User-level Threading: Have Your Cake and Eat It Too

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Motivation

- application programming paradigms
  - network service handling concurrent sessions

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$\Rightarrow$ *performance?*

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⇒ user-level threads!

- key aspect: scheduling
- requirement: user-level I/O blocking

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- *Fred Runtime* rules!

Table of Contents

Problem Statement

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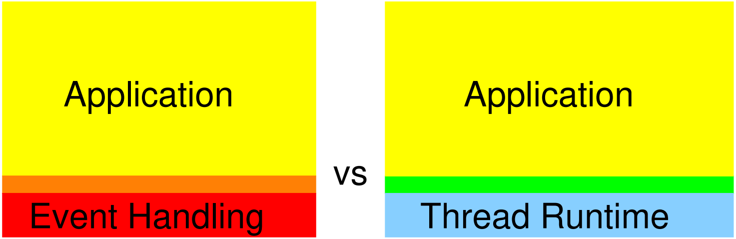
- roadmap
  - build minimum viable user-level threading runtime
  - compare to state of the art threading runtimes
  - evaluate production-grade application

Approach



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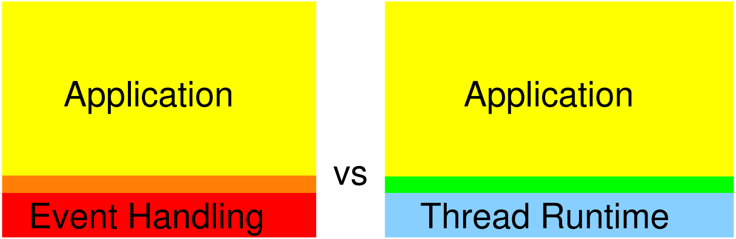
Approach



- Memcached - in-memory key/value store
  - minimum port to thread-per-session
  - fully preserved state machine
  - no structural benefits

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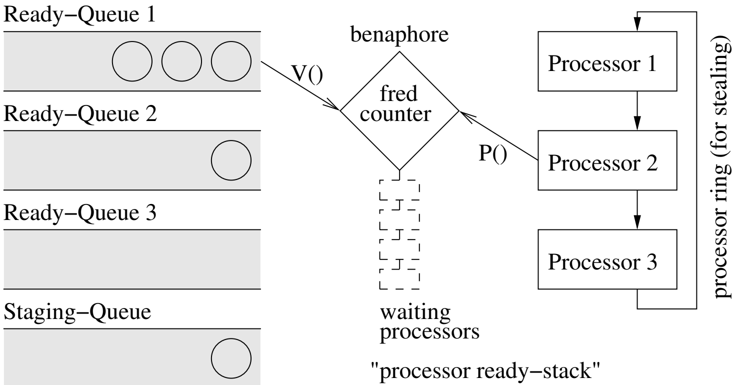
Table of Contents

Scheduler

- performance: simple and lightweight
- scalability: local queueing
- effectiveness: load sharing
- efficiency: idle-sleep

Inverse Shared Ready Stack



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I/O Blocking

- automatically suspend thread during I/O wait
- essential for synchronous control flow
- suspend/resume user-level thread
  - user-level synchronization primitives
  - OS-level notifications

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I/O Notifications

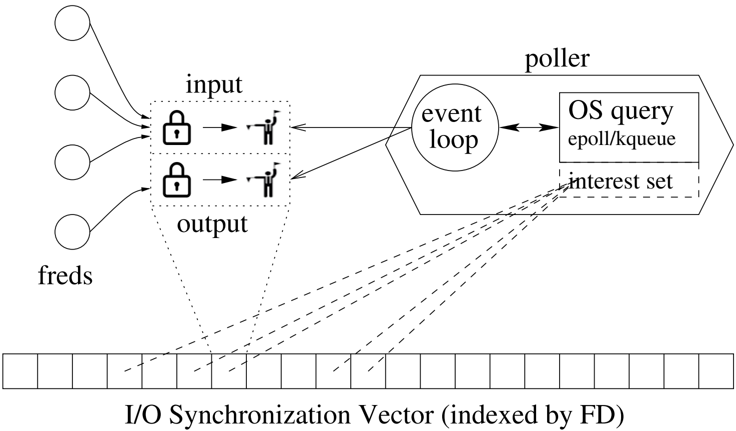

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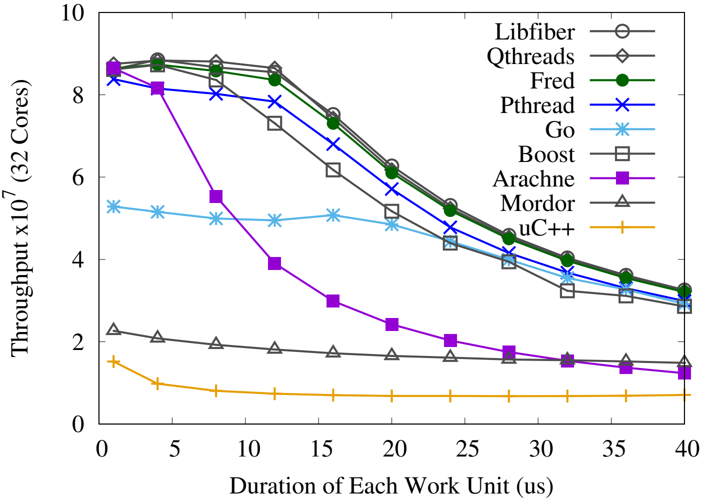
Table of Contents

Threading Benchmarks

- comparison of 9 different threading runtimes
- performance & scalability problems
  - Arachne, Mordor, μC++
- efficiency problems
  - Arachne, Boost, Qthreads
  - busy-looping scheduler
- solid results
  - Fred, Libfiber, Pthreads
  - Go: higher constant scheduling overhead

Performance



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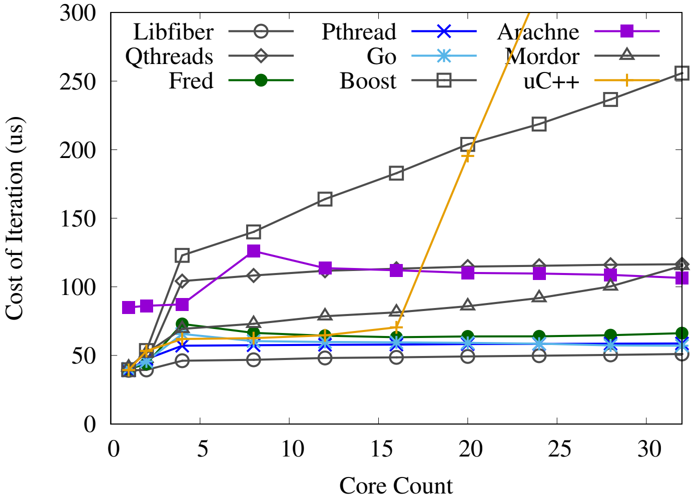
Efficiency

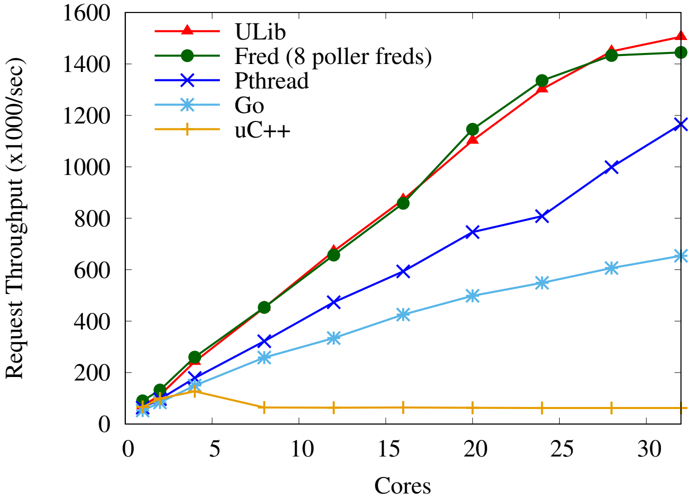


Libfiber
Qthreads
Fred
Pthread
Go
Boost
Arachne
Mordor
uC++
Cost of Iteration (us)
Core Count
300
250
200
150
100
50
0
0
5
10
15
20
25
30

I/O Benchmarks

- I/O stress test for Fred, Go, Libfiber, Pthread
- compared to best-in-class event-based server
  - Libfiber breaks
  - Go and Pthread limited
  - only Fred competitive

I/O Scalability



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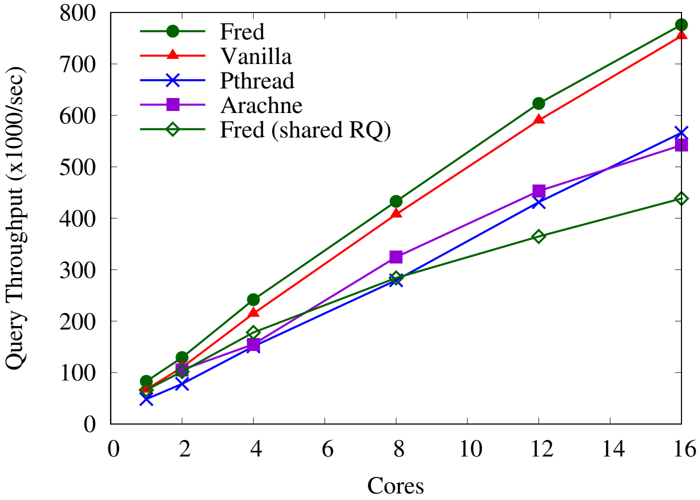
Application Benchmarks

Application Benchmarks

- only Fred competitive with original Memcached
- tail latency results from Arachne paper
  - only apply to special case: #RX queues $<$ #cores
  - performance of Pthread for low connection count!

Throughput



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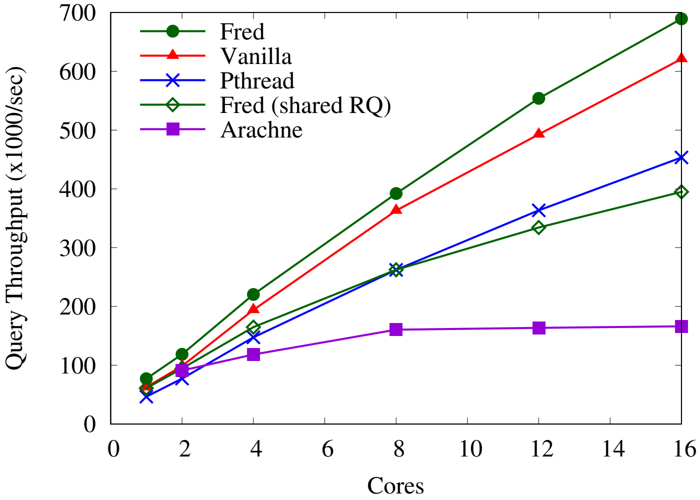
Throughput - more connections



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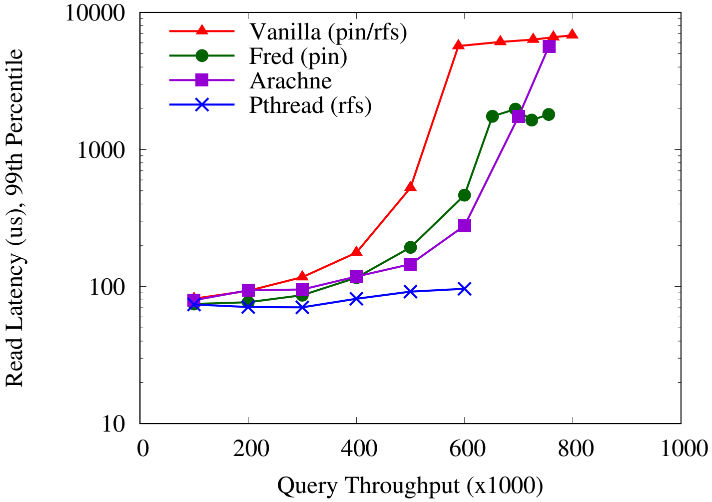
Tail Latency: Arachne Results

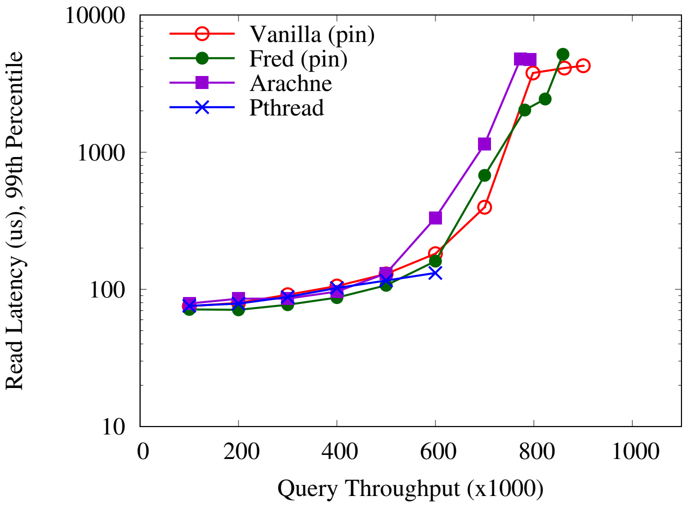


Tail Latency: Explanation

- original experiment: 8 RX queues for 12 cores
- head-of-line blocking?

- modified setup: 16 RX queues for 12 cores
- tail latency discrepancies largely gone...

Tail Latency: Regular



Tail Latency: Higher Connection Count

- 1,536 → 7,680 connections

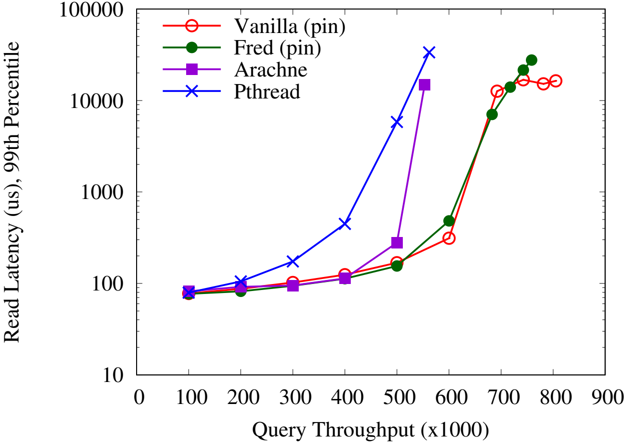


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Table of Contents

Wrap Up

- Fred: nimble user-level threading runtime
- comprehensive performance evaluation
- user-level threading possible at low overhead
- scenarios with improved performance?
- Fred currently the best reference platform