CLOUD COMPUTING

Lecture 27: CS 2110 Spring 2013

Computing has evolved...

- Fifteen years ago: desktop/laptop + clusters
- Then
  - Web sites
  - Social networking sites with photos, etc
  - Cloud computing systems

- Cloud computing model:

Styles of cloud computing

- Supporting Facebook or Google+ ("System as a service" or SaaS)
- Cornell's email and registrar system ("Platform as a service" or PaaS model)
- Rent a big pile of machines for a period of time like Netflix does ("Infrastructure as a service" – IaaS)

Main elements

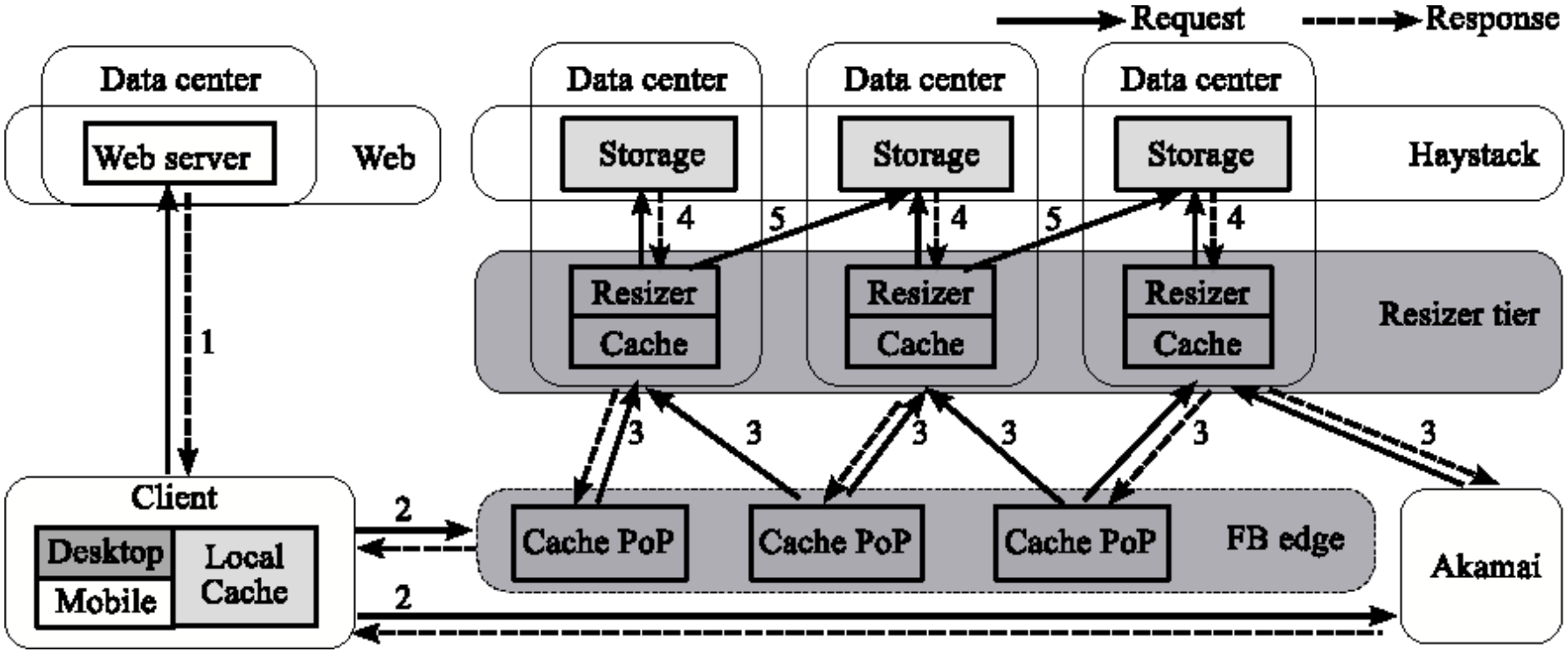
- Client computer (runs a web-enabled application, which could be in Java or could be a browser)
- The Internet (network links, routers, caching, etc)
- Massive back-end databases

Example: Facebook image "stack"

- Role is to serve images (photos, videos) for FB's hundreds of millions of active users
  - About 80B large binary objects ("blob") / day
  - FB has a huge number of big and small data centers
    - "Point of presense" or PoP: some FB owned equipment normally near the user
    - Akamai: A company FB contracts with that caches images
    - FB resizer service: caches but also resizes images
    - Haystack: inside data centers, has the actual pictures (a massive file system)

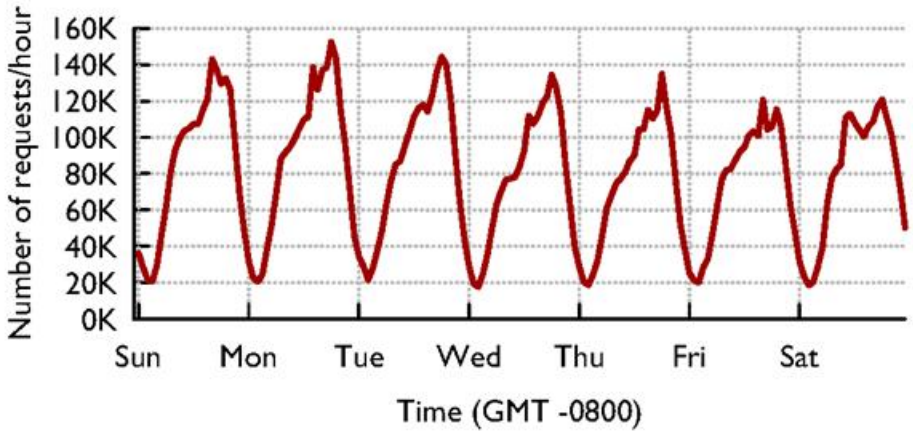
Facebook "architecture"

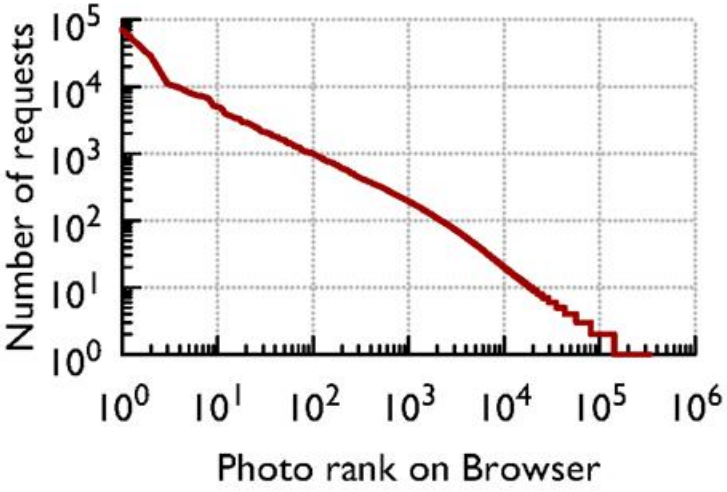
- Think of Facebook as a giant distributed HashMap
  - Key: photo URL (id, size, hints about where to find it...)
  - Value: the blob itself



Facebook traffic for a week

- Client activity varies daily....





- ... and different photos have very different popularity statistics

Facebook's goals?

- Get those photos to you rapidly
- Do it cheaply
- Build an easily scalable infrastructure
  - With more users, just build more data centers
- … they do this using ideas we've seen in cs2110!

Best ways to cache this data?

- Core idea: Build a *distributed photo cache* (like a HashMap, indexed by photo URL)
- Core issue: We could cache data at various places
  - On the client computer itself, near the browser
  - In the PoP
  - In the Resizer layer
  - In front of Haystack
- Where's the best place to cache images?
  - Answer depends on image popularity…

Distributed Hash Tables

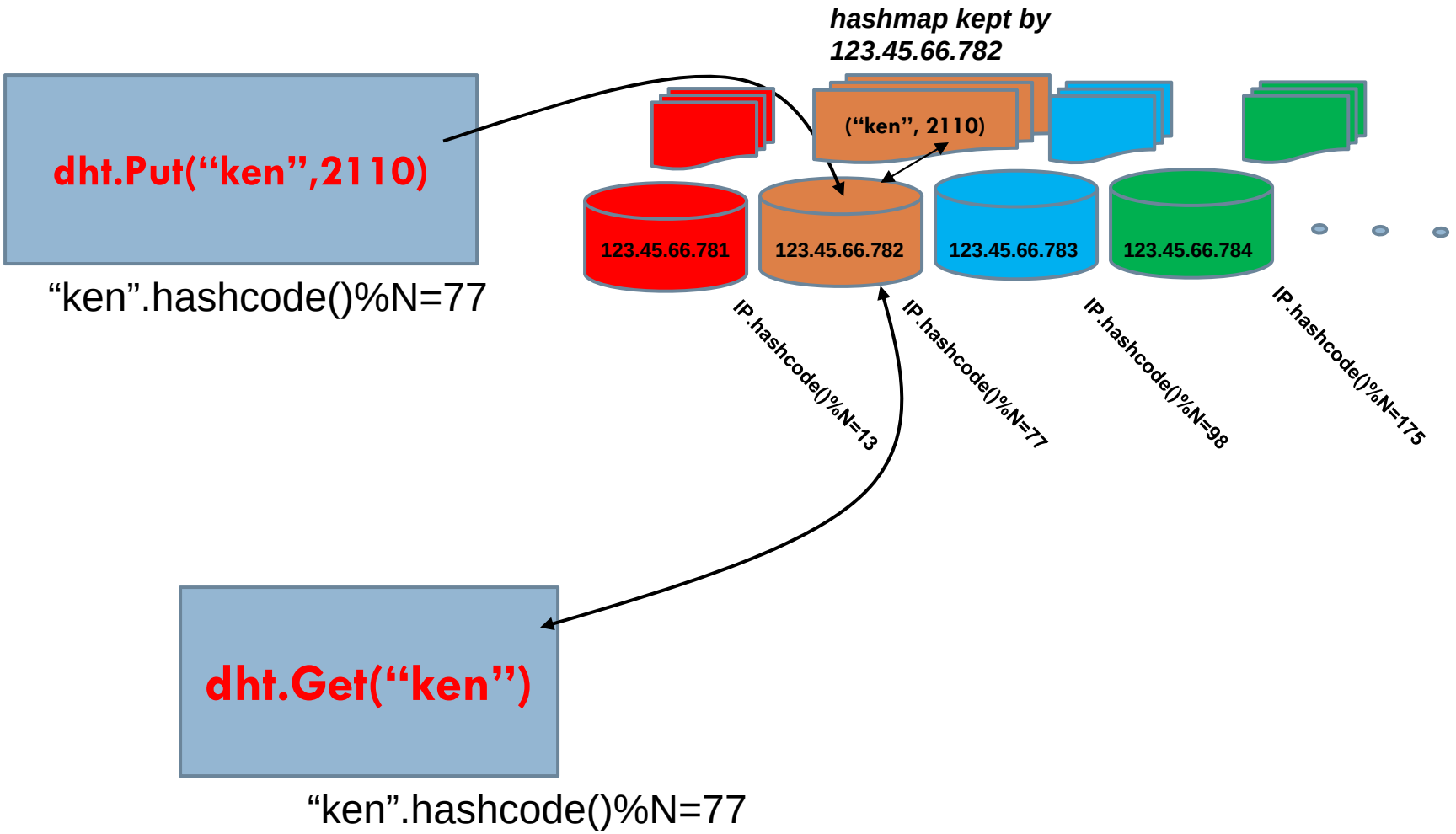
- It is easy for a program on biscuit.cs.cornell.edu to send a message to a program on "jam.cs.cornell.edu"
  - Each program sets up a "network socket
  - Each machine has an IP address, you can look them up and programs can do that too via a simple Java utility
  - Pick a "port number" (this part is a bit of a hack)
  - Build the message (must be in binary format)
  - Java utils has a request

Distributed Hash Tables

- It is easy for a program on biscuit.cs.cornell.edu to send a message to a program on "jam.cs.cornell.edu"
- ... so, given a key and a value
  1. Hash the key
  2. Find the server that "owns" the hashed value
  3. Store the key,value pair in a "local" HashMap there

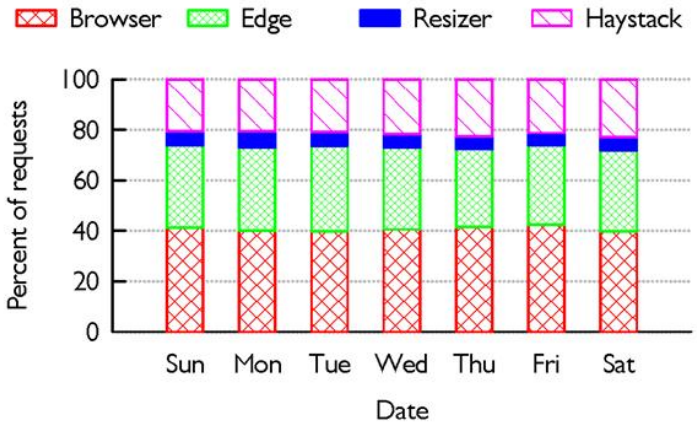
- To get a value, ask the right server to look up key

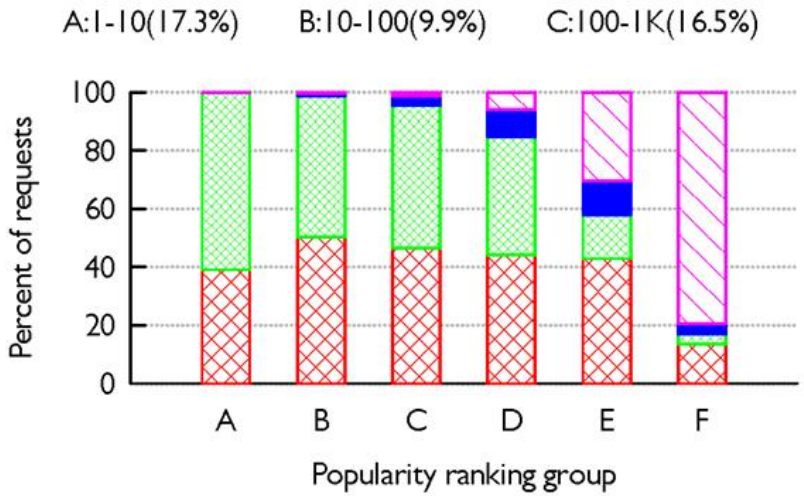
Distributed Hash Tables



Facebook cache effectiveness

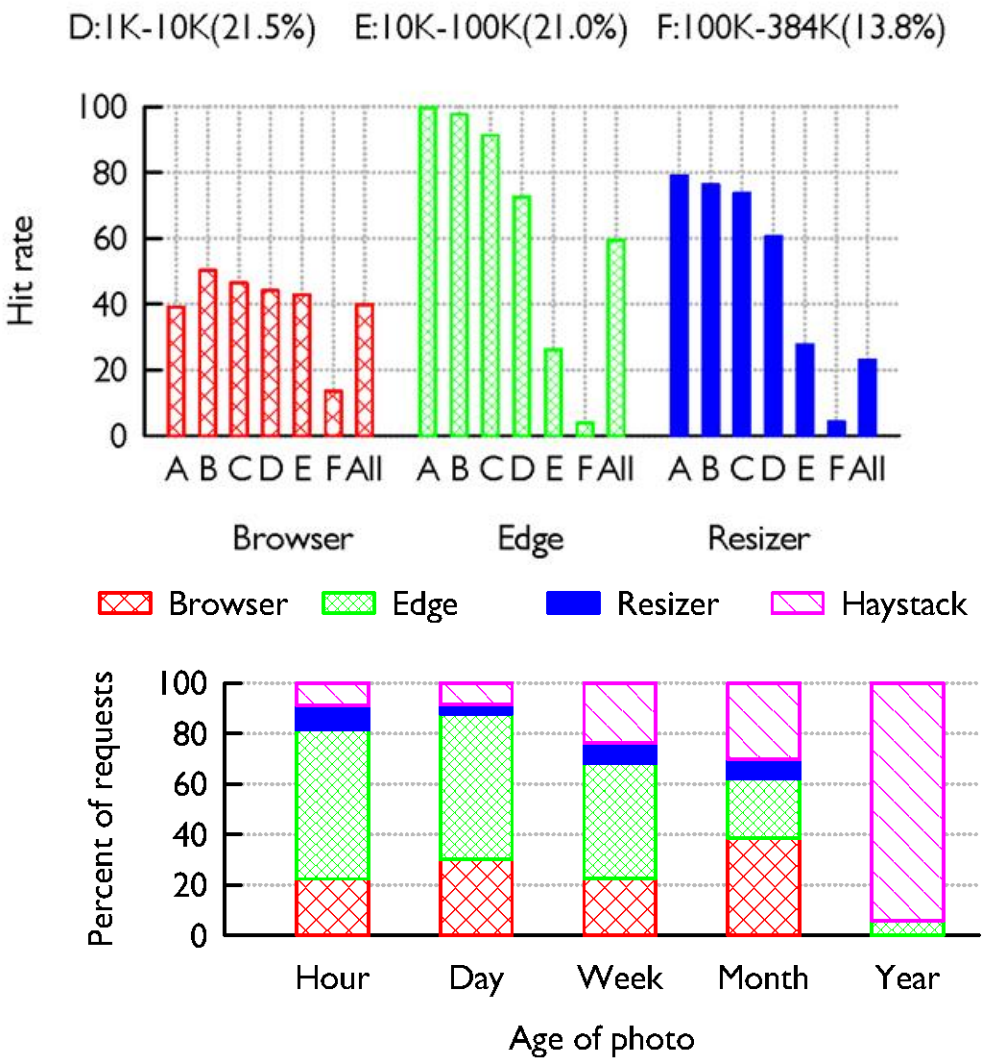
- Existing caches are very effective...
- ... but different layers are more effective for images with different popularity ranks





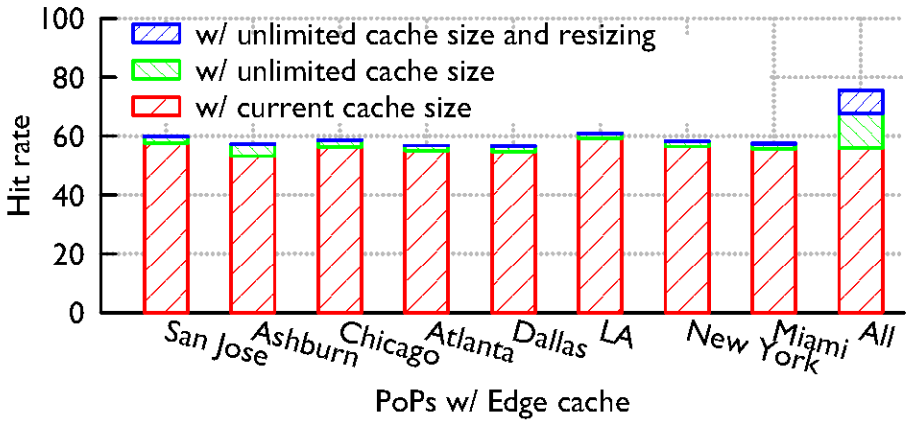
Facebook cache effectiveness

- Each layer should "specialize" in different content.
- Photo age strongly predicts effectiveness of caching

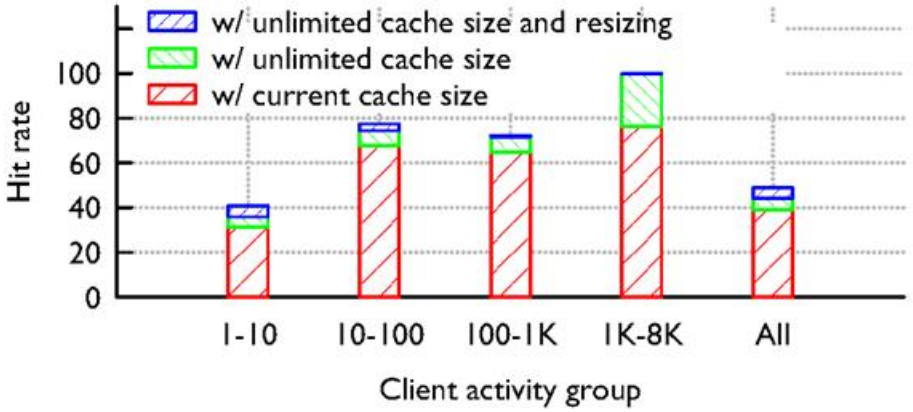


Hypothetical changes to caching?

- We looked at the idea of having Facebook caches collaborate at national scale…



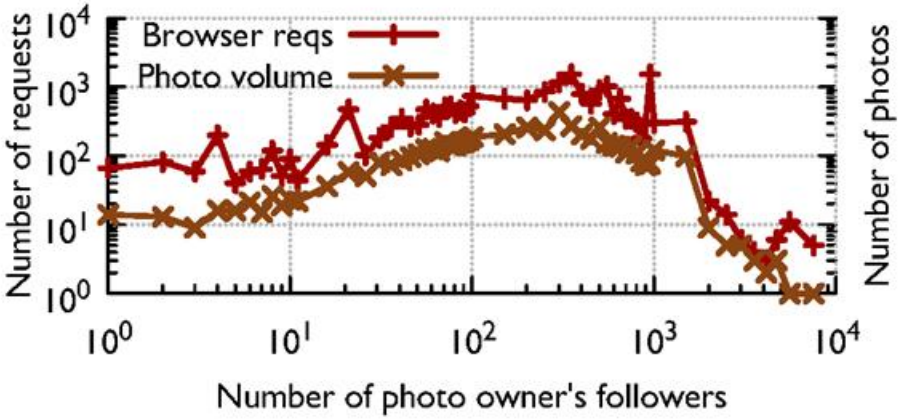
- … and also at how to vary caching based on "busyness" of the client

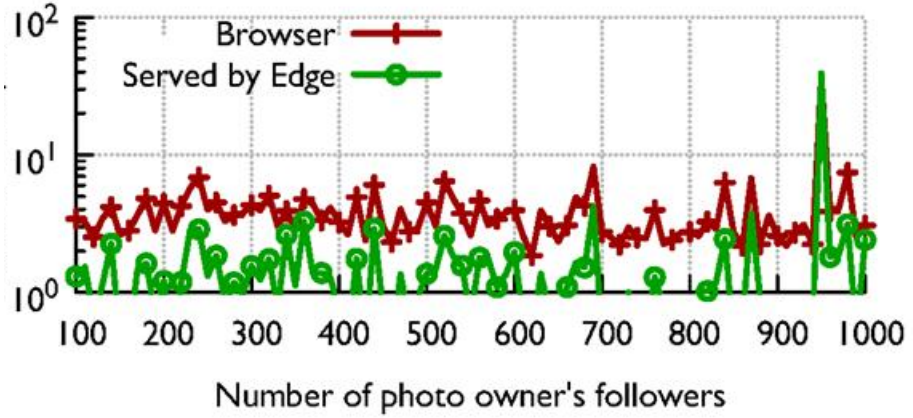


Social networking effect?

- Hypothesis: caching will work best for photos posted by famous people with zillions of followers

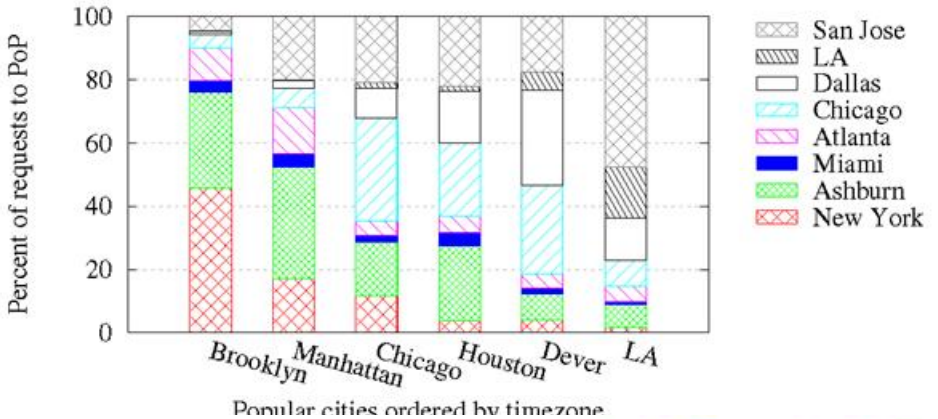
- Actual finding: *not really*

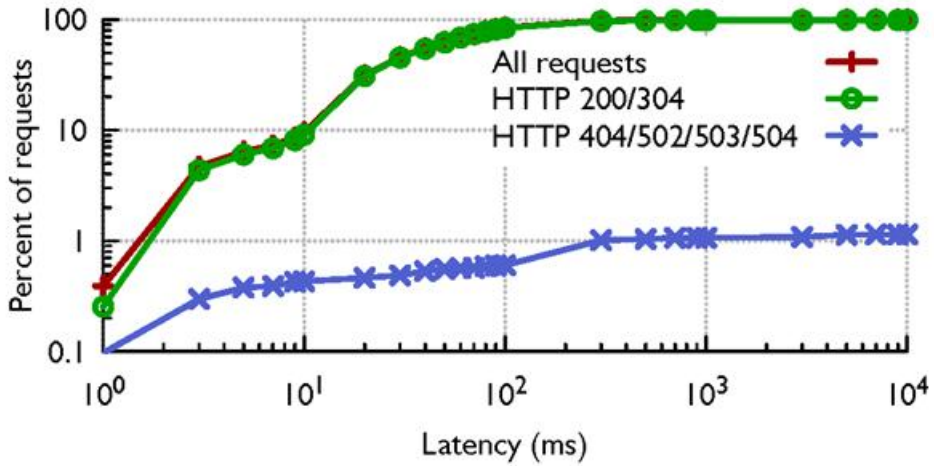




Locality?

- Hypothesis: FB probably serves photos from close to where you are sitting
- Finding: *Not really…*
- *… just the same, if the photo exists, it finds it quickly*





Can one conclude anything?

- Learning what patterns of access arise, and how effective it is to cache given kinds of data at various layers, we can customize cache strategies

- Each layer can look at an image and ask "should I keep a cached copy of this, or not?"

- Smart decisions $\Rightarrow$ Facebook is more effective!

Strategy varies by layer

- Browser should cache less popular content but not bother to cache the very popular stuff
- Akamai/PoP layer should cache the most popular images, etc…

- We also discovered that some layers should "cooperatively" cache even over huge distances
  - Our study discovered that if this were done in the resizer layer, cache hit rates could rise 35%!

Overall picture in cloud computing

- Facebook example illustrates a style of working
  - Identify high-value problems that matter to the community because of the popularity of the service, the cost of operating it, the speed achieved, etc
  - Ask how best to solve those problems, ideally using experiments to gain insight
  - Then build better solutions

- Let's look at another example of this pattern

HIGH ASSURANCE DISTRIBUTED COMPUTING

Using Isis2: isis2.codeplex.com

High assurance cloud computing

- Ken's research on Isis^2 system
  - Today's cloud isn't very effective for supporting applications that need strong guarantees
  - Goal: create a cloud infrastructure that helps people build applications that can sensitive data/problems

- Target settings:
  - Smart electric power grid
  - Medical devices for ambulatory patients
  - Soldiers in on the front lines
  - Self-driving cars

Isis^2 System

- New C# library (but callable from any .NET language) offering replication techniques for cloud computing developers
- Intended to be as easy to use as a GUI framework
- Research challenges: many hard problems…

- **Elasticity (sudden scale changes)**
- **Potentially heavily loads**
- **High node failure rates**
- **Concurrent (multithreaded) apps**

- **Long scheduling delays, resource contention**
- **Bursts of message loss**
- **Need for very rapid response times**
- **Community skeptical of "assurance properties"**

Isis^2 makes developer's life easier


```
Group g = new Group("myGroup");
g.ViewHandlers += delegate(View v) {
      Console.Title = "myGroup members: "+v.members;
};
g.Handlers[UPDATE] += delegate(string s, double v) {
      Values[s] = v;
};
g.Handlers[LOOKUP] += delegate(string s) {
       g.Reply(Values[s]);
};
g.Join();

g.Send(UPDATE, "Harry", 20.75);

List<double> resultlist = new List<double>;
nr = g.Query(LOOKUP, ALL, "Harry", EOL, resultlist);
```

- First sets up group
- Join makes this entity a member. State transfer isn't shown
- Then can multicast, query. Runtime callbacks to the "delegates" as events arrive
- Easy to request security (g.SetSecure), persistence
- "Consistency" model dictates the ordering aseen for event upcalls and the assumptions user can make

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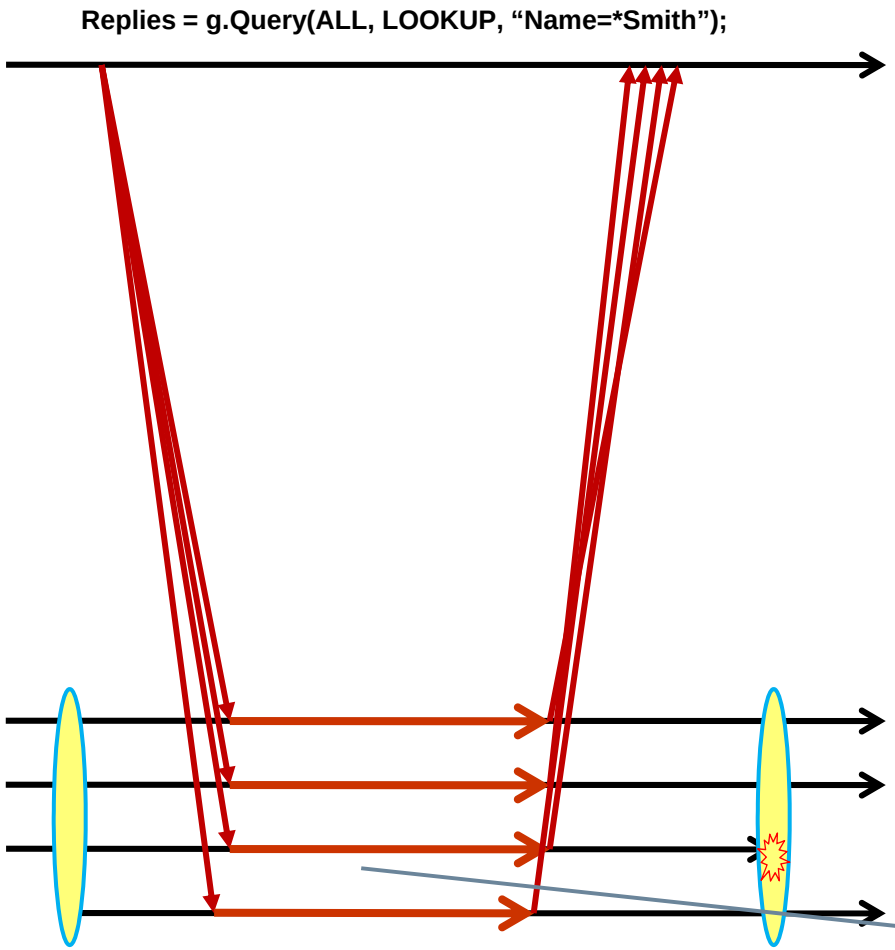
Example: Parallel search

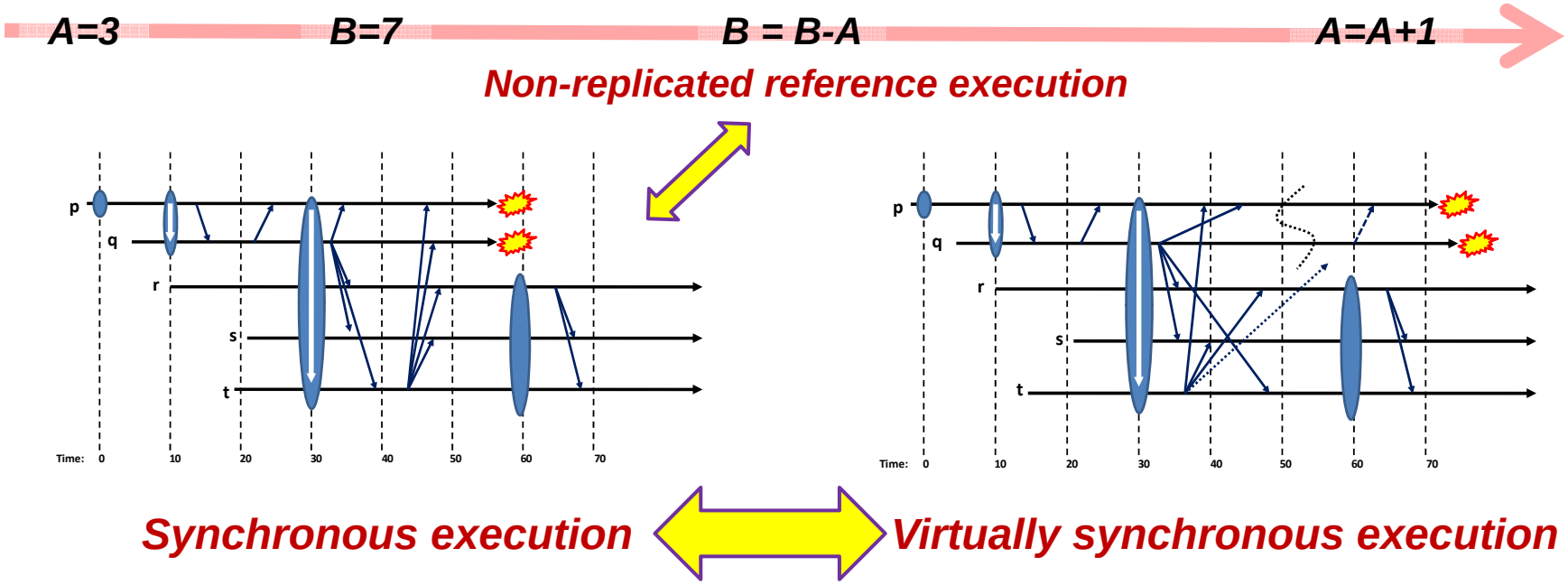


- With *n* programs in the group we get a possible n-fold speedup for our query
- The service lives "in the cloud". This one runs on 4 machines

Here we use LINQ which is the C# analog of JQL (LINQ came first)

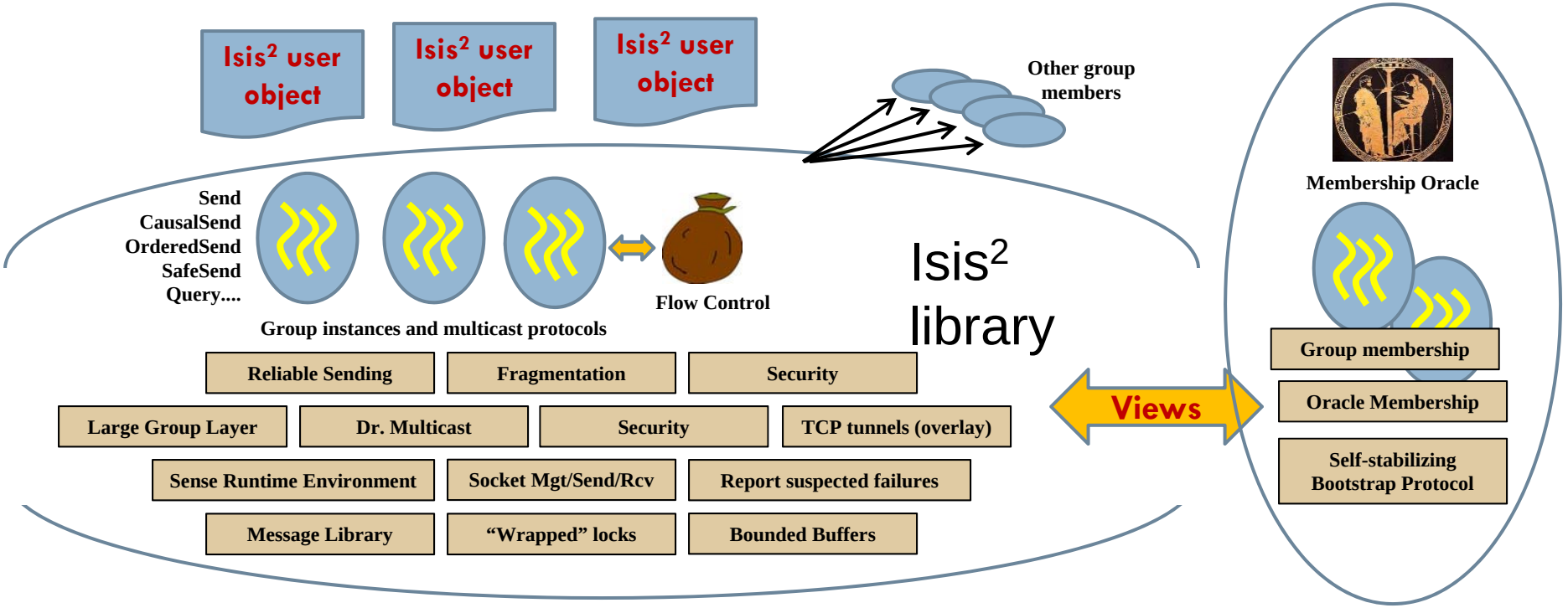
Consitency model: How users "think" about Isis^2

- **Virtual synchrony is a "consistency" model:**
  - ***Membership epochs:*** *begin when a new configuration is installed and reported by delivery of a new "view" and associated state*
  - ***Protocols run "during" a single epoch:*** *rather than overcome failure, we reconfigure when a failure occurs*



The system itself is a "community"

- Isis^2 is complex and concurrent... many interacting component parts that operate in concert



Use cases? The first Isis was used for...

- The New York Stock Exchange
- The French Air Traffic Control System
- The US Navy AEGIS warship

We're using Isis^2 in the "Smart Grid"

GridCloud **Cloud-hosted high-assurance system to monitor the electric power grid**

sponsored by the Department of Energy ARPA-E program

Goal

Demonstrate a cloud-scale monitoring infrastructure able to host "smart grid" applications: the code that will make the power grid "smart"

Use cases

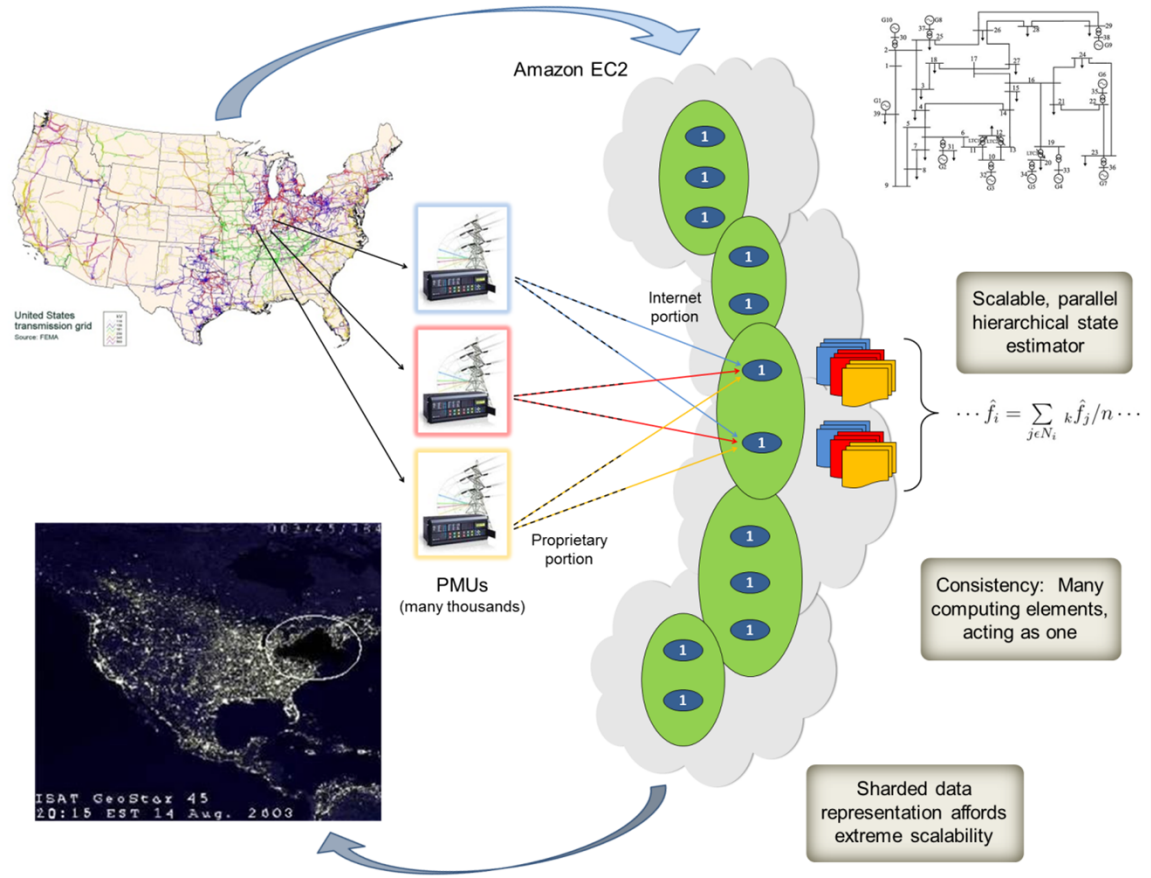
- Routine balancing of loads and generation
- Grid Protection
- Adaptation after topology changes
- Integration of renewable energy

Challenges

Cloud lacks consistency, assurance, and timing guarantees. Industry demands very strong control over data flow with provable security.

Status

We're using Isis^2 to manage a structure in which replicated data permits high assurance reactive smart-grid monitoring and control. GridCloud features state estimation and GridStat software from Washington State University.



Definitions

PMU

A sensor (synchrophasor) used to measure voltage and phase angle of a power bus

State Estimator (SE)

Code that computes the state of a regional grid using PMU data as input

Cornell University


Ken Birman


Robbert van Renesse


Ketan Maheshwari

Washington State University


Dave Bakken


Anjan Bose


Carl Hauser

www.cs.cornell.edu/Projects/Gridcontrol/

Prepared for the 2013 ARPA-E Energy Innovation Summit

Cornell University

WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

Summary

- The OO Java ideas we've learned matter!
  - The code people write at Facebook, or create using Isis^2, is very familiar looking
  - Not much harder than writing a GUI!

- Cornell has a great cloud computing group working on all sorts of cutting-edge questions