

Network Traffic Evolution

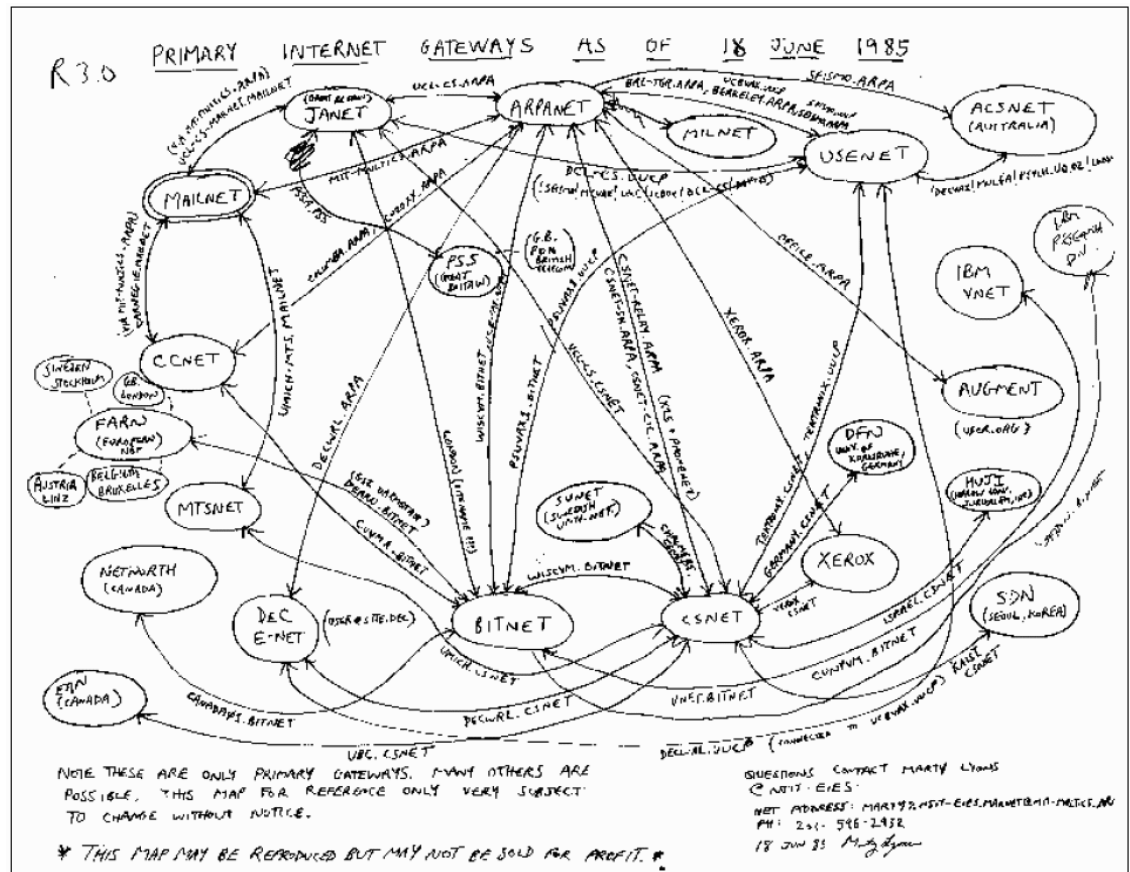
Prof. Anja Feldmann, Ph.D.

The Internet

- *As with any new facility, there will be a period of very light usage until the community of users experiments with the network and begins to depend upon it. One of our goals must be to stimulate the immediate and easy use by a wide class of users.*
- Steve Crocker; Host Software; [RFC 1](#); 7 April 1969.

The Internet in the early days

- Applications such as telnet, FTP, Usenet newsgroups, IRC, MUDs and mailing lists to empower a community to share information
- Marshall McLuhan foresees the global village



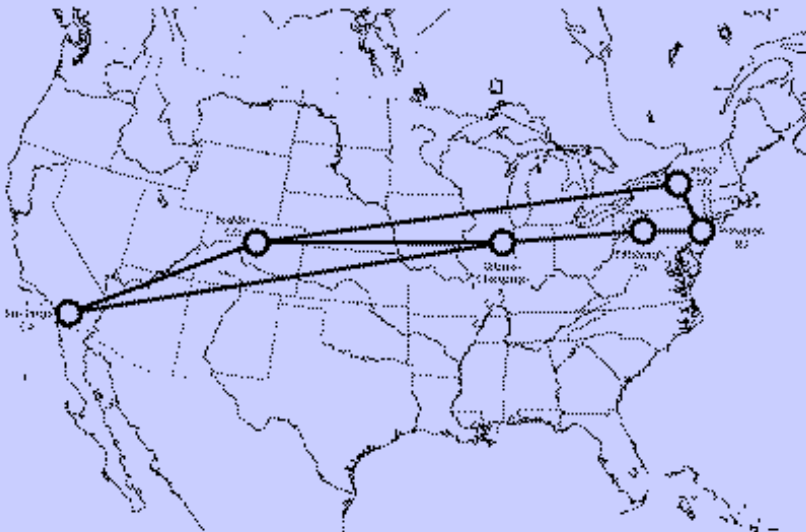
Internet history: ARPANET

- ❑ 10:30 PM on October 29'th, 1969 the first packets between 2 ARPANET nodes
- ❑ Mar. 1970, first ARPANET node on the US east coast.
- ❑ Sep. 1971 remote access via Terminal Interface Processor (TIP)
- ❑ Dec. 1972. 24 sites on the ARPANET
- ❑ Dec. 1973. 37 sites on the ARPANET, including satellite link from California to Hawaii.
- ❑ 1973, University College of London, England and Royal Radar Establishment, Norway connected to the ARPANET.
- ❑ Jun. 1974 62 computers connected to the ARPANET.
- ❑ Mar. 1977 111 computers on the ARPANET.
- ❑ 1983 an unclassified military only network, MILNET, split off from the ARPANET.
- ❑ 1985. ARPANET gateways to external networks across North America, Europe, and in Australia, and the Internet was global in scope.
- ❑ 1990. The ARPANET was retired in 1990. NSFNET took over for most universities.

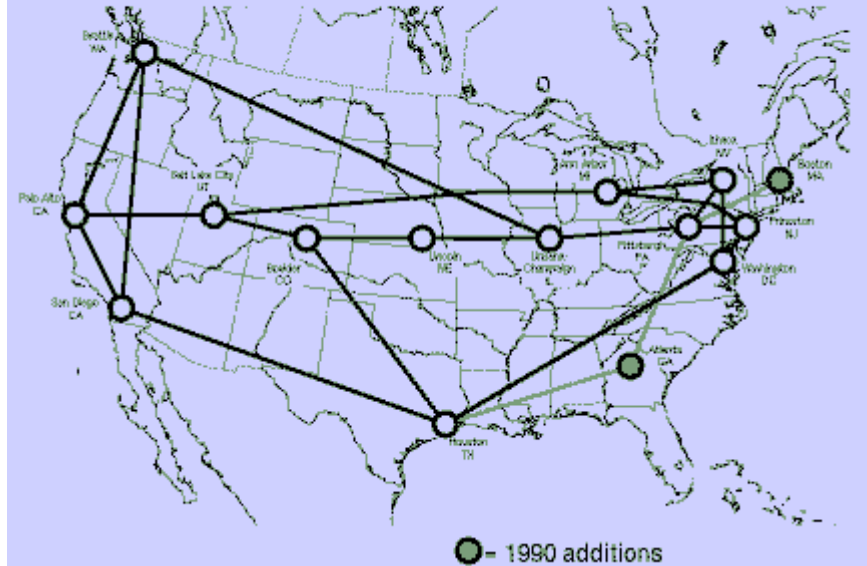
Internet history: NSFNET 1987-1995

- ❑ As part of the NSFNET contract, Krol authored the [Hitchhiker's Guide to the Internet](#) to provide a help manual for NSFNET users, providing one of the first comprehensive surveys of the Internet.

NSFNET Backbone network
Fuzzball nodes, 56 kbps
July 1986 - July 1988



NSFNET Backbone network
IBM NSS nodes, 1,544 kbps (T1) topology
July 1989 - November 1992

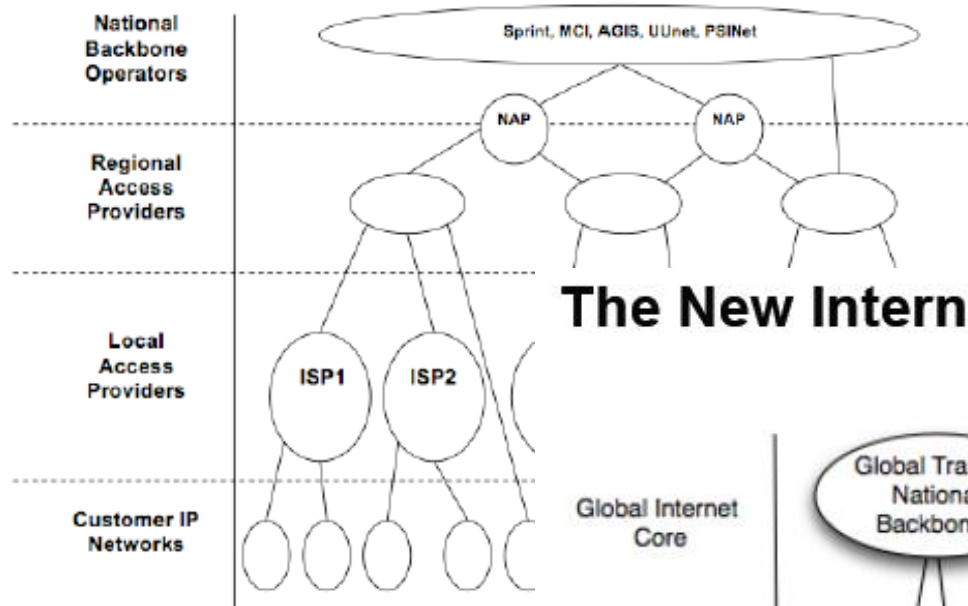


Internet history: NSFNET stats

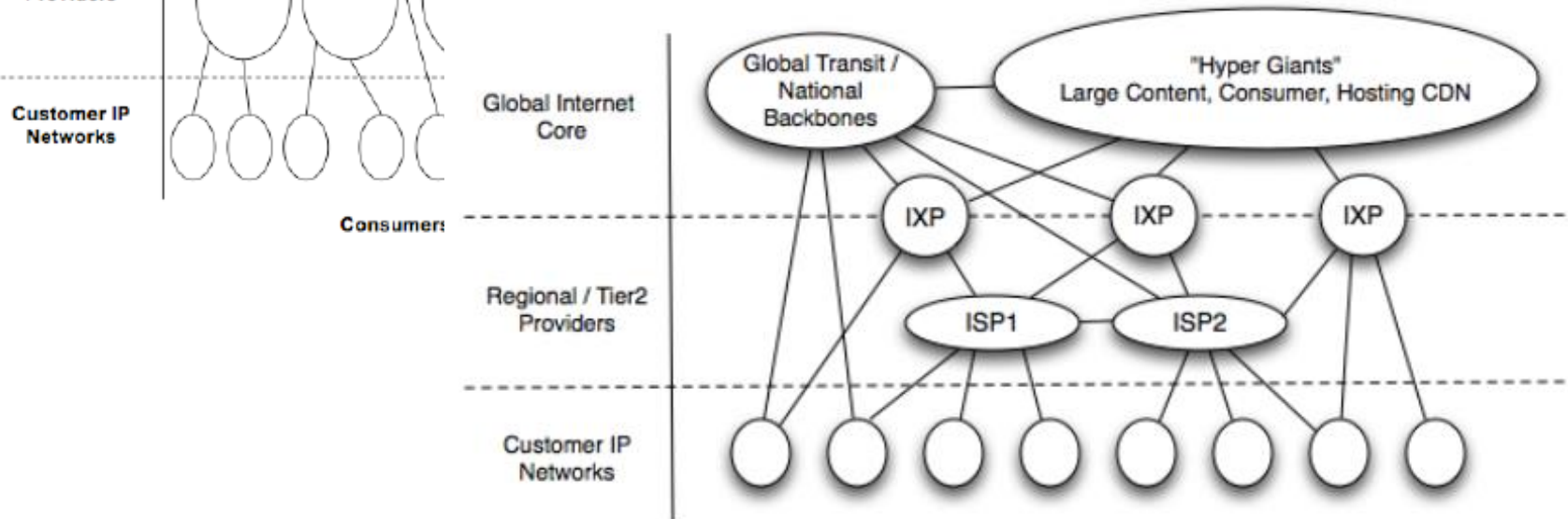
- ❑ By January, 1992, the NSFNET traffic exceeded 12 billion packets (1 trillion bytes) of traffic a month. By November the traffic had doubled, and NSFNET was connected to more than 7,500 networks, one third of which were outside the United States.
- ❑ In December, 1992, the NSFNET backbone was completely converted to a T3 or 44.736 Mbps capacity, capable of transmitting 4 and a half million characters a second.
- ❑ In 1994, the traffic on NSFNET broke the 10 trillion bytes a month level.

Today's Internet

Textbook Internet (1995 – 2007)



The New Internet



Questions to be answered

- ❑ What creates the structure of the Internet
- ❑ How does an ISP topology look like?
- ❑ How is reachability guaranteed?
- ❑ Which route does my traffic take?
 - Is it the “best” route?
 - Which of multiple servers should one choose?
 - How does traffic flow?
 - What is the traffic matrix
 - Who is providing the content?
 - Are CDNs dominating?
 - Is Google dominating?

Network Dynamics: User population

□ Number of Internet hosts

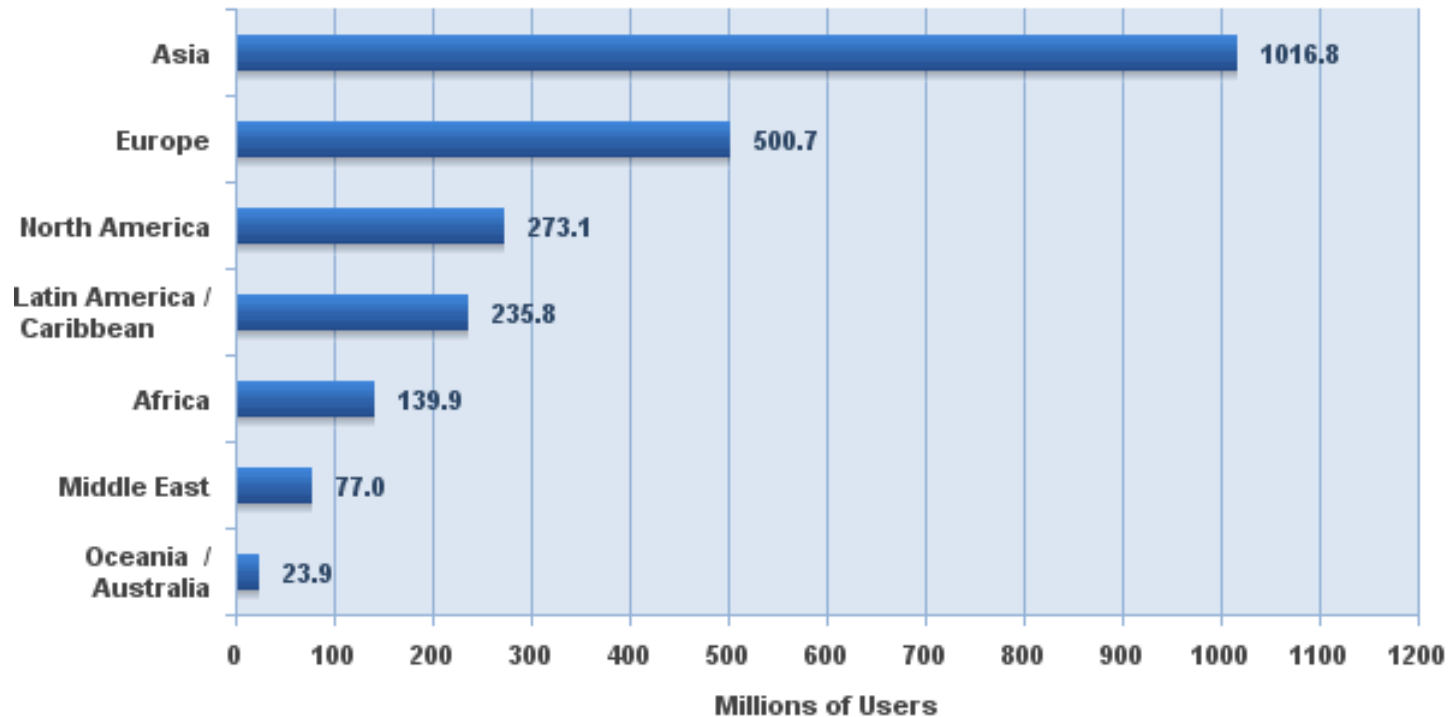
- Early 1989: 80,000
- Early 1992: 727,000
- Oct. 1993: 2,056,000
- Late 1996: 10,000,000
-

□ Internet traffic volume (Merit; Inc.)

- March 1991: 1.3×10^{12} bytes/month
- March 1994; 1.1×10^{13} bytes/month
- ...

Internet users

Internet Users in the World by Geographic Regions - 2011



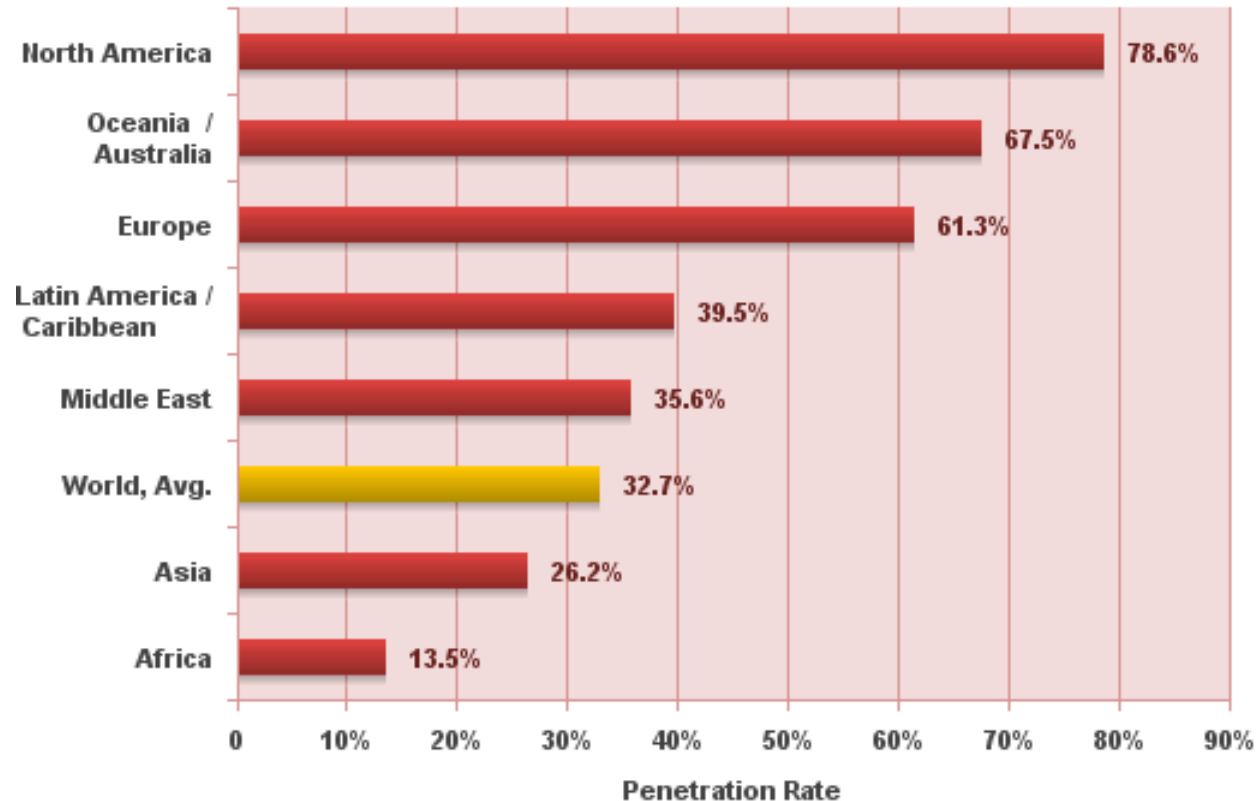
Source: Internet World Stats - www.internetworldstats.com/stats.htm

Estimated Internet users are 2,267,233,742 on December 31, 2011

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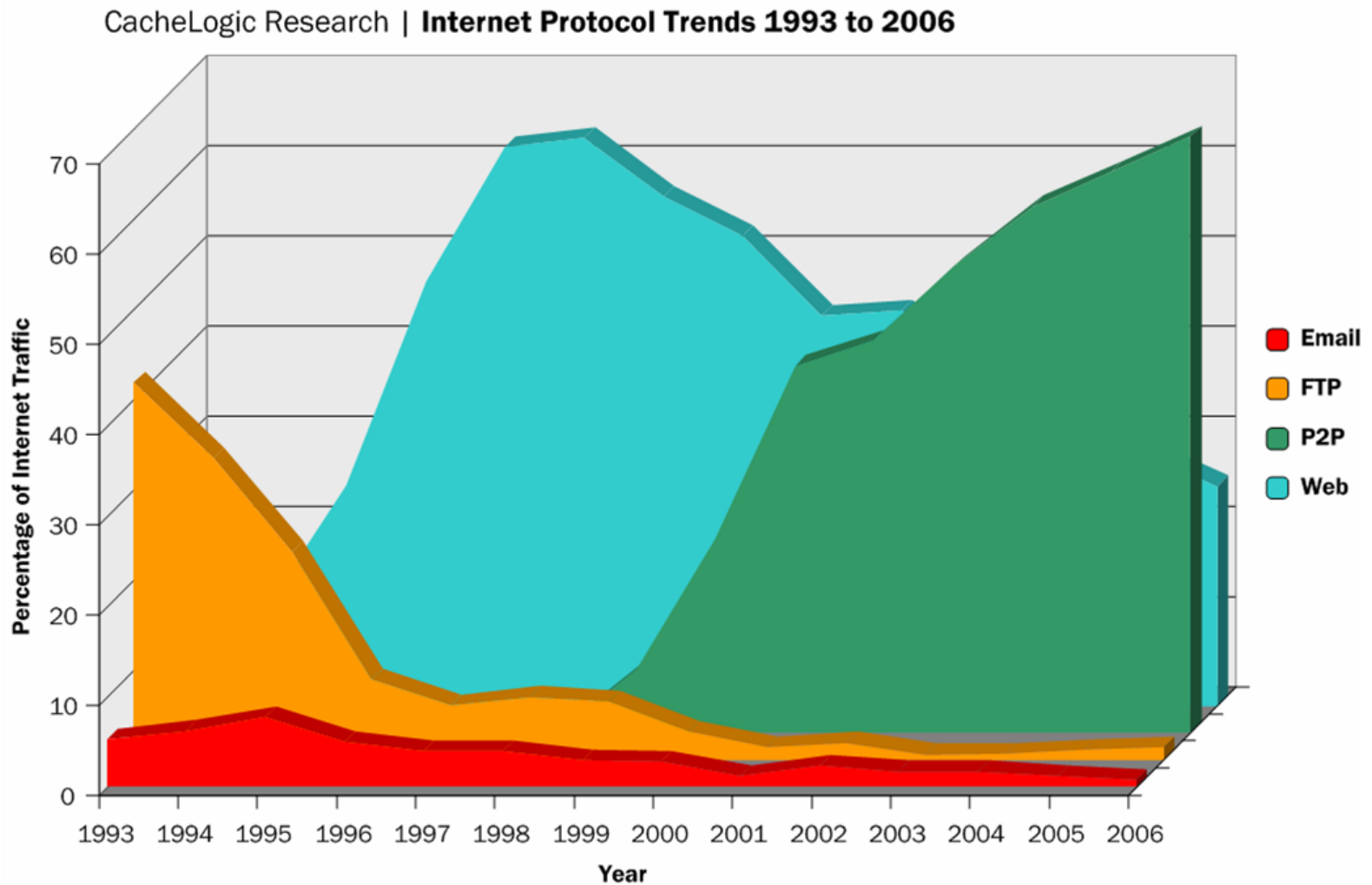
Internet penetration rates

World Internet Penetration Rates by Geographic Regions - 2011



Source: Internet World Stats - www.internetworldstats.com/stats.htm
Penetration Rates are based on a world population of 6,930,055,154 and 2,267,233,742 estimated Internet users on December 31, 2011.
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Application mix?



Netdynamics – „Killer application“

□ WWW and the Internet

- 1993: ... Hardly any WWW traffic on the Internet
- 1994: ... About 10% of total Internet traffic is WWW
- 95/96: ... Up to 60-70% of overall Internet traffic is WWW
-??????...

Incoming AT&T traffic by port

(18 hours of traffic to AT&T dial clients on July 22, 1997)

Name	port	% bytes	% packets	bytes per packet
world-wide-web	80	56.75	44.79	819
netnews	119	24.65	12.90	1235
pop-3 mail	110	1.88	3.17	384
cuseeme	7648	0.95	1.85	333
secure web	443	0.74	0.79	603
internet chat	6667	0.27	0.74	239
file transfer	20	0.65	0.64	659
domain name	53	0.19	0.58	210
. . .				

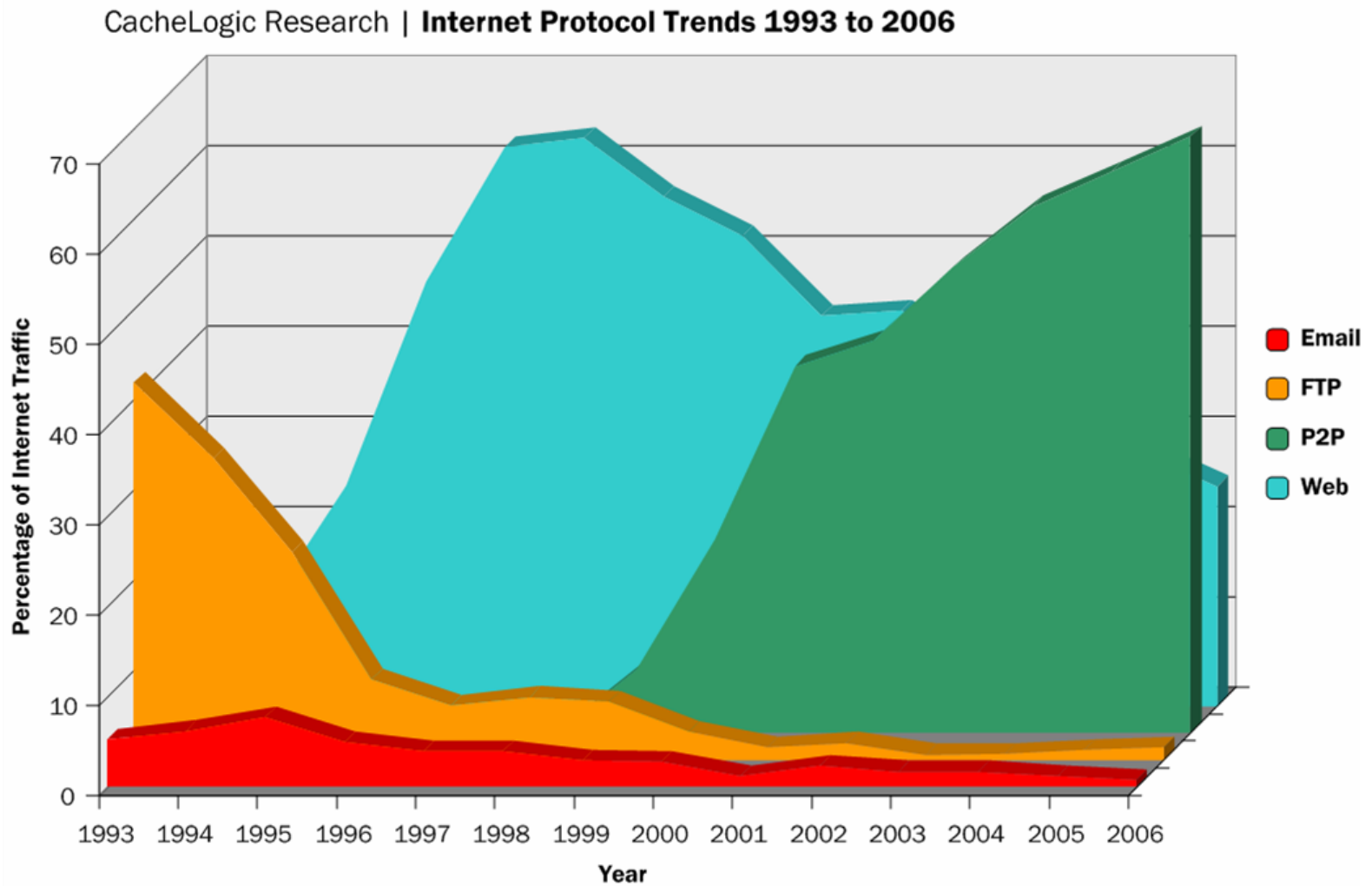
World Wide Web traffic dominates traffic mix

MWN traffic by port

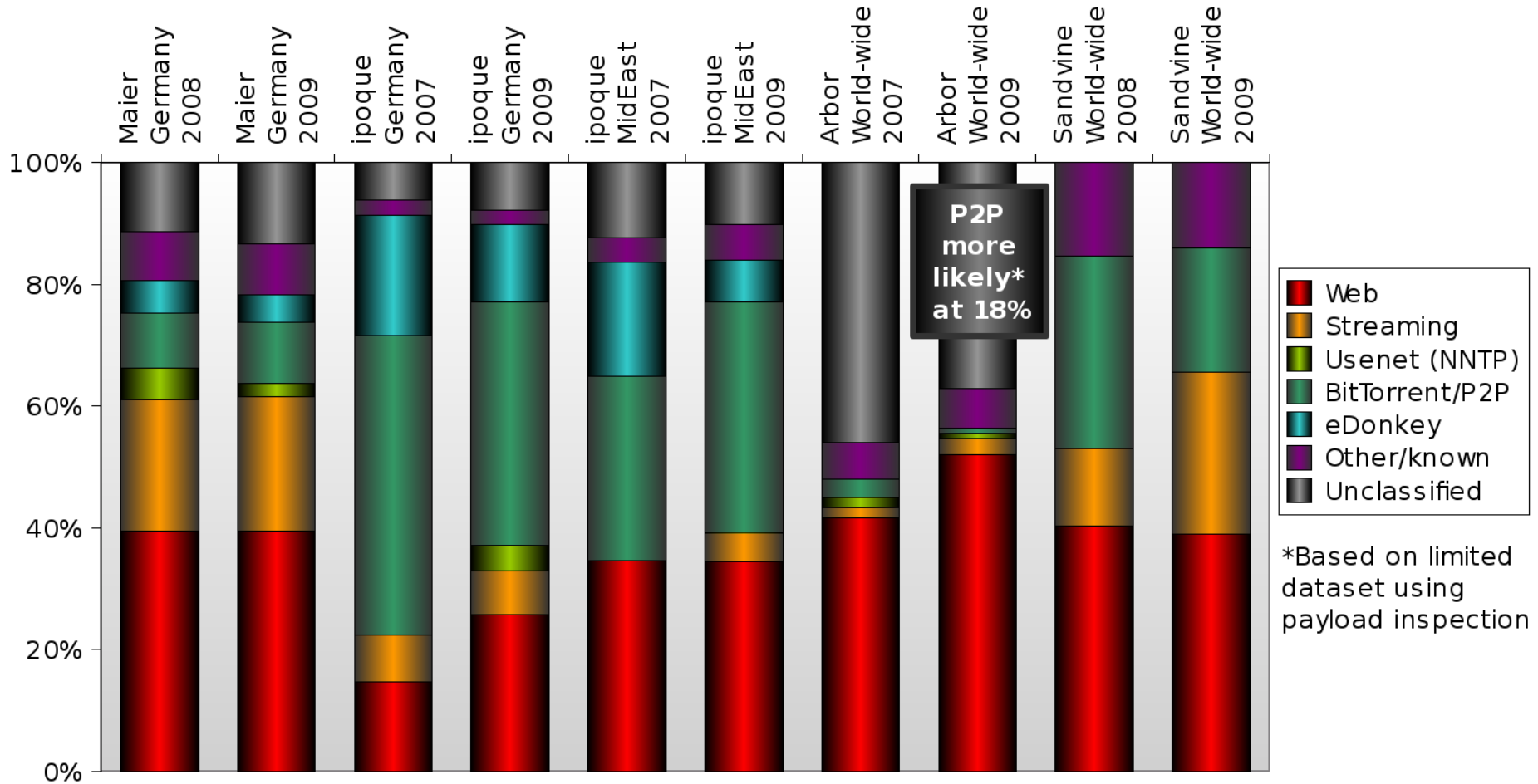
(24 hours of traffic to/from MWN clients in 2006)

Port		% Conns	% Success	% Payload
Web	80	70.82%	68.13%	72.59%
	445	3.53%	0.01%	0.00%
Web	443	2.34%	2.08%	1.29%
SSH	22	2.12%	1.75%	1.71%
Mail	25	1.85%	1.05%	1.71%
	1042	1.66%	0.00%	0.00%
	1433	1.06%	0.00%	0.00%
	135	1.04%	0.00%	0.00%
< 1024		83.68%	73.73%	79.05%
> 1024		16.32%	4.08%	20.95%

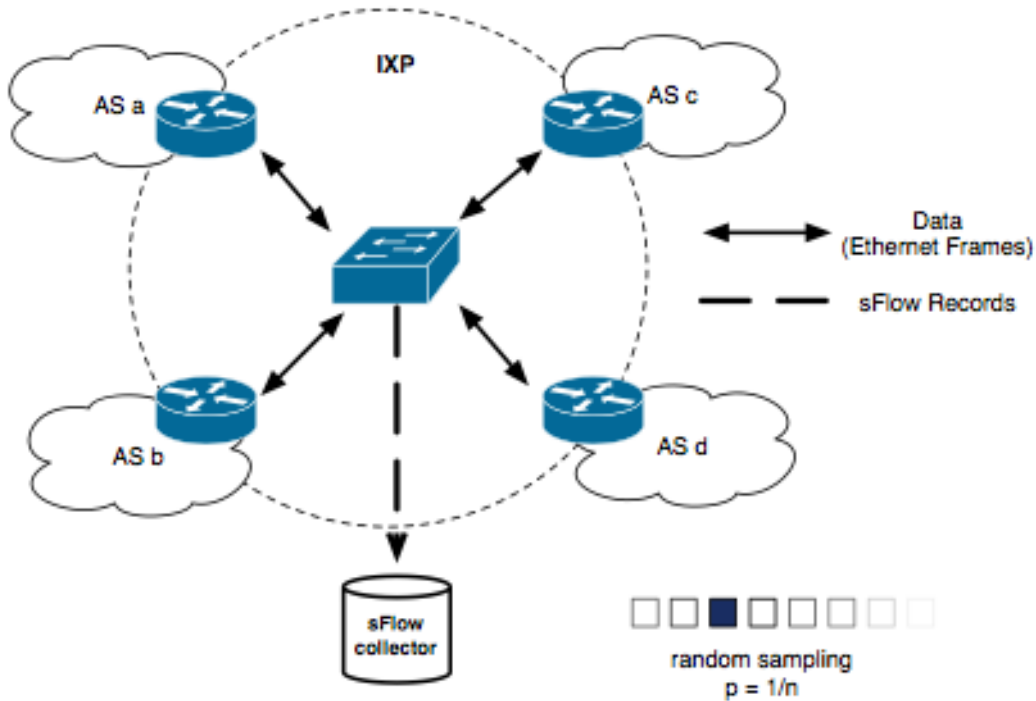
Application mix?



Application mix – different locations?



A Large European IXP

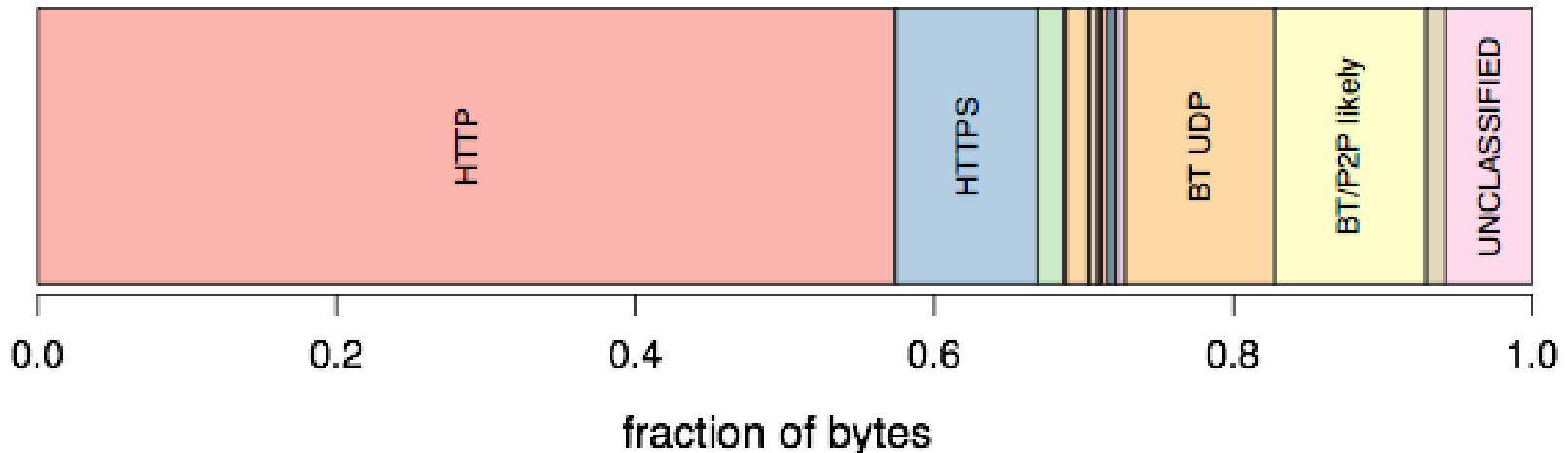


- Daily traffic (2013):
~14 PB
- sFlow export
- Random Sampling
1/16K Packets
- Snaplen
128 Bytes
- Weekly Snapshots
dating back to 2011

Sample snapshot (2013-09, 496 networks, 1 week)

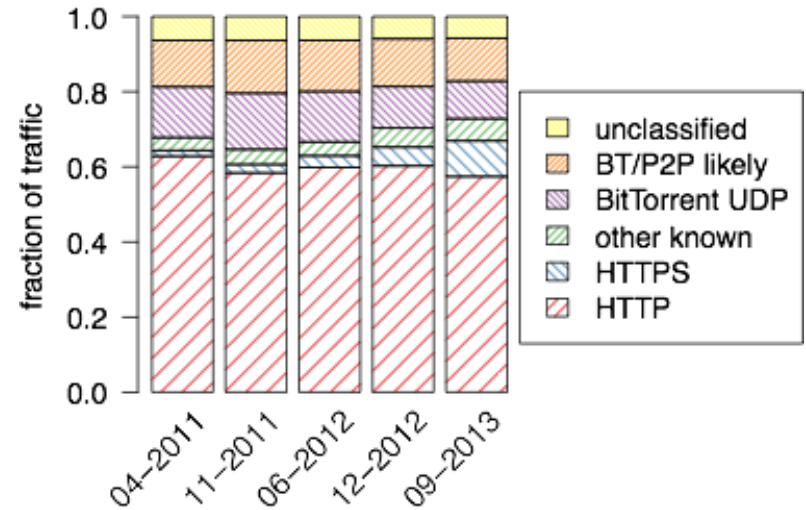
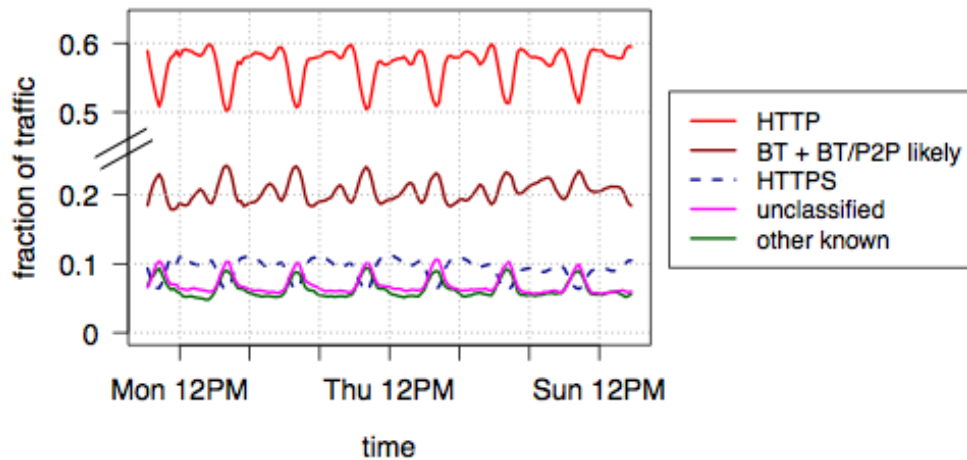
packets sampled	bytes sampled	IPv4 / IPv6	TCP / UDP
9.3B	5.9TB	99.37% / 0.63%	83.7% / 16.3%

The Application Mix: Aggregate



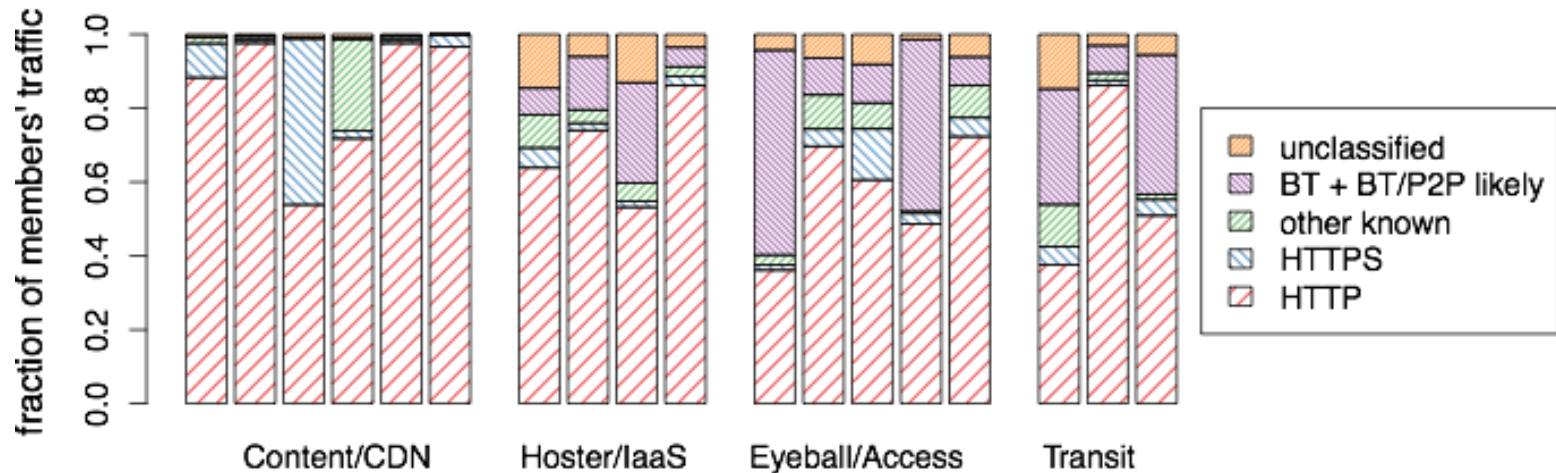
- HTTP(S) dominates $\sim 67\%$
- Other applications (e.g., RTMP, mail, news) $\sim 6\%$
- BitTorrent/BT/P2P likely $\sim 22\%$
- Unclassified $\sim 5\%$

Application Mix: Over Time



- Diurnal patterns, e.g., P2P dominates in off-hours
- Historical view shows increasing dominance of HTTP(S) and significant HTTPS increase in 2013.

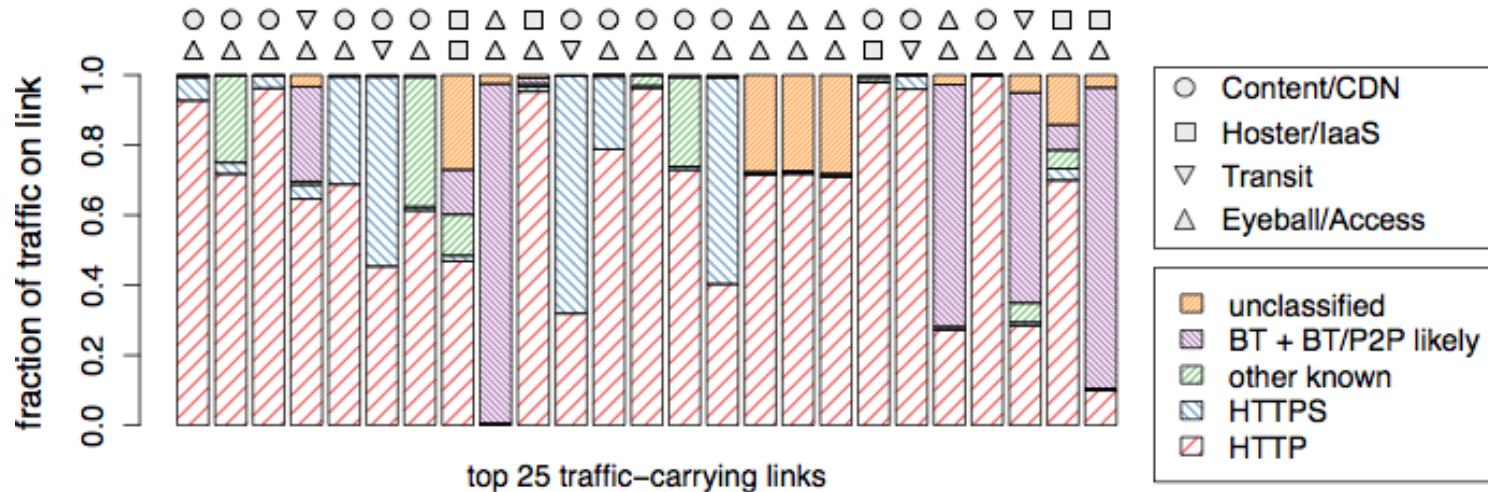
Application Mix: Network Type



- ❑ Content/Content distribution networks (CDN) almost 100% HTTP
- ❑ HTTPS increase caused by a few networks
- ❑ Peer to peer not only between Eyeballs! Hoster/IaaS too!

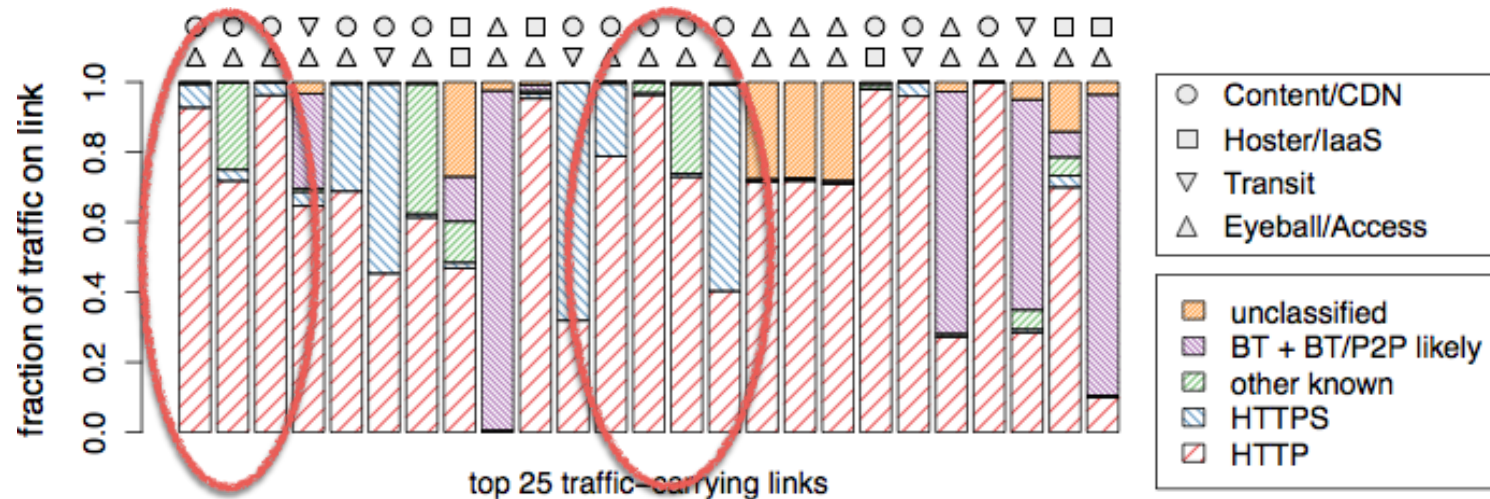
A closer look can result in different appmix!

Application Mix: Per Link



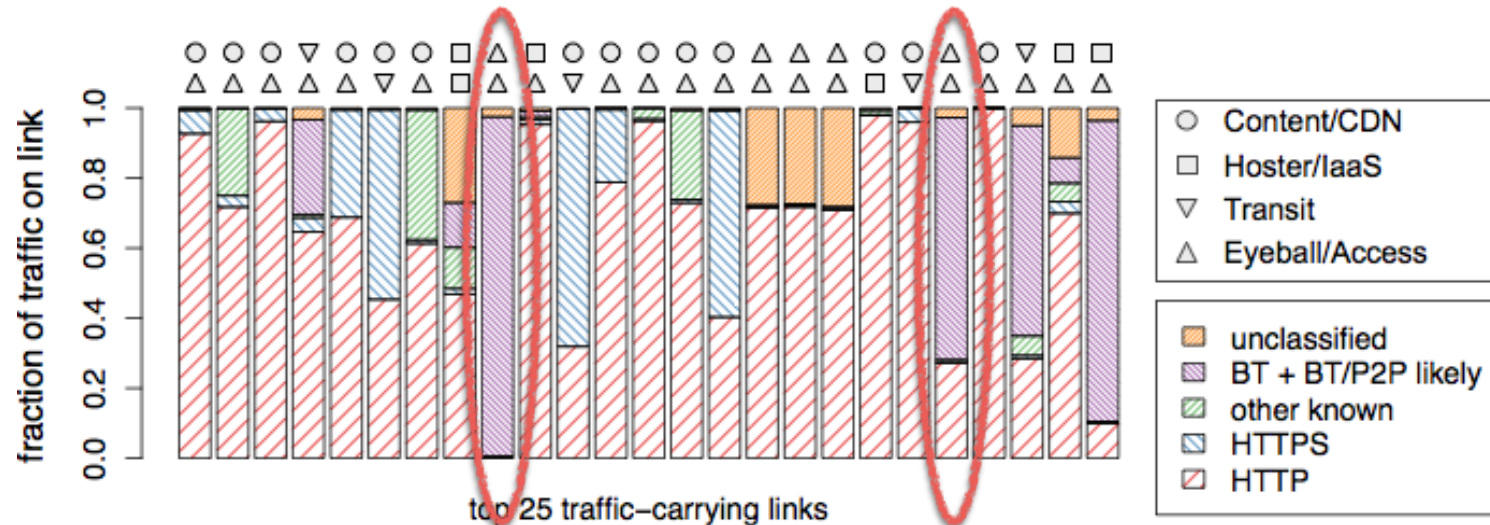
- ❑ Aggregate mix not representative of single link
- ❑ Many links just have one dominant protocol
- ❑ Business type of the AS gives hints on app mix

Application Mix: Per Link



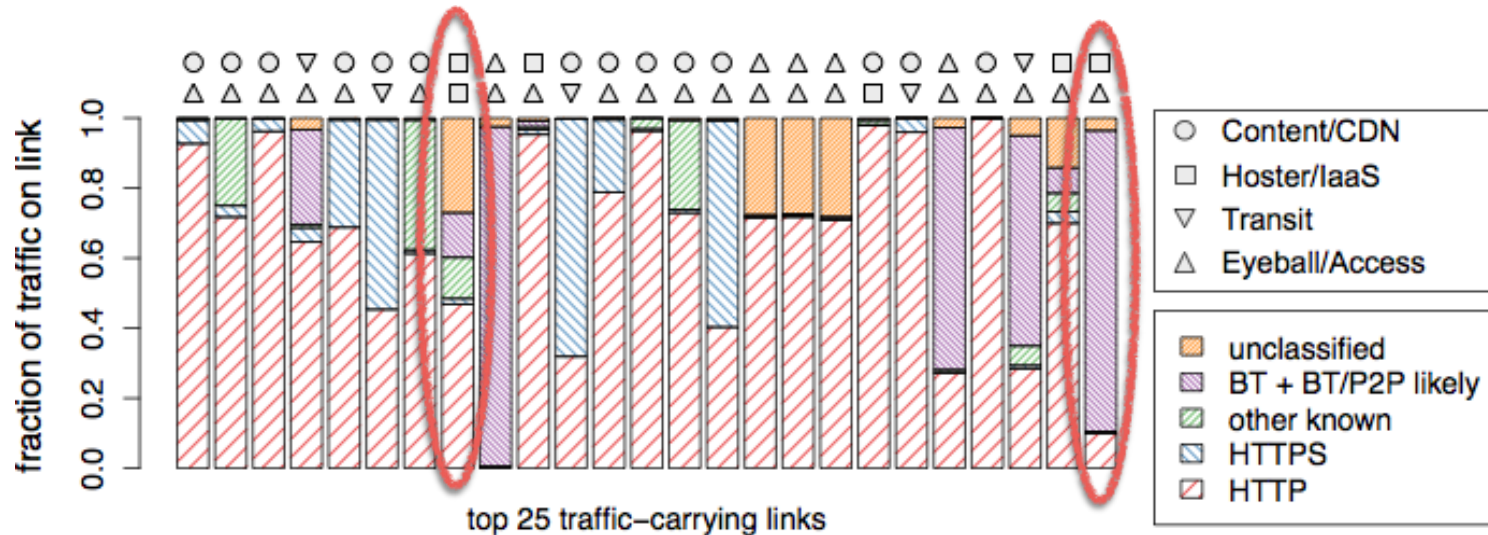
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Application Mix: Per Link



hoster/IaaS: diverse application mix

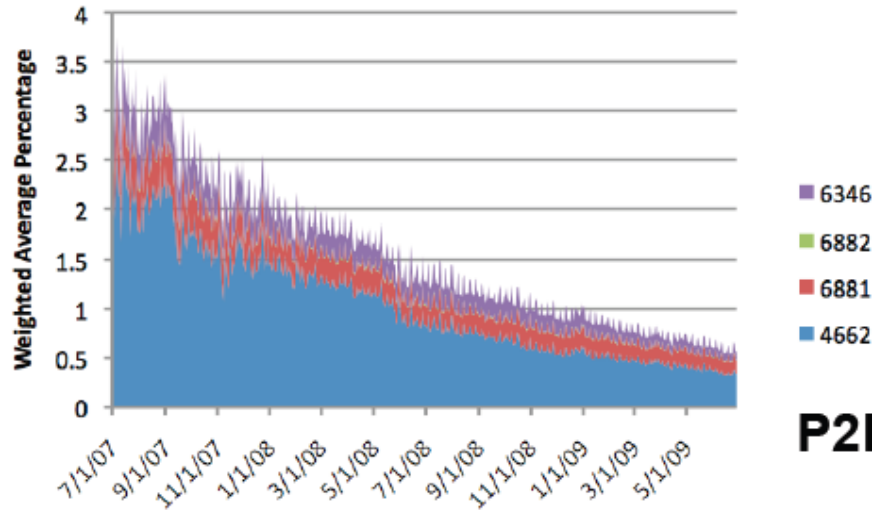
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Questions to be answered

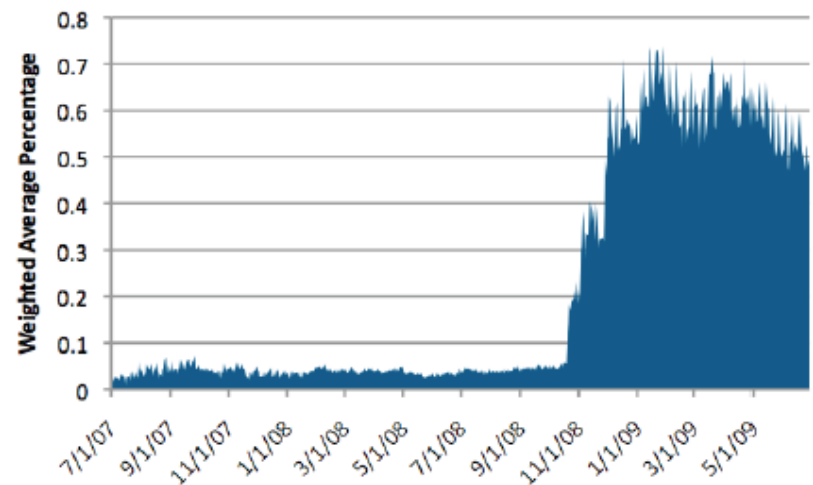
- ❑ Why do the results vary by study?
- ❑ What does it mean to be representative?
- ❑ How can one determine the application mix?
- ❑ What about user privacy?

P2P vs. Direct Download Providers

Global P2P Trends



P2P Replaced by Direct Download



Questions to be answered

- ❑ Why do the results vary by study?
- ❑ What does it mean to be representative?
- ❑ How can one determine the application mix?
- ❑ What about user privacy?
- ❑ What about individual applications?
 - P2P
 - Gaming
 - Online Social Networks
 - ...