Low Latency Java in the Real World

LMAX Exchange and the Zing® JVM

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About the Author: Gil Tene

- co-founder, CTO @Azul Systems
- Has been working on "think different" GC approaches since 2002
- A Long history building Virtual & Physical Machines, Operating Systems, Enterprise apps, etc…
- Depresses people by demonstrating how terribly wrong their latency measurements are…

* working on real-world trash compaction issues, circa 2004

About the Author: Mark Price

- Senior Developer at LMAX Exchange
- Performance enthusiast
- Touched pretty much everything at LMAX over a period of 8 years…
- Currently focusing on performance and monitoring
- The guy that everyone used to come to with their GC logs…

About me: Matt Schuetze

- Product Management Director at Azul
- Translate Voice of Customer into Zing and Zulu requirements and work items
- Sing the praises of Azul efforts through product launches
- Azul alternate on JCP exec committee, co lead Detroit JUG
- Stand on the shoulders of giants and admit it
- Riding the Java hype cycle roller coaster on a bicycle…

Background

- LMAX Exchange is a venue for low-latency FX trading
- World's first regulated MTF for transparent, order-driven FX trading
- 1st place in Tech Track 100 2014
- We aim to be the world's fastest retail FX exchange
- Open culture. A lot of open source

Zing: what is it good for?

- Not just fast. Always fast.
- Eliminates GC as a problem/concern
  - Addresses all forms of GC pauses, large & small
    - Low latency or Human-scale latency
    - Small or Large heaps, Low or High throughput
    - GC is simply a solved problem. Move on…
- Idiomatic Java code "just works"
  - Even when blips and pauses are not an option

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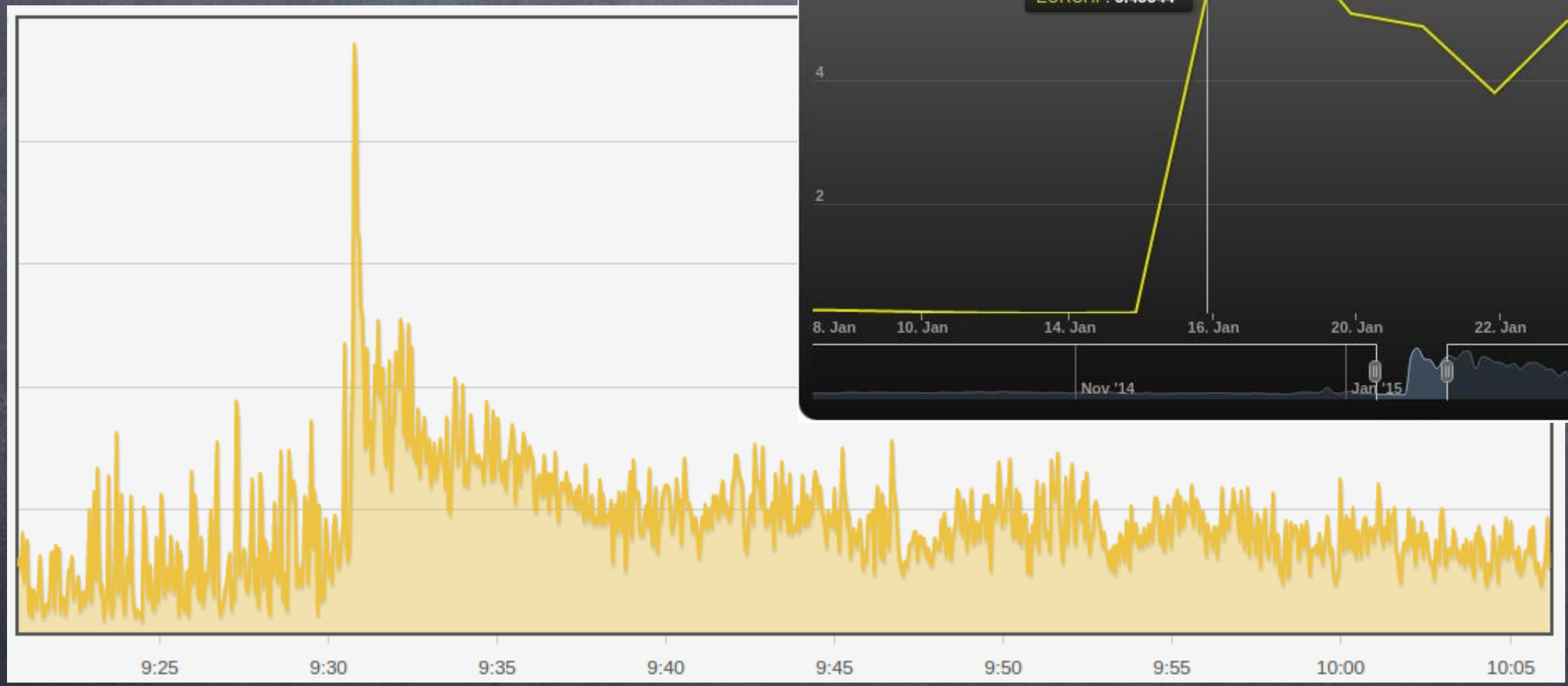
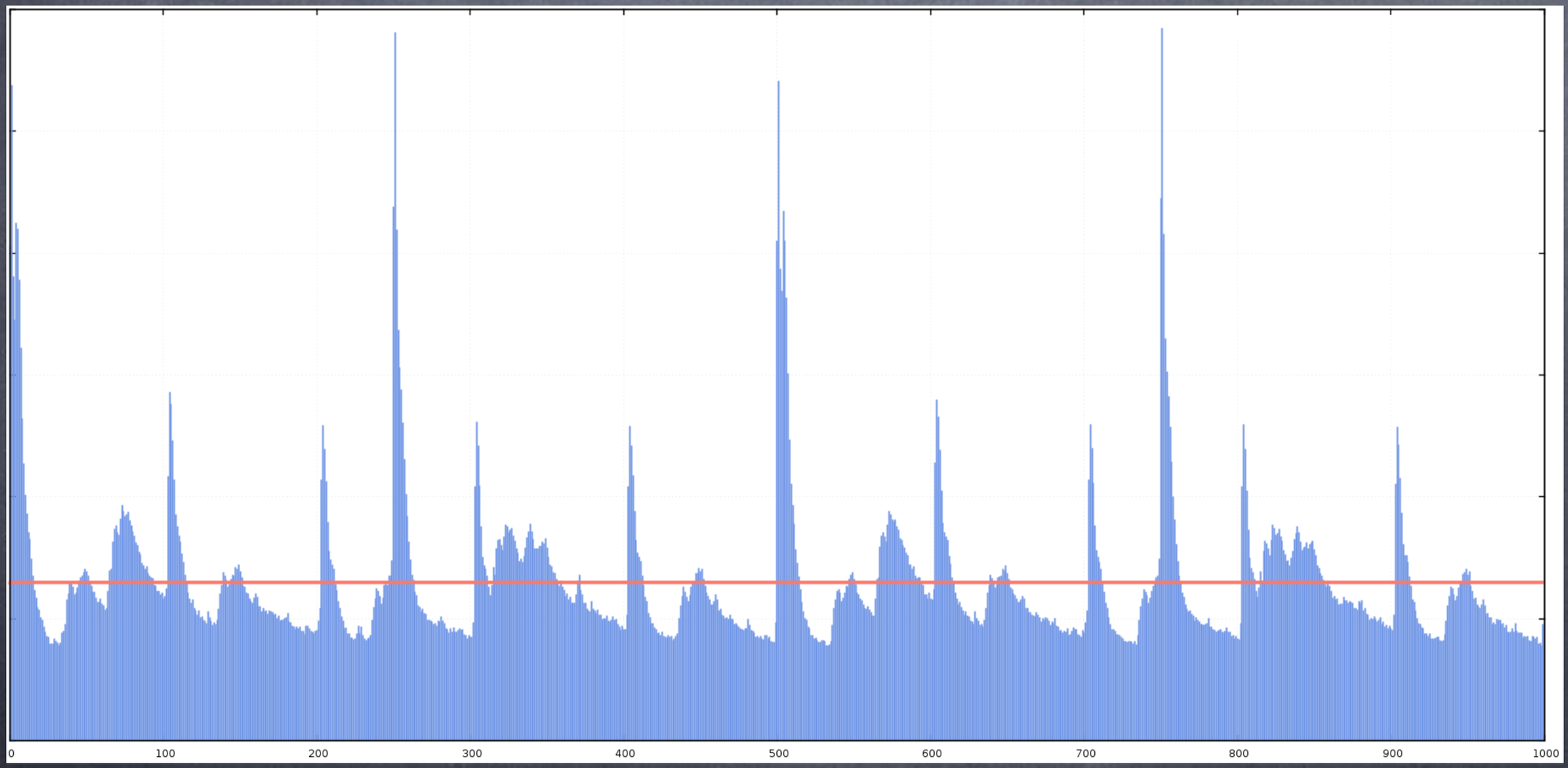
Stay Responsive

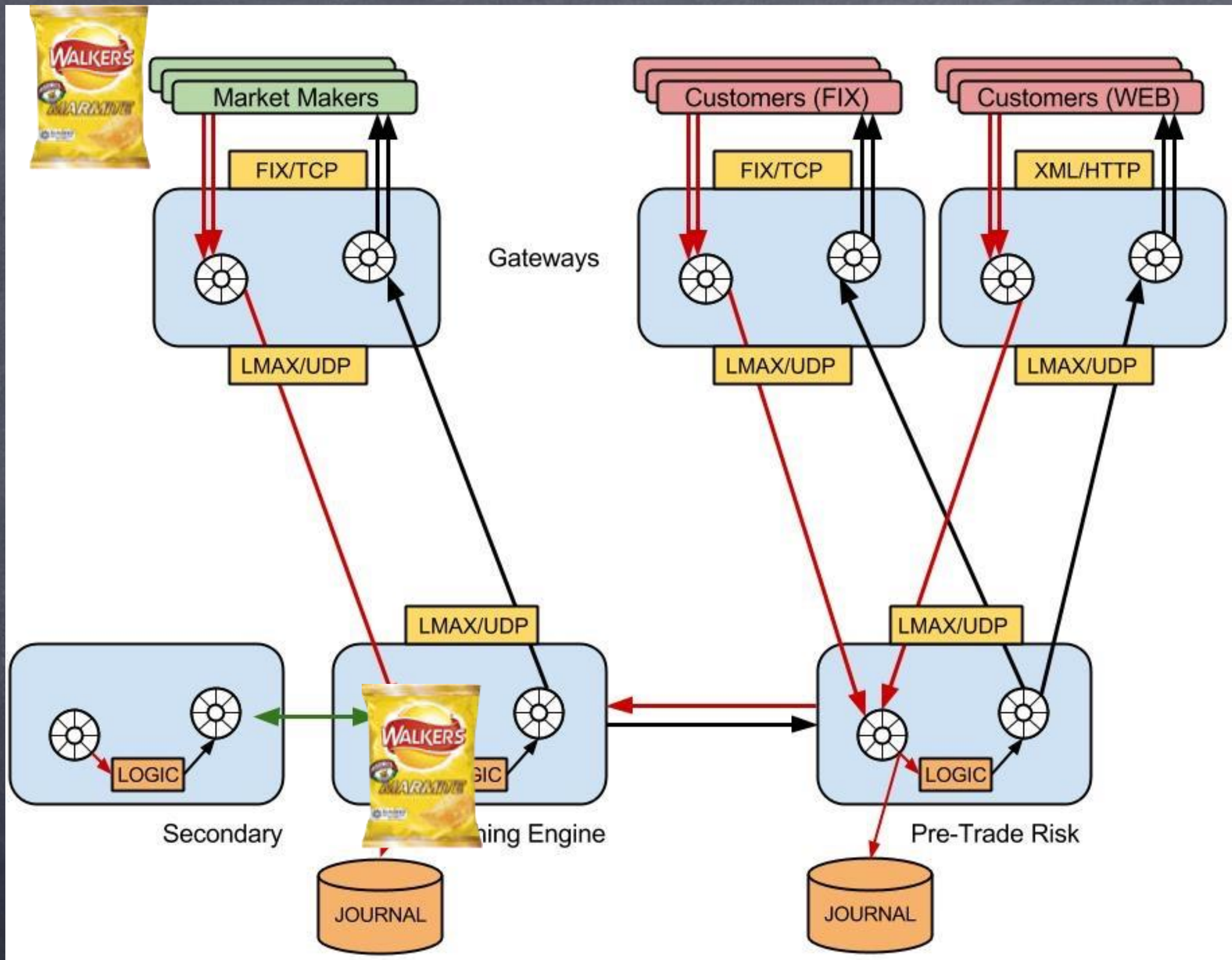


Even when traffic patterns change

Real world traffic patterns

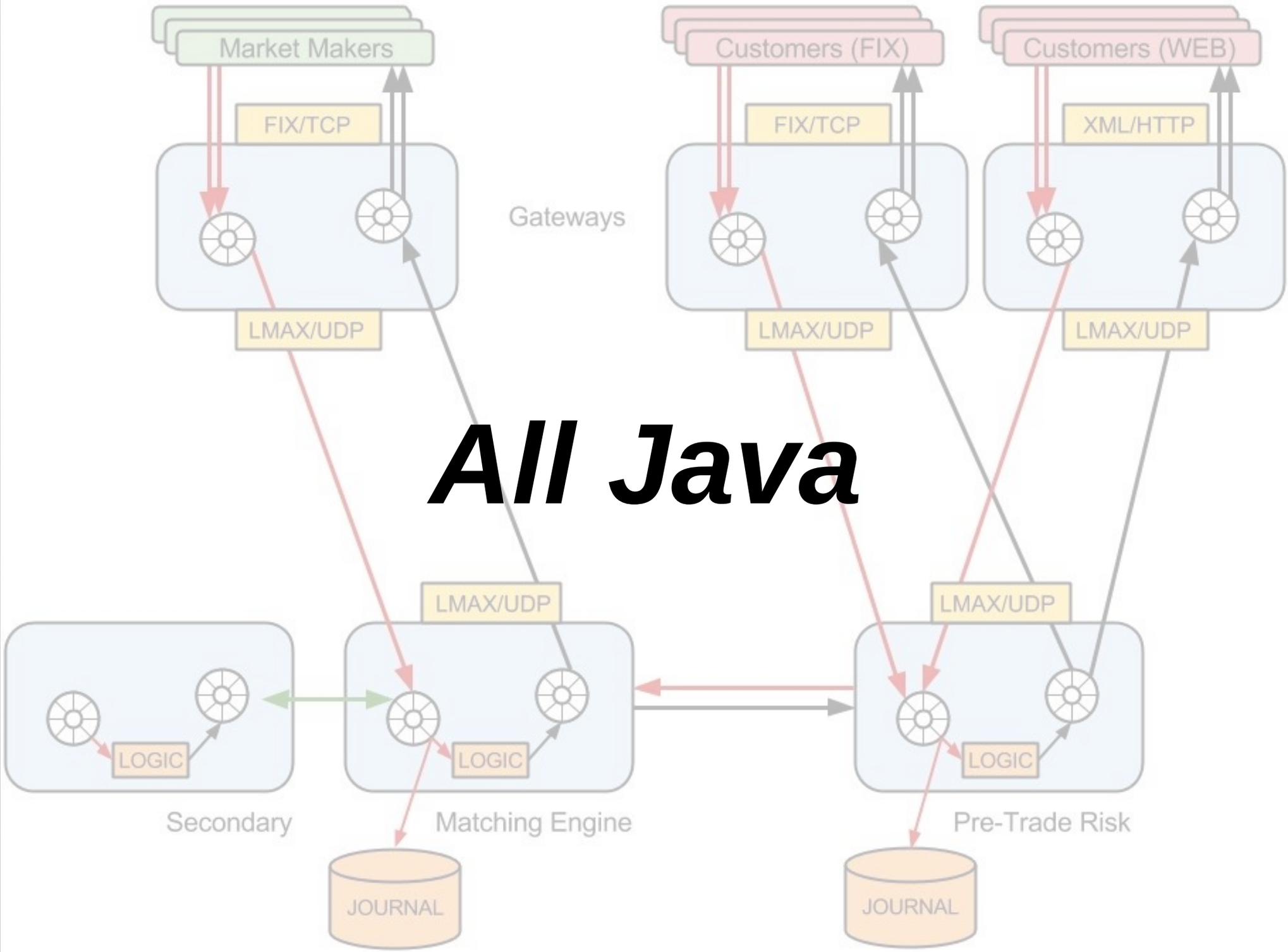


Not constant. Not random either.



Java for low latency

- Seriously?
- Yes...
  - Time to Stability
  - Time to Market
  - Time to Performance
- Overall productivity and delivery benefits trump the various downsides



All Java

The good, the bad, and the ugly

- Java is fast. Java is productive.
  - Good developers will produce good, fast code
  - Bad developers will produce bad, slow code
  - More Java devs than C/C++ devs (good & bad)
- But JVMs are [normally] not consistently fast
  - GC pauses & Deoptimization & Deflation, oh my.
- Low latency "Java" usually:
  - Written in the Java syntax. Avoids idiomatic Java.
  - Avoid using anyone else's code...

Zing's impact on low latency Java

- Zing is a JVM that values consistent speed
  - GC (and JVM) "noise" reduced to below OS "noise"
- Keeps the good
- Removes the bad and the ugly
- Eliminates GC-related engineering efforts
  - All the associated bad and ugly choices
  - Idiomatic Java, not just "Java"

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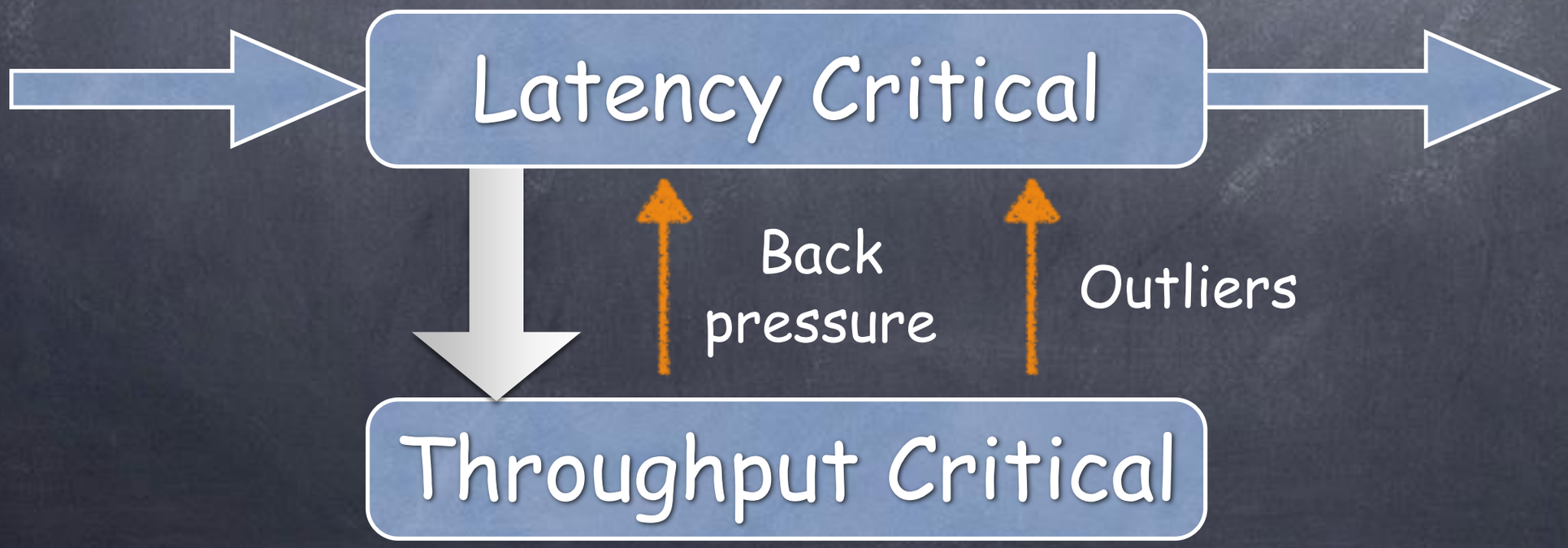
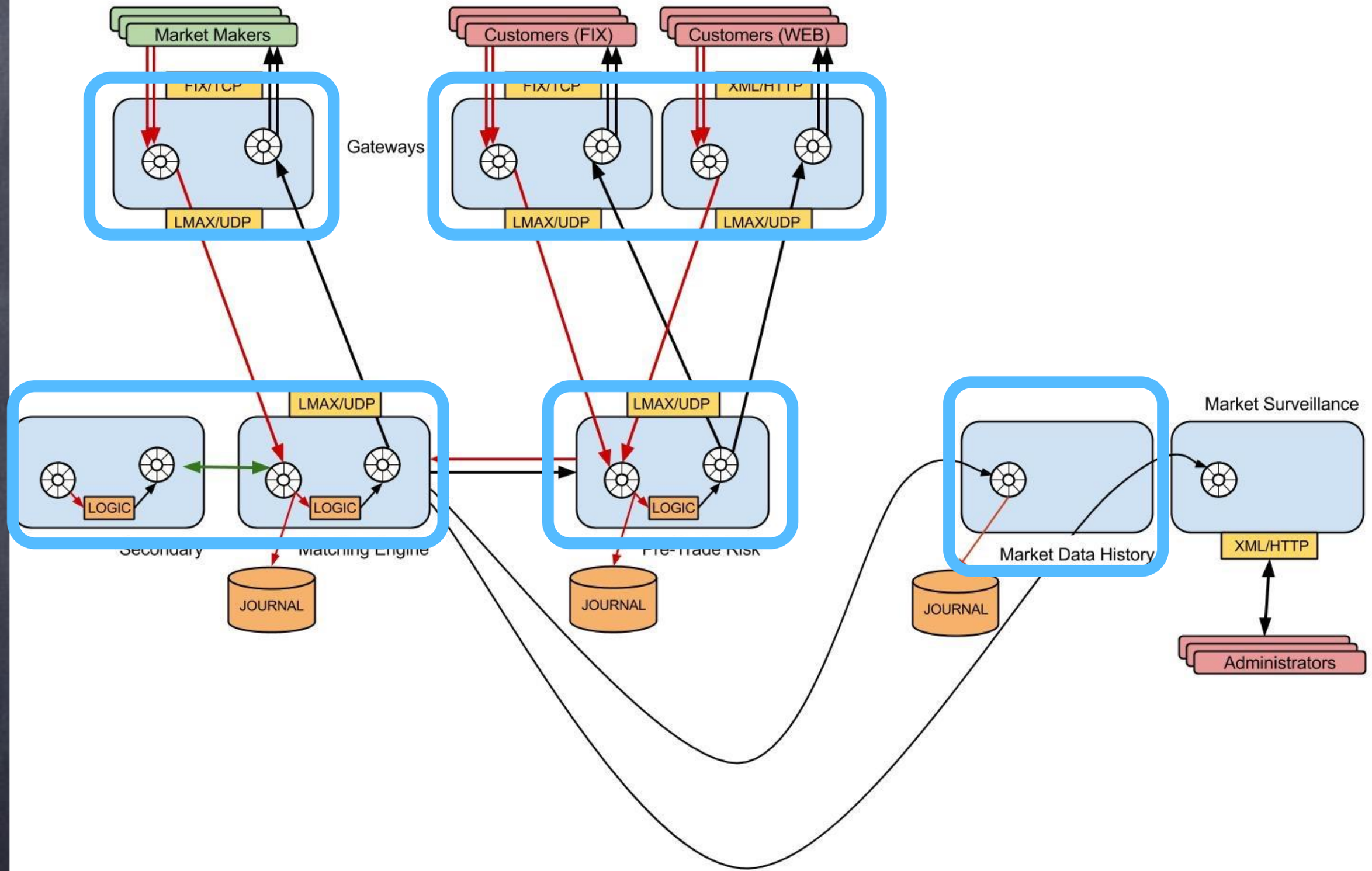
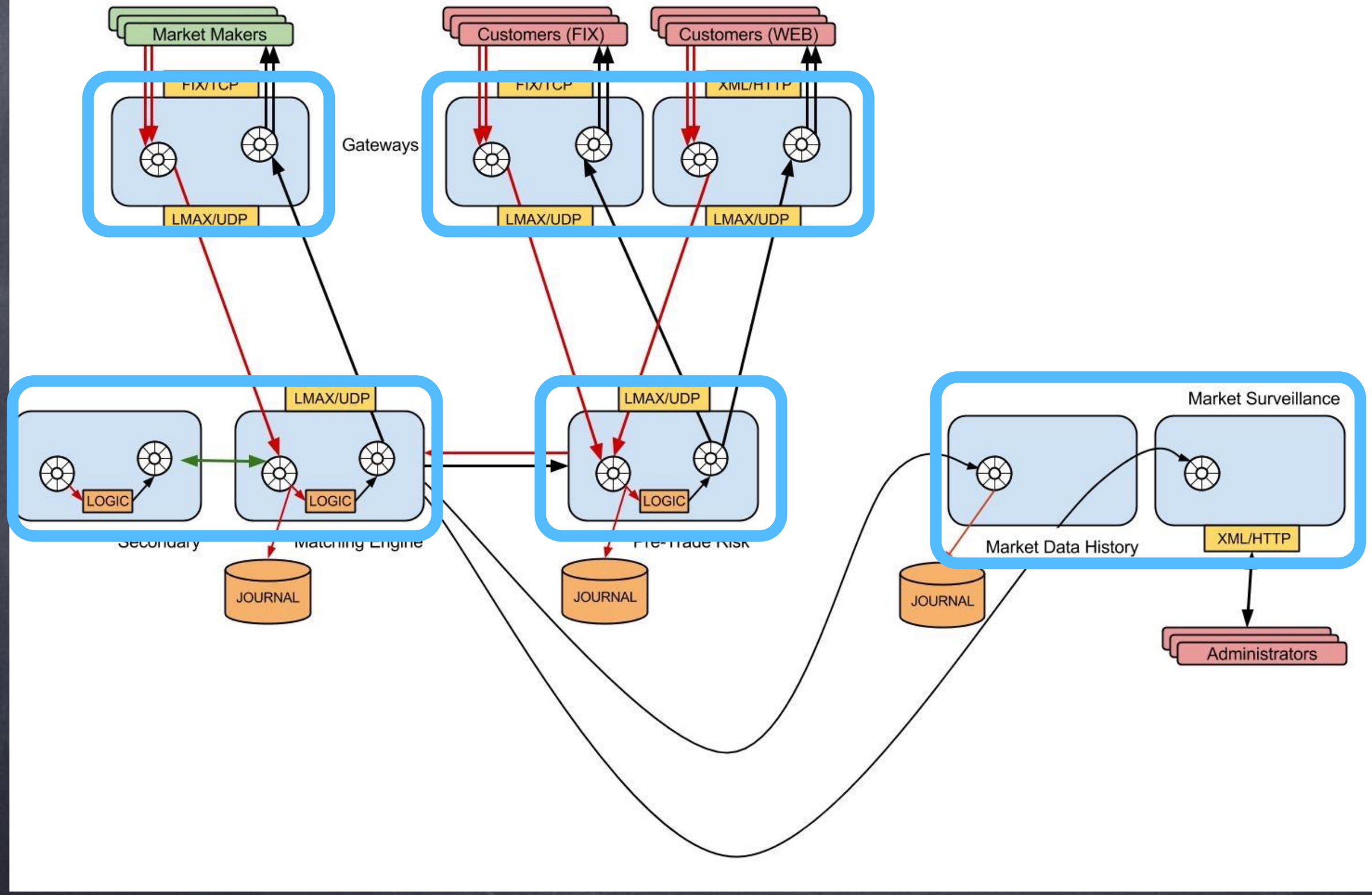
Zing at LMAX Exchange

- Started 2 years ago
- Incremented from most critical to less critical
- Next cover all latency-sensitive system
- Also cover throughput critical systems







Development at LMAX Exchange

- Heavy focus on TDD and CI
- 9000+ acceptance tests
- Performance is treated as just another part of CI
- Regression in performance same as a functional failure
- Confidence to make large changes

Zing at LMAX Exchange: Benefits

- Improved latency behaviors
- Reduced engineering effort
  - No more battling GC in code
  - Performance tuning cycles shorter
- Idiomatic Java is a big deal
  - can avoid converting to "special practices" java
  - can "ease up" on no-allocation coding styles…
  - keep using/leveraging 3rd party code
  - more productive overall…

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Lessons Learned

- Attacking critical parts first:
  - may delay things…
  - critical parts have had engineering effort applied
  - smaller initial gains
  - longer time to gain confidence
- With hindsight:
  - Could have started from "outside in" instead
  - Larger initial gains, shorter time-to-confidence
  - May have gotten to wider deployment faster

Lessons Learned: GC is not the only problem

- GC does tend to dominate outliers (pre-Zing)
  - it is natural to assume all big bad stuff is GC
  - with GC outliers gone, remaining problems surface
- Some harder things:
  - page cache (kernel) lock contention
  - power management tuning in BIOS & OS
  - mapped file access faults & safepoints

Lessons Learned: Proactively override Linux defaults

- Out-of-the box Linux has some bad defaults
  - Bad for things that care about latency…
- E.g. all these should be changed upfront:
  - Page cache: vm.min_free_kbytes [needs >1GB]
  - Transparent Huge Pages (THP) [should be turned off]
  - Swappiness [should be set to 0]
  - zone_reclaim_info [should be set to 0]
- Each can cause multi-100s-of-msec outliers

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Lessons Learned: Measure, Measure, Measure

- We were already measuring & collecting a lot
- But jitter/hiccup/outlier measurement is tough
  - Especially across multiple hops
- Detailed latency distribution measurements
  - Helped triage outlier issues and focus efforts
  - Full percentile spectrum histograms
  - Record system-level "hiccups" everywhere

Real World Results

- Zing helped LMAX tame GC-related latency outliers
  - 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 mins
- No more unexpected/unwanted old-gen pauses caused by external behaviour
  - 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.

Summary

- Java is both viable and profitable for low latency
- With "regular JVMs" you have to jump through some hoops to get there
- Zing helps low latency in Java be as easy as low latency in other languages
- Once you stop dealing with JVM-related issues, you can get on with the interesting stuff

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