Class Meeting: Lectures 15 and 16
HTTP and the Web, Content Distribution Networks

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COS 461: *Computer Networks*

[Selected content adapted from M. Freedman, B. Maggs and S. Shenker]

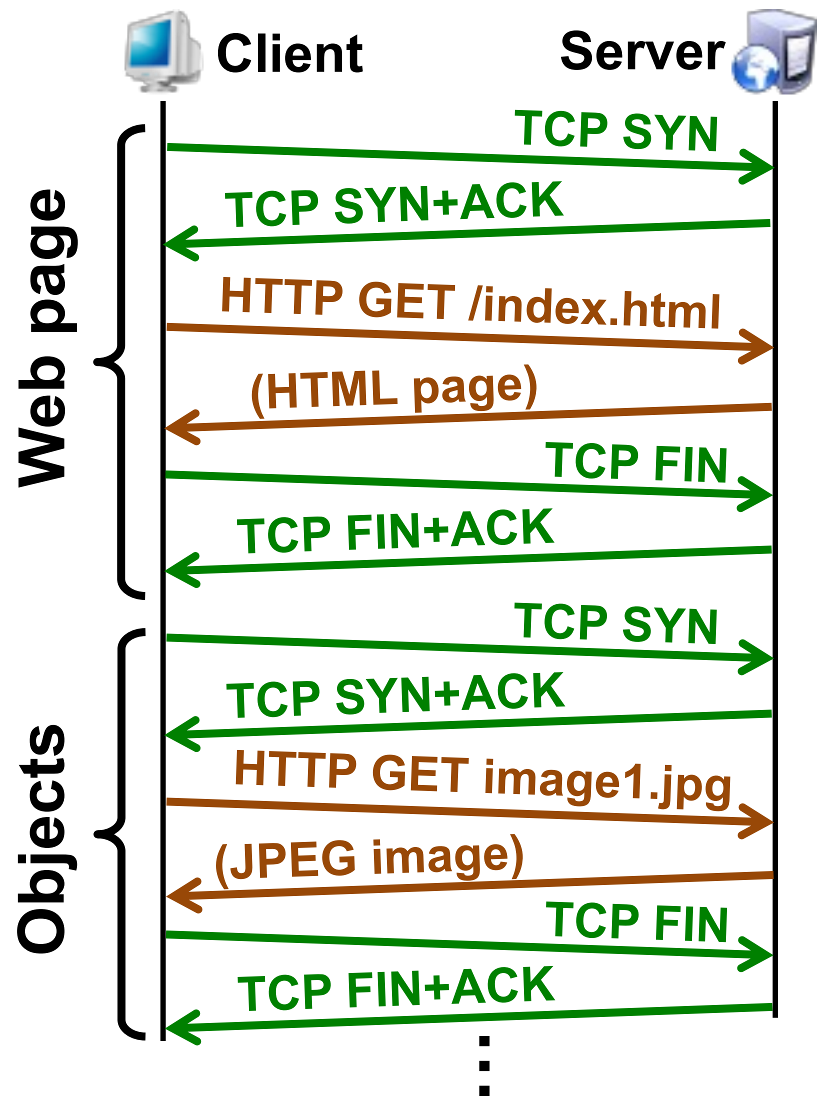
Today

1. The Web: HTTP, hosting, and caching

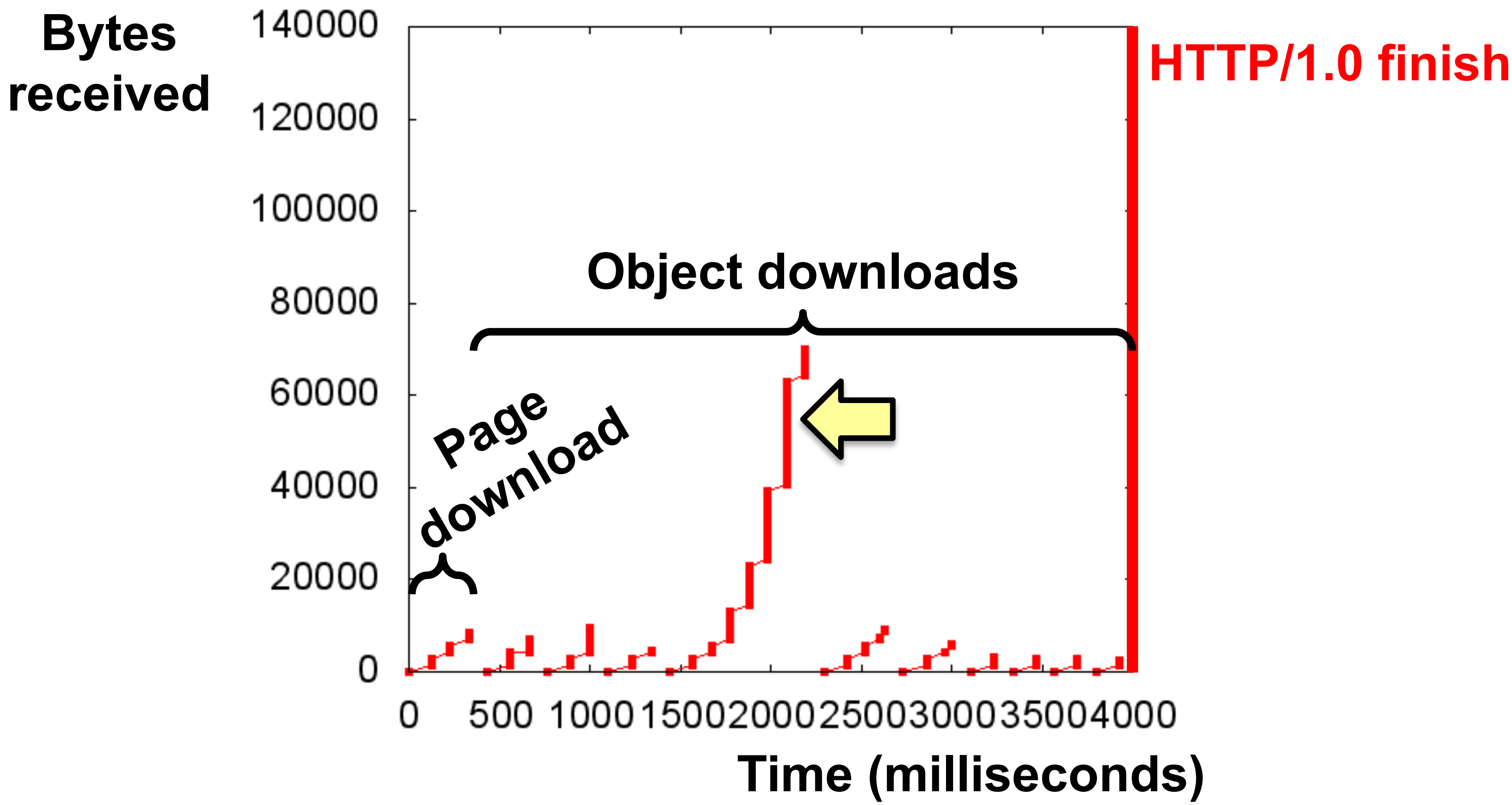
2. Content distribution networks (CDNs)

Anatomy of an HTTP/1.0 web page fetch

- Web page = HTML file + embedded images/objects
- *Stop-and-wait* at the granularity of objects:
  - Close then open new TCP connection for **each object**
    - Incurs a TCP RTT delay each time
  - Each TCP connection may stay in "slow start"



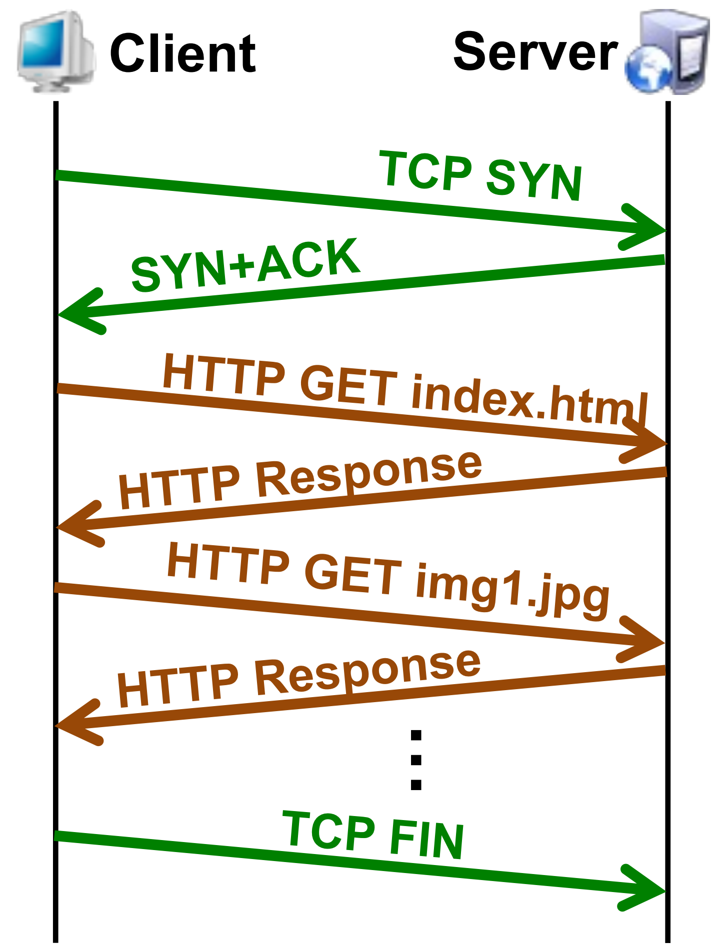
HTTP/1.0 webpage fetch: Timeline



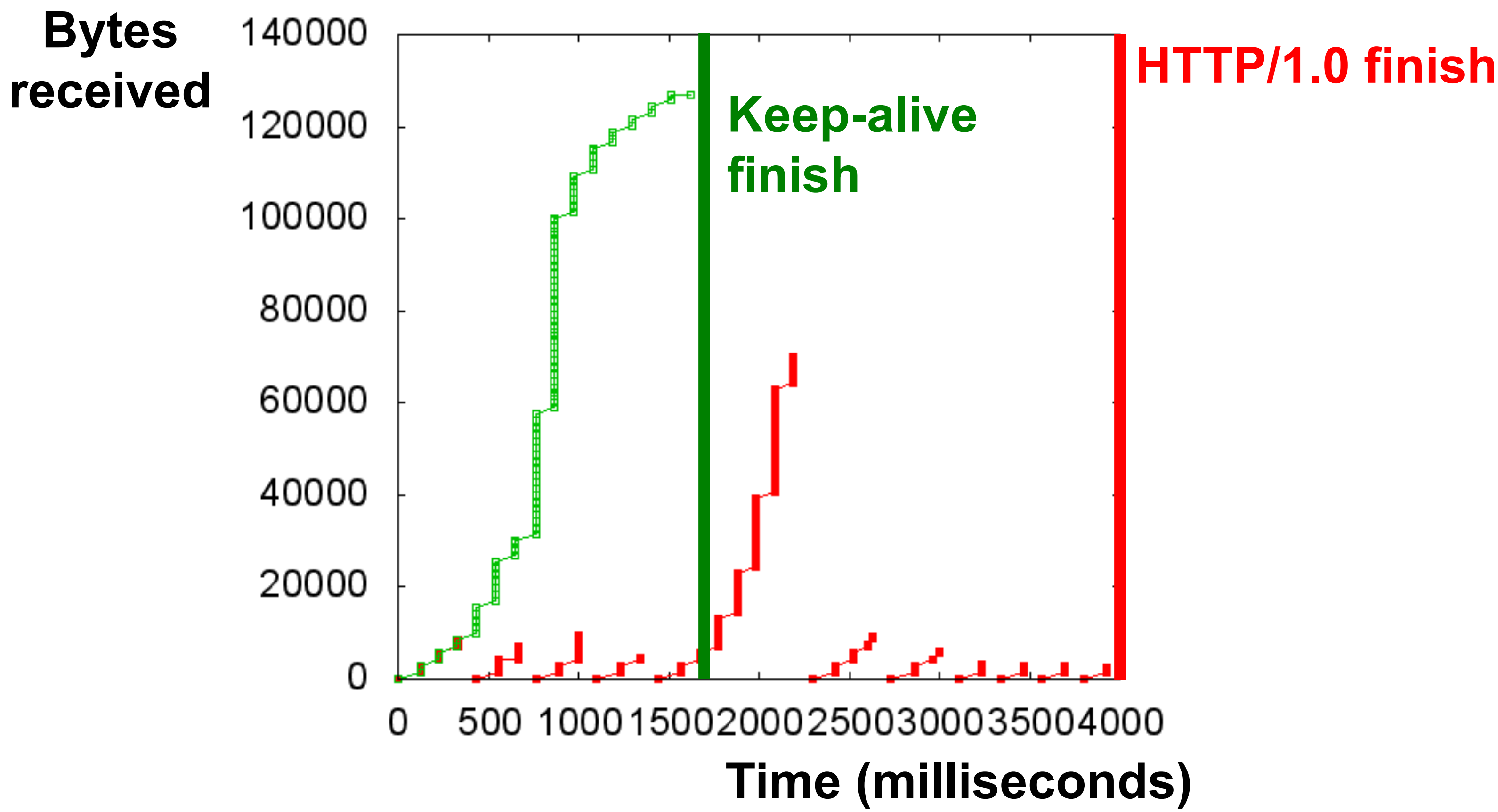
- Fetch 8.5 Kbyte page with 10 objects, most < 10 Kbyte

Letting the TCP connection persist

- Known as *HTTP keepalive*
- **Still stop-and-wait** at the granularity of objects, at the application layer
  - HTTP response fully received before next HTTP GET dispatched
    - ≥ 1 RTT per object



HTTP Keepalive avoids TCP slow starts



Incur one slow start, but stop-and-wait to issue next request

Pipelining within HTTP

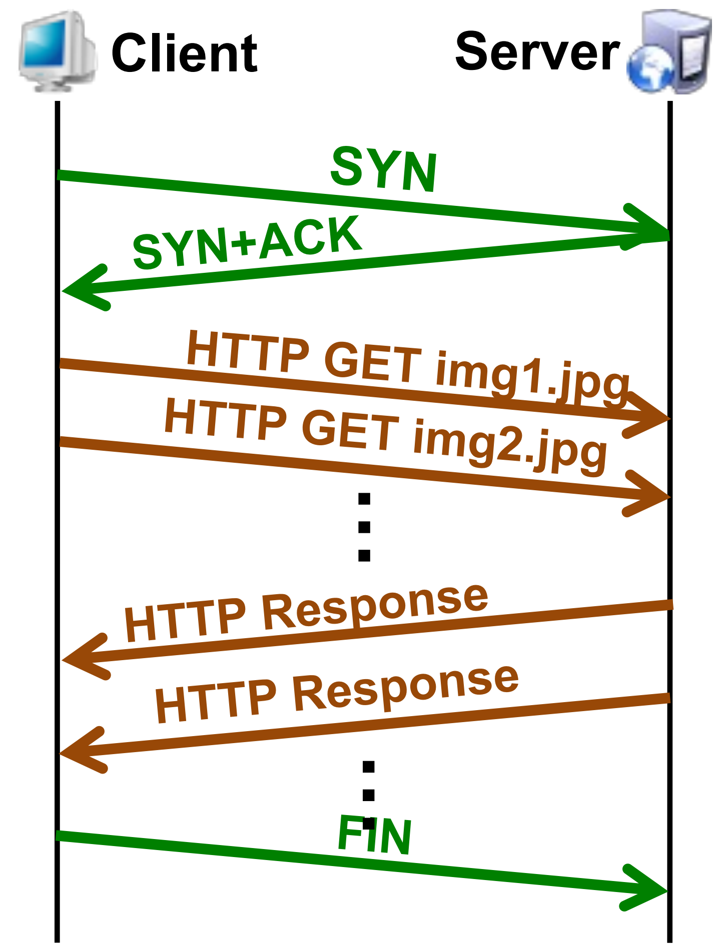
- Idea: Pipeline HTTP GETs and their responses

- Main benefits:

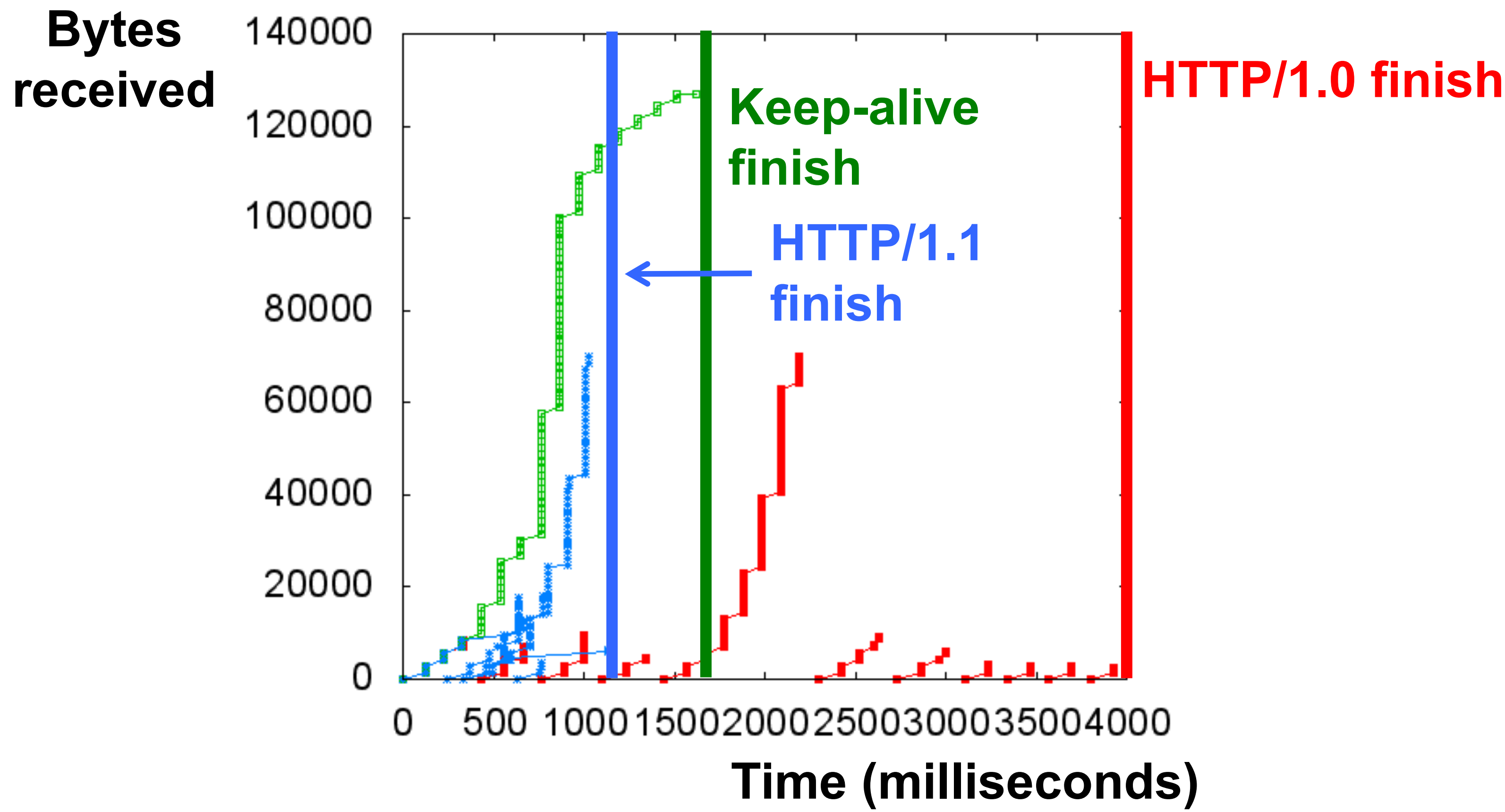
1. Amortizes the RTT across multiple objects retrieved

2. Reduces overhead of HTTP requests, packing multiple requests into one packet

- Implemented in HTTP/1.1



Pipelined HTTP requests overlap RTTs



- Many HTTP requests and TCP connections at once
- Overlaps RTTs of all requests

Today

1. The Web: HTTP, **hosting, and caching**
   - **Handling heavy loads**

2. Content distribution networks (CDNs)

Hosting: Multiple machines per site

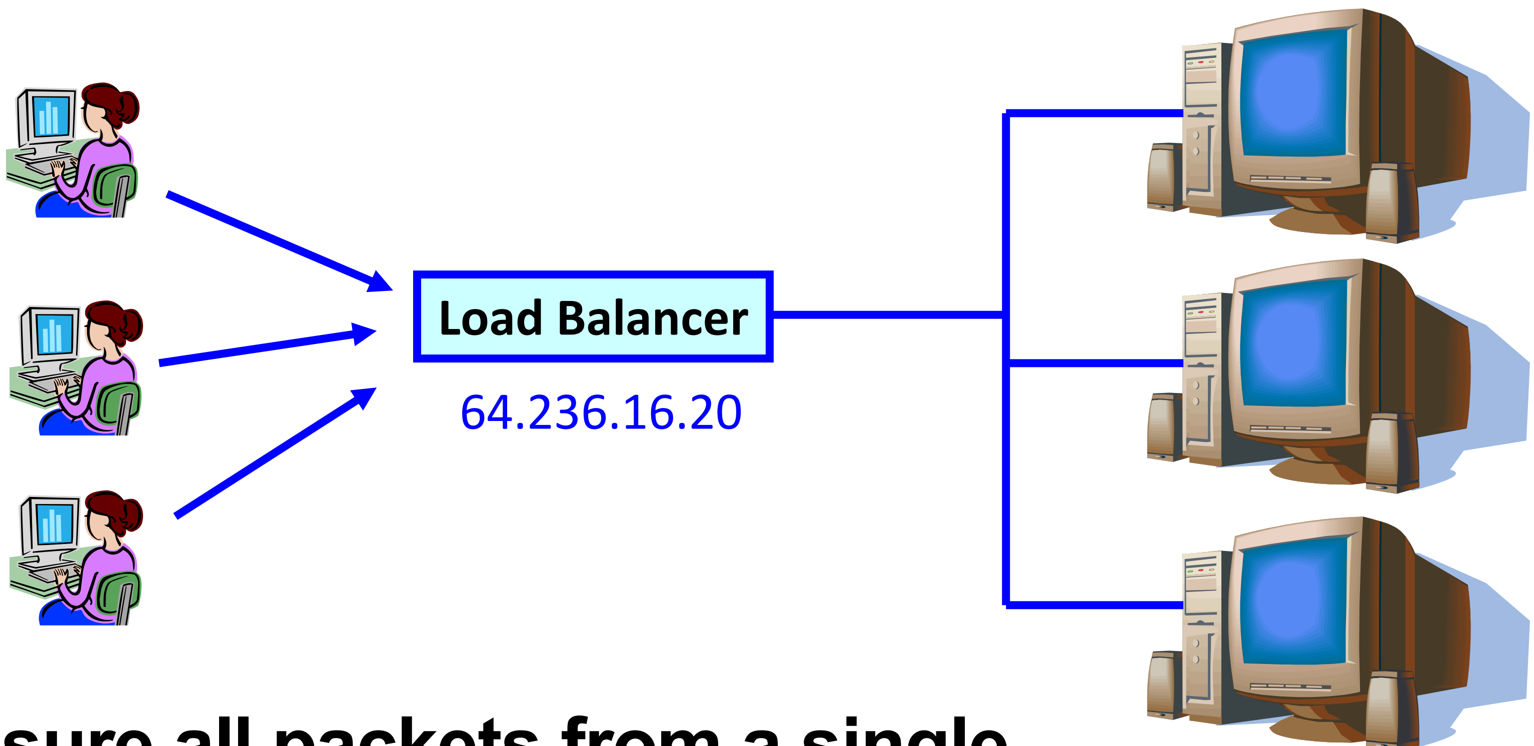
- **Problem:** Overloaded popular web site
  - Replicate the site across multiple machines
    - Helps to handle the load

- Want to direct client to a particular replica. Why?
  - Balance load across server replicas

- **Solution #1:** Manual selection by clients
  - Each replica has its own site name
  - Some Web page lists replicas (*e.g.*, by name, location), asks clients to click link to pick

Hosting: Load-balancer approach

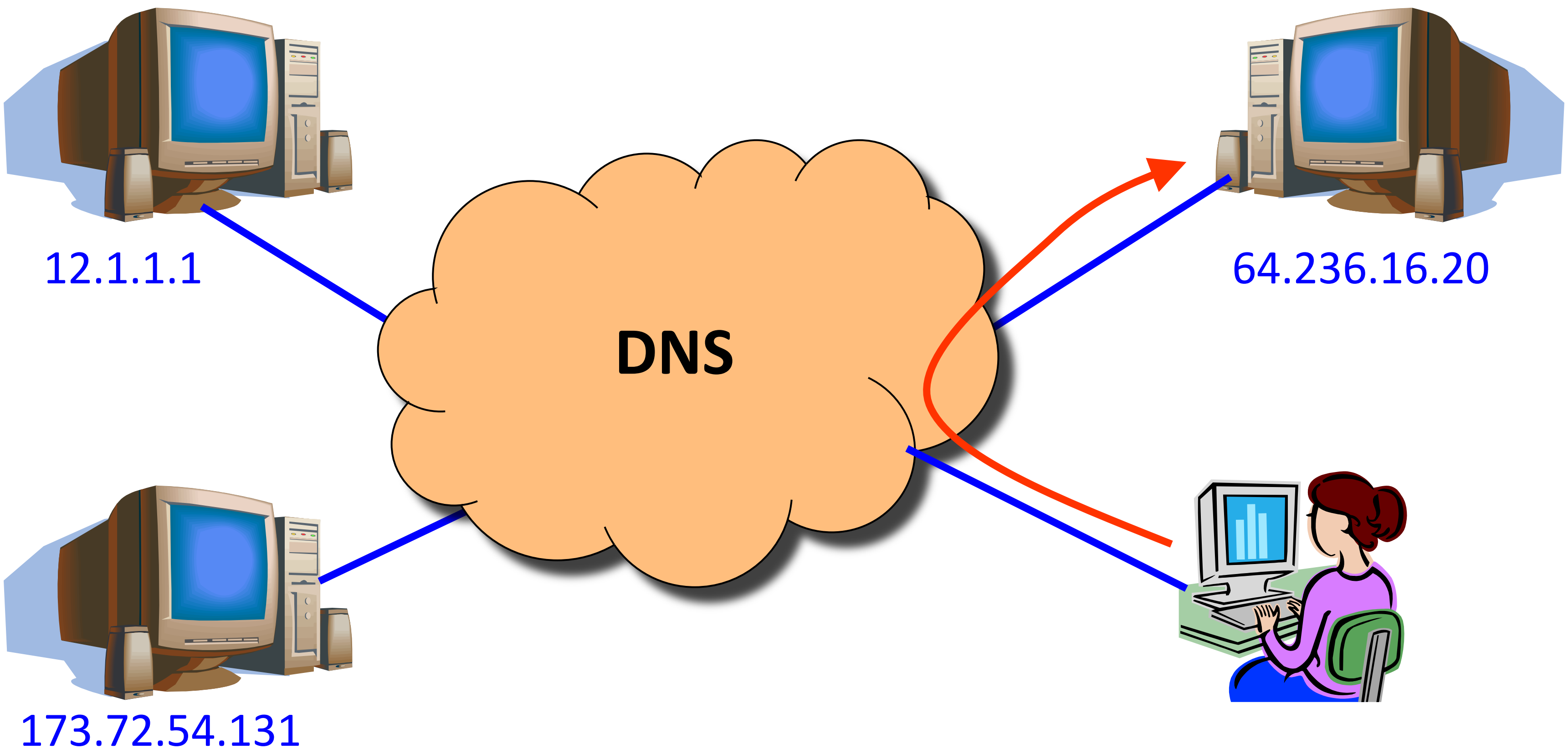
- **Solution #2:** Single IP address, multiple machines
  - Run multiple machines behind a single IP address



  - **Ensure all packets from a single TCP connection go to the same replica**

Hosting: DNS redirection approach

- **Solution #3:** Multiple IP addresses, multiple machines
  - Same DNS name but different IP for each replica
    - DNS server returns IP addresses "round robin"



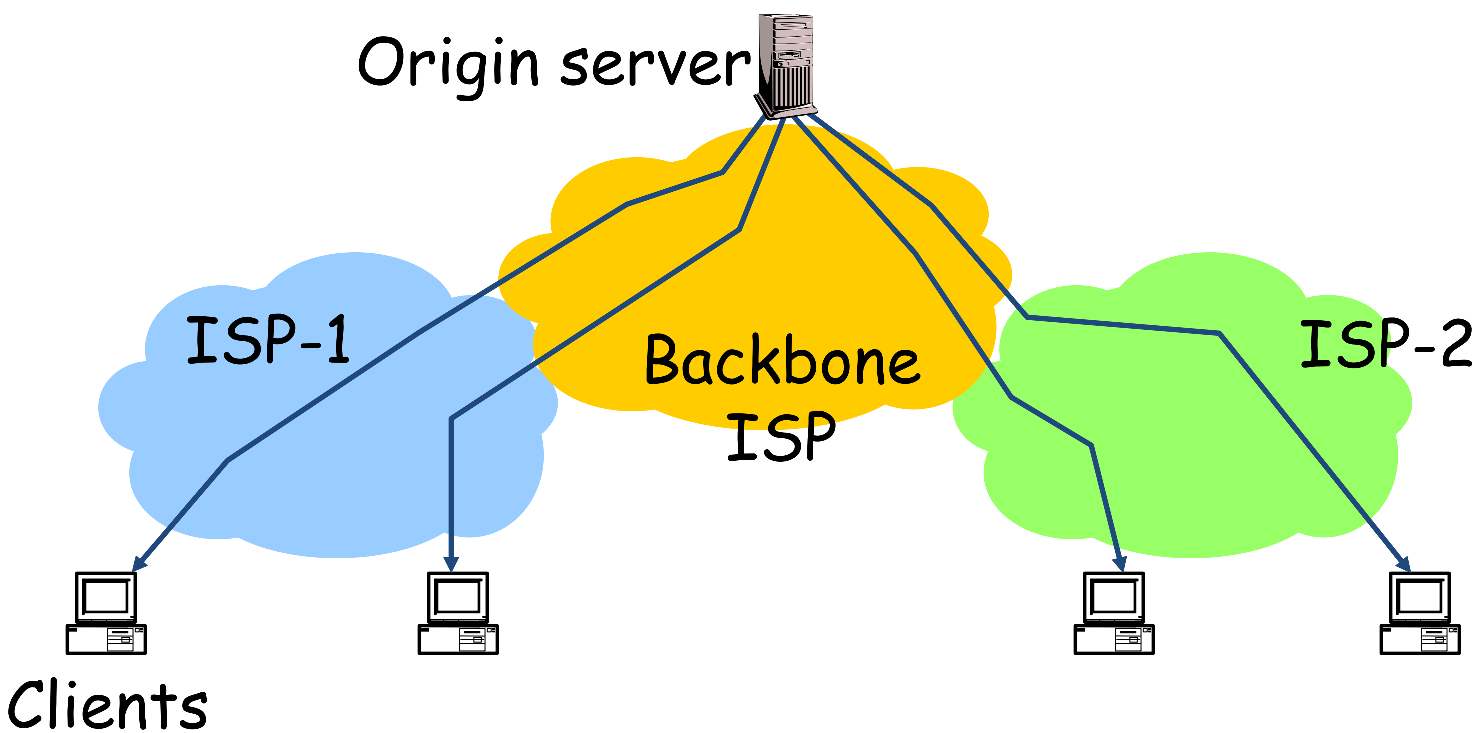
Hosting: Summary

- Load-balancer approach
  - No geographical diversity ✘
  - TCP connection issue ✘
  - Does not reduce network traffic ✘

- DNS redirection
  - No TCP connection issues ✔
  - Simple round-robin server selection
    - May be less responsive ✘
  - Does not reduce network traffic ✘

Web caching

- Many clients transfer the same information
  - Generates **redundant** server and network load
  - Also, clients may experience high **latency**



Why web caching?

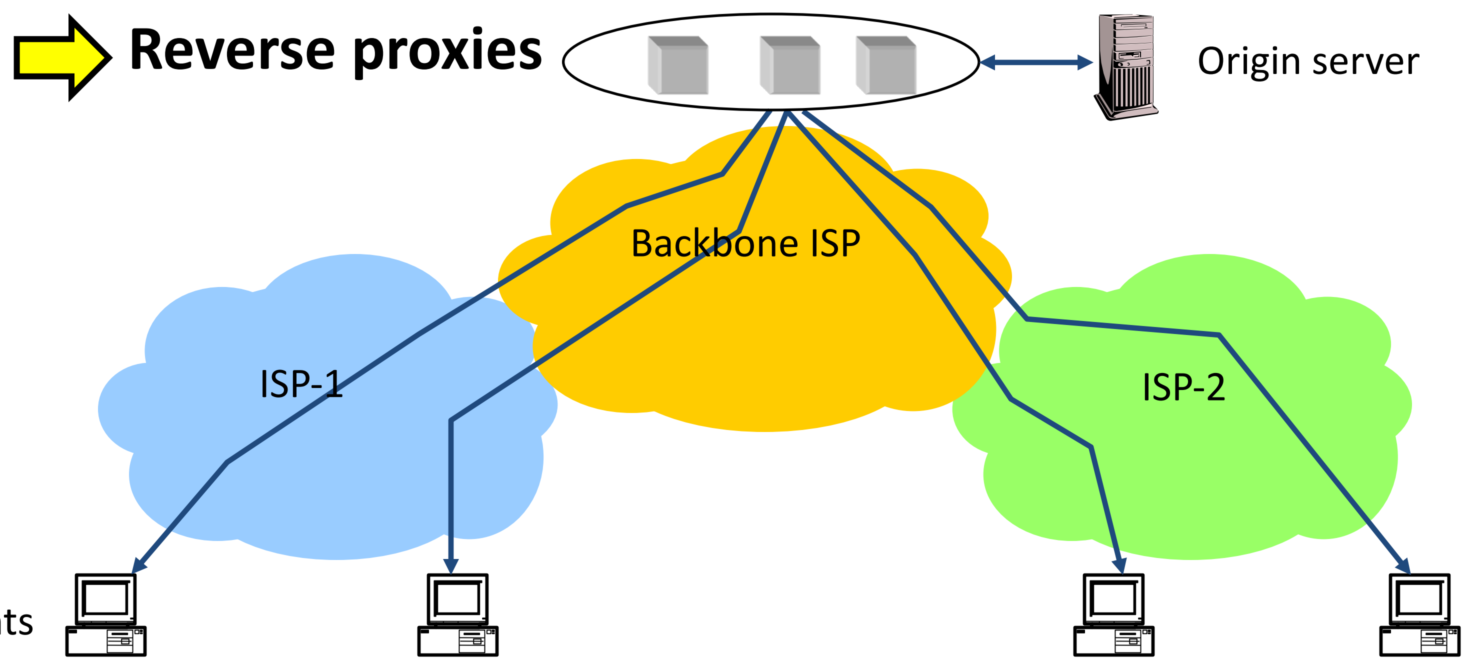
- Motivation for placing content closer to client:
  - User gets better response time
    - Content providers get happier users
  - Network gets reduced load

- Why does caching work? Exploits locality of reference

- How well does caching work?
  - Very well, up to a limit
  - Large overlap in content
  - But many unique requests

Caching with Reverse Proxies

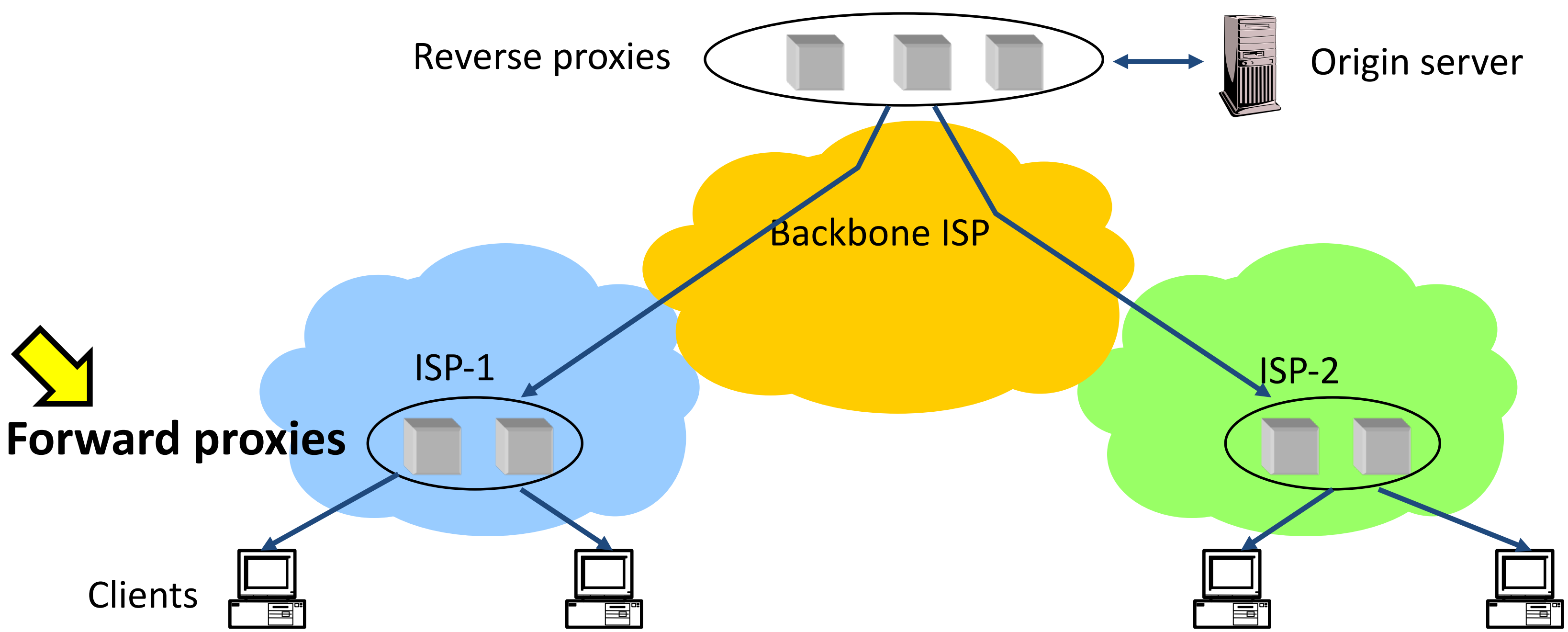
- Cache data close to origin server → decrease server load
  - Typically done by content providers
  - Client thinks it is talking to the origin server (the server with content)
- Does not work for **dynamic content**



Caching with Forward Proxies

- Cache close to clients → less network traffic, less latency
  - Typically done by ISPs or corporate LANs
  - **Client configured** to send HTTP requests to forward proxy

- Reduces traffic on ISP-1's access link, origin server, and backbone ISP



Caching & Load-Balancing: Outstanding problems

- Problem *ca.* 2002: *How to reliably deliver large amounts of content to users worldwide?*
  - Popular event: **"Flash crowds" overwhelm** (replicated) web server, access link, or back-end database infrastructure
  - More rich content: audio, video, photos
- Web caching: Diversity of content requests causes **low cache hit rates (25–40%)**

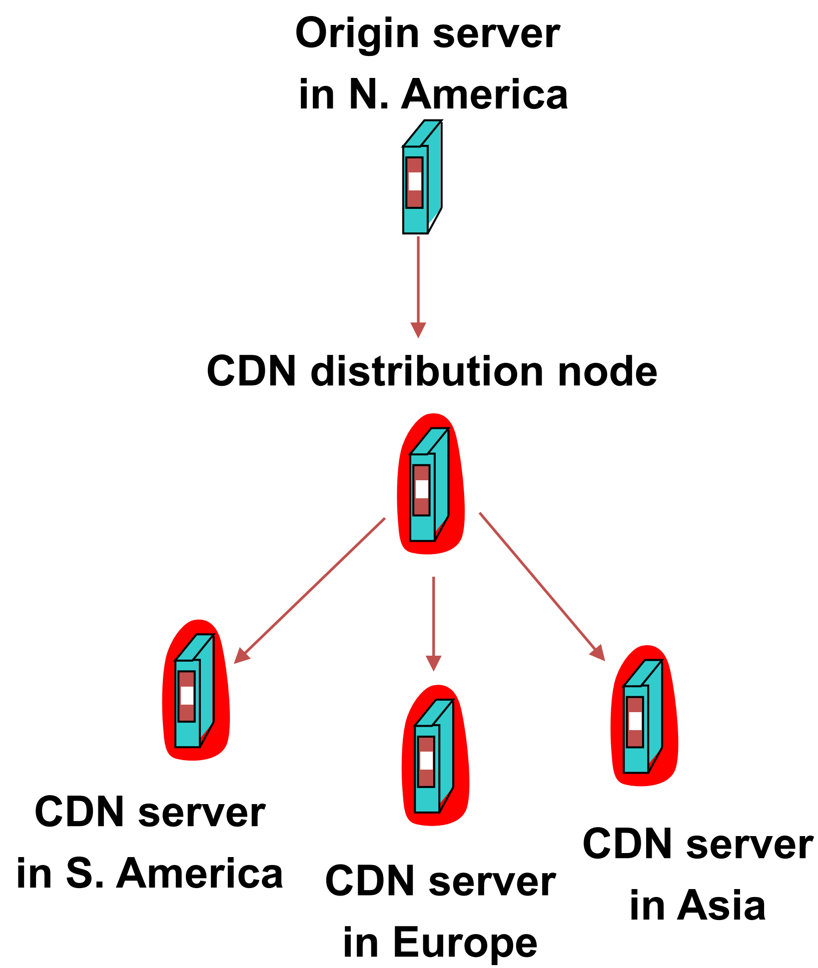
Today

1. The Web: HTTP, hosting, and caching

2. **Content distribution networks (CDNs)**
   – Akamai case study

Content Distribution Networks

- Proactive content replication
  - Content provider (*e.g.* CNN) pushes content out from its own *origin server*
- CDN **replicates** the content
  - On many servers spread throughout the Internet
- Updating the replicas
  - Updates **pushed to replicas** when the content changes



Replica selection: Goals

- Live server
  - For availability

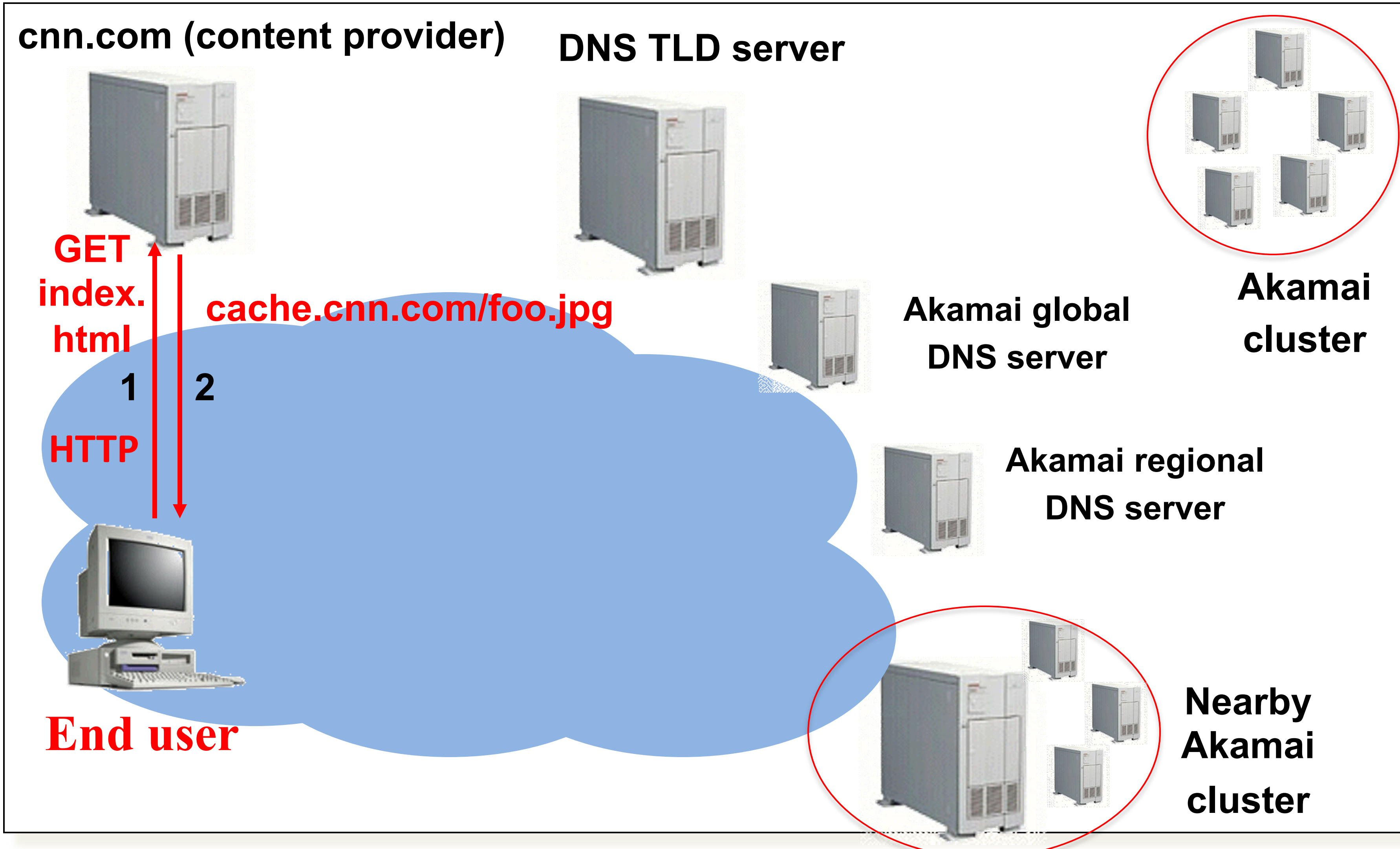
Requires continuous monitoring of liveness, load, and performance

- Lowest load
  - To balance load across the servers
- Closest
  - Nearest geographically, or in round-trip time
- Best performance
  - Throughput, latency, reliability…

Akamai statistics

- Distributed servers
  - Servers: ~100,000
  - Networks: ~1,000
  - Countries: ~70
- Many customers
  - Apple, BBC, FOX, GM IBM, MTV, NASA, NBC, NFL, NPR, Puma, Red Bull, Rutgers, SAP, …
- Client requests
  - 20+M per second
  - Half in the top 45 networks
  - 20% of all Web traffic worldwide

How Akamai Uses DNS



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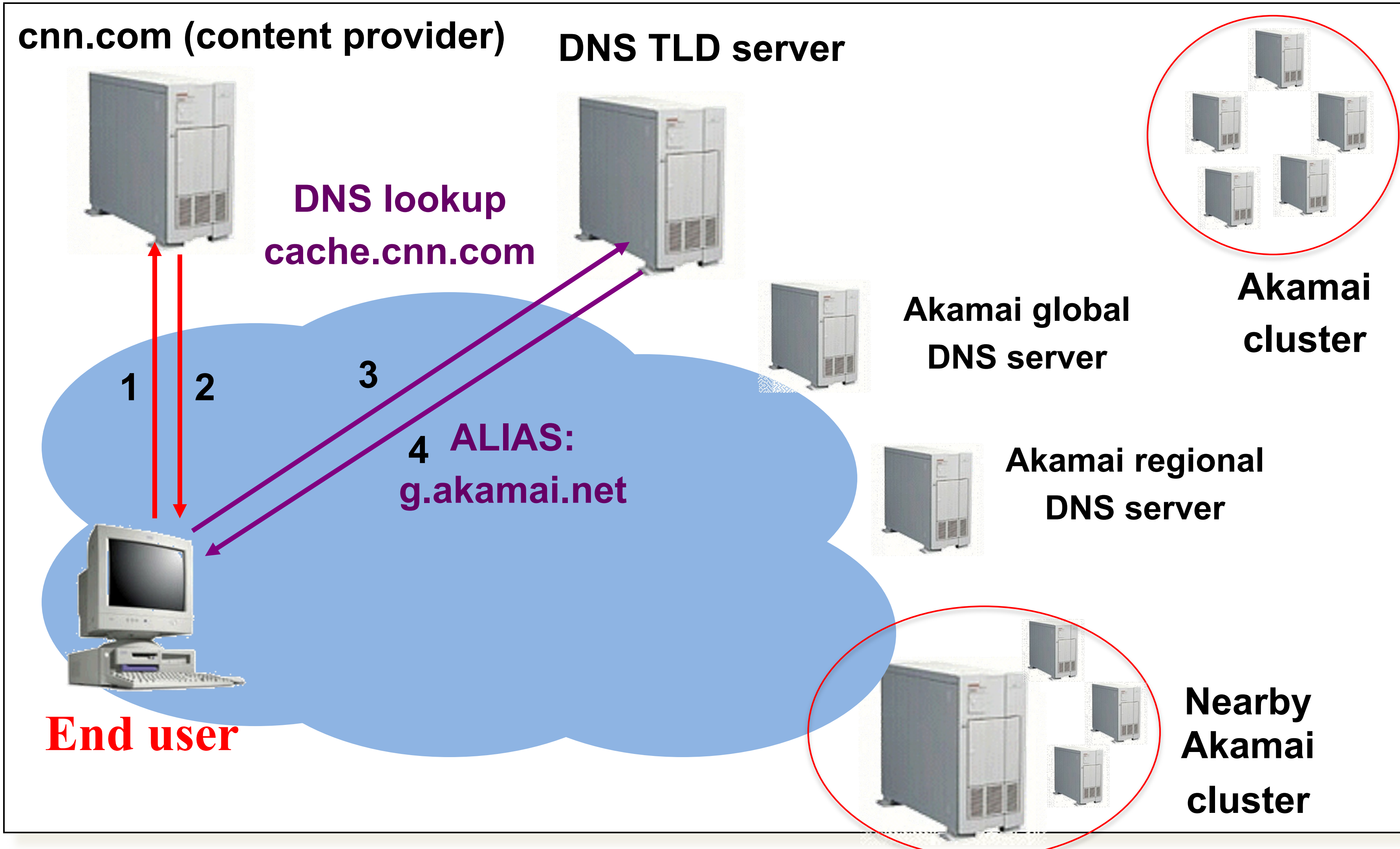

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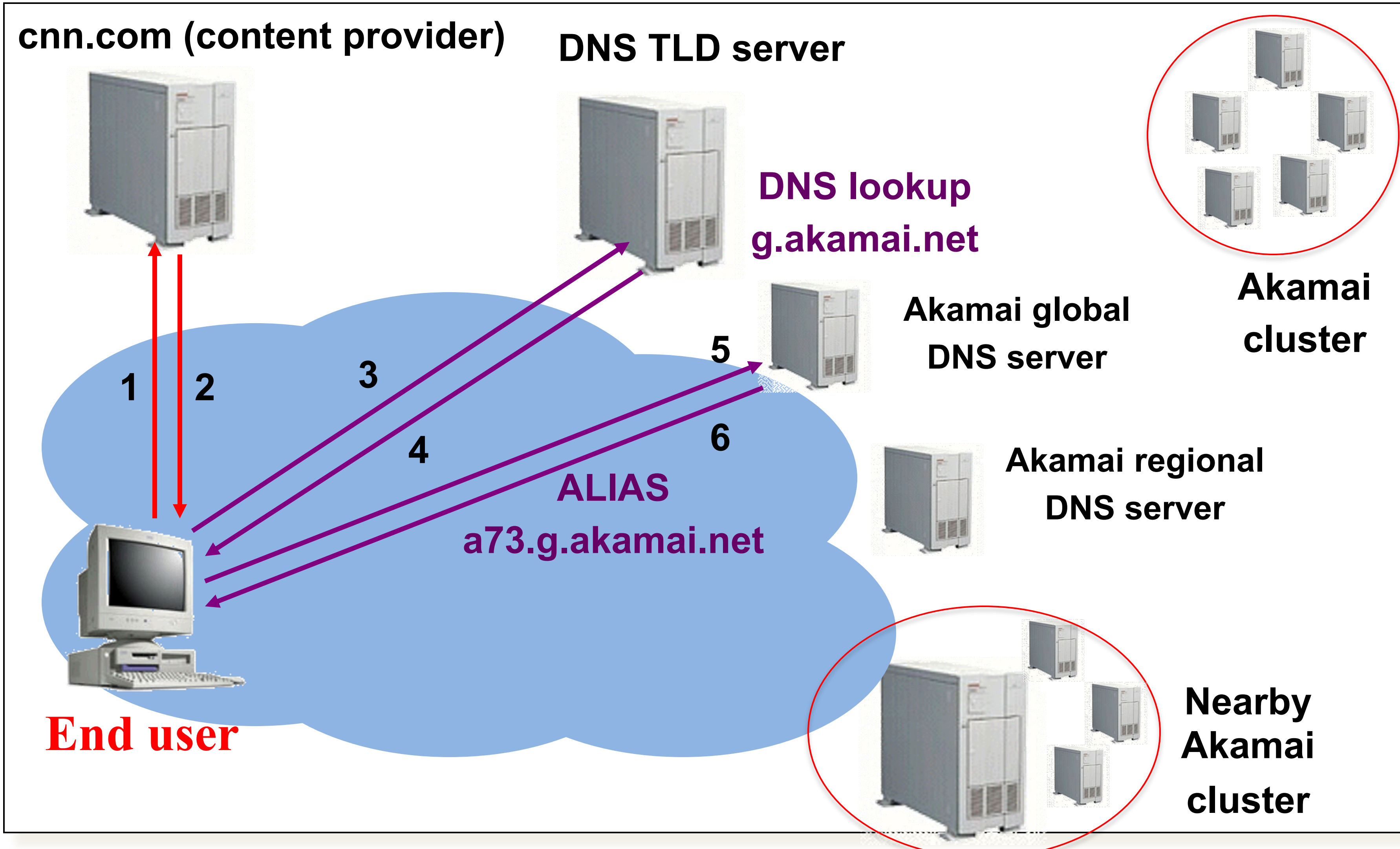

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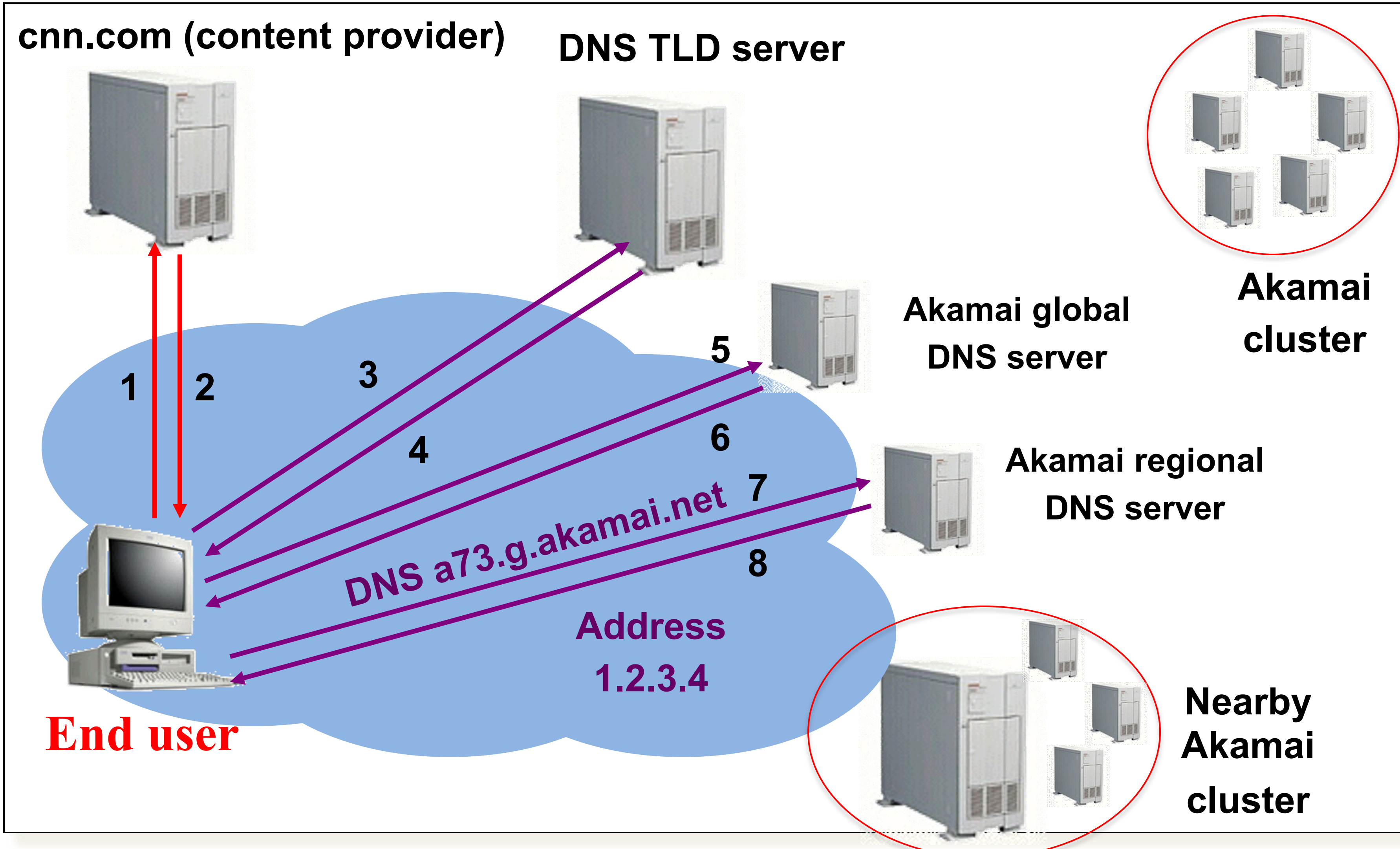

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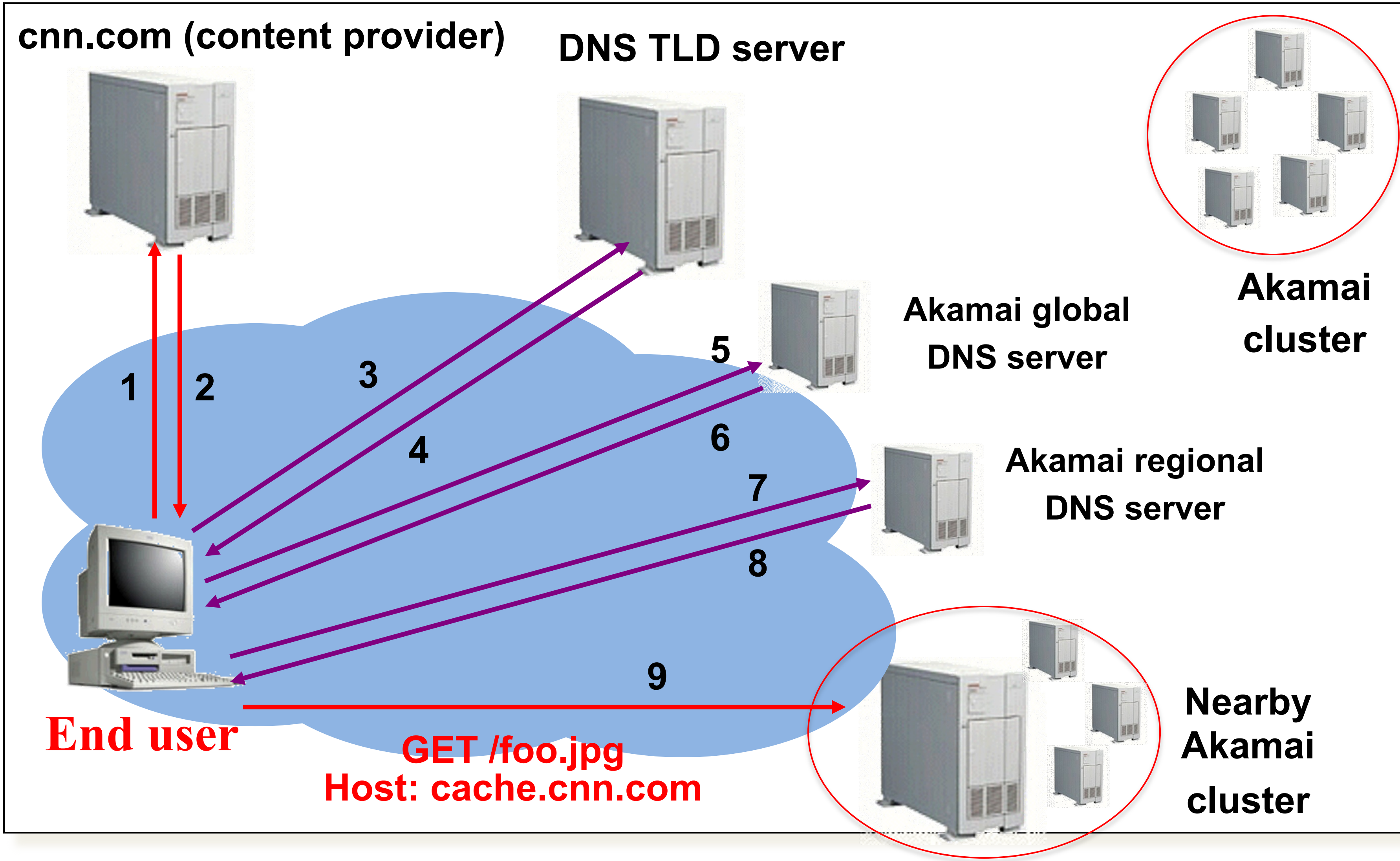

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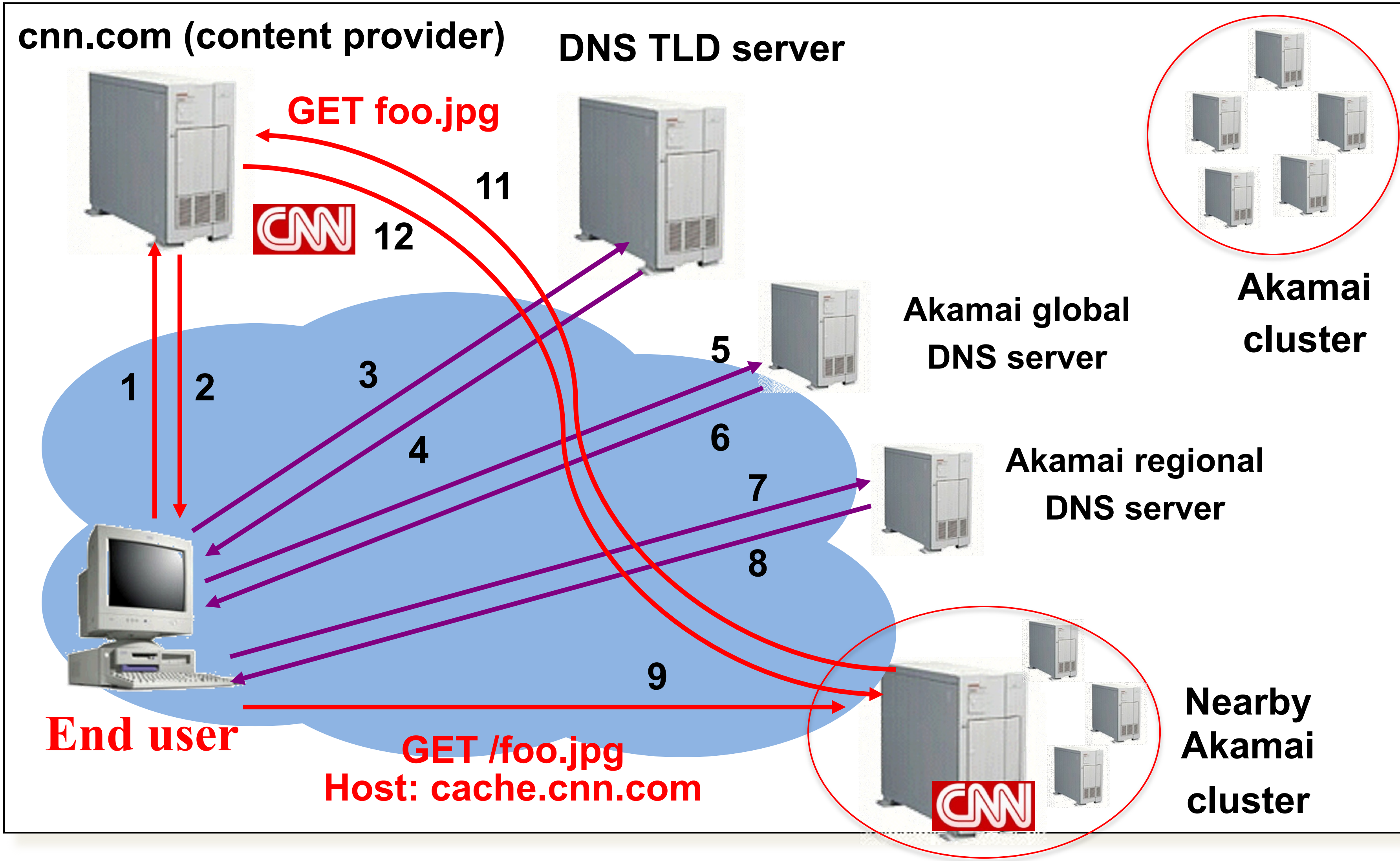

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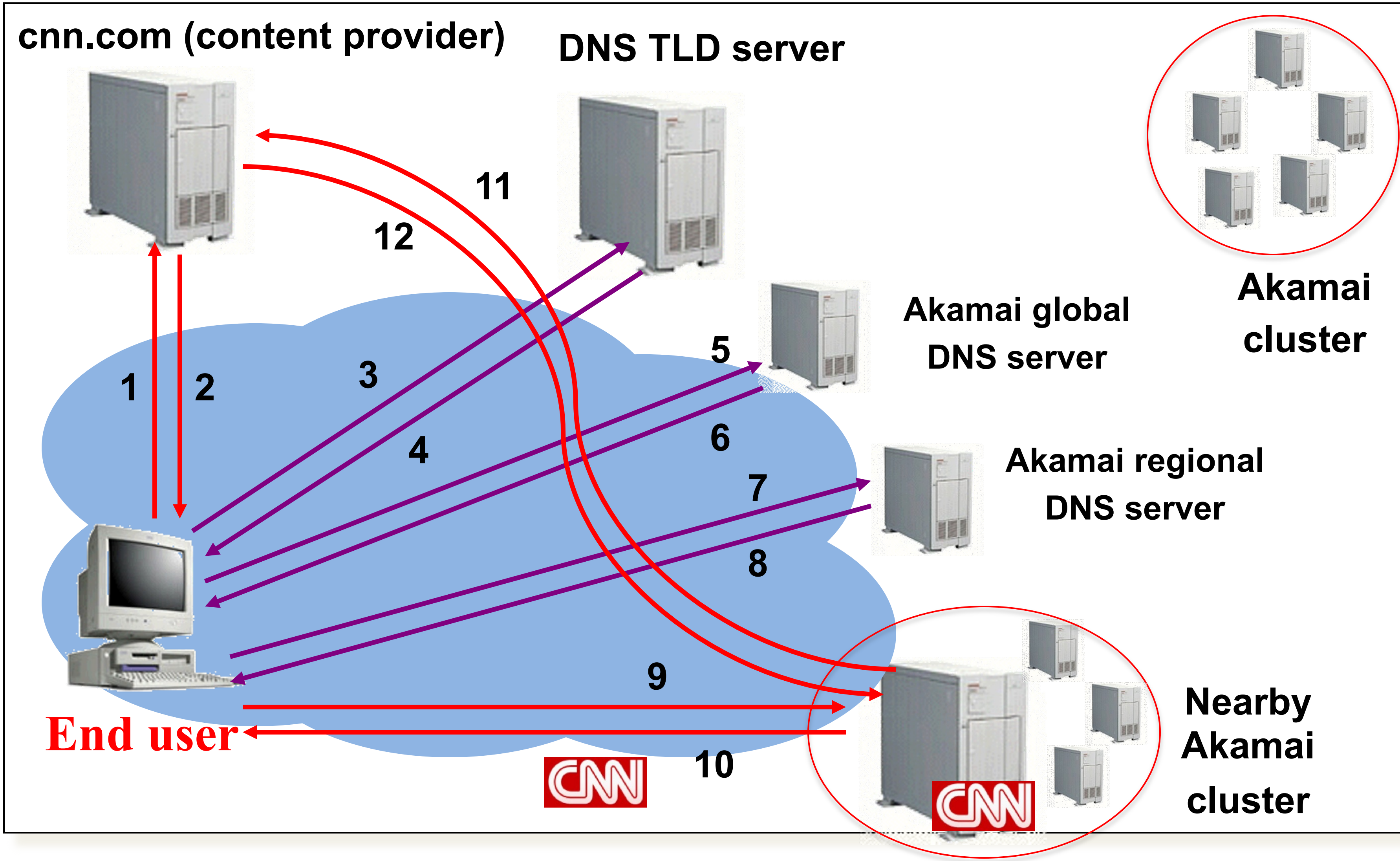
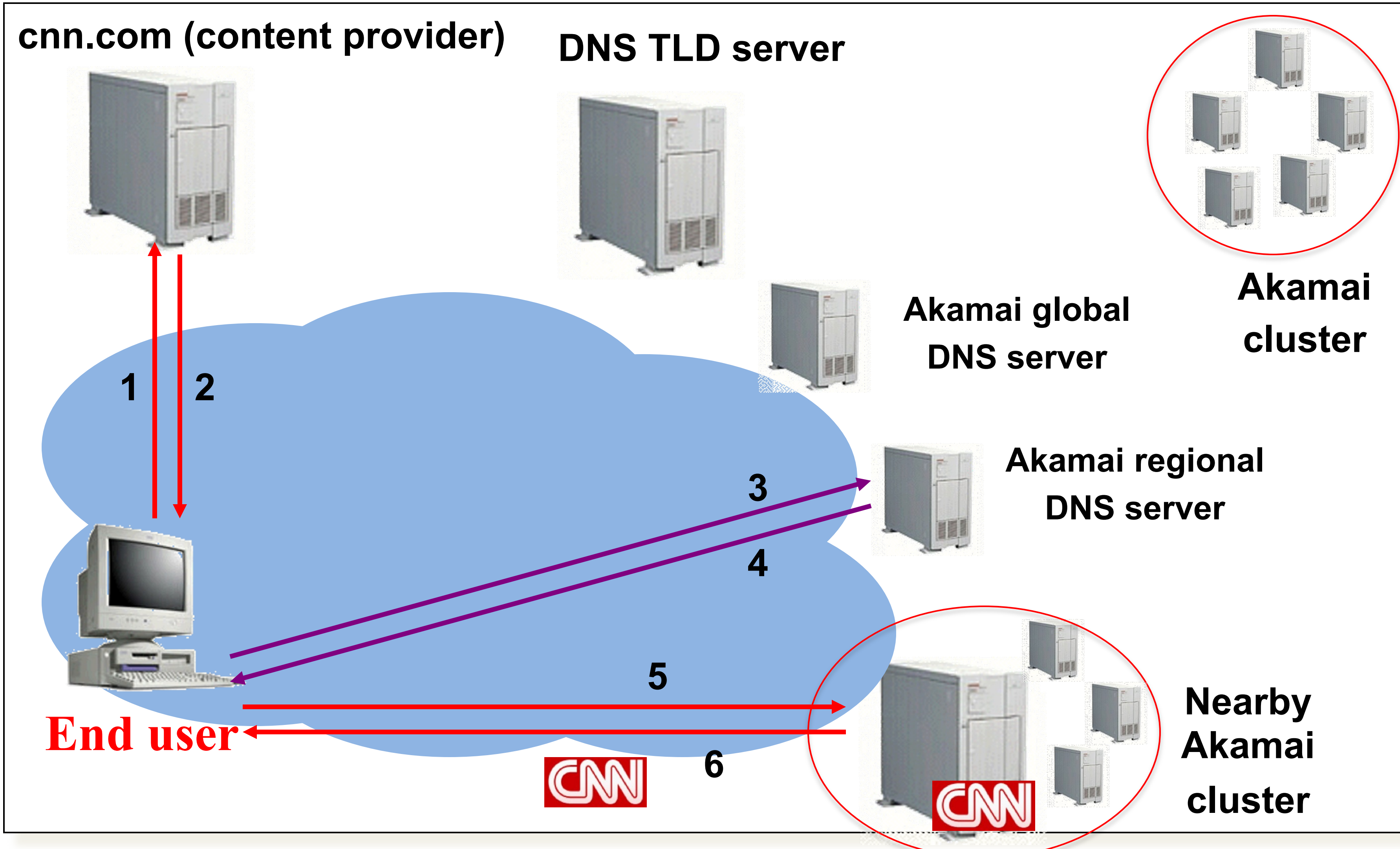


How Akamai Works: Cache Hit



Mapping System

- To make these decisions need a map!

- Equivalence classes of IP addresses
  - IP addresses experiencing similar performance
  - Quantify how well they connect to each other

- **Collect and combine** measurements
  - Ping, traceroute, BGP routes, server logs
    - *e.g.*, over 100 TB of logs per days
  - Network latency, loss, throughput, and connectivity

Routing client requests with the map

- Map each **IP class** to a preferred **server cluster**
  - Based on performance, cluster health, etc.
  - Updated roughly every minute
    - Short, 60-sec DNS TTLs in Akamai regional DNS accomplish this
- Map client request to a server in the cluster
  - **Load balancer** selects a specific server
  - *e.g.*, to **maximize** the cache hit rate

Adapting to failures

- Failing **hard drive** on a server
  - Suspends after finishing "in progress" requests

- Failed **server**
  - Another server takes over for the IP address
  - Low-level map updated **quickly** (load balancer)

- Failed **cluster**, or **network path**
  - High-level map updated **quickly** (ping/traceroute)

Take-away points: CDNs

- Content distribution is hard
  - Many, diverse, changing objects
  - Clients distributed all over the world

- Moving content to the client is key
  - Reduces latency, improves throughput, reliability

- Content distribution solutions **evolved:**
  - Load balancing, reactive caching, to
  - Proactive content distribution networks

Next in 461:

Network Security and Specialized Topics:

- Wireless Networking
- Software-Defined Networking