Enabling Java in Latency Sensitive Environments

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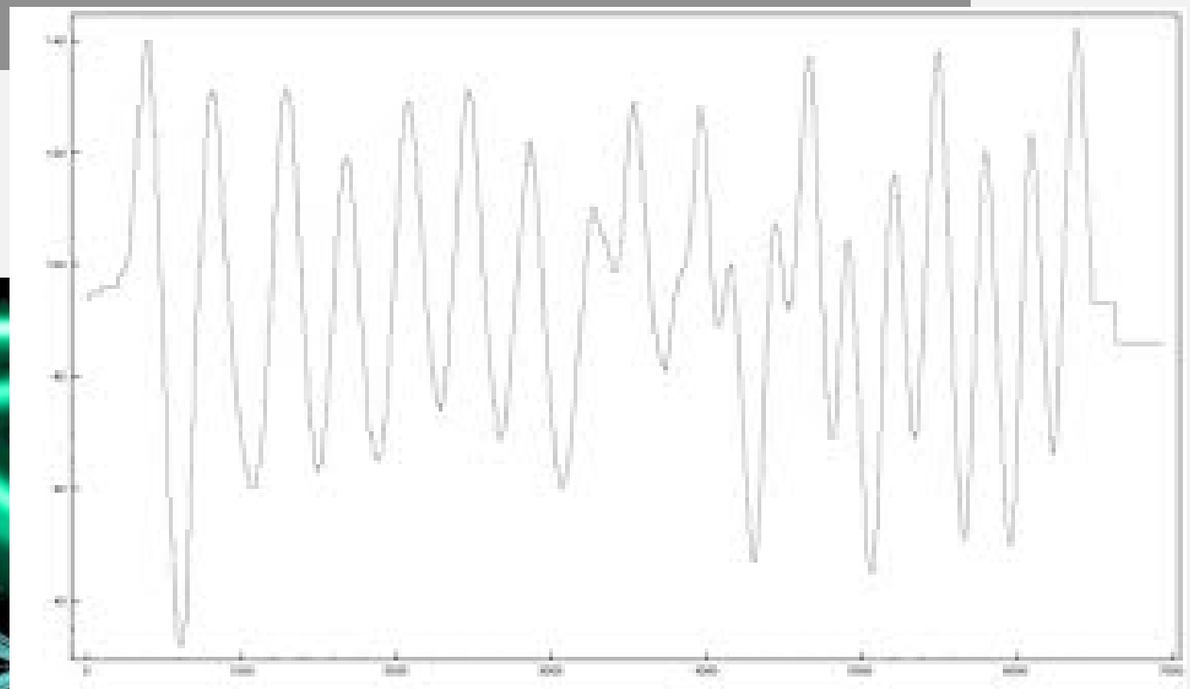
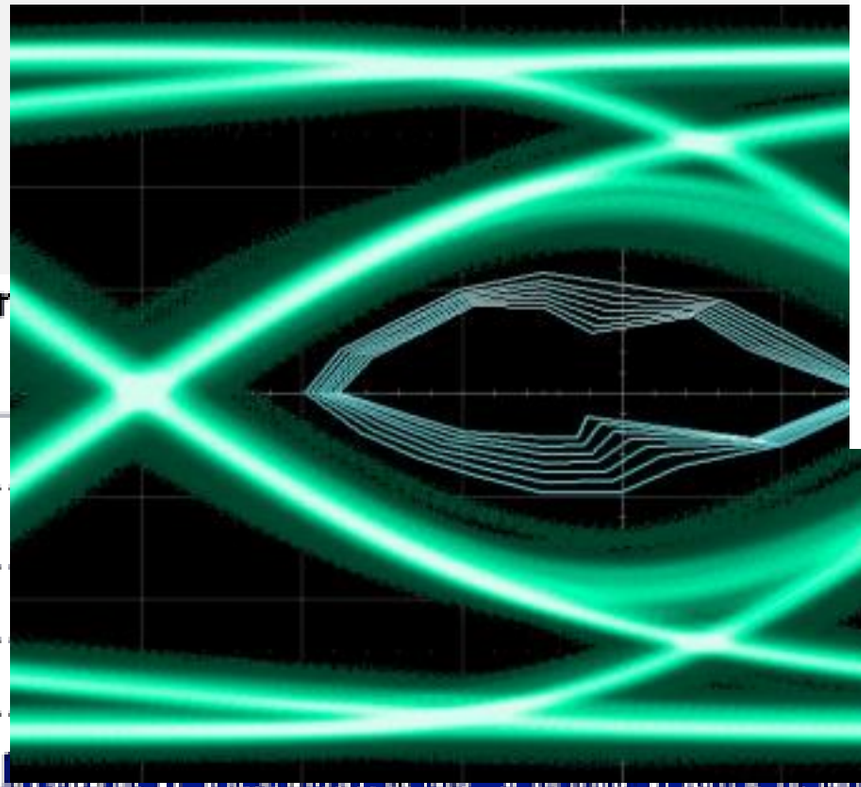
High Level Agenda

Welcome to all Gateway JUG members!

- Intro, jitter vs. JITTER
- Java in a low latency application world
- The (historical) fundamental problems
- What people have done to try to get around them
- What if the fundamental problems were eliminated?
- What 2015 looks like for Low Latency Java developers
- Real World Case Studies

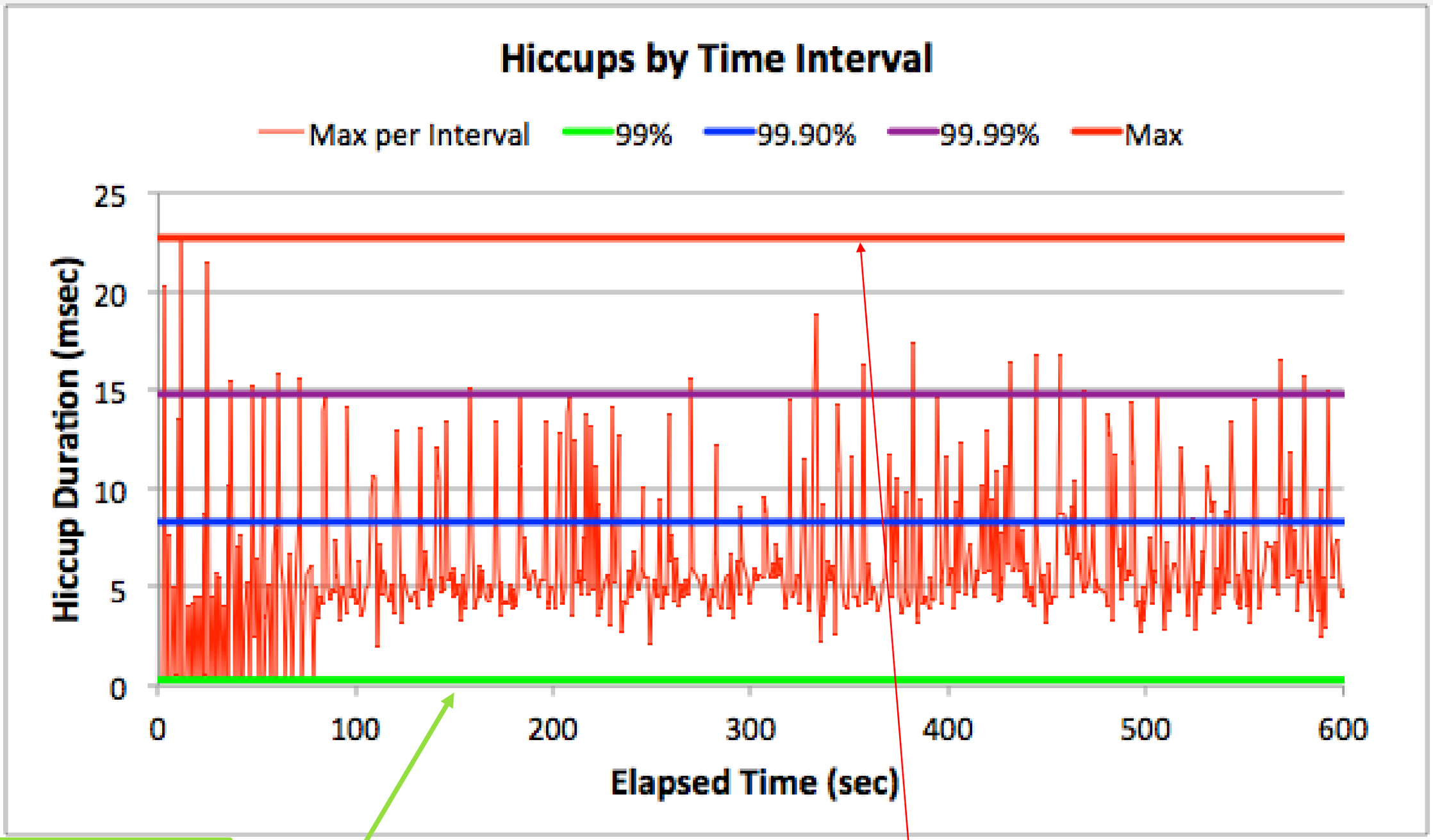
This is Jitter





Is “jitter” a proper word for this?

Answer: no its not jitter at all. It’s phase changes.



99%‘ile is ~60 usec

Max is ~30,000% higher than “typical”

About Azul Systems

Zing, Zulu, and everything about Java Virtual Machines

- We make scalable Virtual Machines
- Have built “whatever it takes to get job done” since 2002
- 3 generations of custom SMP Multi-core HW (Vega)
- **Now Pure software for commodity x86 (Zing)**
- Certified OpenJDK (Zulu)
- Known for Low Latency, Consistent execution, and Large data set excellence

Java in the low latency world

Java in a low latency world

Yep, Java latencies are goin' down for real…

- Why do people use Java for low latency apps?
- Are they crazy?
- No. There are good, easy to articulate reasons
- Projected lifetime cost
- Developer productivity
- Time-to-product, Time-to-market, Time-to-performance ...
- Leverage, ecosystem, ability to hire

e.g. customer answer to: "Why do you use Java in Algo Trading?"

- Strategies have a shelf life
- We have to keep developing and deploying new ones
- Only one out of N is actually productive
- Profitability therefore depends on ability to successfully deploy new strategies, and on the cost of doing so
- Our developers seem to be able to produce 2x-3x as much when using a Java environment as they would with C++ ...

So what is the problem?
Is Java Slow?

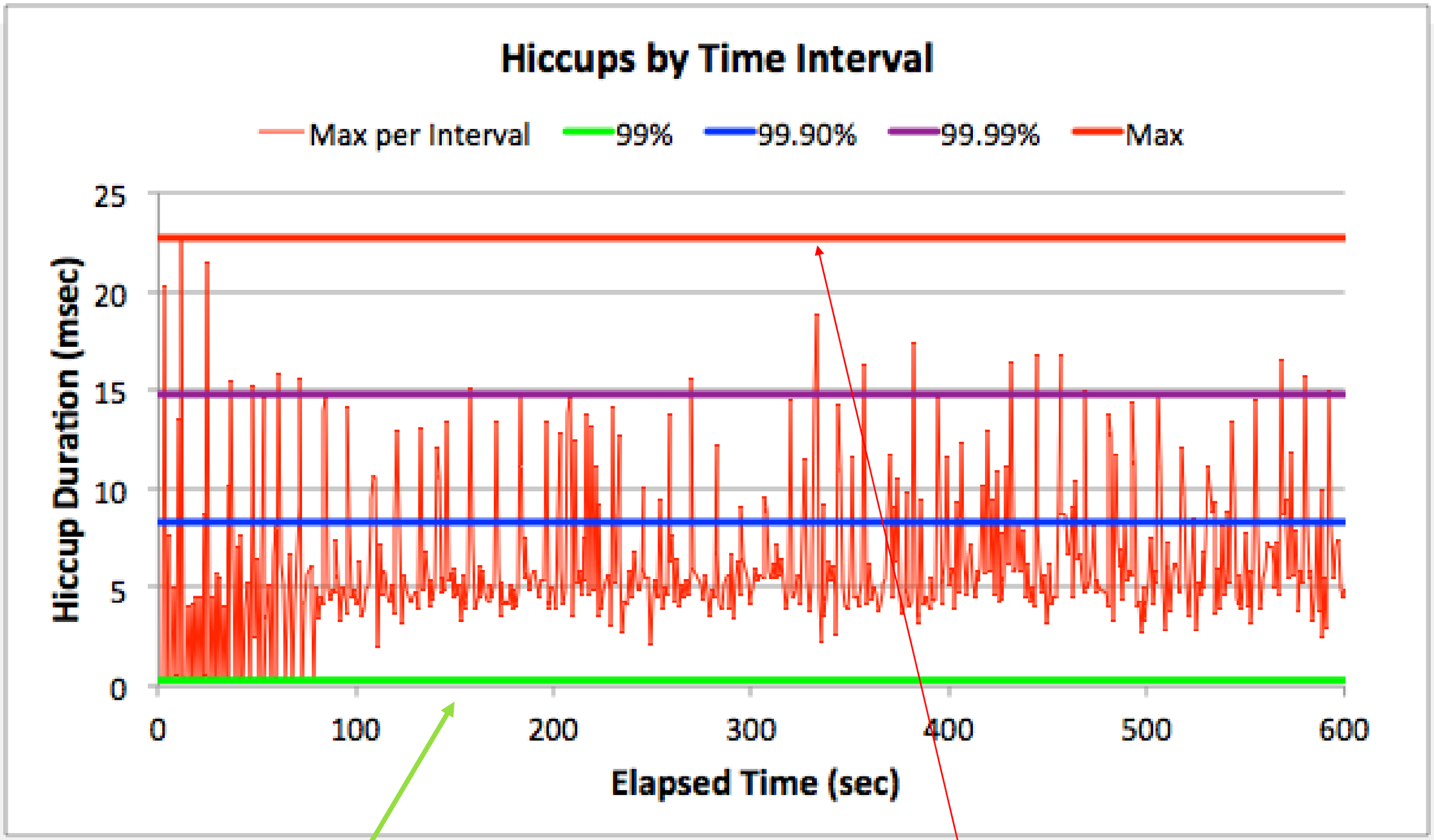
- No
- A good programmer will get roughly the same speed from both Java and C++
- A bad programmer won't get you fast code on either
- The 50%'ile and 90%'ile are typically excellent...
- It's those pesky occasional stutters and stammers and stalls that are the problem...
- Ever hear of Garbage Collection?

Java’s Achilles heel

Stop-The-World Garbage Collection: How bad is it?

- Let’s ignore the bad multi-second pauses for now...
- Low latency applications regularly experience “small”, “minor” GC events that range in the 10s of msec
- Frequency directly related to allocation rate
- In turn, directly related to throughput
- So we have great 50%, 90%. Maybe even 99%
- But 99.9%, 99.99%, Max, all “suck”
- So bad that it affects risk, profitability, service expectations, etc.

STW-GC effects in a low latency application



99%‘ile is ~60 usec

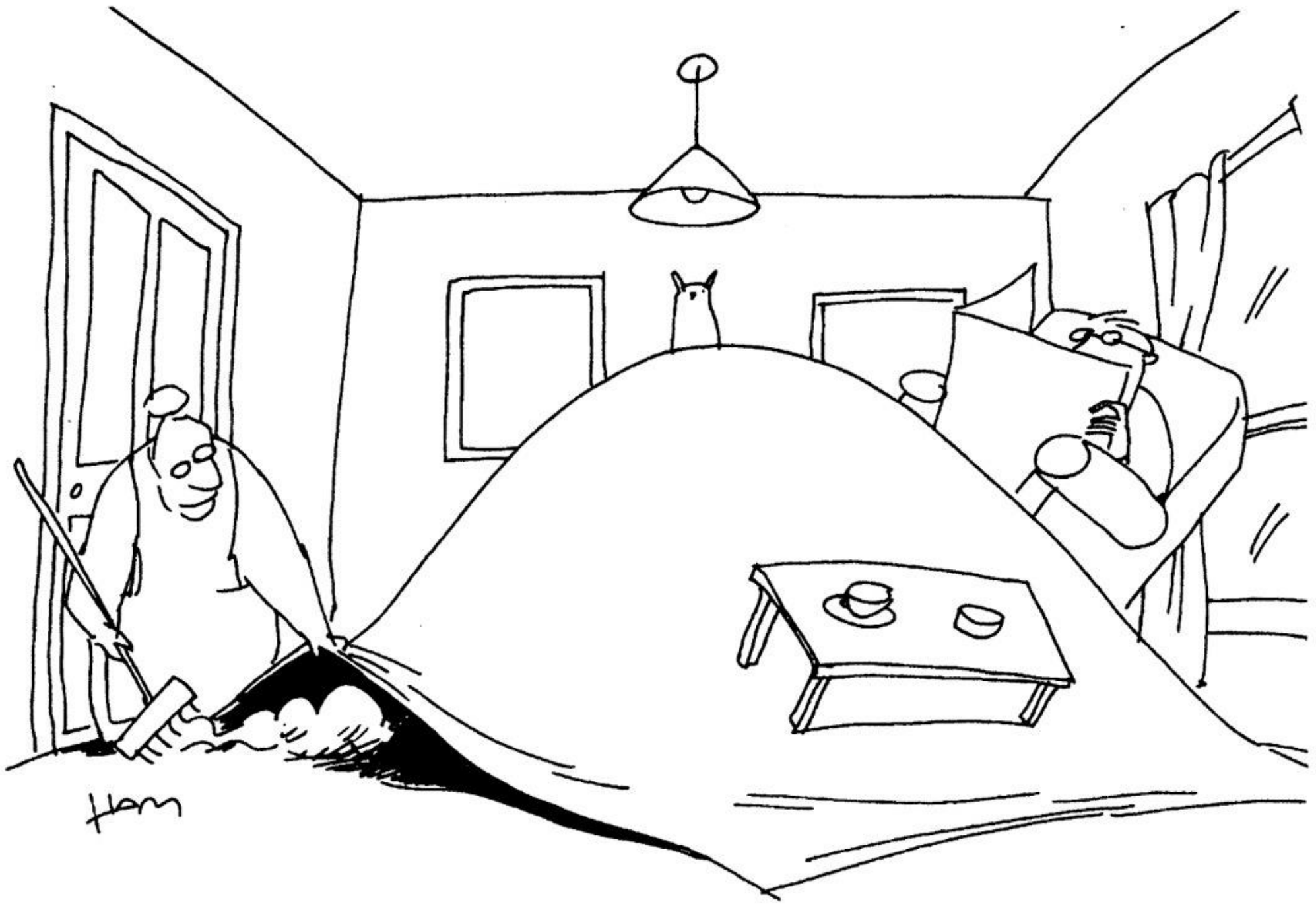
Max is ~30,000% higher than “typical”

One way to deal with Stop-The-World GC

I cannot see it, so it cannot see me.

More Stop-The-World GC avoidance

Time for a bigger rug.



What do actual low latency developers do about it?

- They use “Java” instead of Java
- They write “in the Java syntax”
- They avoid allocation as much as possible
- E.g. They build their own object pools for everything
- They write all the code they use (no 3rd party libs)
- They train developers for their local discipline
- In short: They revert to many of the practices that hurt productivity. They lose out on much of Java.

Another way to cope: “Creative Language”

Drawn from evil vendor marketing literature

“Guarantee a worst case of 5 msec, 99% of the time”

Translation: “1% will be far worse than worst case”

“Mostly” Concurrent, “Mostly” Incremental

Translation: “Will at times exhibit long monolithic stop-the-world pauses”

“Fairly Consistent”

Translation: “Will sometimes show results well outside this range”

“Typical pauses in the tens of milliseconds”

Translation: “Some pauses are much longer than tens of milliseconds”

What do low latency (Java) developers get for all their effort?

- They still see pauses (usually ranging to tens of msec)
- But they get fewer (as in less frequent) pauses
- And they see fewer people able to do the job
- And they have to write EVERYTHING themselves
- And they get to debug malloc/free patterns again
- And they can only use memory in certain ways
- ...
- Some call it “fun”... Others “duct tape engineering”...

There is a fundamental problem:

Stop-The-World GC mechanisms are contradictory to the fundamental requirements of low latency & low jitter apps

Sustainable Throughput

The throughput achieved while safely maintaining service levels

It’s an industry-wide problem

It *was* an industry-wide problem

It’s 2015... Now we have Zing.

The common GC behavior across ALL currently shipping (non-Zing) JVMs

- ALL use a Monolithic Stop-the-world NewGen
  - "small" periodic pauses (small as in 10s of msec)
  - pauses more frequent with higher throughput or allocation rates
- Development focus for ALL is on OldGen collectors
  - Focus is on trying to address the many-second pause problem
  - Usually by sweeping it farther and farther the rug
  - "Mostly X" (e.g. "mostly concurrent") hides the fact that they refer only to the OldGen part of the collector
  - E.g. CMS, G1, Balanced.... all are OldGen-only efforts
- ALL use a Fallback to Full Stop-the-world Collection
  - Used to recover when other mechanisms (inevitably) fail
  - Also hidden under the term "Mostly"...

At Azul, STW-GC was addressed head-on

Trivia: Azul as a company founded predominantly around this one premise plaguing then Java servers

- We decided to focus on the right core problems
  - Scale & productivity being limited by responsiveness
  - Even “short” GC pauses are considered a problem
- Responsiveness must be unlinked from key metrics:
  - Transaction Rate, Concurrent users, Data set size, etc.
  - Heap size, Live Set size, Allocation rate, Mutation rate
  - Responsiveness must be continually sustainable
  - Can’t ignore “rare but periodic” events
- Eliminate ALL Stop-The-World Fallbacks
  - Any STW fallback is a real-world failure

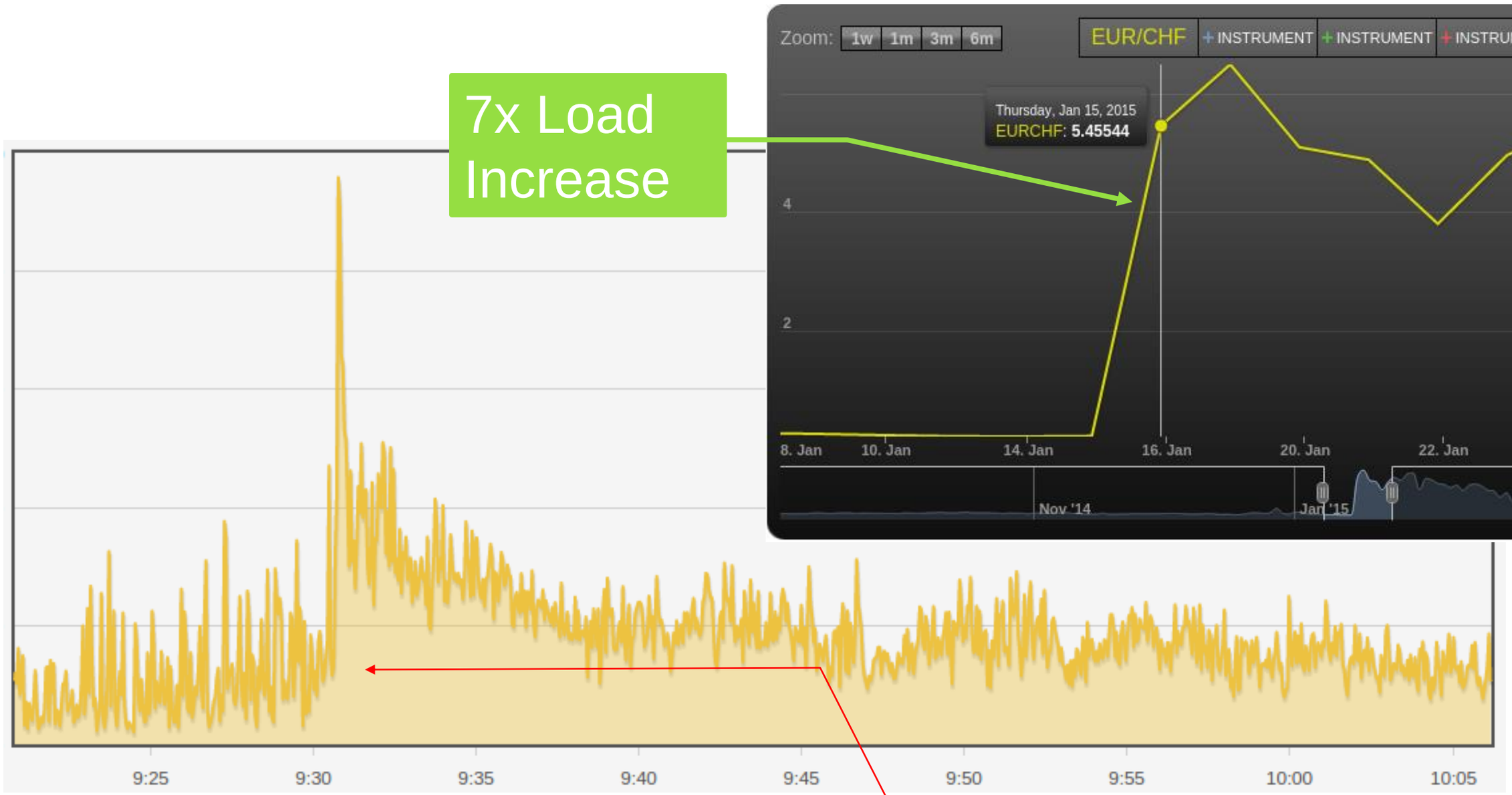
The Zing "C4" Collector
Continuously Concurrent Compacting Collector

- **Concurrent, compacting** old generation
- **Concurrent, compacting** new generation
- No stop-the-world fallback
  - Always compacts, and always does so concurrently

Benefits

Stay Responsive

Even when traffic patterns change without warning

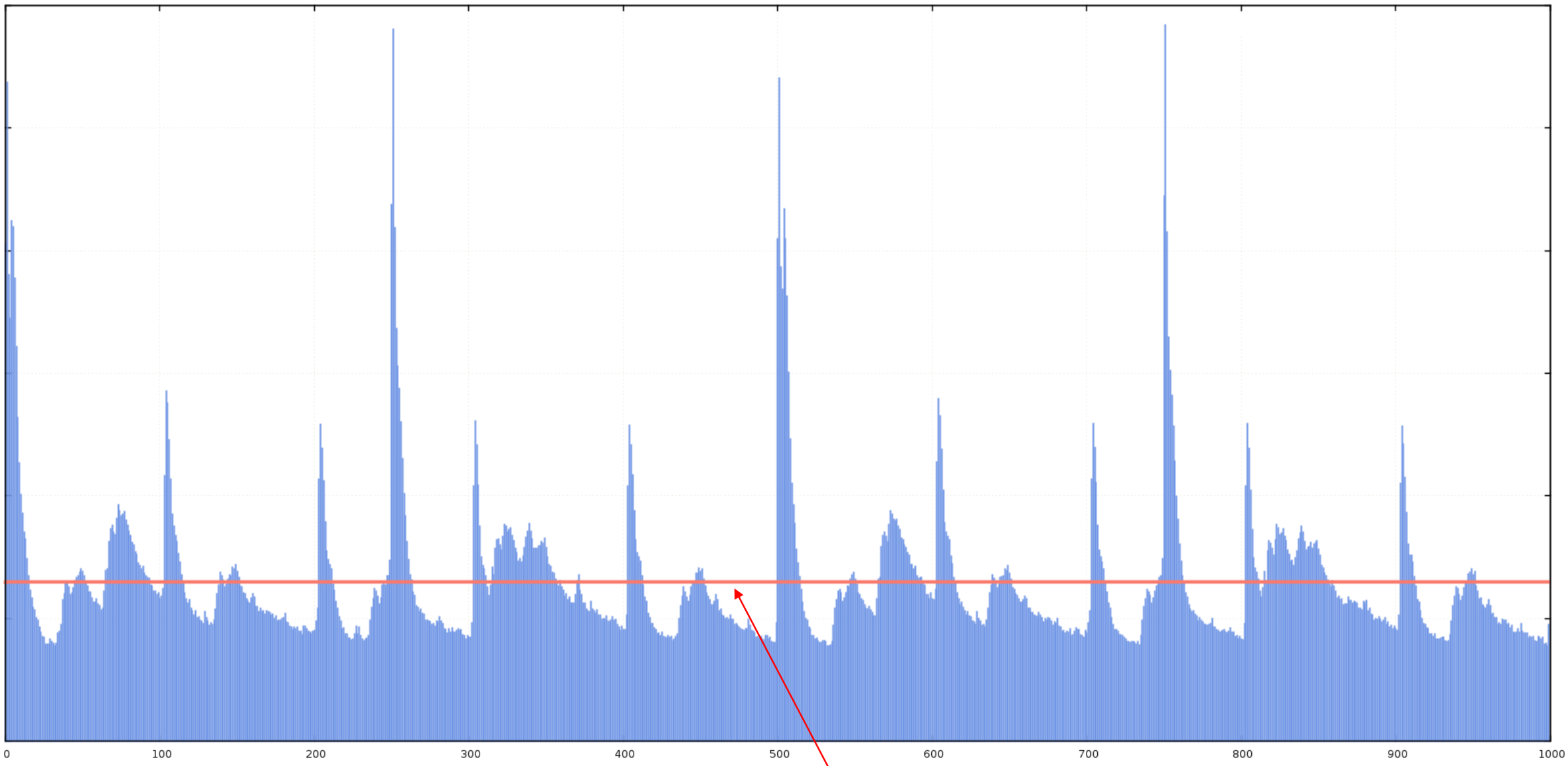


LMAX EXCHANGE™

AZUL SYSTEMS®

Handle Real World traffic patterns

One second view of transactions. Not constant. Not random either. Bursty is normal.



LMAX EXCHANGE™

Red line shows where order pricing arrival rate would be if constant

Achieve Measureable Benefits

From joint LMAX/Azul talk at QCon London, March 2015

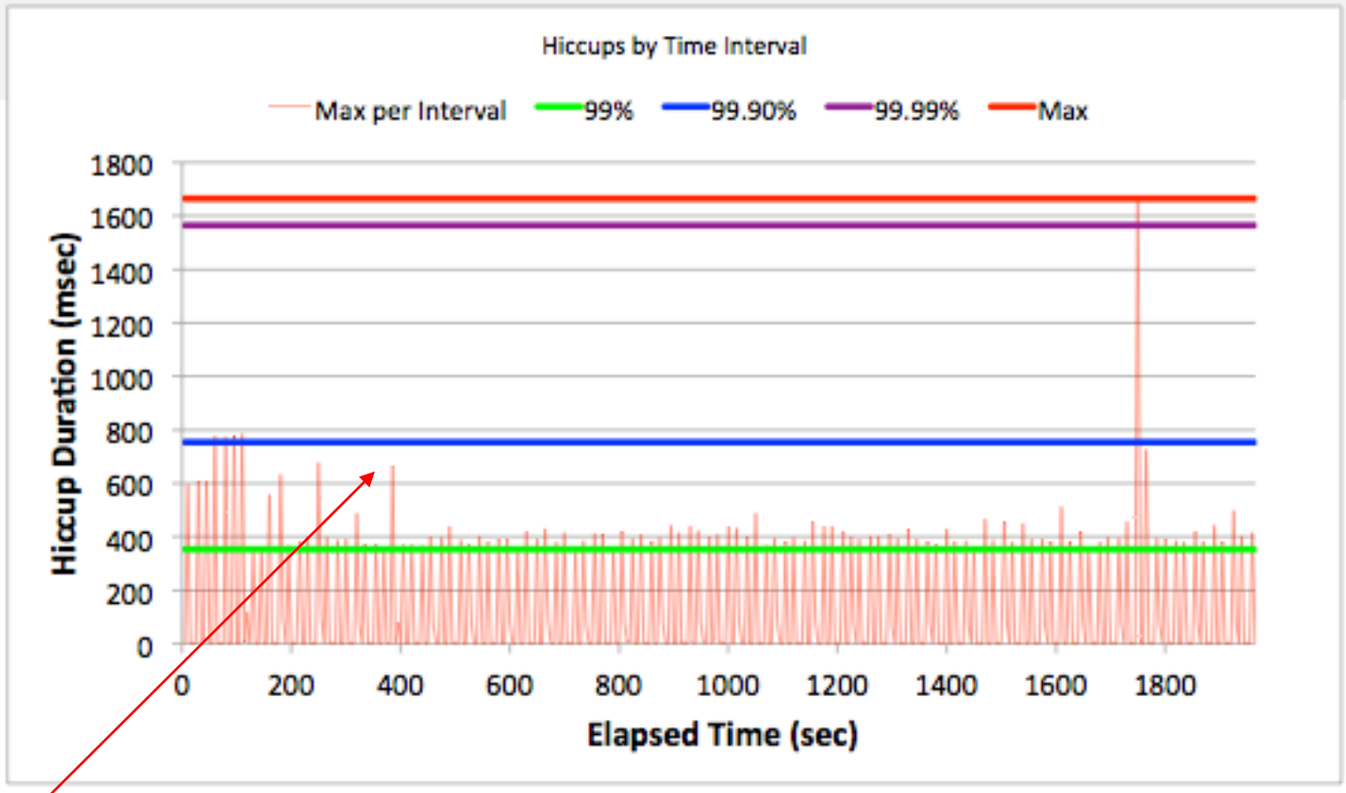
- Zing helped LMAX tame GC-related latency outlier pauses
  - Highly-engineered system: 4ms every 30 seconds down to 1ms every 2 hours
  - Less well-tuned system: 50ms every 30 seconds down to 3ms every 15 minutes
- No more unexpected/unwanted old-gen pauses caused by external behavior
  - CMS STW intra-day, generally ~500ms, gone
  - Removed source of backpressure on latency critical path.
  - Pre-Azul these would occur less predictably, but multiple times a week.

This is not “just Theory”

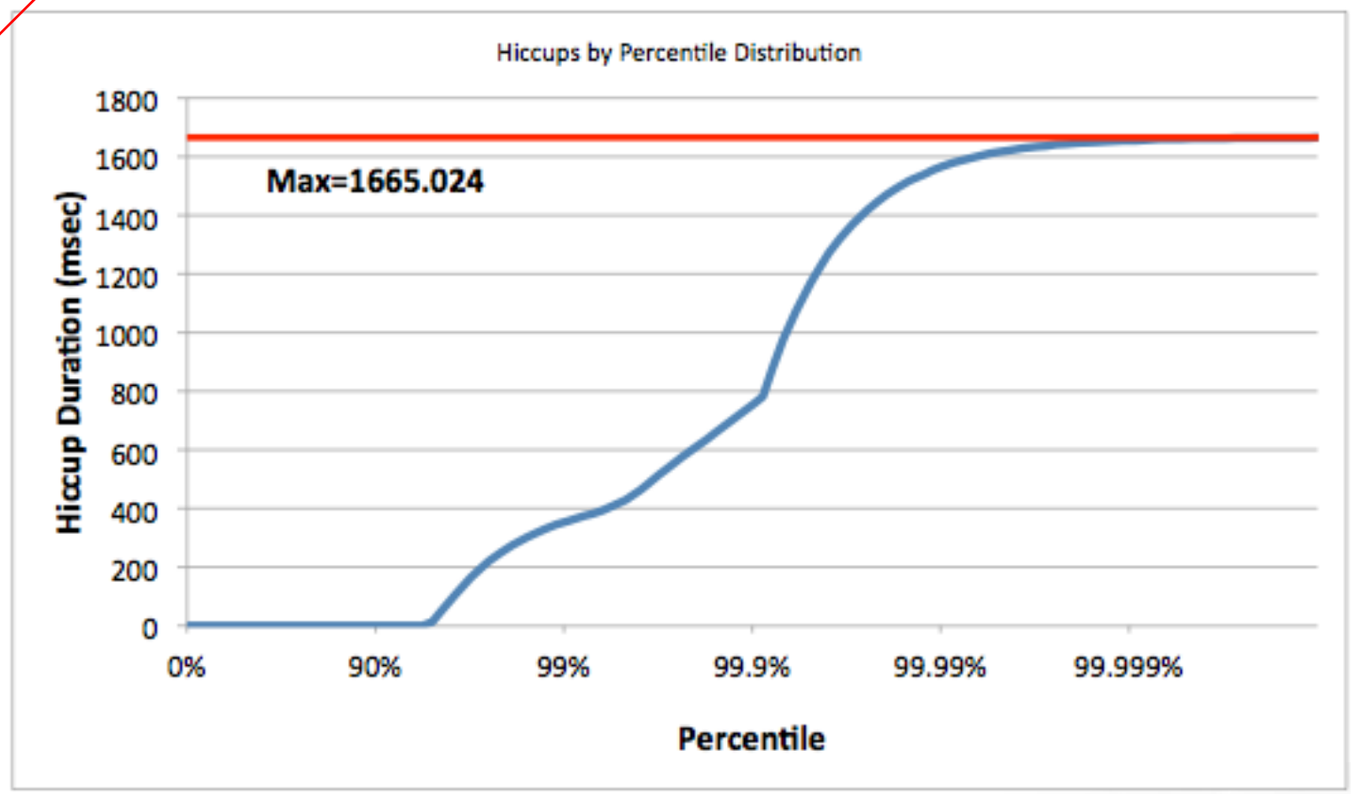
jHiccup

A tool that measures and reports
(as your application is running)
if your JVM is running **all** the time

Discontinuities in Java execution - Easy To Measure

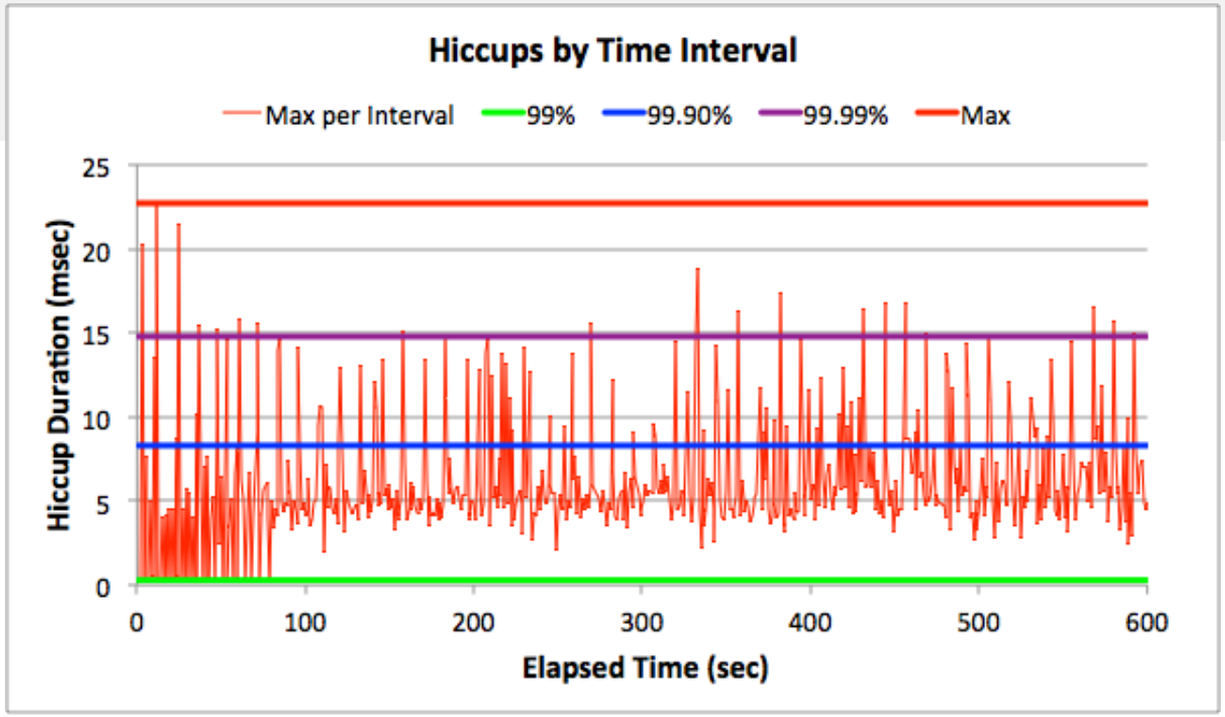


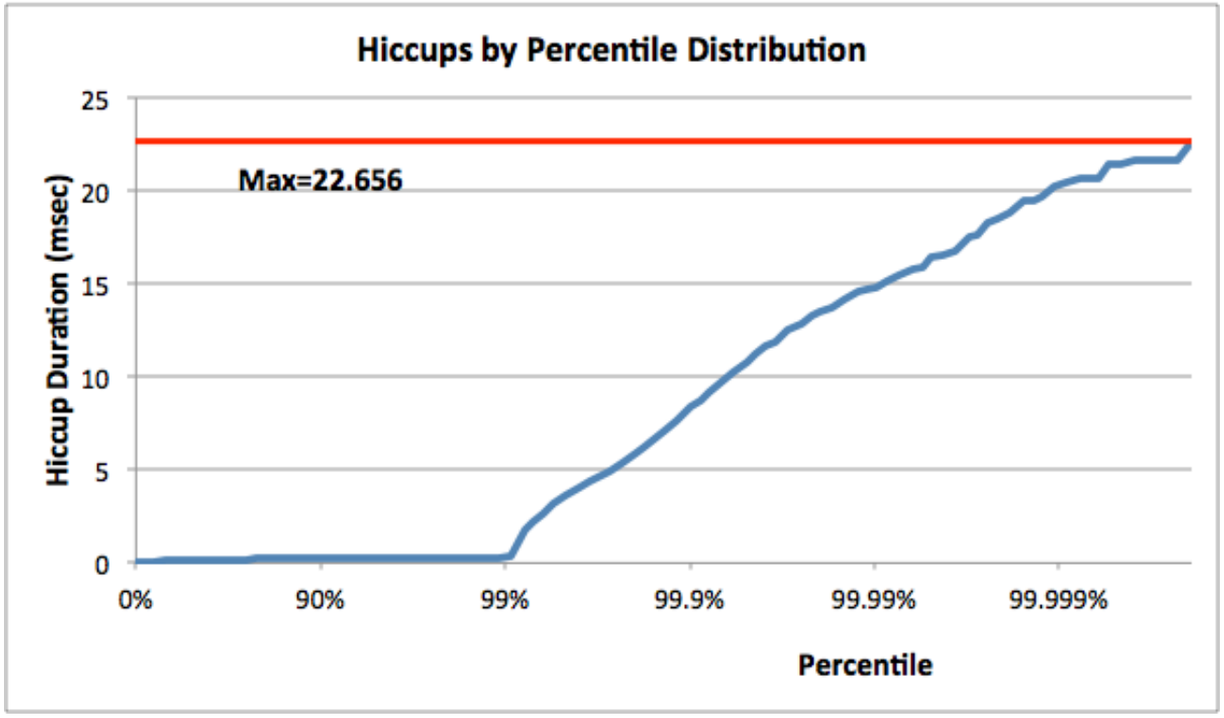
We call these **“hiccups”**



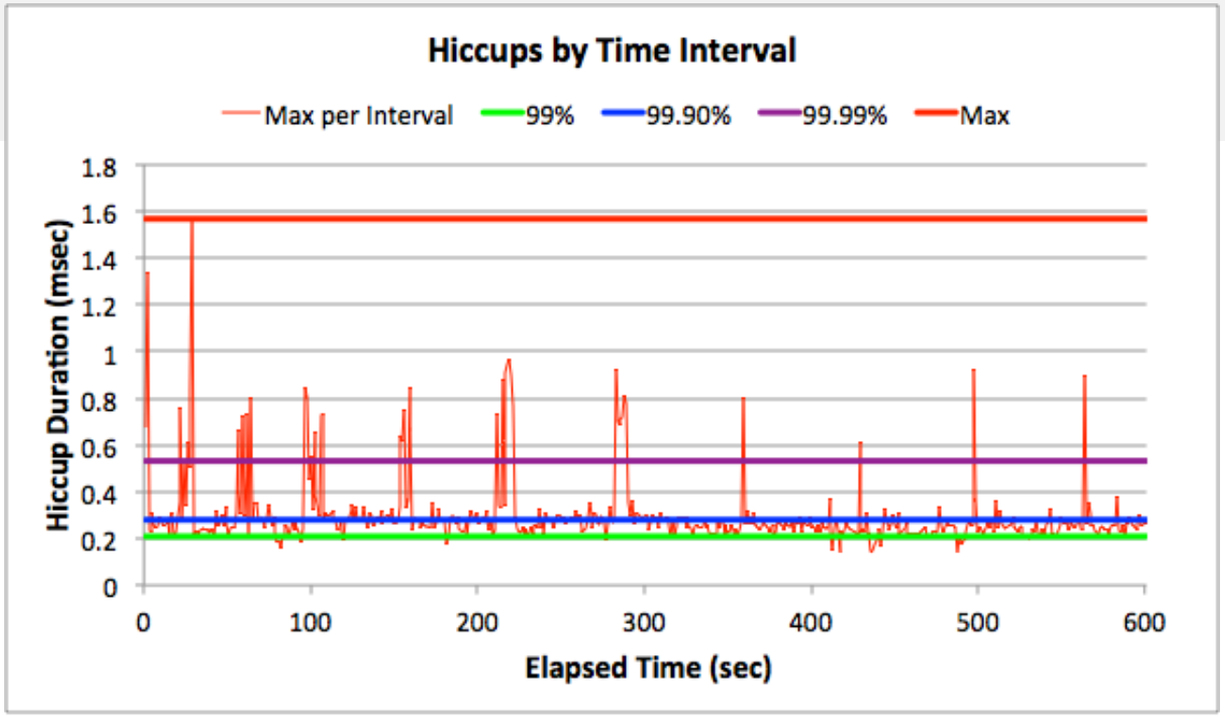
A telco App with a bit of a “problem”

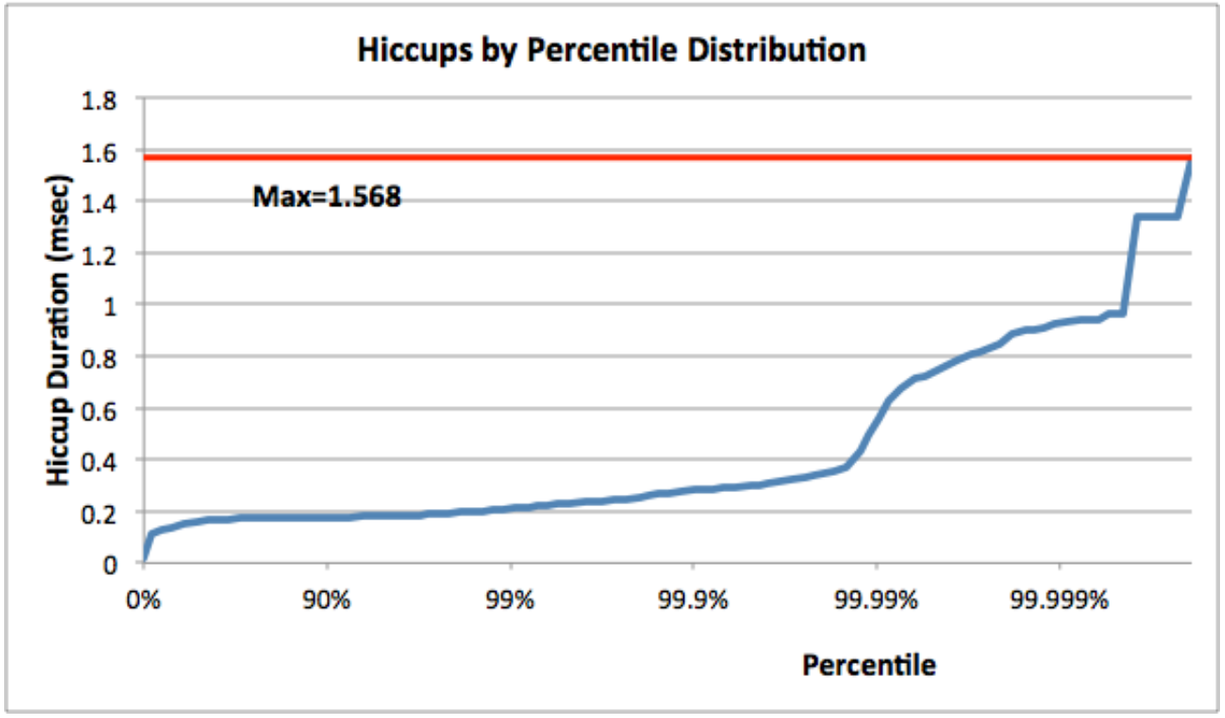
Oracle HotSpot (pure newgen)





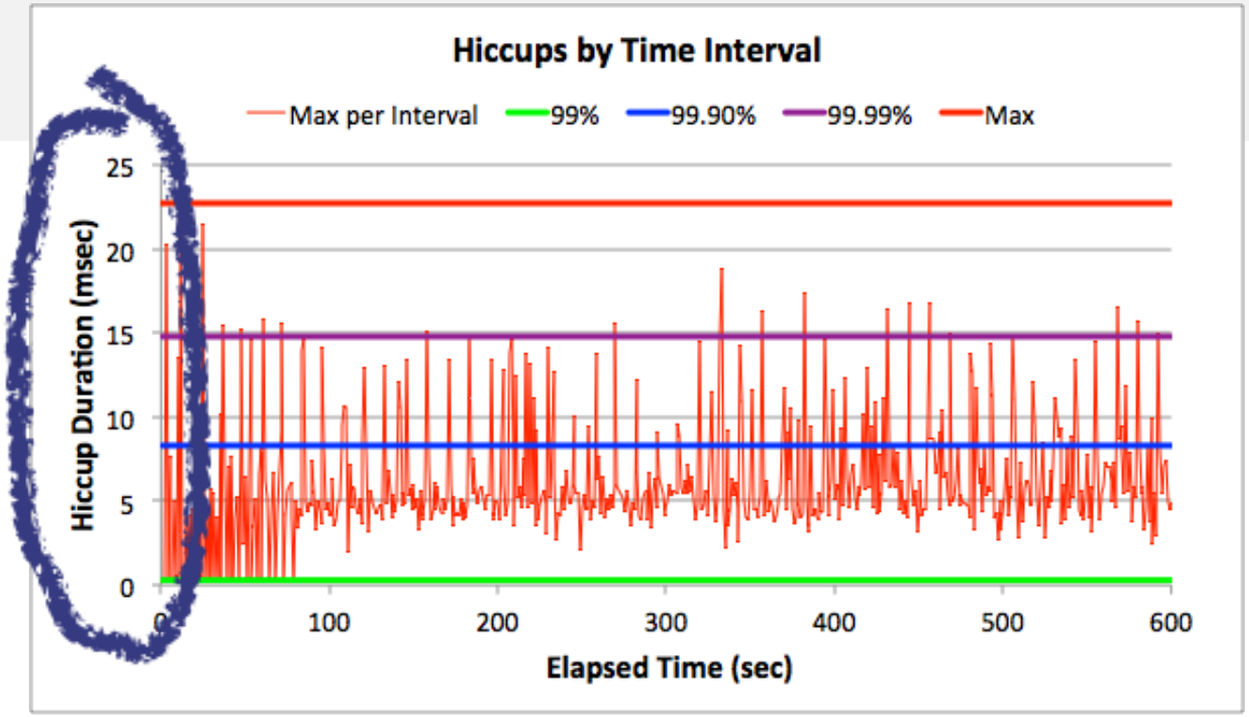
Zing

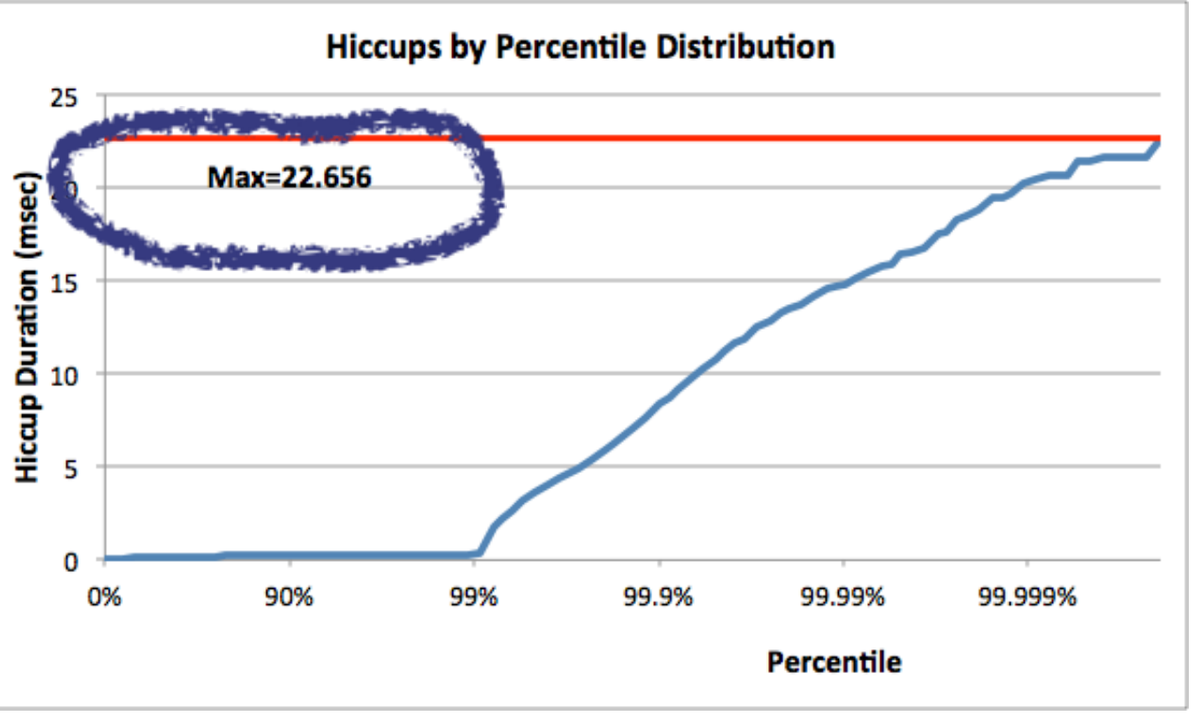




Low latency trading application

Oracle HotSpot (pure newgen)





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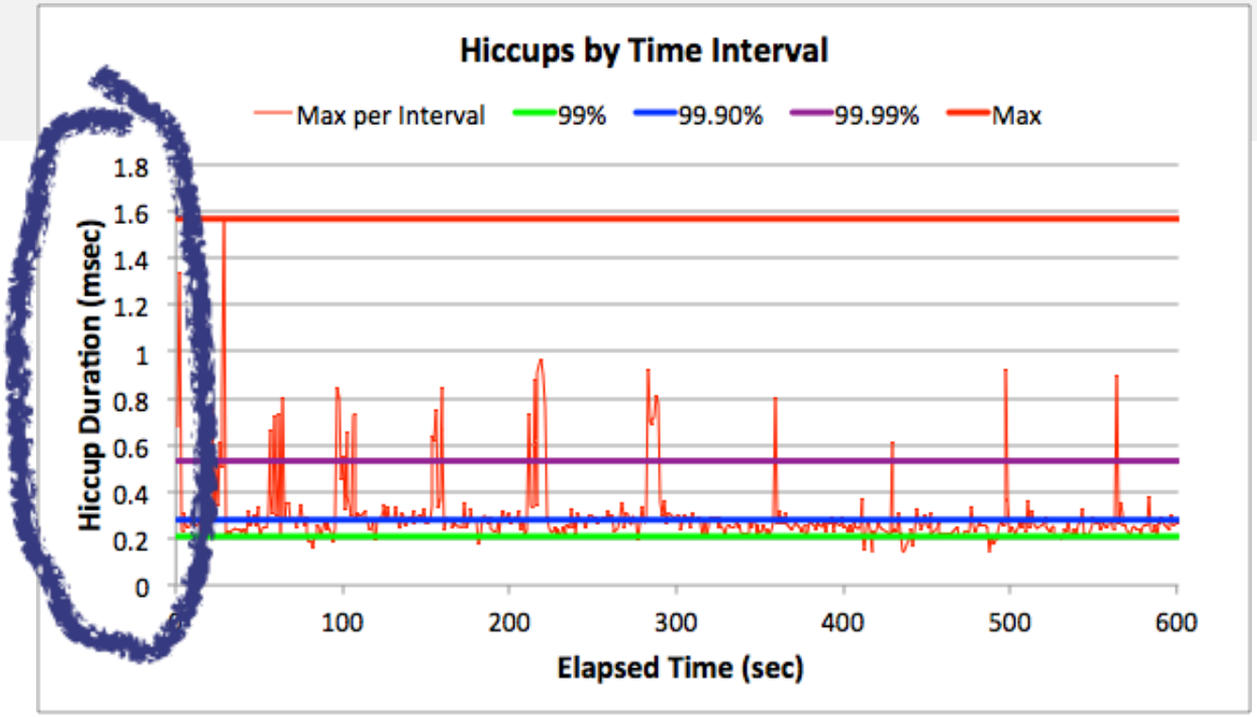

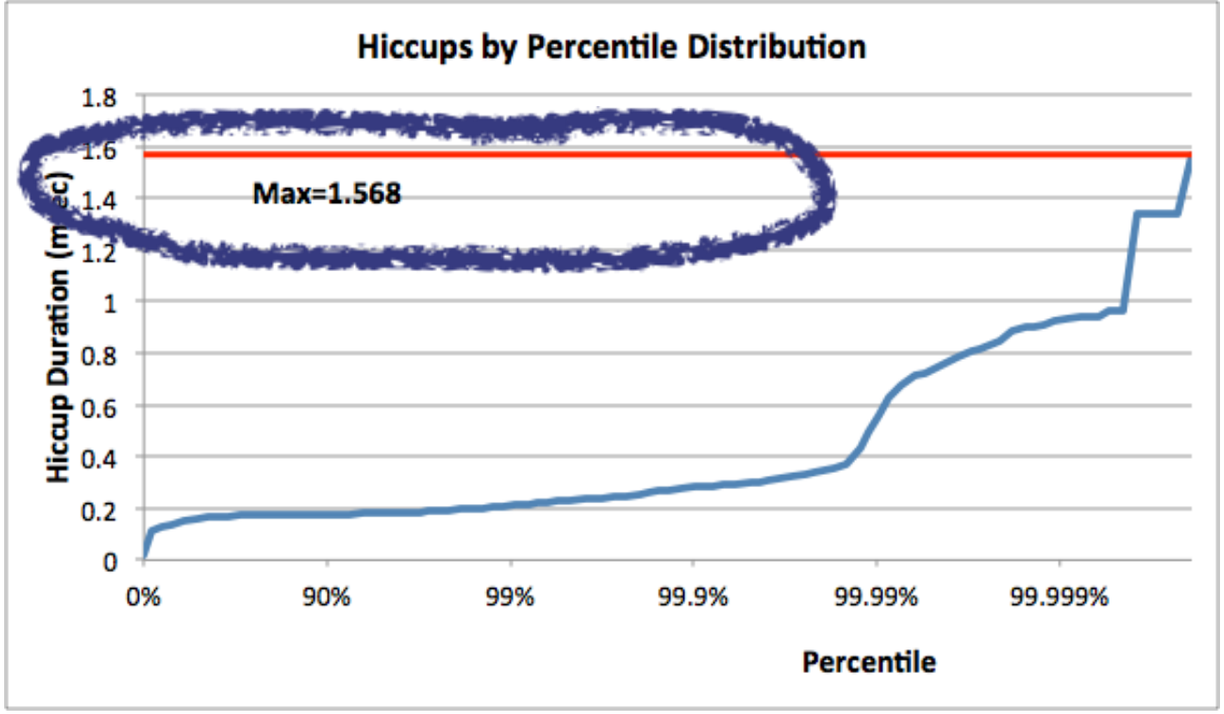

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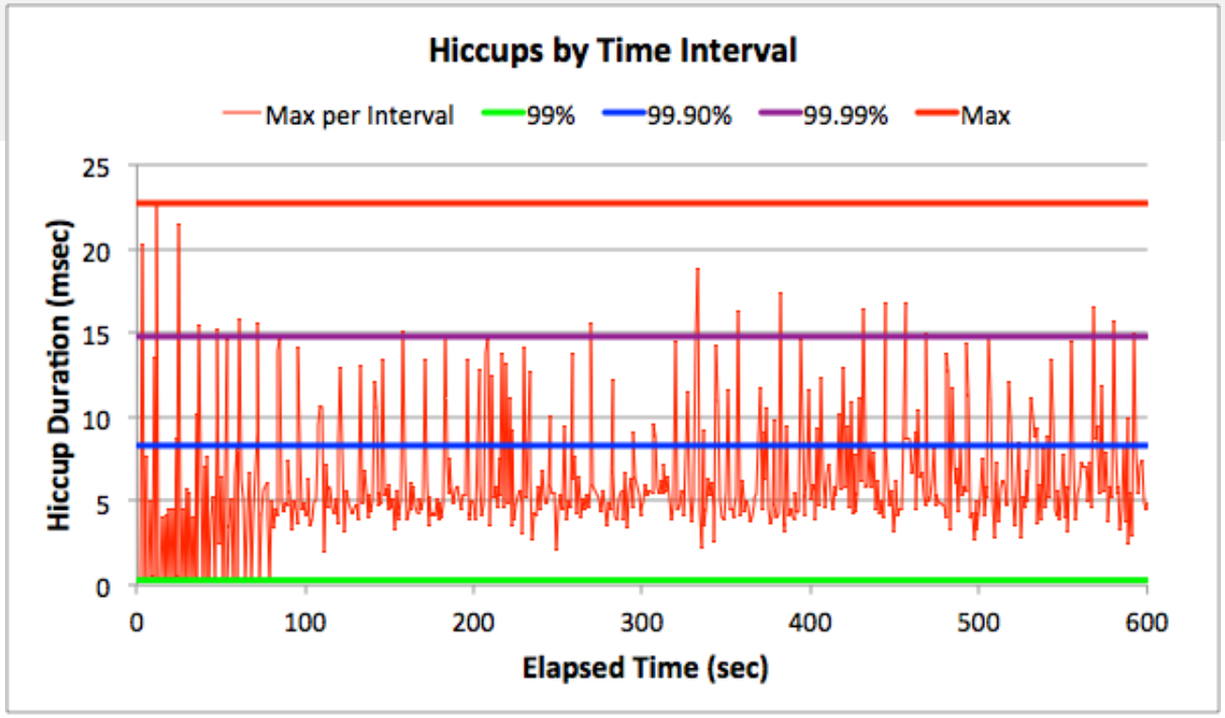

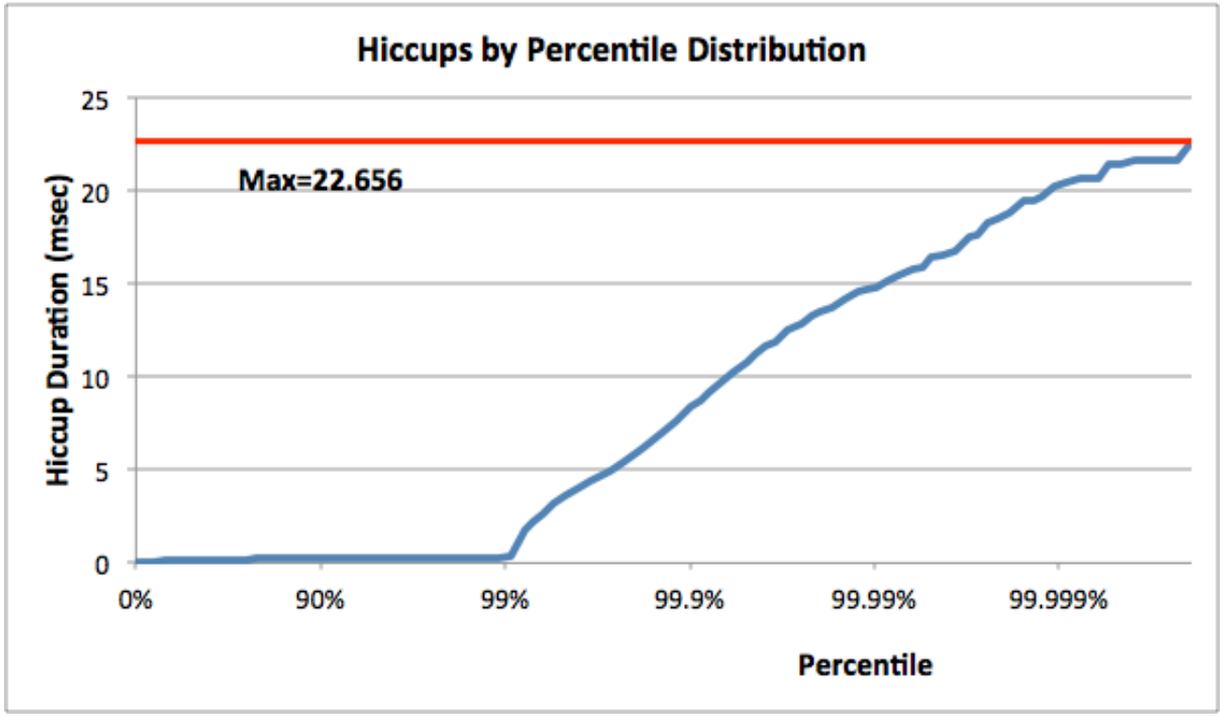

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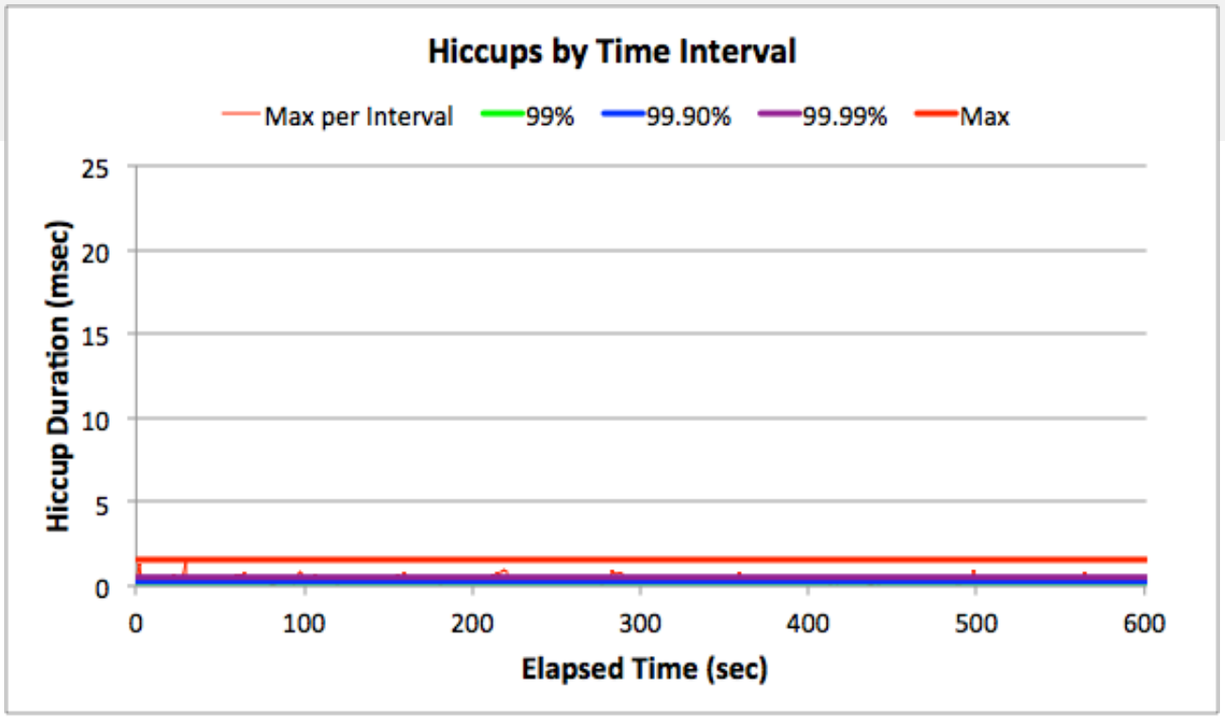
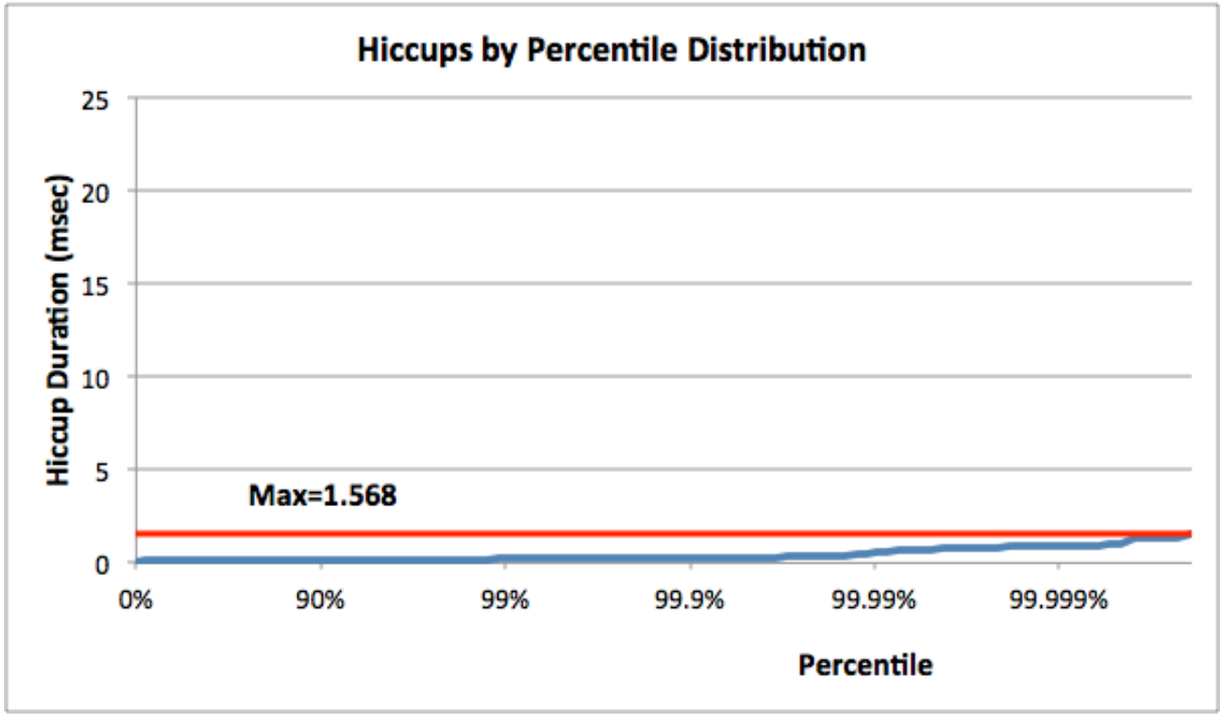


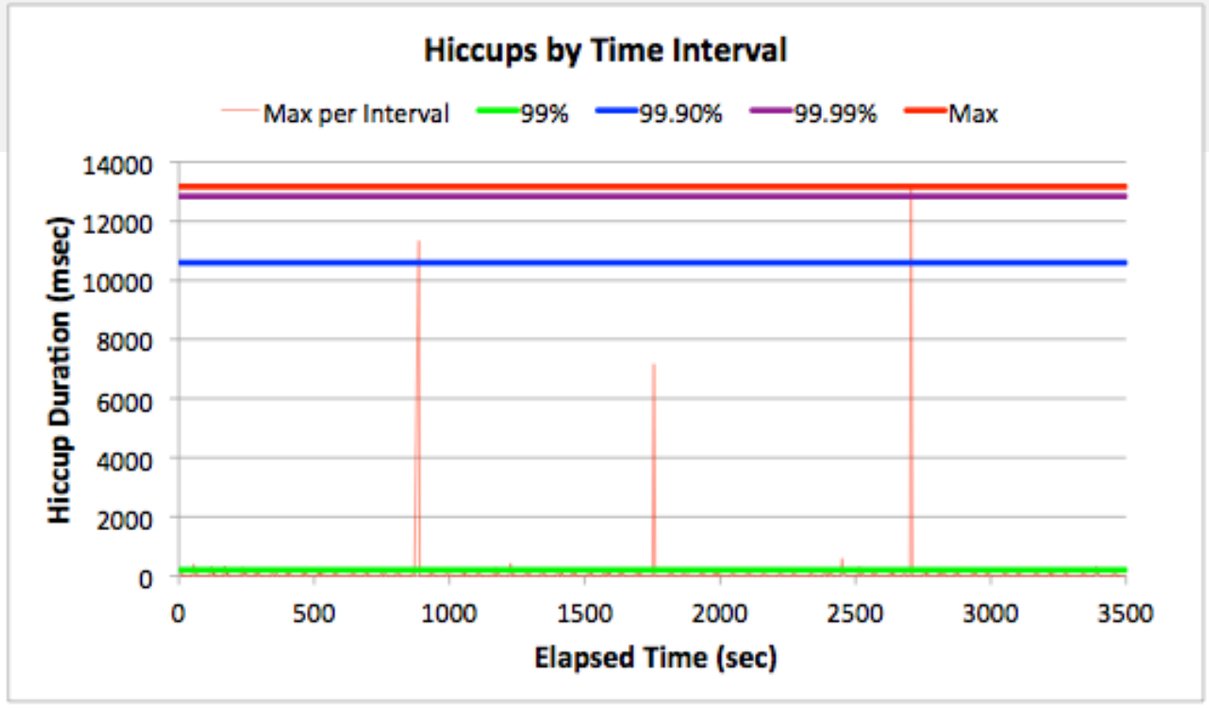


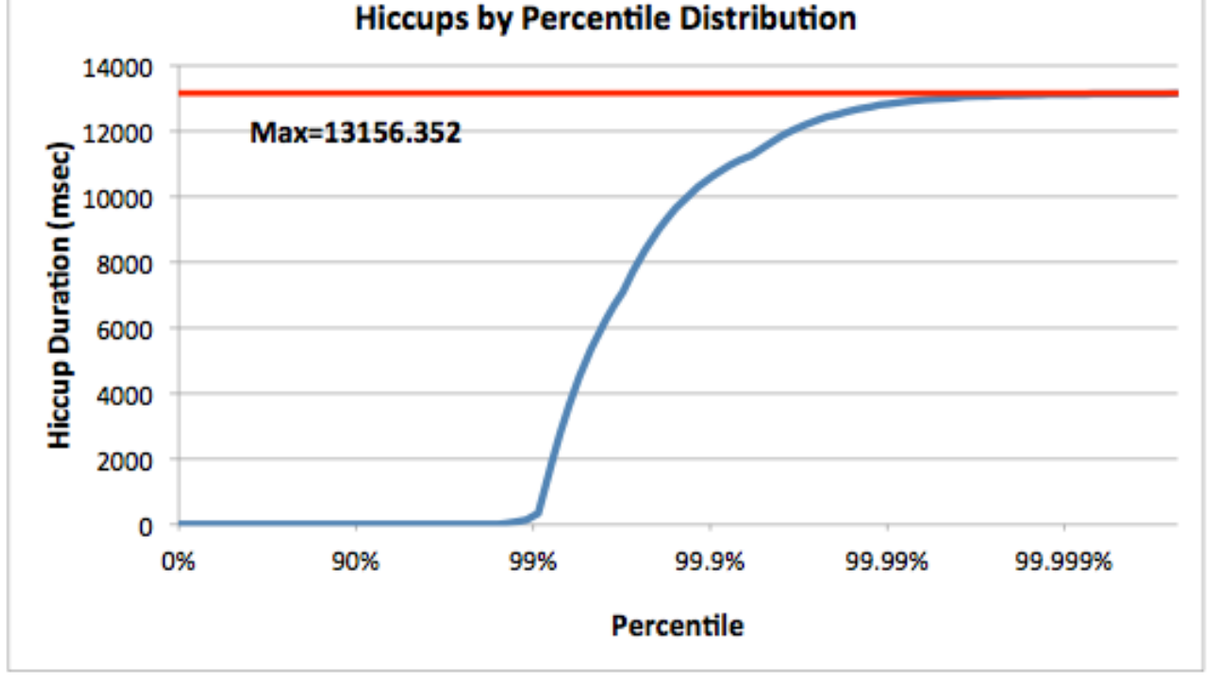
Low latency - Drawn to scale

It’s not just for Low Latency

Just as easy to demonstrate for human-response-time apps

Oracle HotSpot CMS, 1GB in an 8GB heap





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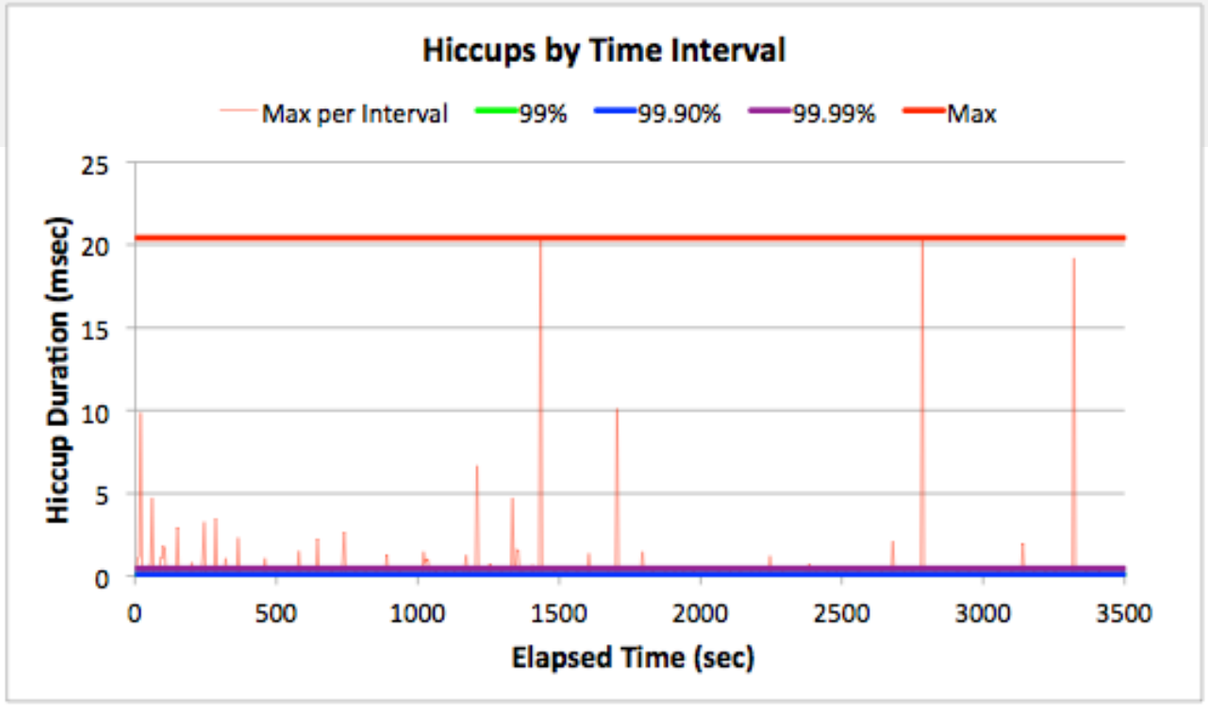

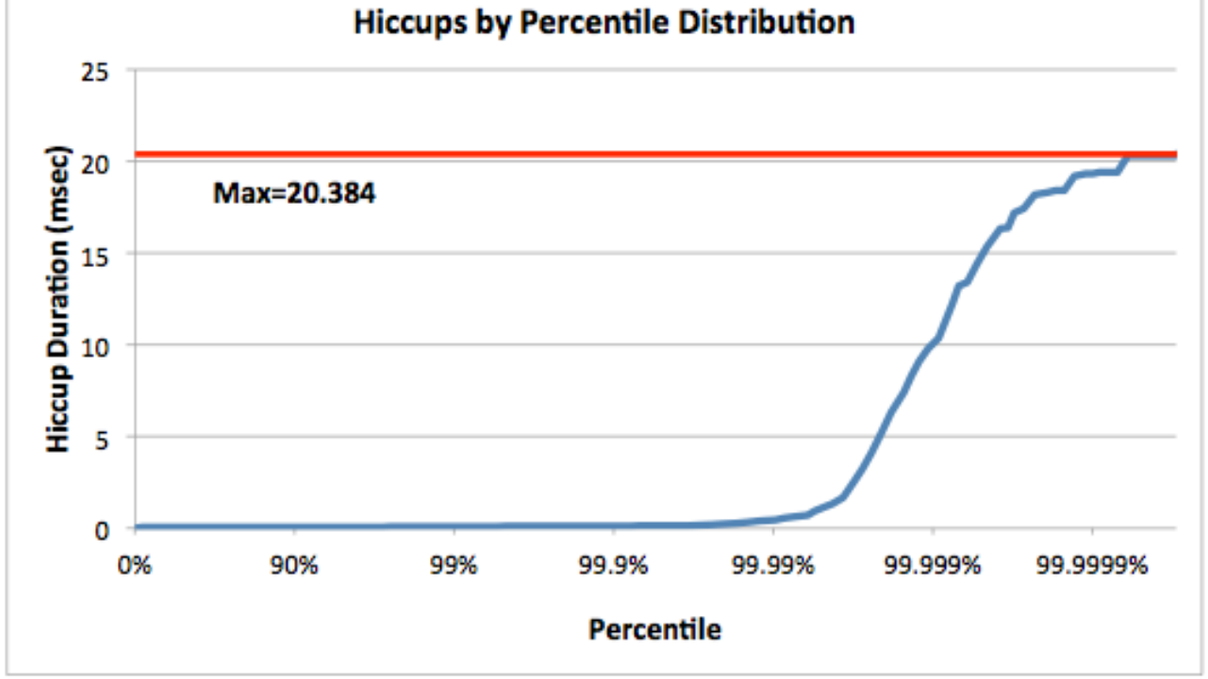

Portal Application, slow Ehcache “churn”

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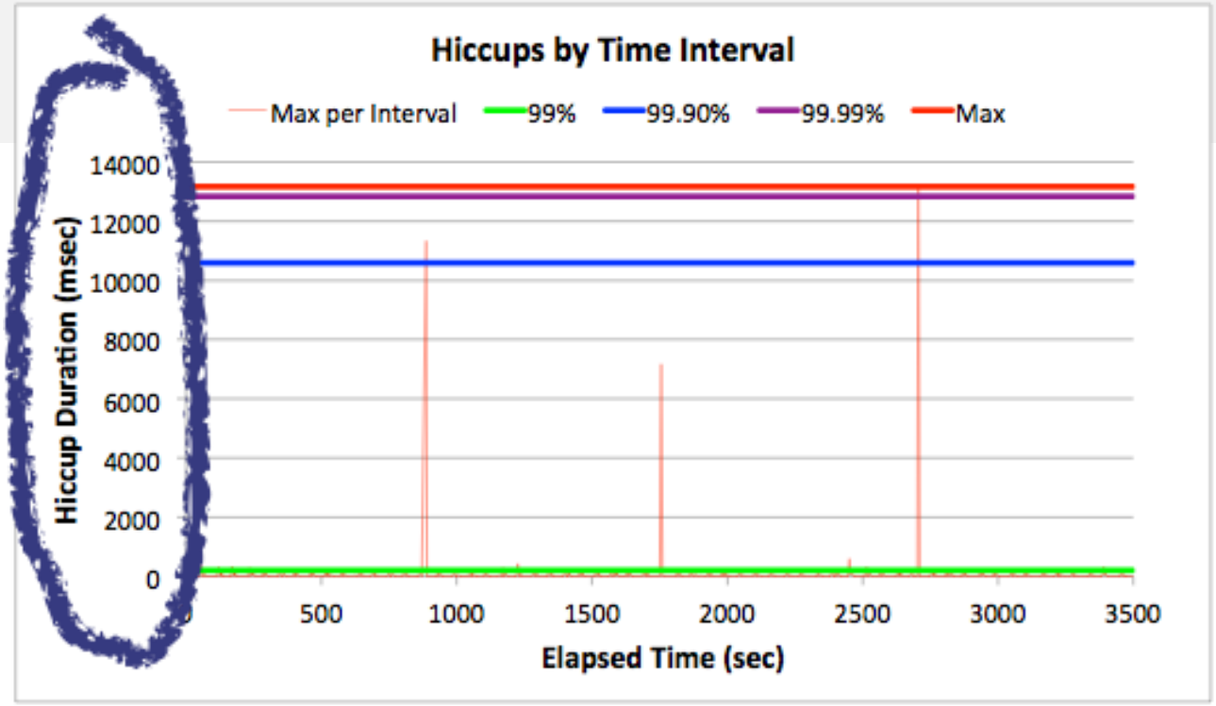

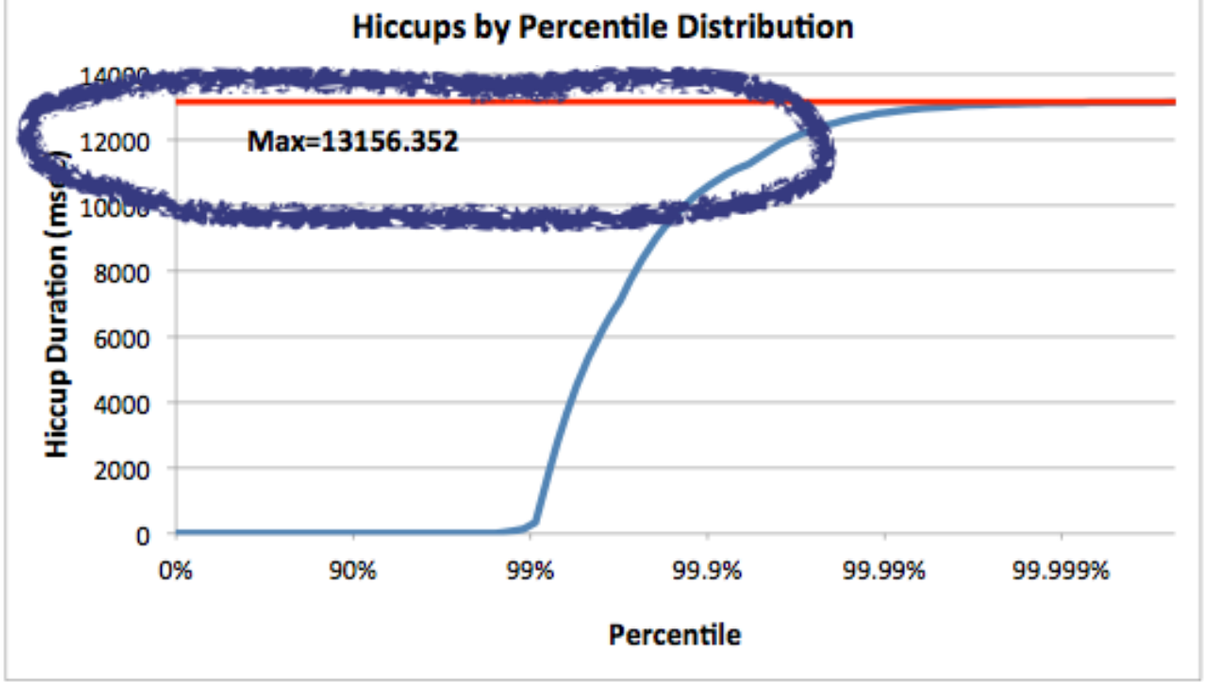

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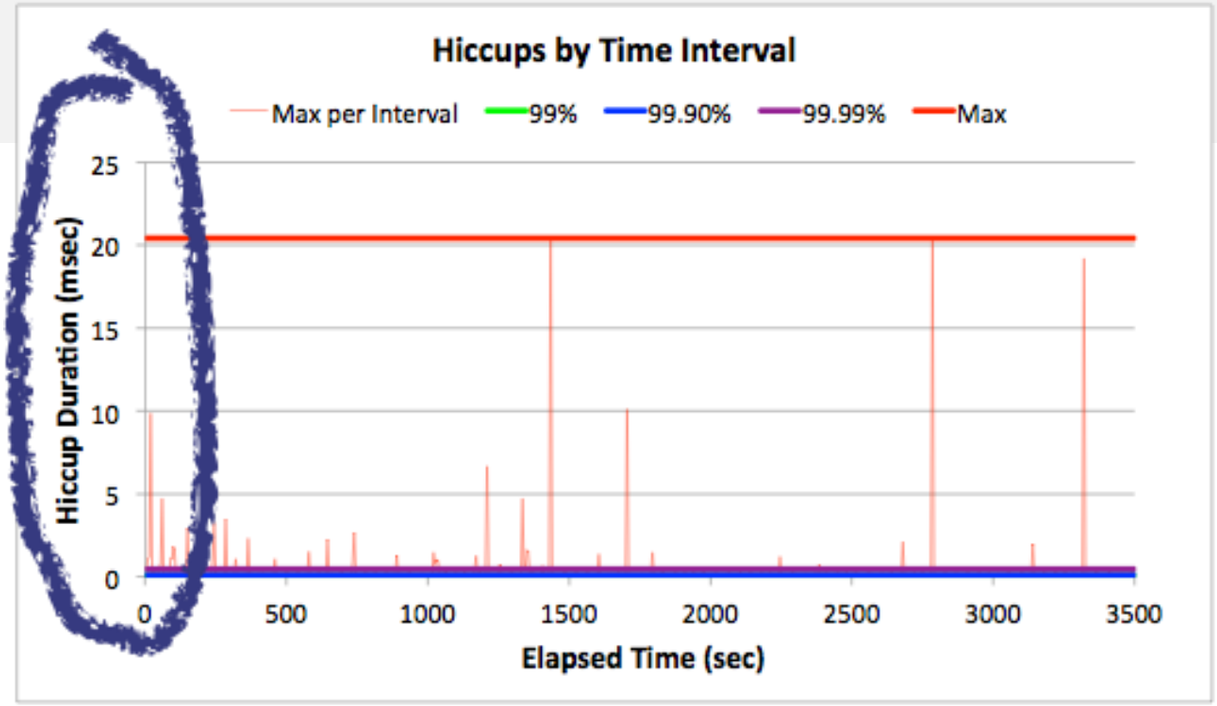

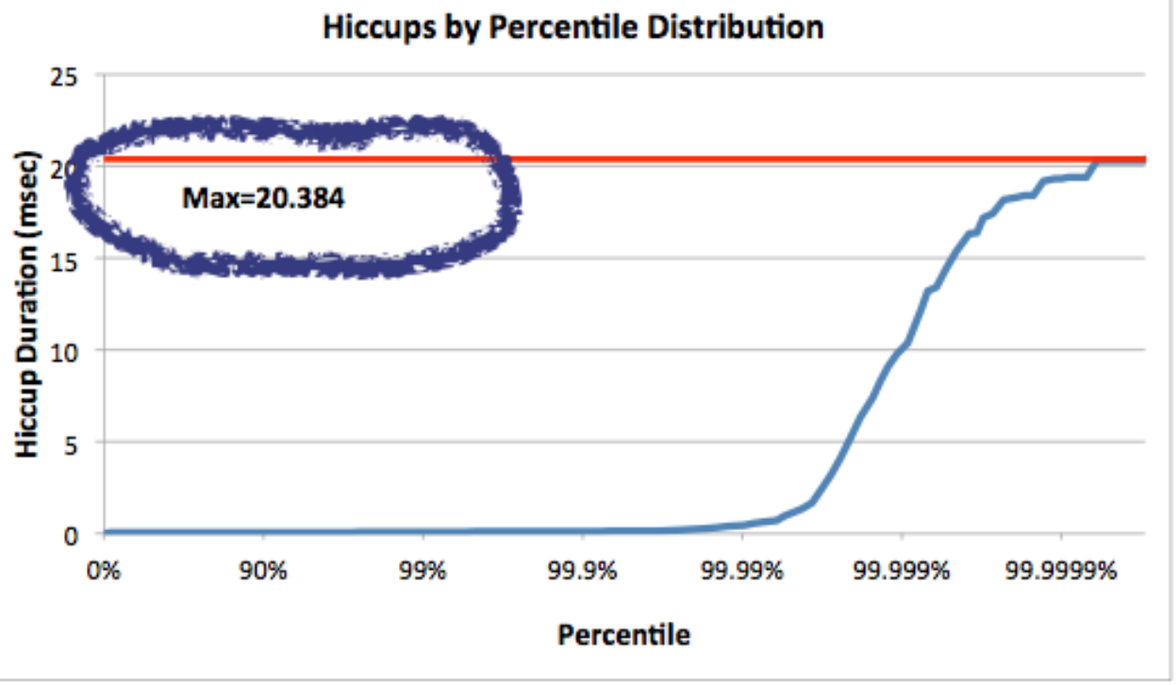

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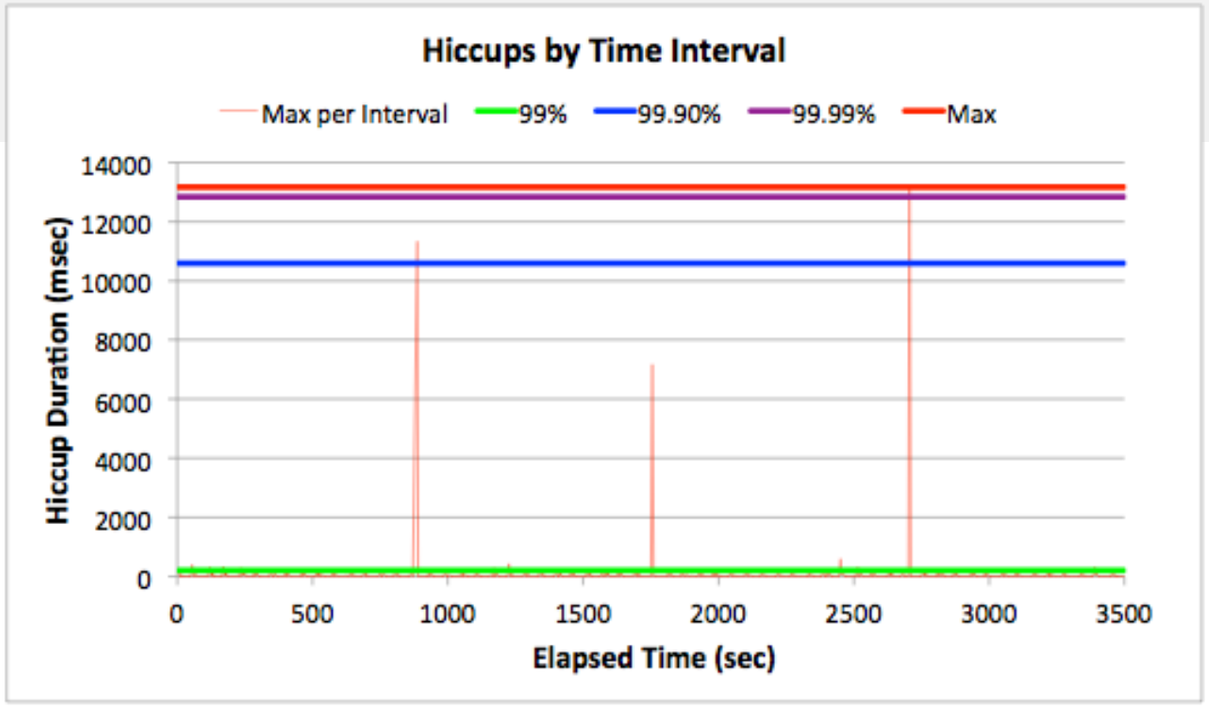

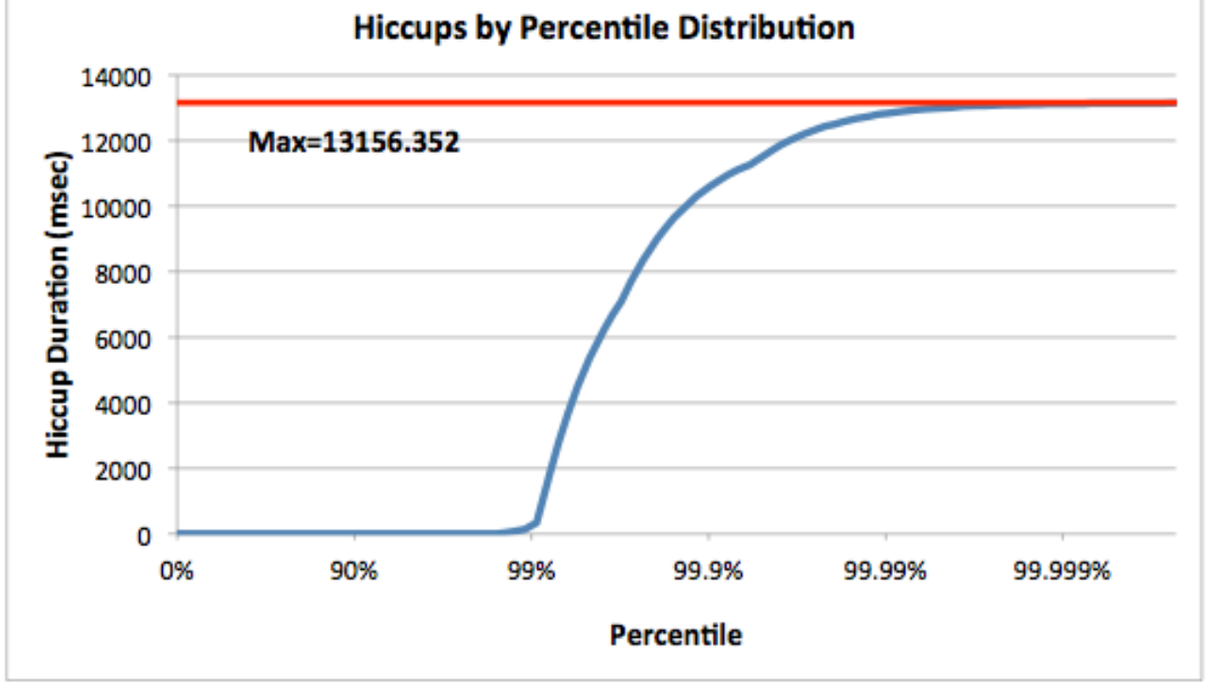

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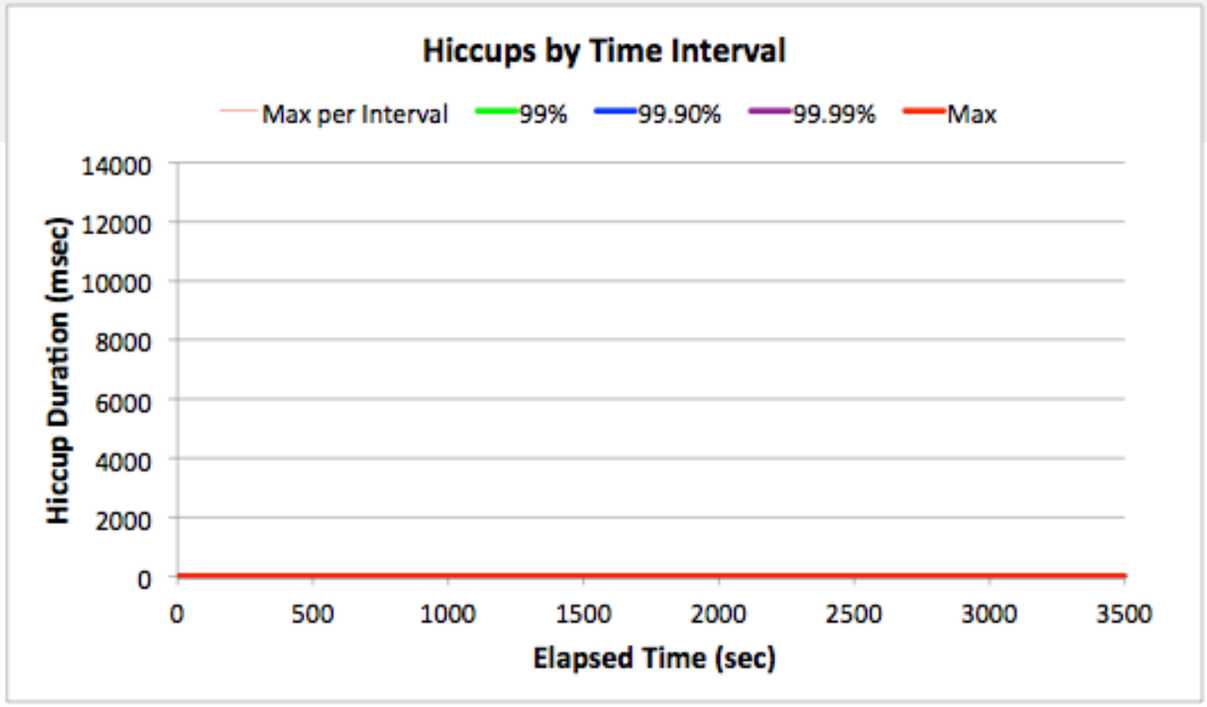
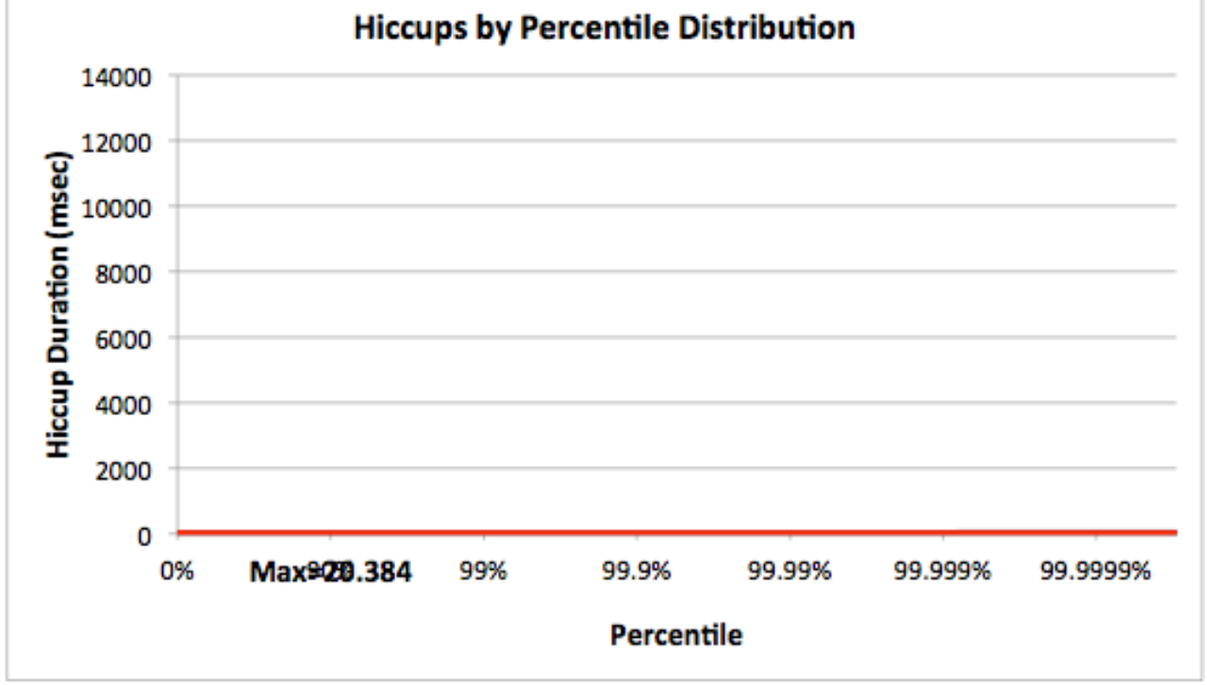


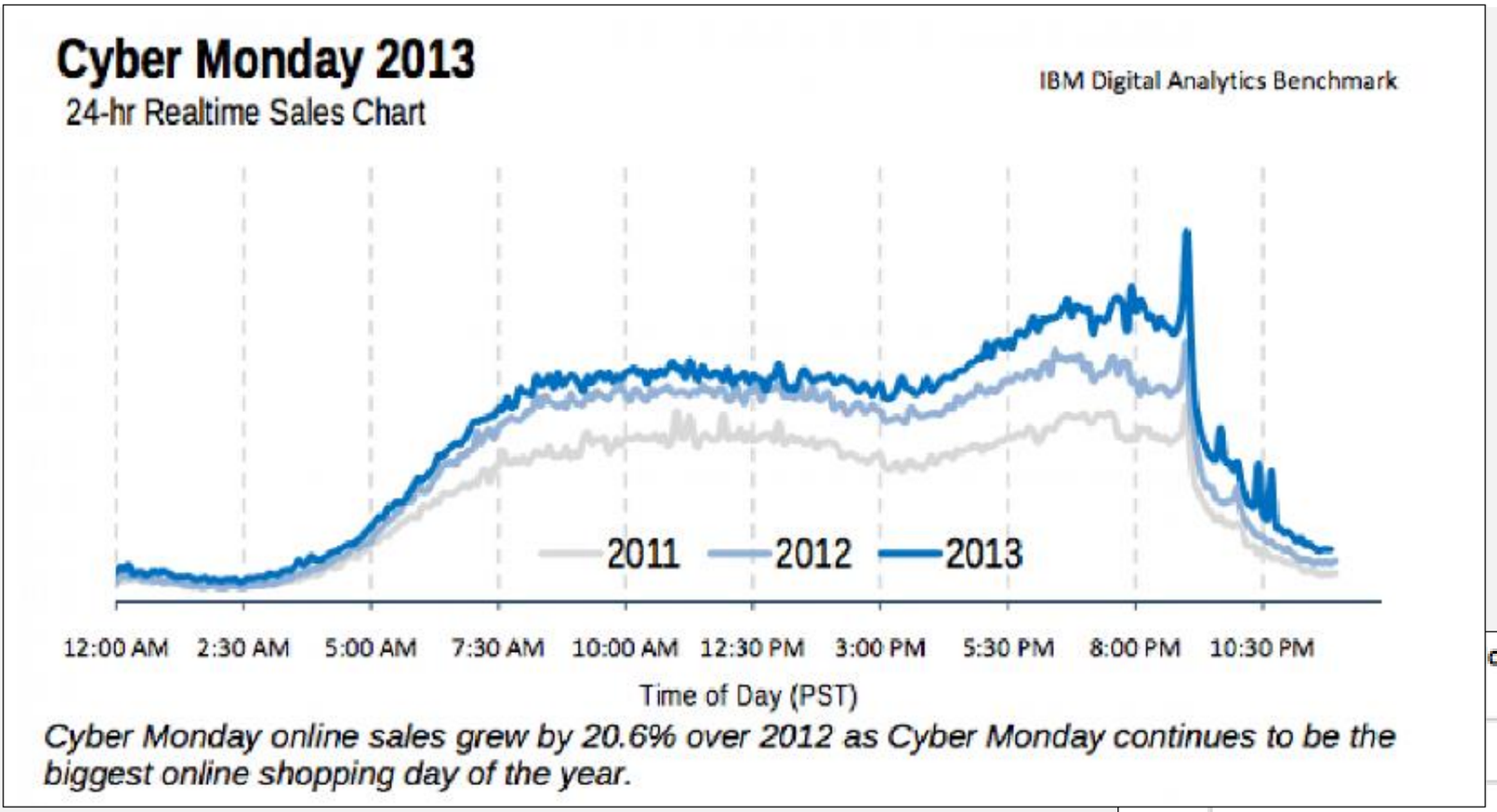


Portal Application - Drawn to scale

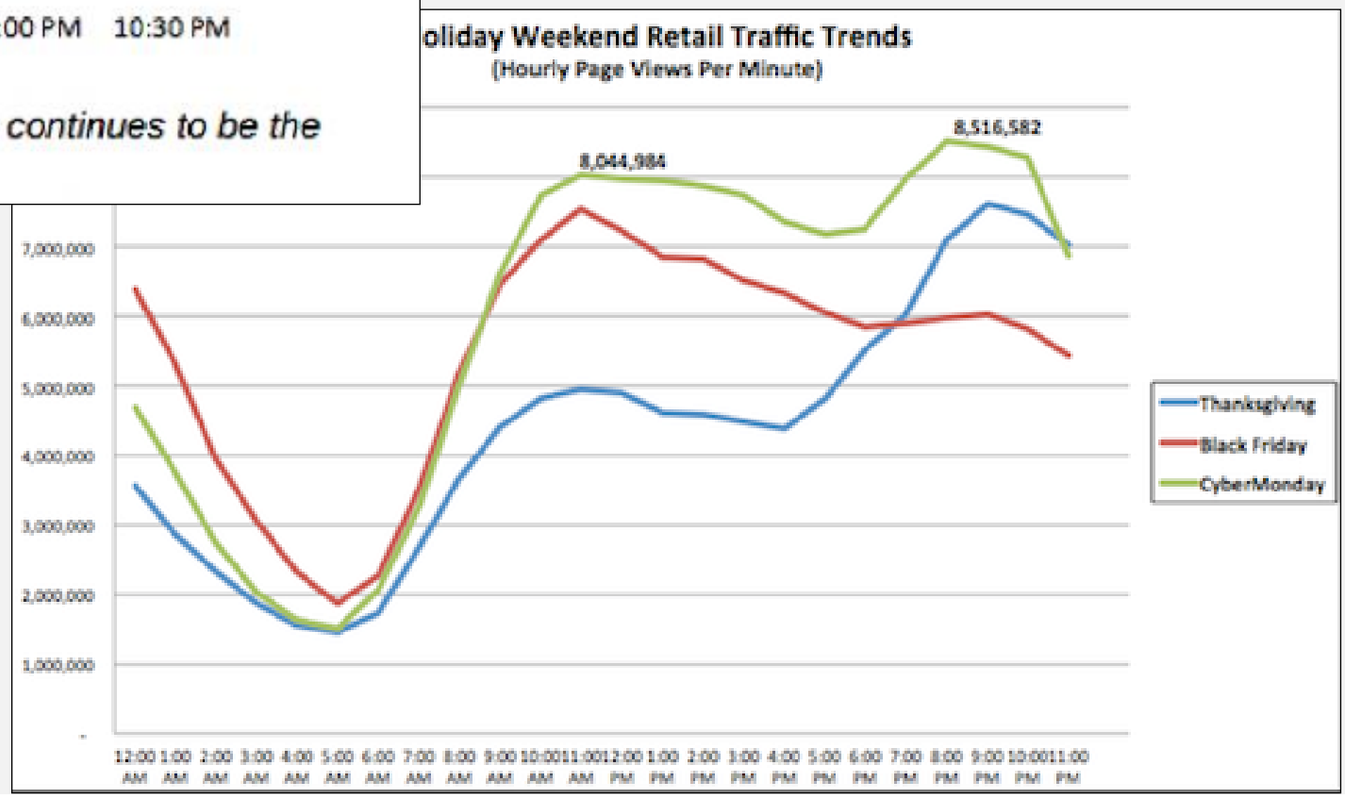
A Recent E-Commerce Case Study

Cyber Monday comes earlier every year…

General trends of real world e-commerce traffic



Cyber Monday online sales grew by 20.6% over 2012 as Cyber Monday continues to be the biggest online shopping day of the year.



Human-Time Real World Latency Case

Specific e-tail customer based in Salt Lake City, Utah.

- Web retail site faces spike loads every year over Thanksgiving through Cyber Monday.
- Site latency suffers at peak viewing and buying times, discouraging shoppers and leaving abandoned carts.
- Hard to predict height of surge, just know its big, far higher than regular traffic 362 other days of the year.
- New features like gallery search (Solr/Lucene) added higher memory footprint, longer GC times.
- Staff spent lots of effort tuning HotSpot.

Real World Latency Results

Timeframe was fall 2014.

- Customer studied Azul, met at Strata, SF
- Discussion led to Zing as viable alternative
- Customer ran pilot tests with positive results. Needed one Linux setting adjustment, otherwise same server gear.
- POC on customer live system (Amazon EC2 nodes) showed better than expected latency profiles.
- No more GC tuning!
- Experienced a stable and profitable Thanksgiving 2014 weekend.

Remind me how GC tuning sucks

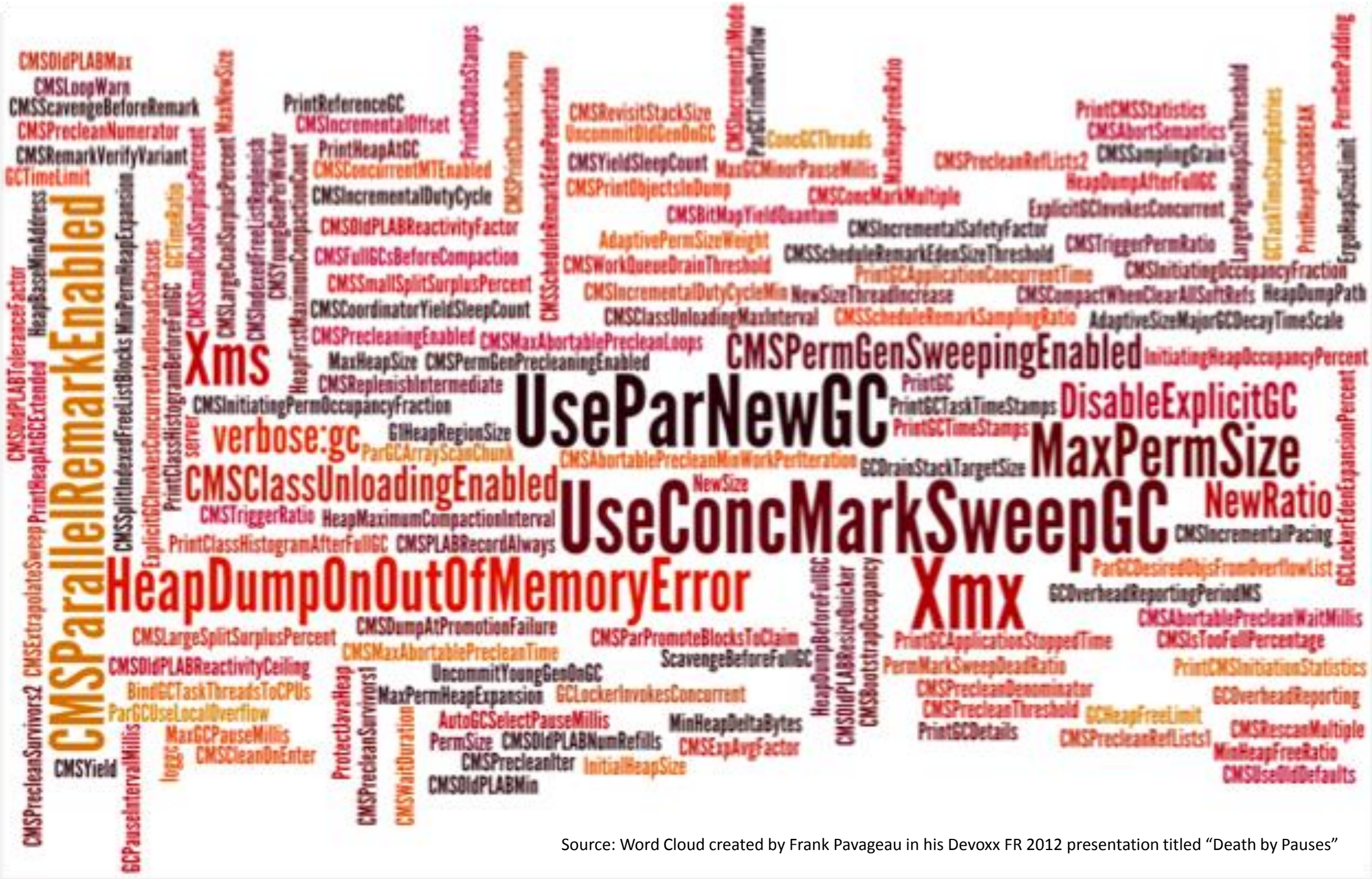
Java GC tuning is “hard”…

- Examples of actual command line GC tuning terms:

Java -Xmx12g -XX:MaxPermSize=64M -XX:PermSize=32M -XX:MaxNewSize=2g
-XX:NewSize=1g -XX:SurvivorRatio=128 -XX:+UseParNewGC
-XX:+UseConcMarkSweepGC -XX:MaxTenuringThreshold=0
-XX:CMSInitiatingOccupancyFraction=60 -XX:+CMSParallelRemarkEnabled
-XX:+UseCMSInitiatingOccupancyOnly -XX:ParallelGCThreads=12
-XX:LargePageSizeInBytes=256m …

Java –Xms8g –Xmx8g –Xmn2g -XX:PermSize=64M -XX:MaxPermSize=256M
-XX:-OmitStackTraceInFastThrow -XX:SurvivorRatio=2 -XX:-UseAdaptiveSizePolicy
-XX:+UseConcMarkSweepGC -XX:+CMSConcurrentMTEnabled
-XX:+CMSParallelRemarkEnabled -XX:+CMSParallelSurvivorRemarkEnabled
-XX:CMSMaxAbortablePrecleanTime=10000 -XX:+UseCMSInitiatingOccupancyOnly
-XX:CMSInitiatingOccupancyFraction=63 -XX:+UseParNewGC –Xnoclassgc …

A few GC tuning flags



Source: Word Cloud created by Frank Pavageau in his Devoxx FR 2012 presentation titled “Death by Pauses”

Complete guide to Zing GC tuning

java -Xmx40g

Any other problems beyond GC?

JVMs make many tradeoffs often trading speed vs. outliers

- Some speed techniques come at extreme outlier costs
  - E.g. (“regular”) biased locking
  - E.g. counted loops optimizations
- Deoptimization
- Lock deflation
- Weak References, Soft References, Finalizers
- Time To Safe Point (TTSP)

Time To Safepoint: Your new #1 enemy

Once GC itself was taken care of

- Many things in a JVM (still) use a global safepoint
- All threads brought to a halt, at a “safe to analyze” point in code, and then released after work is done.
- E.g. GC phase shifts, Deoptimization, Class unloading, Thread Dumps, Lock Deflation, etc. etc.
- A single thread with a long time-to-safepoint path can cause an effective pause for all other threads. Consider this a variation on Amdahl’s law.
- Many code paths in the JVM are long...

Time To Safepoint (TTSP), the most common examples

- Array copies and object clone()
- Counted loops
- Many other variants in the runtime...
- Measure, Measure, Measure...

- Zing has a built-in TTSP profiler
- At Azul, the CTO walks around with a 0.5msec beat down stick...

OS related stuff

Once GC and TTSP are taken care of

- OS related hiccups tend to dominate once GC and TTSP are removed as issues.
- Take scheduling pressure seriously (Duh?)
- Hyper-threading (good? bad?)
- Swapping (Duh!)
- Power management
- Transparent Huge Pages (THP).
- ...

Takeaway: In 2015, “Real” Java is finally viable for low latency applications

- GC is no longer a dominant issue, even for outliers
- 2-3 msec worst case with “easy” tuning
- < 1 msec worst case is very doable
- No need to code in special ways any more
  - You can finally use “real” Java for everything
  - You can finally 3rd party libraries without worries
  - You can finally use as much memory as you want
  - You can finally use regular (good) programmers

One-liner Takeaway:

Zing: the cure for your Java hiccups

Compulsory Marketing Pitch

Azul Hot Topics

Zing 15.05 imminent

- 1TB heap
- ReadyNow!
- JMX
- Oracle Linux

Zing for Cloud

- Amazon AMIs
- Rackspace OnMetal compat
- Docker in R&D

Zing for Big Data

- Cloudera CDH5 cert
- Cassandra paper
- Spark is in Zing open source program

Zulu

- Azure Gallery
- JSE Embedded
- 8u45 available
- 7u80 is a new era

Q&A and In Closing…

- Go get some **Zing** today!
- At very least download **JHiccup**.
- Grab a Zing **Free Trial** card.
- Gooey Butter Cake **vs.** The Concrete

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