Web Proxies, Caching, and CDNs

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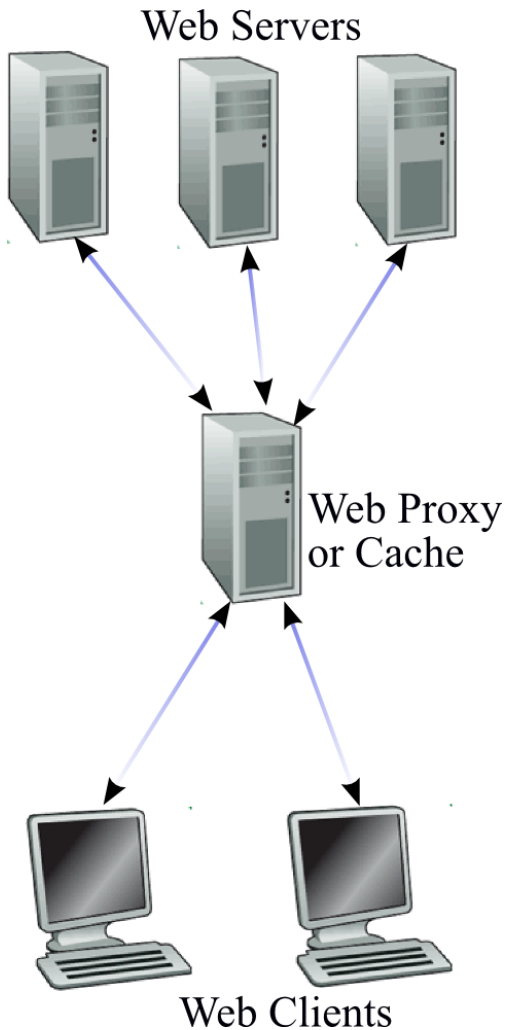
Web Proxies

Proxy

- intermediary between clients and servers
- handles requests internally or passes them on to servers
- examples
  - caching responses
  - anonymizing requests
  - filtering content



Transparent Proxies

- transparent proxy: does not modify the request other than superficially
  - caches place identifying information in headers
- non-transparent proxy: may modify the request or response
  - anonymize request
  - filter content
  - compress response

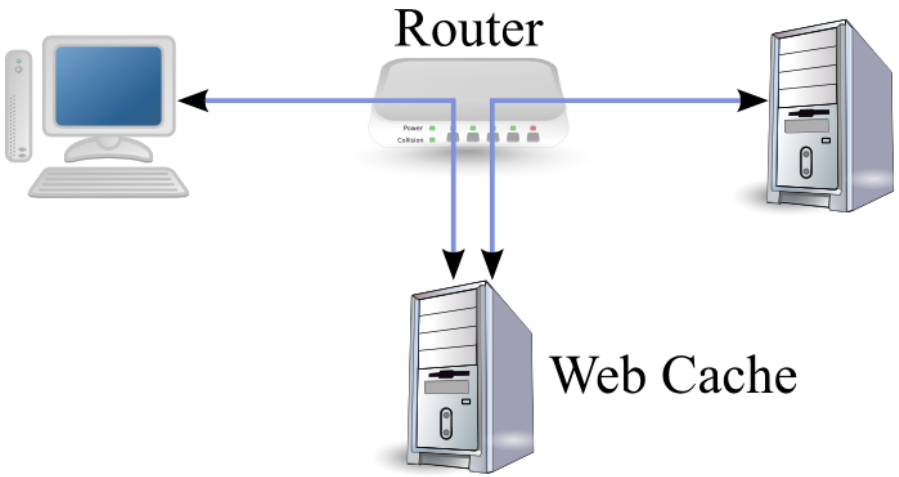
Anonymizing Requests

- anonymizing proxy hides IP address of client (client is not necessarily in the same organization)
  - may not hide the User-Agent header
  - may not drop cookies
- onion routing: setup a sequence of proxies along an unpredictable path, using encryption at each step
  - prevents eavesdropping
  - prevents traffic analysis
  - ▸ http://tor.eff.org/
  - ▸ http://en.wikipedia.org/wiki/Onion_Routing

Filtering Content

- examine application-level HTTP messages to block access to certain content
  - lookup URL in a blacklist of web sites
  - match URL against a list of banned keywords
  - examine response and compare to a list of banned keywords
- BYU CS department uses DansGuardian ▸ dansguardian.org
- ▸ anonymizing software often blocked

Interception Proxies



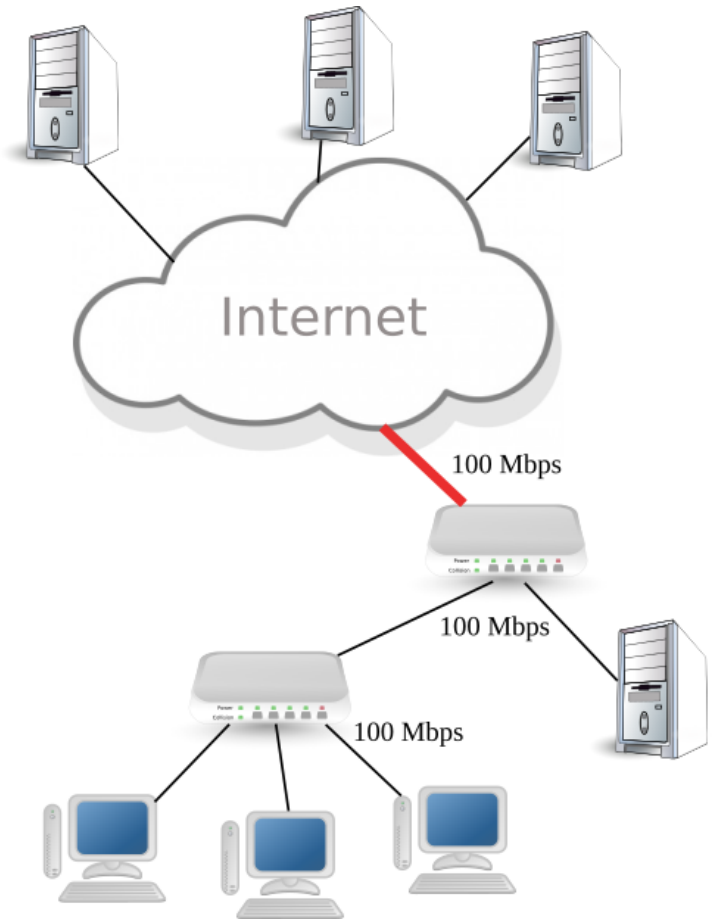
- all web traffic is diverted to the proxy, regardless of user preference

- diverting traffic
  1. router must examine TCP header on all packets
  2. a TCP packet going to port 80 is diverted to the proxy
  3. proxy must accept packets for any destination address going to port 80
  4. proxy then performs its functions – caching, filtering
- breaks the rules and layering of IP, but so do firewalls
- a reality for most major campuses and organizations

Web Caching

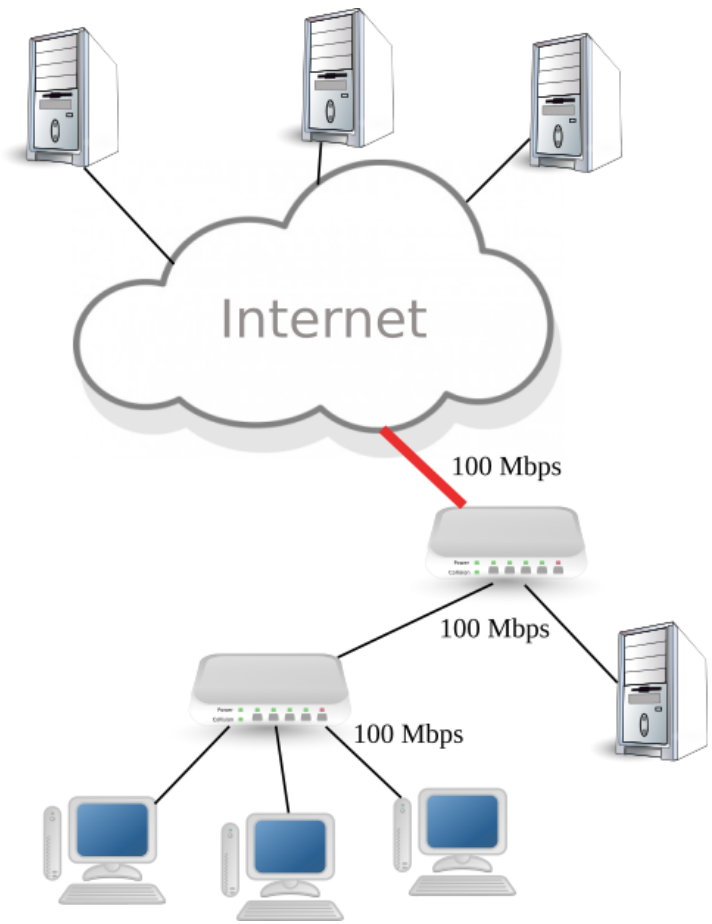
Motivation

- problem: bandwidth bottleneck at a server
- example
  - 100 Mbps connection
  - 2 MB average web page size (with embedded content)
  - 6.25 pages per second
- buy more bandwidth
  - 1 Gbps (10 x more bandwidth)
  - 62.5 requests per second
- hard to scale



Caching Benefits for Organizations

- faster download - web cache is usually on the local network, where there is more available bandwidth
- less congestion - fewer users sharing Internet bandwidth, local networks are usually over-provisioned
- lower bill for Internet access, if based on total usage
- lower latency - shorter propagation delay for closer servers



Caching Benefits for ...

- web servers
  - lower load on the server - can handle more users
  - lower cost since it uses less bandwidth
- the network as a whole
  - less traffic traversing the Internet, since it stays on local networks
  - reduces congestion - lower delay, lower packet loss
  - improves throughput - faster transfer times

Reverse Proxies

- a cache that sits in front of web server
  - provide access to a server behind a firewall
  - centralize security concerns at one server
  - balance load among a set of back-end servers
  - provide one URL space for many different web sites
- can use Apache as either forward or reverse proxy

What is Cacheable?

What is Cacheable?

- `Expires` header
  - date after which the response is considered stale and must be revalidated
  - cache does not need to revalidate item each time it has a cache hit
- `ETag` header
  - tag specific to a resource
  - decouples cache validation from expiration times, since clocks are not synchronized
  - cache uses `If-Match` header to check if the cached item is the same

Server Control over Caching

- `Cache-Control` header specifies directives that MUST be obeyed by a cache regardless of its own algorithms
- restrictions on what is cacheable
  - `public`: item MAY be cached
  - `private`: item MUST NOT be cached
  - `no-cache`: MUST NOT be returned by a cache without validation
- restrictions on what may be stored
  - `no-store`: cache MUST NOT store any part of the request or response

Browser Control over Caching

- expiration mechanism
  - `max-age`: maximum age client wants from cache
  - `max-stale`: gives maximum staleness client wants from cache
  - `min-fresh`: client wants a response that will still be fresh for a minimum amount of time
- cache revalidation and reload
  - `end-to-end reload`: client wants item from origin server, caches MUST NOT return a cached copy
  - `only-if-cached`: client wants item if cached, otherwise an error
  - `must-revalidate`: server says response may be cached, but must be revalidated once it is stale

How is Caching Done?

Web Caching Requirements

- need a cache consistency protocol - check whether objects in cache are up-to-date
- need a cache replacement algorithm - determine which objects to save when the cache is full
- hit rate determined by cache replacement algorithm, workload (object popularity, object size)

Caching Decisions

- check to see if requested object is in cache
- check if client headers allow item to be returned
- perform cache coherence checks
- perform cache replacement if needed

Cache Coherency

- cache must ensure that what is in the cache is consistent with what the server stores
- validating
  - `If-Modified-Since`: using Date
  - `If-Match`: using ETag
- when should the server validate?
  - use a TTL to indicate how much longer the cached response will be valid
  - based on `Expires`, `max-age` directive, or heuristic that examines last modification time and frequency of requests
- see ▸ Squid Cache FAQ for details on Squid coherence algorithm

Cache Replacement Algorithm

- many important factors
- access history: keep objects that are frequently accessed
- expiration time: remove objects that will expire soon
- time since last modification: keep objects that do not change frequently
- cost of fetching the resource: keep in cache if it was expensive to fetch
- cost of storing the resource: removing large objects frees a lot of space, but they are expensive to retain

Common Cache Replacement Algorithms

- Least Recently Used (LRU)
  - mark objects with time of last access
  - evict object that is least recently accessed
  - old and proven in many areas of CS
  - studies show it is not the best for web caching
- Least Frequently Used (LFU)
  - mark objects with how frequently accessed in a given period of time
  - evict object that is least frequently used
- Size of Object (SIZE): evict largest object
- Hyper-G: first LFU, then LRU, then largest
- Greedy-Dual Size
  - compute a utility value for each object
  - evict object with lowest utility
  - utility uses cost of fetching, size, age

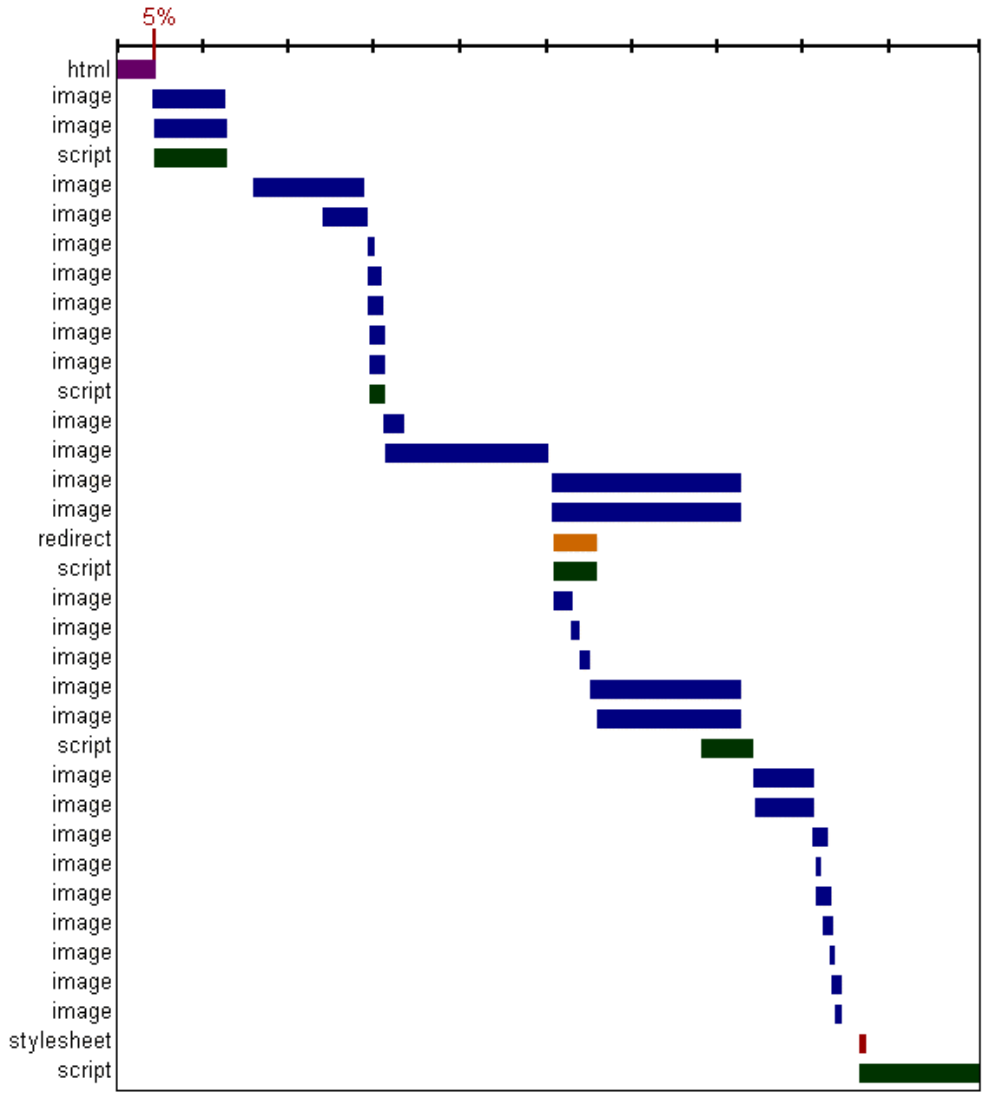
Cache Replacement Lessons

- *memory is cheap*: create a really large cache
- *lots of traffic isn't cacheable*
- *most algorithms are good enough*
- Squid uses LRU, Greedy-Dual Size, LFU with Dynamic Aging

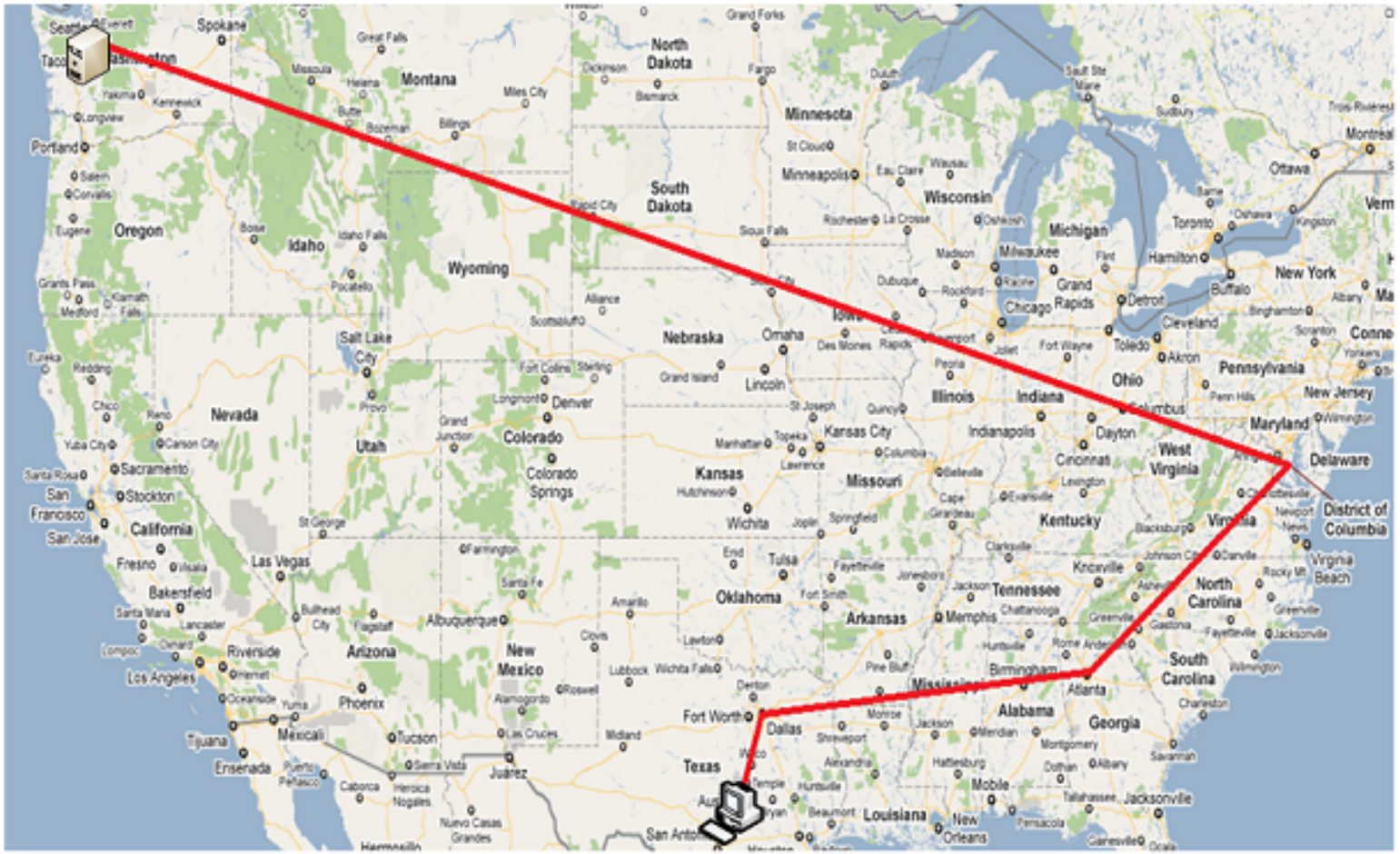
Content Delivery Networks

Web Site Performance

- Steve Souders (Yahoo, Google): 80% of web page download time is spent fetching embedded images and scripts



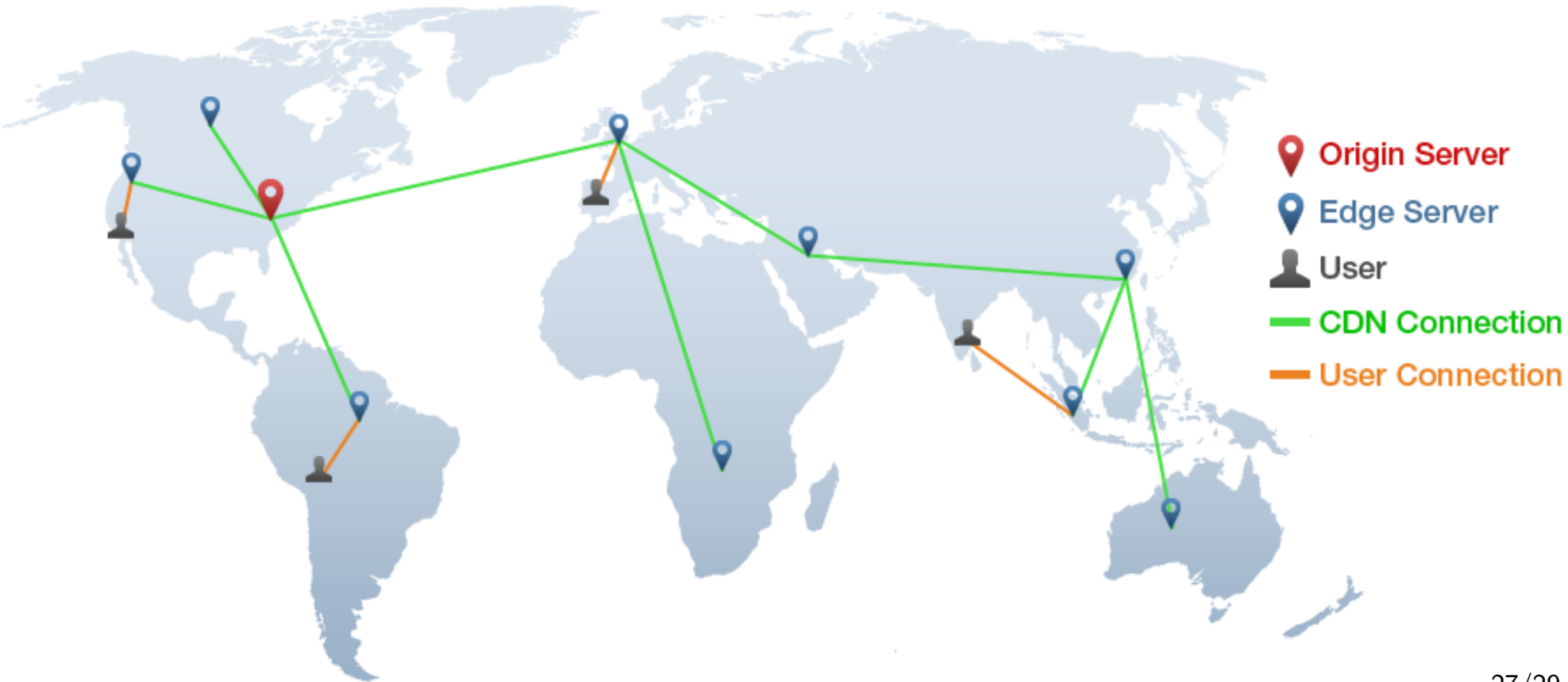
Latency



- want to avoid latency caused by long paths

Content Delivery Network

- replicate content at many caches, typically at the edge of the network
- use domain name of the CDN in your web pages
- client requests routed to a "nearby" server, generally through DNS, reducing loss and delay



DNS Resolution

- authoritative server looks at the IP address of the resolver
- returns a response based on geographical location of resolver, health of server, server load, network delay
- mapping from IP to geographical area is called geolocation

Resources

- started with Akamai: ▸ IEEE Internet Computing paper
- see ▸ Amazon CloudFront