Efficient On-Demand Operations in Distributed Infrastructures

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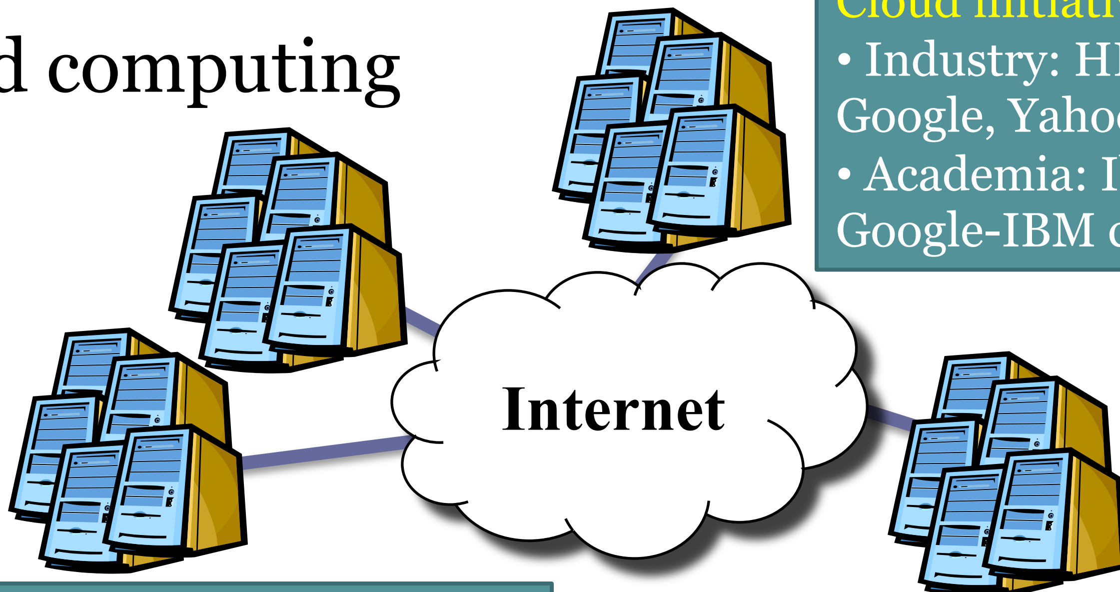
One-Line Summary

We need to design responsive datacenters that handle massive data.

- Will use monitoring (querying) as a main example

The Need

- Cloud computing



Cloud initiatives
- Industry: HP, IBM, Amazon, Google, Yahoo, MS, …
- Academia: Illinois CCT, Google-IBM cluster, etc

Apps in the Cloud
- Social networking sites: facebook, LiveJournal, etc
- In-Cloud desktop software: Google docs, Photoshop express, Apple's MobileMe, etc
- Data-intensive apps: log analysis, scientific computing, etc

Massive data in the Cloud
- Arise in many domains, e.g., scientific computing, social networking sites, web search engines, etc
- TB to PB (e.g., Yahoo 12TB/day)

The Requirement

Responsiveness while handling massive data

- Web 2.0 apps: users expect desktop-quality responsiveness.
- Data-intensive processing: long, long time to finish

Importance

- Amazon: every 100ms of latency cost them 1% in sales.
- Google: an extra .5 seconds in search page generation time dropped traffic by 20%.
- “Users really respond to speed” – Google VP Marissa Mayer
- Coadd took 70 days to complete with over 30 sites and 4,500 CPUs.
  - Coadd? a spatial processing application with 44,000 tasks accessing 588,900 files in total

Not Easy to Do Both

Datacenter monitoring example

- Monitoring responsiveness: quick query results regarding the state of the datacenter

Case of HP OpenView

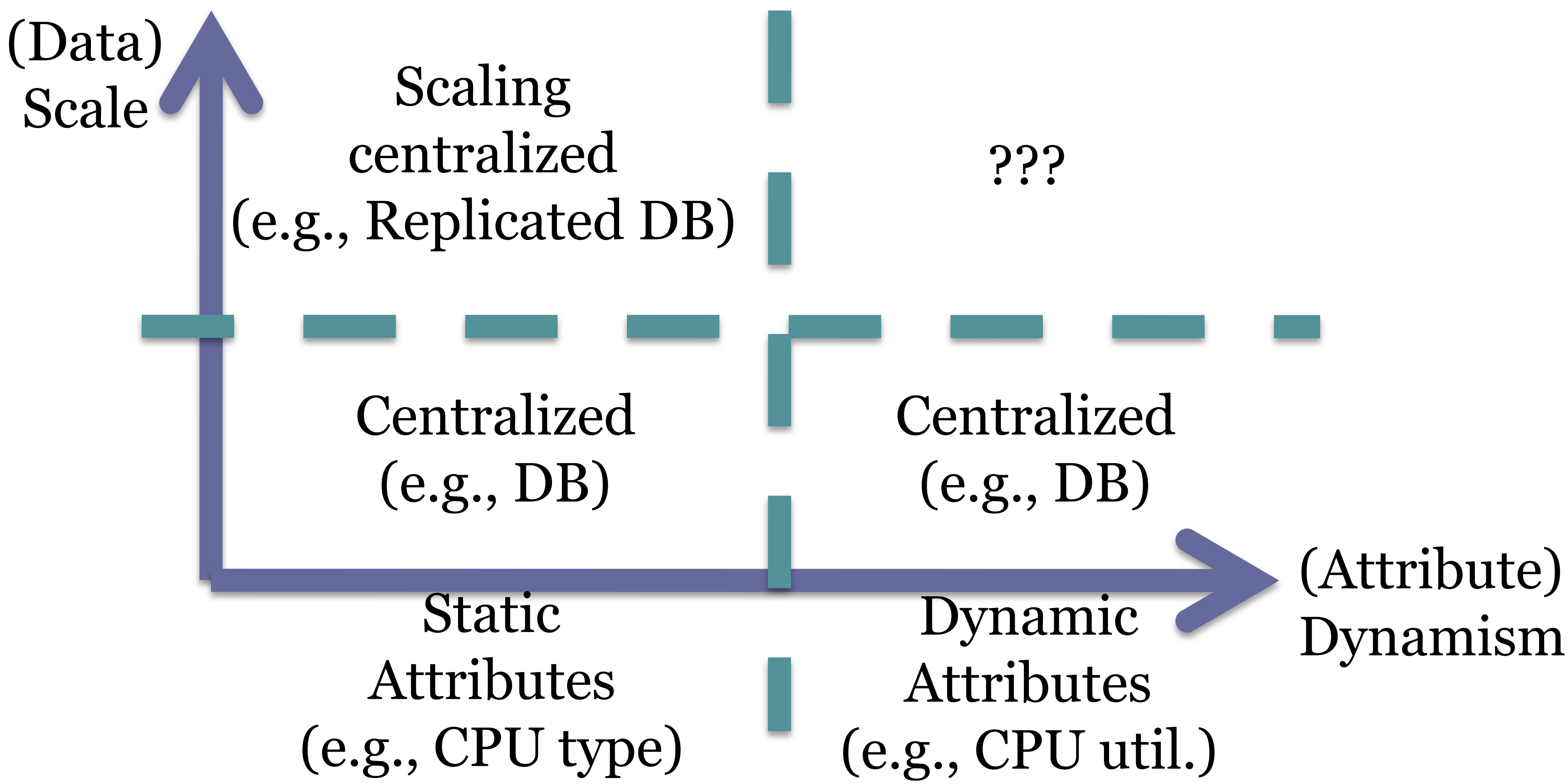
- 144 attributes, store them in a database
- Data scale: # of attributes * # of machines
- First-cut attempt in 2006: “6 ½ hours for 6,200 machines, and 12 hours for 11,500 machines”
- Not possible to query the most up-to-date state

More than merely scale

- Static vs. dynamic attributes

Challenges – Scale & Dynamism

Monitoring example



On-Demand Operations

On-demand operations

- Operations that are responsive in spite of massive data
- Challenges: scale & dynamism

Examples

- On-demand monitoring: quick response even when querying the most up-to-date state of the infrastructure
- On-demand scheduling for data-intensive workload: quick scheduling decisions reflecting the current resource availability

On-Demand Group Querying

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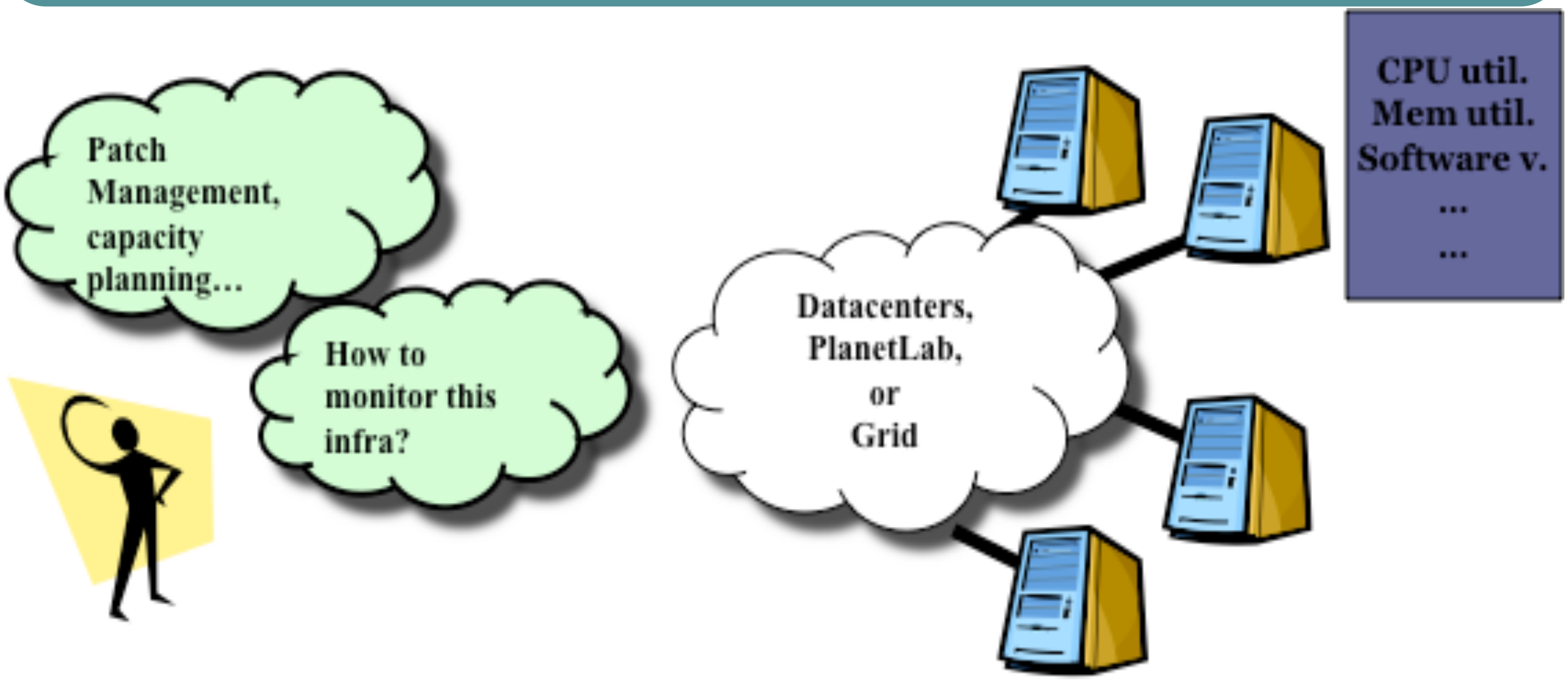
Problem

Group monitoring (querying) in large-scale infrastructures



Necessity

Groups are formed naturally

- A set of machines running a service in a datacenter, PlanetLab Slices, Grid sites, etc

Users want to query attributes from groups

- Avg. CPU utilization of a slice
- Top-3 loaded machines running Linux and executing a MapReduce task
- List of machines in rack R with either CPU util. < 10% or Mem util. < 5% running less than 2 VMs on either Xen or VMware

Requirements

Efficient group support with expressive queries

- Single groups & multiple groups
  - Queries targeting unions and intersections of groups
  - List of machines in rack R with CPU util. < 10% or Mem util. < 5% running less than 2 VMs on Xen or VMware
  - *A and (B or C) and D and (E or F*)
- Static groups & dynamic groups
  - Static groups: Linux machines, web servers, etc
  - Dynamic groups: CPU > 90%, # of VMs < 2, etc
- Query: (Aggregation function, Query attribute, Group predicate)

Responsiveness while handling massive data

- Quick query results even for the most up-to-date state
- Massive data (many attributes over many machines)

Previous Solutions

Centralized DB-based systems

- Collect data to a DB (HP OpenView, IBM Tivoli, …)
- Advantage: very expressive (SQL)
- Disadvantage: can't deliver freshness & scalability at the same time (e.g., every 5 min for CoMon on PL) – gathering all attributes every time

Distributed aggregation systems

- Build end-host aggregation trees (Astrolabe, SDIMS, Seaweed, MON, etc)
- Advantage: scalability with responsiveness
- Disadvantages (next slide)

Previous Solutions

No support for groups

- One group = the entire system
- They all collect data from the entire system

E.g.,

- Just to monitor problematic 3 machines in your PlanetLab slice with 400 machines
- => Need to get data from all 400 machines

Moara Overview

A group-based querying system

- Allows users to target specific groups of machines
- Fast query resolution & expressive group predicates

Group trees

- Moara builds per-group trees & uses these for aggregation
- Different groups can share a tree for scalability.
- Leverages SDIMS (a Pastry-based aggregation framework)

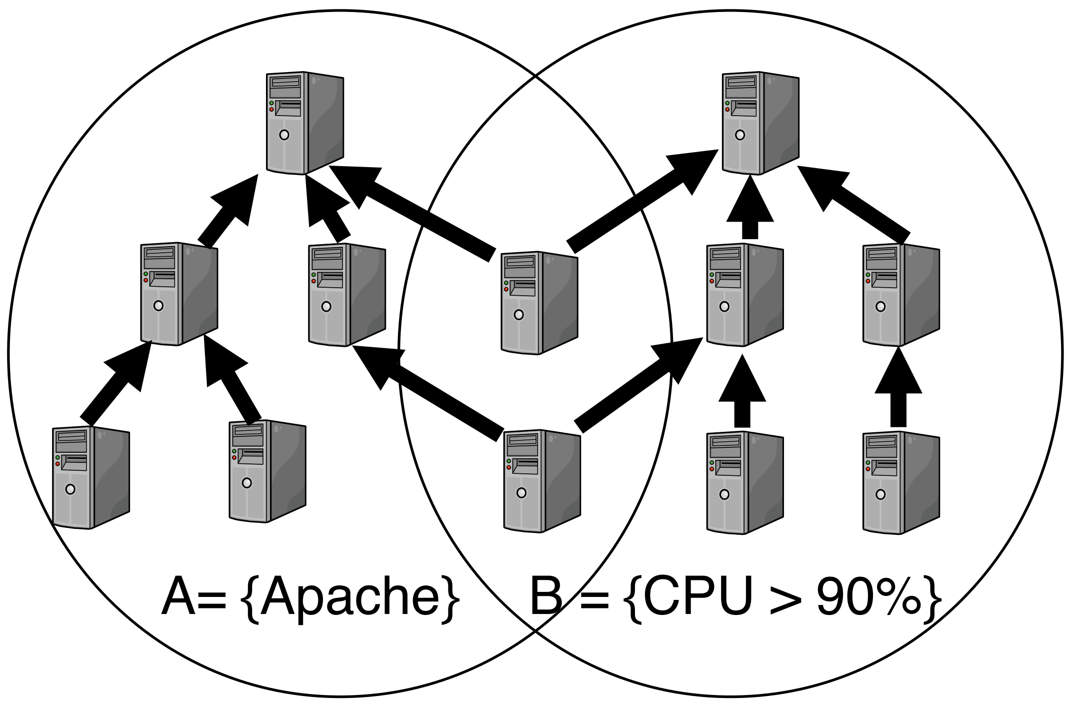
Two optimization techniques

- Multi-group optimization
- Single-group optimization for dynamic groups

Multi-Group Aggregation

Goal

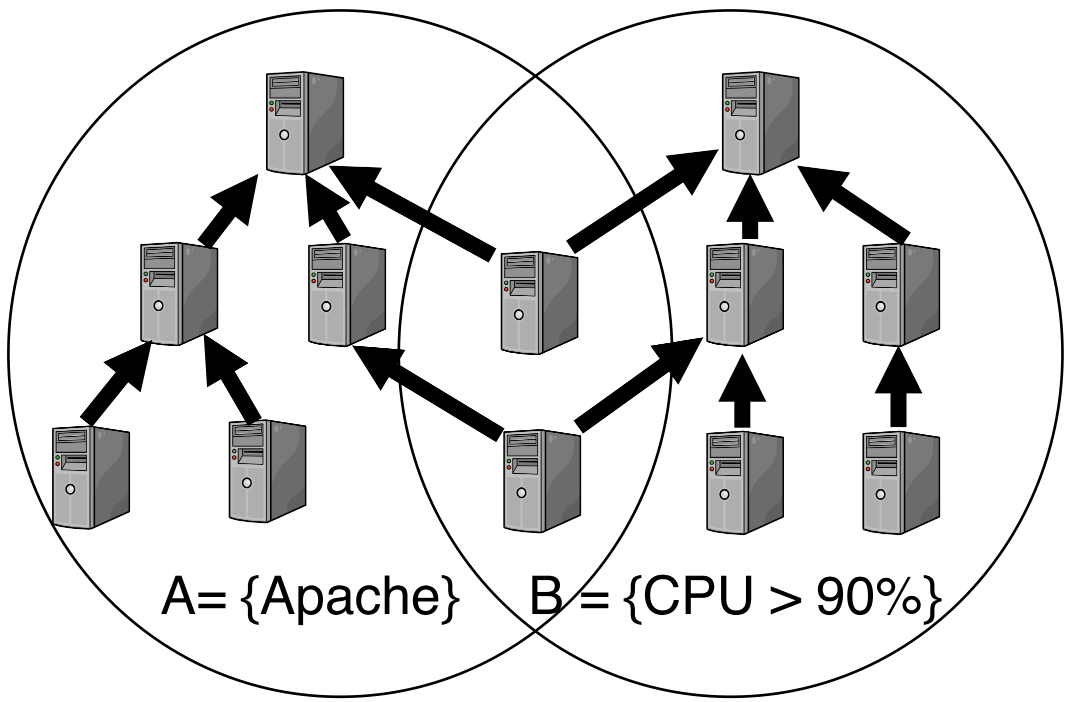
- Quick results with minimum B/W when querying union (*or*) & intersection (*and*) of groups
- E.g., {(*A or B*) *and C*} *or* (*D and E*)?
- Naïve, but correct approach: send a query to every group and collect the data



Multi-Group Aggregation

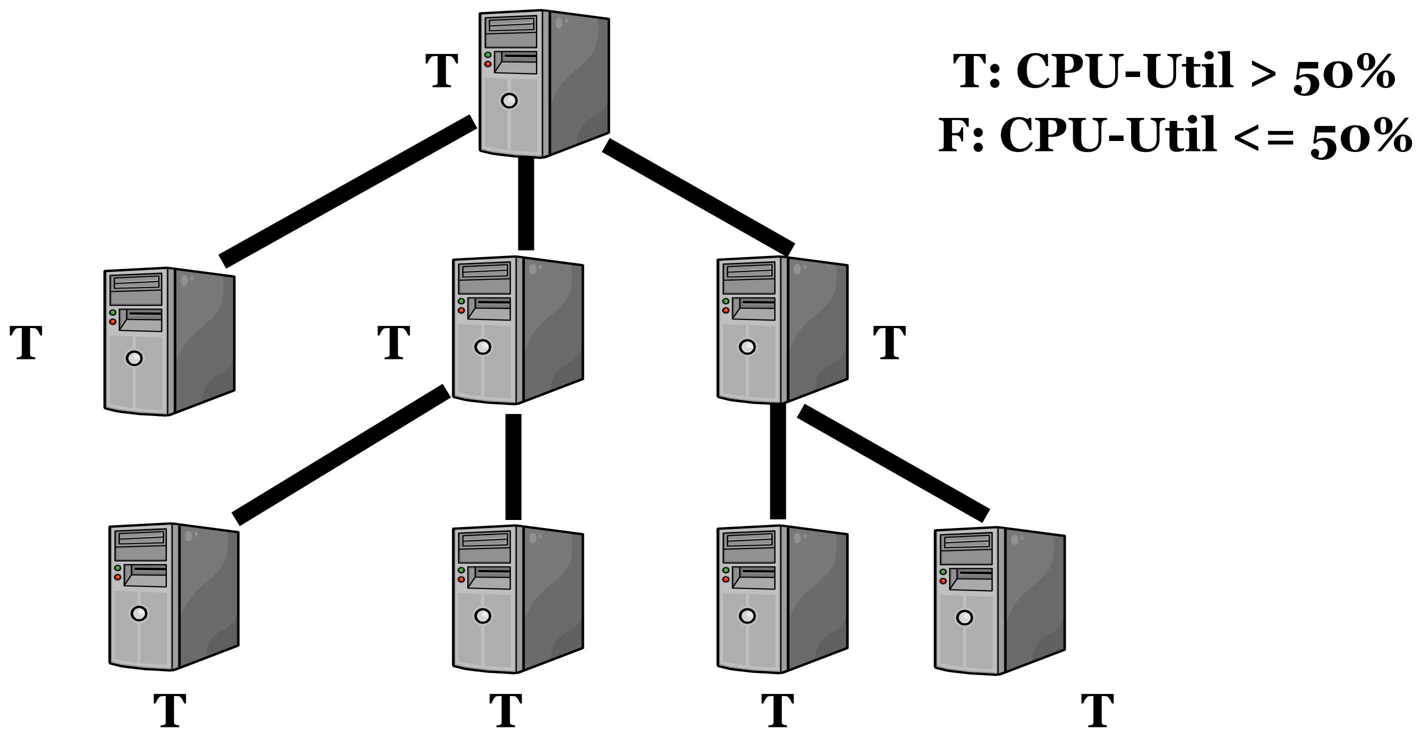
Optimization opportunity for latency and bandwidth

- Querying (*A and B*): need to send queries to only one (smaller) of the two
- What about complex expressions? e.g., {(*A or B*) *and C*} *or* (*D and E*)?
- Solution: CNF transformation & a few more tricks



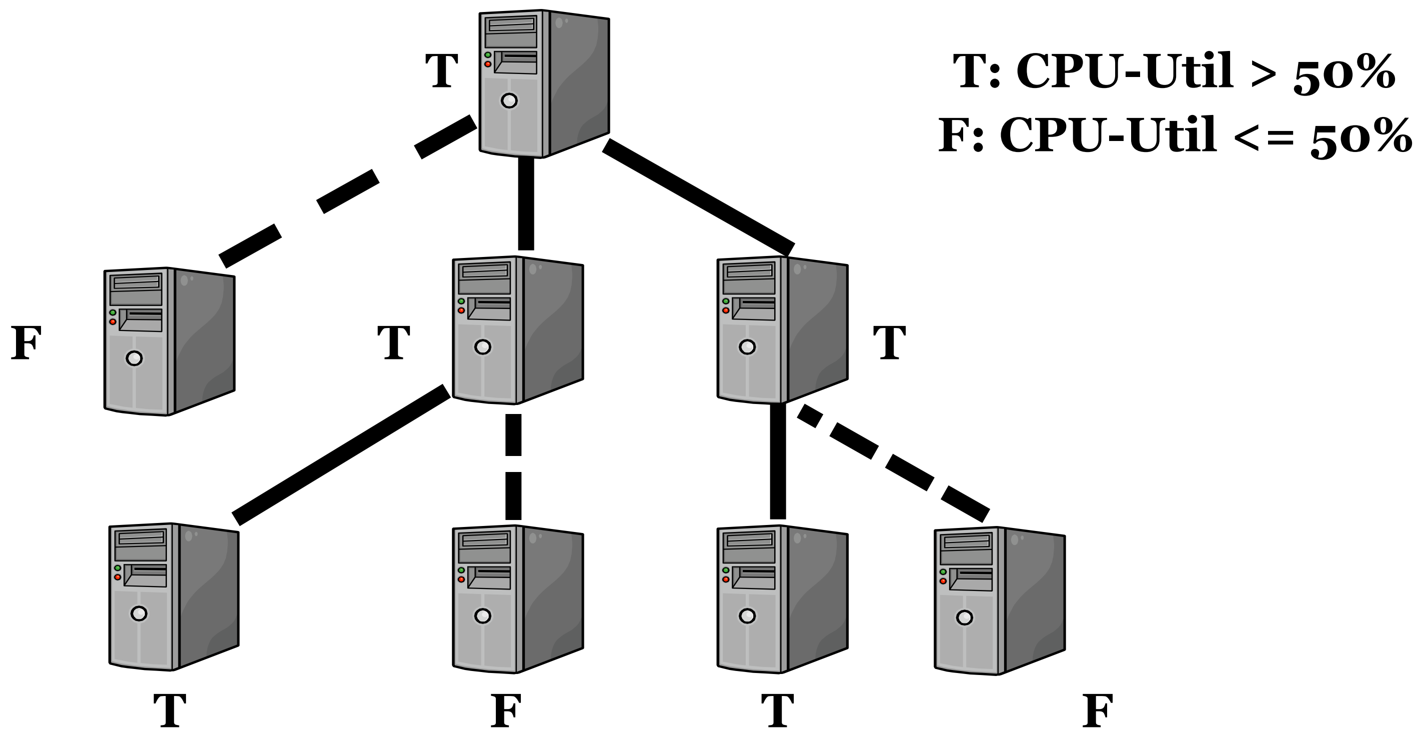
Efficient Dynamic Group Management

Group tree management



Efficient Dynamic Group Management

Group tree management



- Two choices: keep or cut

Efficient Dynamic Group Management

Tradeoff

- Aggressive group tree management: saves per-query cost, but increases management cost
- Lazy group tree management: increases per-query cost, but saves management cost

Adaptive group tree management

- Moara strikes the balance between aggressive and lazy tree management (best of both worlds)
- Adaptively adjust aggressiveness of management by continuously tracking query cost and management cost

Evaluation

PlanetLab: 200 nodes

- Represents wide-area infrastructures

Emulab: 500 instances on 50 machines

- Represents medium-size datacenters

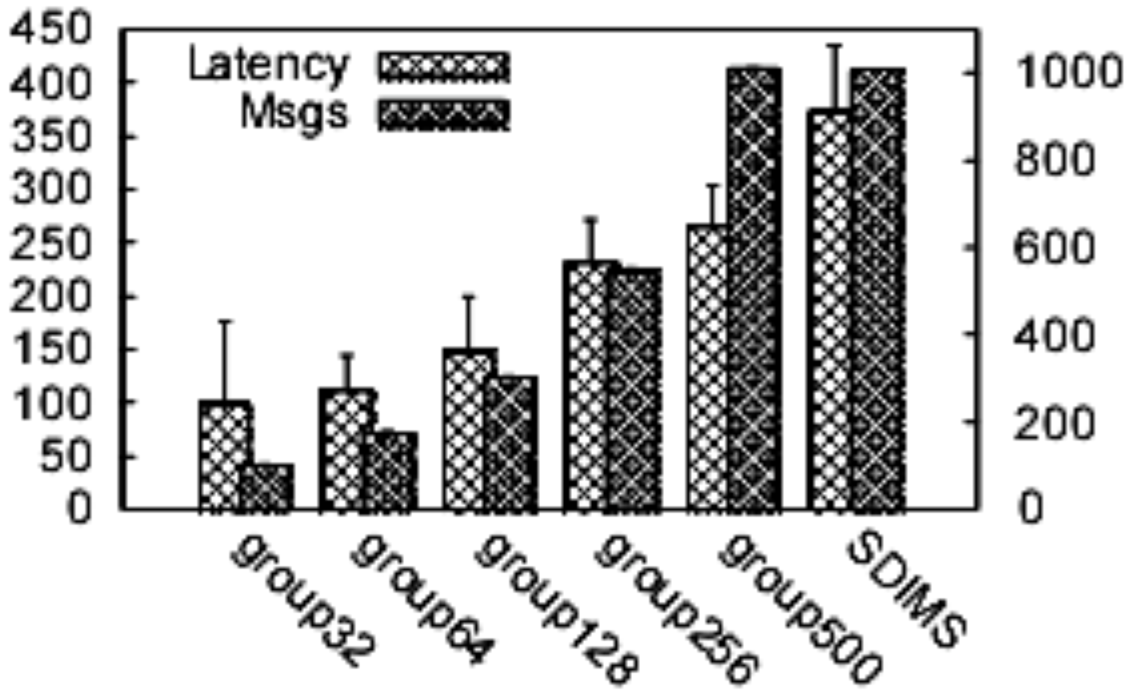
Simulation: up to 10K nodes

- Don't care about latency
- Only measure # of msgs

Emulab

Latency & Bandwidth (static group, 500 instances)

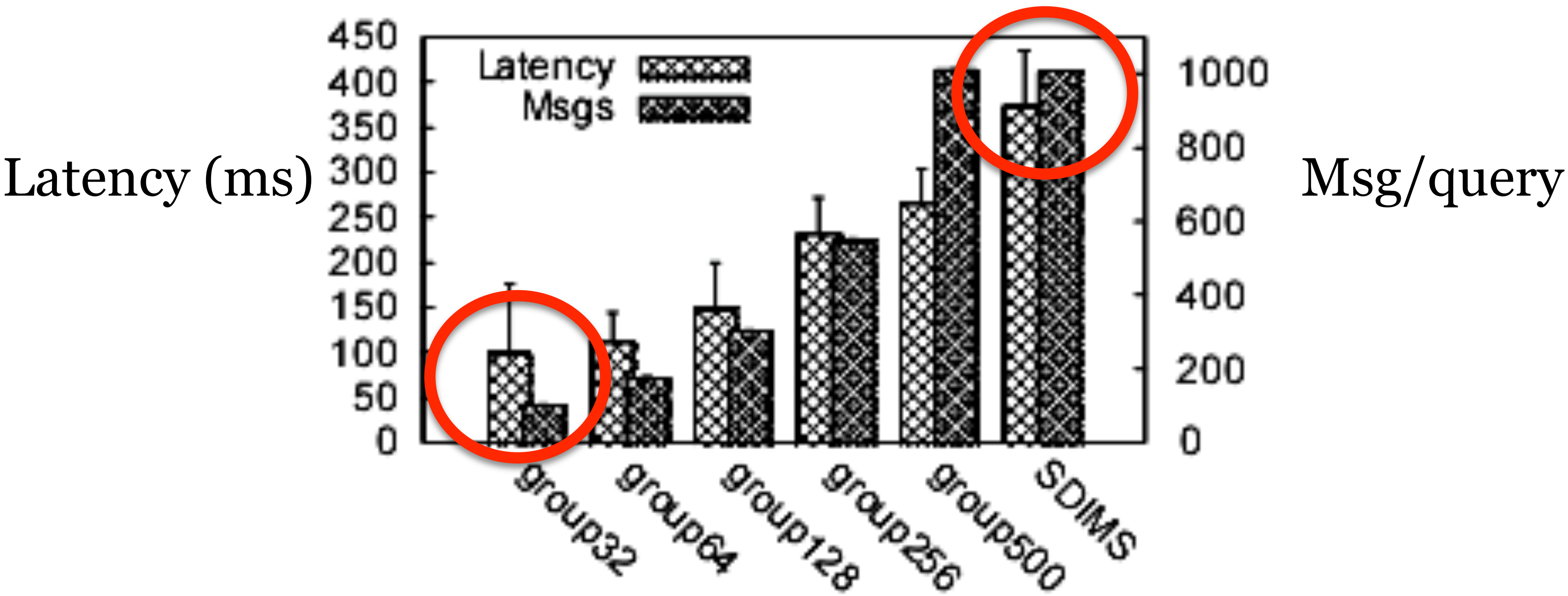
Latency (ms)



Msg/query

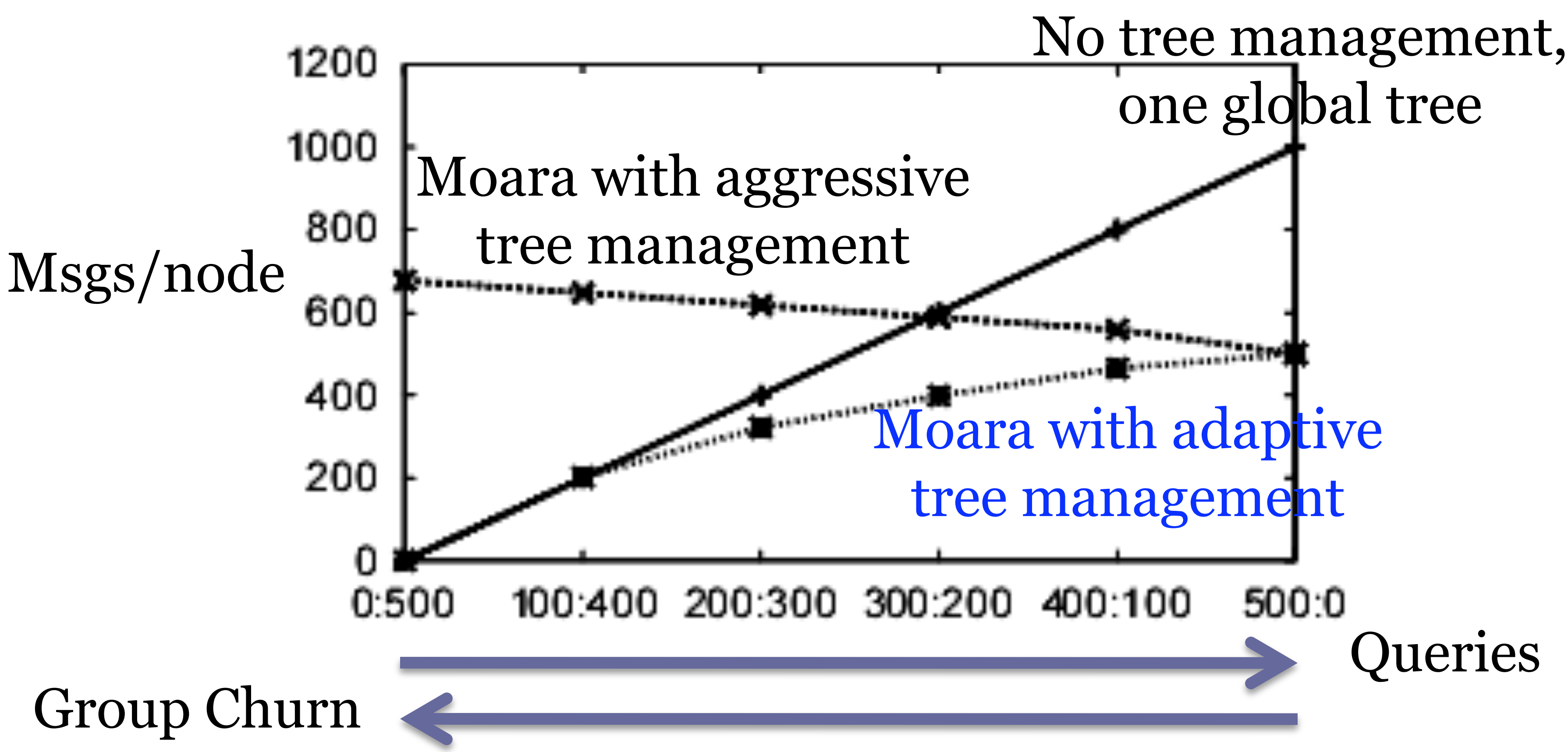
Emulab

Latency & Bandwidth (static group, 500 instances)



Simulation

Adaptive tree mechanism (10K nodes)



Beyond On-Demand Operations

Beyond On-Demand Operations

Data-intensive apps in the Cloud

- Apps access & generate massive amount of data (TB to PB)

Need new solutions to old problems

- E.g., scheduling for data-intensive apps (Hadoop scheduler, worker-centric scheduler – Middleware '07, etc)

New problems

- How to coordinate data management and scheduling
- How to handle intermediate data
  - Data that exists only during the lifetime of an app
  - E.g., data from the Map phase

Beyond On-Demand Operations

Web 2.0 apps in the Cloud

- Problem: responsiveness
- Users expect desktop-quality responsiveness

Best practices

- Make each component as fast as possible
- E.g., multi-layer caching: DB in-memory cache, in-datacenter distributed cache (e.g., memcached), CDN, etc

What's missing? Coordination

- Possibility: Design components that are "aware" of one another.
- To achieve maximum possible performance

Summary

We need to design responsive datacenters that handle massive data.

- Web 2.0 apps in the Cloud
- Data-intensive apps in the Cloud

On-demand operations

- Operations that achieve the goal
- Scale & dynamism are the challenges.