How to do 100K+ TPS at less than 1ms latency

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QCon SF 2010

LMAX

Agenda

- Context Setting
- Tips for high performance computing (HPC)
- What is possible on a single thread???
- New pattern for contended HPC
- Q & A

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Who/What is LMAX?

- The London Multi-Asset Exchange
- Spin-off from Betfair into retail finance
- Access the wholesale financial markets on equal terms for retail traders
- We aim to build the highest performance financial exchange in the world

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What is Extreme Transaction Processing (XTP)?

The Betfair Experience

V

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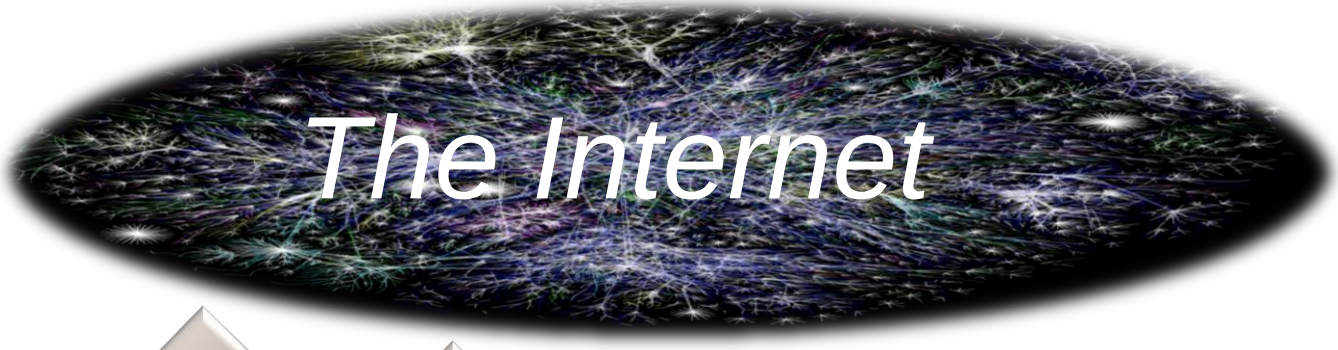
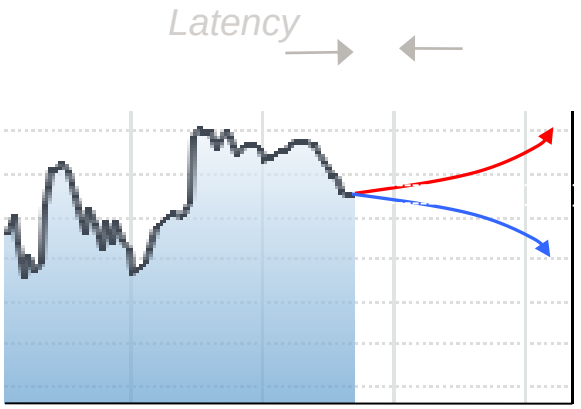
What is Extreme Transaction Processing (XTP)?



The LMAX Model



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How not to solve this problem

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Phasers or Disruptors?

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Tips for high performance computing

1. Show good “Mechanical Sympathy”
2. Keep the working set In-Memory
3. Write cache friendly code
4. Write clean compact code
5. Invest in modelling your domain
6. Take the right approach to concurrency

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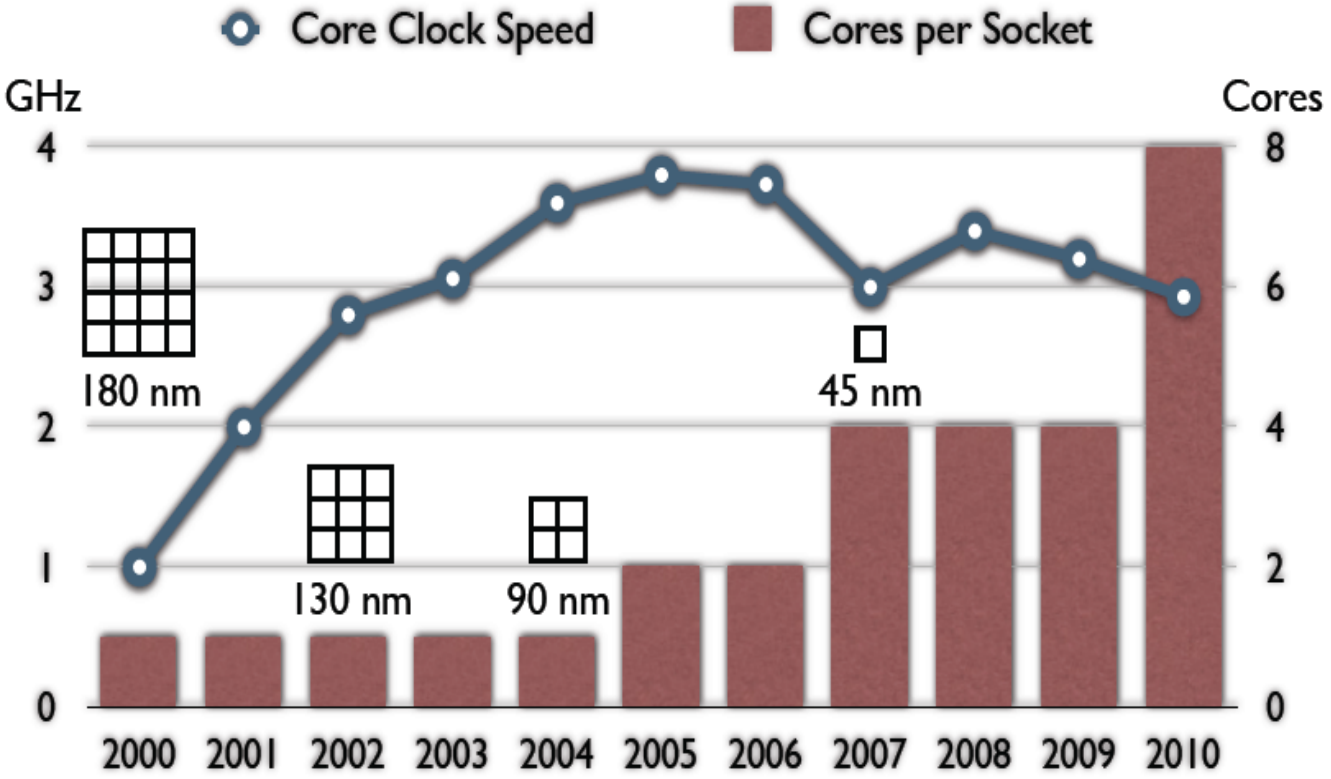
1. Mechanical Sympathy – 1 of 2

Memory

- Latency not significantly changed
- Massive bandwidth increase
- 144GB in a commodity machine

CPUs

- The GHz race is over
- Multi core
- Bigger smarter caches



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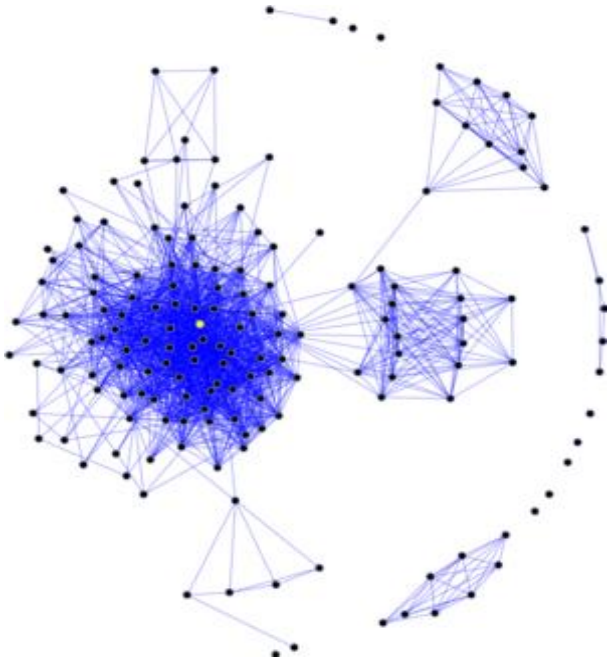
1. Mechanical Sympathy – 2 of 2

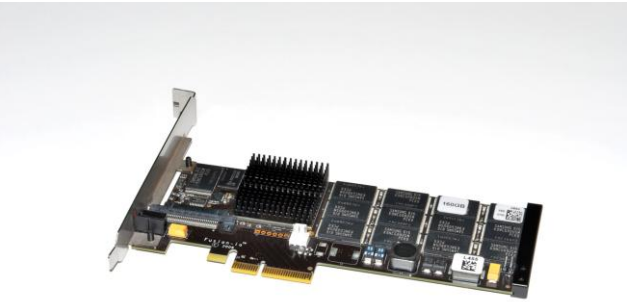
Networks

- Sub 10 microseconds for local hop
- Wide area bandwidth is cheap
- 10GigE is now a commodity
- Multi-cast is getting traction



Storage

- Disk is the new tape! Fast for sequential access
- SSDs for random threaded access
- PCI-e connected storage



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2. Keep the working set In-Memory

Does it feel awkward working with data remote from your address space?

- Keep data and behaviour co-located
- Affords rich interaction at low latency
- Enabled by 64-bit addressing

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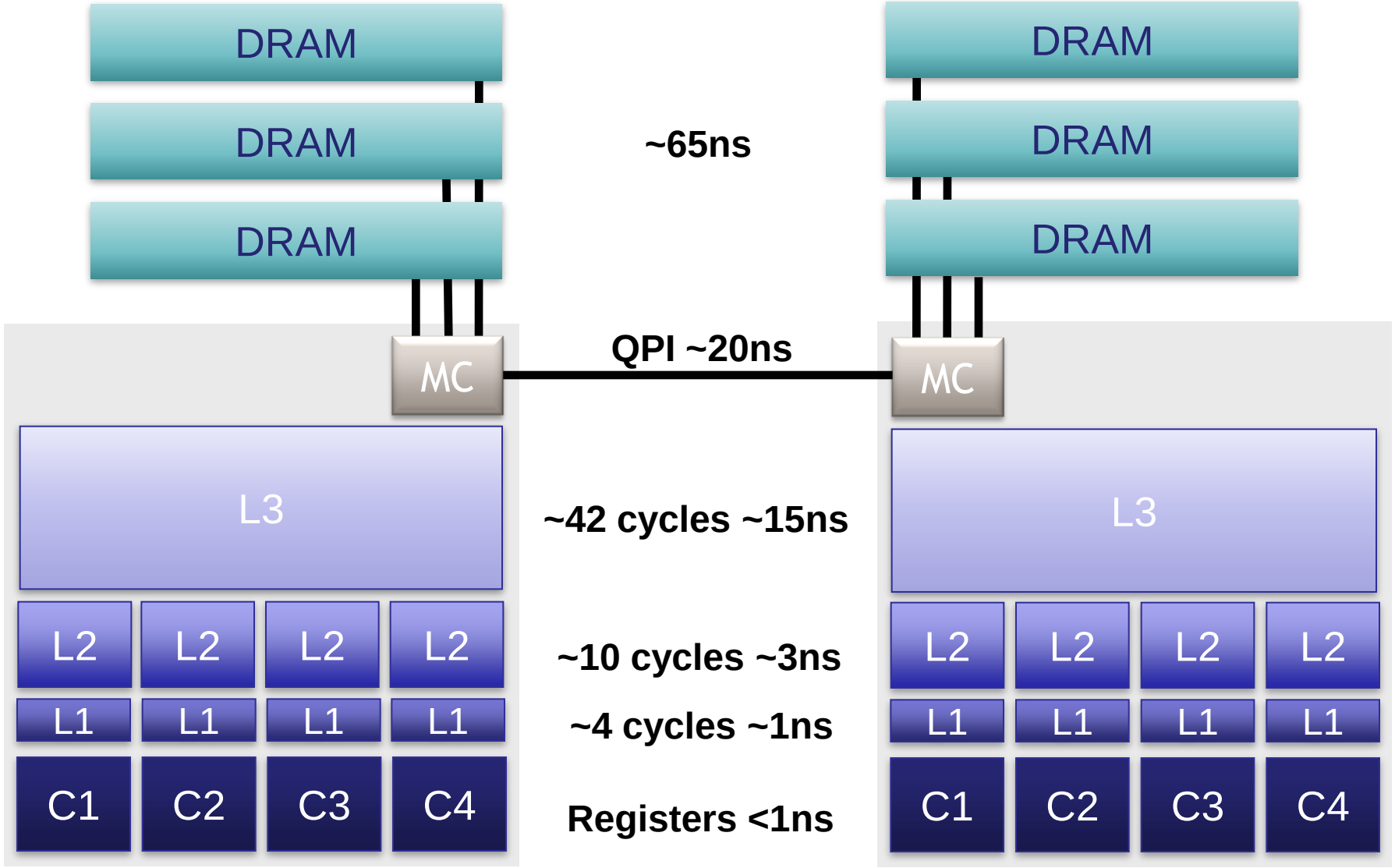
3. Write cache friendly code



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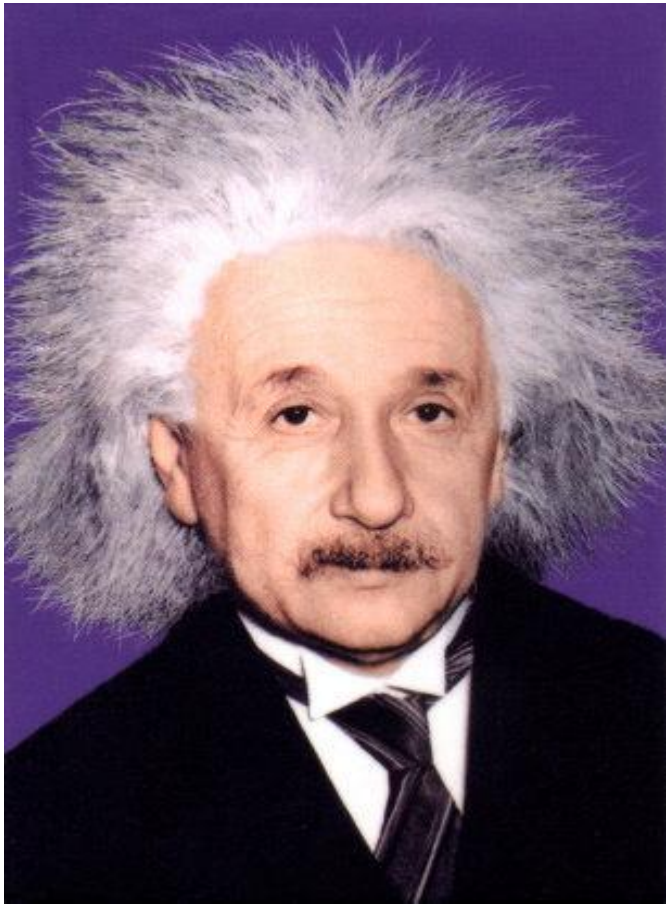
4. Write clean compact code

"Any intelligent fool can make things bigger, more complex, and more violent. It takes a touch of genius -- and a lot of courage -- to move in the opposite direction."

- Hotspot likes small compact methods
- CPU pipelines stall if they cannot predict branches
- If your code is complex you do not properly understand the problem domain
- Nothing in the world is truly complex other than Tax Law



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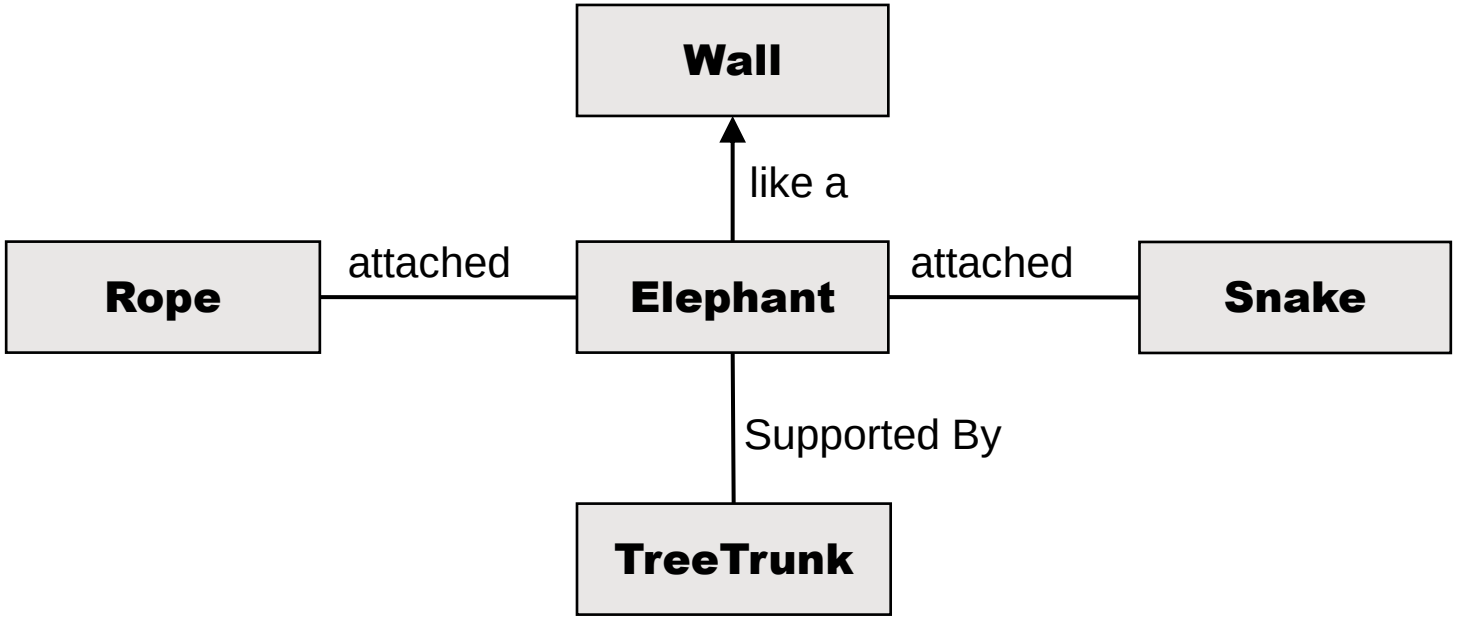
5. Invest in modelling your domain

Model of an elephant based on blind men touching one part each



- **Single responsibility – One class one thing, one method one thing, etc.**
- **Know your data structures and cardinality of relationships**
- **Let the relationships do the work**

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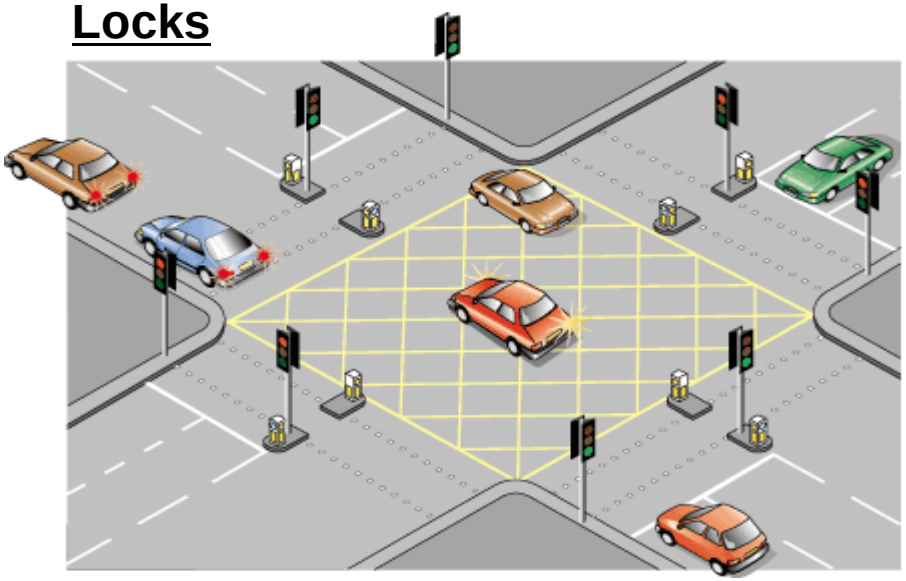
6. Take the right approach to concurrency

Concurrent programming is about 2 things:

***Mutual Exclusion*:** Protect access to contended resources

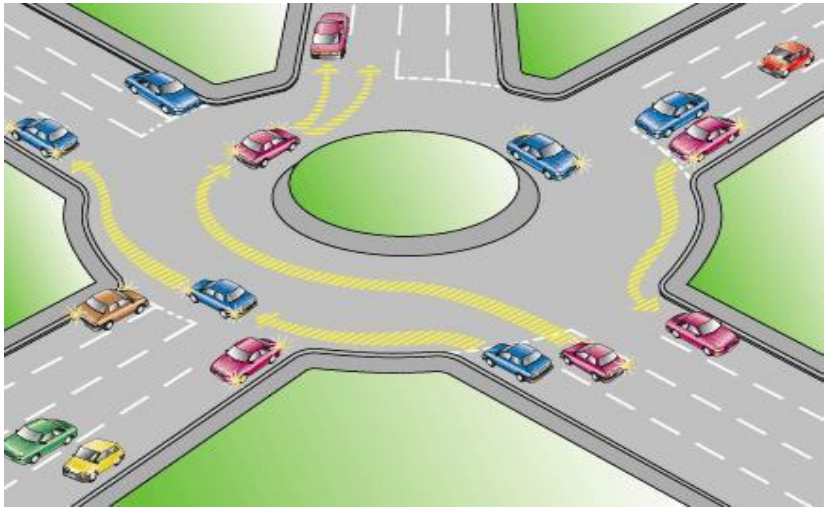
***Visibility of Changes*:** Make the result public in the correct order

Locks



- Context switch to the kernel
- Can always make progress
- Difficult to get right

Atomic/CAS Instructions



- Atomic read-modify-write primitives
- Happen in user space
- Very difficult to get right!

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What is possible when you get this stuff right?

On a single thread you have ~3 billion instructions per second to play with:

10K+ TPS

- If you don't do anything too stupid

100K+ TPS

- With well organised clean code and standard libraries

1m+ TPS

- With custom cache friendly collections
- Good performance tests
- Controlled garbage creation
- Very well modelled domain

- BTW writing good performance tests is often harder than the target code!!!

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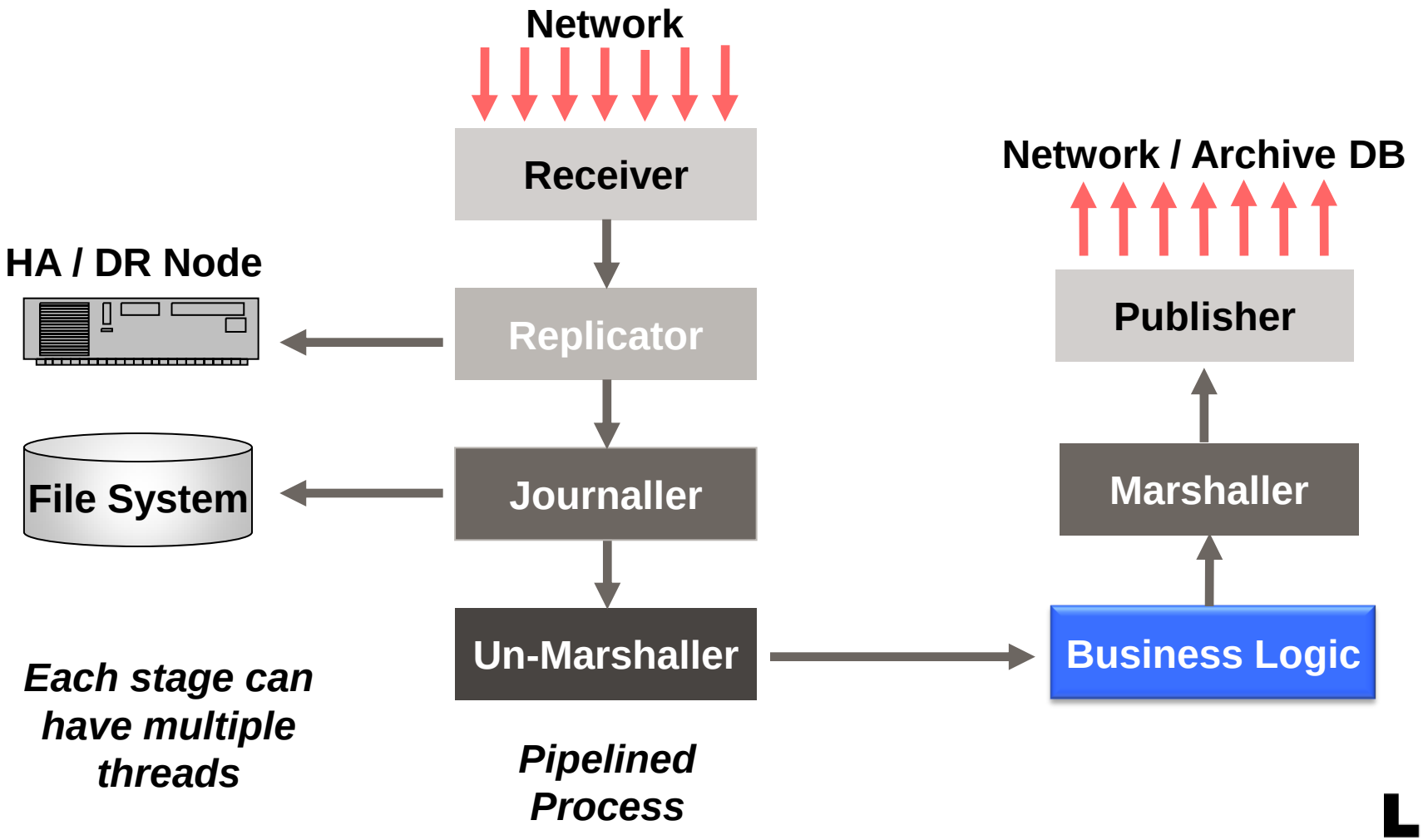
How to address the other non-functional concerns?

- **With a very fast business logic thread we need to feed it reliably**
  - > Did we trick you into thinking we can avoid concurrent programming?



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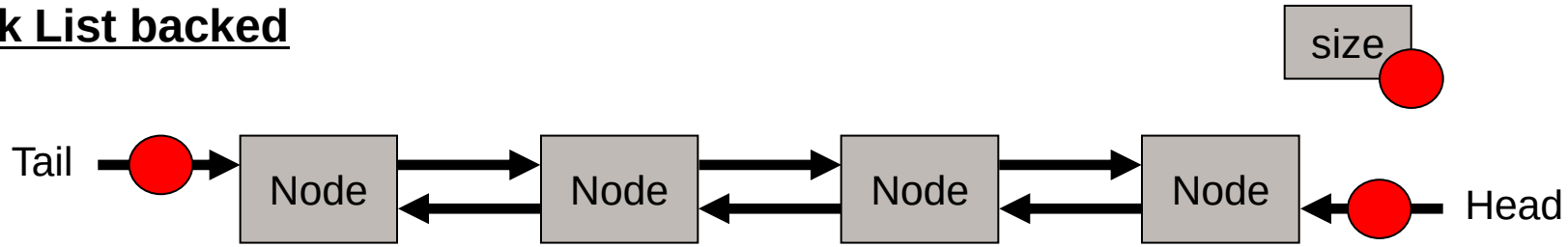
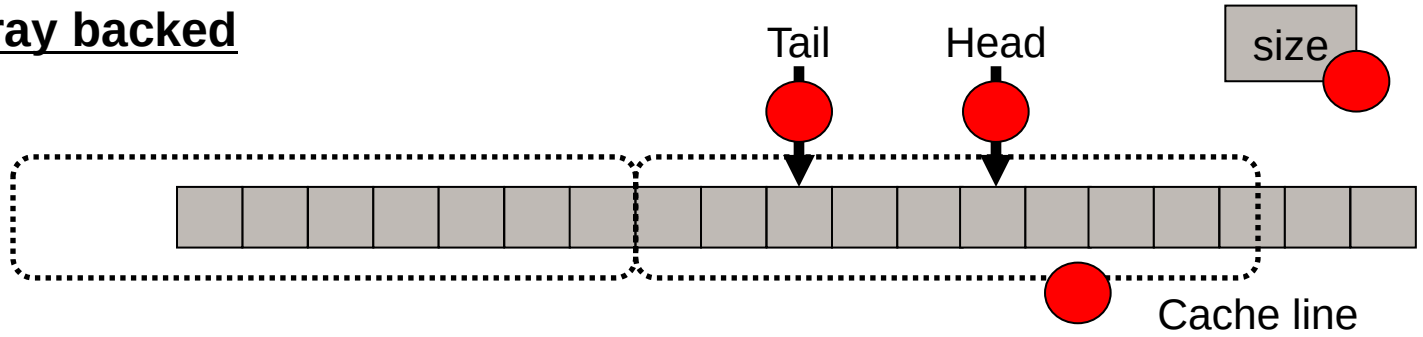
Concurrent access to Queues – The Issues

Link List backed



- Hard to limit size
- O(n) access times if not head or tail
- Generates garbage which can be significant

Array backed



- Cannot resize easily
- Difficult to get *P *C correct
- O(1) access times for any slot and cache friendly

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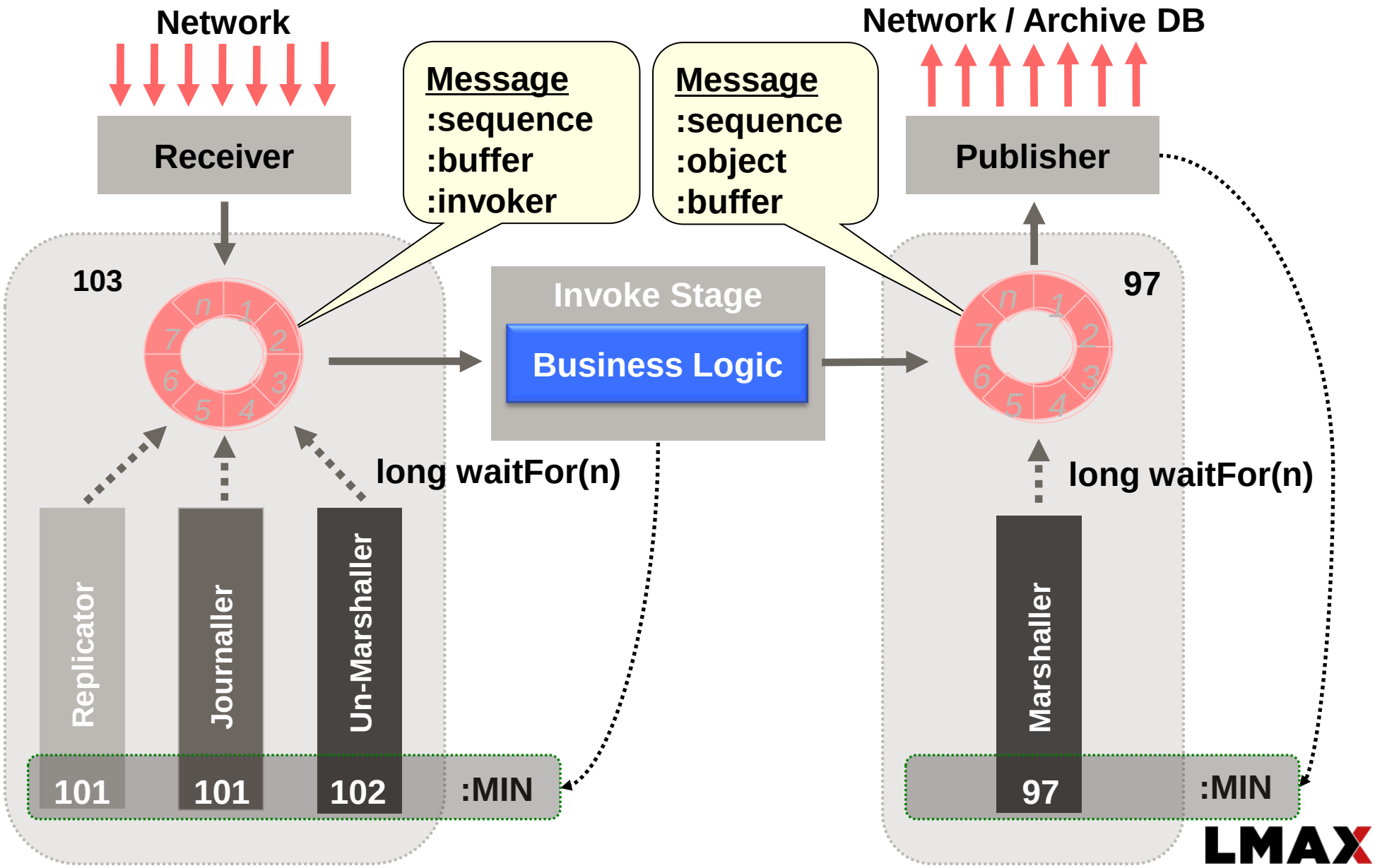
Disruptor


Network
Receiver
Message
:sequence
:buffer
:invoker
Message
:sequence
:object
:buffer
Network / Archive DB
Publisher
103
97
Invoke Stage
Business Logic
long waitFor(n)
long waitFor(n)
Replicator
Journaller
Un-Marshaller
Marshaller
101
101
102
:MIN
97
:MIN
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Quick Recap

- **Most developers have an incorrect view of hardware and what can be achieved on a single thread**
- **On modern processors a cache miss is your biggest cost**
- **Push concurrency into the infrastructure, and make it REALLY fast**
- **Once you have this, you have the world that OO programmers dream of:**
  - Single threaded
  - All in-memory
  - Elegant model
  - Testable code
  - No infrastructure or integration worries

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Wrap up

Q & A

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