SCYLLA

ScyllaDB: Achieving No-Compromise Performance

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Agenda

Background

Goals

Methods

Conclusion

Non-Agenda

- Docker
- Microservices
- Node.js
- Docker
- Orchestration
- JVM GC Tuning
- JSON over HTTP
- Docker

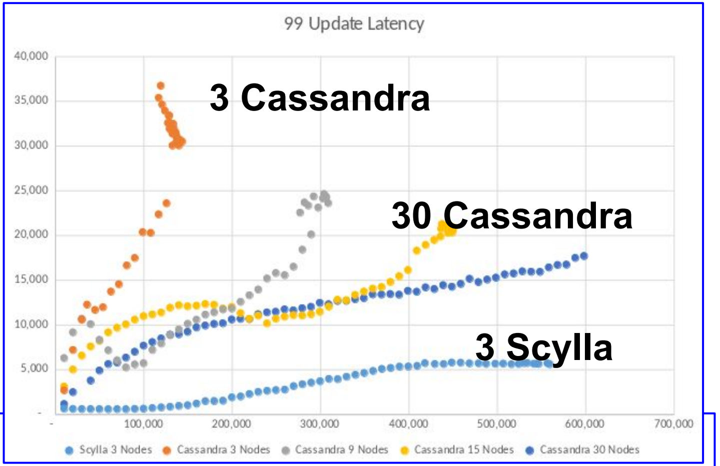
More Non-Agenda

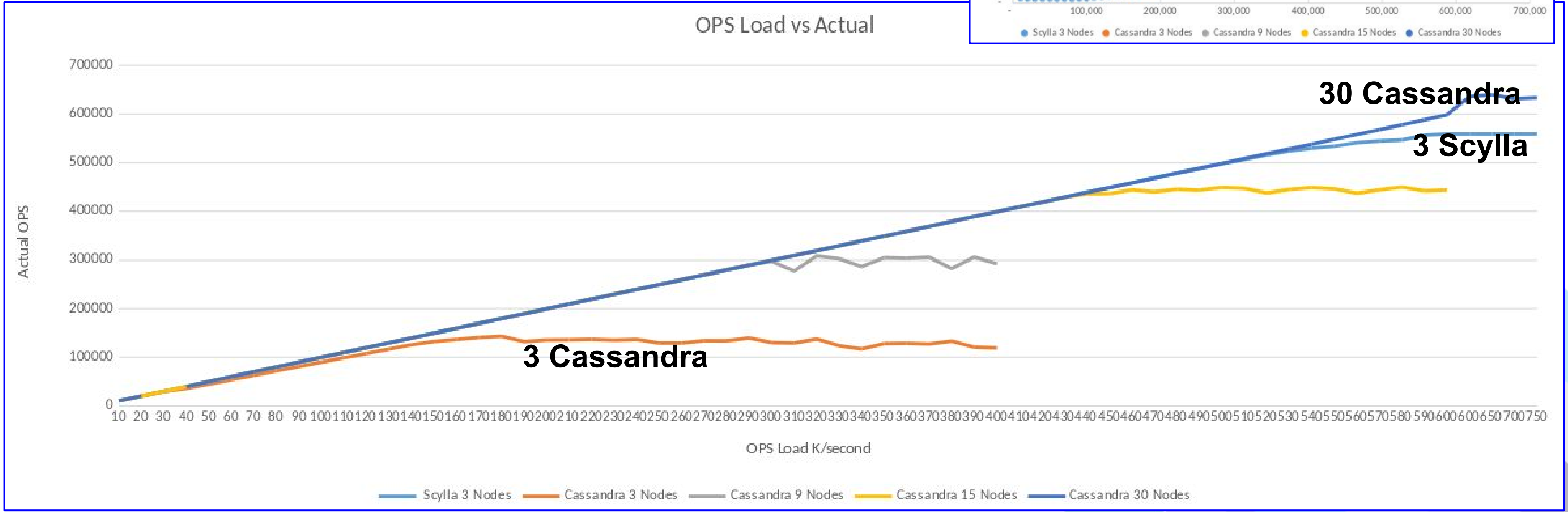
- Cache lines, coherency protocols
- NUMA
- Algorithms are the only thing that matters, everything else is implementation detail
- Docker

Background - ScyllaDB

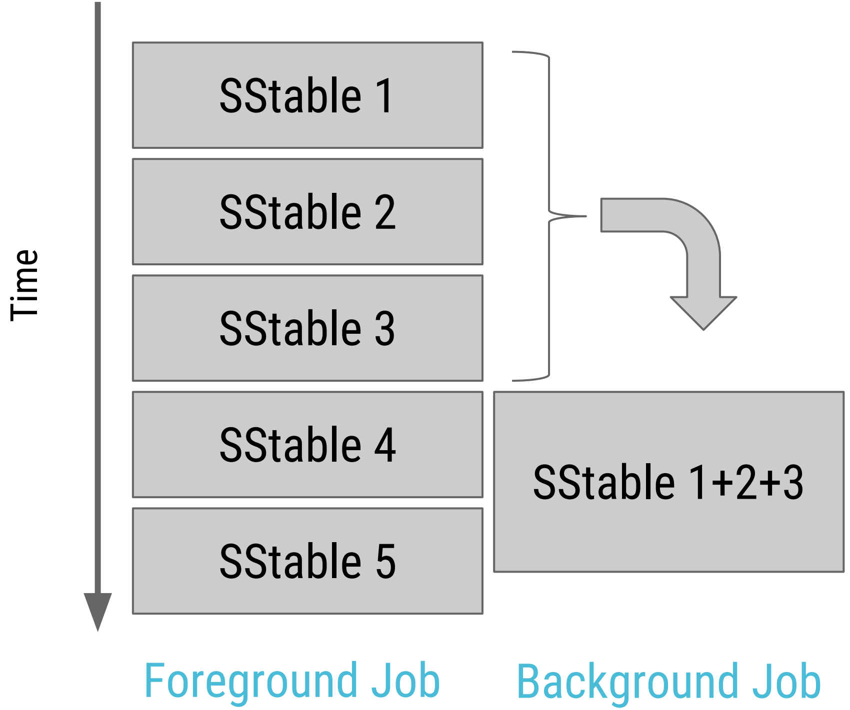
- Clustered NoSQL database compatible with Apache Cassandra
- ~10X performance on same hardware
- Low latency, esp. higher percentiles
- Self tuning
- C++14, fully asynchronous; Seastar!

YCSB Benchmark:
3 node Scylla cluster vs 3, 9, 15, 30 Cassandra machines





Log-Structured Merge Tree



High-level Goals

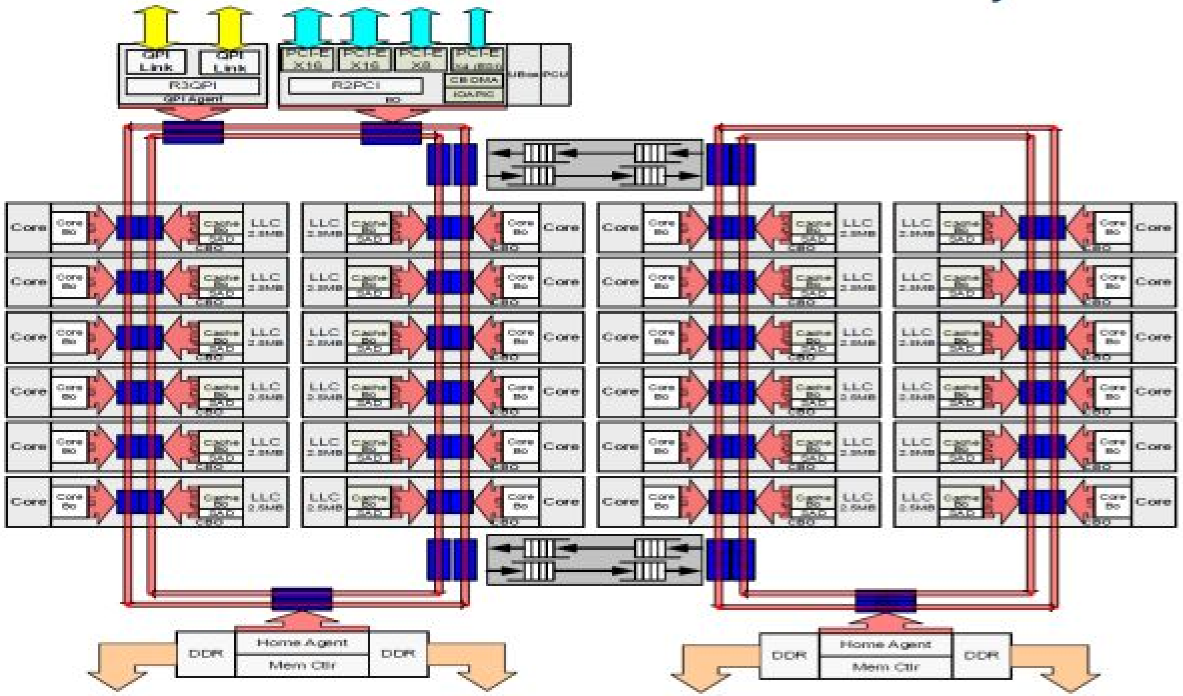
- Efficiency:
    - Make the most out of every cycle
- Utilization:
    - Squeeze every cycle from the machine
- Control
    - Spend the cycles on what we want, when we want

Characterizing the problem

- Large numbers of small operations
  - Make coordination cheap
- Lots of communications
  - Within the machine
  - With disk
  - With other machines

Asynchrony, Everywhere

Intel® Xeon® Processor E5 v4 Product Family HCC

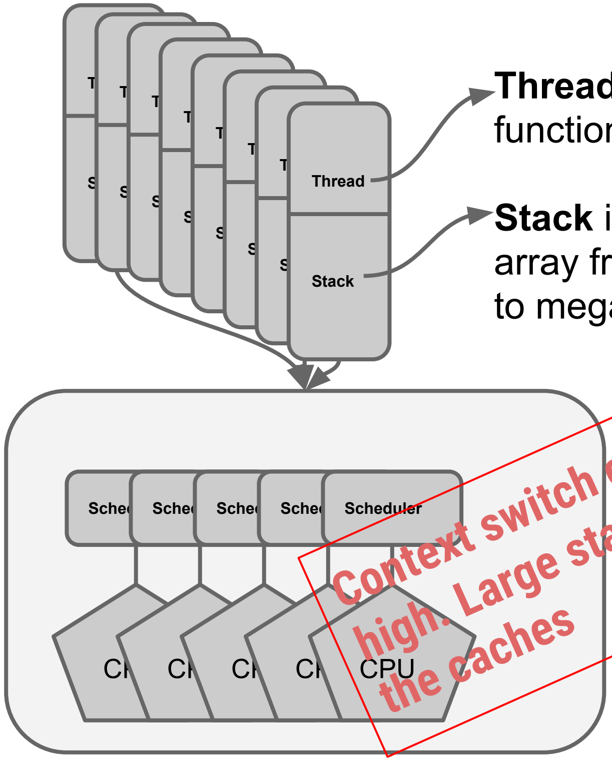


General Architecture

- Thread-per-core design
  - Never block
- Asynchronous networking
- Asynchronous file I/O
- Asynchronous multicore

Scylla has its own task scheduler

Traditional stack

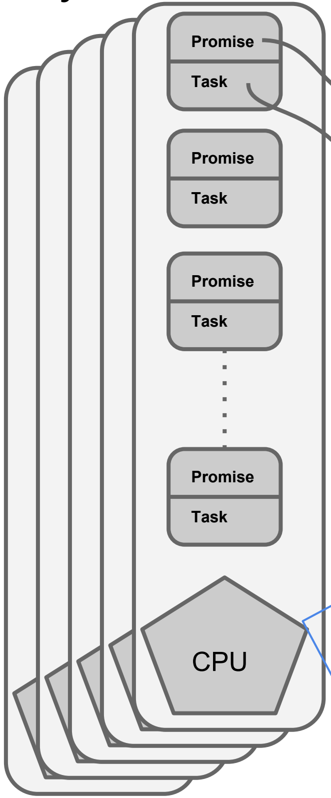


Thread is a function pointer

Stack is a byte array from 64k to megabytes

Context switch cost is high. Large stacks pollutes the caches

Scylla's stack



Promise is a pointer to eventually computed value

Task is a pointer to a lambda function

No sharing, millions of parallel events

The Concurrency Dilemma

Fundamental performance equation

Concurrency = Throughput * Latency

Fundamental performance equation

$$\text{Throughput} = \frac{\text{Concurrency}}{\text{Latency}}$$

Fundamental performance equation

$$\text{Latency} = \frac{\text{Concurrency}}{\text{Throughput}}$$

Lower bounds for concurrency

- Disks want minimum iodepth for full throughput (heads/chips)
- Remote nodes need concurrency to hide network latency and their own min. concurrency
- Compute wants work for each core

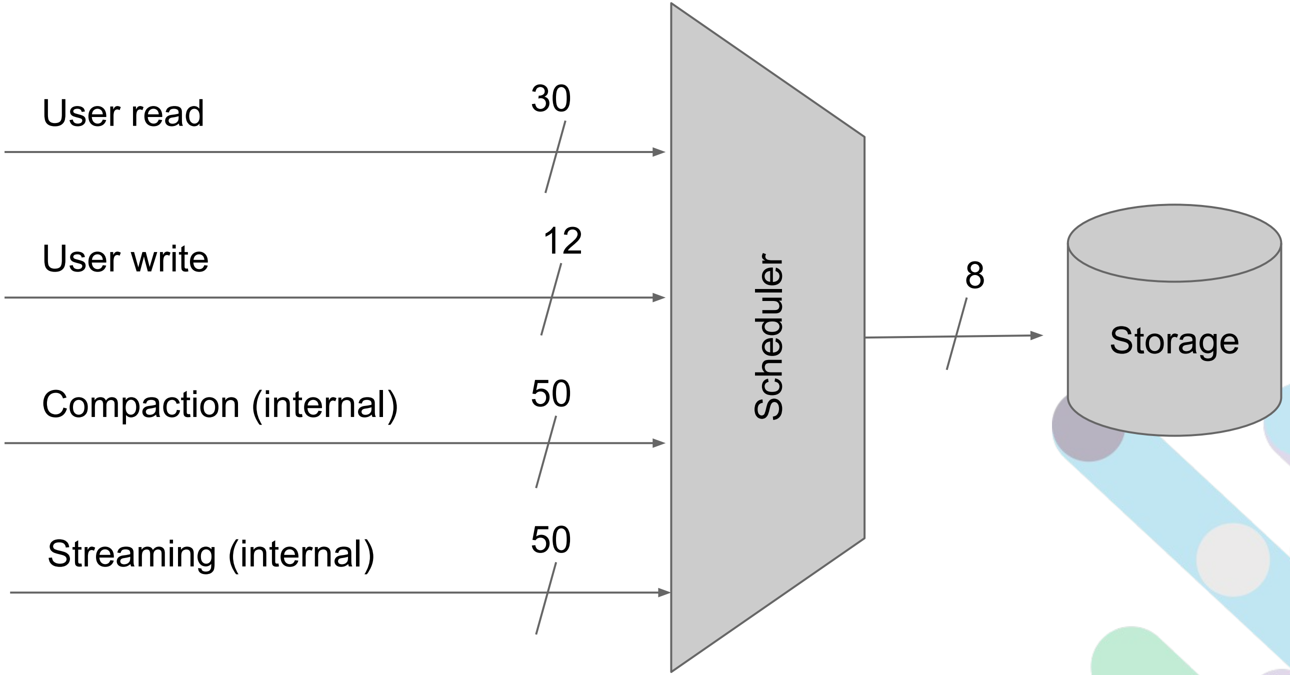
Results of Mathematical Analysis

- Want high concurrency (for throughput)
- Want low concurrency (for latency)
- Resources require concurrency for full utilization

Sources of concurrency

- Users
  - Reduce concurrency / add nodes
- Internal processes
  - Generate as much concurrency as possible
  - Schedule

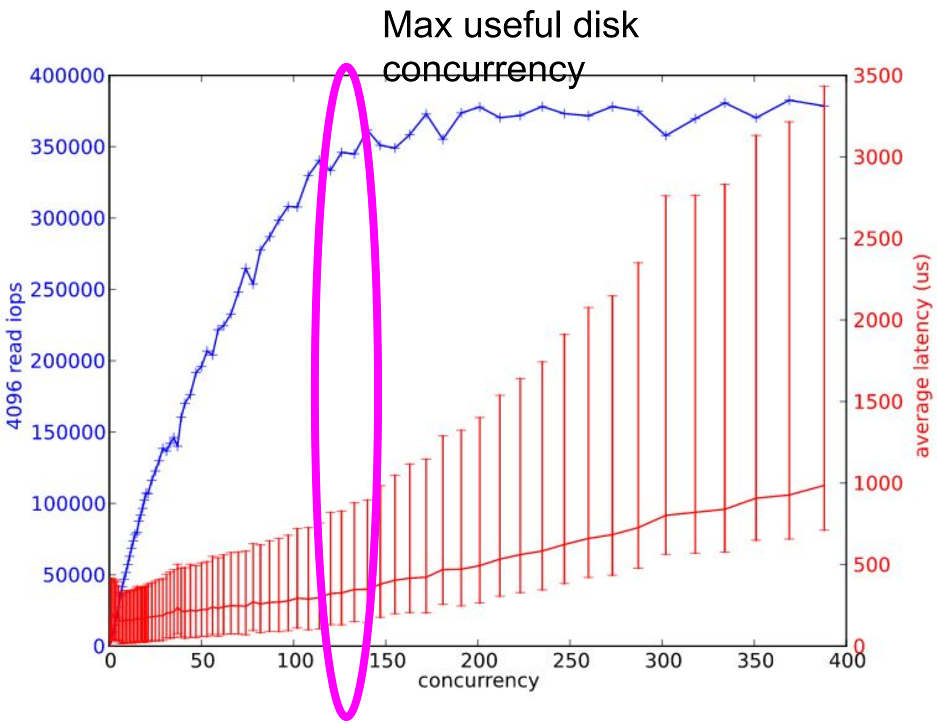
Resource Scheduling



Why not the Linux I/O scheduler?

- Can only communicate priority by originating thread
- Will reorder/merge like crazy
- Disable

Figuring out optimal disk concurrency



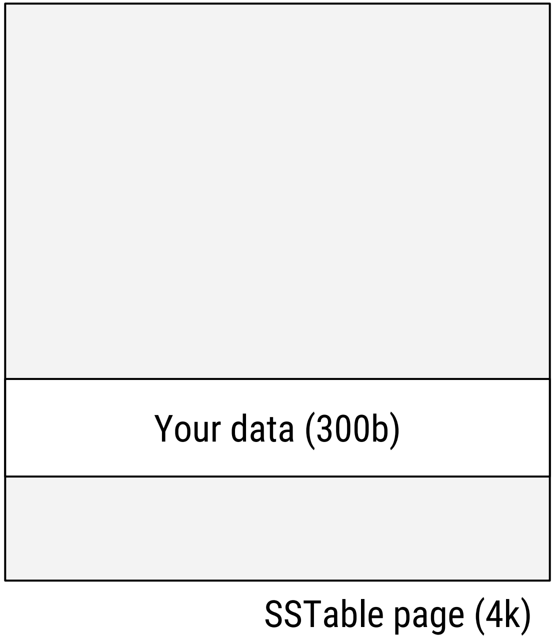
Cache design

Cache files or objects?

Using the kernel page cache

- 4k granularity
- Thread-safe
- Synchronous APIs
- General-purpose
- Lack of control (1)
- Lack of control (2)

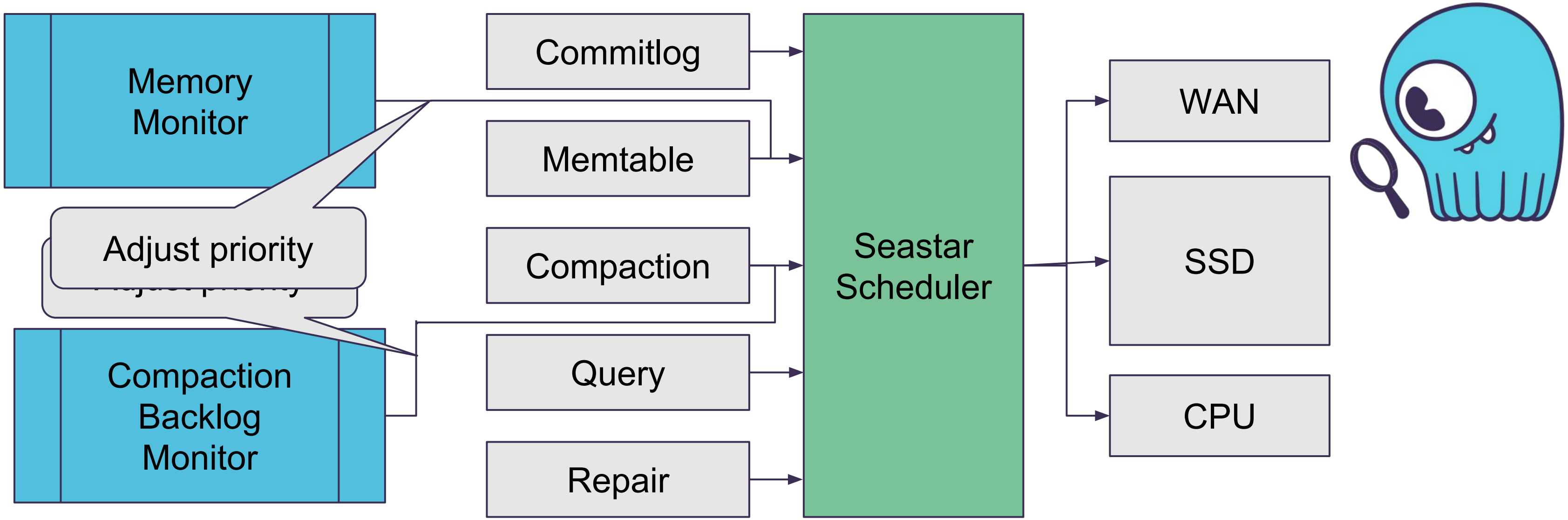
- Exists
- Hundreds of hacker-years
- Handling lots of edge cases


Your data (300b)
SSTable page (4k)

Workload Conditioning

Workload Conditioning

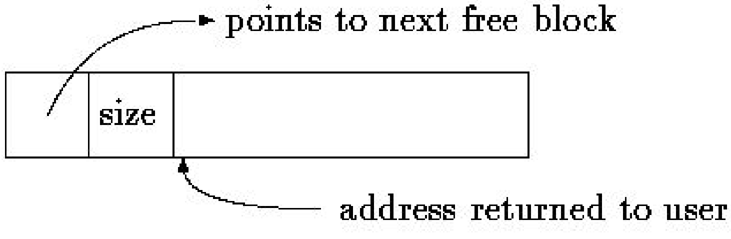
- Internal feedback loops to balance competing loads



Replacing the system memory allocator

System memory allocator problems

- Thread safe
- Allocation back pressure



A block returned by **malloc**

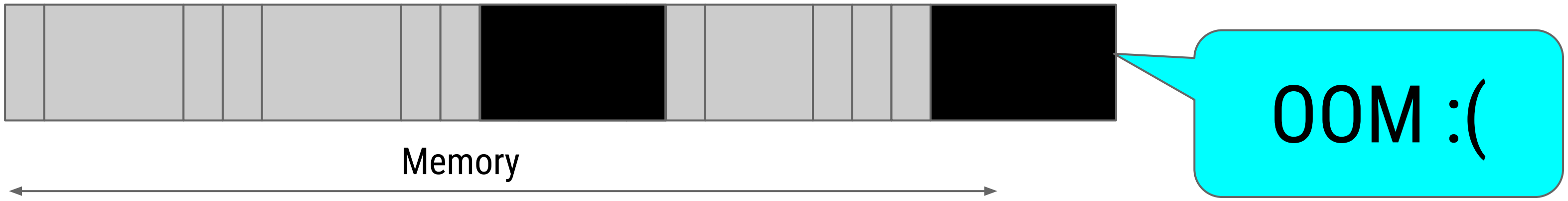
Seastar memory allocator

- Non-Thread safe!
  - Each core gets a private memory pool
- Allocation back pressure
  - Allocator calls a callback when low on memory
  - Scylla evicts cache in response

One allocator is not enough

Remaining problems with malloc/free

- Memory gets fragmented over time
  - If workload changes sizes of allocated objects
- Allocating a large contiguous block requires evicting most of cache


Memory
OOM :(

Log-structured memory allocation

- The cache
  - Large majority of memory allocated
  - Small subset of allocation sites
- Teach allocator how to move allocated objects around
  - Updating references

Log-structured memory allocation

Fancy Animation

Future Improvements

Userspace TCP/IP stack

- Thread-per-core design
- Use DPDK to drive hardware
- Present as experimental mode
  - Needs more testing and productization

Query Compilation to Native Code

- Use LLVM to JIT-compile CQL queries
- Embed database schema and internal object layouts into the query

Conclusions

- Full control of the software stack can generate big payoffs
- Careful system design can maximize throughput
- Without sacrificing latency
- Without requiring endless end-user tuning
- While having a lot of fun

How to interact

- Download: http://www.scylladb.com
- Twitter: @ScyllaDB
- Source: http://github.com/scylladb/scylla
- Mailing lists: scylladb-user @ groups.google.com
- Company site & blog: http://www.scylladb.com

SCYLLA

THE SCYLLA IS THE LIMIT

Thank you.