Tail Latency

15-719 / 18-847b

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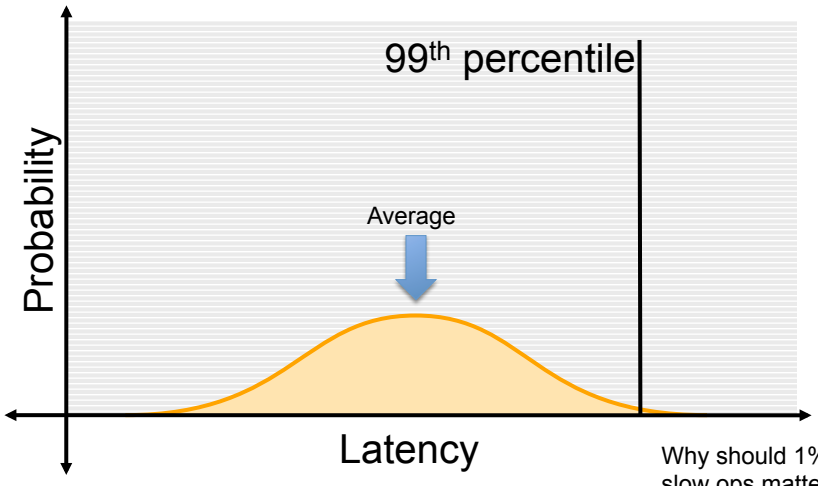
A hypothetical service time (latency) distribution



Why should 1% slow ops matter?

Service times vary for many reasons

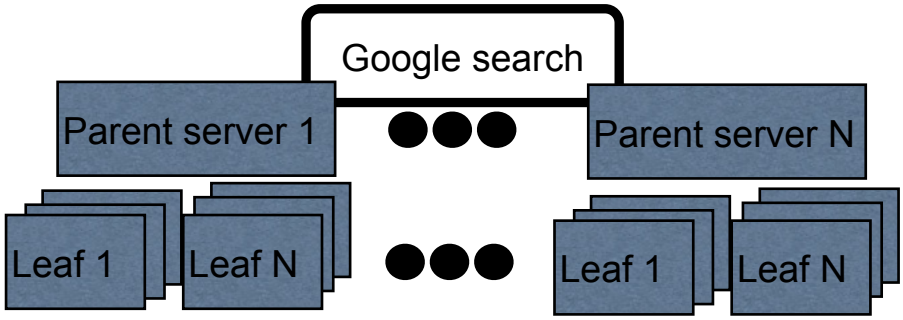
- Interference within shared infrastructure
  - Bobtail paper ….. More VMs than cores in "cheap" EC2 instances, so easy to be allocated a VM sharing with too many compute-bound VMs
- Lots of other causes too
  - Background/maintenance activities
    - garbage collection, log compaction, virus scanning, backup, etc.
    - HPC calls this "OS jitter"
  - Dynamic and "static" hardware variations (e.g., power caps, disk heads)
  - Complex queuing and caching policies

Service time variation is a big deal in cloud services

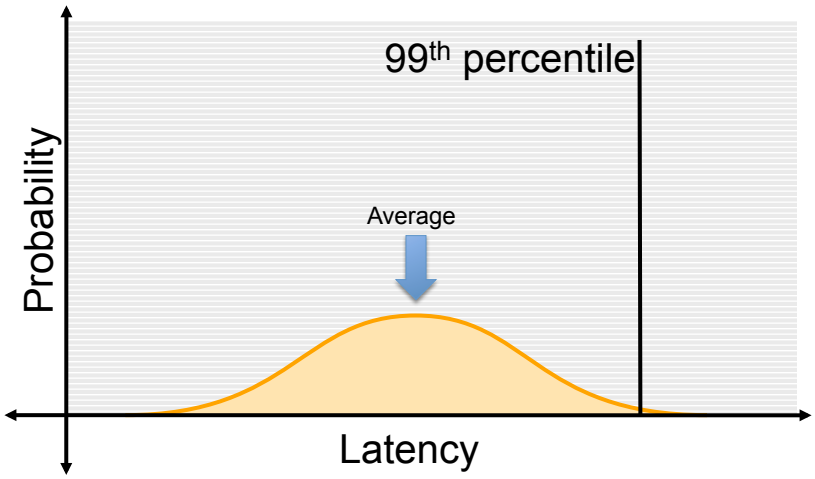
- Very slow responses make for angry users
  - better to have them all be a little slow, than to have some very slow
  - e.g., below 100ms is plenty fast for humans
- Big jobs often wait for the last task to finish
  - so, runtime is the max task time rather than the average
    - think map-reduce, for example
  - again, better to have them all be a little slower, than to have few very slow

Tail latency & fan-out

- Matters to apps with large fan-outs of leaf tasks
  - Such fan-out parallelizes work
    - to lower latency perhaps
  - But, if app must wait until all leaves reply…
    - Example from reading: Google search works this way



Why? Recall this graph from earlier

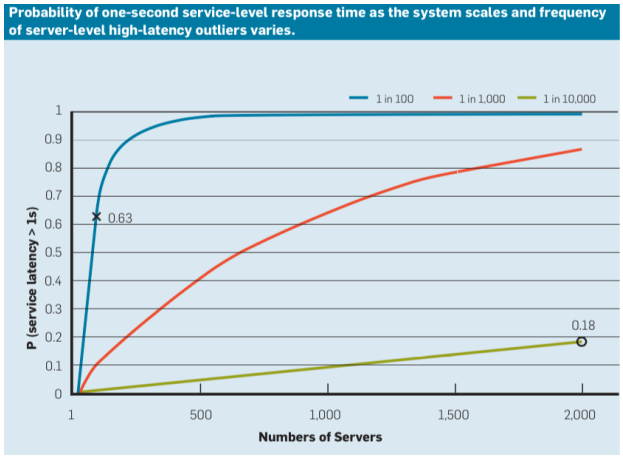


Tail latency & fan-out

- Consider a system with one-wide fan-out
  - Assume 100 leaf nodes
  - Assume each leaf node has 99%tile latency of 1 second
- What is the probability of a single user request taking more than than second?
  - 1 – probability of all 100 leaf accesses < 1 sec
  - ~63%

Bigger fan-outs suffer more

- What if only 1 in 1000 nodes see latency > 1 sec?
  - Fanout of 1000 sees ~63% slow requests
- At .01% slow ops fanout of 2000 sees ~20% slow requests



Dean, CACM13

One approach: reduce service time variation

- Great option, when it's possible
  - But, it's really difficult to do comprehensively
- Some approaches
  - Prioritize
    - do the stuff that is being waited for first (before background stuff)
    - do the stuff that is "falling behind" first
  - Manage background activities
    - synchronize schedulable maintenance stuff among machines
      - HPC deals with OS jitter this way (on global barrier sync)
    - do other background stuff when not busy with stuff

Alternate approach: "tail tolerance techniques"

- Design system assuming service time variation is inevitable
  - and do things to make tail latencies less problematic
- Some approaches
  - "hedged" requests (or "speculative" redundant requests)
    - ask more than one server to do the work (e.g., read replica, compute map)
    - take the first response to arrive and ignore the slow one
    - great for hiding infrequent slow responses, especially if 2nd request is delayed
  - "tied" requests (aggressive hedging)
    - ask more than one server immediately, but let them know you did
    - when one finishes (or starts), it "cancels" the other/redundant request
    - addresses infrequent slow responses faster with less redundant work
  - "micro-partitioning" migrate (replicate?) 5% of partitions on imbalance
  - "probation" elimination of node from datapath until its specs get better

Special app-specific "tail tolerance techniques"

- Some apps offer special opportunities or challenges
  - e.g., large information-retrieval (IR) apps like "fuzzy" search
- Positive ex.: an IR service can answer without all leaves responses
  - Why: a query displaying most possible answers is usually "good enough"
  - So, just return what is available within acceptable time limit
- Negative ex.: some queries can sometimes cause deterministic failure
  - Bugs in the system, perhaps, triggered by specific queries
  - Executing same query on all leaves causes "soft crash" outage latencies
  - "Canary requests" are one or two requests sent first to test the waters
    - If these crash, system can tolerate and this request is suppressed
  - Dean13 claims benefit of avoiding crashes worth extra round of latency

Next week

- Project 3 coming ☺

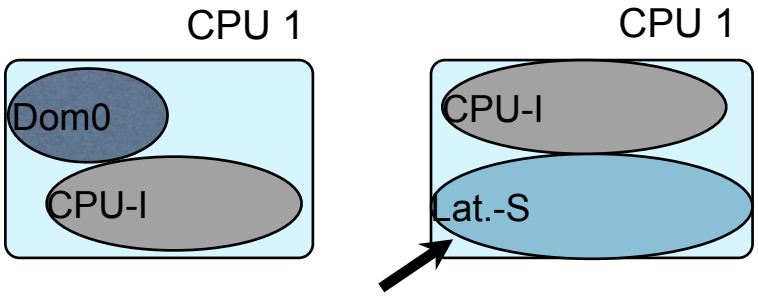
Bobtail Overview

- Paper examines RTTs in AWS EC2
  - Within a single Availability Zone (AZ) and across AZs in US East
  - Compares RTTs to 'dedicated' datacenters
- Finds that median (0.6ms/1ms) is similar
- But, finds that 99.9th percentile is ~ 2X worse
  - Good nodes: 99.9th percentile < 10ms
  - 40-50% of nodes within AZs are bad
    - Some AZs return no bad nodes…
  - Bad nodes are persistent

Root-cause analysis

- High-tail latencies caused by…
  - Co-scheduling of latency/CPU-intensive jobs with more jobs than cores
  - Interaction with Xen (AWS hypervisor)
- Xen Details
  - Has 1 privileged VM (called *domo),* typically pinned on 1-2 cores
  - Allows for multiple guest VMs, scheduled over remaining cores
  - Uses credit-based scheduling
    - Each VM given 30ms of credit
      - Drained in 10ms increments
    - VMs with remaining credit can be BOOSTED (run first when one VM yields)

When does problem manifest?



Latency sensitive job might have to wait an entire round to be woken up! (10ms or more)

Why doesn't BOOST help?

- When CPU-intensive jobs that take < 100% CPU can also enter BOOST queue
  - E.g., jobs that run for 28 ms in each round
- BOOST queue serviced in FIFO order