Low level Java programming With examples from OpenHFT

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Higher Frequency Trading.

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About Us...

Higher Frequency Trading is a small consulting and software development house specialising in:

- Low latency, high throughput software
- 6 developers + 3 staff in Europe and USA.
- Sponsor HFT related open source projects
- Core Java engineering

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About Me…

- CEO and Principal Consultant
- Third on Stackoverflow for Java, most Java Performance answers.
- Vanilla Java blog with 3 million views
- Founder of the Performance Java User's Group
- An Australian, based in the U.K.

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What Is The Problem We Solve?

"I want to be able to read and write my data to a persisted, distributed system, with the speed of in memory data structures"

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Agenda

What are our Open Source products used for?

Where to start with low latency?

When you know you have a problem, what can you do?

Chronicle scaling Vertically and Horizontally

- Shares data structure between processes
- Replication between machines
- Build on a low level library Java Lang.
- Millions of operations per second.
- Micro-second latency. No TCP locally.
- Synchronous logging to the OS.
- Apache 2.0 available on GitHub
- Persisted via the OS.

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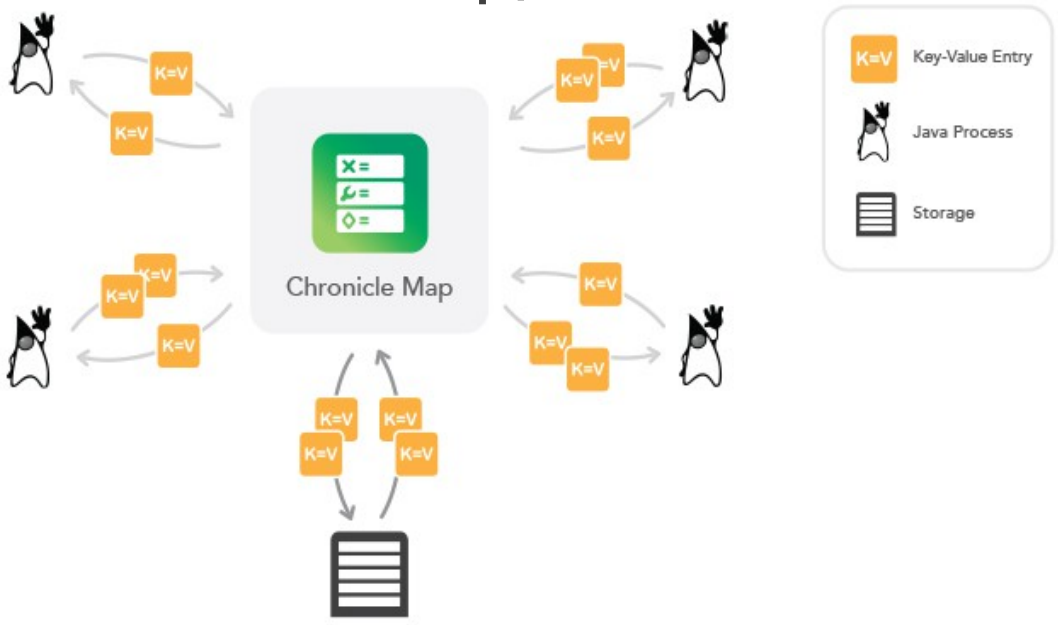
What is Chronicle Map/Set?



- Low latency persisted key-value store.
- Latency between processes around 200 ns.
- In specialized cases, latencies < 25 ns.
- Throughputs up to 30 million/second.

What is Chronicle Map/Set?

- ConcurrentMap or Set interface
- Designed for reactive programming
- Replication via TCP and UDP.
- Apache 2.0 open source library.
- Pure Java, supported on Windows, Linux, Mac OSX.

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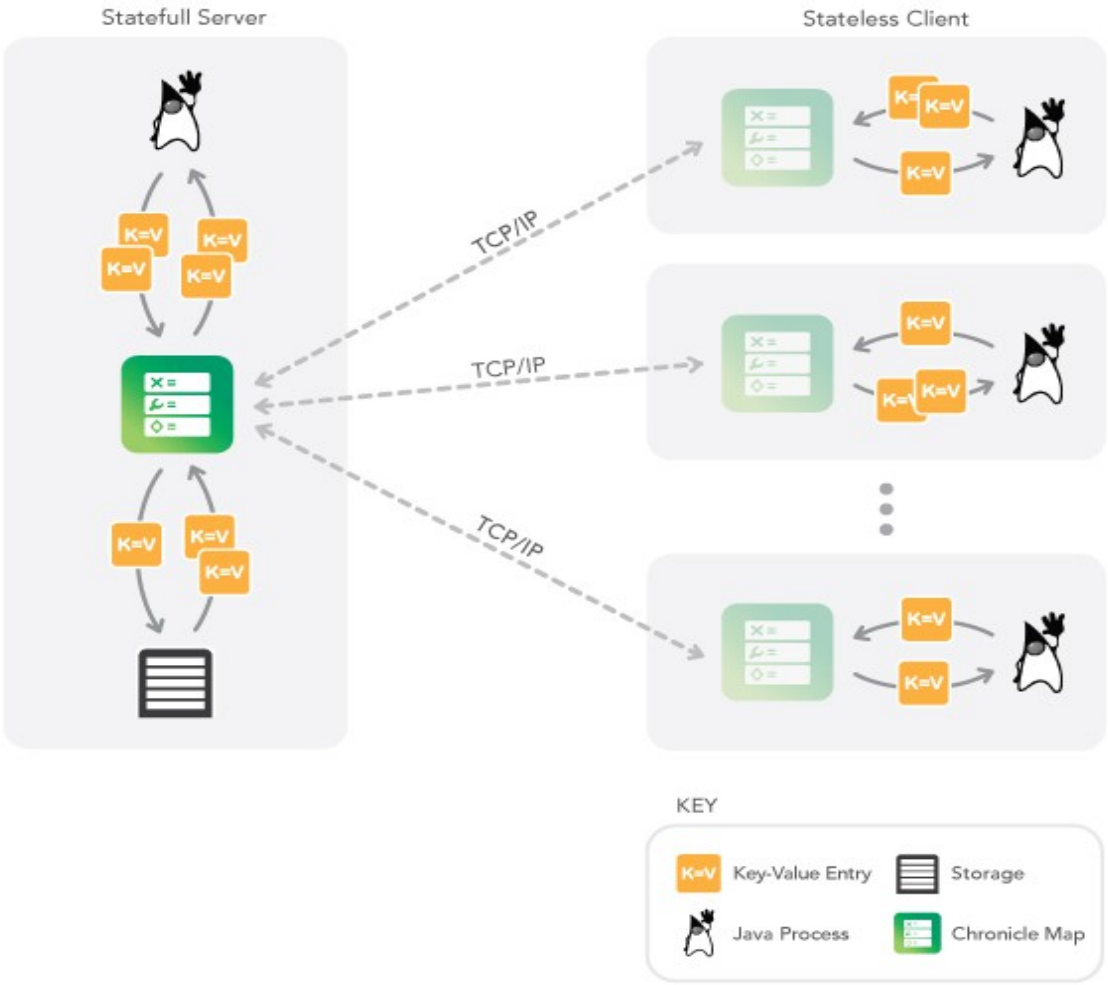
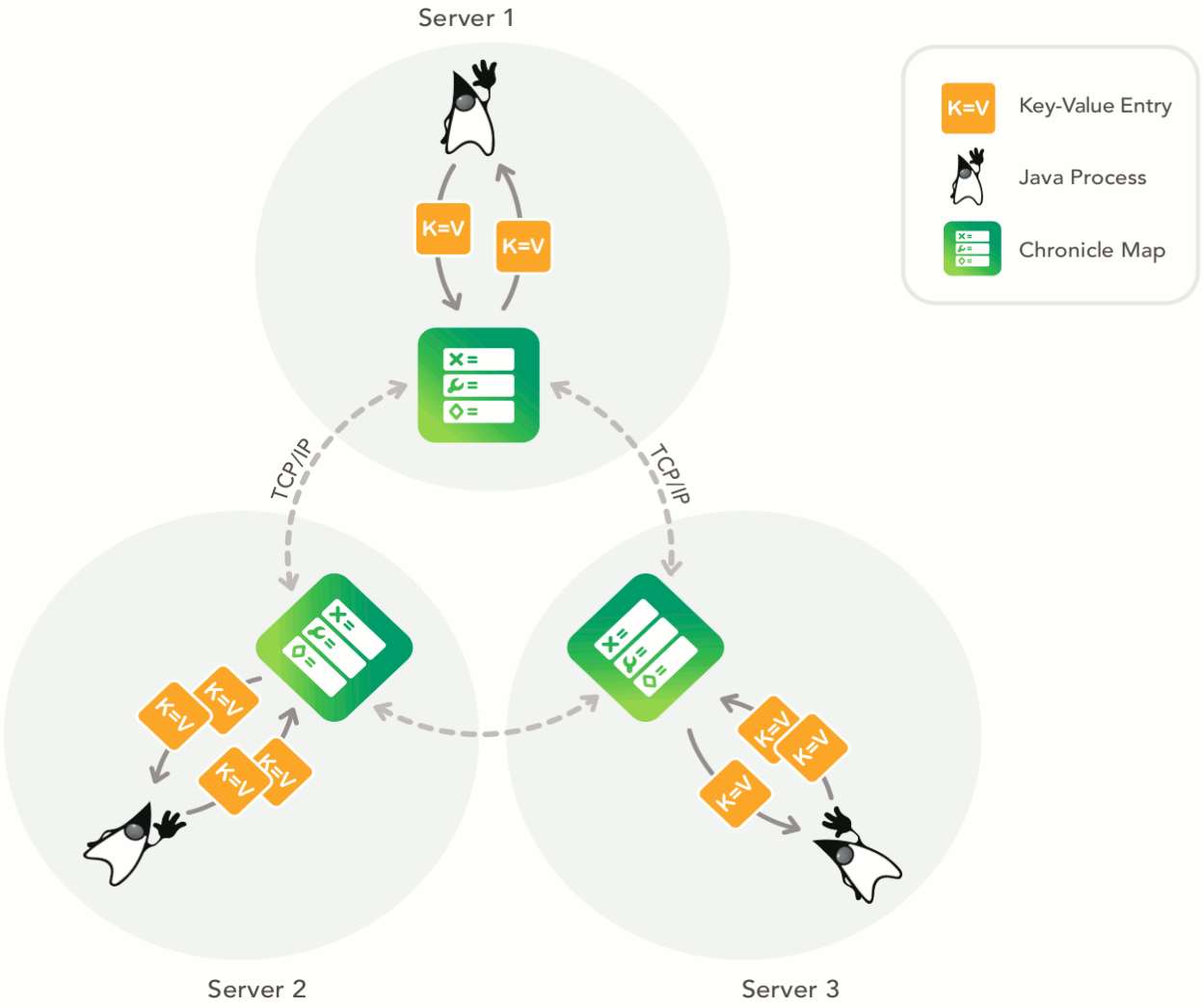
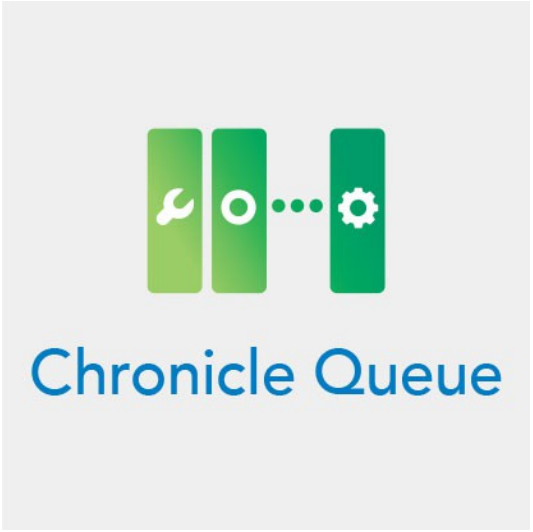

Statefull Server
Stateless Client
K=V
TCP/IP
TCP/IP
TCP/IP
KEY
Key-Value Entry
Storage
Java Process
Chronicle Map


Server 1
K=V
K=V
TCP/IP
TCP/IP
Server 2
Server 3
K=V
Key-Value Entry
Java Process
Chronicle Map

What is Chronicle Queue?

- Low latency journaling and logging.
- Low latency cross JVM communication.
- Designed for reactive programming
- Throughputs up to 40 million/second.



What is Chronicle Queue?

- Latencies between processes of 200 nano-seconds.
- Sustain rates of 400 MB/s, peaks much higher.
- Replication via TCP.
- Apache 2.0 open source library.
- Pure Java, supported on Windows, Linux, Mac OSX.

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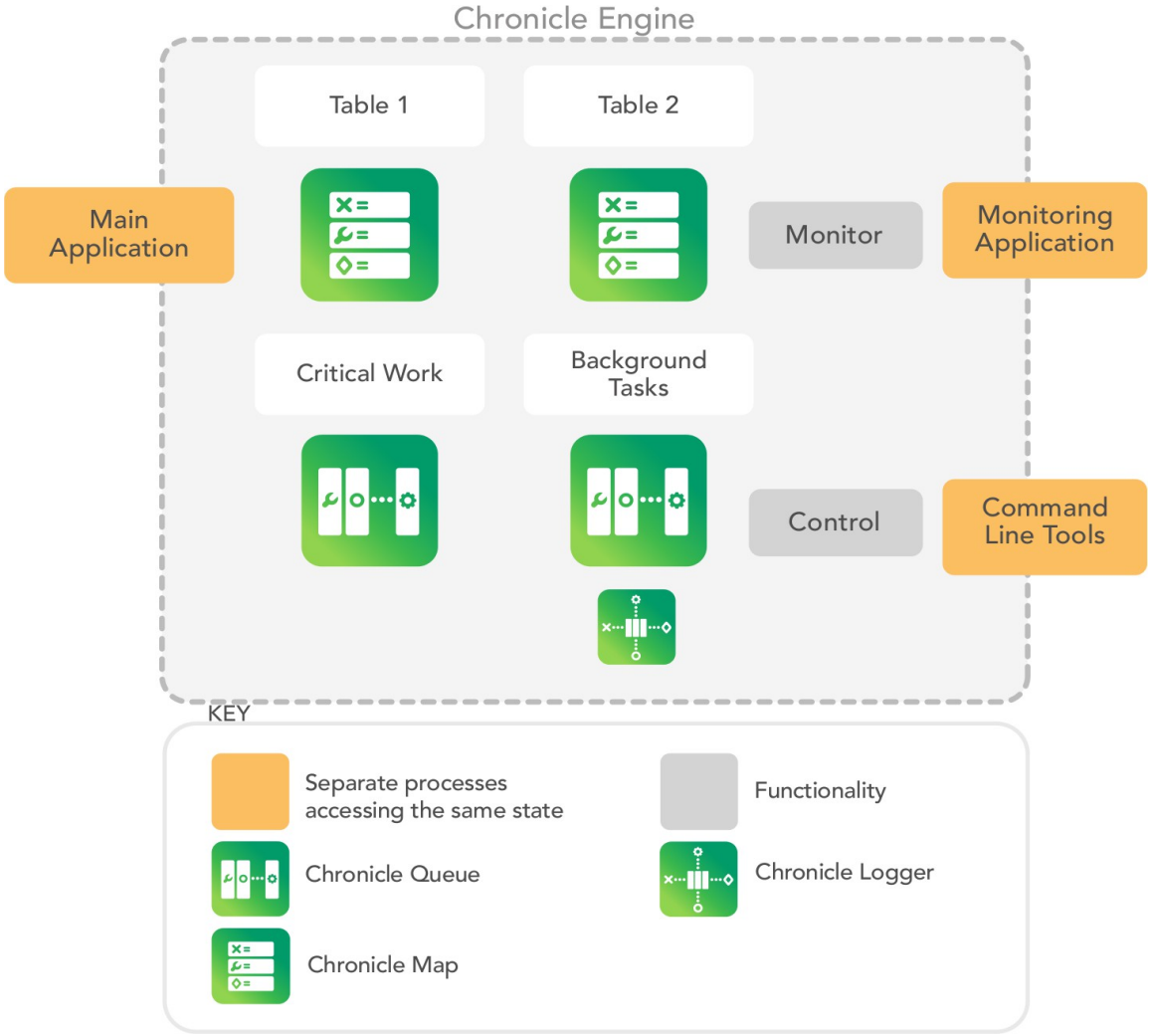
Chronicle monitoring a legacy application



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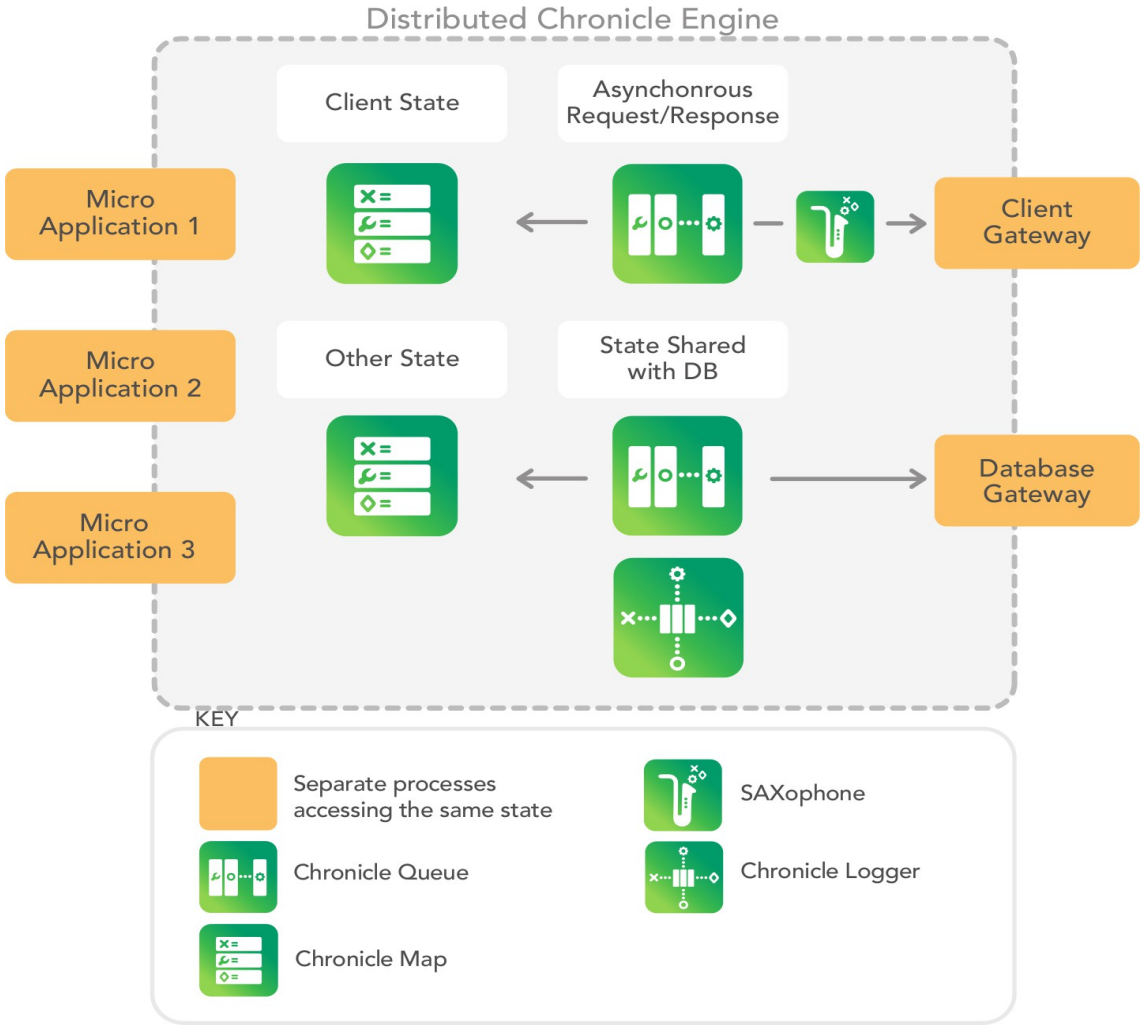
Chronicle journalling multiple applications



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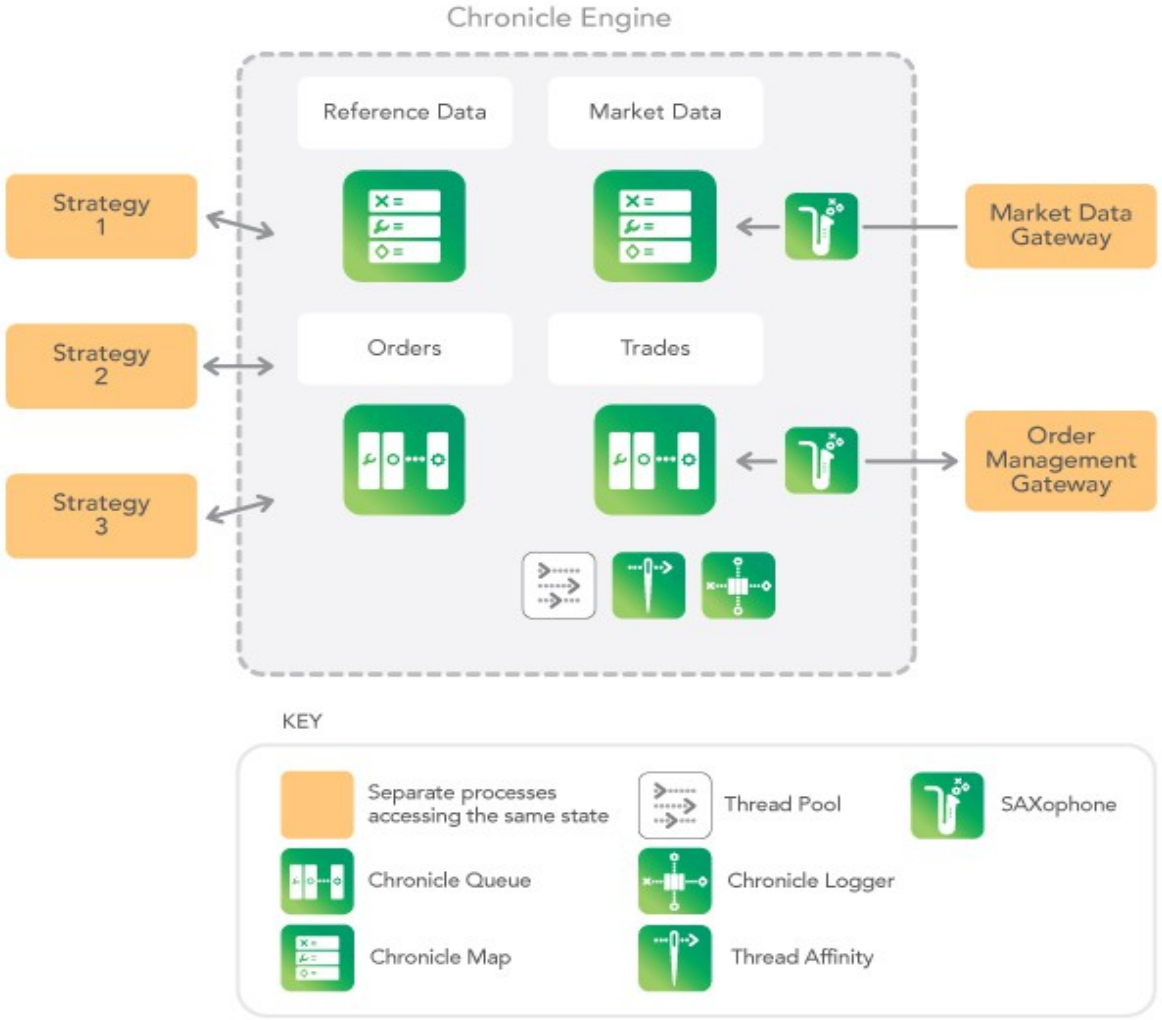
Chronicle for low latency trading



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Short demo using OSResizesMain

```
peter@chronos: ~
top - 17:04:58 up 19:25,  2 users,  load average: 0.94, 0.96, 0.69
Tasks: 220 total,   1 running, 219 sleeping,   0 stopped,   0 zombie
Cpu(s): 15.8%us, 19.3%sy,  0.2%ni, 64.5%id,  0.2%wa,  0.0%hi,  0.1%si,  0.0%st
Mem:   7690672k total,  5767192k used,  1923480k free,    84588k buffers
Swap: 15788028k total,   197112k used, 15590916k free,  1456056k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
17599 peter     20   0  125t 192m 108m S   99  2.6   0:06.40 java
17066 peter     20   0 5696m 1.3g  33m S   27 17.2   4:43.45 java
```

Note: The “VIRT” virtual memory size is 125t for 125 TB, actual usage 97M
System memory: 7.7 GB, Extents of map: 137439.0 GB, disk used: 97MB,
addressRange: 233a777f000-7f33a8000000
$ ls -lh /tmp/oversized*
-rw-rw-r-- 1 peter peter **126T** Oct 20 17:03 /tmp/over-sized...
$ du -h /tmp/oversized*
97M /tmp/over-sized....

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Where to start with low latency?

You need to measure first.

- What is the end to end use case you need to improve?
- Is it throughput or latency you need to improve?
- Throughput or average latency hides poor latencies.
- Avoid co-ordinated omission. See Gil Tene's talks.

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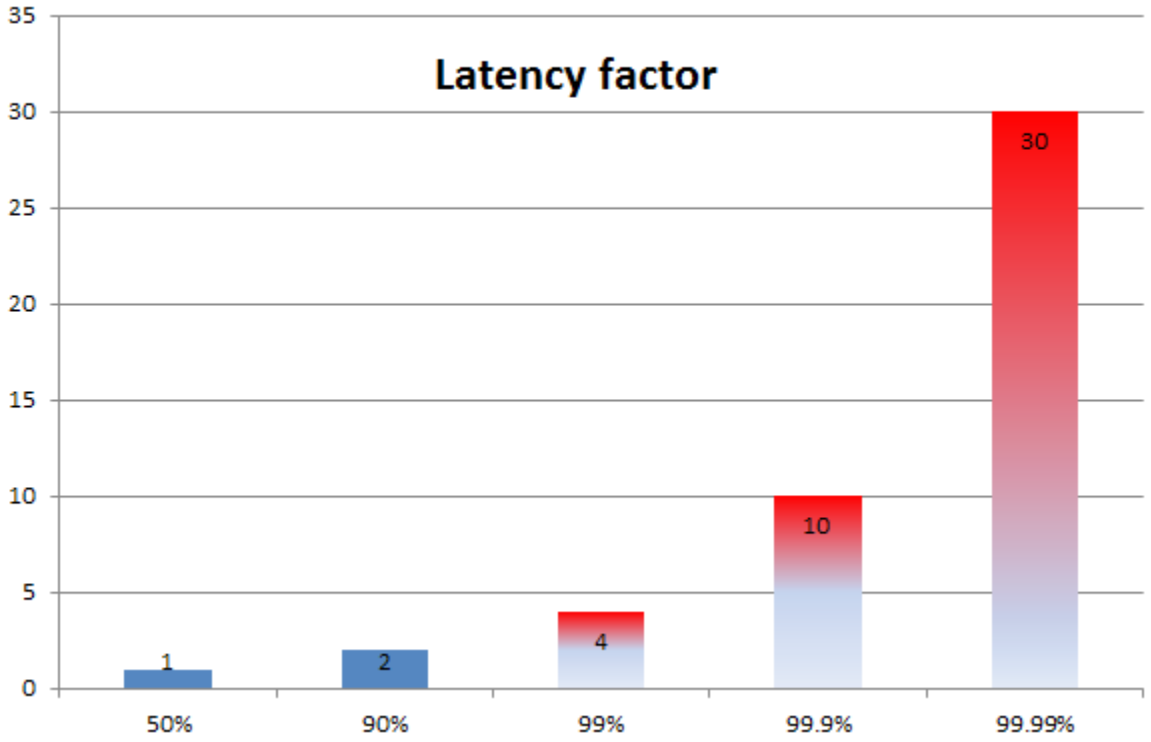
Looking at the latency percentiles



Tools to help you measure

- A commercial profiler. e.g. YourKit.
- Instrument timings in production.
- Record and replay production loads.
- Avoid co-ordinated omission. See Gil Tene's talks.
- If you can't change the code, Censum can help you tune your GC pause times.
- Azul's Zing “solves” GC pause times, but has many other tools to reduce jitter.

What to look for when profiling

- Reducing the allocation rate is often a quick win.
- Memory profile to reduce garbage produced.
- When CPU profiling, leave the memory profiler on.
- If the profiler is no long helpful, application instrumentation can take it to the next level.

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When you know you have a problem, what can you do about it?

Is garbage unavoidable?

- You can always reduce it further and further, but at some point it's not worth it.
- For a web service, 500 MB/s might be ok.
- For a trading system, 500 KB/s might be ok.
- If you produce 250 KB/s it will take you 24 hours to fill a 24 GB Eden space.

Common things to tune.

A common source of garbage is Iterators.

```
for (String s : arrayList) { }
```

Creates an Iterator, however

```
for (int i = 0, len = arrayList.size(); i < len; i++) {
    String s = arrayList.get(i);

}
```

Doesn't create an Iterator.

Common things to tune.

BigDecimal can be a massive source of garbage.

```
BigDecimal a = b.add(c)
                .divide(BigDecimal.TWO, 2, ROUND_HALF_UP);
```

The same as double produces no garbage.

```
double a = round(b + c, 2);
```

You have to have a library to support rounding. Without it you will get rounding and representation errors.

Be aware of your memory speeds.

	concurrency	Clock cycles	Seconds
L1 caches	multi-core	4	1 seconds
L2 cache	multi-core	10	3 seconds
L3 cache	socket wide	40-75	15 seconds
Main memory	System wide	200	50 seconds.
SSD access	System wide	50,000	14 hours
Local Network	Network	180,000	2 days
HDD	System wide	30,000,000	1 year.

To maximise performance you want to spend as much time in L3, or ideally L1/L2 caches as possible.

Memory access is faster with less garbage

Reducing garbage minimises filling your caches with garbage.

If you are producing 300 MB/s of garbage your L1 cache will be filled with garbage is about 100 micro-seconds, your L2 cache will be filled in under 1 milli-second.

The L3 cache and main memory shared and the more you use this, the less scalability you will get from your multi-cores.

Faster memory access

- Reduce garbage
- Reduce pointer chasing
- Use primitives instead of objects.
- Avoid false sharing for highly contended mutated values

Lock free coding

- AtomicLong.addAndGet(n)
- Unsafe.compareAndSwapLong
- Unsafe.getAndAddLong

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Using off heap memory

- Reduce GC work load.
- More control over layout
- Data can be persisted
- Data can be embedded into multiple processes.
- Can exploit virtual memory allocation instead of main memory allocation.

Low latency network connections

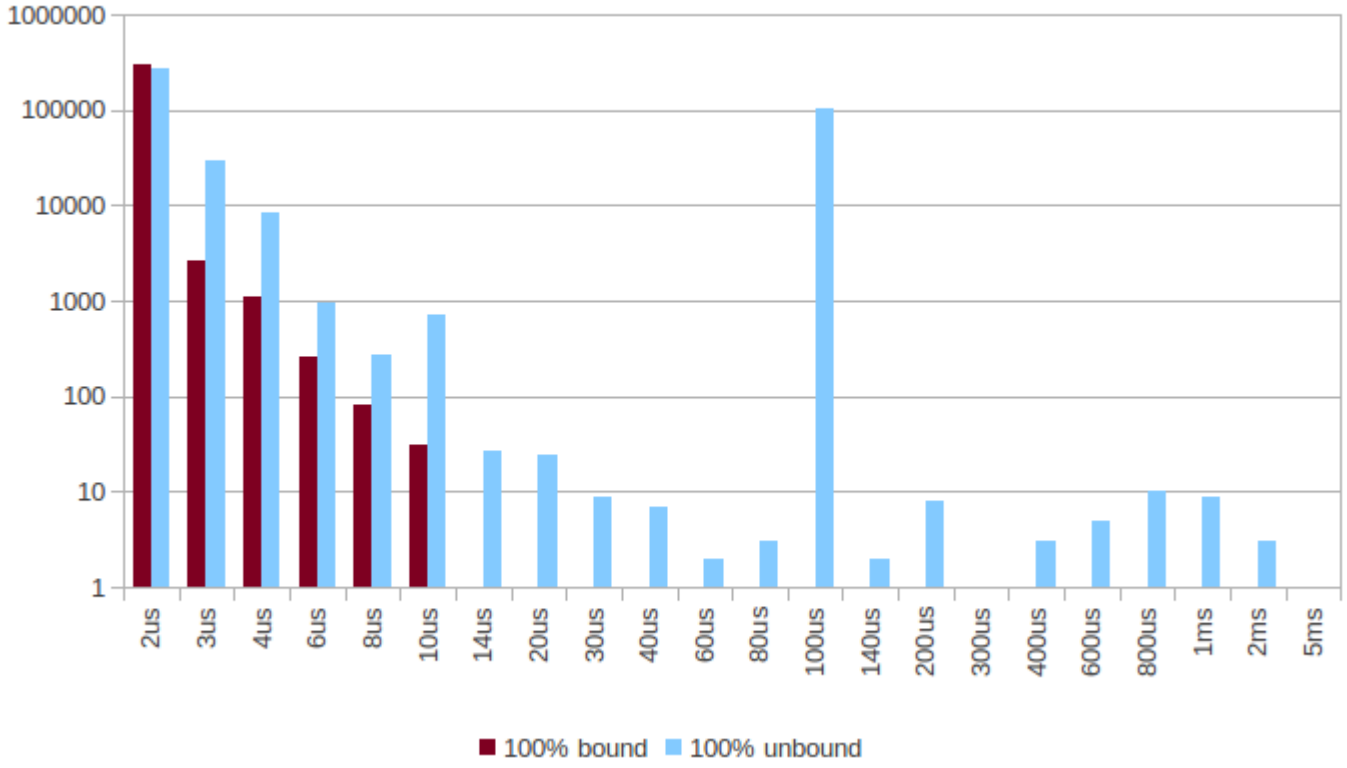
- Kernel by pass network cards e.g. Solarflare
- Single hop latencies around 5 micro-seconds
- Make scaling to more machines practical when tens of micro-seconds matter.

Reducing micro-jitter

- Unless you isolate a CPU, it will get interrupted by the scheduler a lot.
- You can see delays of 1 – 5 ms every hour on an otherwise idle machine.
- On a virtualised machine, you can see delays of 50 ms.
- Java Thread Affinity library can declaratively layout your critical threads.

Reducing micro-jitter

Number of interrupts per hour by length.



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Q & A

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