Distributed Systems
23. Content Delivery Networks (CDN)

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Motivation

- Serving web content from one location presents problems
  - Scalability
  - Reliability
  - Performance

- "Flash crowd" problem
  - What if everyone comes to your site at once?

- Cache content and serve requests from multiple servers at the network edge (close to the user)
  - Reduce demand on site's infrastructure
  - Provide faster service to users
    - Content comes from nearby servers

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Focus on Content

- Computing is still done by the site host's server(s)
- Offload the static parts – they often make up the bulk of the bytes:
  - Images
  - Video
  - CSS files
  - Static pages

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Serving & Consuming Content

Every request goes to the server.
Repeated requests from one client may be optimized by browser-based caching
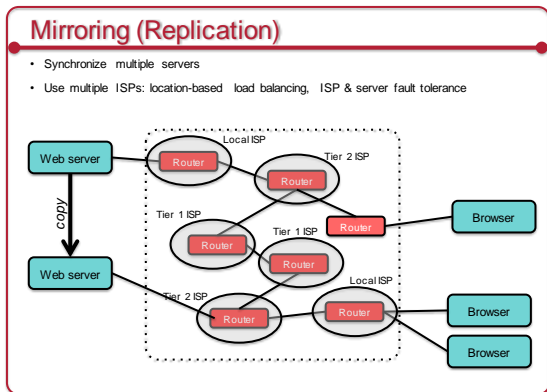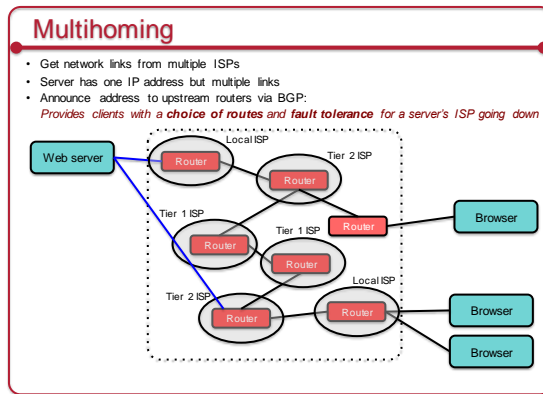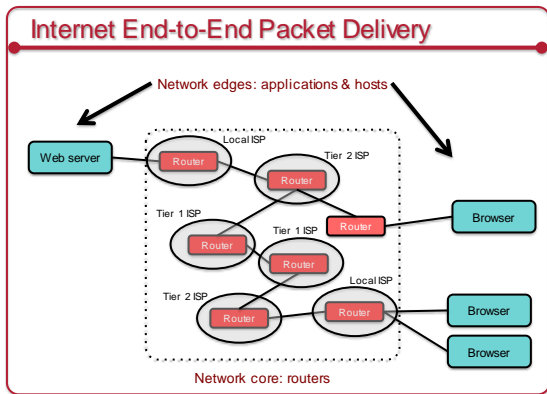 – but that cached data is local to the browser

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Caching Proxies

Caching proxy in an organization.
Take advantage of what others before you have recently accessed.

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Load Balancing

Increase capacity at the server.
Internet connectivity can be a bottleneck … + latency from client to server.

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Internet End-to-End Packet Delivery

Network edges: applications & hosts

Web server — Router — Local ISP — Router — Tier 2 ISP

Tier 1 ISP — Router — Router — Browser

Router — Tier 1 ISP — Router

Tier 2 ISP — Router — Local ISP — Router — Browser / Browser

Network core: routers

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Multihoming

- Get network links from multiple ISPs
- Server has one IP address but multiple links
- Announce address to upstream routers via BGP:
  *Provides clients with a **choice of routes** and **fault tolerance** for a server's ISP going down*

Web server — Router — Local ISP — Router — Tier 2 ISP

Tier 1 ISP — Router — Router — Browser

Tier 1 ISP — Router

Tier 2 ISP — Router — Local ISP — Router — Browser / Browser

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Mirroring (Replication)

- Synchronize multiple servers
- Use multiple ISPs: location-based load balancing, ISP & server fault tolerance

Web server — Router — Local ISP — Router — Tier 2 ISP

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Tier 1 ISP — Router — Router — Browser

Router — Tier 1 ISP — Router

Web server — Tier 2 ISP — Router — Local ISP — Router — Browser / Browser

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Improving scalability, availability, & performance

- **Scalability**
  - Load balance among multiple servers
  - Multiple ISPs if network congestion is a concern
- **Availability**
  - Replicate servers
  - Multiple data centers & ISPs
- **Performance**
  - Mirror (replicate) servers for load balancing
  - Cache content and serve requests from multiple servers at the network edge (close to the user)
    - Reduce demand on site's infrastructure
    - Provide faster service to users
      - Content comes from nearby servers

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But these approaches have problems!

- **Local balancing**
  - Data center or ISP can fail
- **Multihoming**
  - IP protocols (BGP) are often not quick to find new routes
- **Mirroring at multiple sites**
  - Synchronization can be difficult
- **Proxy servers**
  - Typically a client-side solution
  - Low cache hit rates

All require extra capacity and extra capital costs

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Akamai Distributed Caching

- Company evolved from MIT research

- "*Invent a better way to deliver Internet content*"

- Tackle the "flash crowd" problem

- Akamai runs on 216,000 servers in 1,500 networks across 120 countries
  - Delivers 15-30% of all web traffic
    … reaching over 30 Terabits per second

http://www.akamai.com/html/about/facts_figures.html

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Akamai's goal

Try to serve clients from servers likely to have the content

– **Nearest**: lowest round-trip time
– **Available**: server that is not too loaded
– **Likely**: server that is likely to have the data

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Overlay Network

- The Internet is a collection of many autonomous networks
  – Connectivity is based on business decisions
    • Peering agreements, not performance
  – An ISP's top performance incentives are:
    • Last-mile connectivity to end users
    • Connectivity to servers on the ISP

- The Overlay network
  – Collection of caching servers at many, many ISPs
  – All know about each other

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Overlay Network

1. Domain name lookup
   – Translated by mapping system to an edge server that can serve the content
   – Use **custom DNS servers**
     • Take requestor's address into into account to find the *nearest* edge

2. Browser sends request to the given edge server
   – Edge server may be able to serve content from its cache
   – May need to contact the origin server via the transport system

Origin server

Transport system

Edge servers

Clients

mapping system
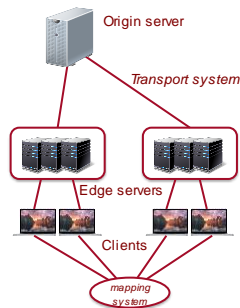
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Mapping: Domain Name Lookup

- Akamai uses **Dynamic DNS servers**

- Resolve a host name based on:
  – user location (minimize network distance)
  – server health
  – server load
  – network status
  – load balancing

- Try to find an edge server at the customer's ISP

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Akamai collects network performance data

- Map network topology
  – Based on BGP and *traceroute* information
  – Estimate hops and transit time

- Content servers report their load to a monitoring application

- Monitoring app publishes load reports to a local (Akamai) DNS server

- Akamai DNS server determines which IP addresses to return when resolving names

- **Load shedding**:
  – If servers get too loaded, the DNS server will not respond with those addresses

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Benefits of an overlay network CDN

1. Caching

2. Routing

3. Security

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Caching

- Goal: Increase hit rate on edge servers
  - Reduce hits on origin servers
- Static content can be served from caches
  - Dynamic content still goes back to the origin
- Two-level caching
  - If edge servers don't have the data, check with parent servers

Origin server

Parent servers

Edge servers

Clients
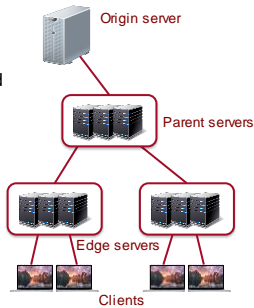
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Types of content

- Static content
  - Cached depending on original site's requirements (never to forever)
- Dynamic content
  - Caching proxies cannot do this
  - Akamai uses *Edge Side Includes* technology (www.esi.org)
    - Assembles dynamic content on edge servers
    - Similar to server-side includes
    - Page is broken into fragments with independent caching properties
    - Assembled on demand
- Streaming media
  - Live stream is sent to an entry-point server in the Akamai network
  - Stream is delivered from the entry-point server to multiple edge servers
  - Edge servers serve content to end users.

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Routing

- Route to parent servers or origin via the overlay network
- Routing decision factors:
  - measured latency
  - packet loss
  - available bandwidth
- Results in ranked list of alternate paths from edge to origin
- Each intermediate node acts as a forwarder
  - Keep TCP connections active for efficiency

Origin server

Alt. Path 2

Alt. Path 1

Direct path

Alt. Path 3

Edge servers
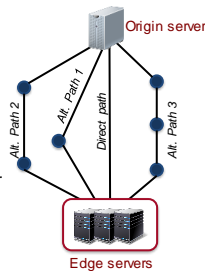
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Security

- High capacity
  - Overwhelm DDoS attacks
- Expertise
  - Maintain systems and software
- Extra security software
  - Hardened network stack
  - Detect & defend attacks
- Shield the origin
  - Attacks hit the CDN, not the origin
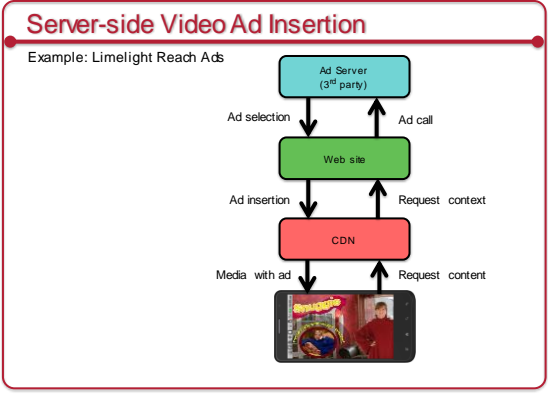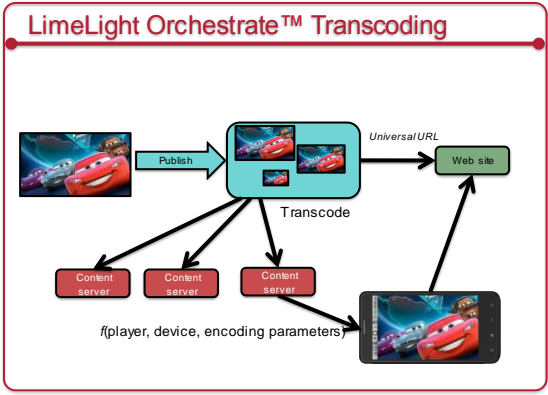
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Other Things CDNs Do

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Signed URLs in Amazon CloudFront

- Example: Amazon CloudFront CDN
  - Similar in concept to Akamai
  - Requests for content are routed to the nearest edge location
    - Cached content with original located at *origin servers*
  - Integrates with back-end Amazon services
- Private content: provide special URLs for restricted content
  - Control access to content via a signed URL
  - URL contains:
    - policy or a reference to a policy
    - Signature = encrypted hash
      - URL cannot be modified
  - Policies include:
    - Validity: start time & expiration time
    - Range of IP addresses that are allowed to access the object

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Limelight Orchestrate™

- Focus on video distribution and content management
- Video transcoding
  - Encode video to a variety of formats
  - Support playback on various devices: different formats & bitrates
- Ad insertion
  - Integrate with ad servers (DoubleClick, LiveRail, Tremor, YuMe)
  - Pre-roll, post-roll, mid-roll, overlay, etc.

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LimeLight Orchestrate™ Transcoding

Publish

Universal URL

Web site

Transcode

Content server

Content server

Content server

f(player, device, encoding parameters)

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Server-side Video Ad Insertion

Example: Limelight Reach Ads

Ad Server
(3rd party)

Ad selection   Ad call

Web site

Ad insertion   Request context

CDN

Media with ad   Request content

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The End