# Distributed Systems

## Content Delivery Networks

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University of Edinburgh, 2015

# OVERVIEW

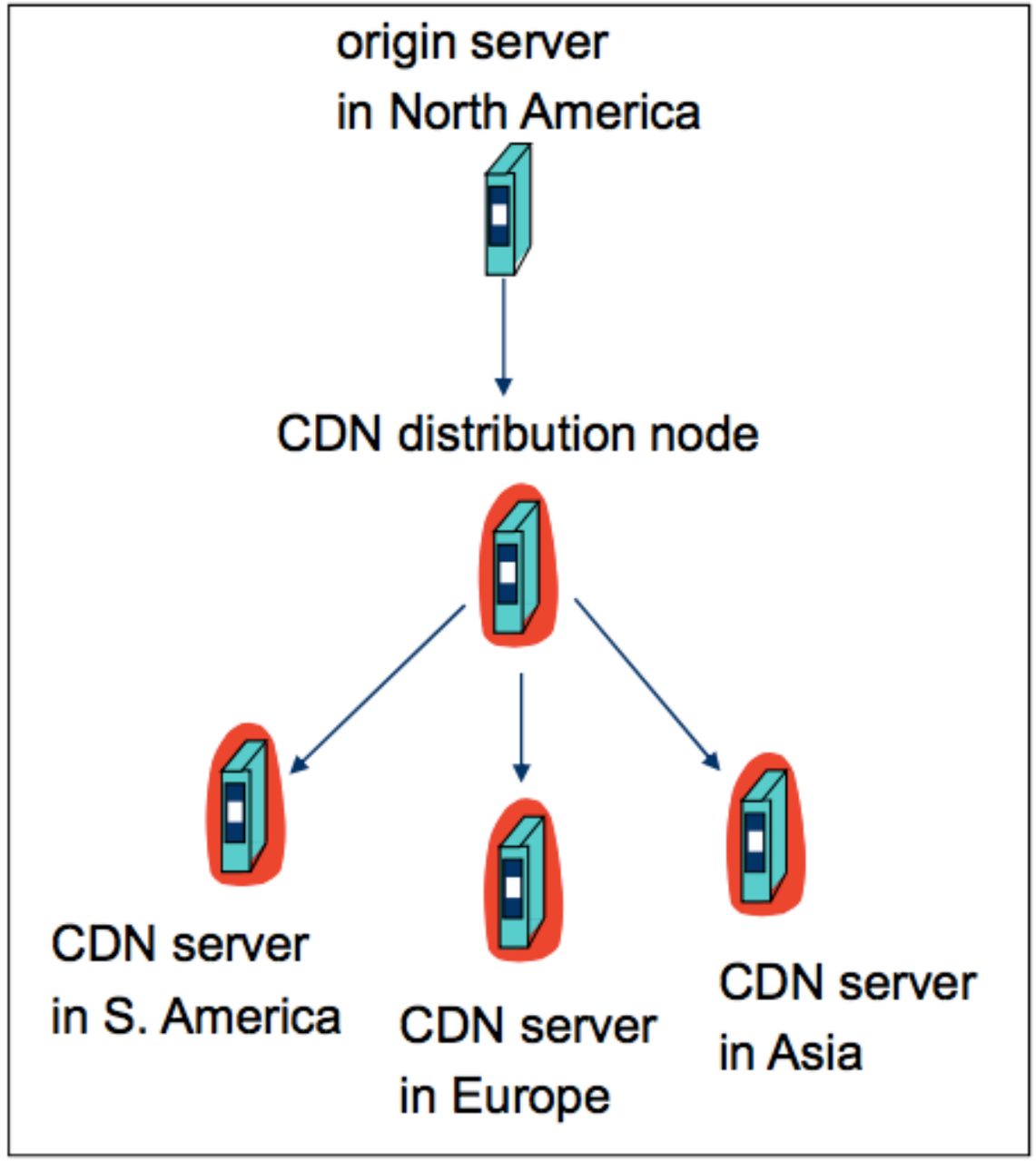
- Motivation
- Edge servers
- Content delivery
- Mapping
- Impact on Internet

# CONTENT DELIVERY NETWORKS

- The content providers are the CDN customers.

Content replication

- CDN company installs hundreds of CDN servers throughout Internet
  - Close to users
- CDN replicates its customers' content in CDN servers. When provider updates content, CDN updates servers



# CONTENT DELIVERY NETWORKS

## REAL-WORLD RELEVANCE

### Political Sites Scale Up for Election Night Traffic

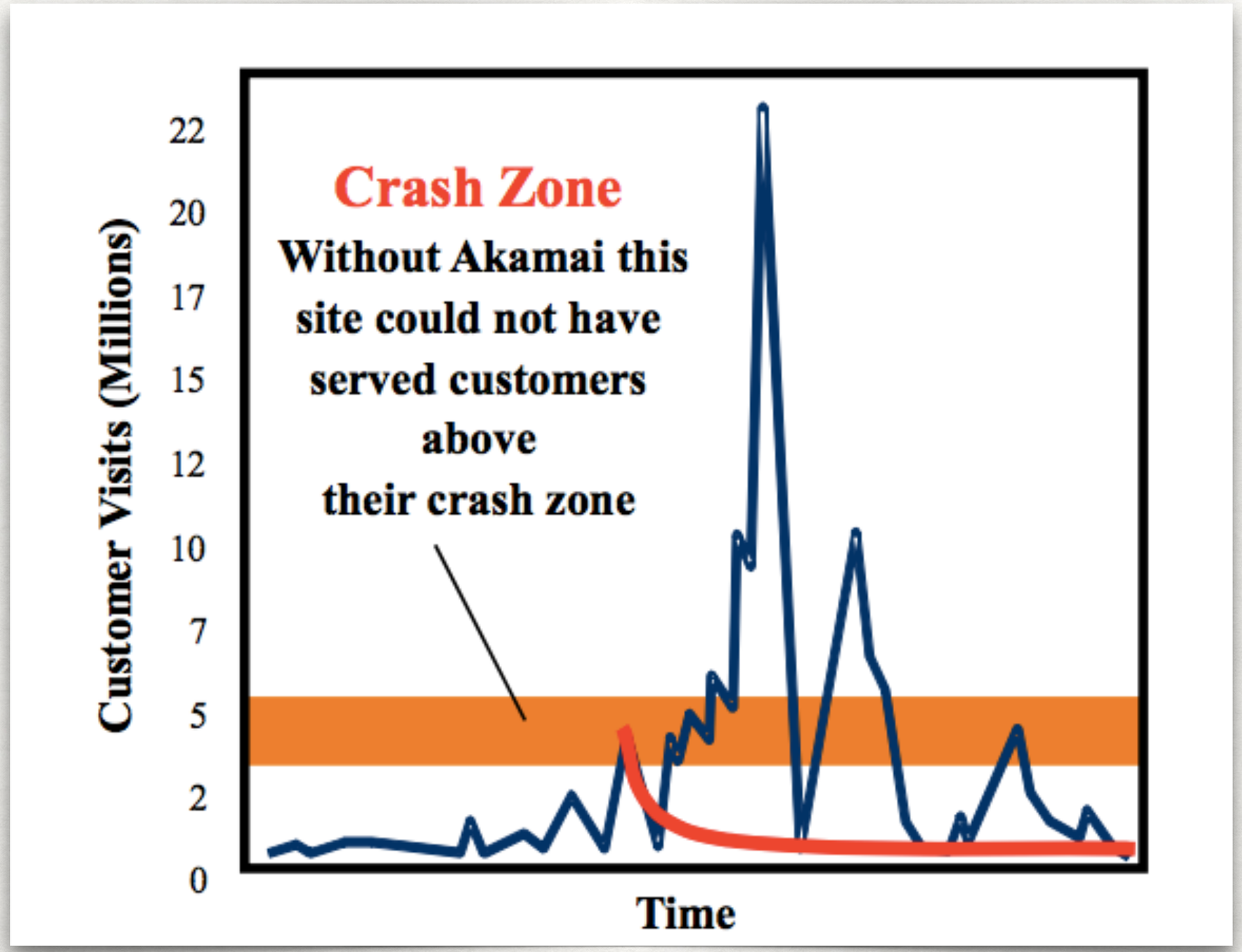
BY RICH MILLER ON NOVEMBER 4, 2008 2 COMMENTS

2 Like 0 Tweet Share 0 G+1

Election Night is one of the great scheduled scalability challenges. The extraordinary interest in the U.S. Presidential election is likely to translate into enormous web traffic tonight, and news sites and political blogs have had months to prepare. This is the political equivalent of the Super Bowl, and sites are scaling up to meet the challenge. Several hosting companies report increased sales of dedicated servers, and election traffic will likely be a boon to content delivery networks (CDNs).

# CASE STUDY ON RELIABILITY AND SCALABILITY

## THE 2000 ELECTION



# CONTENT DELIVERY NETWORKS

## WHAT IS THE CDN?

- Edge Caches: work with ISP and networks everywhere to install edge caches
  - Edge = close to customers
- Content delivery: getting content to the edge caches
  - Content can be objects, video, or entire web sites
- Mapping: find the “closest” edge server for each user and deliver content from that server
  - Network proximity not the same as geographic proximity
  - Focus is on performance as observed by user (quality)

# CONTENT DELIVERY NETWORKS

## POTENTIAL BENEFITS

- Very good scalability
  - Near infinite if deployed properly
- Good economies at large scales
  - Infrastructure is shared efficiently by customers
  - Statistical multiplexing: hot sites use more resources
- Avoids congestion and long latencies
  - Through mapping to closest server
- Can be extremely reliable
  - Very high degree of redundancy
  - Can mitigate some DoS attacks

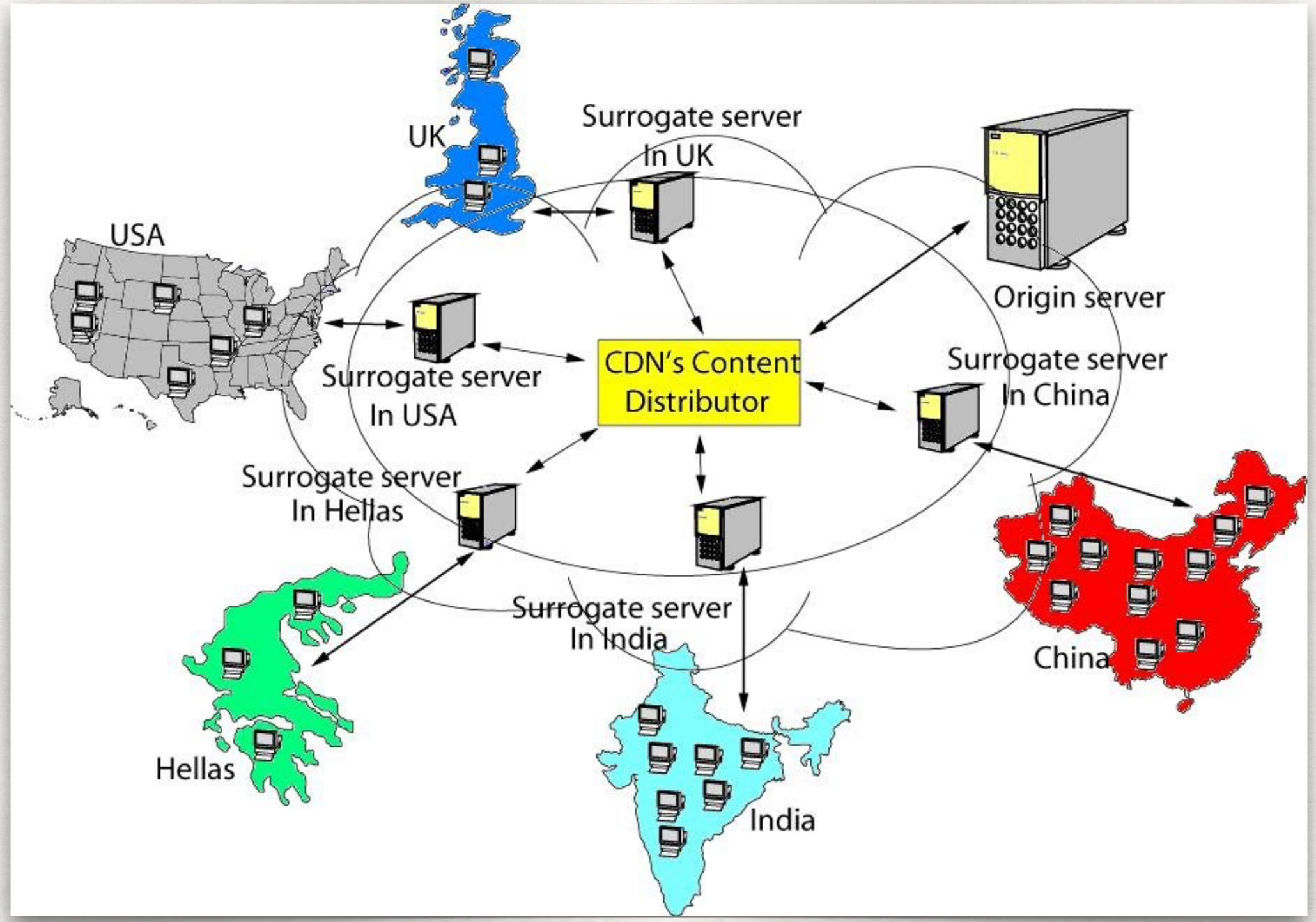
# CONTENT DELIVERY NETWORKS

## EDGE CACHES

- Region – set of caches managed as a cluster
  - May have a specific function: http, streaming, …
- Availability is a major concern in architecture design
- Redundancy at the network level
  - See next slide
- Dealing with server failures
  - Servers do fail occasionally
  - Each server has a “buddy” which is constantly trading hellos
  - If hellos stop, buddy starts to respond directly to requests for primary server
  - Users in the middle of a download may have to hit “reload”
  - No one else will notice any interruption

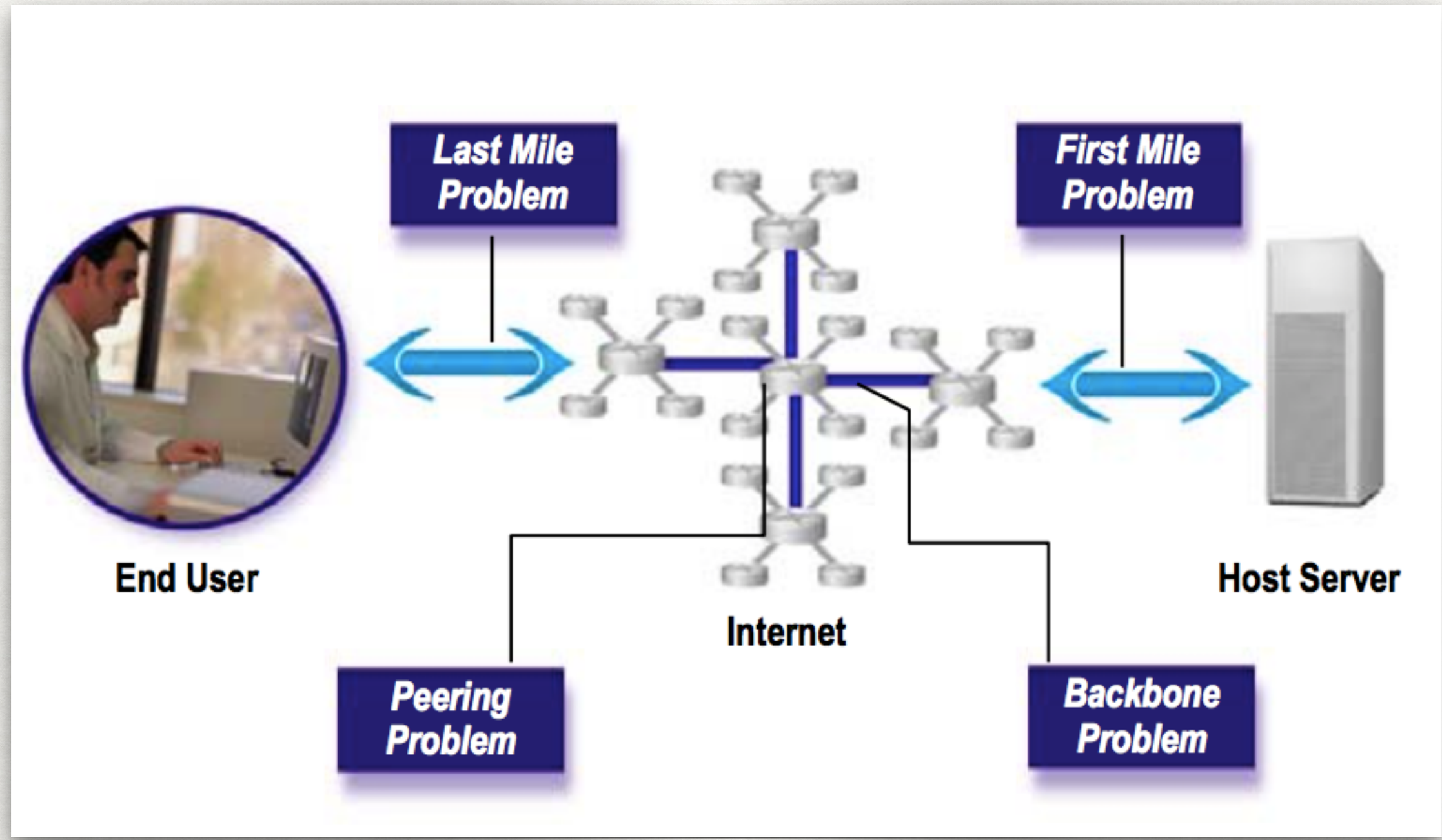
# CONTENT DELIVERY NETWORKS

## EXAMPLE CONFIGURATION



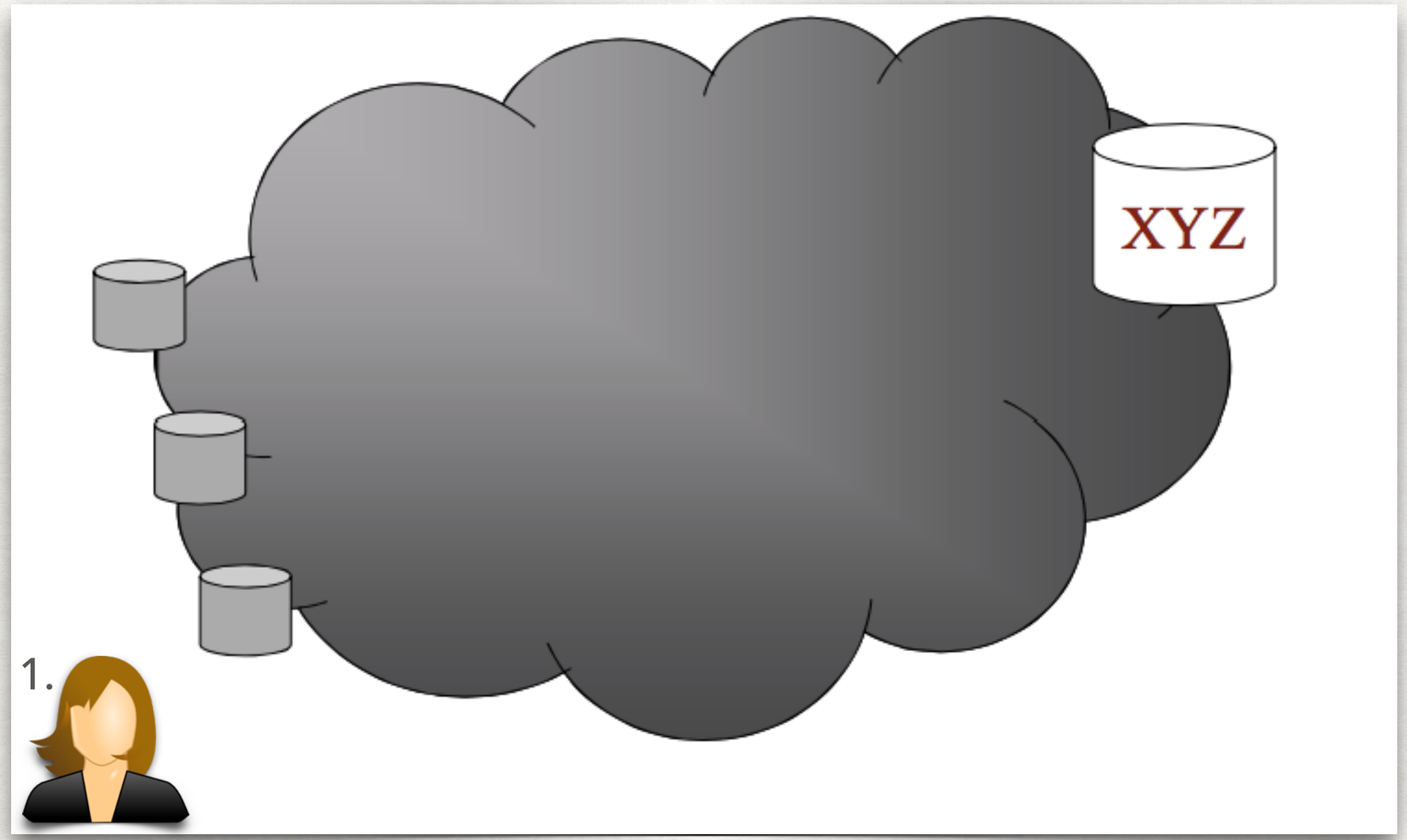
# CONTENT DELIVERY NETWORKS

## POSSIBLE BOTTLENECKS



# CONTENT DELIVERY NETWORKS

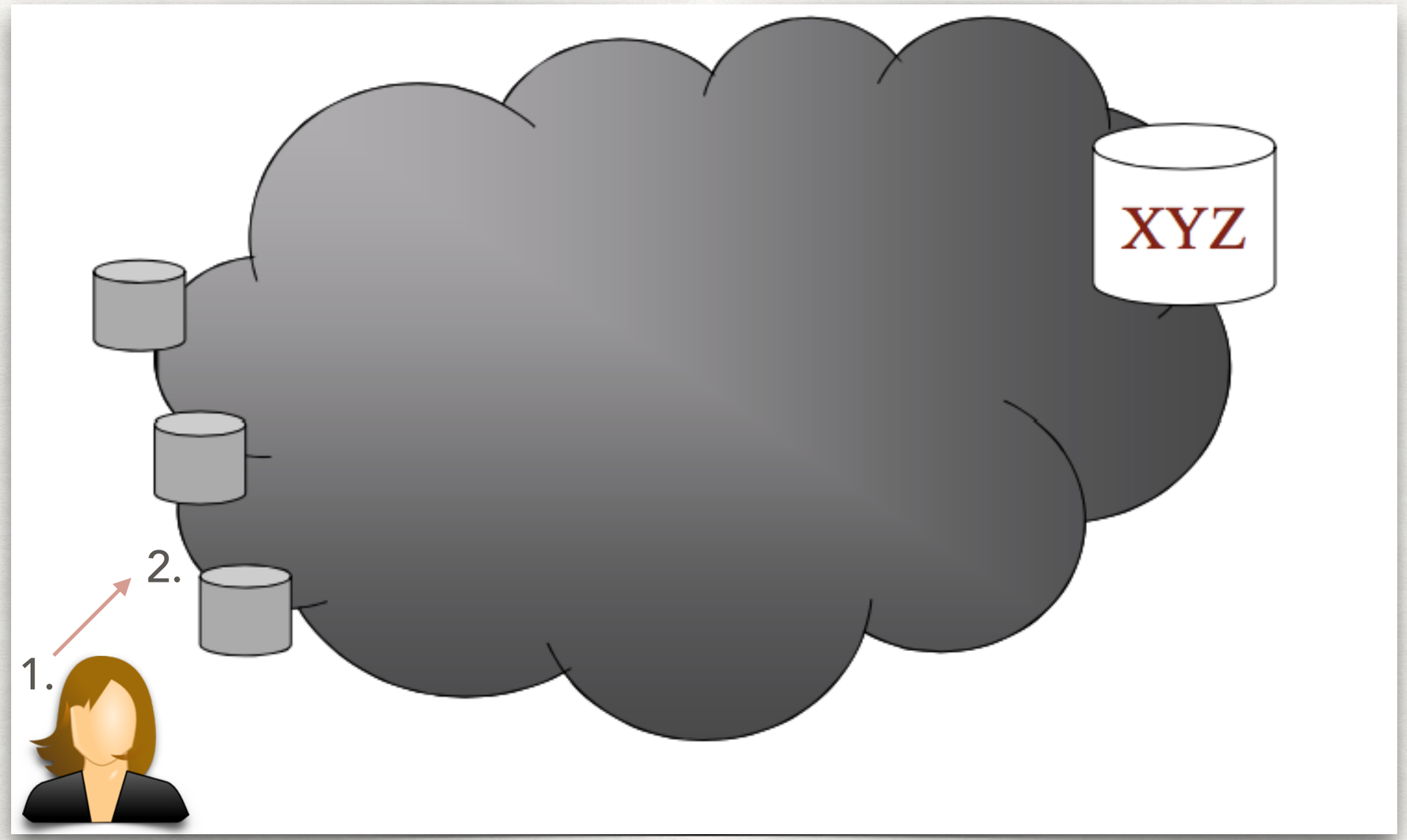
## PROCESS FLOW




1. User wants to download distributed web content

# CONTENT DELIVERY NETWORKS

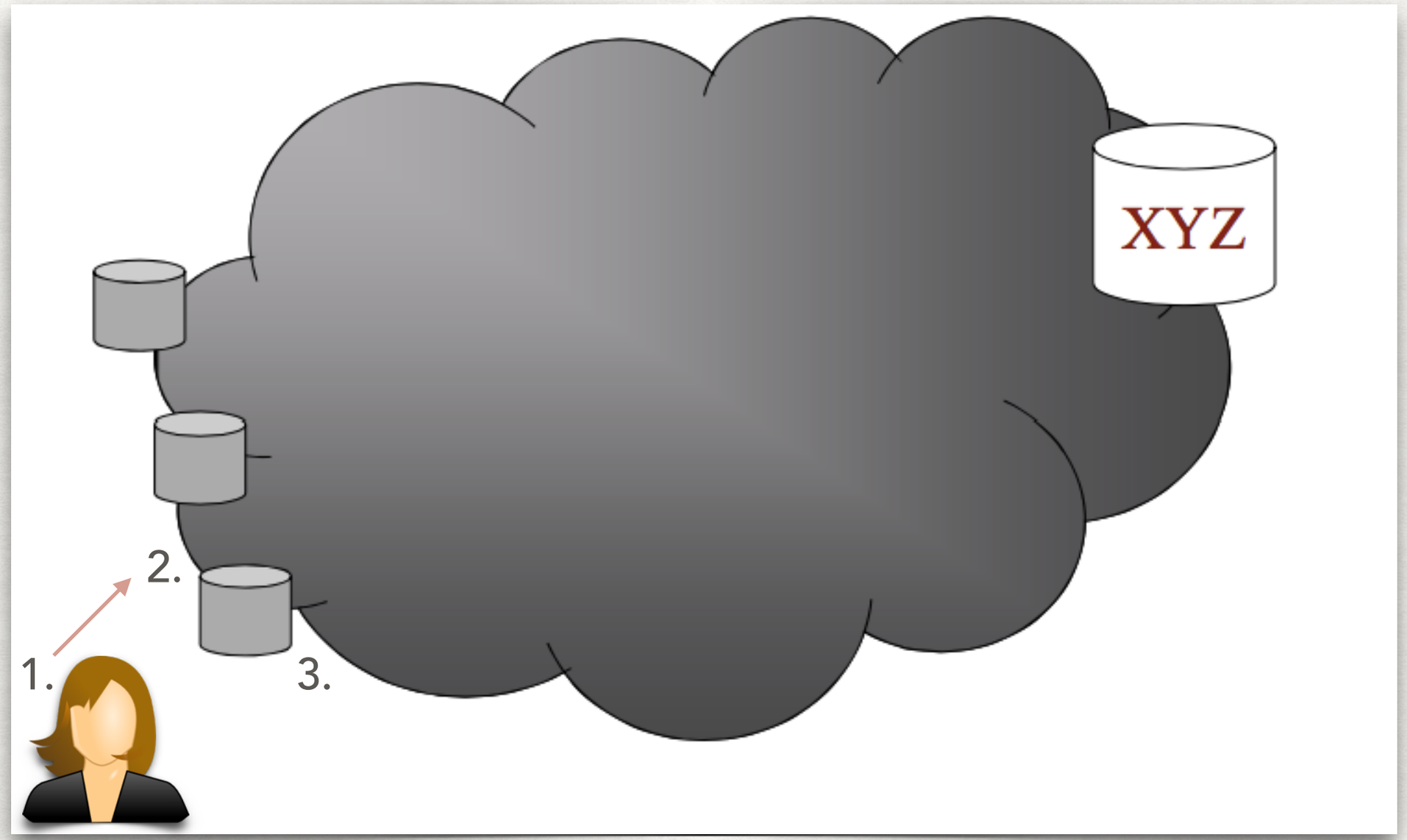
## PROCESS FLOW




2. User is directed through Akamai's dynamic mapping to the "closest" edge cache

# CONTENT DELIVERY NETWORKS

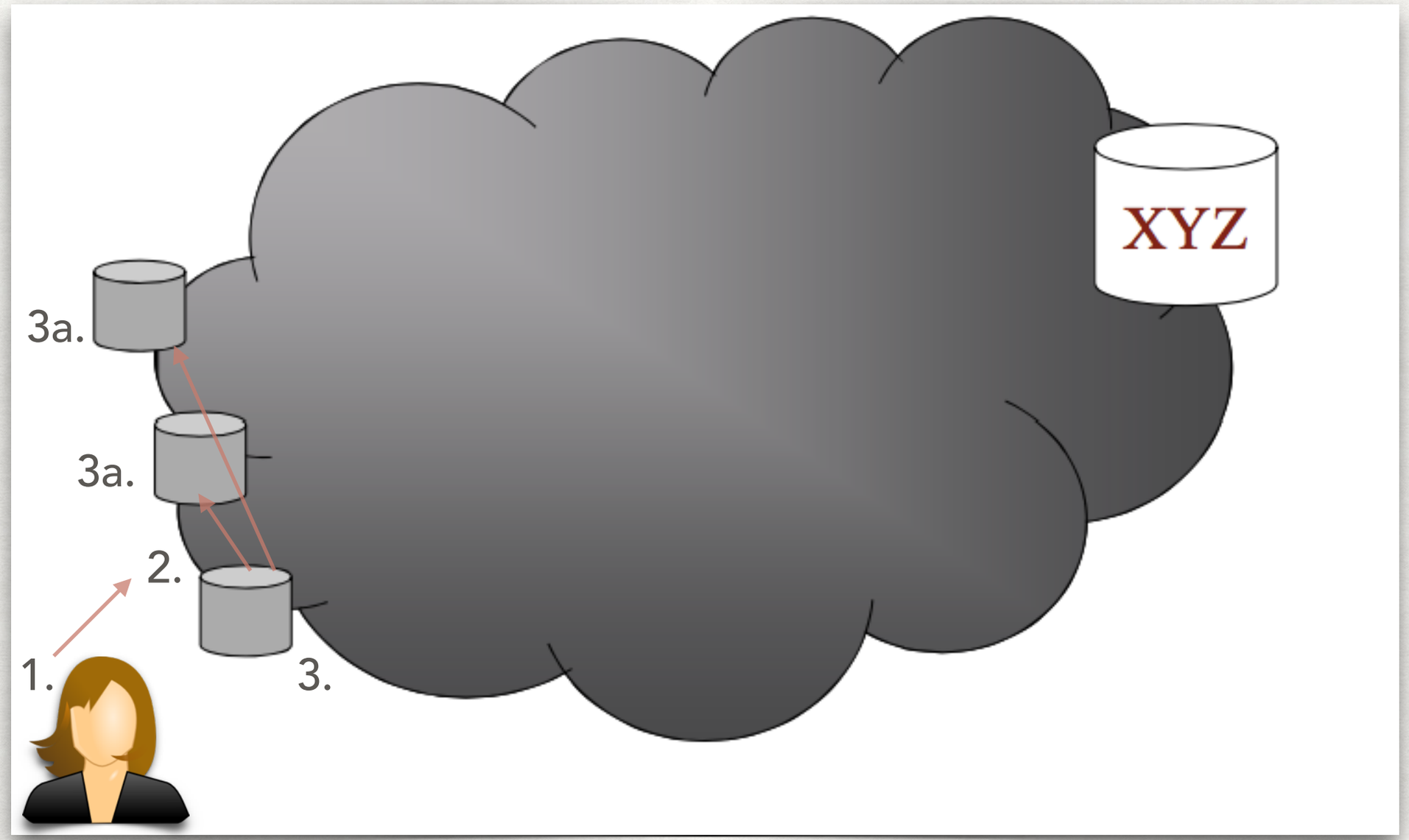
## PROCESS FLOW




3. Edge cache searches local hard drive for content

# CONTENT DELIVERY NETWORKS

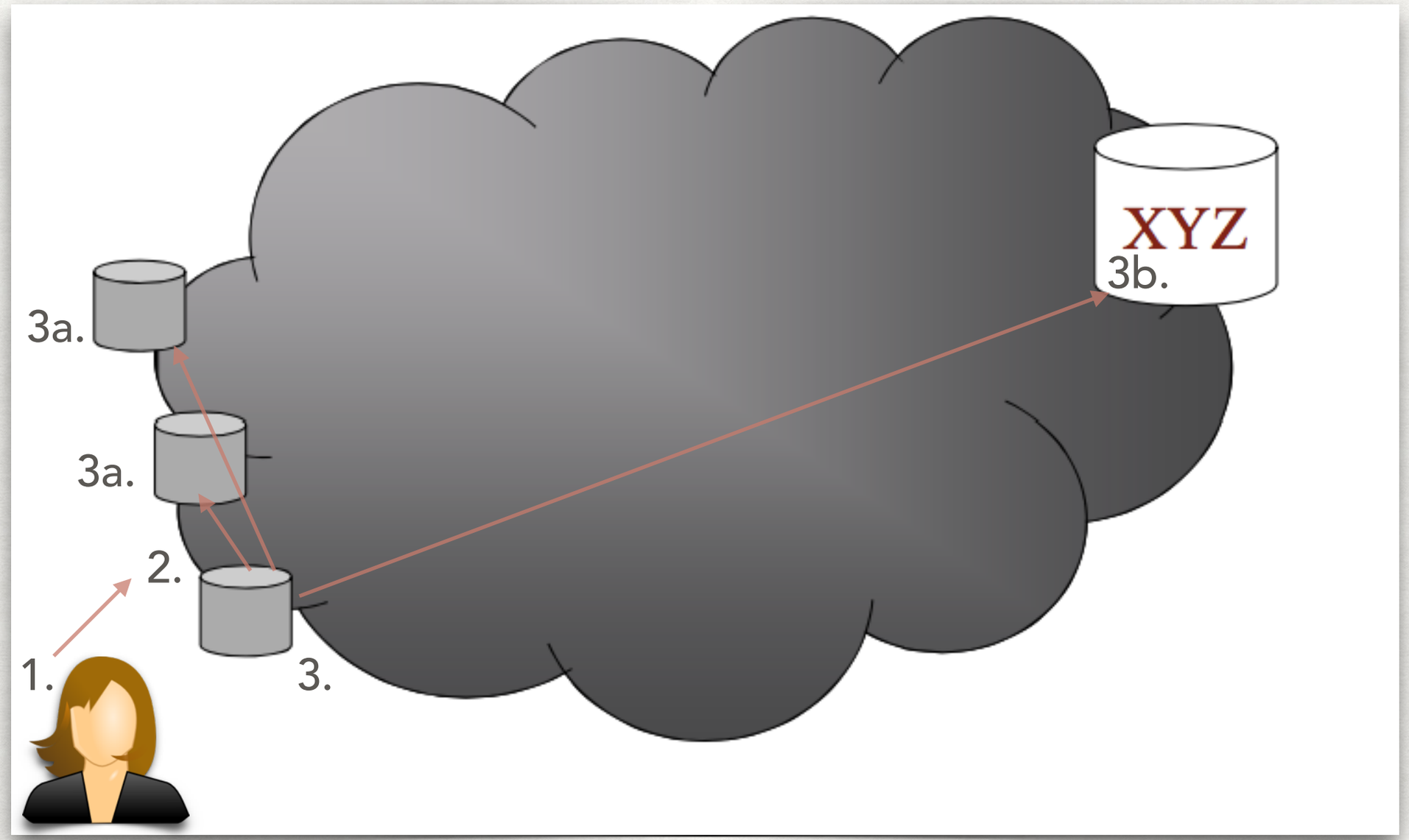
## PROCESS FLOW




3a. If requested object is not on local hard drive,
edge cache checks other edge caches in same region for object

# CONTENT DELIVERY NETWORKS

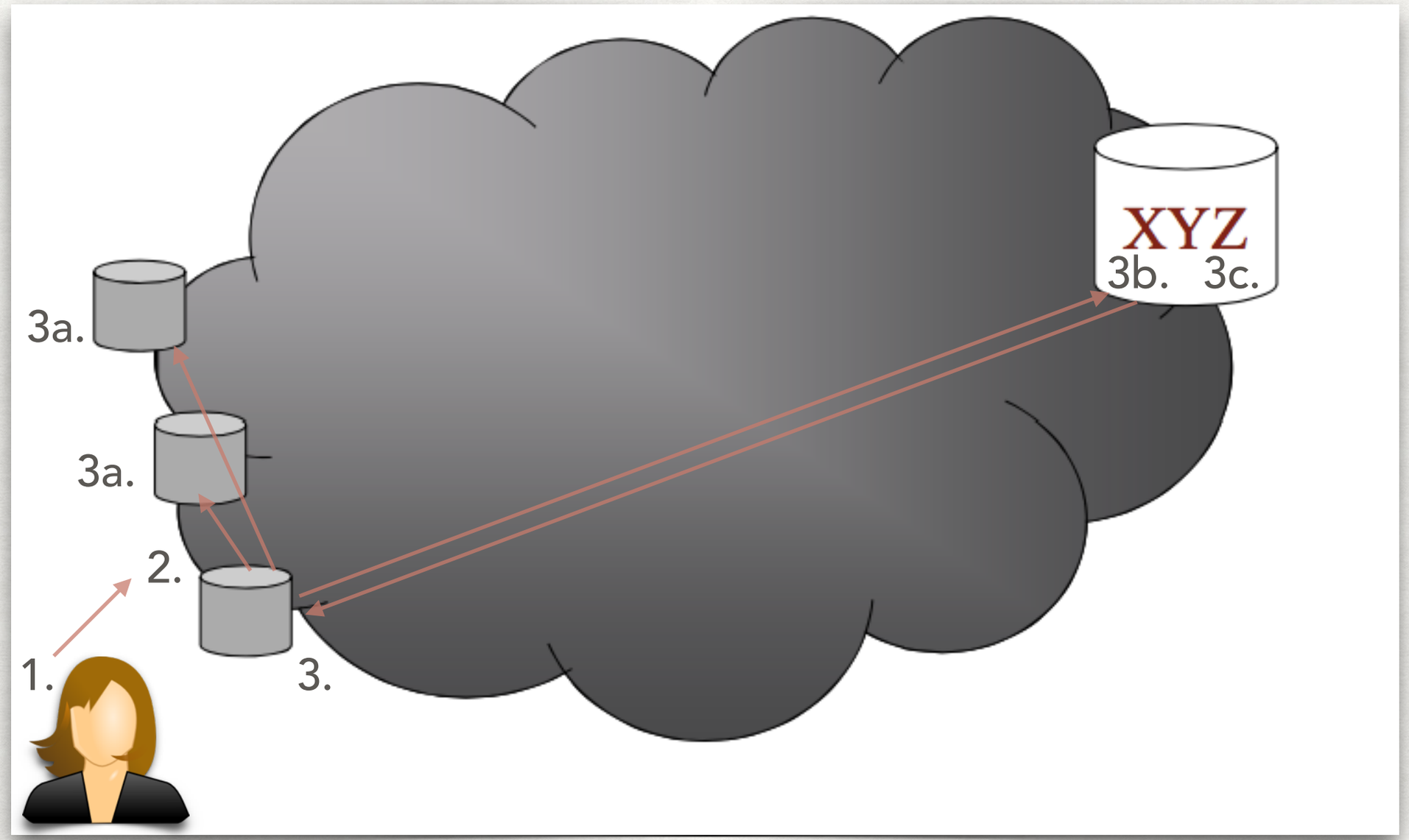
## PROCESS FLOW




3b. If requested object is not cached or not fresh, edge cache sends an HTTP GET the origin server

# CONTENT DELIVERY NETWORKS

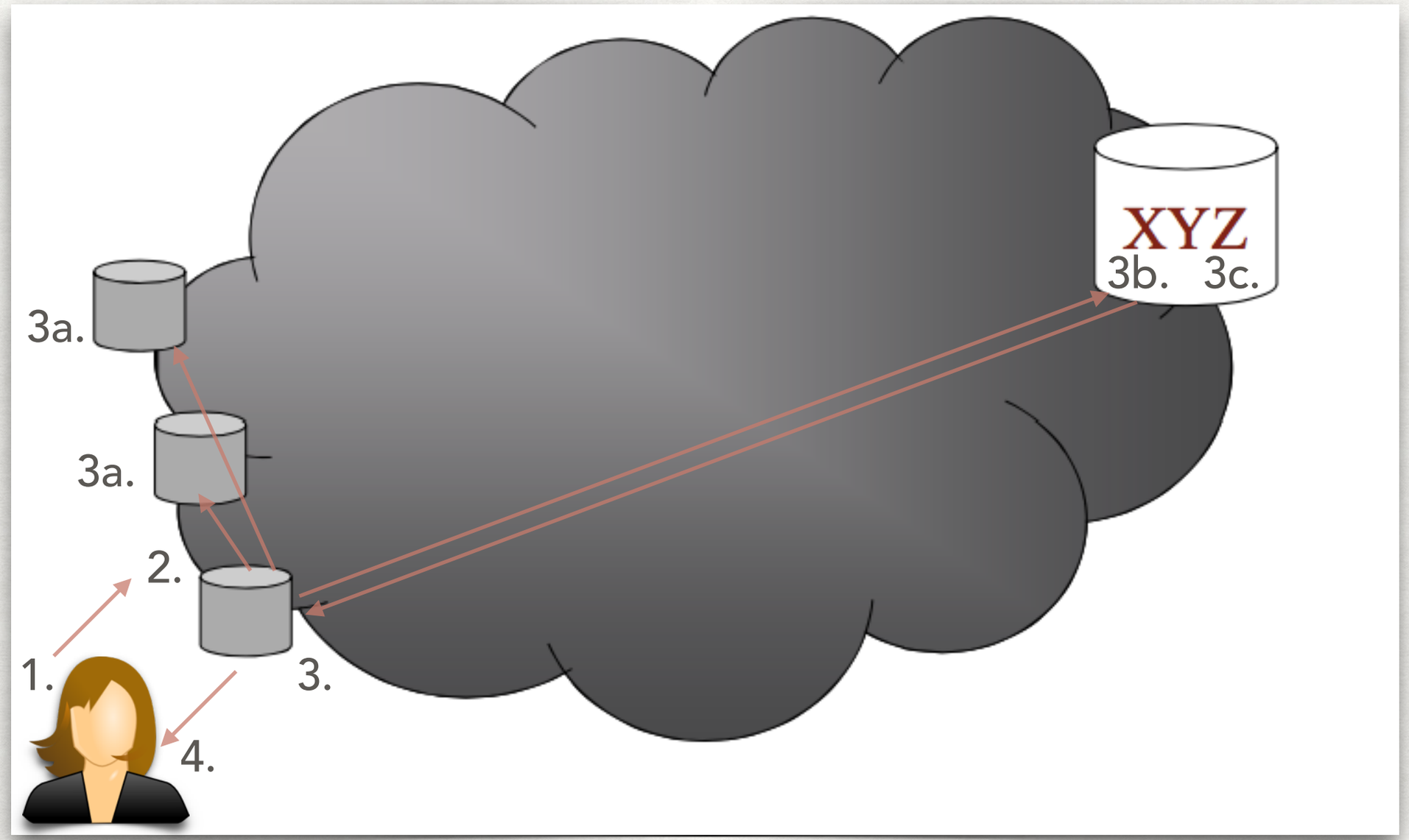
## PROCESS FLOW




3c. Origin server delivers object to edge cache over optimized connection

# CONTENT DELIVERY NETWORKS

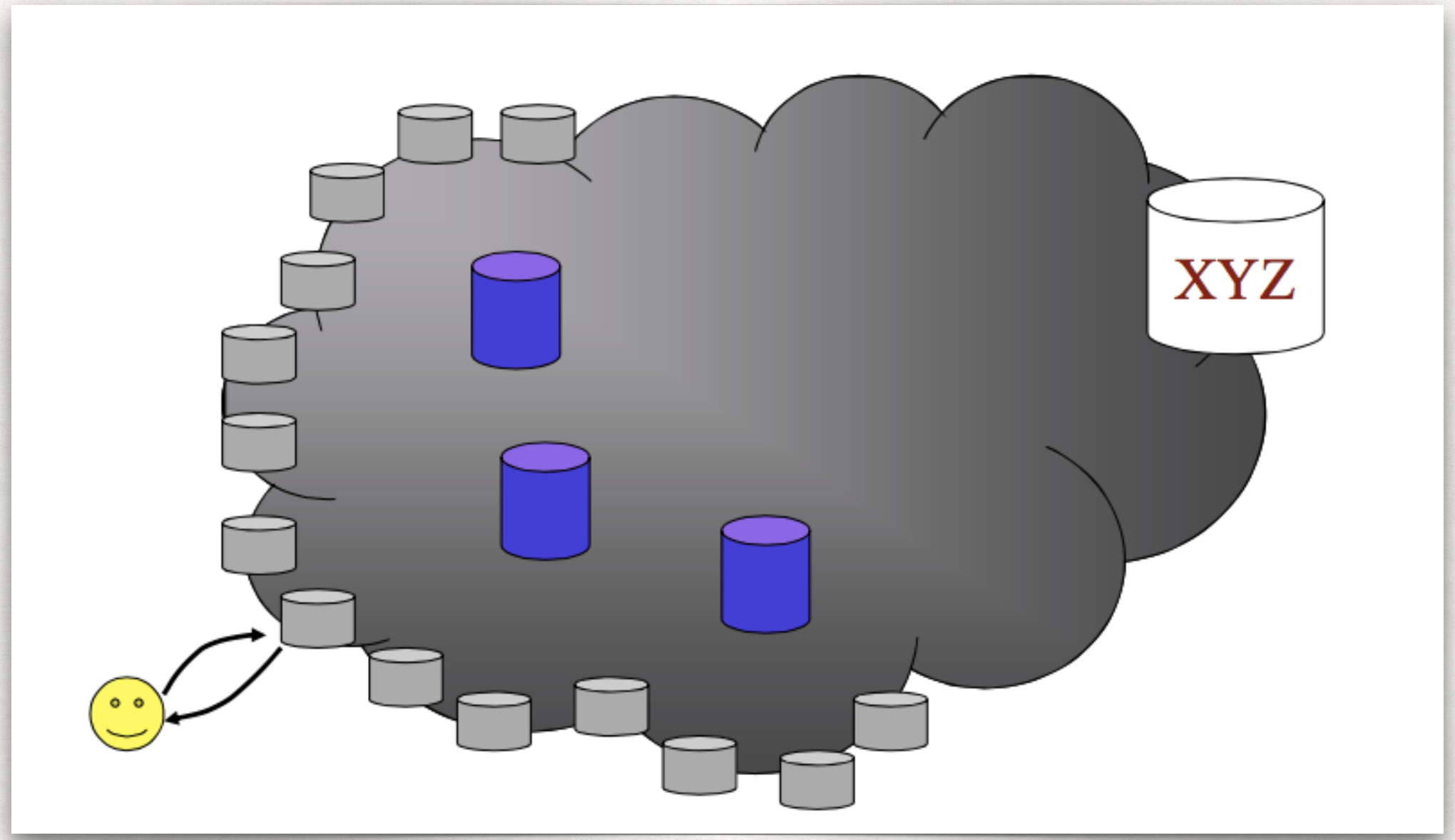
## PROCESS FLOW




4. Edge server delivers content to end user

# CONTENT DELIVERY NETWORKS

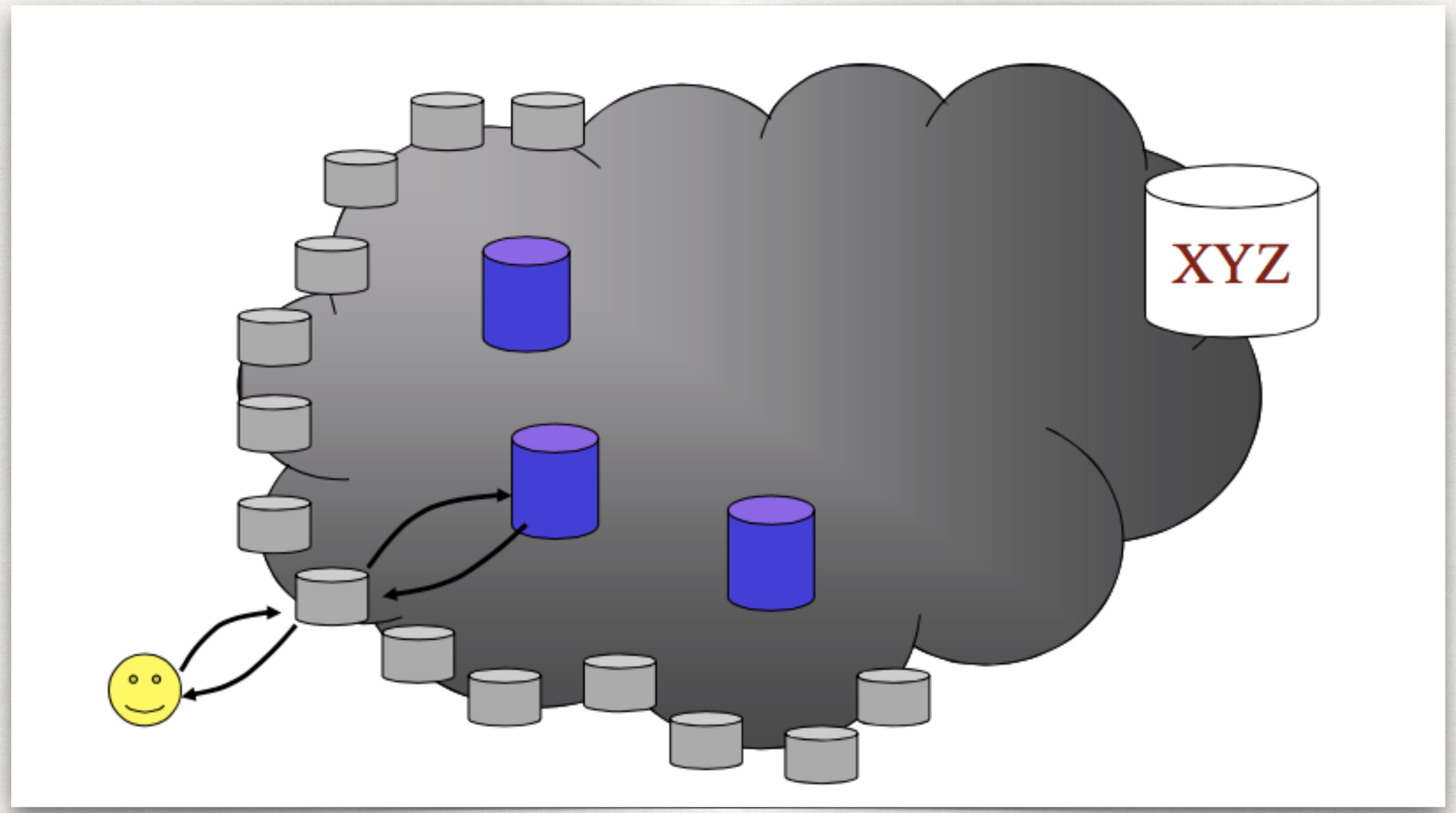
## CORE HIERARCHY REGIONS




1. User requests content and is mapped to optimal edge Akamai server

# CONTENT DELIVERY NETWORKS

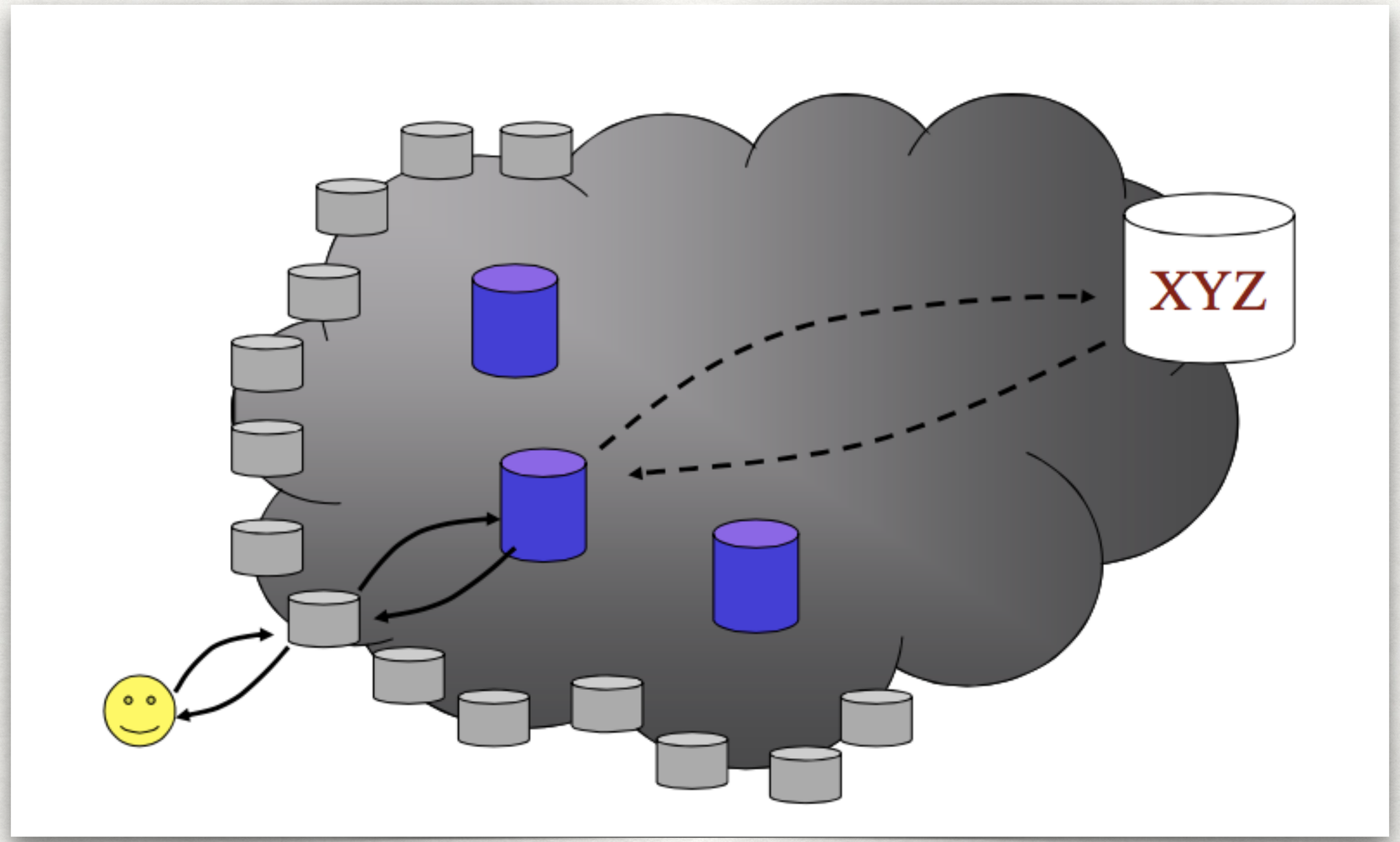
## CORE HIERARCHY REGIONS




2. If content is not present in the region, it is requested from most optimal core region

# CONTENT DELIVERY NETWORKS

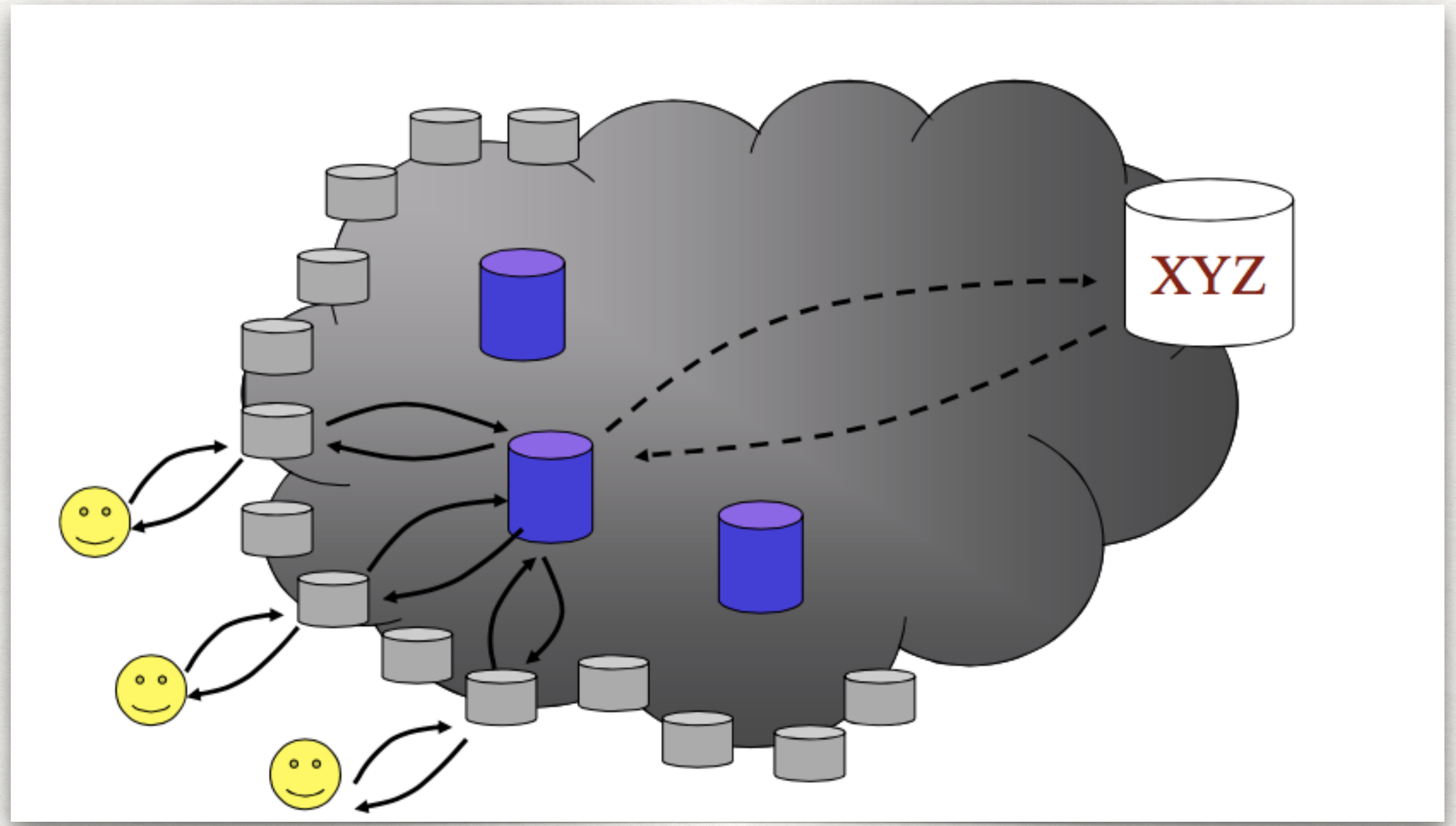
## CORE HIERARCHY REGIONS




3. Core region makes one request back to origin server

# CONTENT DELIVERY NETWORKS

## CORE HIERARCHY REGIONS




4. Core region can serve many edge regions with one request to origin server

# CONTENT DELIVERY NETWORKS

## CORE HIERARCHY FEATURES

**Reduces traffic back to origin server**

- Reduces infrastructure needs of customer
- Provides best protection against flash crowds
  - Especially important for large files (*e.g.* Operating System updates or video files)

**Improved end-user response time**

- Core regions are well connected
- Optimized connection speeds object delivery

# CONTENT DELIVERY NETWORKS

## MAPPING: SERVER SELECTION

- Which server?
  - Lowest load → to balance load on servers
  - Best performance → to improve client performance
    - Based on Geography? RTT? Throughput? Load?
  - Any alive node → to provide fault tolerance
- How to direct clients to a particular server?
  - As part of routing → anycast, cluster load balancing
    - Not covered ☹
  - As part of application → HTTP redirect
  - As part of naming → DNS

# CONTENT DELIVERY NETWORKS

## APPLICATION BASED MAPPING

- HTTP supports simple way to indicate that Web page has moved (30X responses)
- Server receives Get request from client
  - Decides which server is best suited for particular client and object
  - Returns HTTP redirect to that server
- Can make informed application specific decision
- May introduce additional overhead → multiple connection setup, name lookups, etc.
- While good solution in general, but…
  - HTTP Redirect has some design flaws

# CONTENT DELIVERY NETWORKS

## NAMING BASED MAPPING

- Client does name lookup for service
- Name server chooses appropriate server address
  - A-record returned is “best” one for the client
- What information can name server base decision on?
  - Server load/location → must be collected
  - Information in the name lookup request
    - Name service client → typically the local name server for client

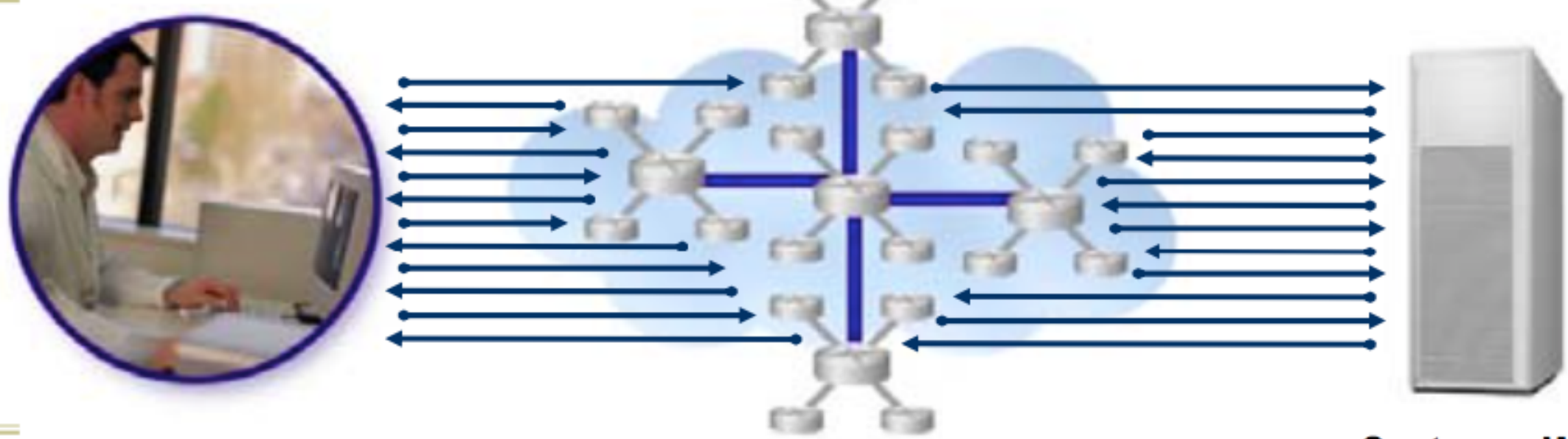
# CONTENT DELIVERY NETWORKS

## MAPPING ALGORITHMS

- Three main components to finding “closest” edge cache to end user from a Network point of view:
  - Packet Loss + Throughput + Latency
  - Listed in order of importance (roughly)
- Mapping also takes into account edge cache performance
  - Does a server have an object on its hard drive?
  - Uses consistent hashing algorithm
  - Does the edge cache have CPU, RAM, bandwidth, etc. available to serve end-user?

# CONTENT DELIVERY NETWORKS

## ACCESS TO WEB SITE WITHOUT CDN



End User

Customer Web Server

**1** User enters standard URL

www.customer.com

**2** Customer's Web Server returns HTML with embedded URLs

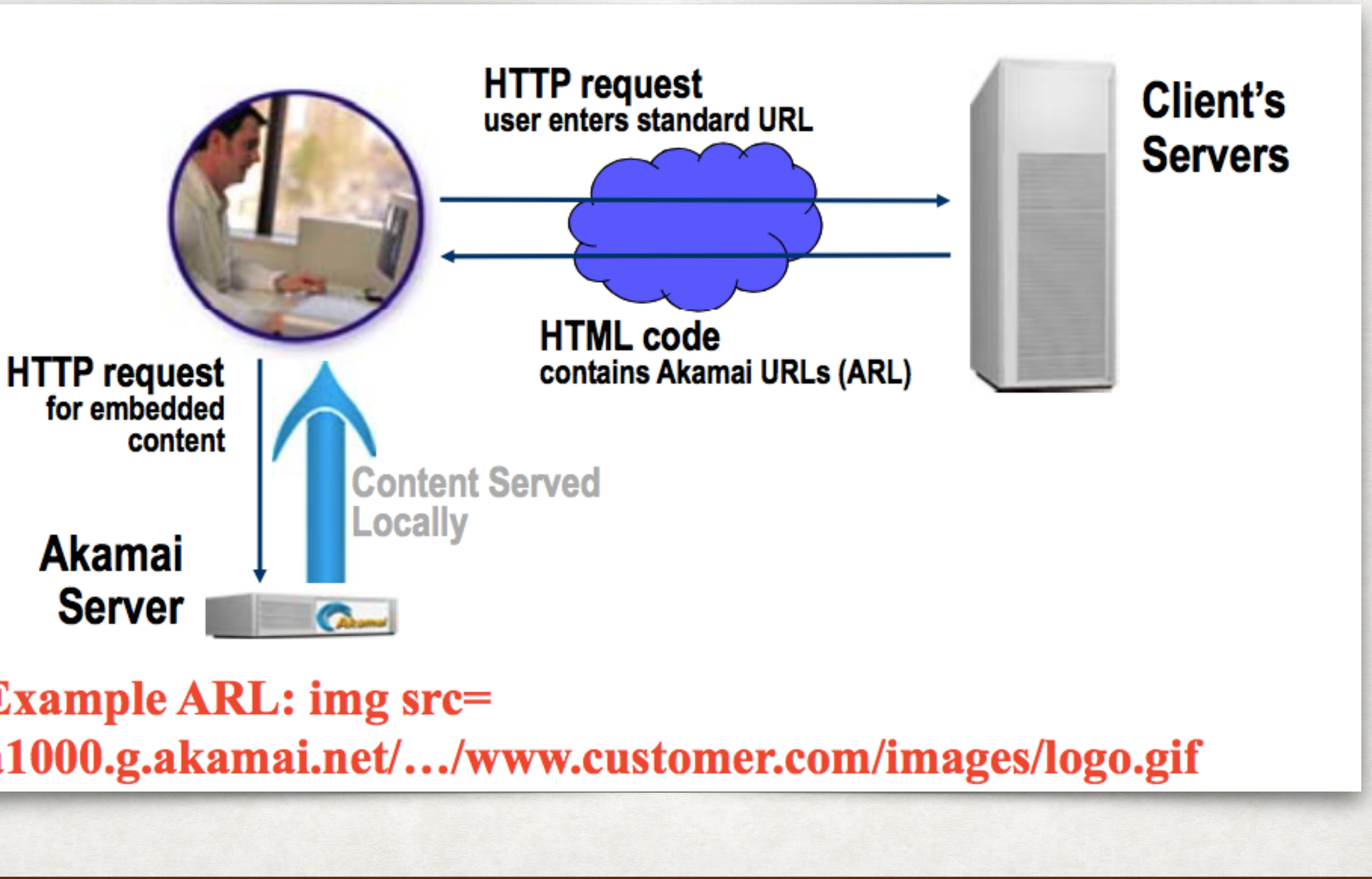
**3** User's browser requests embedded objects from customer Web server

**4** Objects served with round trips across the Internet

<img src=/images/logo.gif>

# CONTENT DELIVERY NETWORKS

## FREEFLOW – AKAMAI'S OBJECT DELIVERY SERVICE




**Example ARL: img src= a1000.g.akamai.net/…/www.customer.com/images/logo.gif**

# CONTENT DELIVERY NETWORKS

## STEPS IN CONTENT RETRIEVAL

- Clients fetch html document from primary server
  - E.g. fetch index.html from cnn.com
- URLs for replicated content are replaced in html
  - E.g. <img src="http://cnn.com/af/x.gif"> replaced with <img src="http://a73.g.akamaitech.net/7/23/cnn.com/af/x.gif">
  - Note that modified name includes original file name
  - Drawback: must modify the content
- Client is forced to resolve aXYZ.g.akamaitech.net hostname
- Focus is on static content
  - Can be freely cached

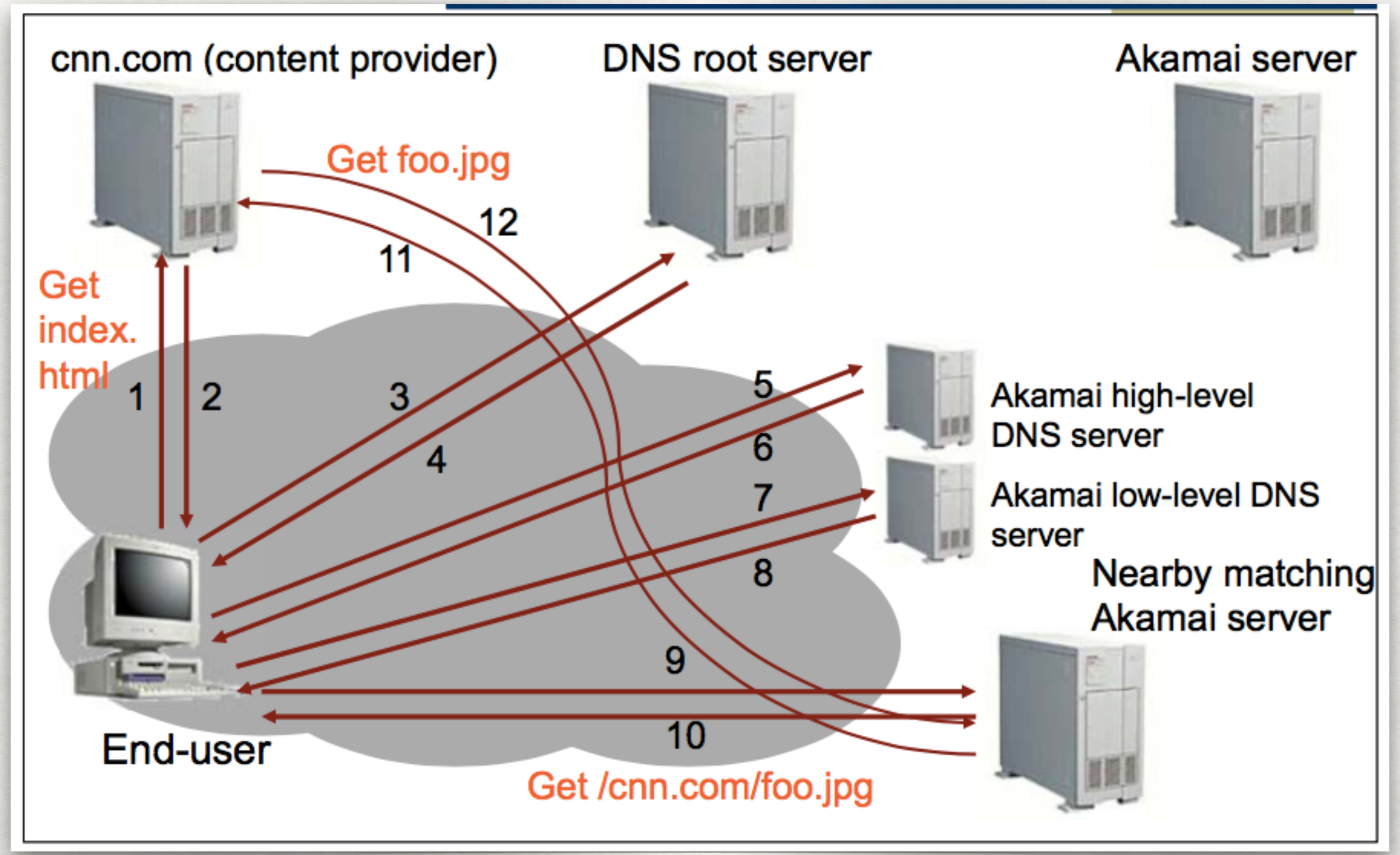
# CONTENT DELIVERY NETWORKS

## RESOLUTION OF MODIFIED NAME

- Root server gives NS record for akamai.net
- Akamai.net name server returns NS record for g.akamaitech.net
  - Name server chosen to be in region of client's name server
  - TTL is large
- G.akamaitech.net nameserver chooses server in region
  - Should try to chose server that has file in cache - How to choose?
  - Uses aXYZ name and hash
  - TTL is small → why?

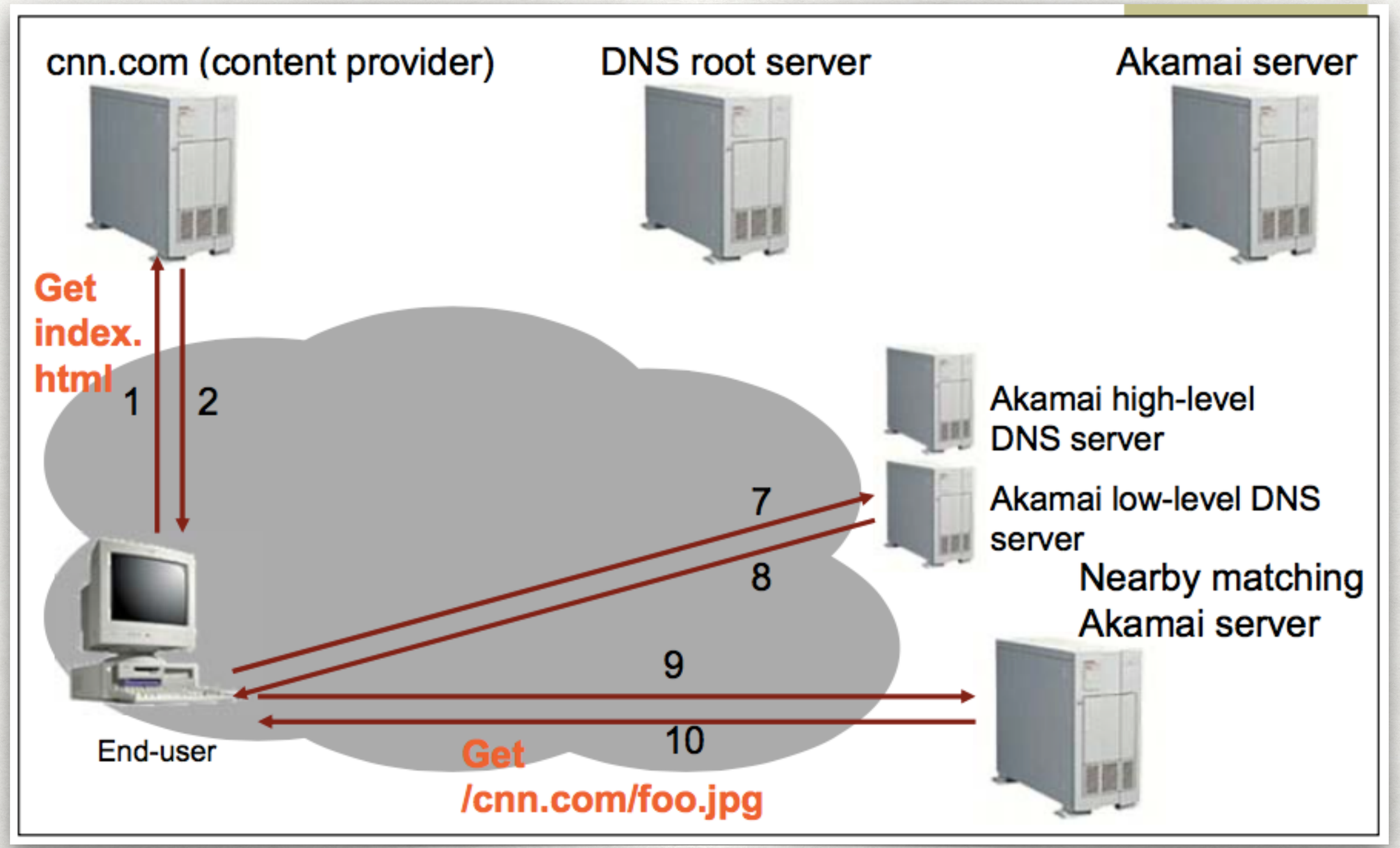
# CONTENT DELIVERY NETWORKS

## HOW AKAMAI WORKS



# CONTENT DELIVERY NETWORKS

## AKAMAI – SUBSEQUENT REQUESTS



# CONTENT DELIVERY NETWORKS

## EDGESUITE – AKAMAI'S SITE DELIVERY SERVICE

**Customer CNAME's (aliases)**

**www.customer.com**

- Anyone looking up www.customer.com will be redirected to an Akamai hostname - "customer.d4p.net"
  - No, I do not know why we use "d4p.net". ☺
- customer.d4p.net is CNAME'd to aXXX.g.akamai.net
- Standard Akamai mapping magic sends returns the closest edge server for aXXX.g.akamai.net

# CONTENT DELIVERY NETWORKS

## EDGESUITE – AKAMAI'S SITE DELIVERY SERVICE

**End user never communicates with origin server**

- Content retrieved from private hostname, e.g., "origin.customer.com?
- High reliability
  - Thousands of servers backing each other up
  - If one geographic area is disabled, no other area is affected
  - Mitigates some DoS attacks

**Uncacheable content is tunneled back to origin**

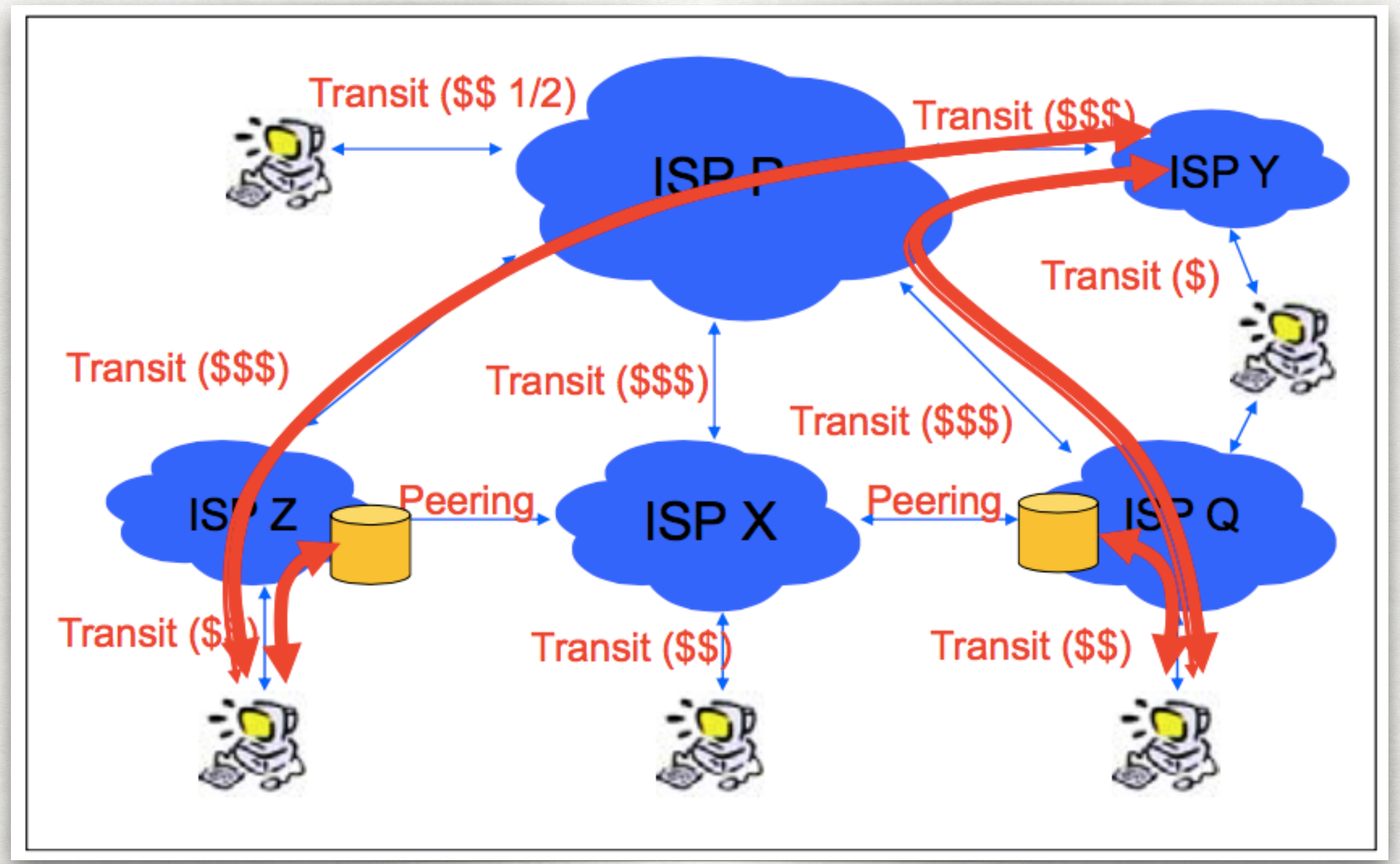
- Can reduce need for tunneling with server-side scripts running on edge caches – now very common

**Persistent TCP connections increase performance**

- Helps with downloading of objects to end caches

# CONTENT DELIVERY NETWORKS

## CHANGE IN TRAFFIC WITH CDN EDGE CACHES



# CONTENT DELIVERY NETWORKS

## IMPACT OF CDN GROWTH

- Flattening of the Internet
  - More content is served from the edge of the network
  - Also see an increase in peering
  - More traffic remains at edge – reduced load on core
- Changes in the economic relationships
  - Caches benefit users: better performance, reliability
  - Happy customers benefit the CDN
  - ISP benefits since more content is served locally
    - Reduces traffic from provider – direct economic benefit
  - CDNs sometimes place caches in “eye ball” ISPs for free, but economic models change all the time

# CONTENT DELIVERY NETWORKS

## SOME RECENT TRENDS

- If CDN's can deploy caches, why can't I?
- Content providers have started to deploy CDNs
  - Reduce cost, assuming you are large enough
  - Optimize caching to their specific requiremens
  - Can still use CDNs, e.g., in certain regions, ….
- Internet Service Providers also try deploy CDNs
  - Sometimes difficult to build the business relationships with content owners – too many ISPs!
  - How about the know-how?
  - Hybrid solutions are emerging, e.g., ISPs install hardware and license software from CDNs

# CONTENT DELIVERY NETWORKS

## SUMMARY

- Caching improves web performance
- Caching only at client is only partial solution
  - Not enough locality
- Content Delivery Networks move data closer to user, balance load, increase availability, …
  - Is having impact on structure of the Internet
  - No longer just a solution for static content