phones will dominate the future internet." *ACM SIGCOMM Computer Communication Review* 35.2 (2005): 83-86.

TIME TO RETHINK INTERNET ARCHITECTURE

TIME TO BE CREATIVE!

Technology trends and future demands

- Industrial Internet of Things
- Extreme sensing
- In-body Internet
- Deep Space Internet
- Hackers
- Need for privacy
- Quality of Service

TIME TO BE CREATIVE!

Technology trends and future demands

- Industrial Internet of Things
- Extreme sensing
- In-body Internet
- Deep Space Internet
- Hackers
- Spam
- Privacy
- Quality of Service

What should be our new design philosophy?

How can we design our future networks to be legacy compatible?


It's in
Your Hands
Now...