CSE 486/586 Distributed Systems
Case Study: Facebook Photo Stores

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Engineering a System

- Generally, when you engineer a system, you need to understand your workload.
  - And design your system according to the workload
  - (Perhaps not in the beginning since there's no workload)
- Engineering principle
  - Make the common case fast, and rare cases correct
  - (From Patterson & Hennessy books)
  - This principle cuts through generations of systems.
- Example?
  - Caching
- Knowing common cases == understanding your workload
  - E.g., read dominated? Write dominated? Mixed?
- We'll look at Facebook's example.

Facebook Workload

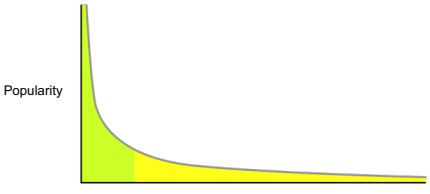
- What are the most frequent things you do on Facebook?
  - Read/write wall posts/comments/likes
  - View/upload photos
  - Very different in their characteristics
- Read/write wall posts/comments/likes
  - Mix of reads and writes so more care is necessary in terms of consistency
  - But small in size so probably less performance sensitive
- Photos
  - Write-once, read-many so less care is necessary in terms of consistency
  - But large in size so more performance sensitive

Facebook Photo Workload

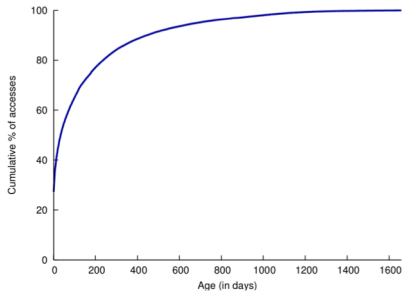
- (This is from 2010.)
- 260 billion images (~20 PB)
- 1 billion new photos per week (~60 TB)
- One million image views per second at peak
- Two characteristics: Facebook has analyzed their photo workload and discovered two characteristics.
  - The popularity distribution follows Zipf.
  - Popularity changes over time as photos "age."

Zipf distribution

- Based on the power law
- Models a lot of natural phenomena
- Social graphs, media popularity, wealth distribution, etc.
- A lot of Web contents too.



Popularity Comes with Age



Facebook Photo Distribution

- "Hot" vs. "warm" vs. "cold" photos
  - Hot: Popular, a lot of views (approx. 90% of views)
  - Warm: Somewhat popular, but still a lot of views in aggregate
  - Cold: Unpopular, occasional views

Handling Different Types of Photos

- Hot photos
  - Facebook uses a CDN (Content Distribution Network) for these.
  - Very good performance, but no reliability guarantee
  - CDN is a cache, not a permanent storage.
- Warm photos
  - Facebook has designed its own storage called Haystack.
  - Balances performance and reliability
- Cold photos
  - Facebook has designed an "archival" storage called f4.
  - Aims for storage efficiency when storing replicated photos (but not high performance)

CSE 486/586 Administrivia

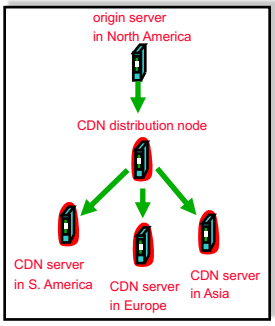
- PA4 deadline: 5/10
- Survey & course evaluation
  - Survey: https://forms.gle/eg1wHN2G8S6GVz3e9
  - Course evaluation: https://www.smartevals.com/login.aspx?s=buffalo
- If both have 80% or more participation,
  - For each of you, I'll take the better one between the midterm and the final, and give the 30% weight for the better one and the 20% weight for the other one.
  - (Currently, it's 20% for the midterm and 30% for the final.)
- No recitation this week; replaced with office hours

CDN for Hot Photos

- Content providers are CDN customers

Content replication

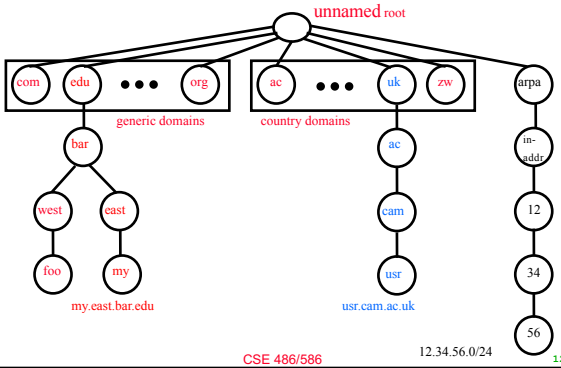
- CDN company (e.g., Akamai) installs thousands of servers throughout Internet
  - In large datacenters close to users
- CDN replicates customers' content
- When provider updates content, CDN updates servers



Domain Name System

- For a given user, how to locate a close server?
- Many CDNs rely on Domain Name System (DNS)
  - DNS maps a DNS name to an IP address or another DNS name (alias).
  - E.g., www.cse.buffalo.edu
    - » Domain: registrar for each top-level domain
    - » Host name: local administrator assigns to each host
- Properties of DNS
  - Hierarchical name space
  - Distributed over a collection of DNS servers
- Hierarchy of DNS servers
  - Root servers
  - Top-level domain (TLD) servers
  - Authoritative DNS servers

Distributed Hierarchical Database



DNS Root Servers

- 1088 instances operated by the 12 independent root server operators (see http://www.root-servers.org/)
- Labeled A through M

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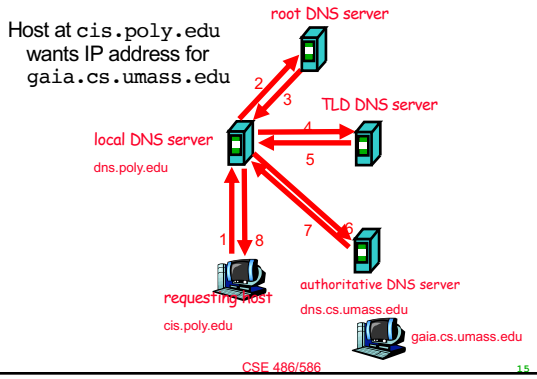
TLD and Authoritative DNS Servers

- Top-level domain (TLD) servers
  - Generic domains (e.g., com, org, edu)
  - Country domains (e.g., uk, fr, ca, jp)
  - Typically managed professionally
    - » Network Solutions maintains servers for "com"
    - » Educause maintains servers for "edu"
- Authoritative DNS servers
  - Provide public records for hosts at an organization
  - For the organization's servers (e.g., Web and mail)
  - Can be maintained locally or by a service provider

Example

Host at `cis.poly.edu` wants IP address for `gaia.cs.umass.edu`



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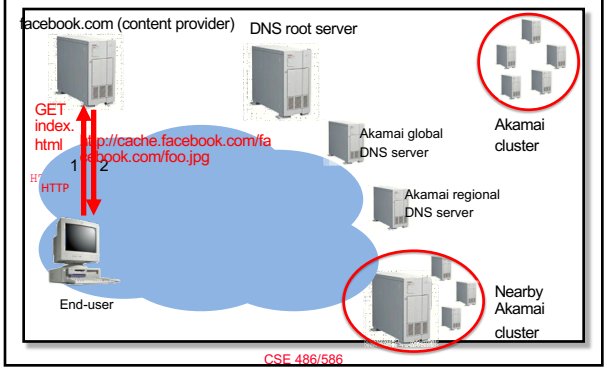
How a CDN Works



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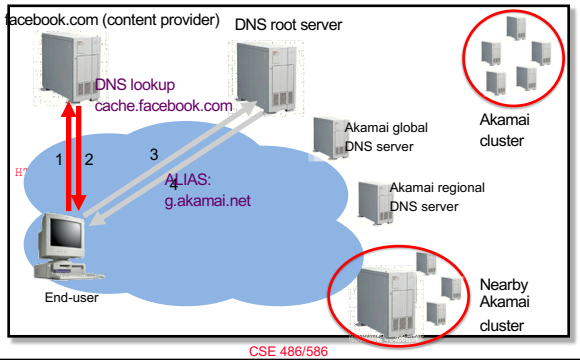

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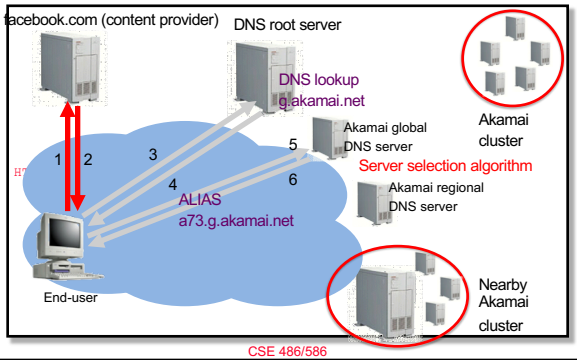

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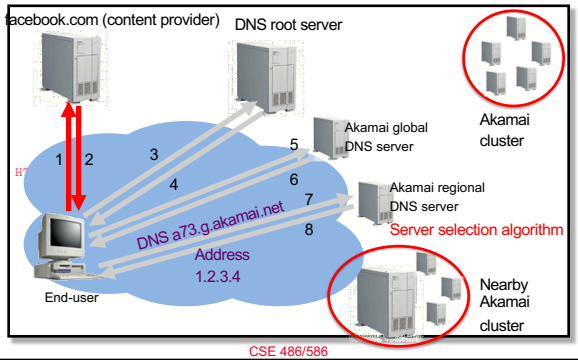

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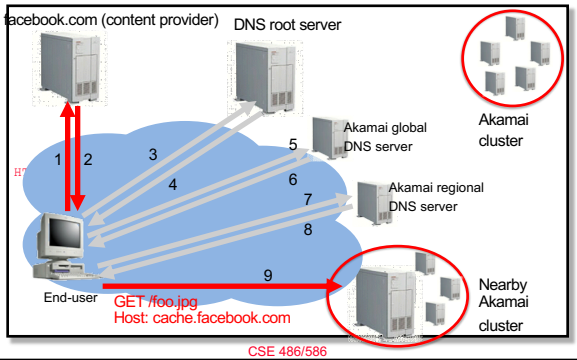

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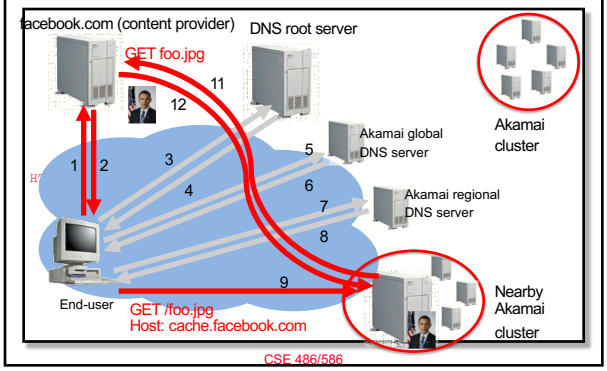

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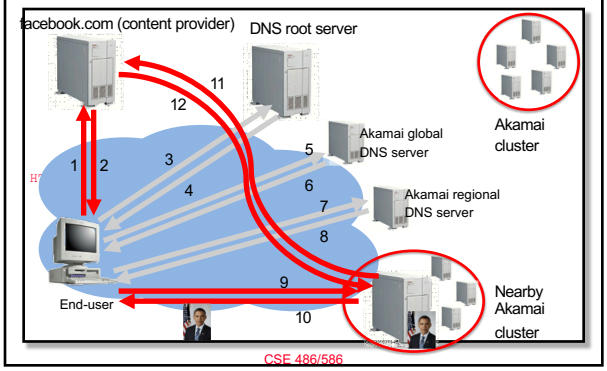

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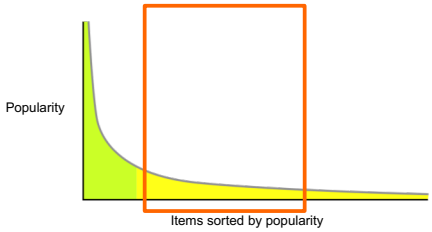
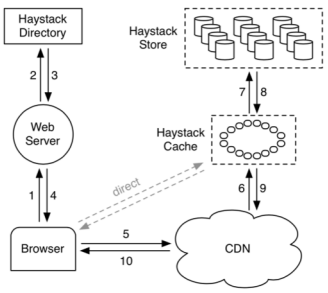


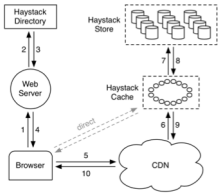
Handling Warm Photos: Haystack

- Designed for performance and reliability
- "Default" photo storage



Haystack Directory

- Helps the URL construction for an image
  - http://⟨CDN⟩/⟨Cache⟩/⟨Machine id⟩/⟨Logical volume, Photo⟩
  - Staged lookup
  - CDN strips out its portion.
  - Cache strips out its portion.
  - Machine strips out its portion



- Logical & physical volumes
  - A logical volume is replicated as multiple physical volumes
  - Physical volumes are stored.
  - Each volume contains multiple photos.

Haystack Cache & Store

- Haystack cache
  - Facebook-operated second-level cache using DHT
  - Photo IDs as keys
  - Further removes traffic to Store
- Haystack store
  - Maintains physical volumes
  - One volume is a single large file (100GB) with many photos (needles)
  - Performance-optimized: requires a single disk read for image retrieval

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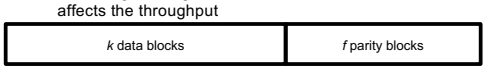
CDN / Haystack / f4

- CDN absorbs much traffic for hot photos.
- Haystack's tradeoff: good throughput and reliability, but somewhat inefficient storage space usage (mainly due to replication).
- f4's tradeoff: less throughput, but more storage efficient.
  - ~ 1 month after upload, photos/videos are moved to f4.
  - f4 uses *an error-correcting coding scheme* to efficiently replicate data.

f4's Replication

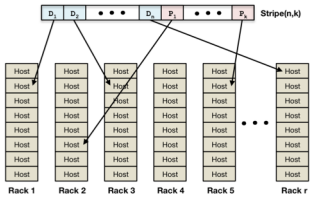
- (n, k) Reed-Solomon code
  - k data blocks, f==(n-k) parity blocks, n total blocks
  - Upon a failure, any k blocks can reconstruct the lost block.
  - Can tolerate up to f block failures
  - Need to go through coder/decoder for read/write, which affects the throughput



- Parity example: XOR
  - (Reed-Solomon uses something more complicated that this.)
  - XOR bits, e.g., (0, 1, 1, 0) → P: 0
  - Reconstruction after failures: (0, 1, ✖, 0) → P: 0

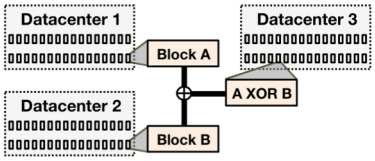
f4: Single Datacenter

- Within a single data center, (14, 10) Reed-Solomon code
  - This tolerates up to 4 block failures
  - 1.4X storage usage per block
- Distribute blocks across different racks
  - This tolerates four host/rack failures



f4: Cross-Datacenter

- Additional parity block
  - Can tolerate a single datacenter failure



- Overall average space usage per block: 2.1X
  - E.g., average for block A & B: (1.4*2 + 1.4)/2 = 2.1
- With 2.1X space usage,
  - 4 host/rack failures tolerated
  - 1 datacenter failure tolerated

Summary

- Engineering a system needs workload understanding.
- Facebook photo workload
  - Hot, warm, and cold.
- CDN for hot photos
  - Performance
- Haystack for warm photos
  - Performance & reliability
- f4 for cold photos
  - Reliability and storage efficiency

Acknowledgements

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