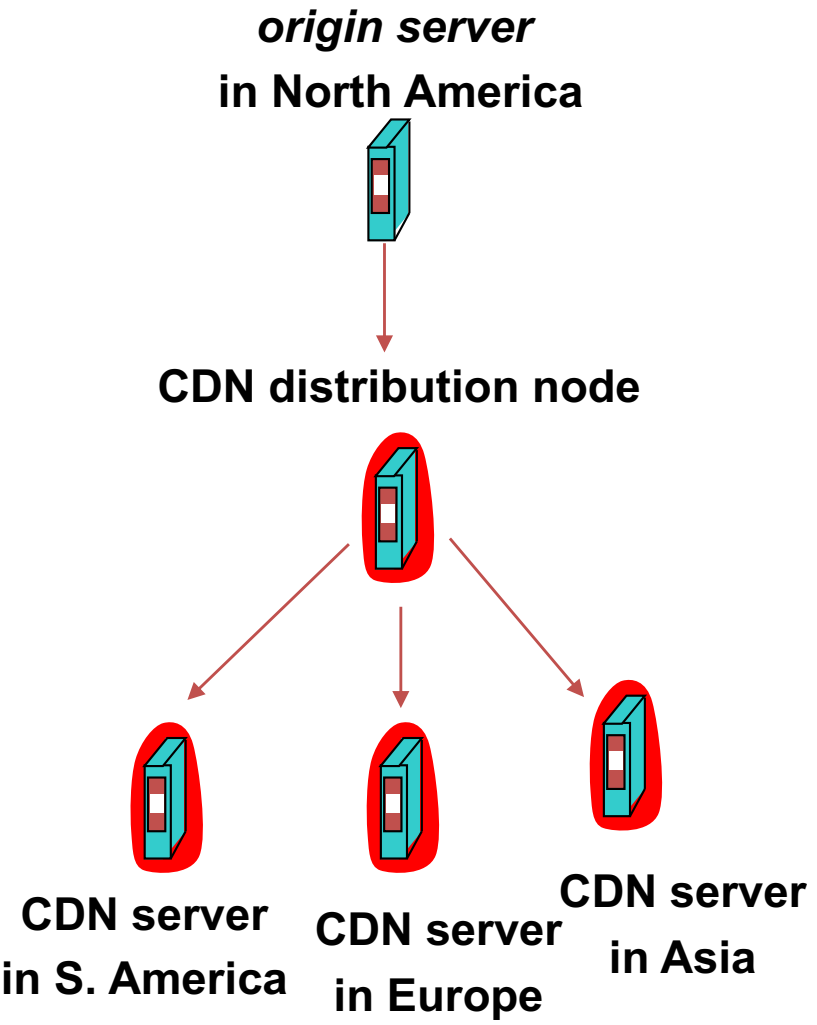
Content Distribution Network (CDN)

- 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
  - Reactive by TTL or updates pushed to replicas when the content changes



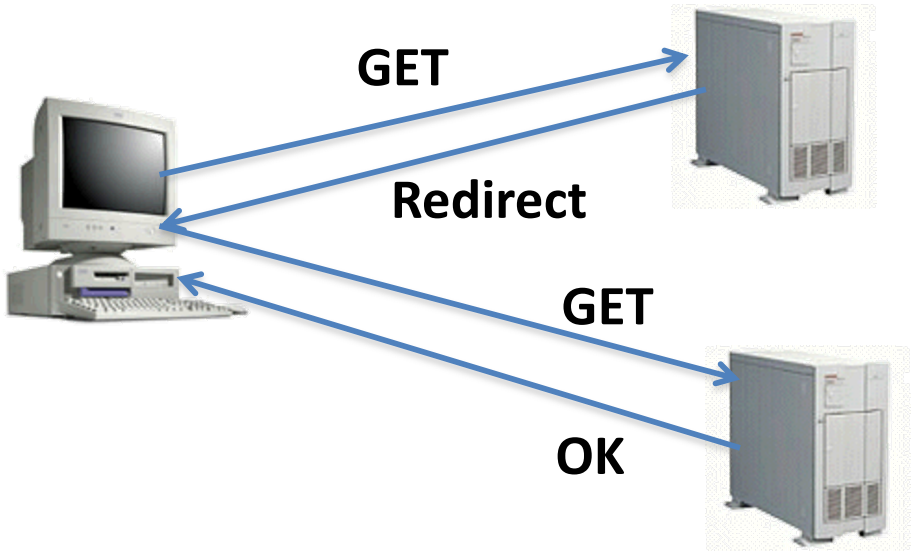
Server Selection Policy

- 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, …

Requires continuous monitoring of liveness, load, and performance

Server Selection Mechanism

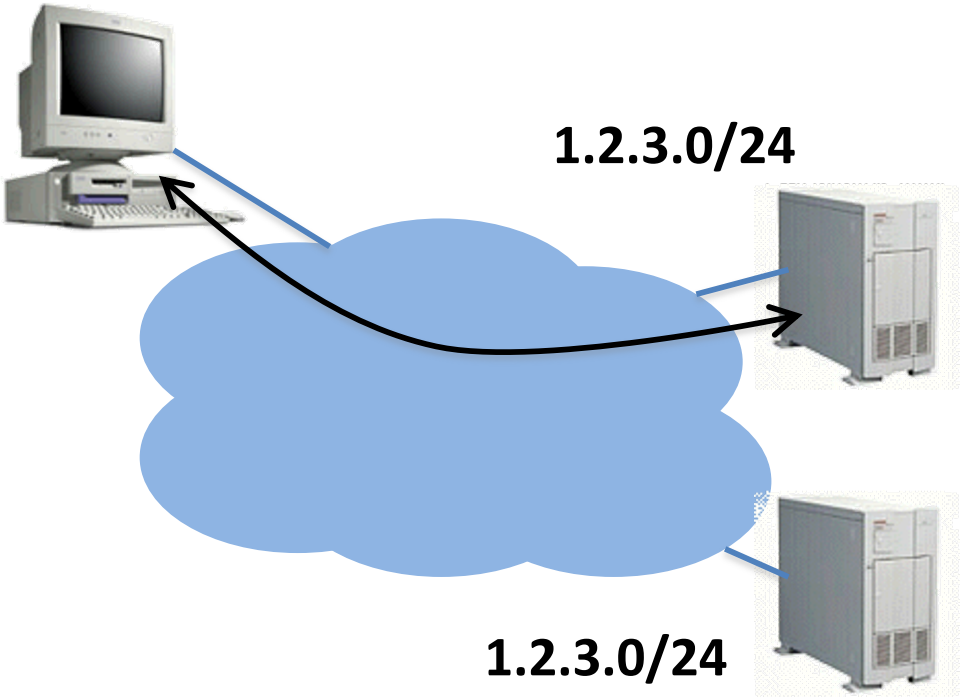
- Application
  - HTTP redirection



- 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

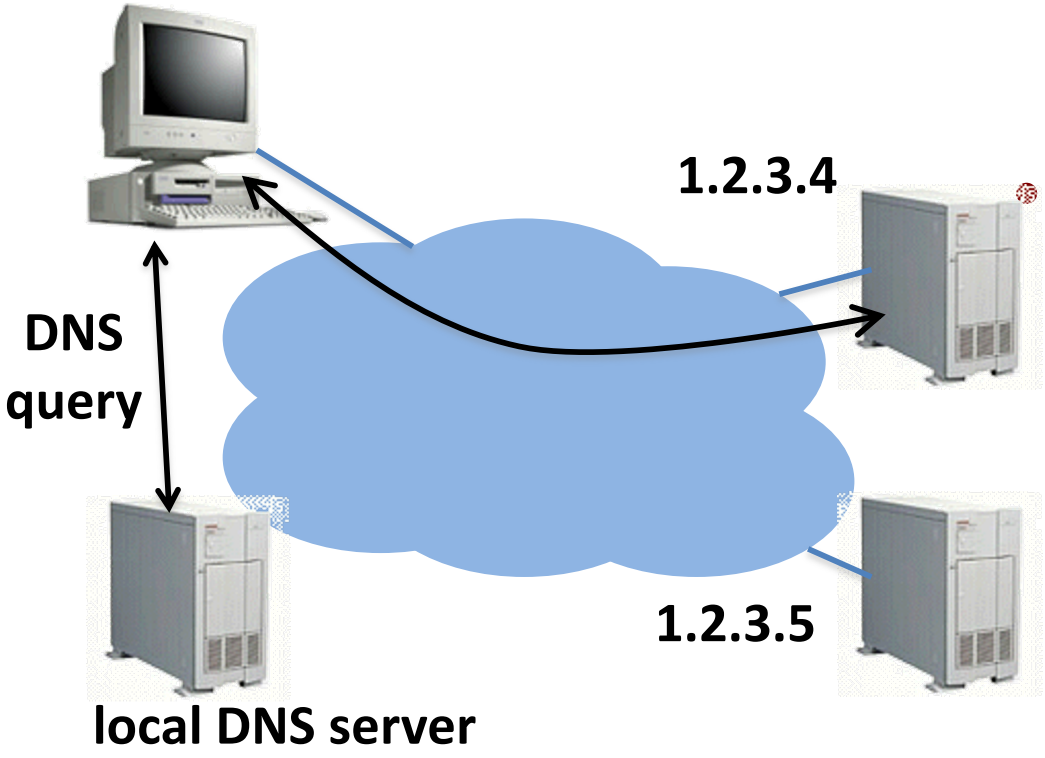
- Routing
  - Anycast routing



- 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

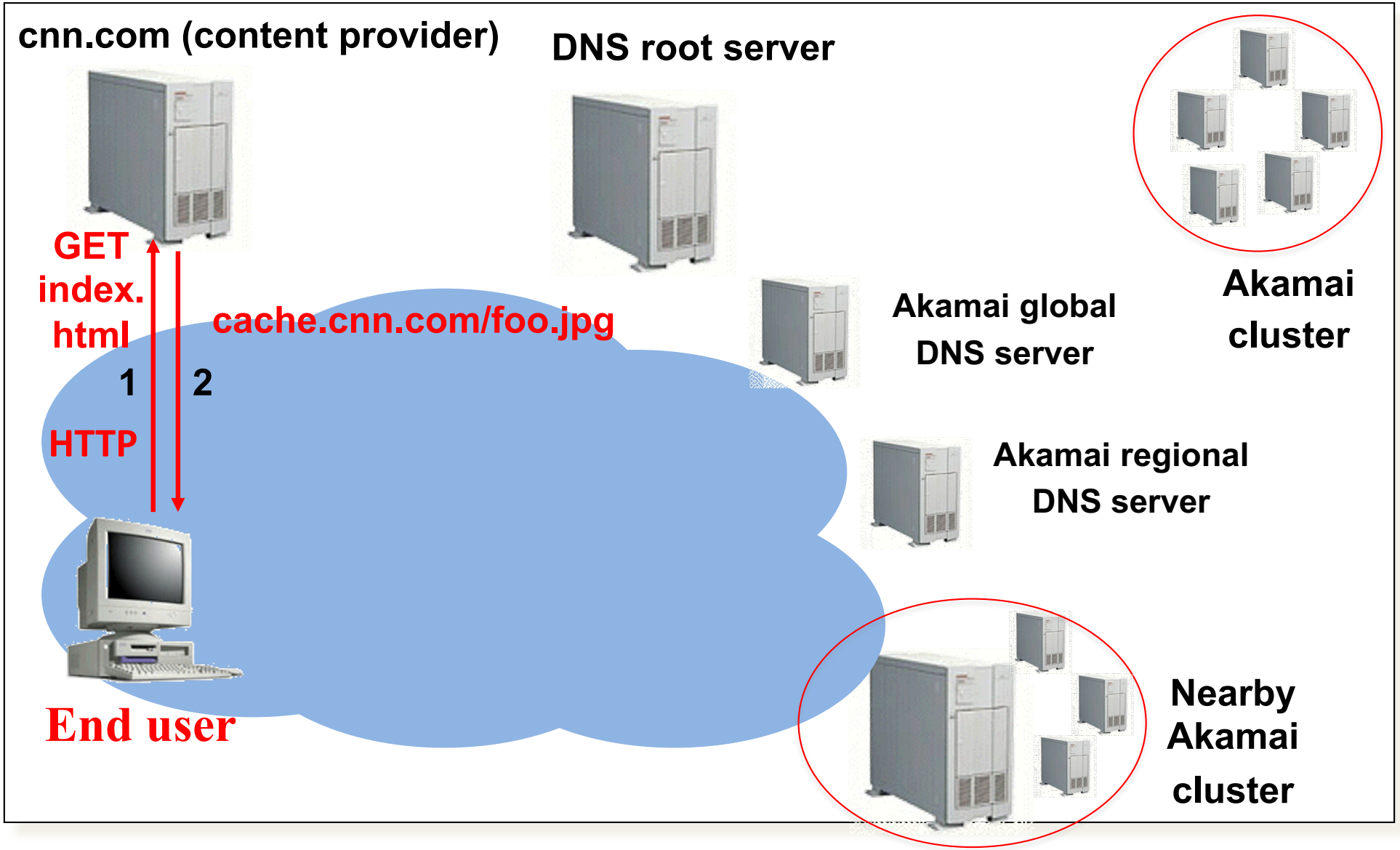
- Based on IP address of local DNS server
- "Hidden load" effect
- DNS TTL limits adaptation

How Akamai Works

Akamai Statistics

- Distributed servers
  - Servers: ~275,000
  - Networks: 1,500
  - Countries: 136
- Many customers
  - 50% of Fortune Global 500
- Network
  - Up to 50 Tbps daily
  - 2019 Cricket World Cup: 25.3M concurrent viewers
  - 85% of Internet is one network hop from Akamai servers

How Akamai Uses DNS



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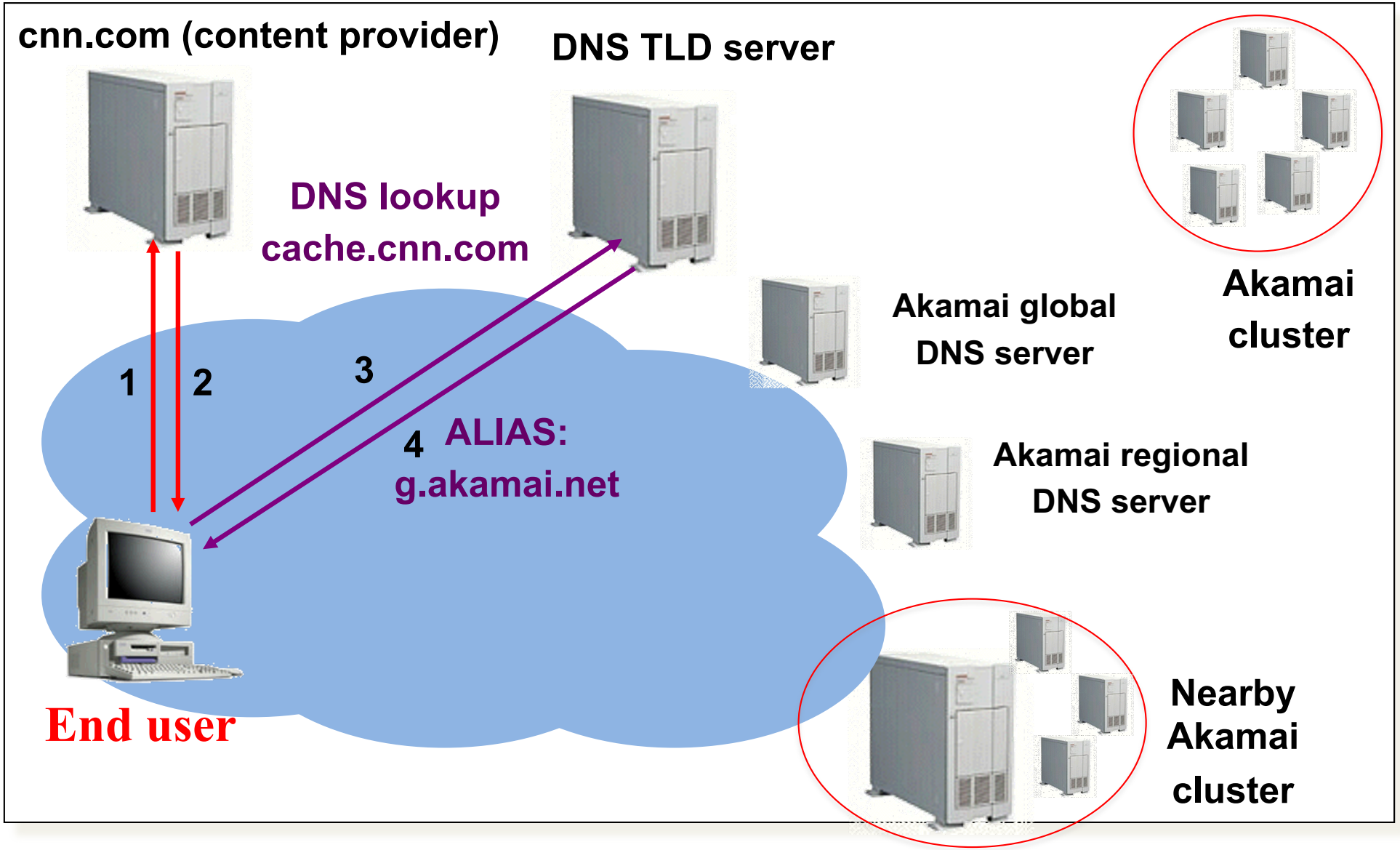

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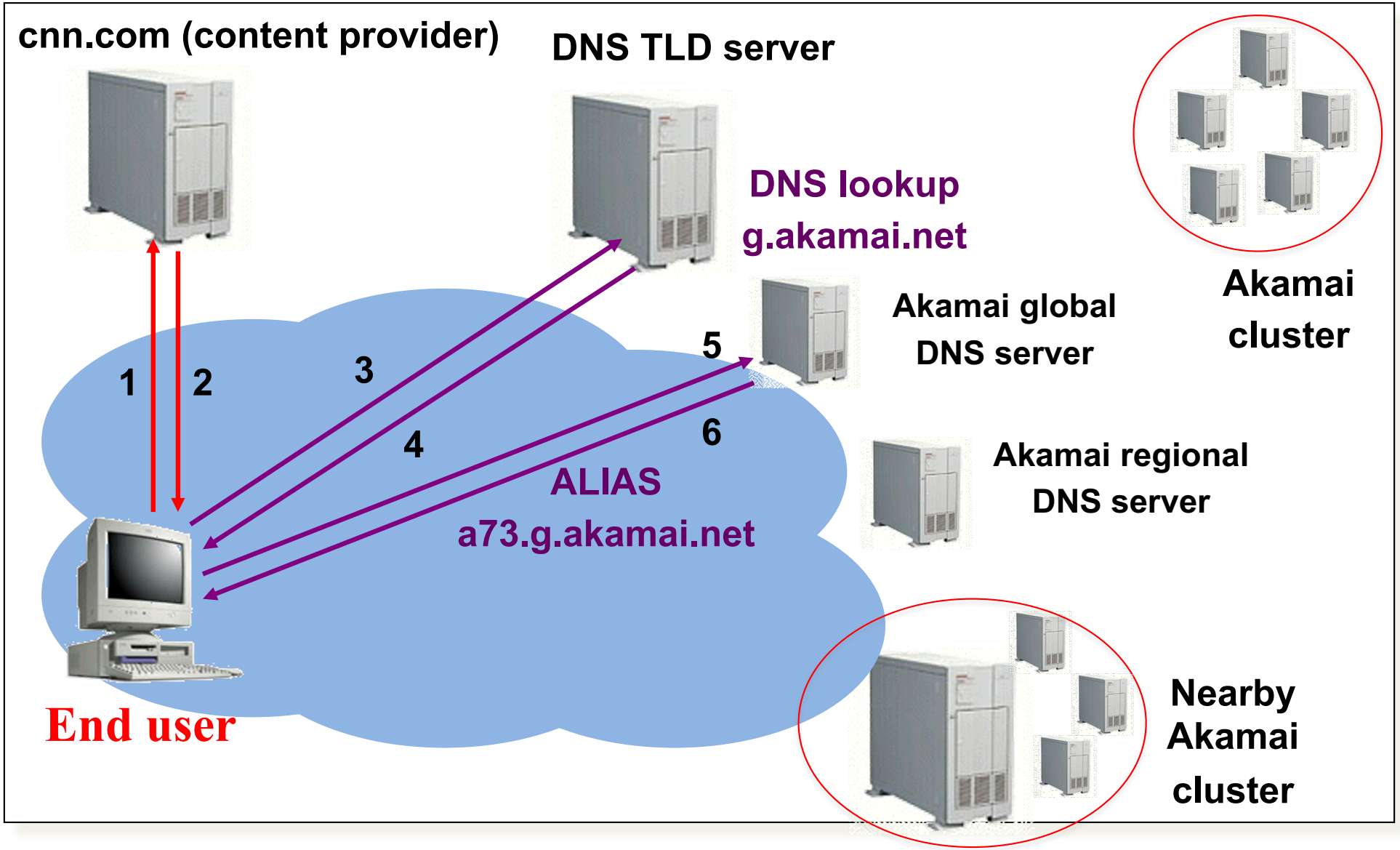

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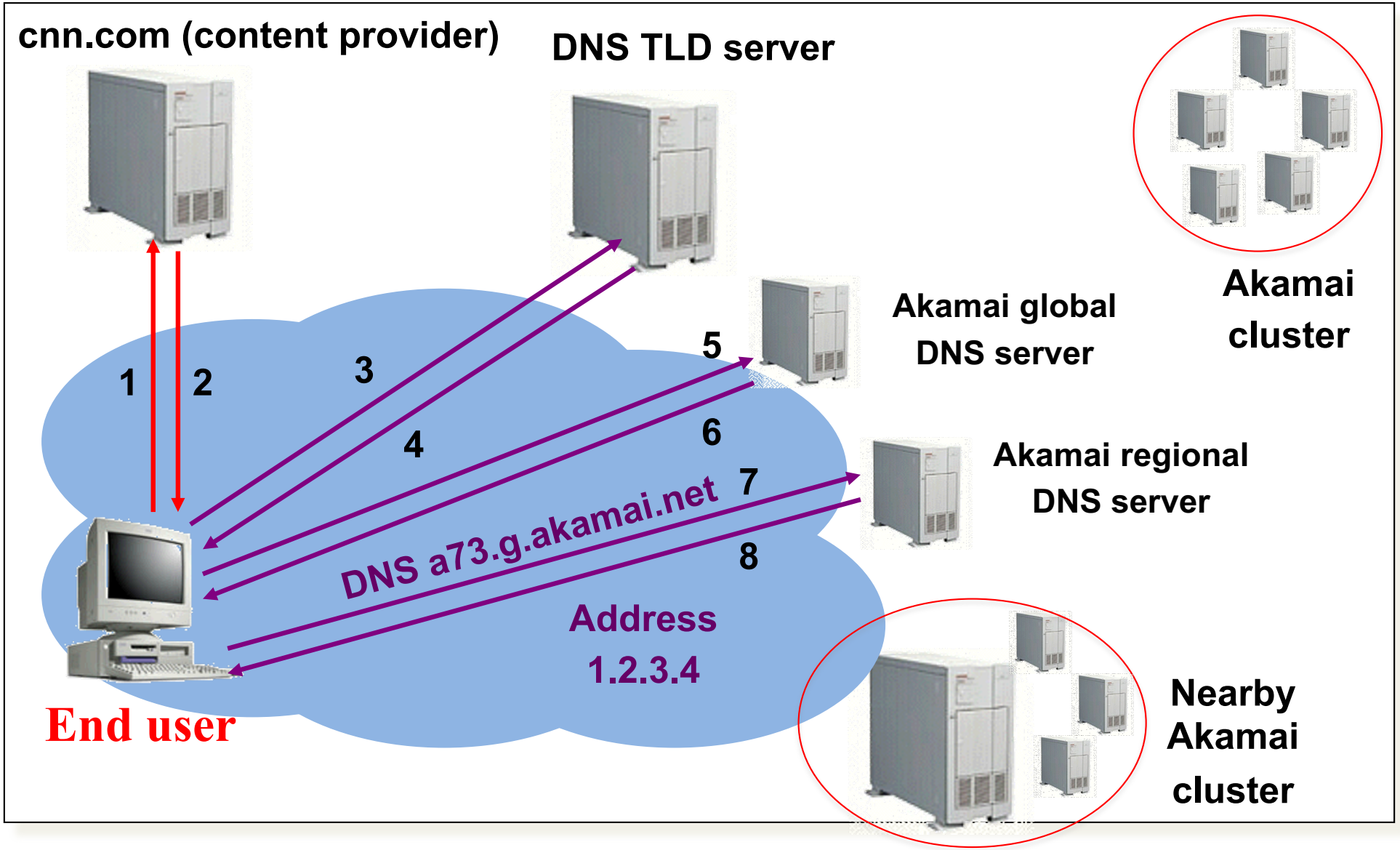

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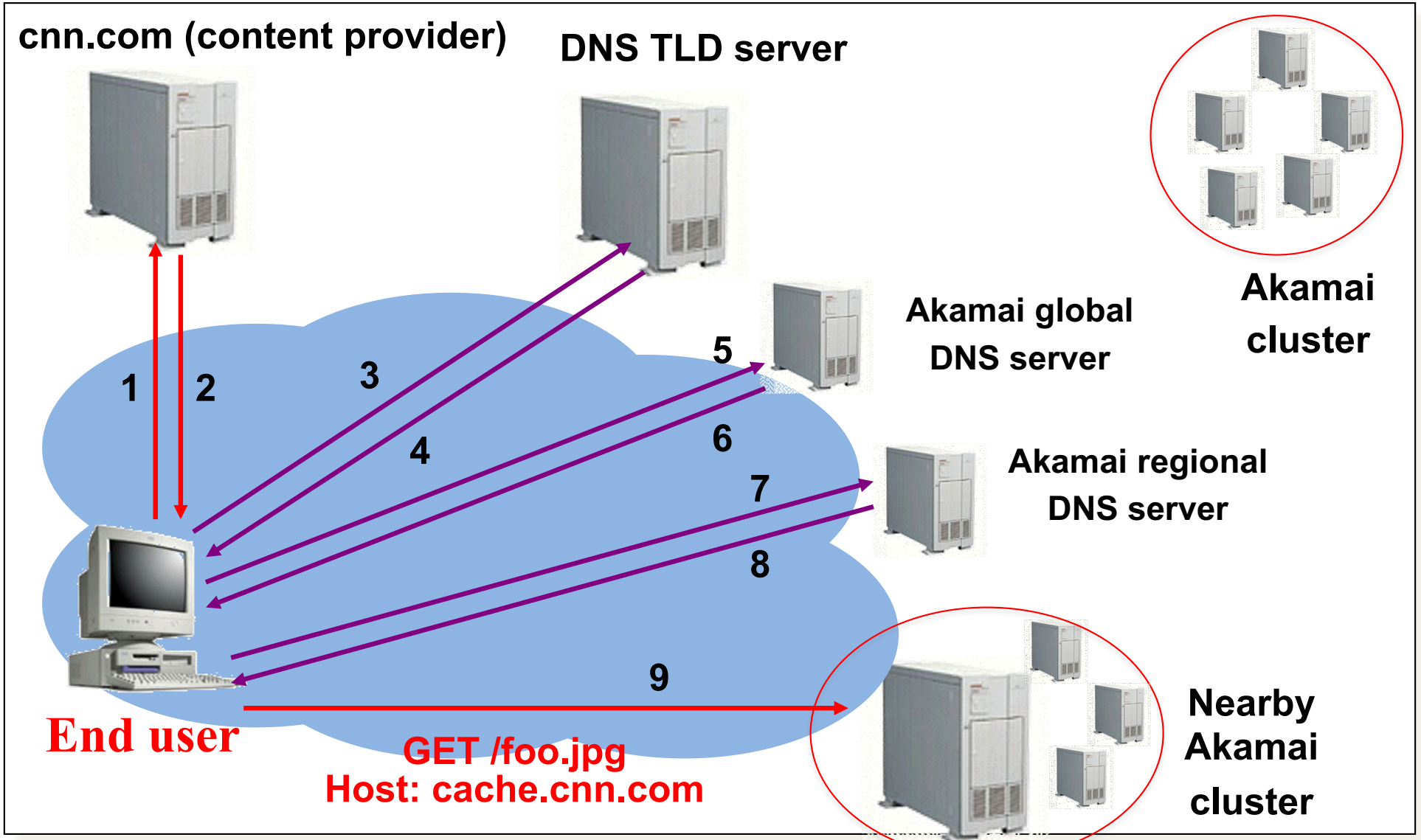

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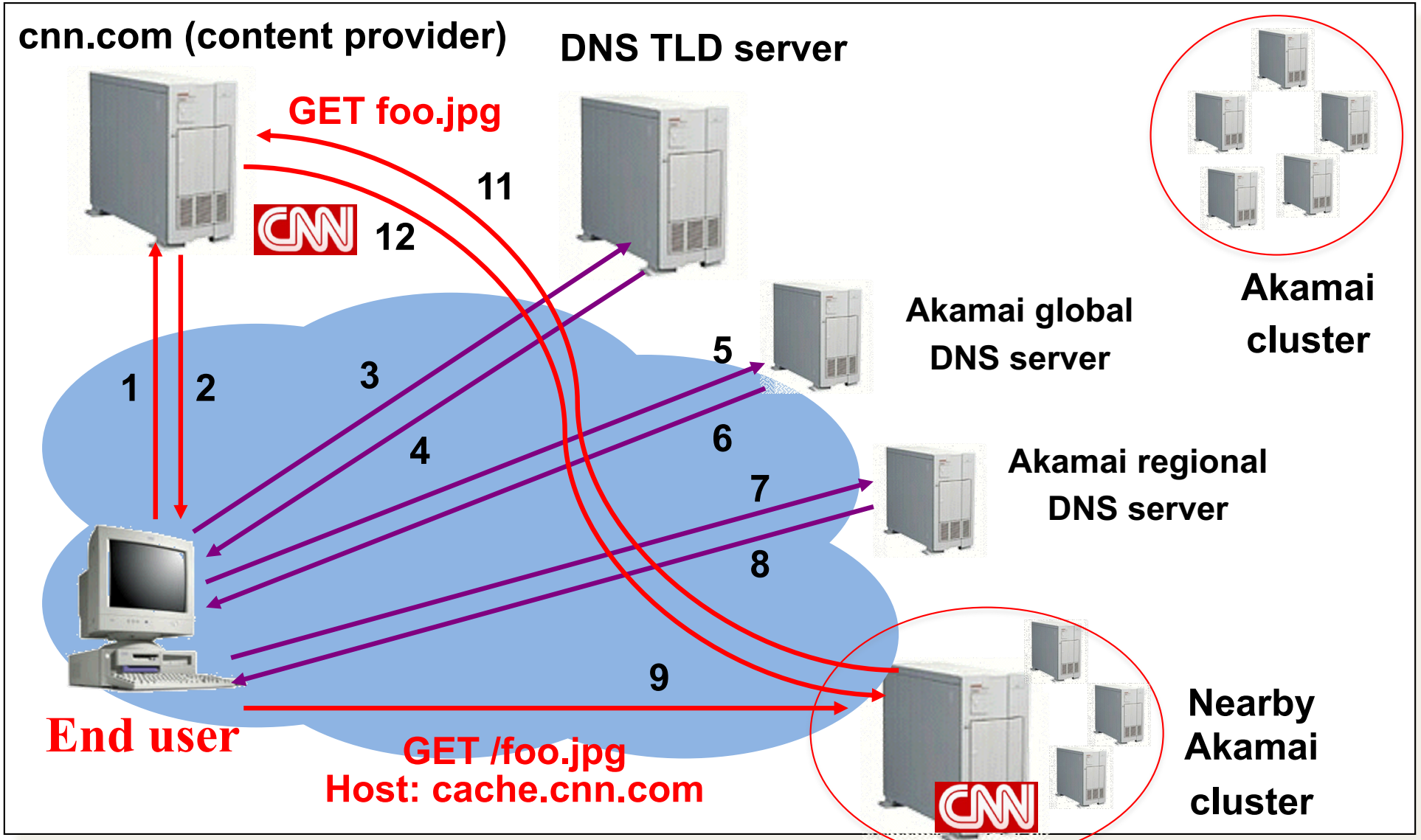

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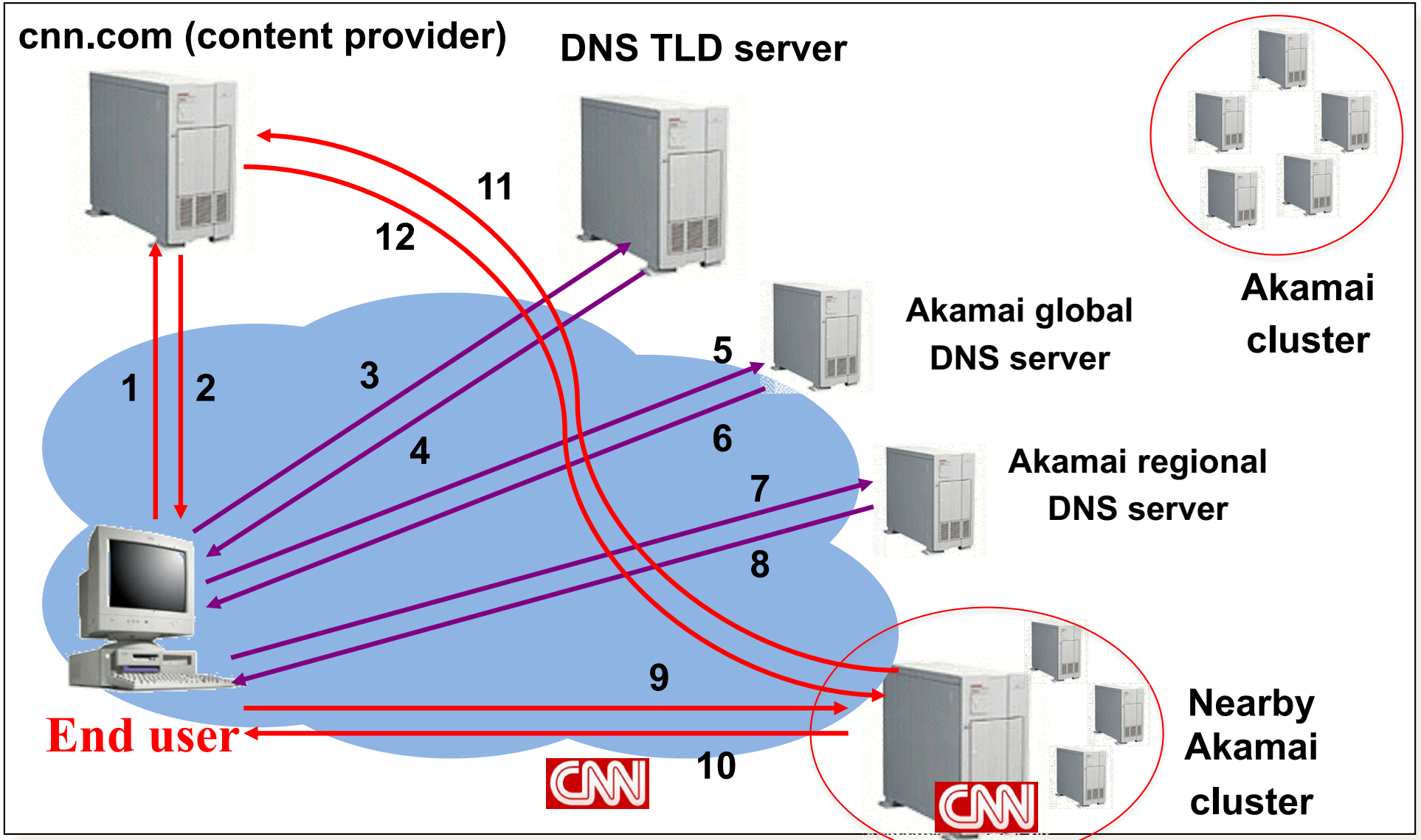
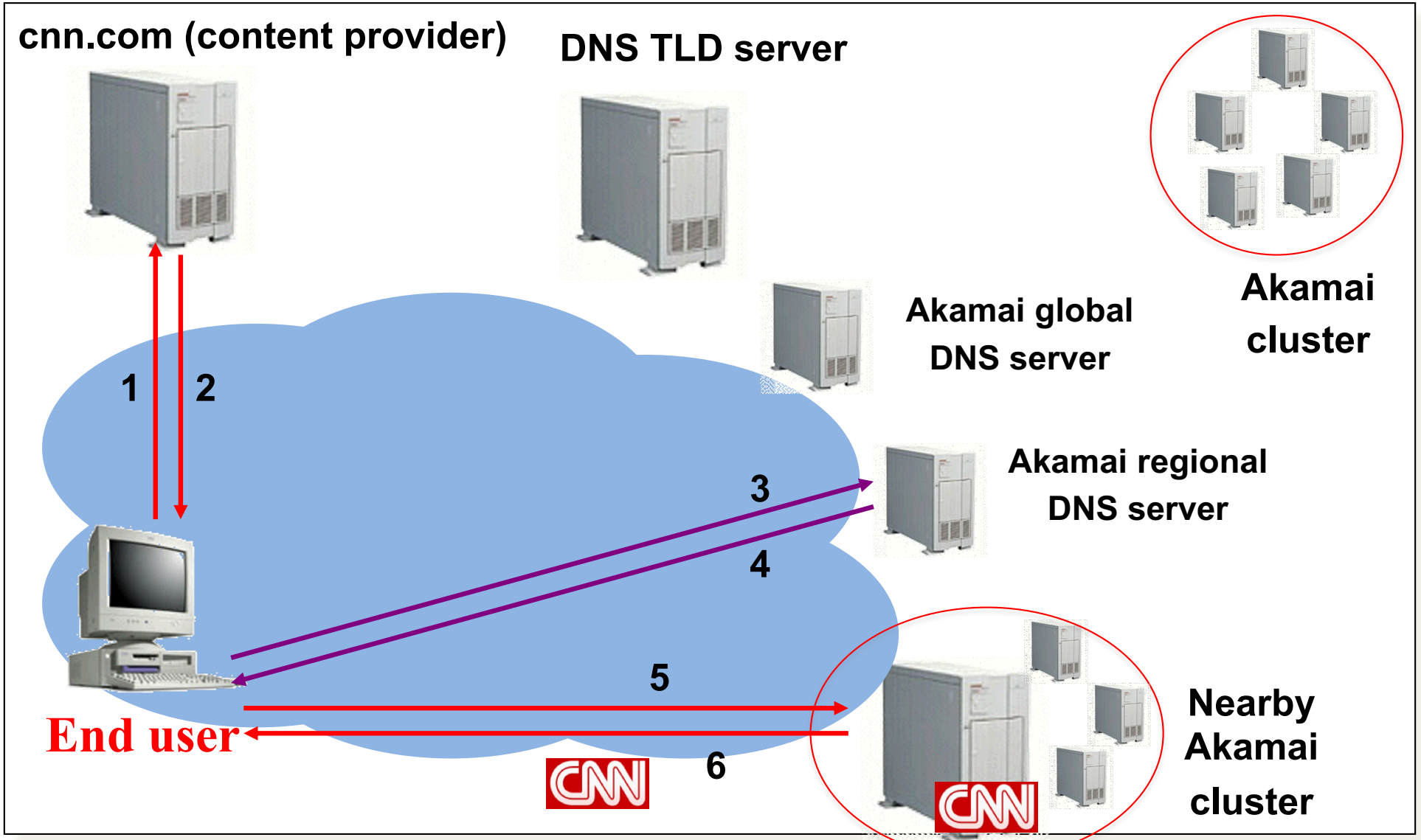


How Akamai Works: Cache Hit



Mapping System

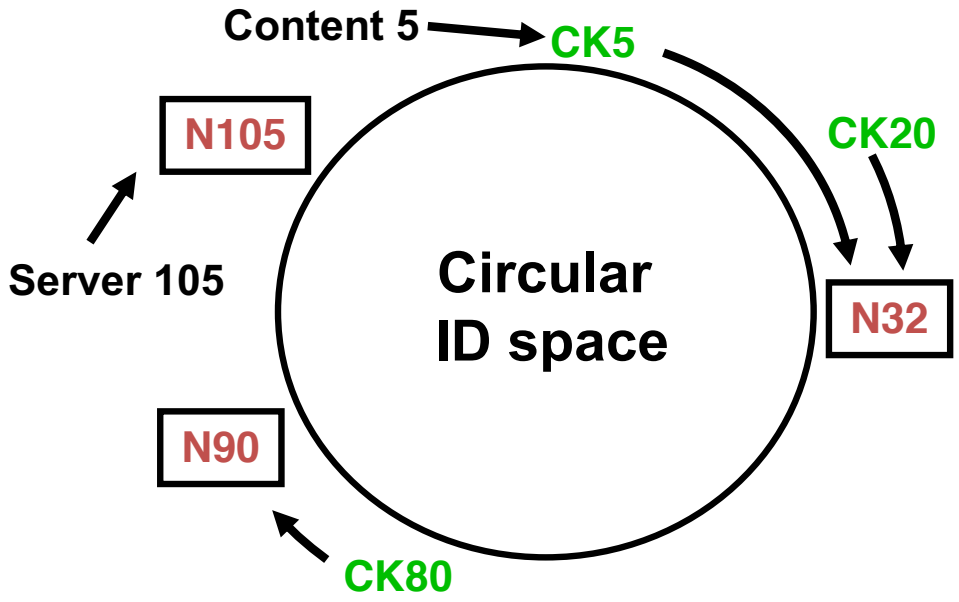
- Equivalence classes of IP addresses
  - IP addresses experiencing similar performance
  - Quantify how well they connect to each other
- Collect and combine measurements
  - Ping, traceroute, BGP routes, server logs
    - E.g., over 100 TB of logs per days
  - Network latency, loss, and connectivity

Routing Client Requests within 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

Selecting server inside cluster

- "Consistent hashing"
  - content_key = hash(URL) mod N
  - node_key = hash(server ID) mod N
  - Content belongs to server's node_key is "closest" to URL's content_key



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
- Failed cluster or network path
  - High-level map updated quickly
- Failed path to customer's origin server
  - Route packets through an intermediate node

Akamai Transport Optimizations

- Bad Internet routes
  - Overlay routing through an intermediate server
- Packet loss
  - Sending redundant data over multiple paths
- TCP connection set-up/teardown
  - Pools of persistent connections
- TCP congestion window and round-trip time
  - Estimates based on network latency measurements

Akamai Application Optimizations

- Slow download of embedded objects
  - Prefetch when HTML page is requested
- Large objects
  - Content compression
- Slow applications
  - Moving applications to edge servers
  - E.g., content aggregation and transformation
  - E.g., static databases (e.g., product catalogs)

Conclusion

- Content distribution is hard
  - Many, diverse, changing objects
  - Clients distributed all over the world
- Moving content towards client is key
  - Reduces latency, improves throughput, reliability
- Contribution distribution solutions evolved
  - Reactive caching, load balancing, to
  - Proactive content distribution networks