AVAILABILITY AND PERFORMANCE

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ATTRIBUTION

- These slides incorporate material from:
    - Jeffrey Dean and Luiz André Barroso. The tail at scale.

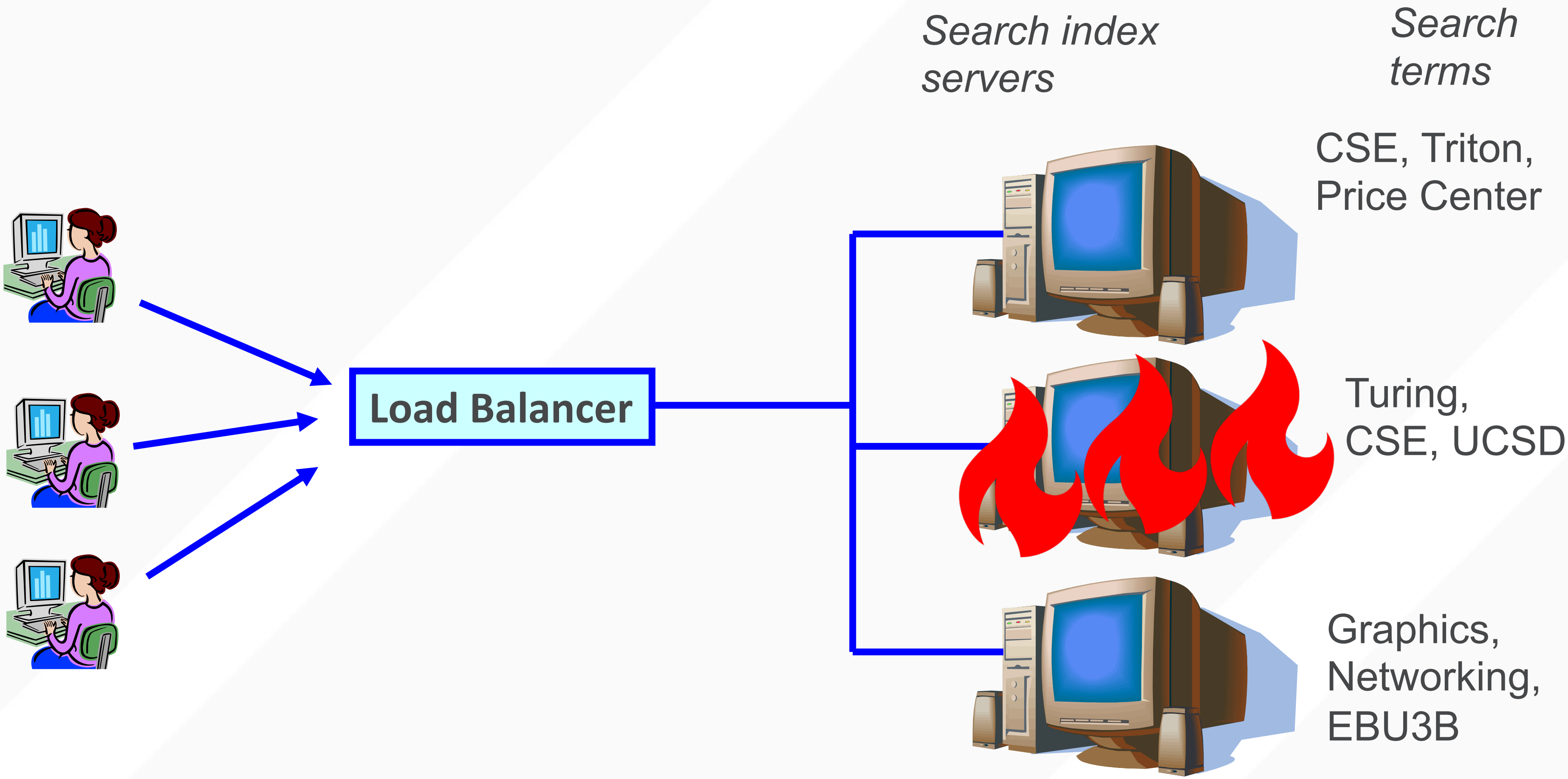
READING FOR THIS TOPIC

Head of Google ai; (Co-)designed Google's Ad engine, Web crawler, indexer, and query serving system. Created Spanner, BigTable, MapReduce, LevelDB, TensorFlow (AI/ML system), …

Google Fellow, VP of Engineering, Technical lead of Google's infrastructure and datacenters

Jeffrey Dean and Luiz André Barroso. The tail at scale. Communication of the ACM 56, 2 (February 2013), 74-80. DOI: https://doi.org/10.1145/2408776.2408794

AVAILABILITY



AVAILABILITY METRICS

- Mean time between failures (MTBF)
- Mean time to repair (MTTR)
- Availability = (MTBF – MTTR)/MTBF
- Example:
  - MTBF = 10 minutes
  - MTTR = 1 minute
  - A = (10 – 1) / 10 = 90% availability
- Can improve availability by increasing MTBF or by reducing MTTR
  - Ideally, systems never fail but much easier to test reduction in MTTR than improvement in MTBF

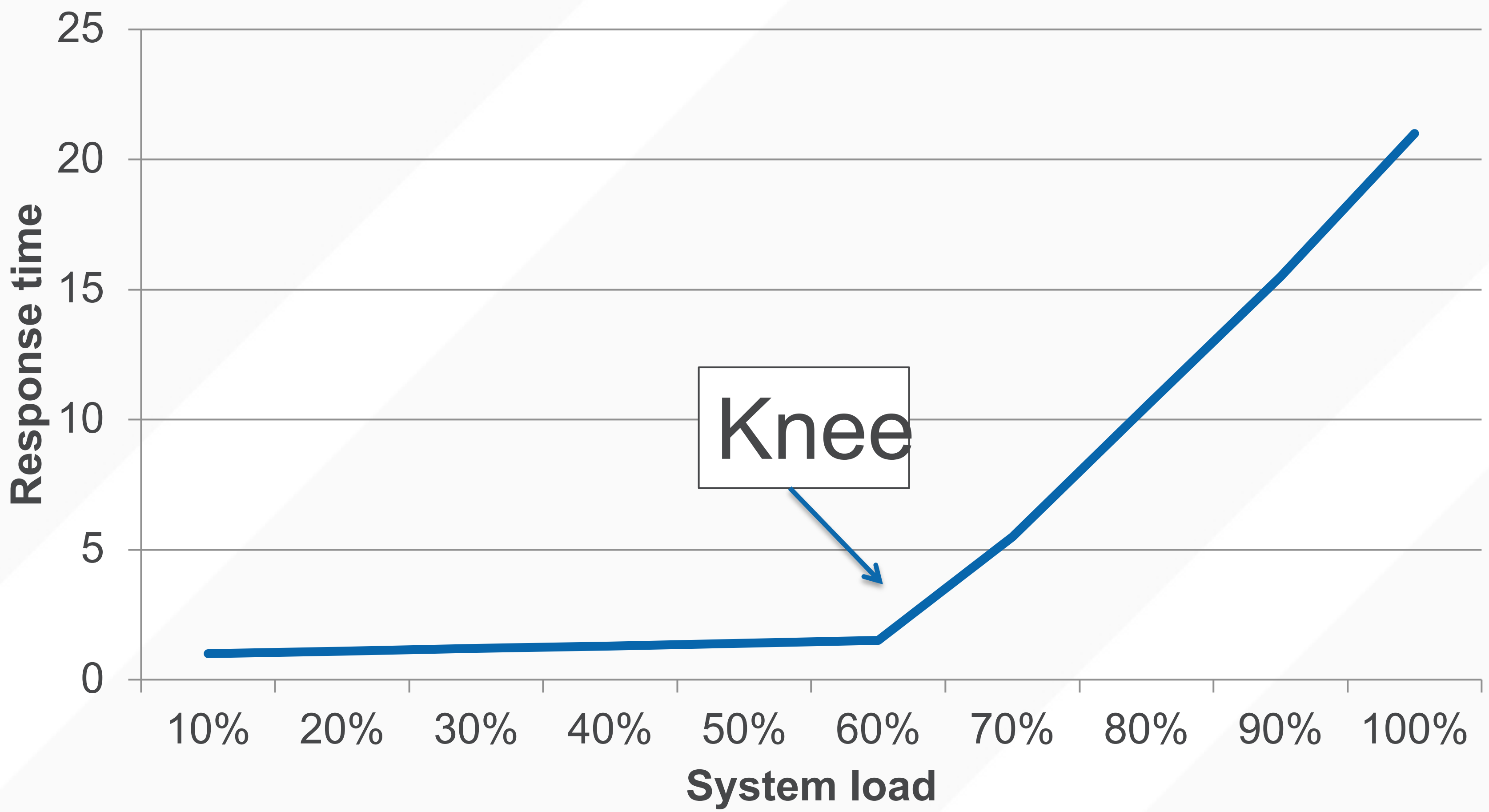
HARVEST AND YIELD

- *yield = queries completed/queries offered*
  - In some sense more interesting than availability because it focuses on client perceptions rather than server perceptions
  - If a service fails when no one was accessing it…
- *harvest = data available/complete data*
  - How much of the database is reflected in each query?
- Should faults affect yield, harvest or both?

DQ PRINCIPLE

- *Data per query* * *queries per second* → *constant*
- At high levels of utilization, can increase queries per second by reducing the amount of input for each response
- Adding nodes or software optimizations changes the constant

PERFORMANCE “HOCKEY STICK” GRAPH



TAIL TOLERANCE: DEPENDENT/SEQUENTIAL PATTERN

- Consider iterative lookups in a service to build a web page
  - E.g., Facebook
- Issue request, get response, based on response, issue new request, etc…
- How many iterations can we issue within a deadline D?

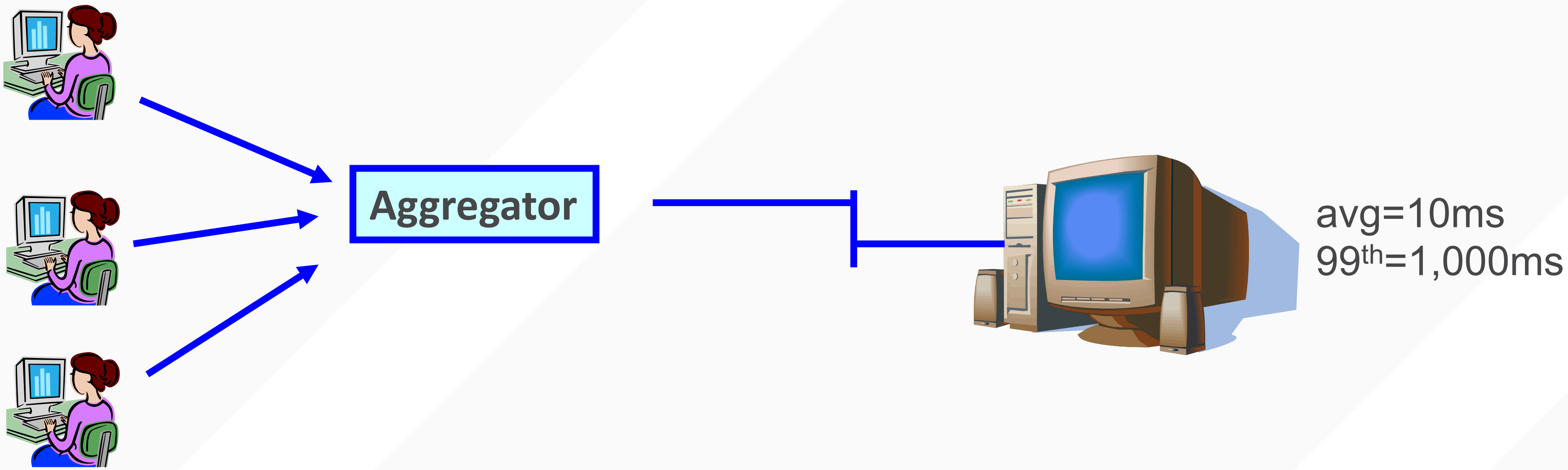
EFFECT OF LATENCY VARIATION

service to feel responsive.

Variability in the latency distribution of individual components is magnified at the service level; for example, consider a system where each server typically responds in 10ms but with a 99th-percentile latency of one second. If a user request is handled on just one such server, one user request in 100 will be slow (one second). The figure here outlines how service-level latency in this hypothetical scenario is affected by very

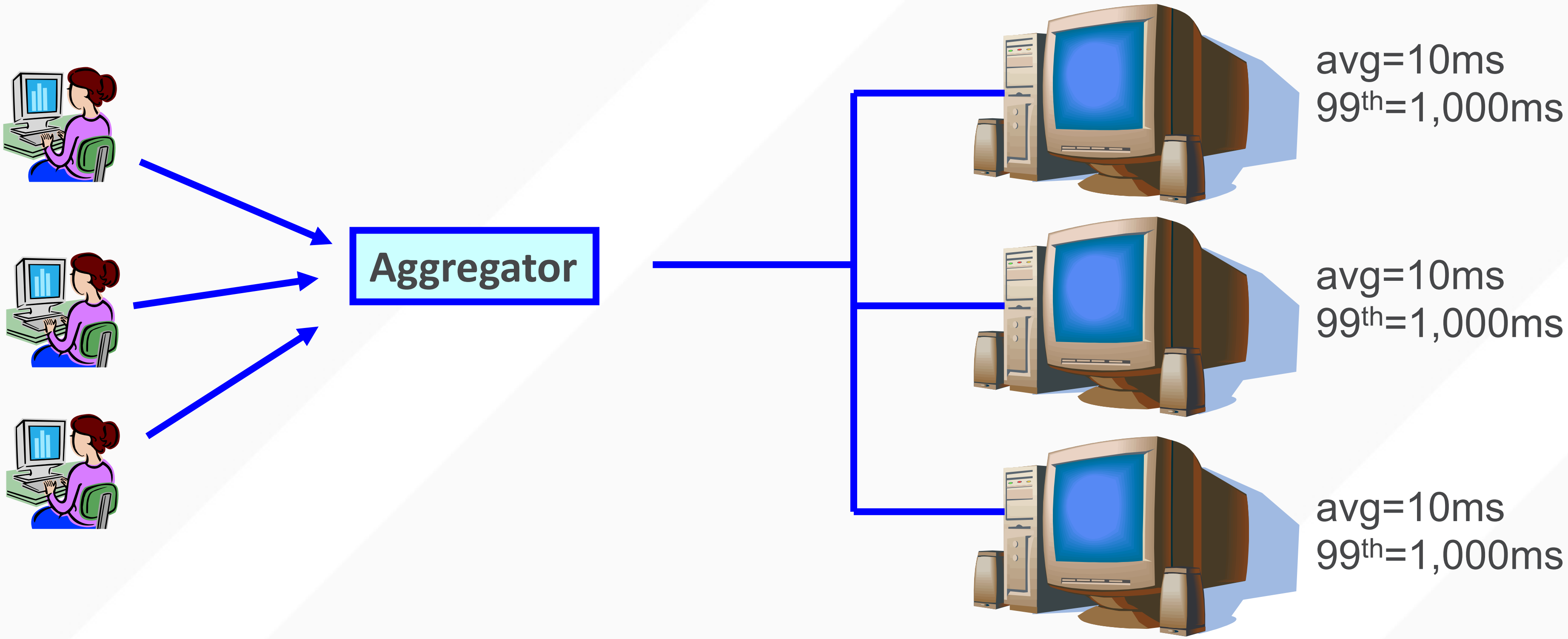
higher-level queuing. Di
vice classes can be used
uling requests for whic
ing over non-interactiv
low-level queues short
policies take effect mor
ample, the storage ser
cluster-level file-system
few operations outstan
erating system's disk
maintaining their own
of pending disk reques

PERFORMANCE NOT AT SCALE



- What is the expected time to service one request to one server?
  - 10ms? more? less?

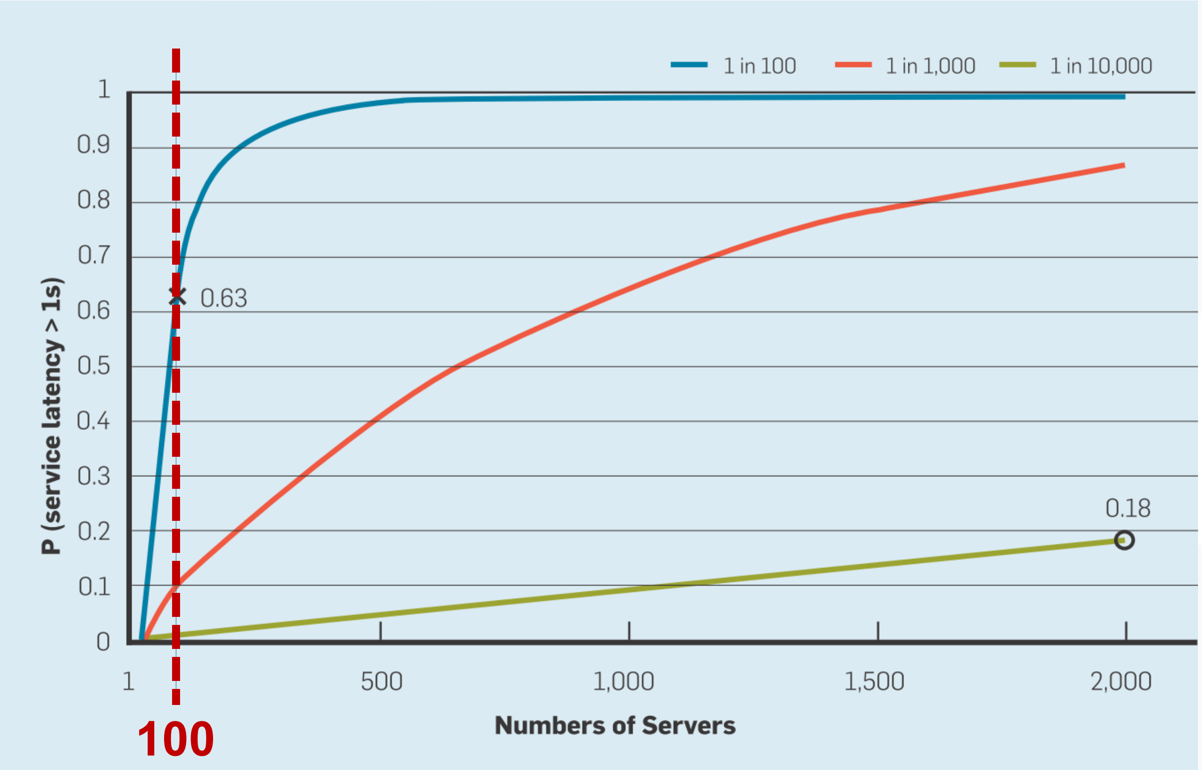
PERFORMANCE AT SCALE



- What is the expected time to service three correlated requests to three servers?
  - Must wait until all complete before the load balancer can return a result to the user
  - 10ms? more? less?

COMPONENT VARIABILITY AMPLIFIED BY SCALE

- Latency variability is magnified at the service level.



REQUEST LATENCY MEASUREMENT

	50%ile latency	95%ile latency	99%ile latency
One random leaf finishes	1ms	5ms	10ms
95% of all leaf requests finish	12ms	32ms	$\boxed{\text{70ms}}$
100% of all leaf requests finish	40ms	87ms	$\boxed{\text{140ms}}$

50%+

- Key Observation:
  - 5% servers contribute nearly 50% latency.
  - *Why not just rid of those “slow” 5% of the servers?*

FACTORS OF VARIABLE RESPONSE TIME

- Shared Resources (Local)
  - CPU cores
  - Processors caches
  - Memory bandwidth
- Global Resource Sharing
  - Network switches
  - Shared file systems
- Daemons
  - Scheduled Procedures

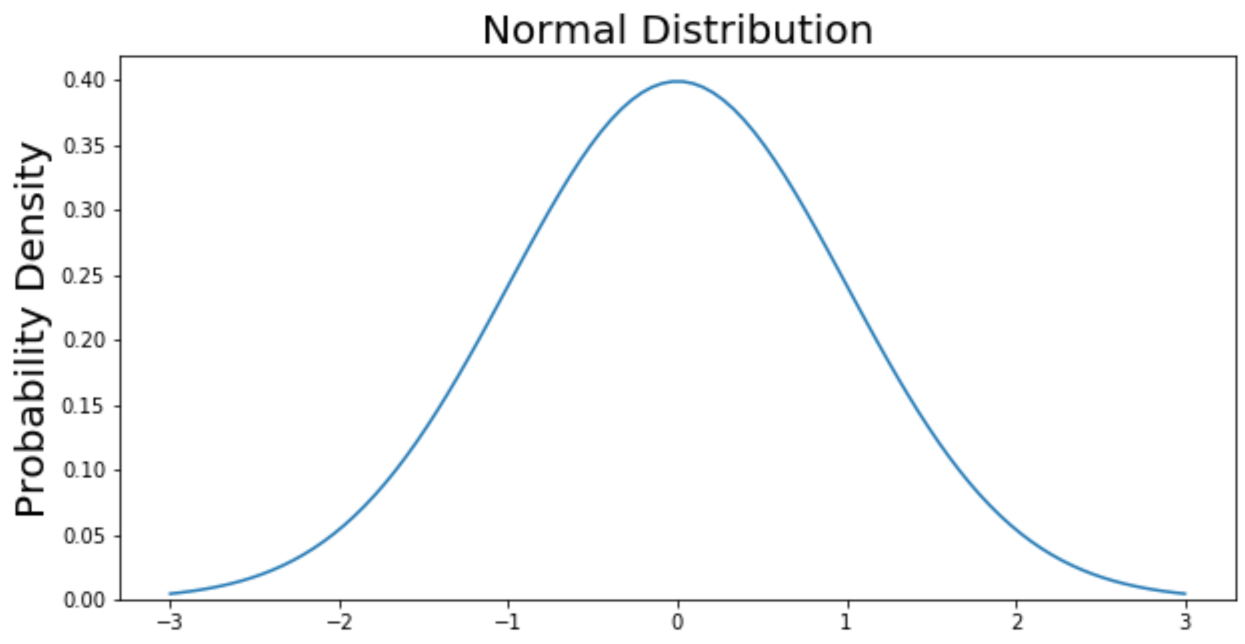
FACTORS OF VARIABLE RESPONSE TIME

- Maintenance Activities
  - Data reconstruction in distributed file systems
  - Periodic log compactions in storage systems
  - Periodic garbage collection in garbage-collected languages
- Queueing
  - Queueing in intermediate servers and network switches

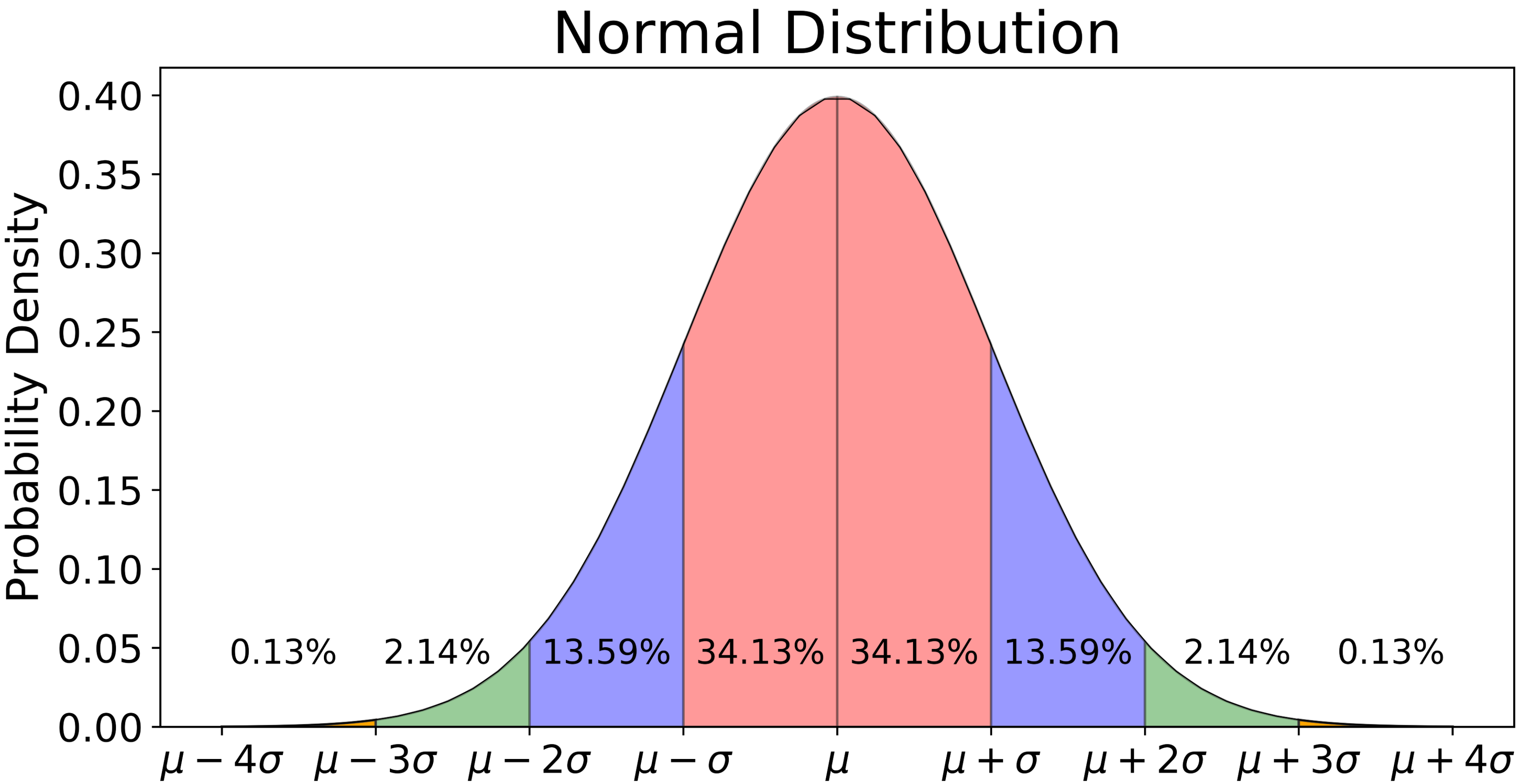
FACTORS OF VARIABLE RESPONSE TIME

- Power Limits
  - Throttling due to thermal effects on CPUs
- Garbage Collection
  - Random access in solid-state storage devices
  - Twitter's interesting take on GC…
- Energy Management
  - Power saving modes
  - Switching from inactive to active modes

RANDOM VARIABLES: NORM(0,1)



RANDOM VARIABLES: NORM(μ, σ)



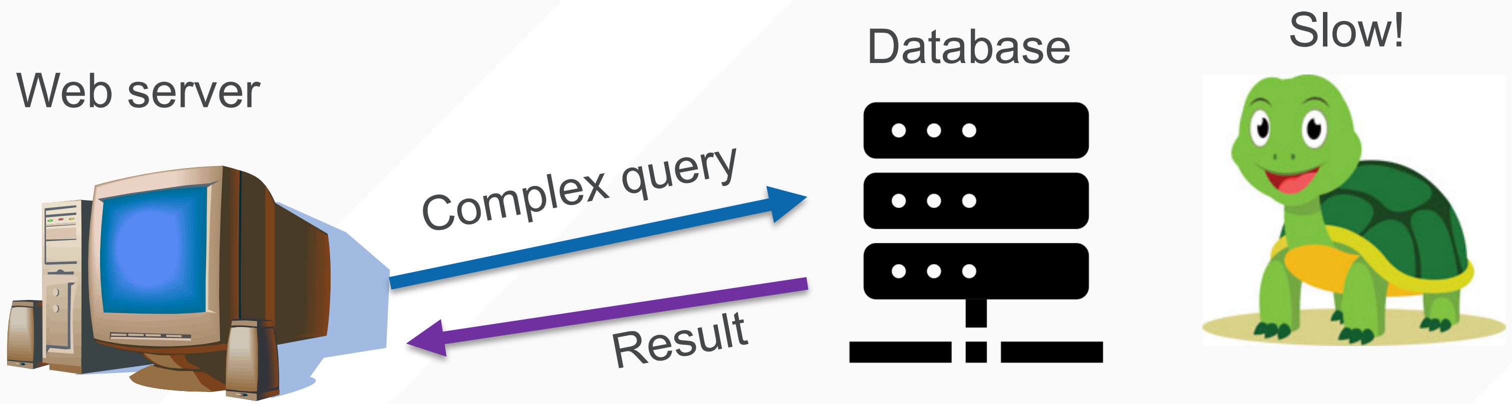
EXPLORING NORMAL RANDOM VARIABLES WITH GOOGLE SHEETS

- You too can generate observations of a normal random variable by adding this to a google sheets (or excel, numbers, etc) document:
  - `=NORMINV(rand(),0,1)`

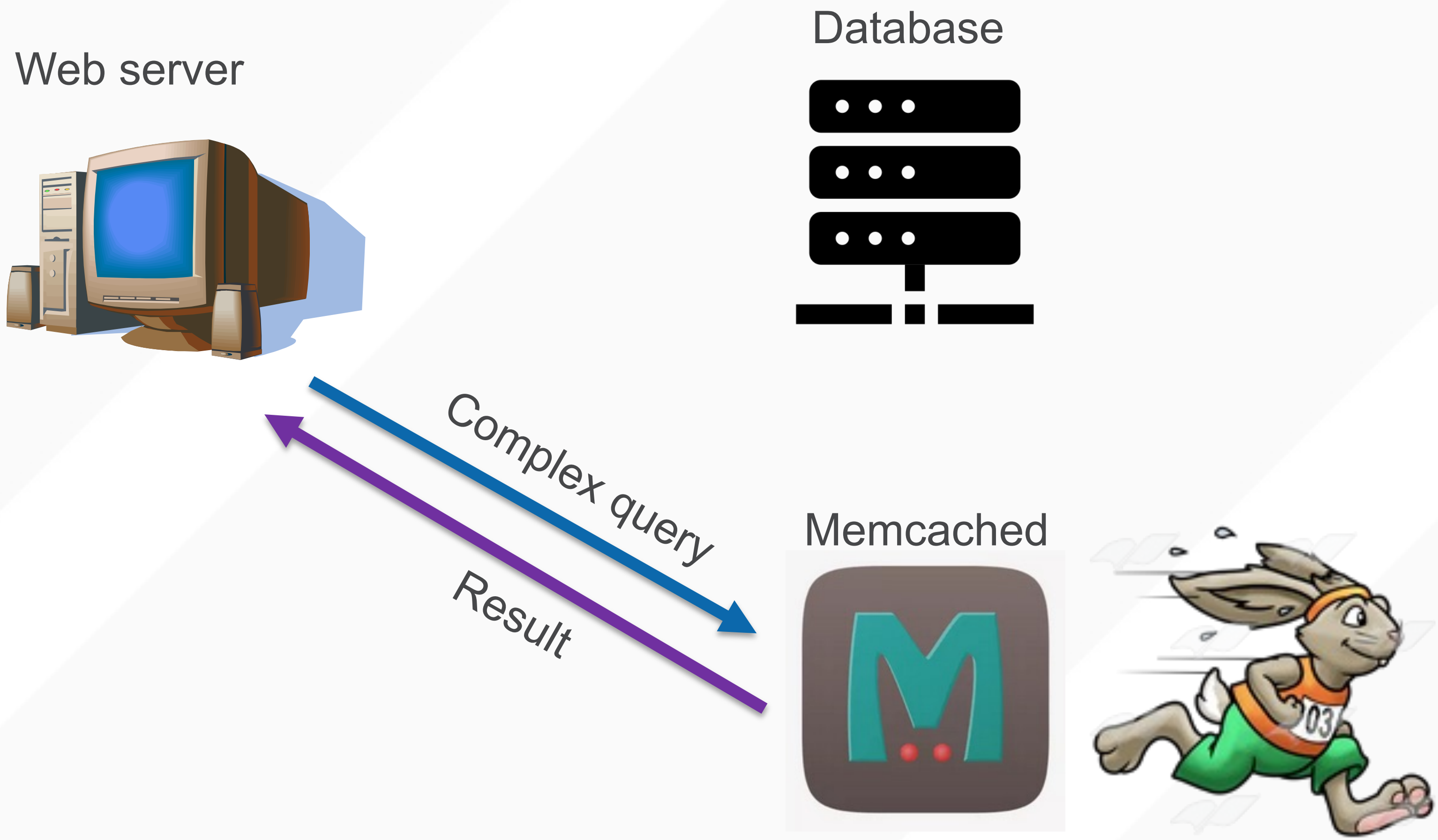
CASE STUDY: MEMCACHED

- Popular in-memory cache
- Simple get() and put() interface
- Useful for caching popular or expensive requests

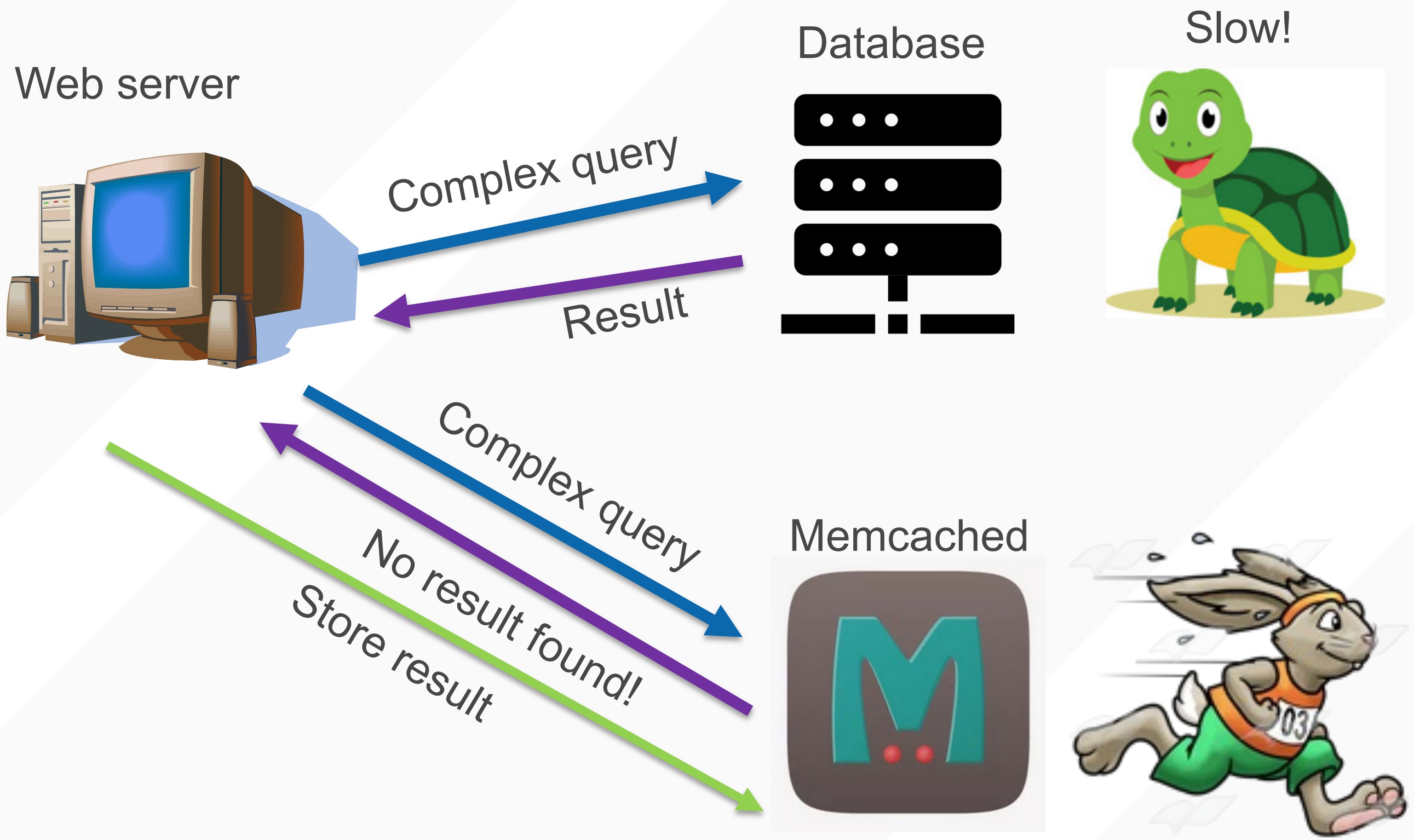
BASELINE: DATABASE-DRIVEN WEB QUERY



MEMCACHED EXAMPLE: CACHE HIT



MEMCACHED EXAMPLE: CACHE MISS



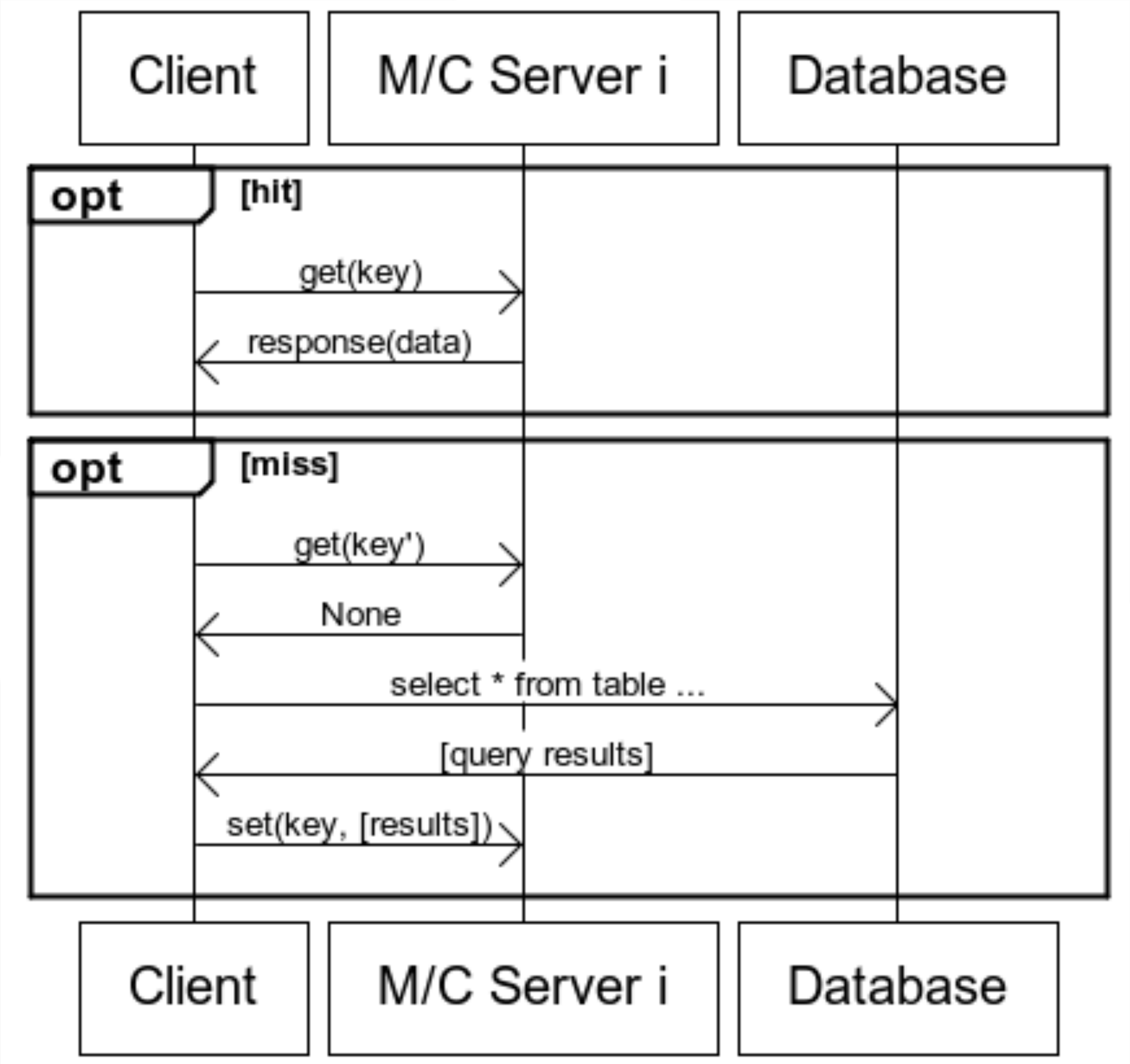
CASE STUDY: MEMCACHED

- Popular in-memory cache
- Simple get() and put() interface
- Useful for caching popular or expensive requests
- LRU replacement policy

```
function get_foo(foo_id)
    foo = memcached_get("foo:" . foo_id)
    return foo if defined foo

    foo = fetch_foo_from_database(foo_id)
    memcached_set("foo:" . foo_id, foo)
    return foo
end
```

MEMCACHED DATA FLOW

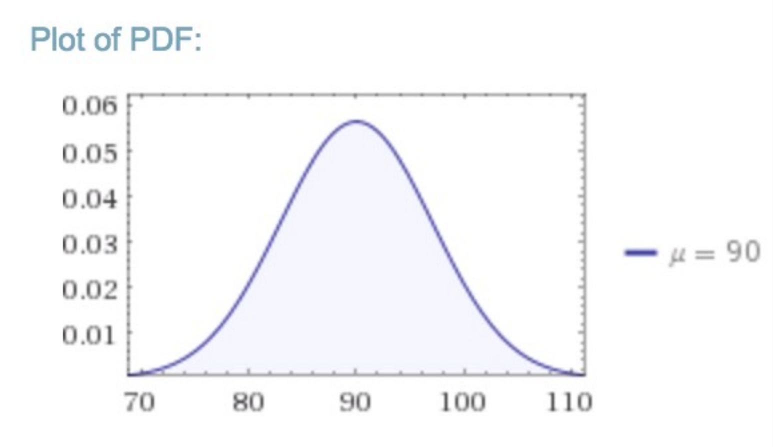


EXPERIMENT: GET/SET WITH MEMCACHED

`[demo code]`

TAIL TOLERANCE: PARTITION/AGGREGATE

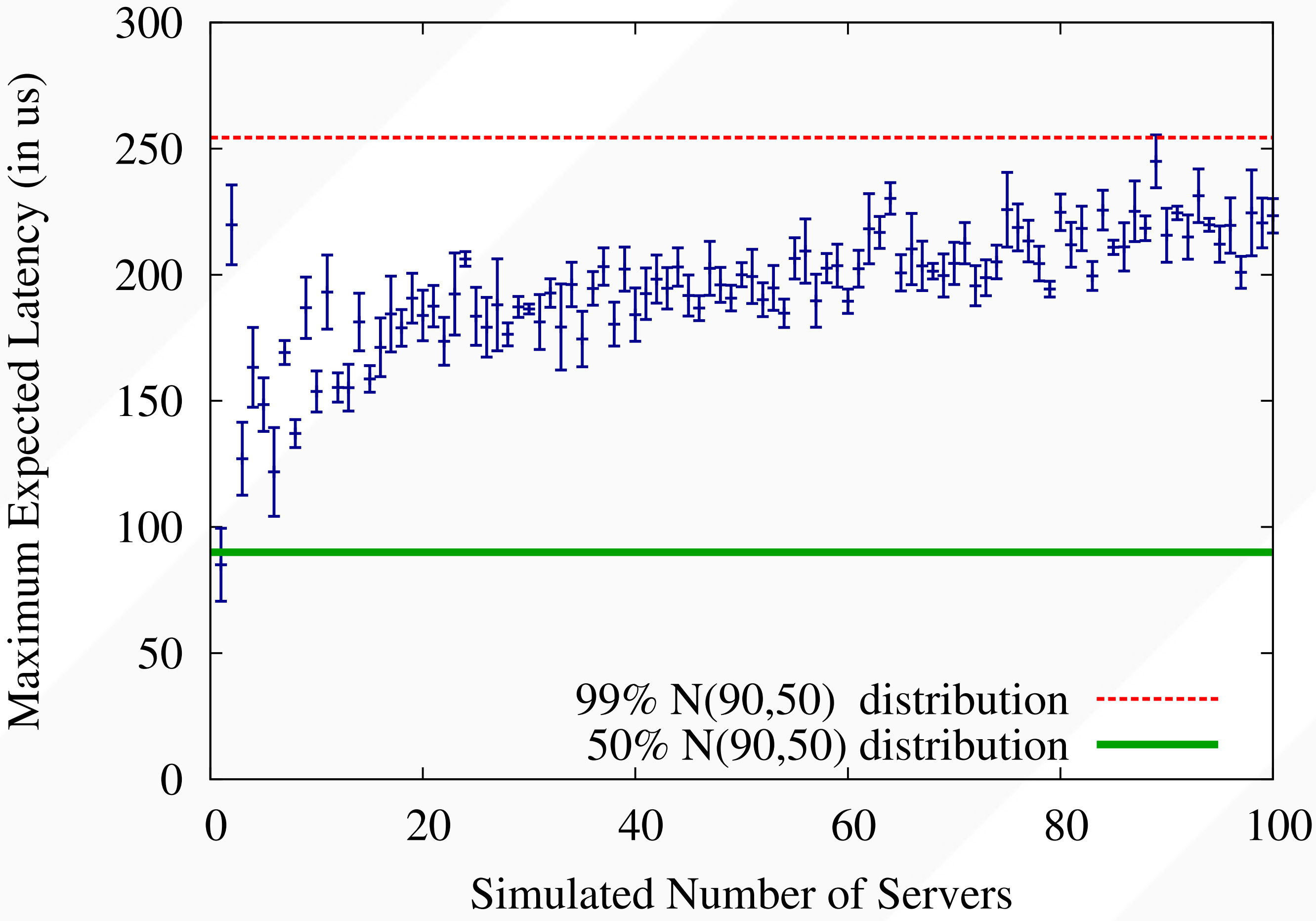
- Consider distributed memcached cluster
  - Single client issues request to S memcached servers
    - Waits until all S are returned
  - Service time of a memcached server is normal w/ μ = 90us, σ = 7us
    - Roughly based on measurements from my former student



EXPLORING NORMAL RANDOM VARIABLES WITH GOOGLE SHEETS

- You too can generate observations of a normal random variable by adding this to a google sheets (or excel, numbers, etc) document:
  - Based on Memcached:
  - `=NORMINV(rand(),90,7)`

MATLAB SIMULATION



WITHIN REQUEST SHORT-TERM ADAPTATIONS

- Tied Requests
  - Hedged requests with cancellation mechanism.

	Mostly idle cluster			With concurrent terasort		
	No hedge	Tied request after 1ms		No hedge	Tied request after 1ms	
50%ile	19ms	16ms	(–16%)	24ms	19ms	(–21%)
90%ile	38ms	29ms	(–24%)	56ms	38ms	(–32%)
99%ile	67ms	42ms	(–37%)	108ms	67ms	(–38%)
99.9%ile	98ms	61ms	(–38%)	159ms	108ms	(–32%)

REDUCING COMPONENT VARIABILITY

- Differentiating Service Classes
  - Differentiate non-interactive requests
- High Level Queuing
  - Keep low level queues short
- Reduce Head-of-line Blocking
  - Break long-running requests into a sequence of smaller requests.
- Synchronize Disruption
  - Do background activities altogether.

LARGE INFORMATION RETRIEVAL SYSTEMS

- Google search engine
  - No certain answers
- “Good Enough”
  - Google’s IR systems are tuned to occasionally respond with good-enough results when an acceptable fraction of the overall corpus has been searched.

LARGE INFORMATION RETRIEVAL SYSTEMS

- Canary Requests
  - Some requests exercising an untested code path may cause crashes or long delays.
  - Send requests to one or two leaf servers for testing.
  - The remaining servers are only queried if the root gets a successful response from the canary in a reasonable period of time.

HARDWARE TRENDS AND THEIR EFFECTS

- Hardware will only be more and more diverse
  - So tolerating variability through software techniques are even more important over time.
- Higher bandwidth reduces per-message overheads.
  - It further reduces the cost of tied requests (making it more likely that cancellation messages are received in time).

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