Measuring and Optimizing Tail Latency

Kathryn S McKinley, Google

CRA-W Undergraduate Town Hall
April 5th, 2018

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Speaker & Moderator

Kathryn S McKinley

Dr. Kathryn S. McKinley is a Senior Research Scientist at Google and previously was a Researcher at Microsoft and an Endowed Professorship at The University of Texas at Austin. Her research spans programming languages, compilers, runtime systems, architecture, performance, and energy. She and her collaborators have produced several widely used tools: the DaCapo Java Benchmarks (30,000+ downloads), the TRIPS Compiler, Hoard memory manager, MMTk memory management toolkit, and the Immix garbage collector.

She served as program chair for ASPLOS, PACT, PLDI, ISMM, and CGO. She is currently a CRA and CRA-W Board member. Dr. McKinley was honored to testify to the House Science Committee (Feb. 14, 2013). She is an IEEE and ACM Fellow. She has graduated 22 PhD students.

Lori Pollock

Dr. Lori Pollock is a Professor in Computer and Information Sciences at University of Delaware. Her current research focuses on program analysis for building better software maintenance tools, software testing, energy-efficient software and computer science education. Dr. Pollock is an ACM Distinguished Scientist and was awarded the University of Delaware's Excellence in Teaching Award and the E.A. Trabant Award for Women's Equity.

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Measuring and Optimizing Tail Latency

Kathryn S McKinley, Google

Xi Yang, Stephen M Blackburn,
Md Haque, Sameh Elnikety, Yuxiong He, Ricardo Bianchini

Google Cloud

Tail Latency Matters

TOP PRIORITY

Google Australia

Bing

400 millisecond delay decreased searches/user by 0.59%. [Jack Brutlag, Google]

Two second slowdown reduced revenue/user by 4.3%. [Eric Schurman, Bing]

Photo: Google/Connie Zhou

Datacenter economics quick facts*

~ $500,000	Cost of small datacenter
~3,000,000	US datacenters in 2016
~ $1.5 trillion	US Capital investment to date
~ $3,000,000,000	KW dollars / year
~ $30,000,000	Savings from 1% less work
Lots more	by not building a datacenter

*Shehabi et al., United States Data Center Energy Usage Report, Lawrence Berkeley, 2016.

Tail Latency

TOP PRIORITY

Efficiency

Google Cloud

Tail Latency

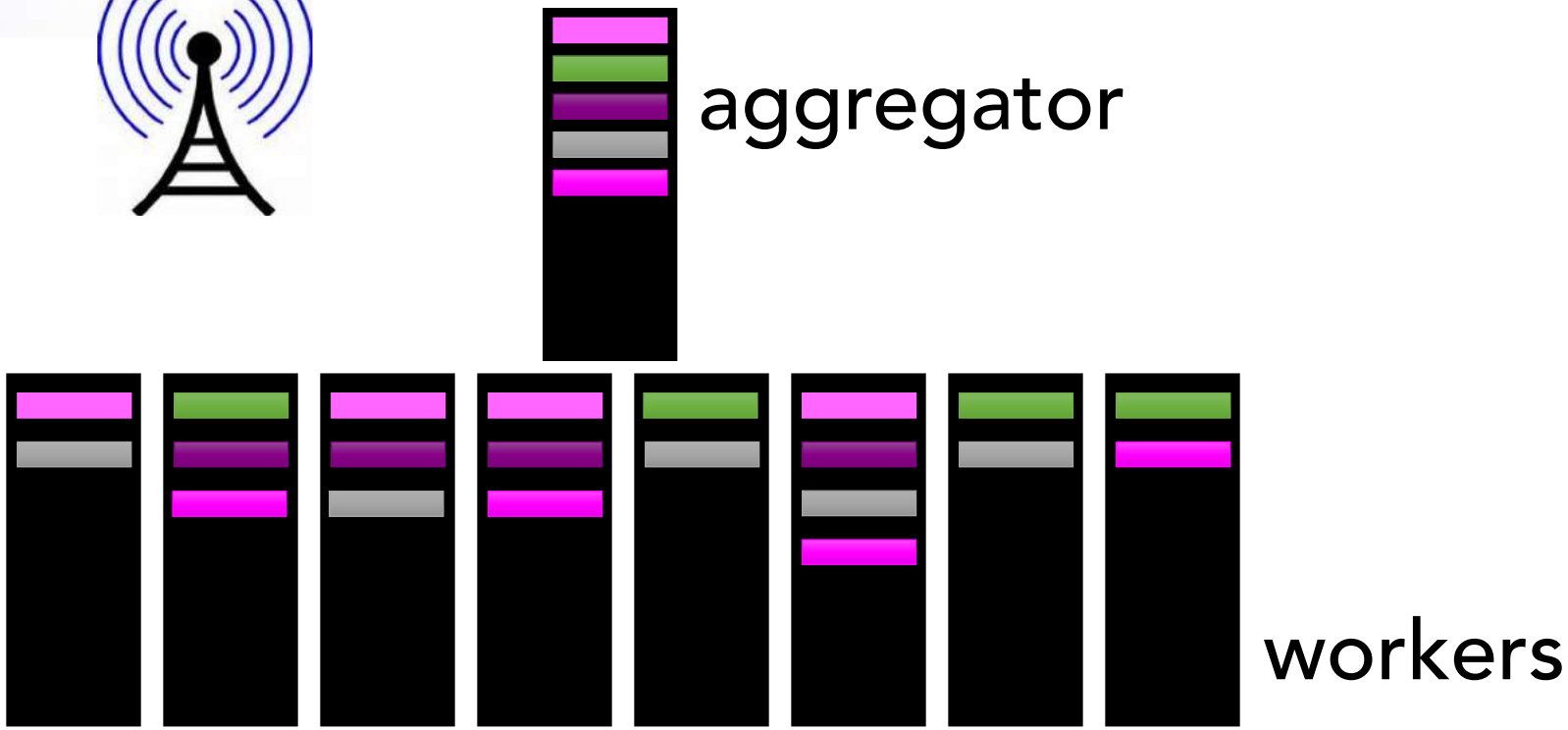
BOTH ?!

Efficiency

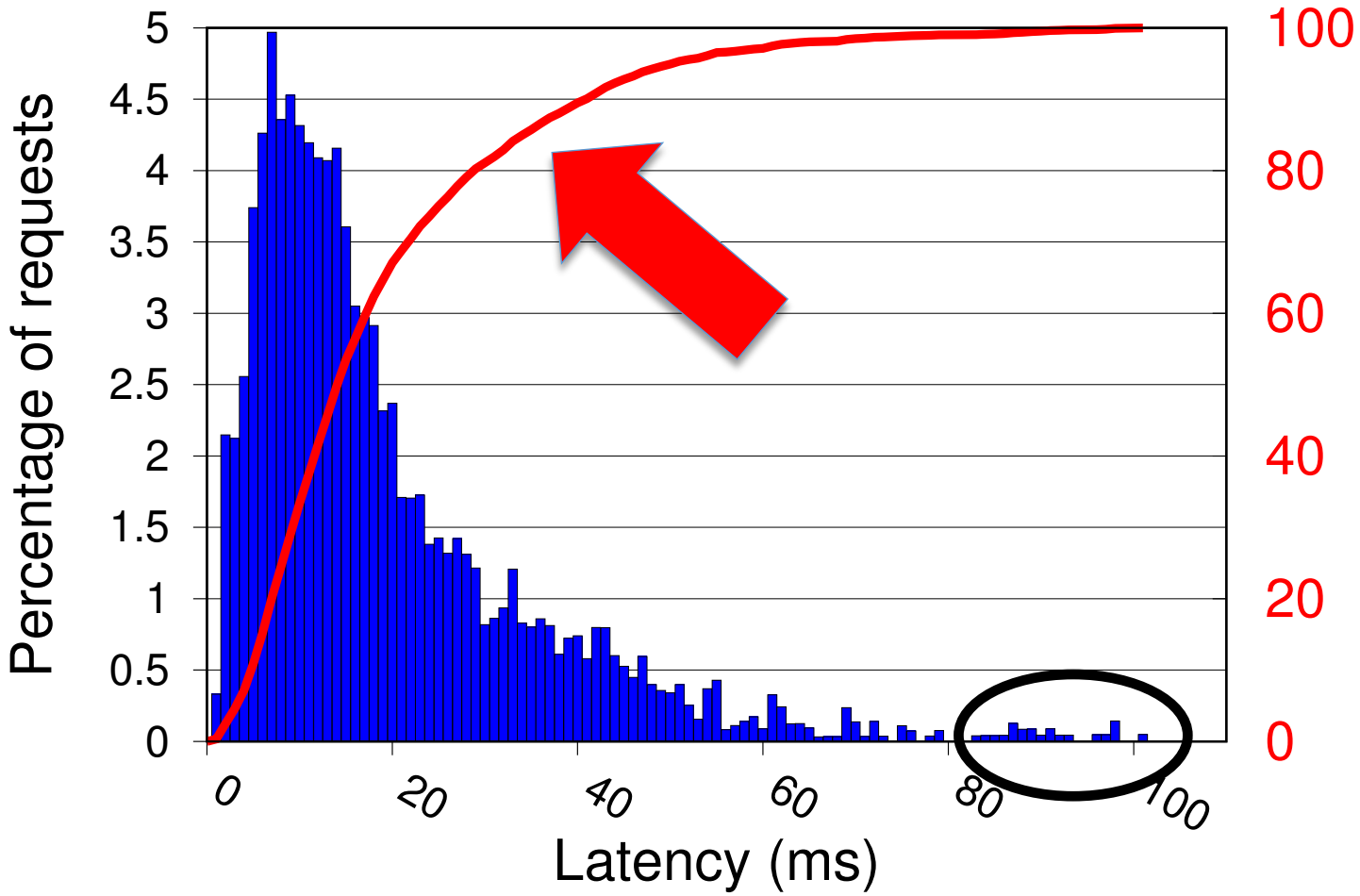
Google Cloud

Server architecture

client



Characteristics of interactive services



LC

Bursty, diurnal

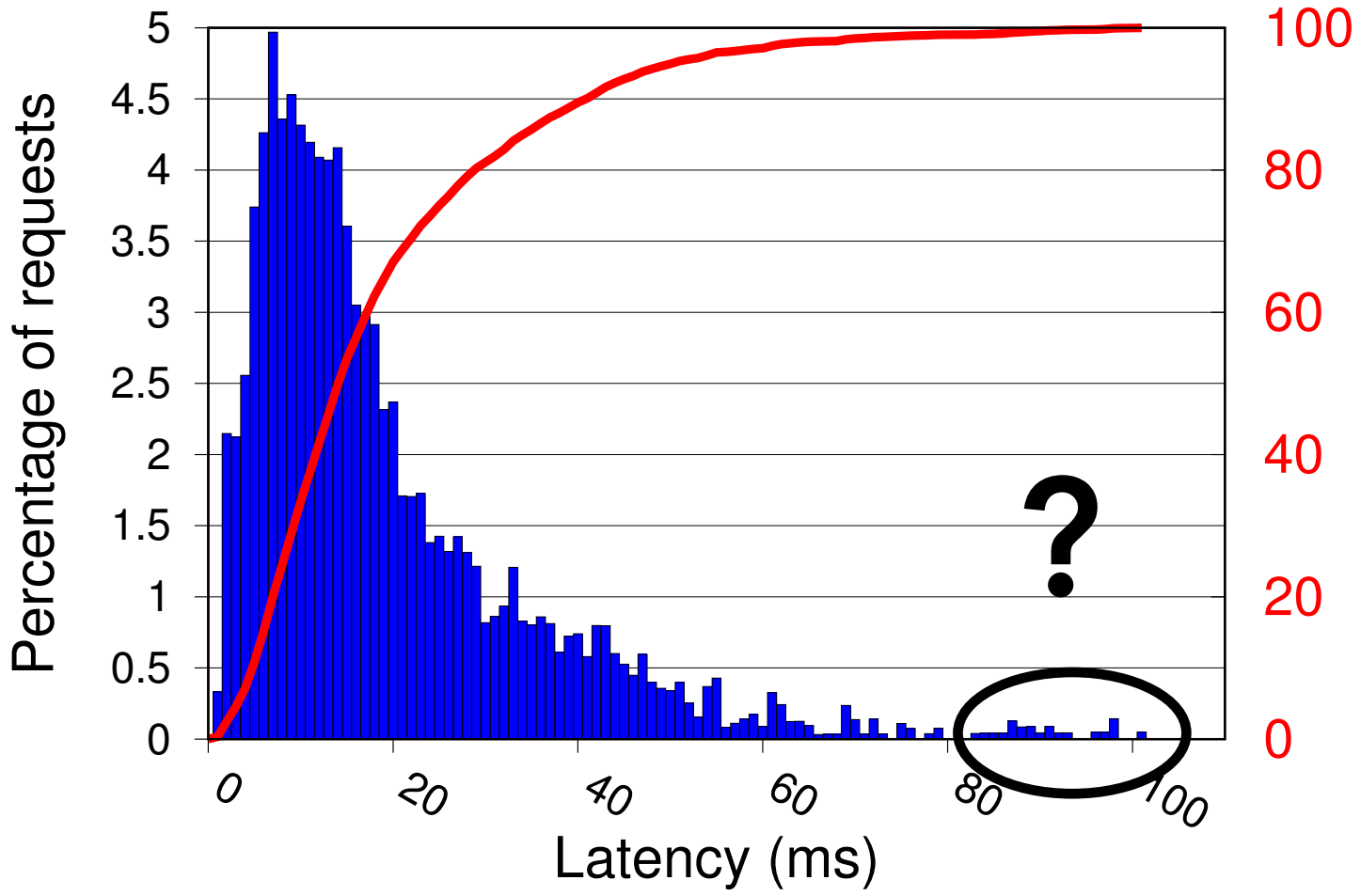
CDF changes slowly

Slowest server dictates tail

Orders of magnitude diff

average & tail - 99th %tile

What is in the tail?

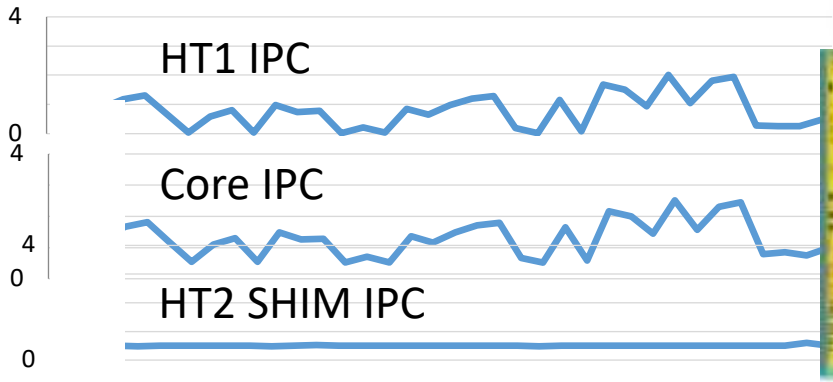


Cycle-level on-line profiling tool

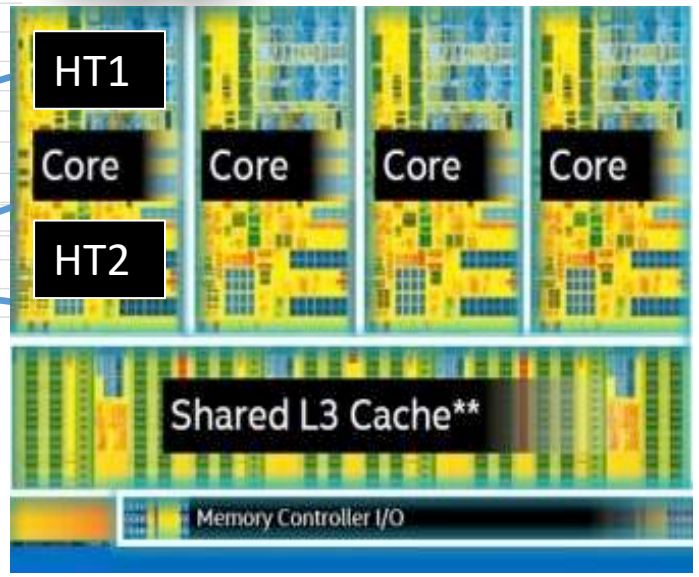
[ISCA'15 (Top Picks HM), ATC'16]

Insight Hardware & software generate signals without instrumentation

	counters	tags
performance counters	✓	✓
memory locations	✓	✓



HT1 IPC = Core IPC – HT2 SHIM IPC



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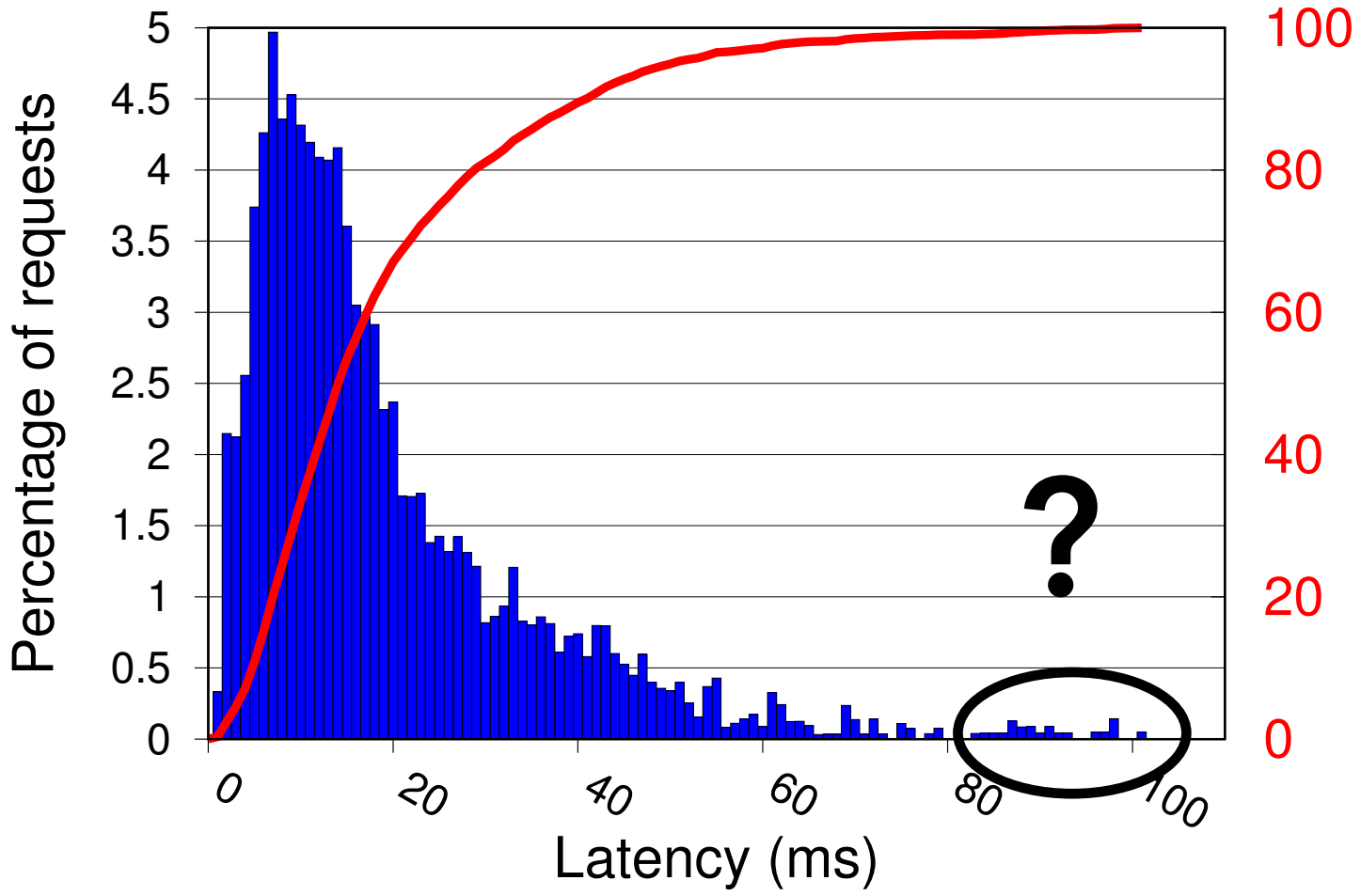
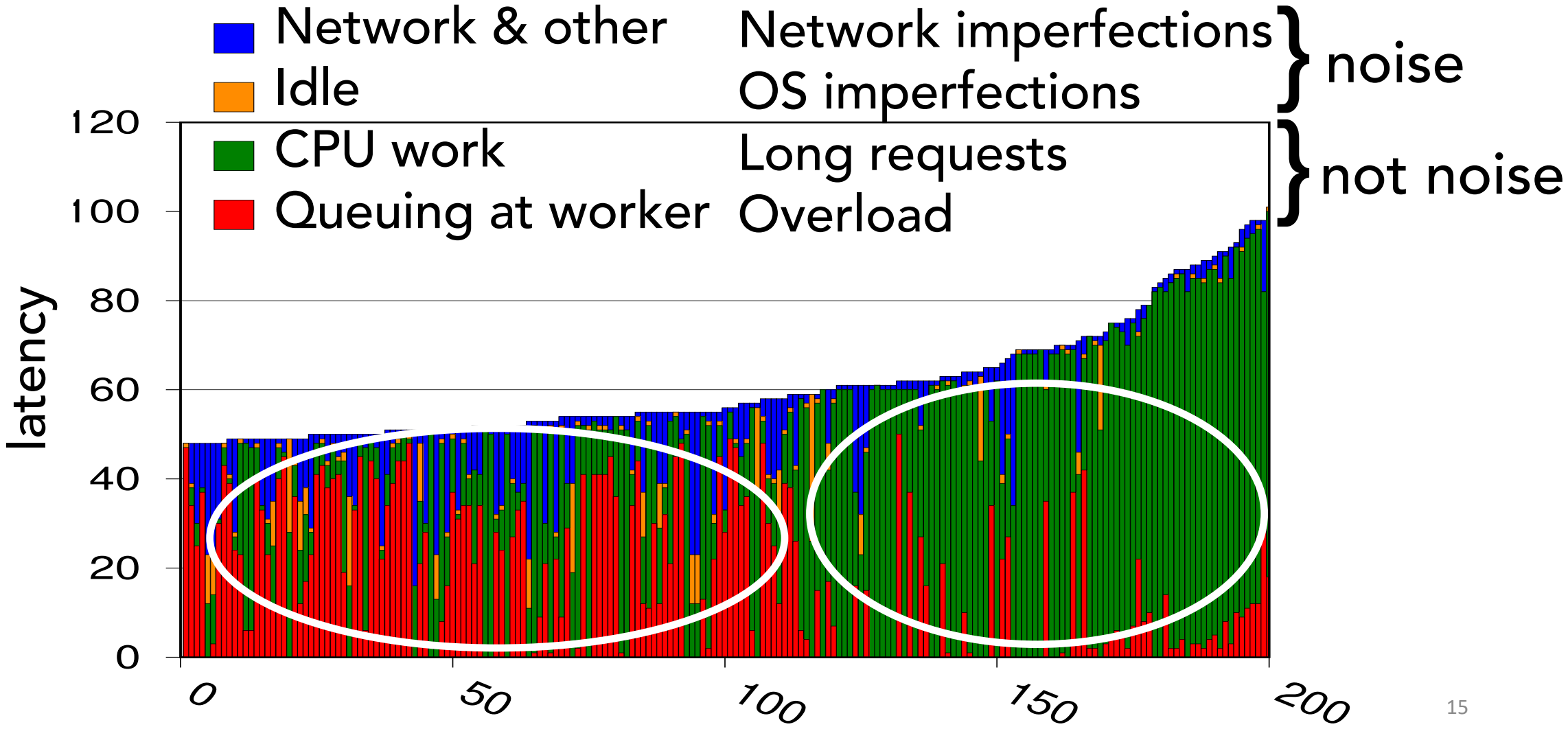


The Tail Longest 200 requests



Optimizing the tail

Diagnosing the tail with continuous profiling

Noise systems are not perfect

Queuing too much load is bad, but so is over provisioning

Work many requests are long

Insights Use the CDF off line

Long requests reveal themselves, treat them specially

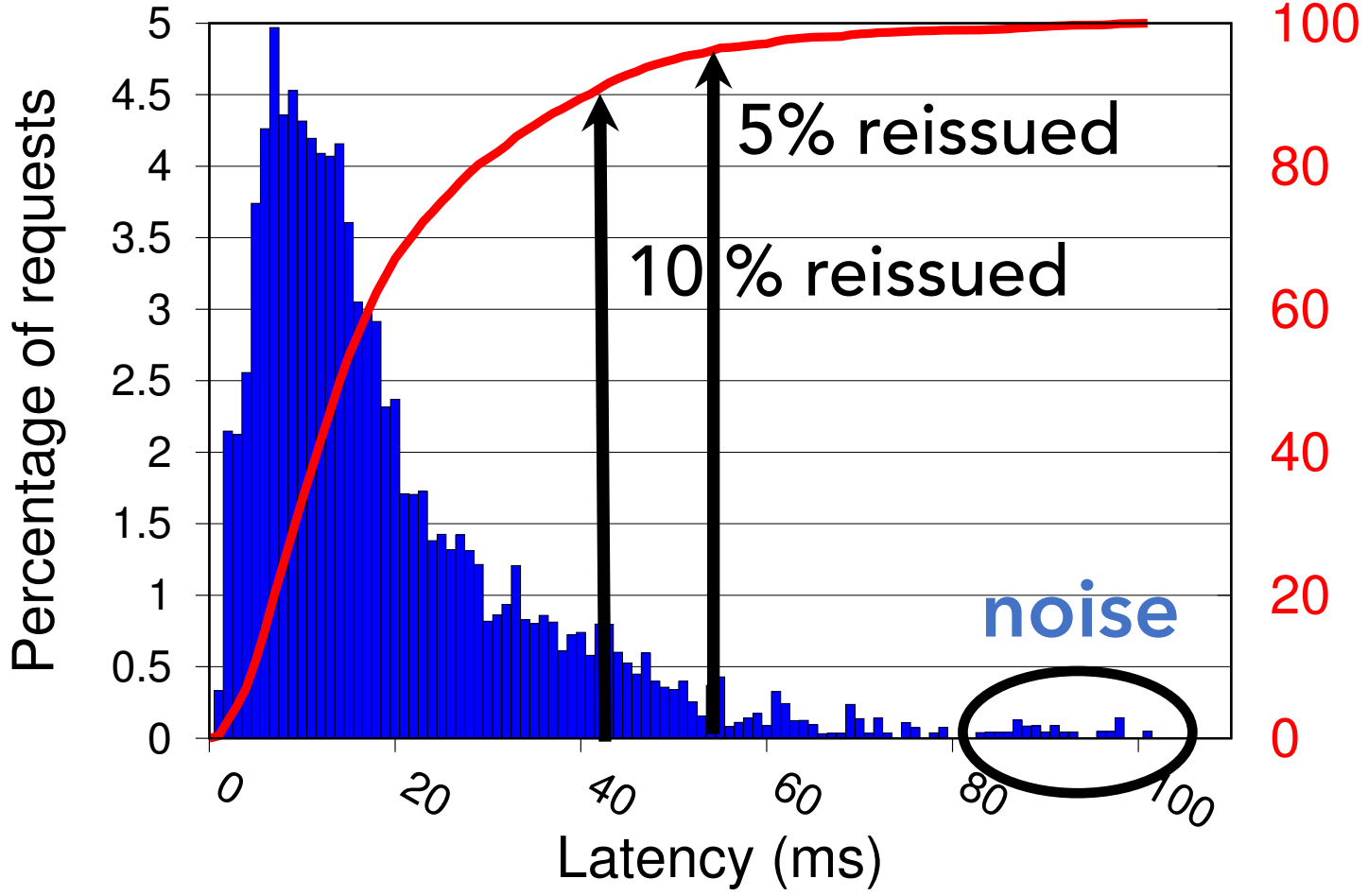
Insight

Long requests reveal themselves

Regardless of the cause

Noise Replicate & reissue

The Tail at Scale, Dean & Barroso, CACM'13



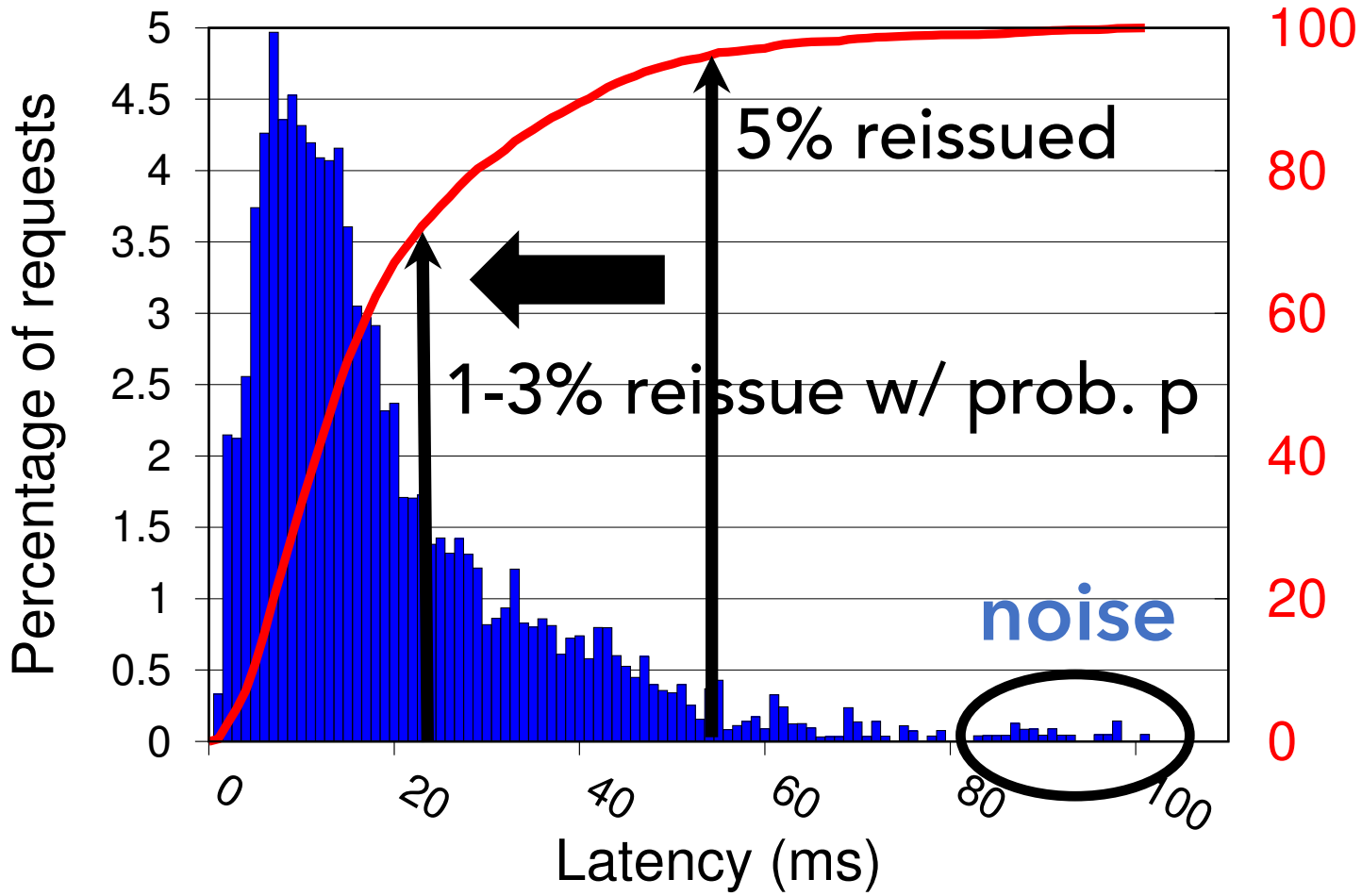
All requests?

CFD for cost & potential

Fixed issue time

Probabilistic reissue

Optimal Reissue Policies for Reducing Tail Latencies, Kaler, He, & Elnickety , SPAA'17

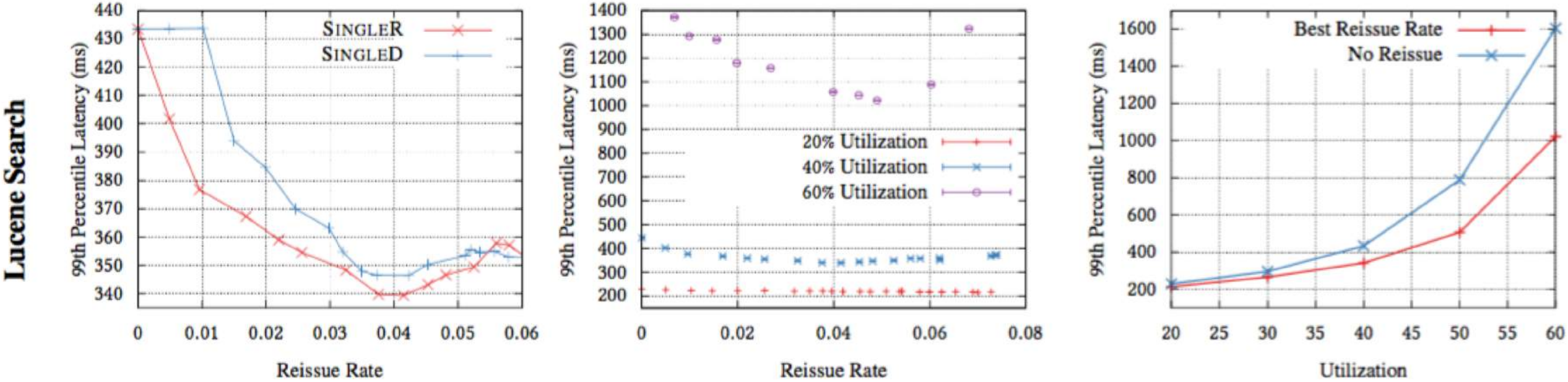


Adding randomness to reissue makes *one* earlier reissue time d (vs n) optimal

Probability is proportional to reissue budget & noise in tail

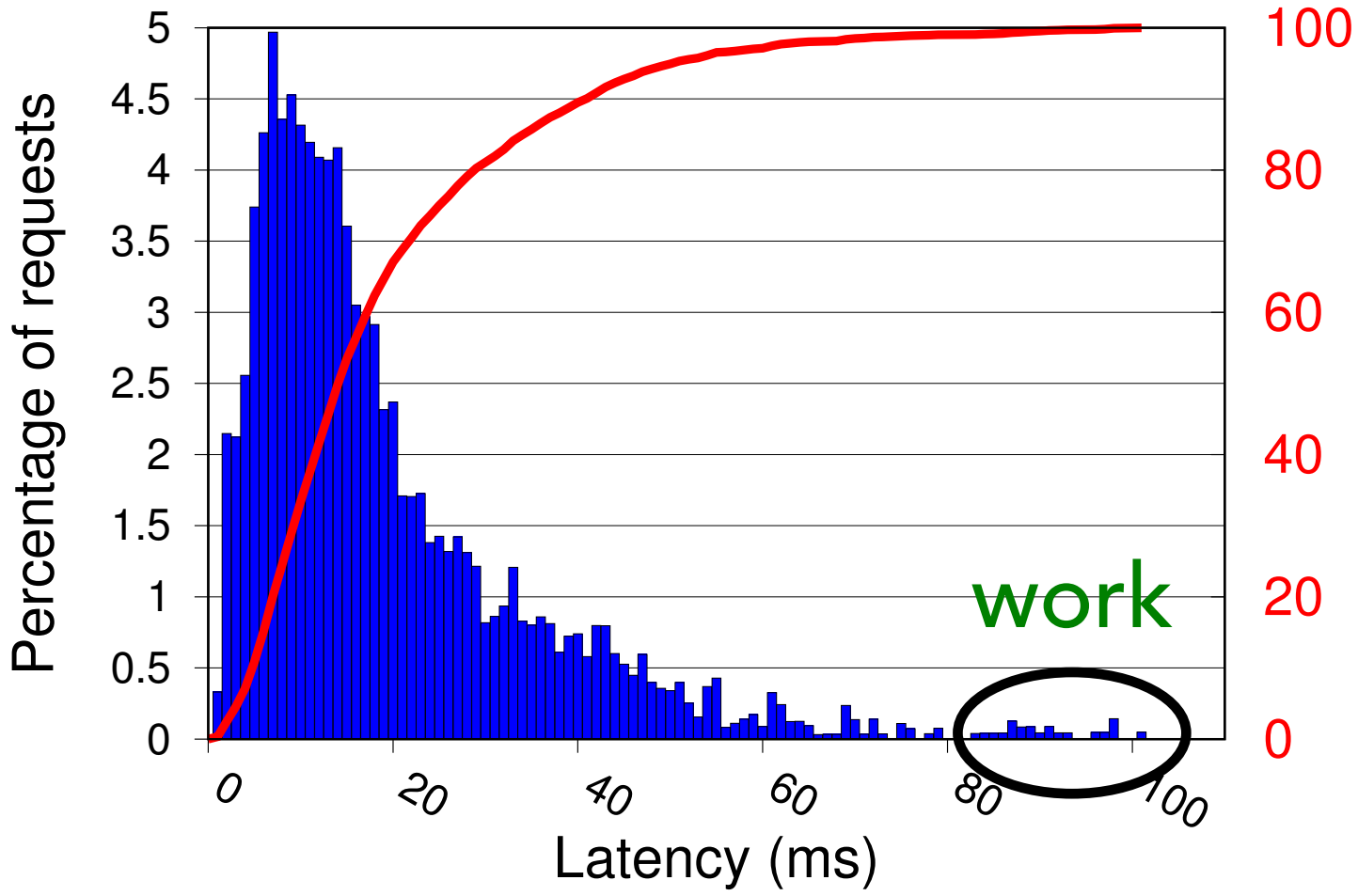
Single R Probabilistic reissue

Optimal Reissue Policies for Reducing Tail Latencies, Kaler, He, & Elnickety , SPAA'17



(a) SINGLER vs SINGLED (b) Latency vs Reissue Rate (c) Best Latency vs Utilization

Work Speed up the tail *efficiently*

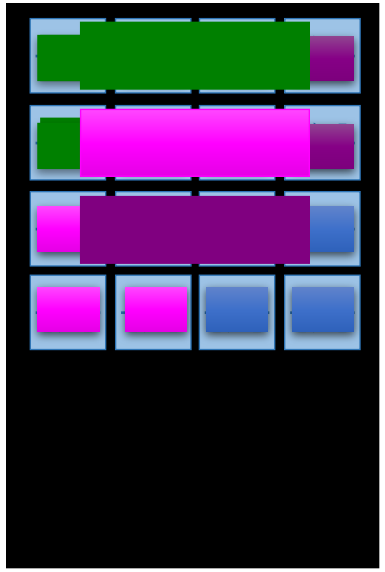


Judicious parallelism
[ASPLOS'15]

DVFS faster on the tail
[DISC'14, MICRO'17]

Asymmetric multicore
[DISC'14, MICRO'17]

Work Parallelism



Parallelism historically for **throughput**

Idea Parallelism for **tail latency**

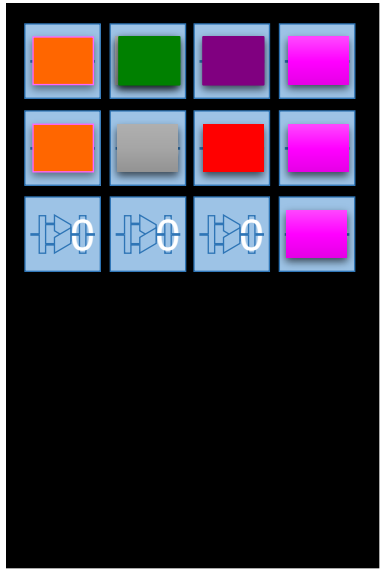
Queuing theory

Optimizing average latency maximizes throughput

But not the tail!

Shortening the tail reduces queuing latency

Parallelism



Parallelism historically for **throughput**

Idea Parallelism for **tail latency**

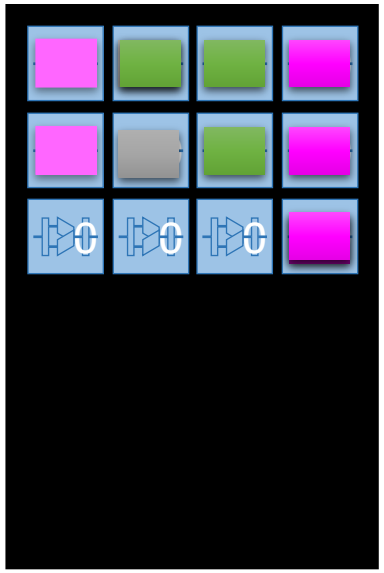
Insight Long requests reveal themselves

Approach Incrementally add parallelism to long requests – the tail – based on request progress & load

Few to Many

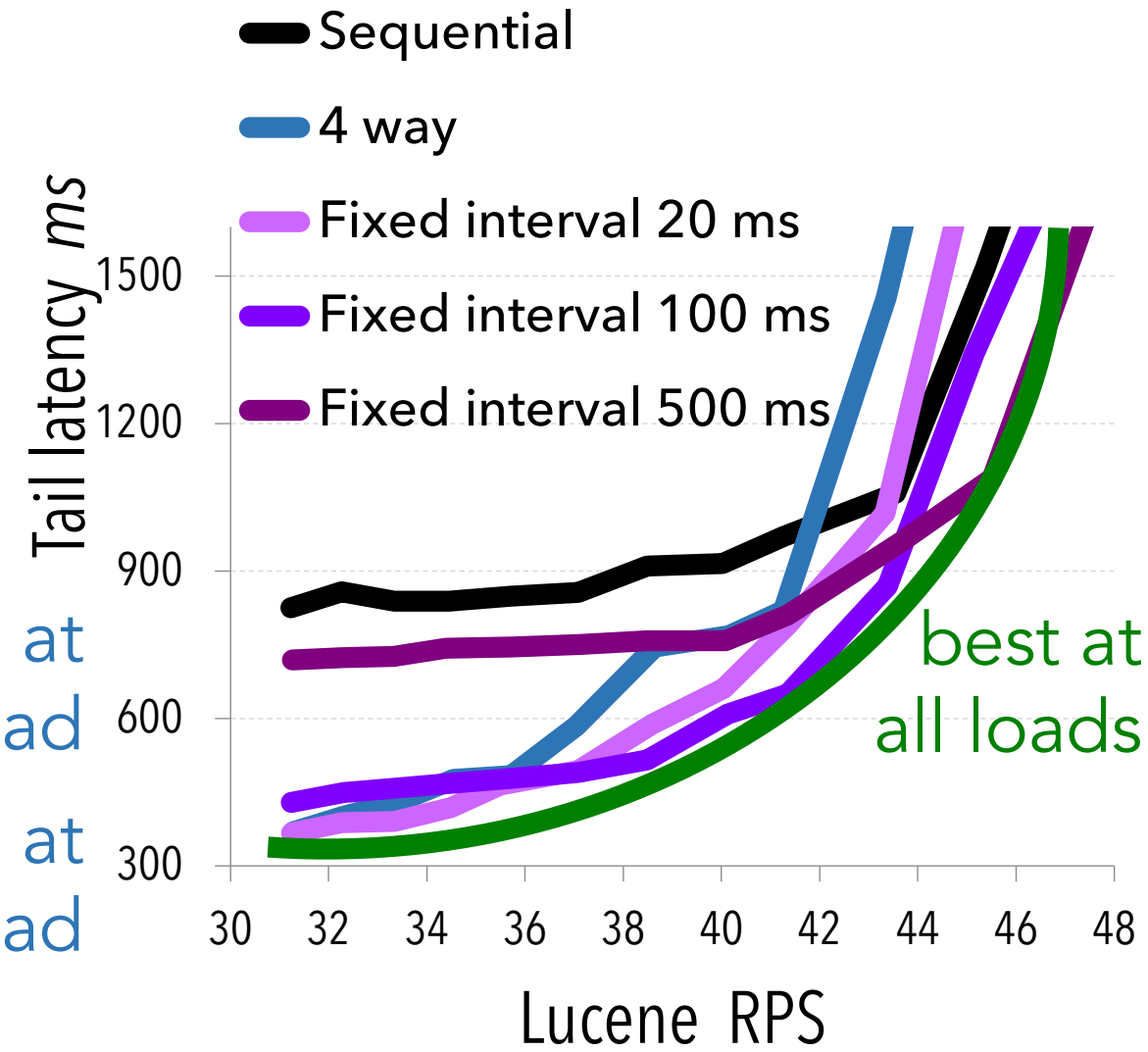
Fixed: add thread every d *ms*

Dynamic: use load



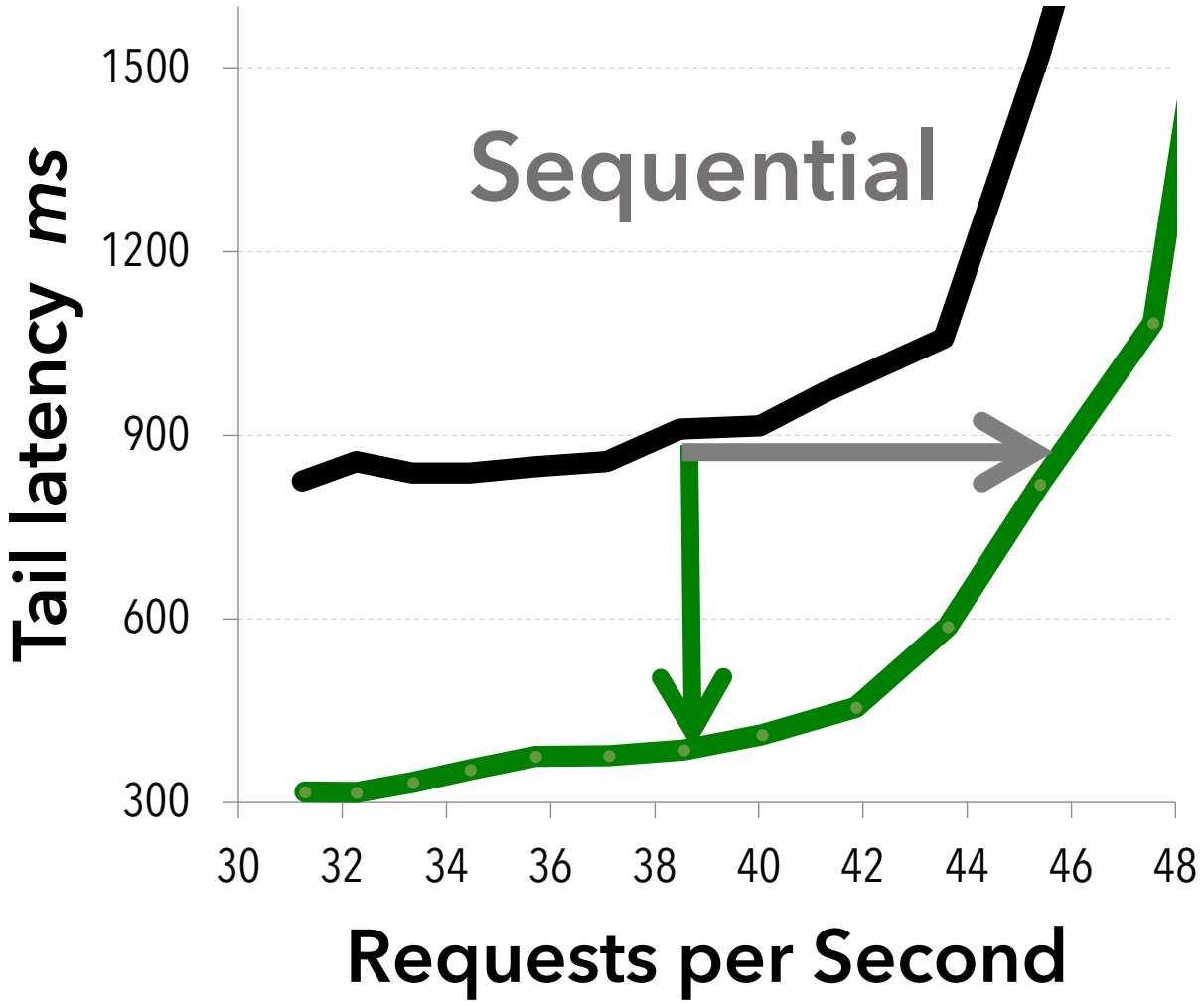
short delay good at low load

long delay good at high load



best at all loads

Evaluation 2x8 64 bit 2.3 GHz Xeon, 64 GB

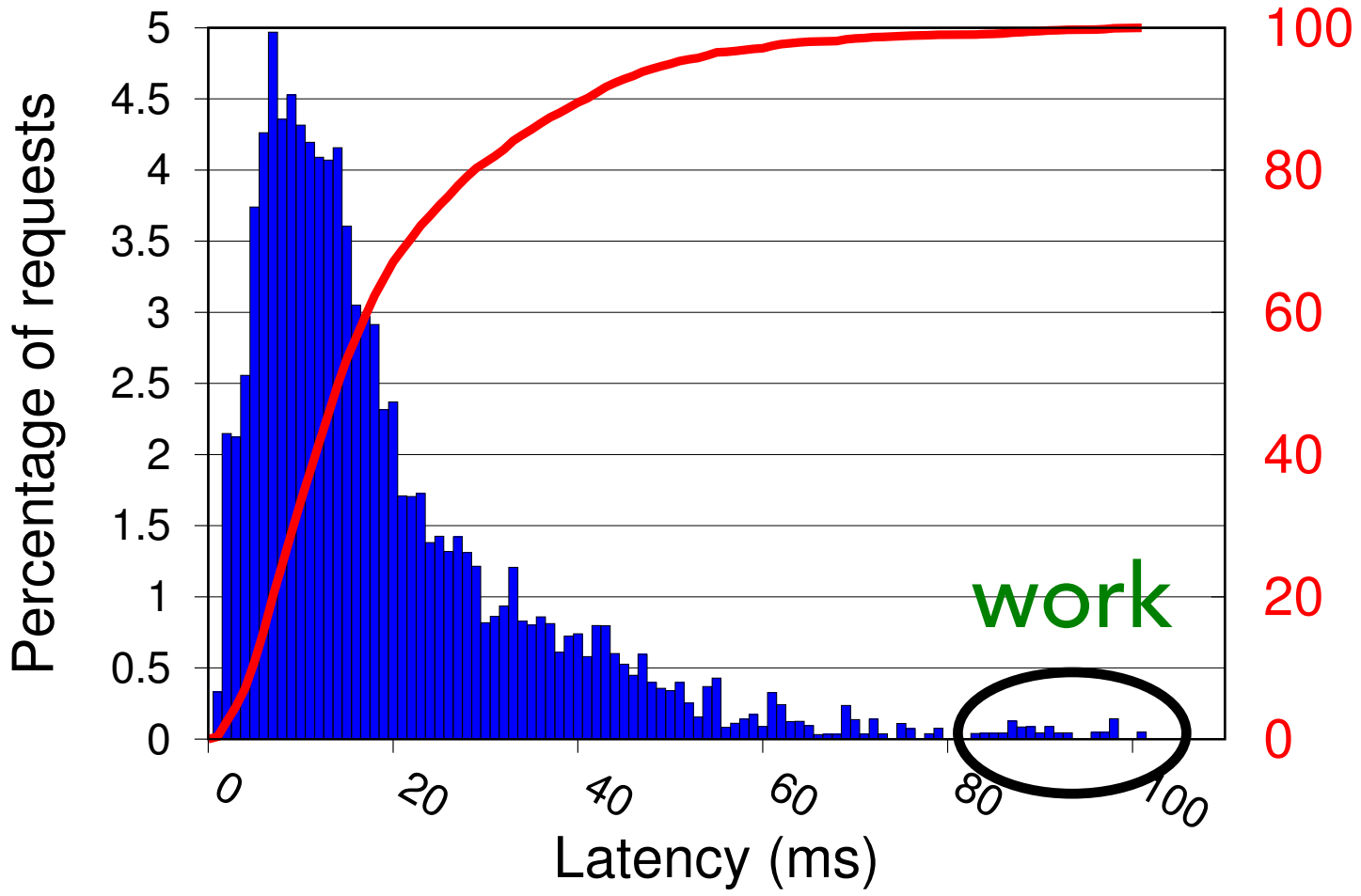


Dynamic parallelism
Few to Many

21% fewer servers

or reduce tail by 28%

Work speed up the tail *efficiently*



Judicious parallelism
[ASPLOS'15] ✔

Tail Latency

BOTH !

Efficiency

Google Cloud

Efficiency at scale for interactive workloads

Diagnosing the tail with continuous profiling

Noise	replication, systems are not perfect
Queuing	replication + judicious choice
Work	judicious use of resources on long requests

Request latency CDF is a powerful tool

Tail efficiency ≠ average or throughput

Hardware heterogeneity

Questions?

Professional and Research Relationships

Your Academic Village

- Peer students
- Students senior & junior to you
- Teaching assistants
- PhD students
- Faculty

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My Professional Village

- Researchers in all career stages
  - Undergrads, PhD students, post docs
  - Faculty, industrial researchers, staff, administrators
- Industrial village
  - Software engineers in all career stages
  - Managers, directors, admins,
  - in/out my management chain

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Faculty Mentors

Don Johnson

My Professor

Ken Kennedy

PhD Advisor

Dave Stemple

Dept. Chair

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Building a Village

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Networking is….

Building and sustaining professional relationships

- Participating in an academic / research community
- Finding people you like and you learn from, and building a relationship

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Networking is *not*….

- Using people
- A substitute for quality work

But I am Horrible at Small Talk

- You have CS in common
- Networking is not genetic
- It is a research skill
  - **Practice**
  - **Meet people**
  - **Learn**
  - **Go places**
  - **Volunteer!**
  - **Sustain your relationships**

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With whom do you network?

- People you like
- People senior to you, who can show you the way
- People at different career stages, so you can anticipate
- Your peers

Peer Mentors

Mary Hall

Doug Burger

Margaret Martonosi

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Your Village Will

- Write letters for grad school, jobs, etc.
- Help you solve problems
- Point you in good directions
- Encourage you
- Choose you for important roles
- You will do the same or more for them
- Make your life and work more fun and meaningful