Internet Measurement
& Analysis (IMA)

Measuring the Web: Part I

Content Delivery Networks' Infrastructure

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Acknowledgement

Material presented in these slides is borrowed from presentations by:
Mike Freedman (Princeton University),
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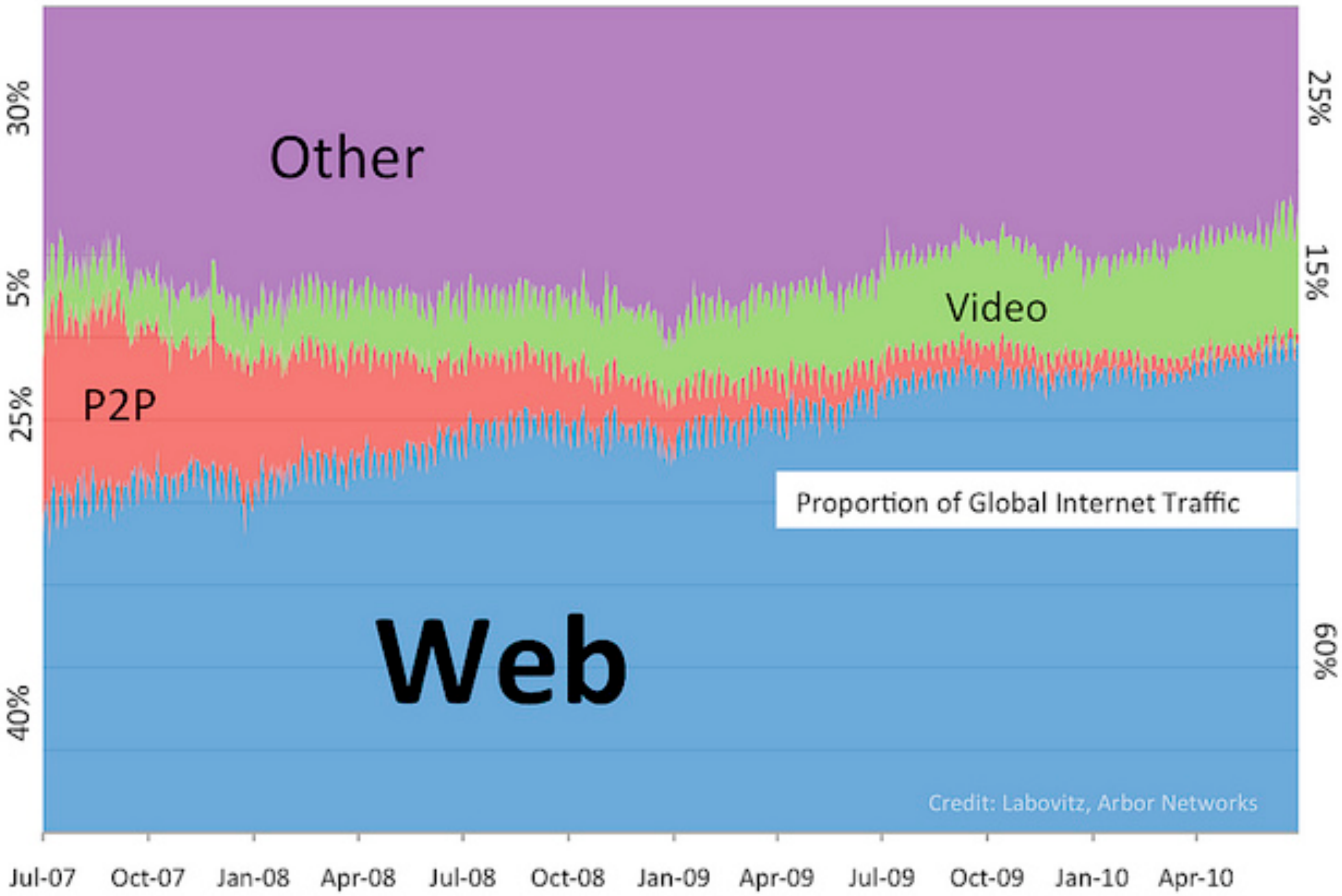
Fabian Bustamante (Northeastern University),
Tobias Flach (University of South California),
Bruce Maggs (Duke University/Akamai)

Today's Internet Traffic

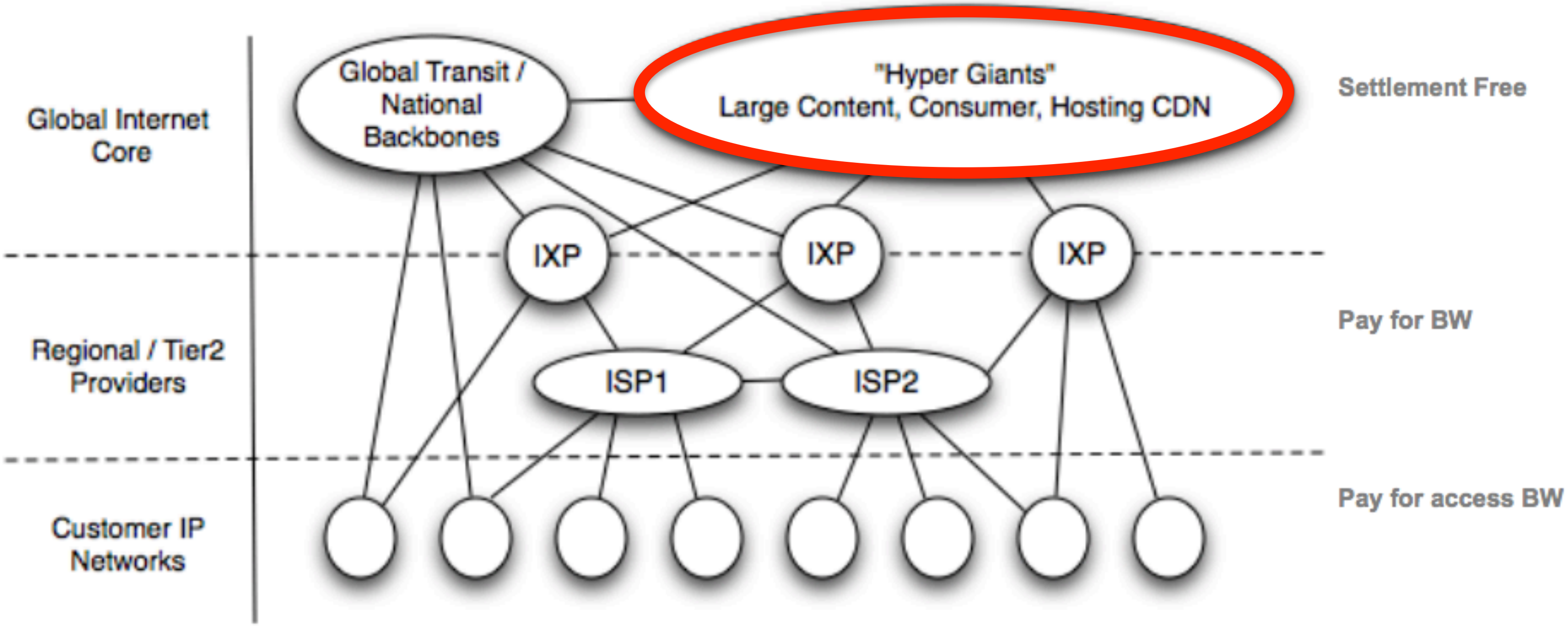


– Web becomes main transport for video and everything else

– Thousands small web sites subsumed by large content Providers

- Web today is around 80% traffic

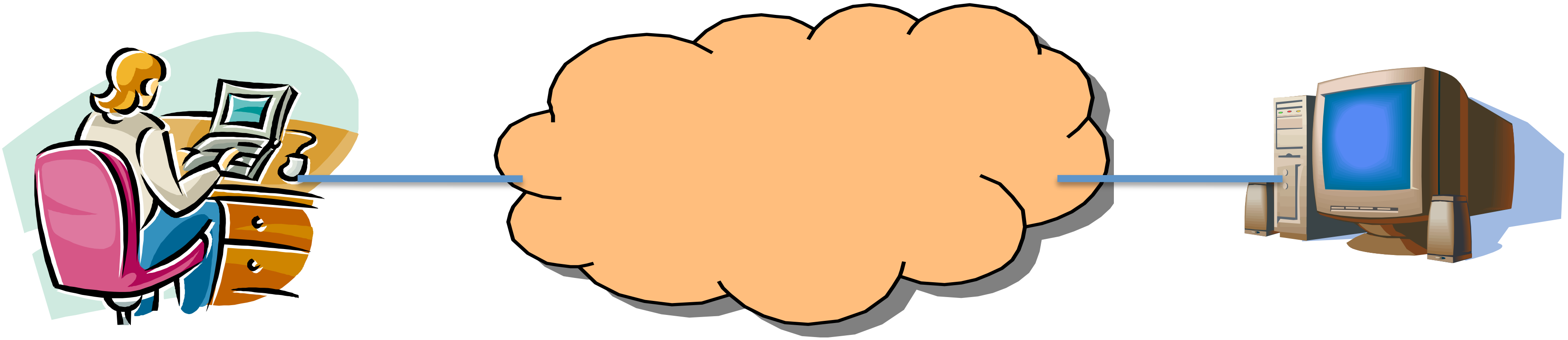
The New Internet



- Flatter and much more densely interconnected Internet
- Disintermediation between content and “eyeball” networks
- New commercial models between content, consumer and transit

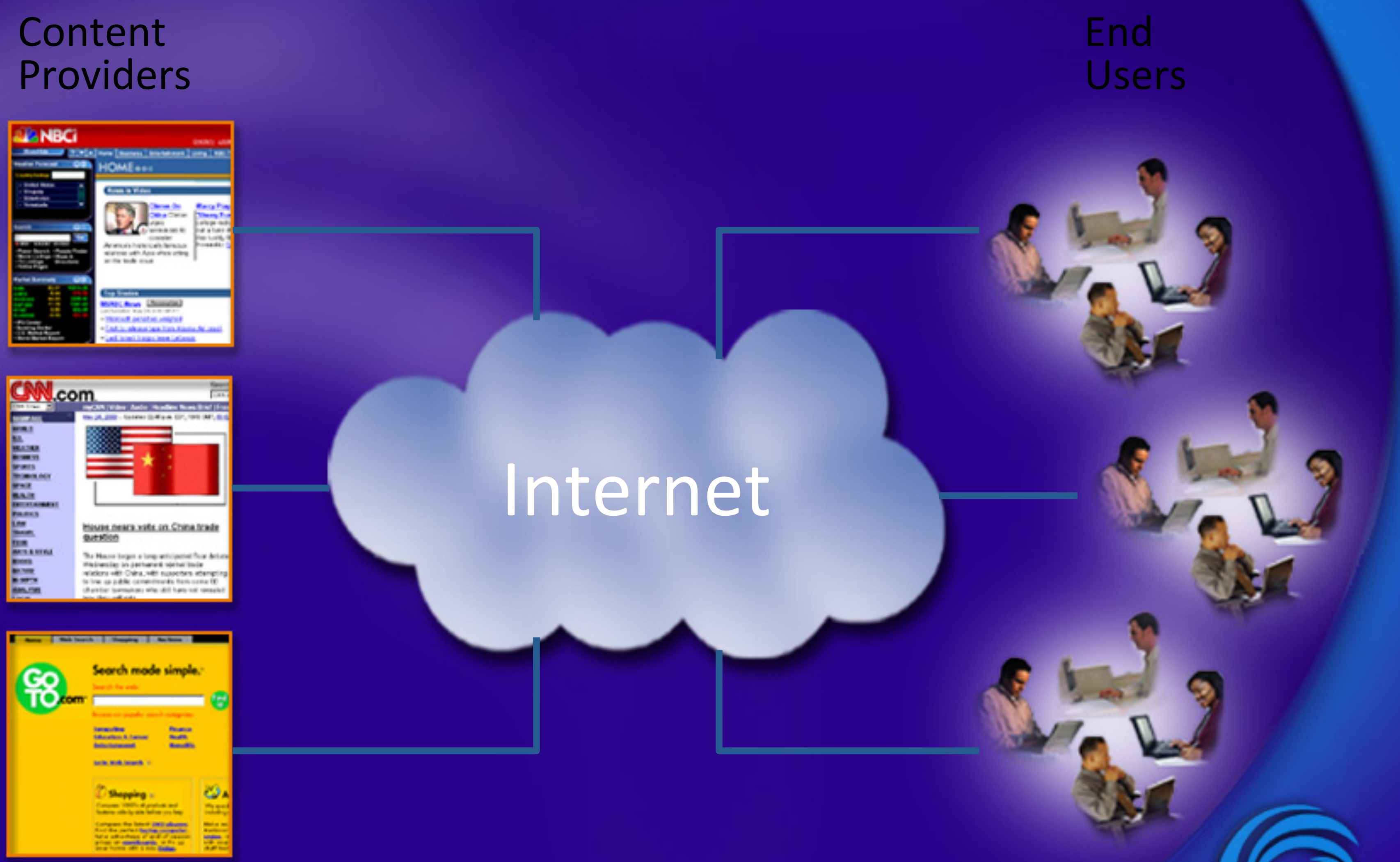
Source: “Interdomain Internet Traffic” SIGCOMM 2010

Single Server, Poor Performance

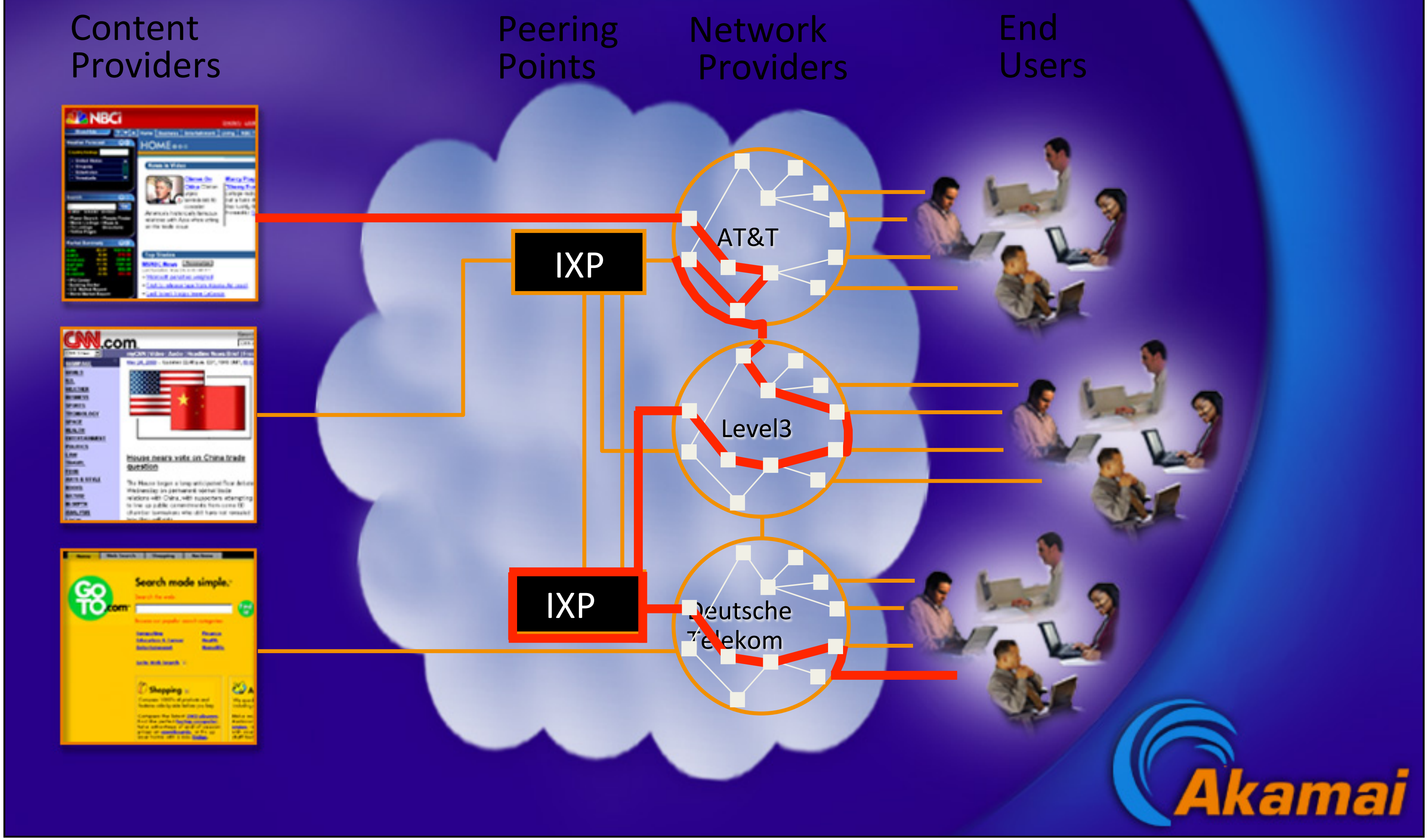


- Single server
  - Single point of failure
  - Easily overloaded
  - Far from most clients
- Popular content
  - Popular site
  - "Flash crowd" (aka "Slashdot effect")
  - Denial of Service attack

The Web:
Simple on the Outside…



...But Problematic on the Inside

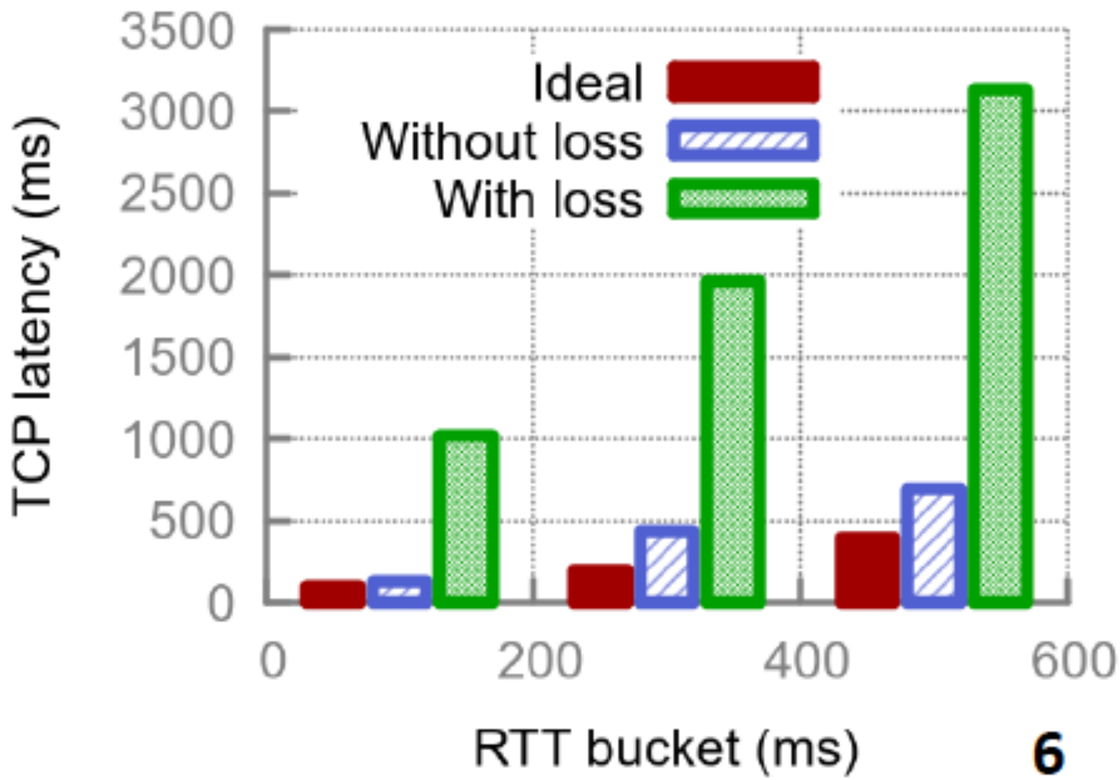


For TCP Distance Matters

Loss makes Web latency 5 times slower

Delays caused by TCP loss detection and recovery

6% of transfers between Google and clients are lossy



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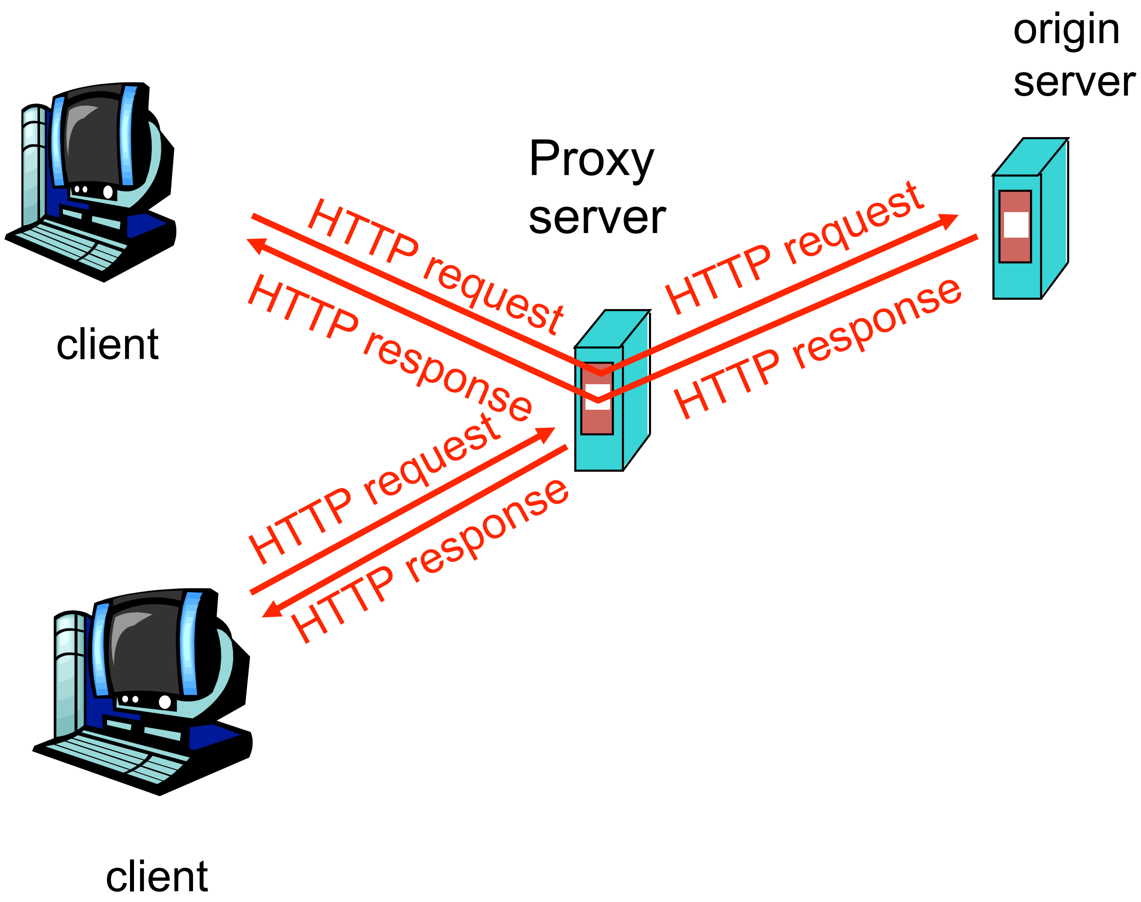
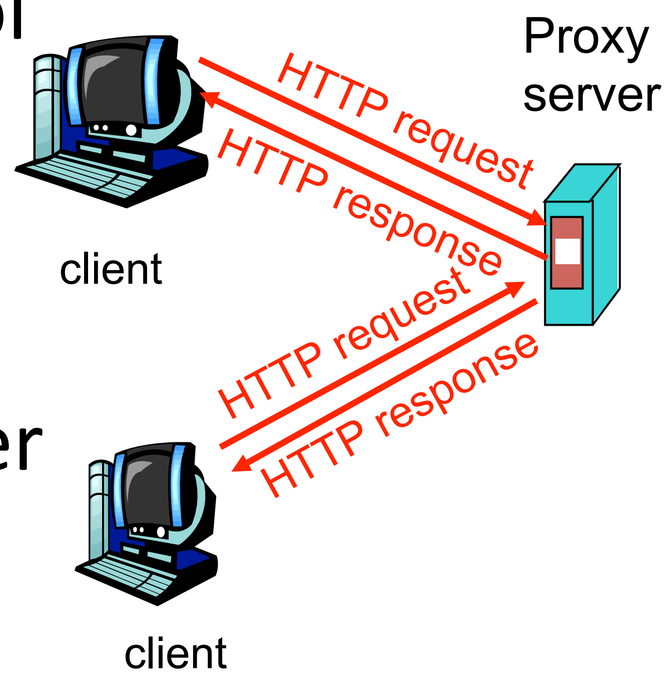
Utilizing Caching: Proxy Caches



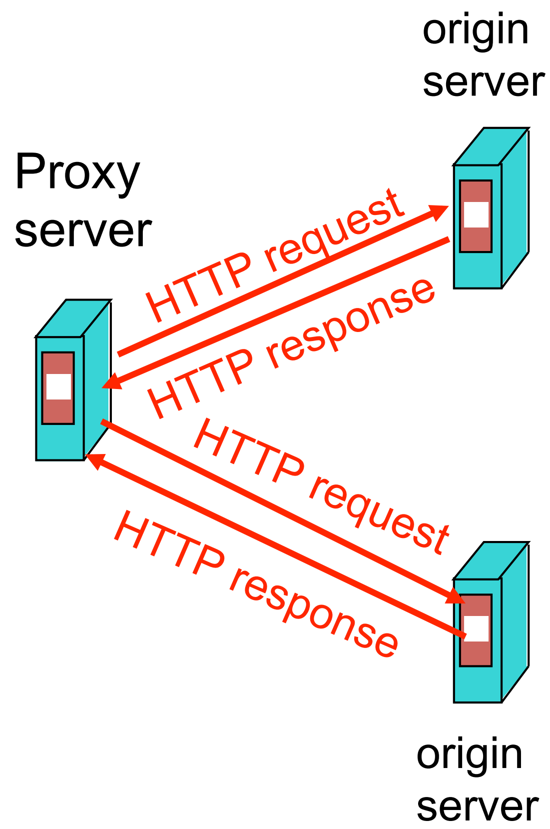
Forward Proxy

- Cache "close" to the client
  - Under administrative control of client-side AS
- Explicit proxy
  - Requires configuring browser
- Implicit/Transparent proxy
  - Service provider deploys an "on path" proxy
  - ... that intercepts and handles Web requests



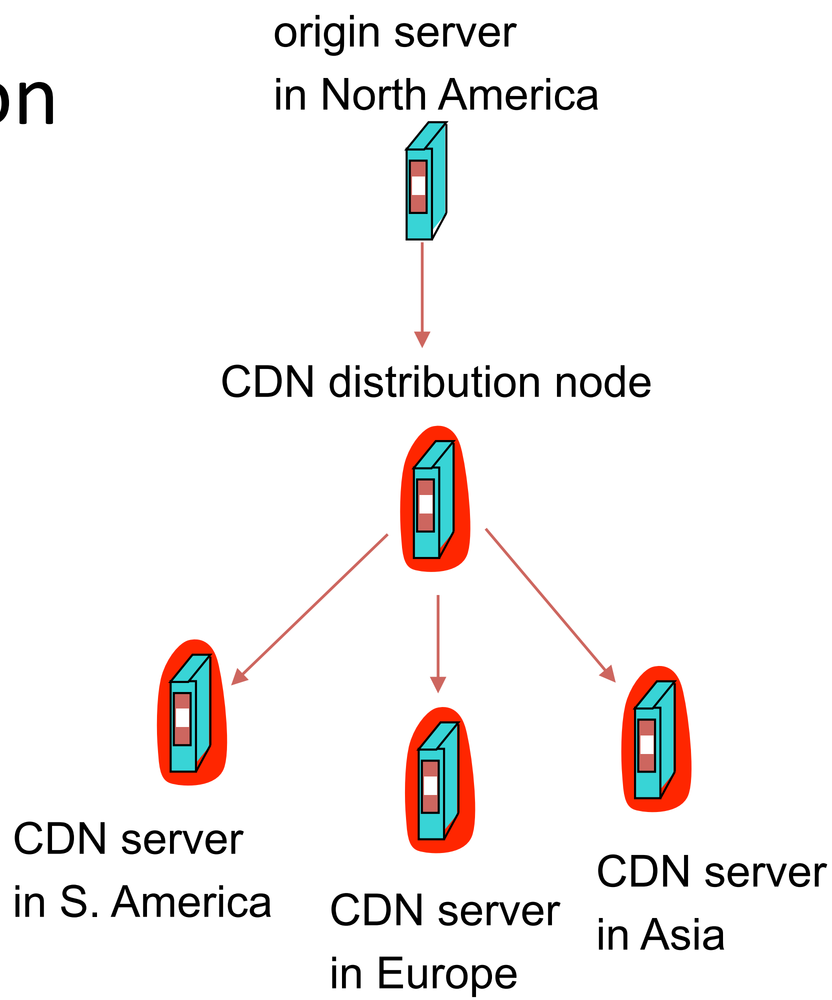
Reverse Proxy

- Cache "close" to server
  - Either proxy run by server or in third-party content distribution network (CDN)
- Directing clients to the proxy
  - Map the site name to the IP address of the proxy



Content Distribution Network

- Proactive content replication
  - Content provider (e.g., CNN) contracts with a CDN
- CDN replicates the content
  - On many servers spread throughout the Internet
- Updating the replicas
  - Updates pushed to replicas when the content changes



Server Selection Policy

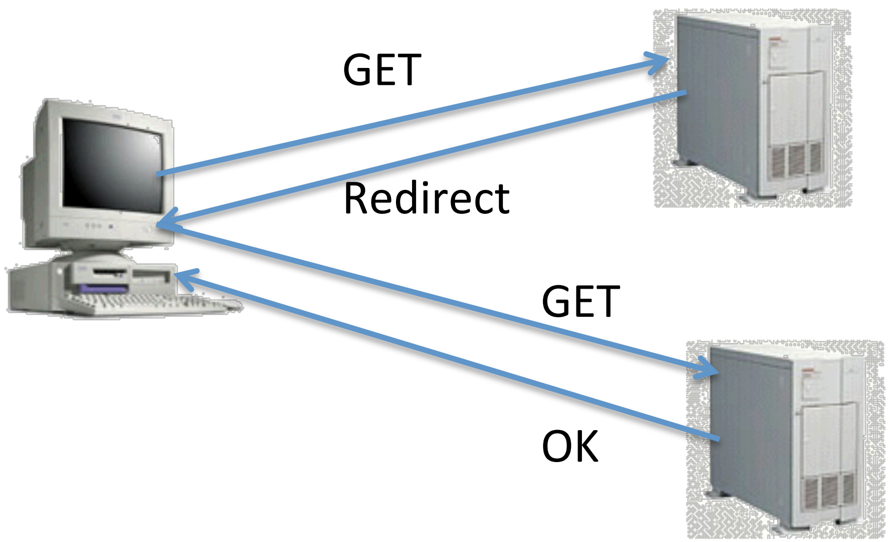
Requires continuous monitoring of liveness, load, and performance.

Monitoring includes traceroutes, pings, BGP updates etc

- Live server
  - For availability
- Lowest load
  - To balance load across the servers
- Closest
  - Nearest geographically, or in round-trip time
- Best performance
  - Throughput, latency, …
- Cheapest bandwidth, electricity, …

Server Selection Mechanism

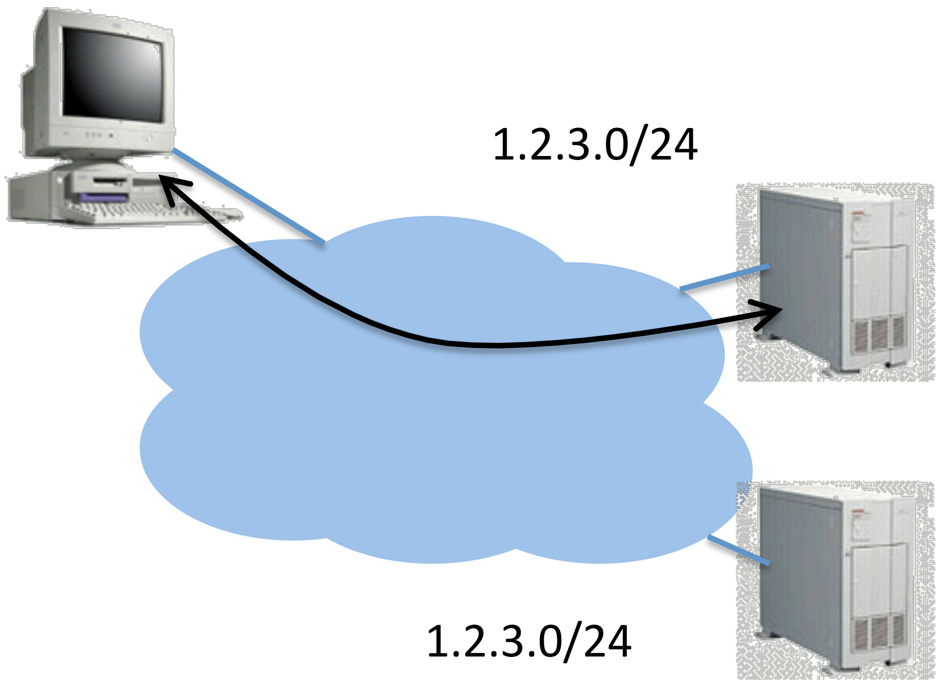
- Application
  - HTTP redirection



- Advantages
  - Fine-grain control
  - Selection based on client IP address
- Disadvantages
  - Extra round-trips for TCP connection to server
  - Overhead on the server

Server Selection Mechanism

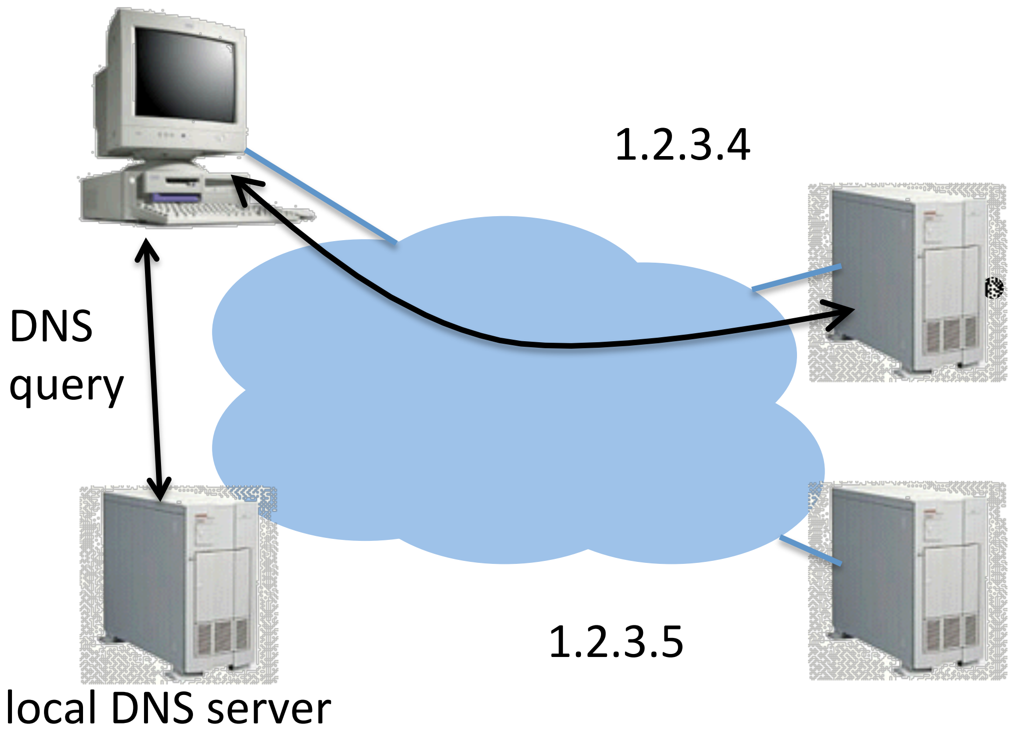
- Routing
  - Anycast routing



- Advantages
  - No extra round trips
  - Route to nearby server
- Disadvantages
  - Does not consider network or server load
  - Different packets may go to different servers
  - Used only for simple request-response apps

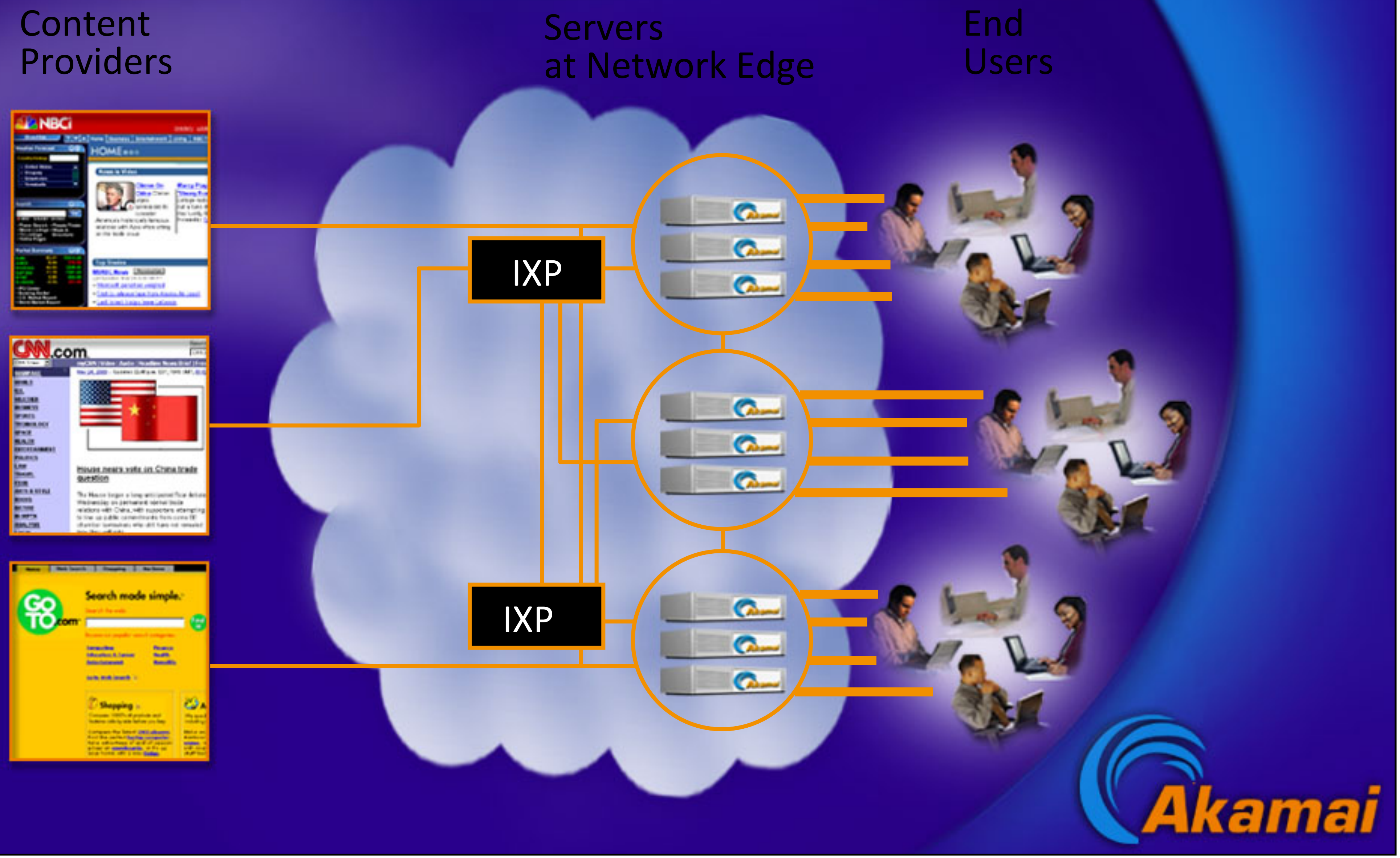
Server Selection Mechanism

- Naming
  - DNS-based server selection



- Advantages
  - Avoid TCP set-up delay
  - DNS caching reduces overhead
  - Relatively fine control
- Disadvantage
  - Based on IP address of local DNS server
  - “Hidden load” effect
  - DNS TTL limits adaptation

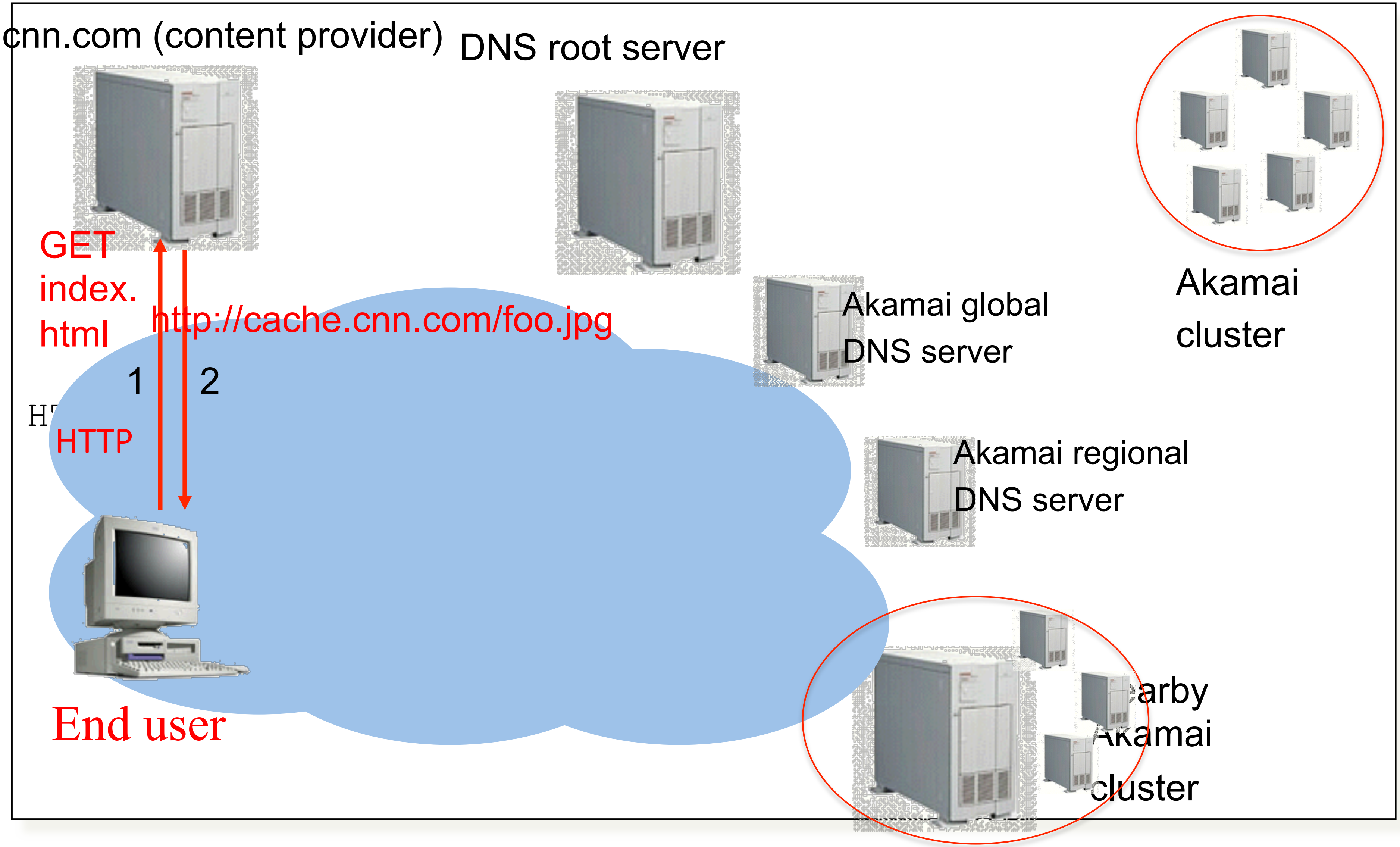
CDN example: Akamai



Akamai Statistics

- Distributed servers
  - Servers: ~150,000
  - Networks: ~1,100
  - Countries: ~90
- Many customers
  - Web portals
  - Streaming
  - E-commerce
- Client requests
  - Hundreds of billions per day
  - 15-20% of all Web traffic worldwide

How Akamai Uses DNS



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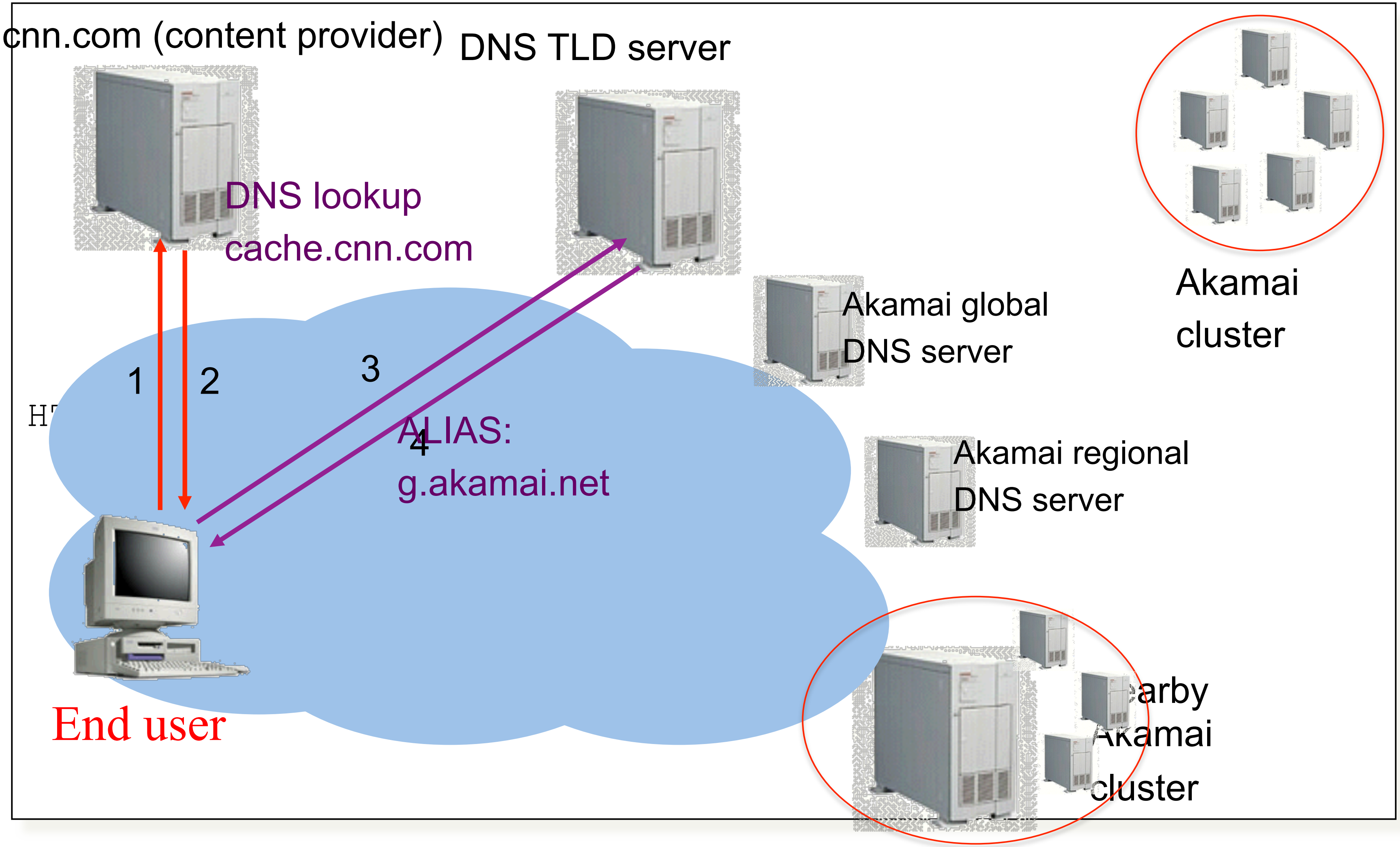

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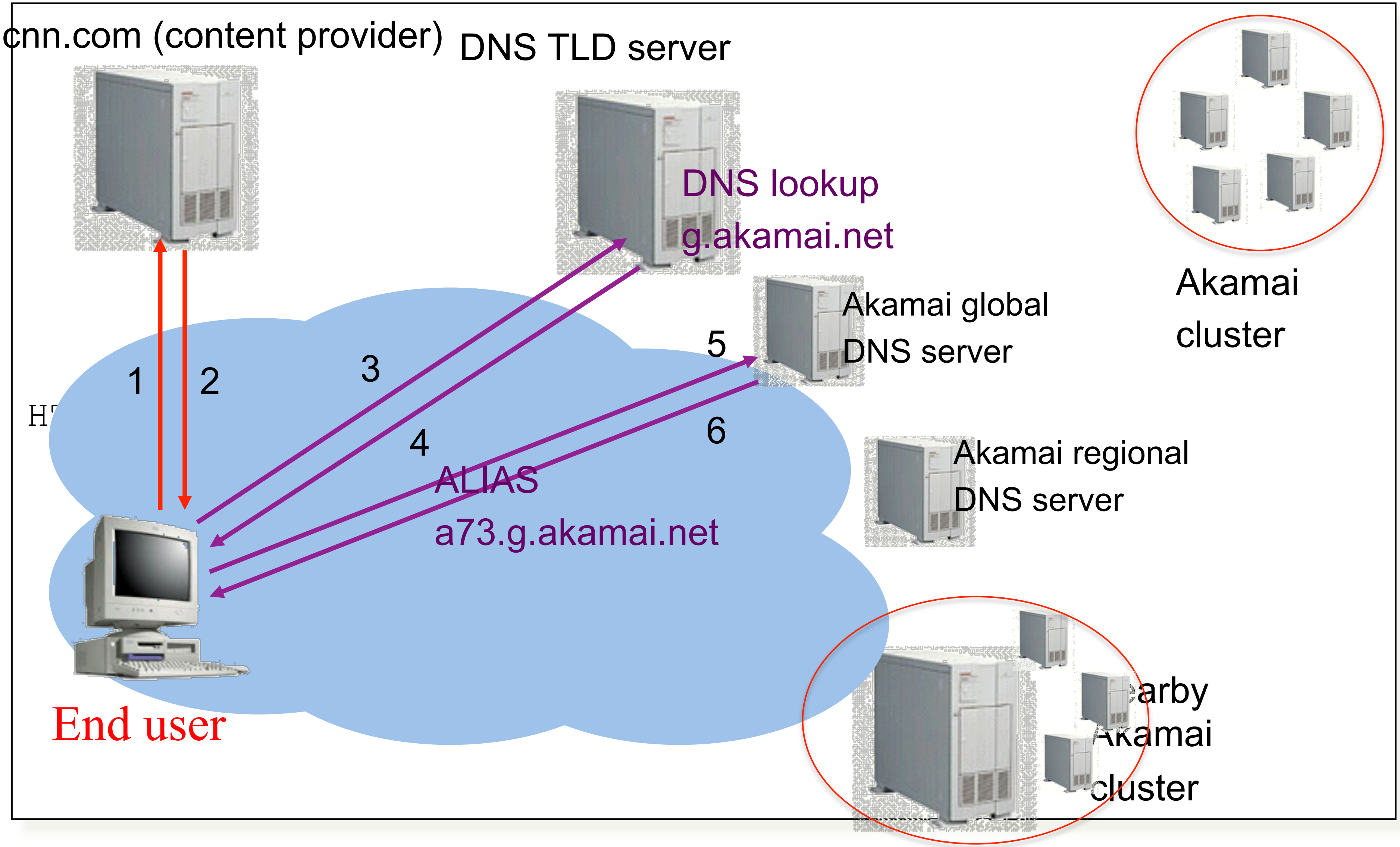

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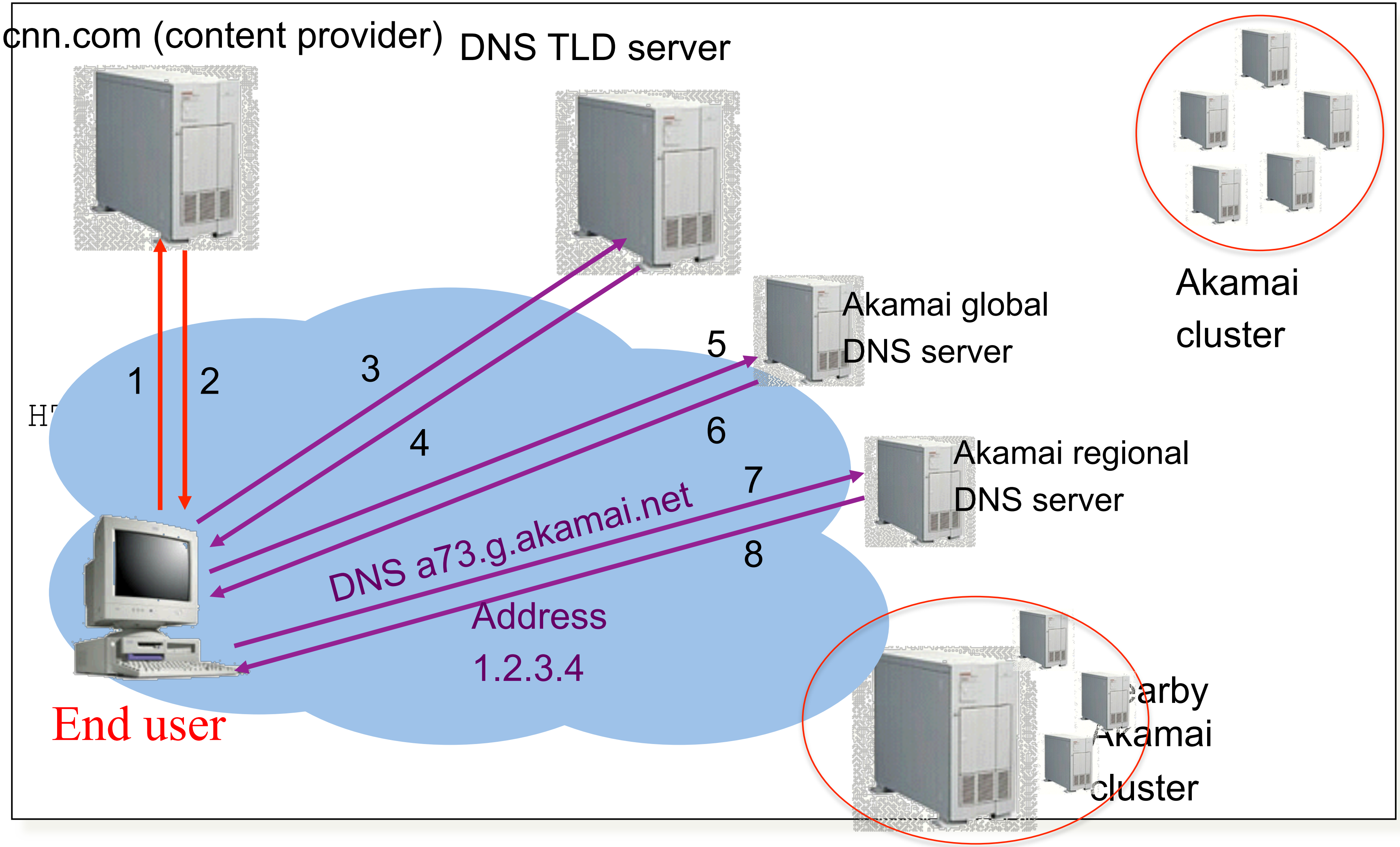

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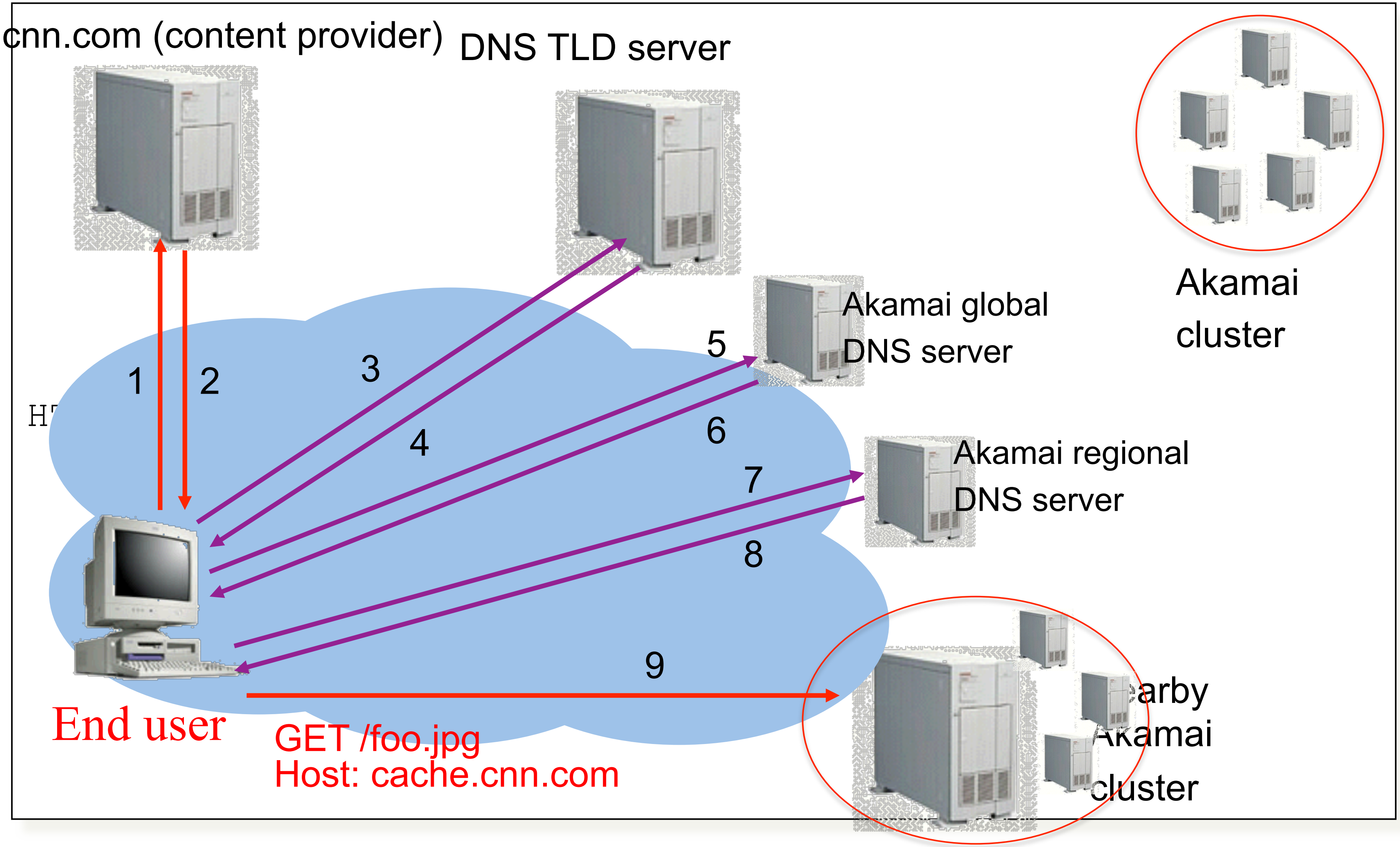

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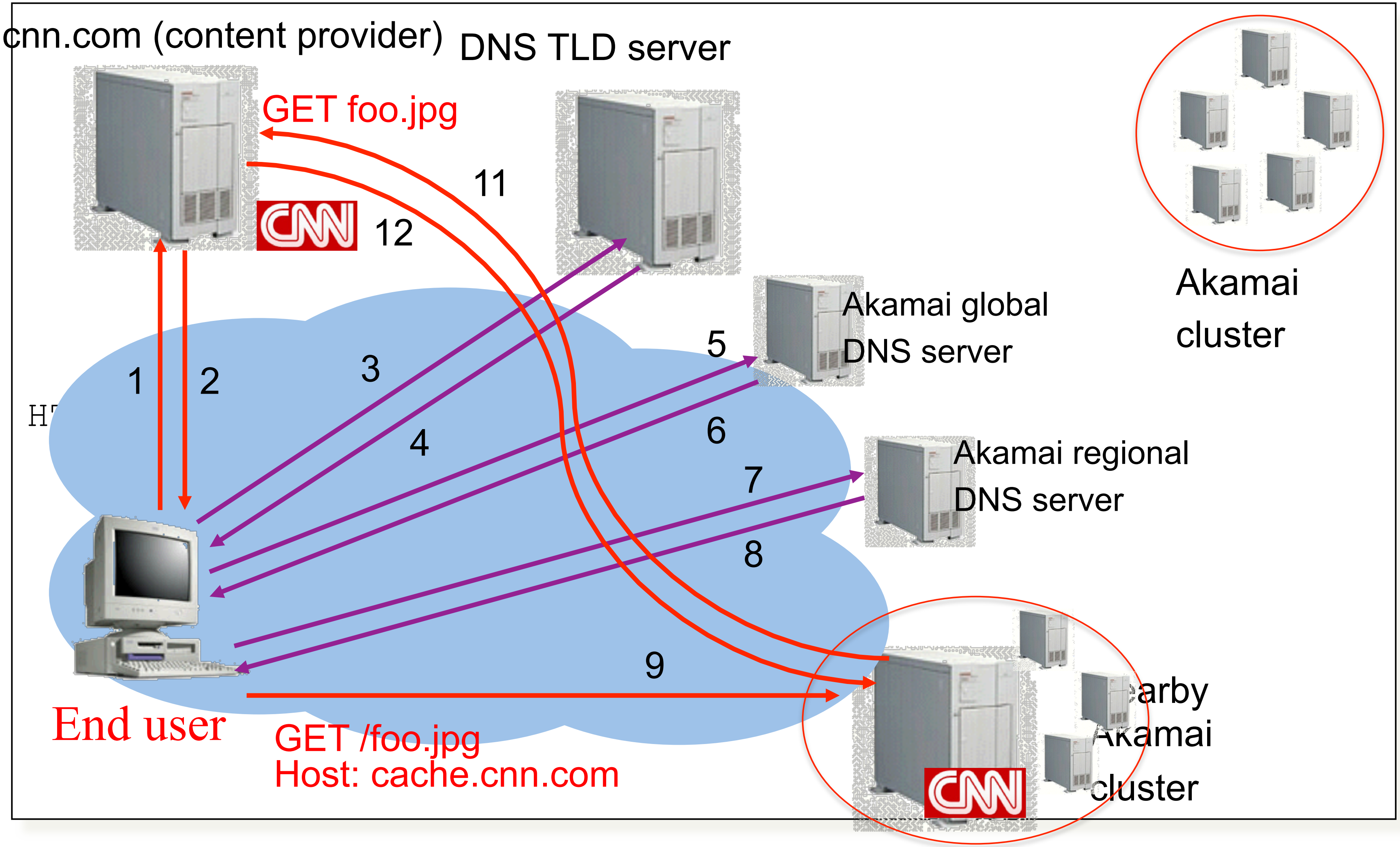

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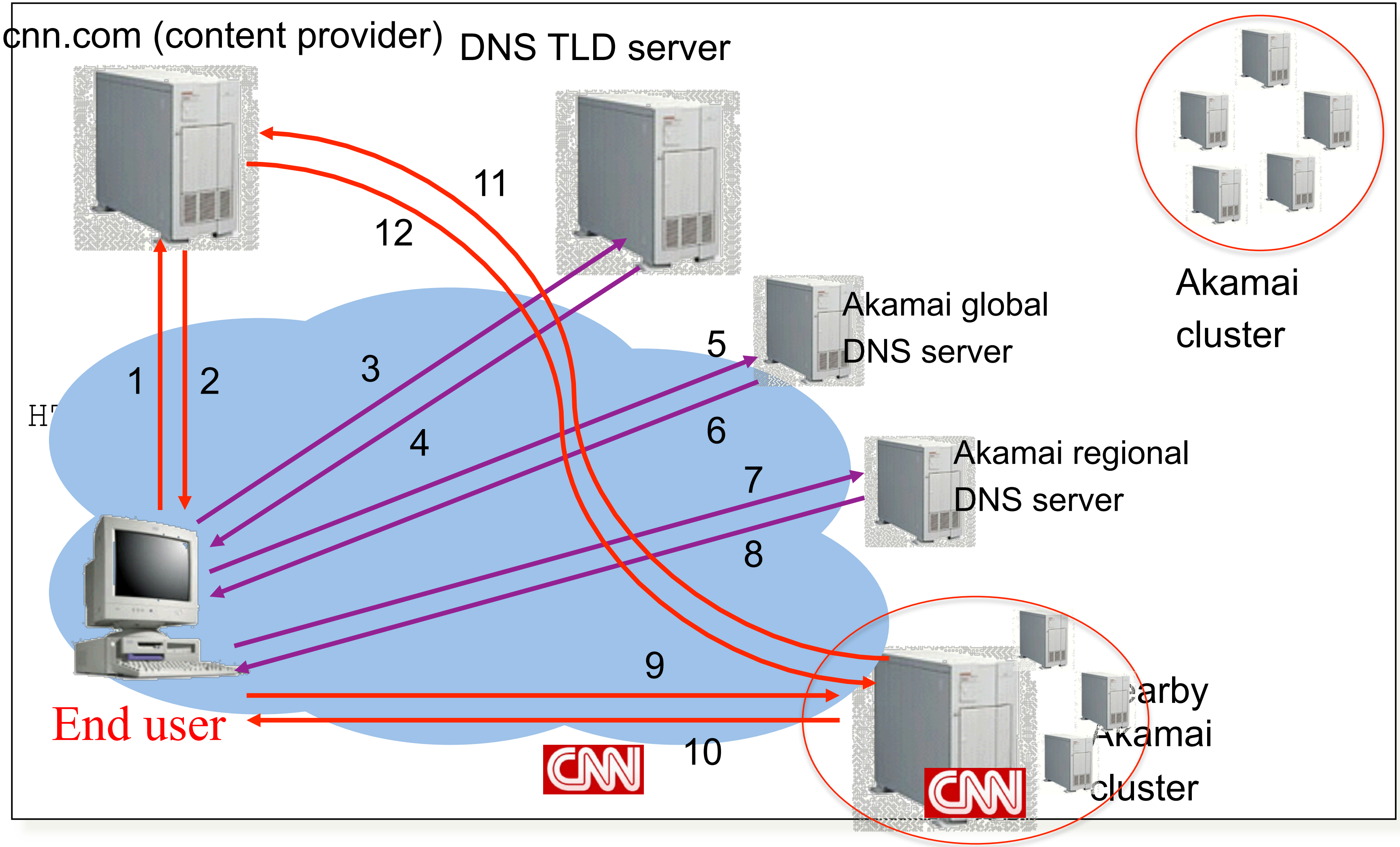
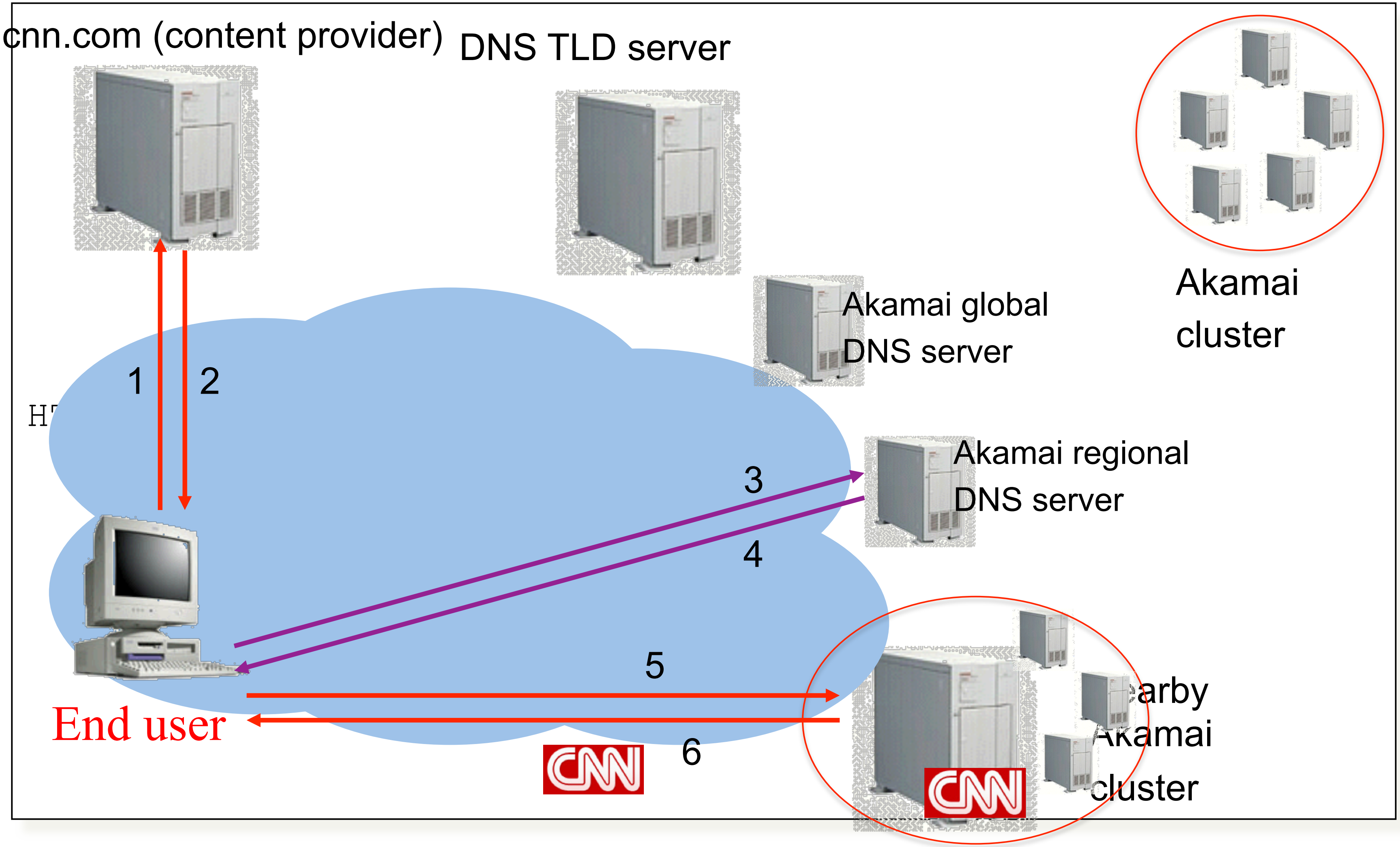
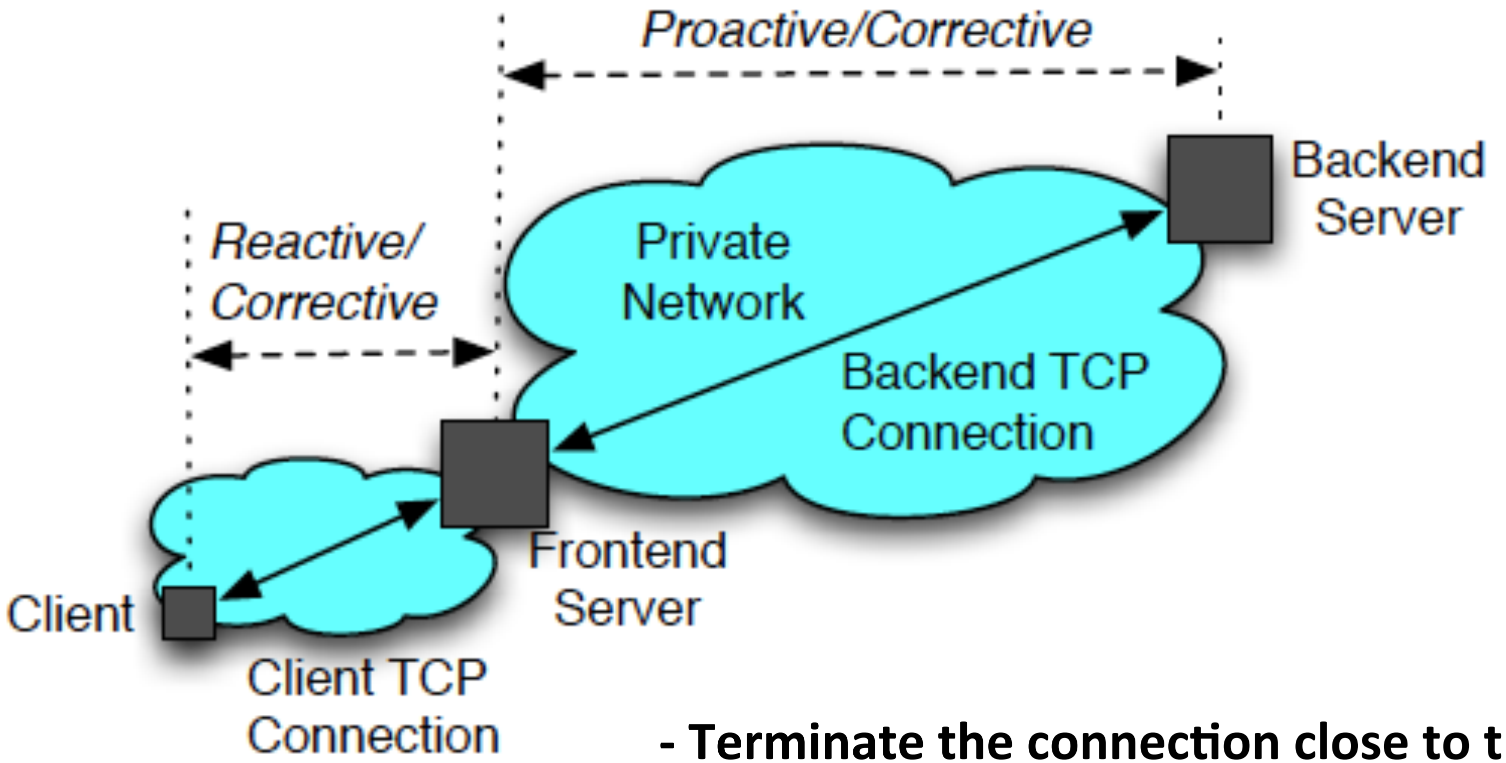


How Akamai Works: Cache Hit



Optimizations to Improve Performance and Increase Cache Hit



- Terminate the connection close to the end-user
- Utilize proprietary protocols between the servers

Example

```
georgios@giant:~$ dig www.audi.de

; <<>> DiG 9.9.5-9+deb8u11-Debian <<>> www.audi.de
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 40837
;; flags: qr rd ra; QUERY: 1, ANSWER: 3, AUTHORITY: 13, ADDITIONAL: 23

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.audi.de.                   IN      A

;; ANSWER SECTION:
www.audi.de.            333     IN      CNAME   www.audi.de.edgekey.net.
www.audi.de.edgekey.net. 21599  IN      CNAME   e9504.c.akamaiedge.net.
e9504.c.akamaiedge.net. 19      IN      A       23.43.125.172

;; AUTHORITY SECTION:
net.                    8514    IN      NS      h.gtld-servers.net.
net.                    8514    IN      NS      a.gtld-servers.net.
net.                    8514    IN      NS      i.gtld-servers.net.
net.                    8514    IN      NS      j.gtld-servers.net.
net.                    8514    IN      NS      l.gtld-servers.net.
net.                    8514    IN      NS      c.gtld-servers.net.
net.                    8514    IN      NS      d.gtld-servers.net.
net.                    8514    IN      NS      e.gtld-servers.net.
net.                    8514    IN      NS      f.gtld-servers.net.
net.                    8514    IN      NS      b.gtld-servers.net.
net.                    8514    IN      NS      m.gtld-servers.net.
net.                    8514    IN      NS      k.gtld-servers.net.
net.                    8514    IN      NS      g.gtld-servers.net.
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;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.audi.de.                   IN      A

;; ANSWER SECTION:
www.audi.de.            333     IN      CNAME   www.audi.de.edgekey.net.
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net.                    8514    IN      NS      j.gtld-servers.net.
net.                    8514    IN      NS      l.gtld-servers.net.
net.                    8514    IN      NS      c.gtld-servers.net.
net.                    8514    IN      NS      d.gtld-servers.net.
net.                    8514    IN      NS      e.gtld-servers.net.
net.                    8514    IN      NS      f.gtld-servers.net.
net.                    8514    IN      NS      b.gtld-servers.net.
net.                    8514    IN      NS      m.gtld-servers.net.
net.                    8514    IN      NS      k.gtld-servers.net.
net.                    8514    IN      NS      g.gtld-servers.net.
```

Redirection

Example

```
georgios@giant:~$ dig www.audi.de

; <<>> DiG 9.9.5-9+deb8u11-Debian <<>> www.audi.de
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 40837
;; flags: qr rd ra; QUERY: 1, ANSWER: 3, AUTHORITY: 13, ADDITIONAL: 2

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.audi.de.                    IN      A

;; ANSWER SECTION:
www.audi.de.            333      IN      CNAME   www.audi.de.edgekey.net.
www.audi.de.edgekey.net. 21599   IN      CNAME   e9504.c.akamaiedge.net.
e9504.c.akamaiedge.net. 19       IN      A       23.43.125.172

;; AUTHORITY SECTION:
net.
net.
net.
net.
net.
net.
net.
net.
net.
net.
net.
net.
net.
```

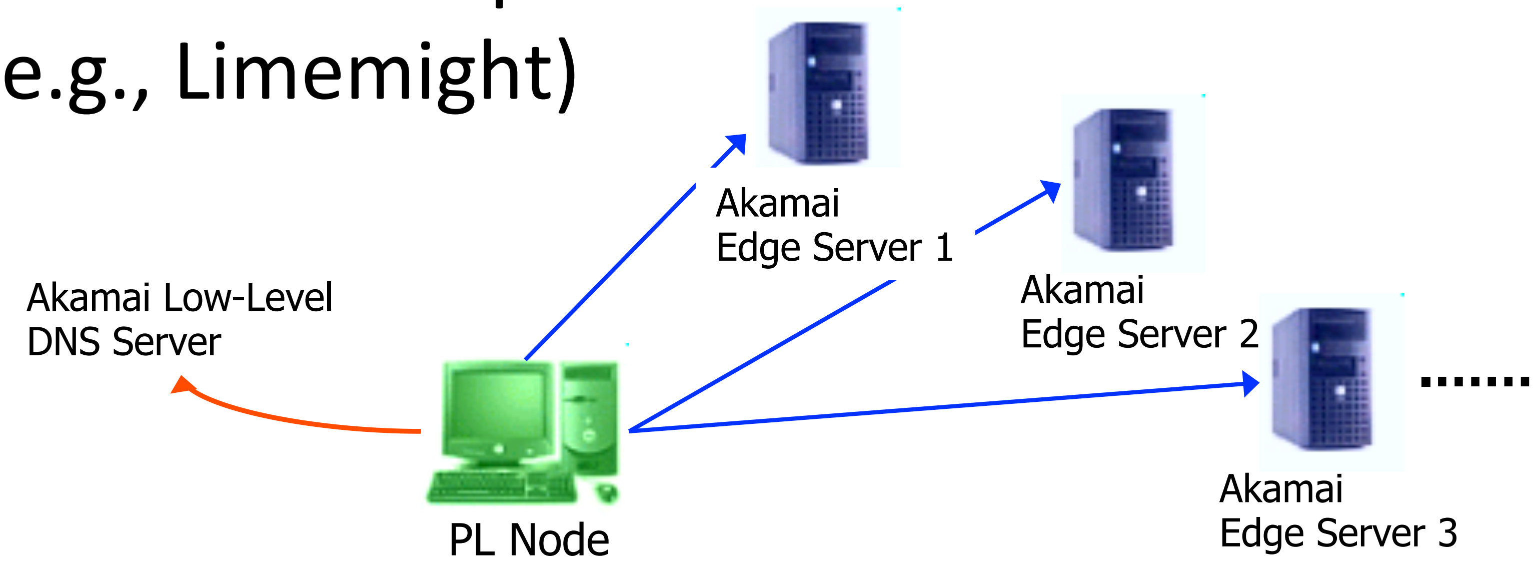
Redirection

$curl --insecure -v –H Host:www.audi.com
http://23.43.125.172/index.html

$curl --cert my-ca.crt –H Host:www.audi.com
http://23.43.125.172/index.html

Measuring CDNs

- Utilize a number of vantage points or Open DNS resolvers
- Every e.g., 60 secs, each vantage point queries an appropriate URL delivered by Akamai, or CNAMES (e.g., *.akamai.net)
- Similar technique can be used for other CDNs (e.g., Limemight)



Measuring CDNs

By utilizing a large number of vantage points or open resolvers it is possible to collect all the IPs of the CDNs!

Example of measurement in 2009:

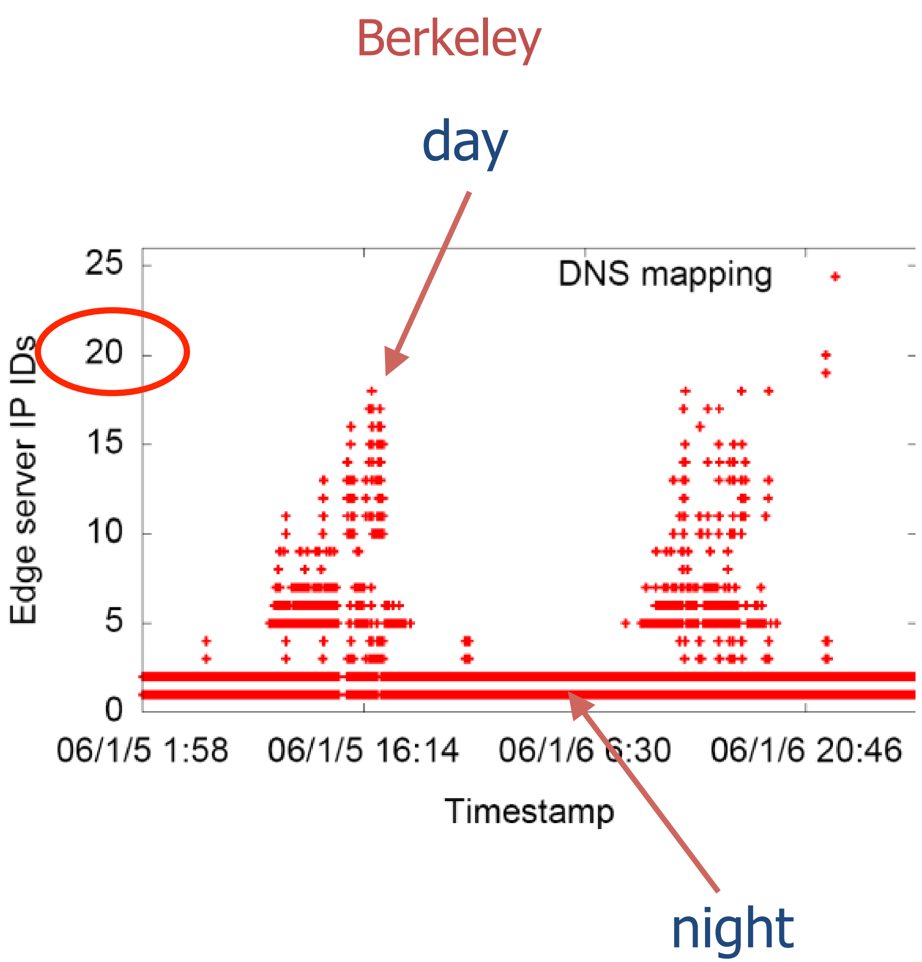
AKAMAI CDN: Country # of IP

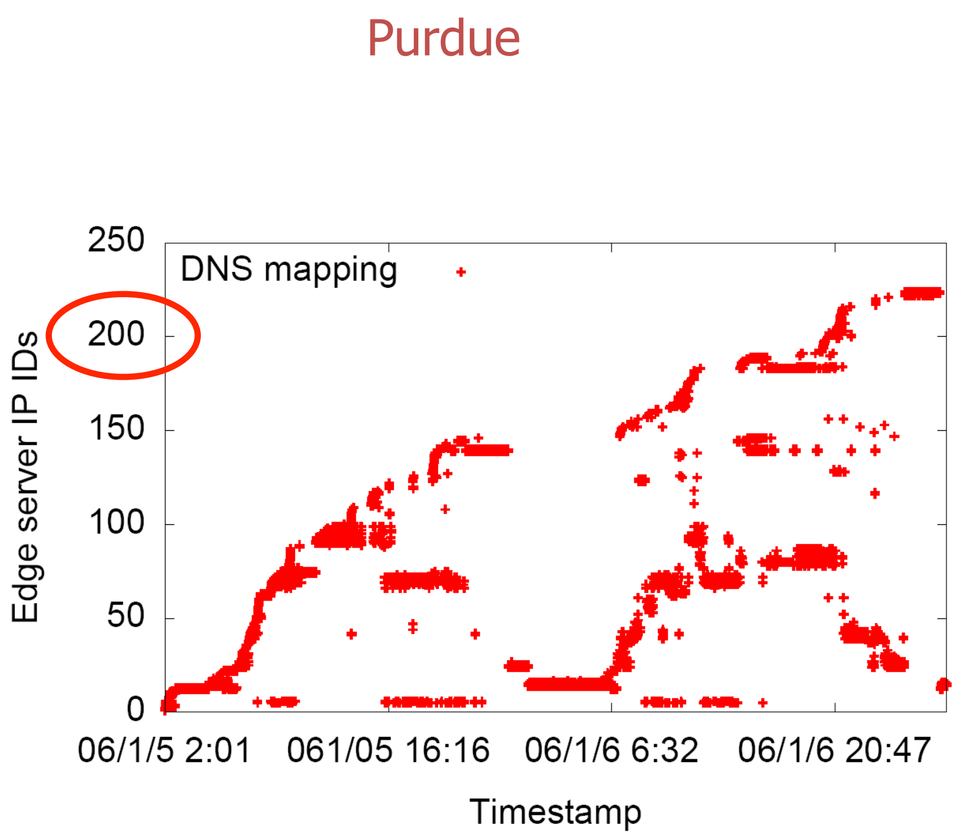
United States 16,843
United Kingdom 1,690
Japan 1,622
Germany 1,103
Netherlands 857
France 722
Australia 514
Canada 438
Sweden 396
Hong Kong SAR 370
Others 3018
Total 27,573

Limelight CDN: Country # of IP

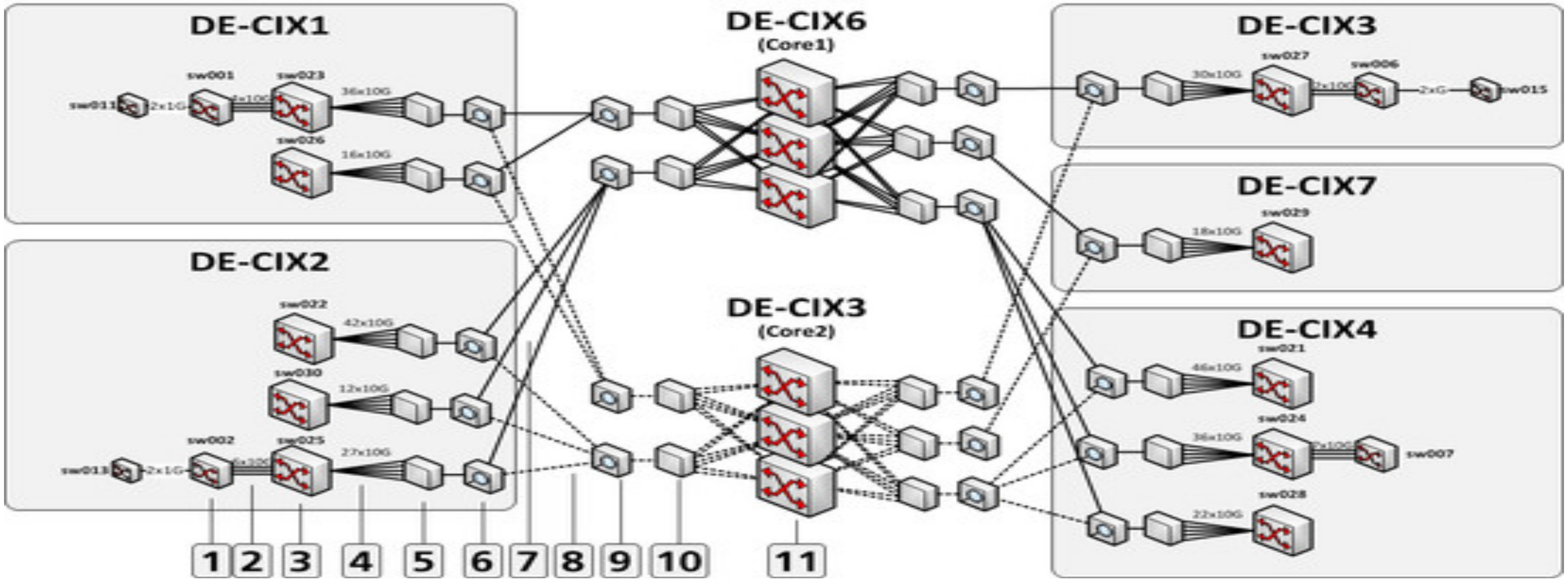
United States 2,830
Germany 314
United Kingdom 300
Netherlands 199
Japan 126
Canada 121
France 120
Hong Kong SAR 83
China 53
Australia 1
Total 4,147

Measuring CDNs



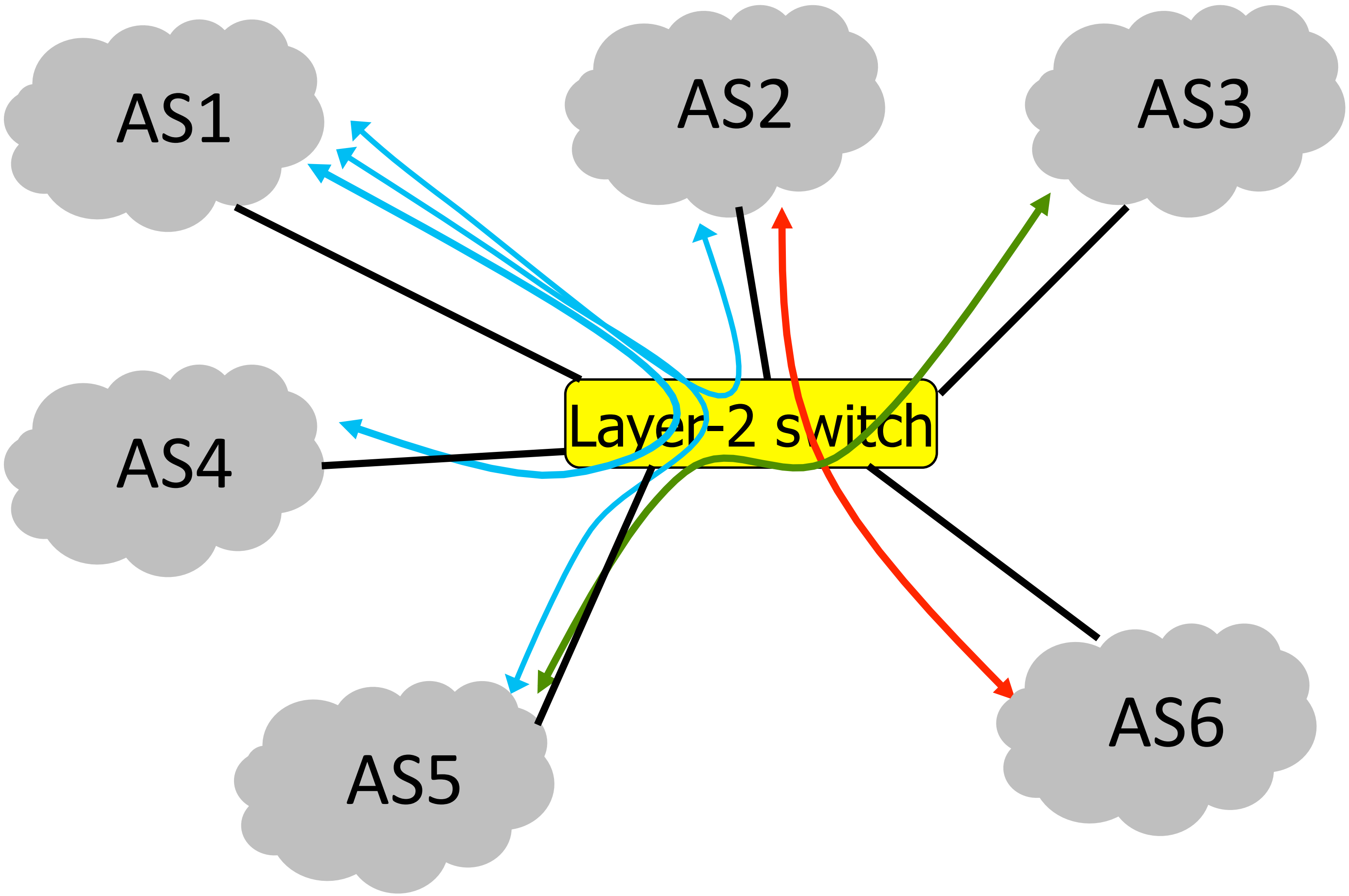


Where to Measure CDN and Web traffic? Option 1: IXP infrastructure

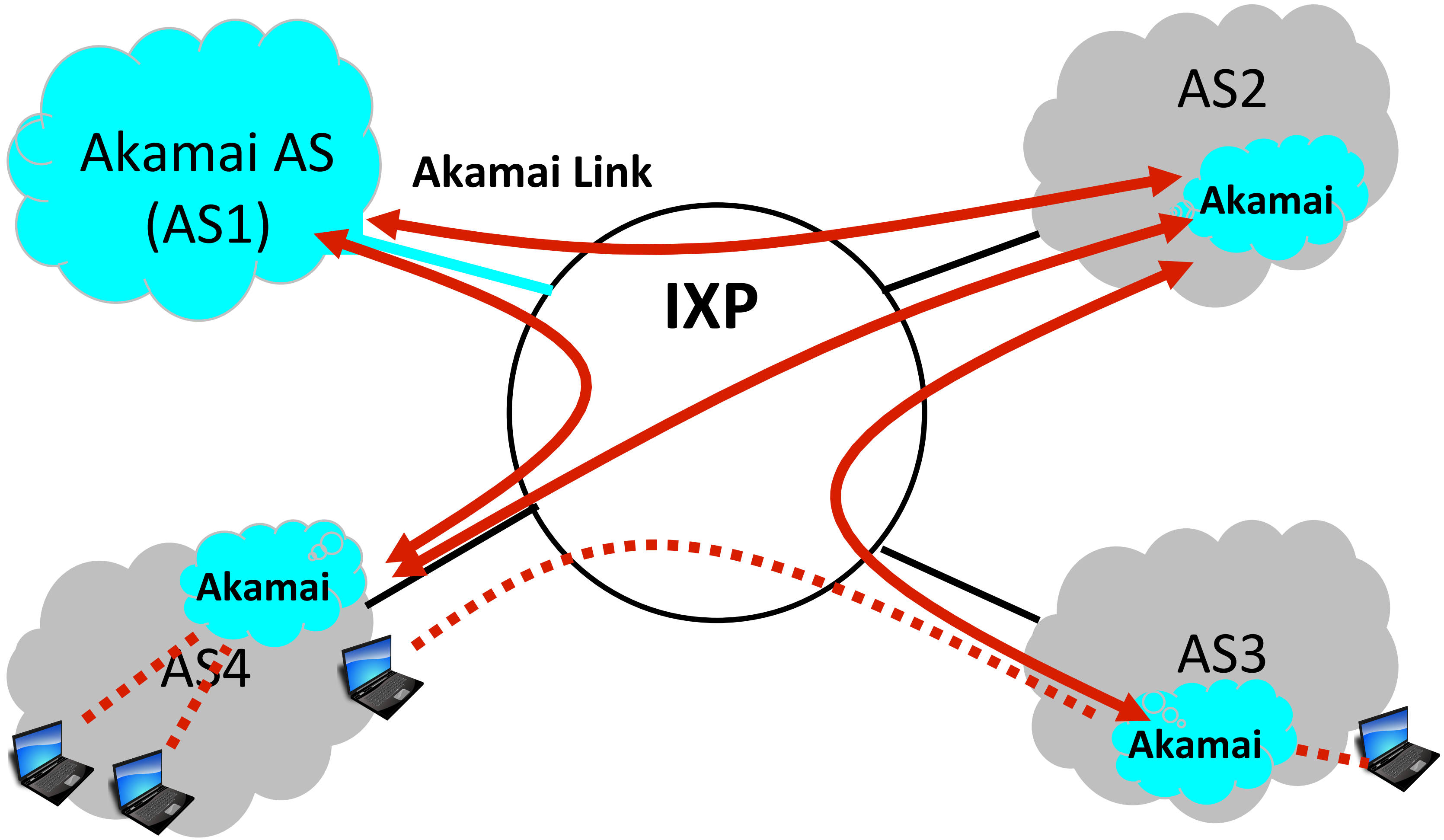


- Complex system
- Centralized monitoring

Internet eXchange Point (IXP)

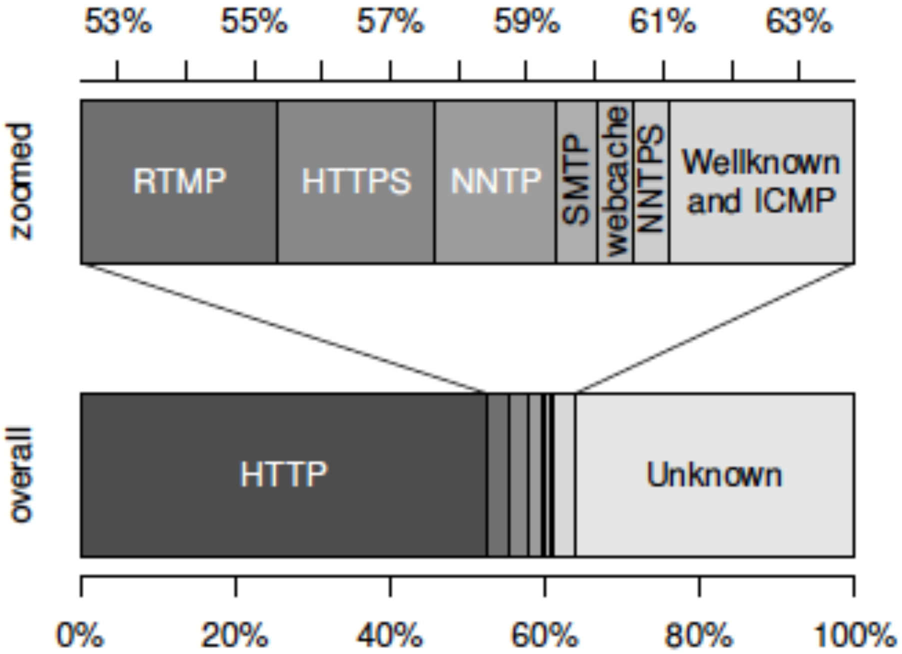


Estimation of CDN and Web traffic



IXP Results

- Around 70% of the traffic is Web (Large IXP, 2012)



- A relative small number of large CDNs, Hosters, and Streaming providers are responsible for >50% of the traffic

Where to Measure CDN and Web traffic? Option 2: Private peering locations

- ARBOR study:

- 110+ ISPs / content providers
- Including 3,000 edge routers and 100,000 interfaces
- And an estimated ~25% all inter-domain traffic

- AT&T Backbone study: Backbone, access, and mobile network

- Deutsche Telekom Study: Passive measurements from 20K residential users

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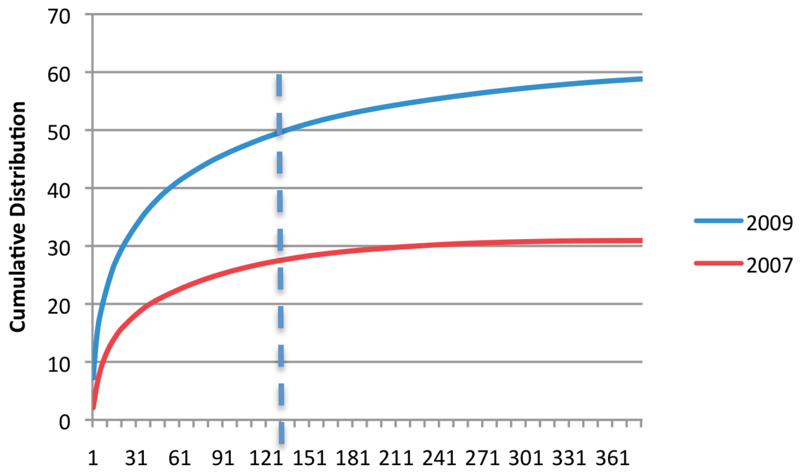
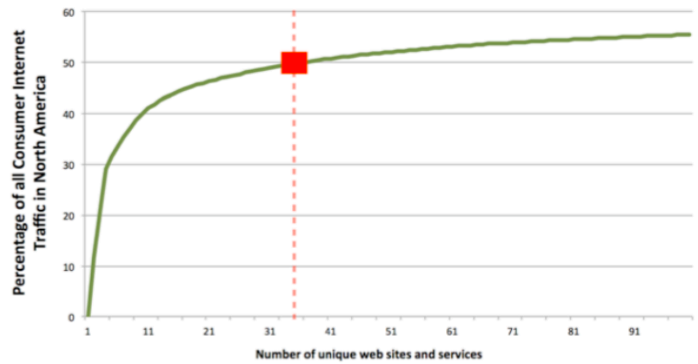
A Few Large CDNs and Datacenters are responsible for most of the Web



Arbor Study (2009-13):
Consolidation of Web Traffic

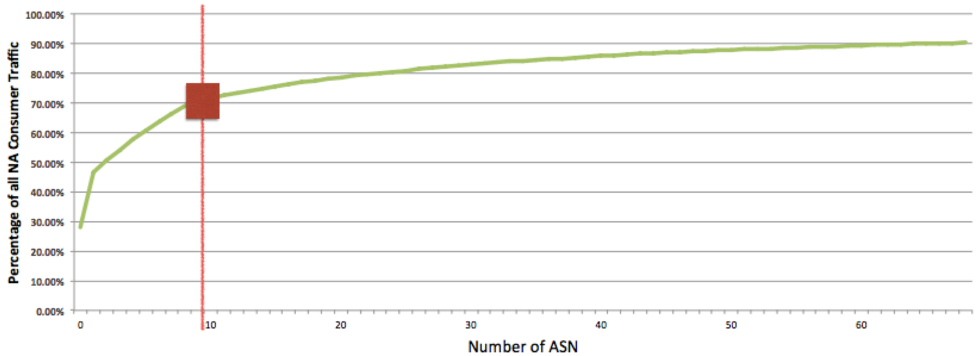
%Traffic due to CDNs
2009: 25%
2011: 35%
2013: 50%
2016: 90%

Internet Trends 2013



On average, **35 ASN generate 50% of consumer traffic** in 2013. CDF of ingress peak traffic to participating providers in North America in May 2013.

Internet Trends 2016



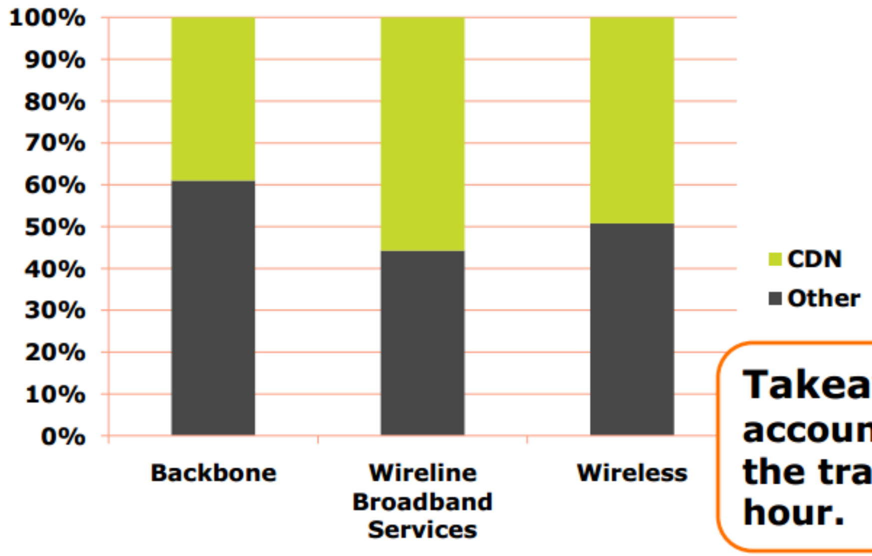
On average, **10 ASN generate 70% of consumer traffic** in 2016. 30 ASN contribute more than 80% of all traffic. Extremely heavy tailed distribution.

Where to Measure CDN and Web traffic? Option 2: Private peering locations

- AT&T Backbone study: Backbone, access, and mobile network

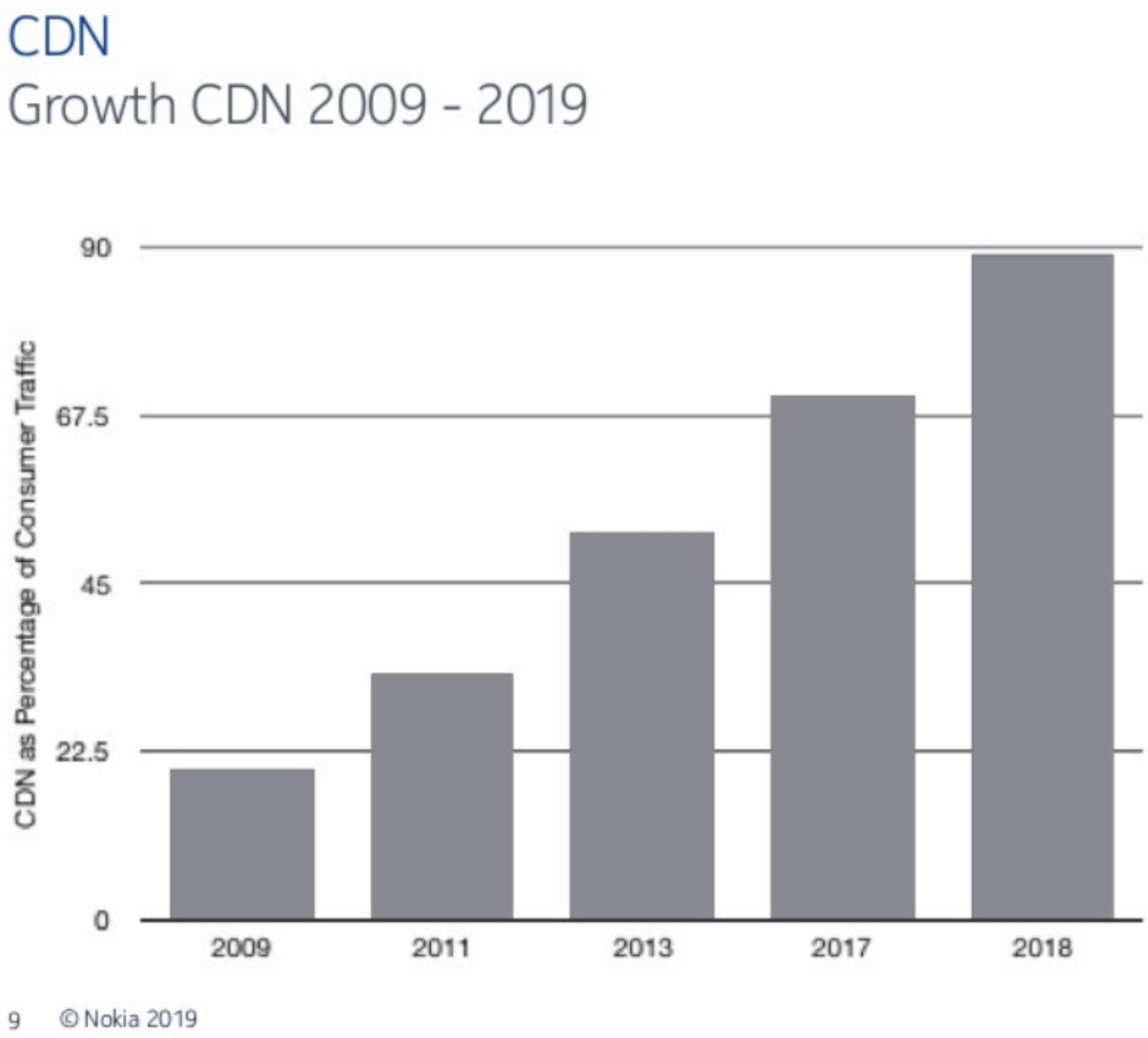
A Few Large CDNs and Datacenters are responsible for most of the Web

AT&T Study (2010)



Takeaway: A few CDNs account for 39% to 55% of the traffic during the busy hour.

How much Traffic is CDN?



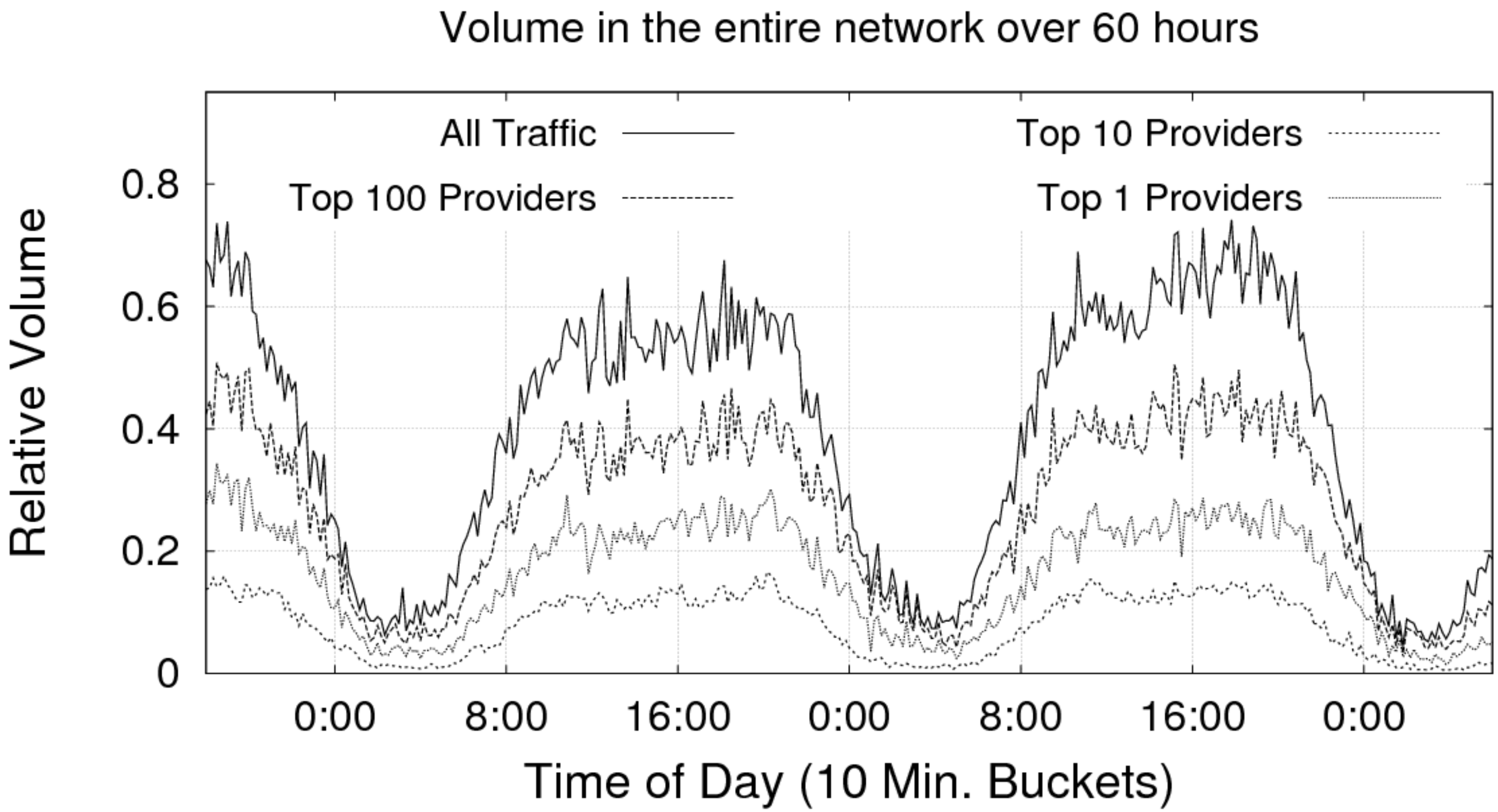
- Globally CDN account for 90% of consumer traffic by 2018
- Definition of CDN blurs as more content providers deploy edge cache and compute
- Nature of traffic changes as adaptive bit rate becomes the norm with automated traffic direction

Where to Measure CDN and Web traffic? Option 2: Private peering locations

- Deutsche Telekom Study: Passive measurements from 20K residential users

A Few Large CDNs and Datacenters are responsible for most of the Web

Deutsche Telekom Study (ca 2010-2013)



Readings

“The Akamai Network: A Platform for High-Performance Internet Applications”. Erik Nygren, Ramesh K. Sitaraman, and Jennifer Sun. SIGOPS 44(3), 2010

“Reducing Web Latency: the Virtue of Gentle Aggregation”, Tobias Flach et al. SIGCOMM 2013.