
# A Quest for Predictable Latency

## *Adventures in Java Concurrency*

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MKE

*If a system does not respond in a timely manner then it is effectively unavailable*

1. It's all about the Blocking
2. What do we mean by Latency
3. Adventures with Locks and queues
4. Some Alternative FIFOs
5. Where can we go Next

# *1. It's all about the Blocking*

# What is preventing progress?

A thread is **blocked** when it cannot make progress

# There are two major causes of blocking

# Blocking

- Systemic Pauses
  - JVM Safepoints (GC, etc.)
  - Transparent Huge Pages (Linux)
  - Hardware (C-States, SMIs)

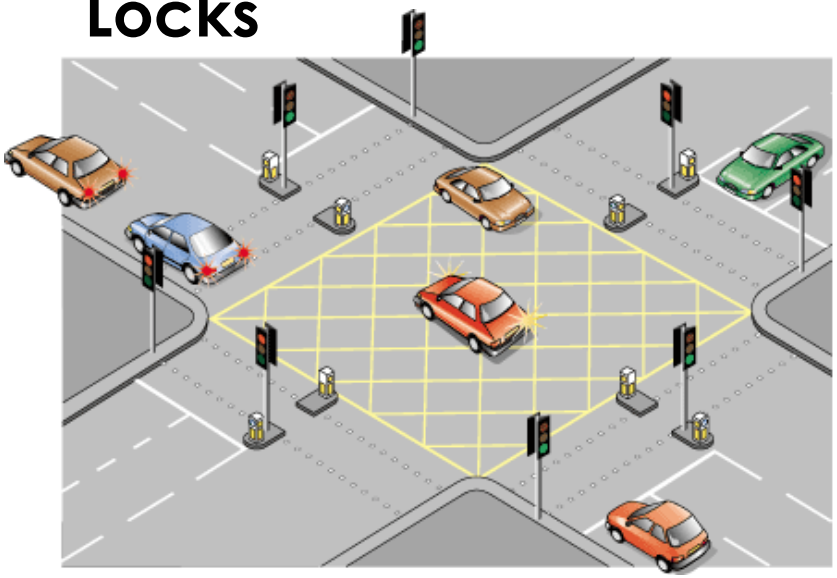
# Blocking

- Systemic Pauses
  - JVM Safepoints (GC, etc.)
  - Transparent Huge Pages (Linux)
  - Hardware (C-States, SMIs)

- Concurrent Algorithms
  - Notifying Completion
  - Mutual Exclusion (Contention)
  - Synchronisation / Rendezvous

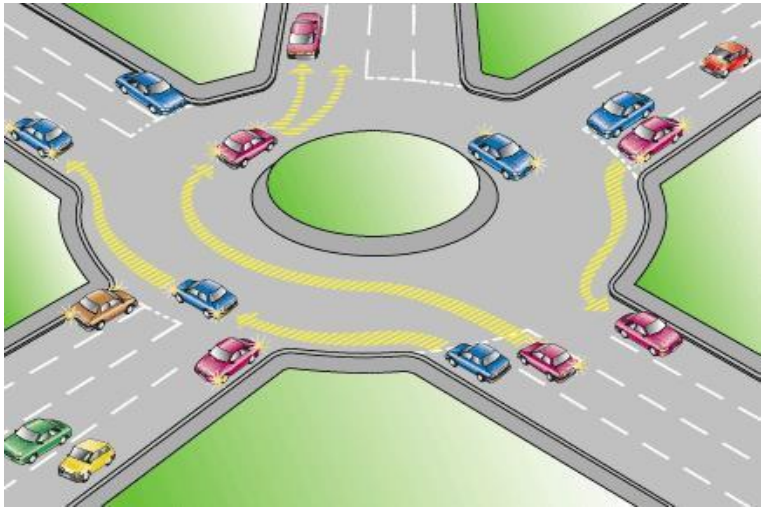
# Concurrent Algorithms

## Locks



- Call into kernel on contention
- Always blocking
- Difficult to get right

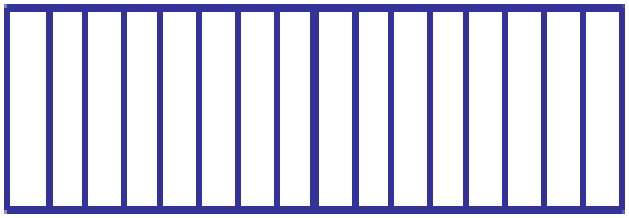
## Atomic/CAS Instructions

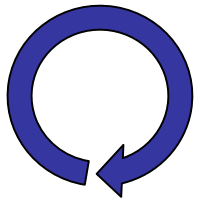


- Execute in user space
- Can be non-blocking
- Very difficult to get right

# *2. What do we mean by Latency*

# Queuing Theory





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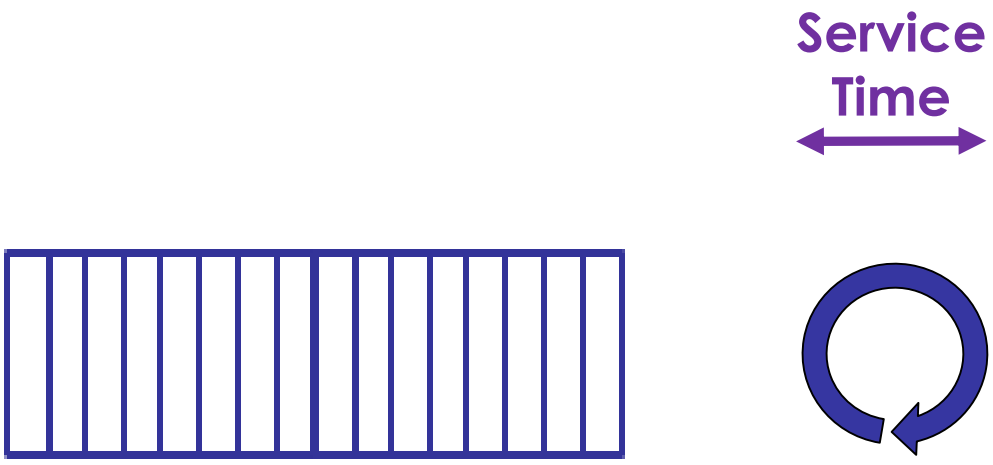

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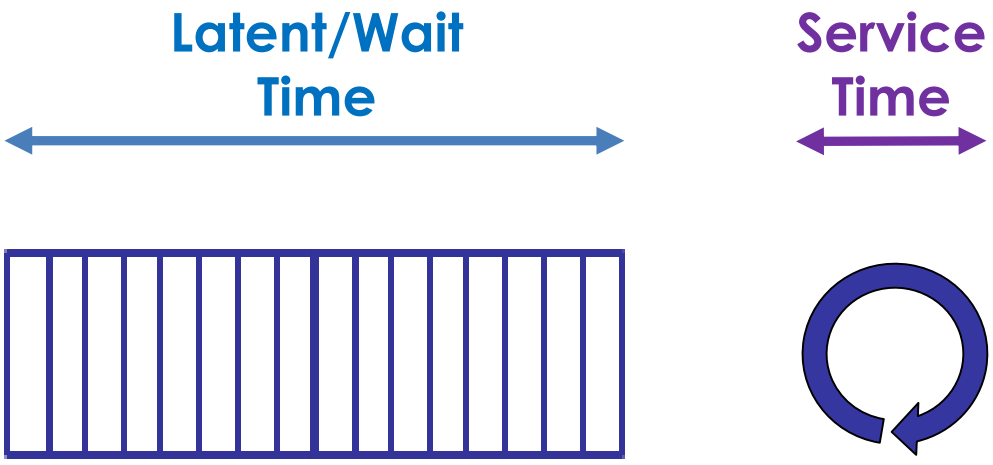

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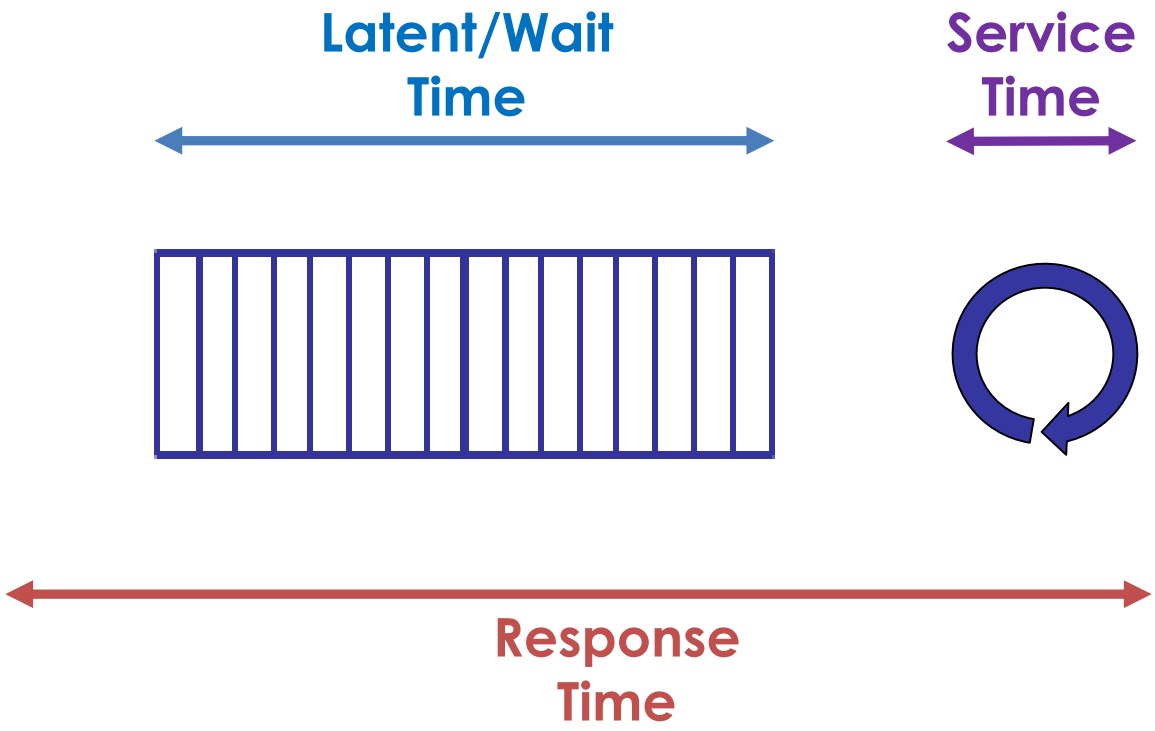

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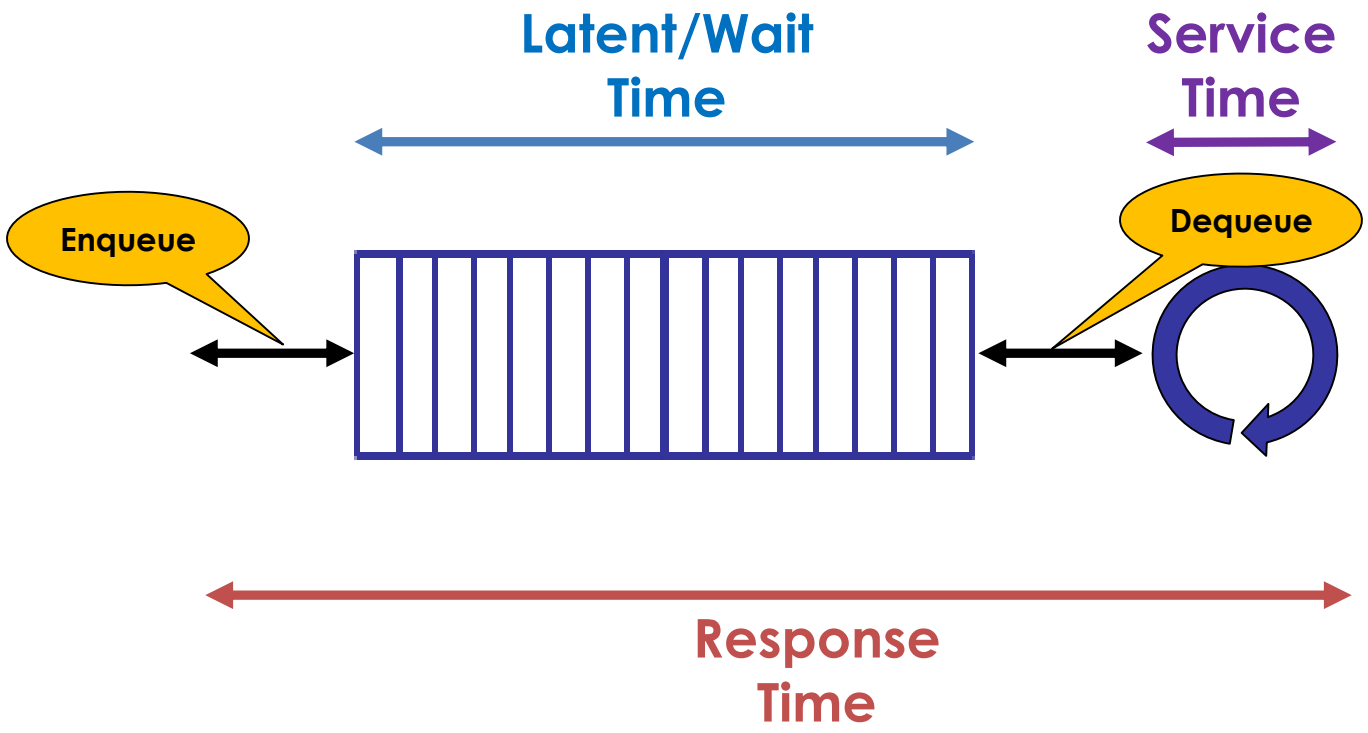

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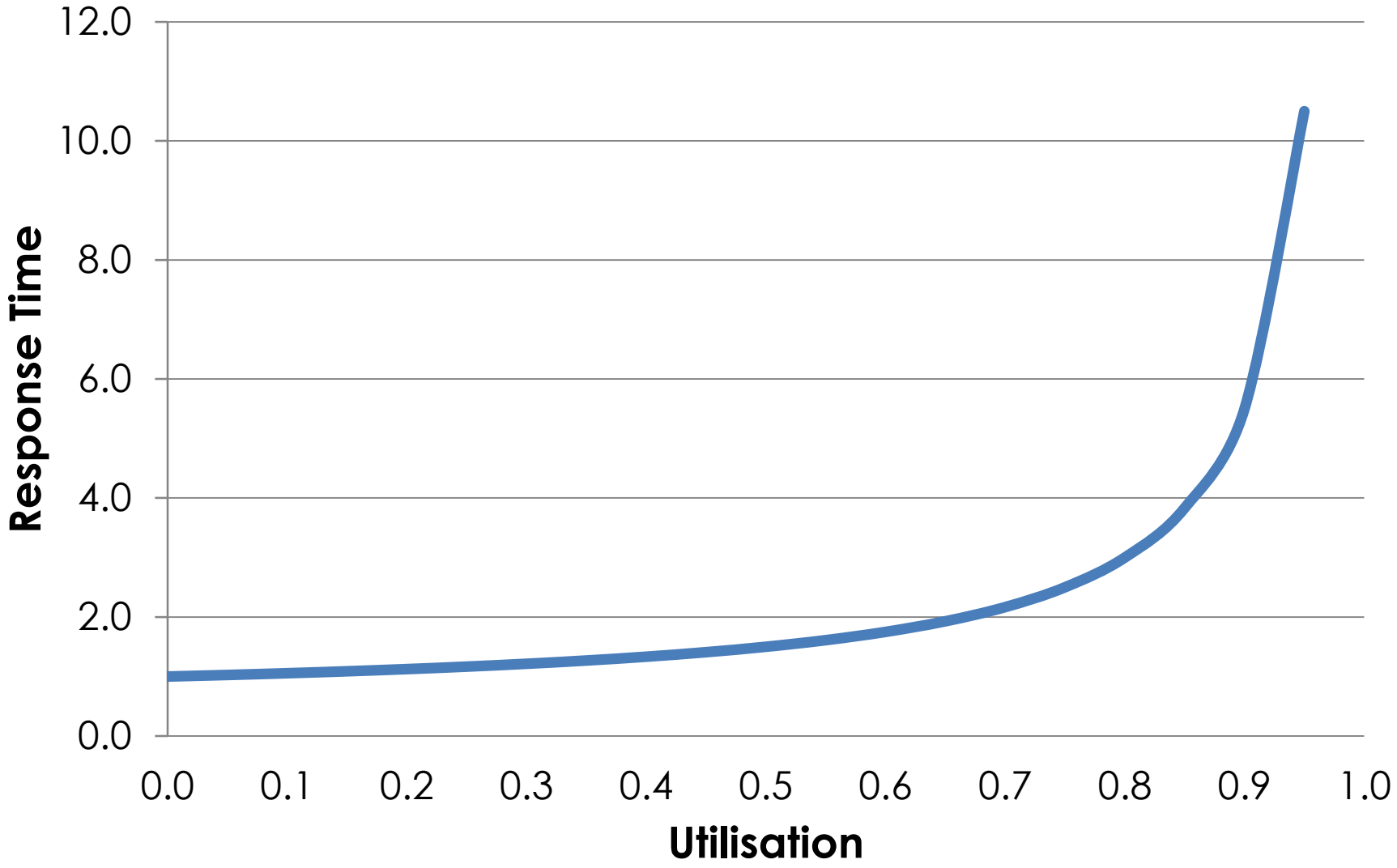
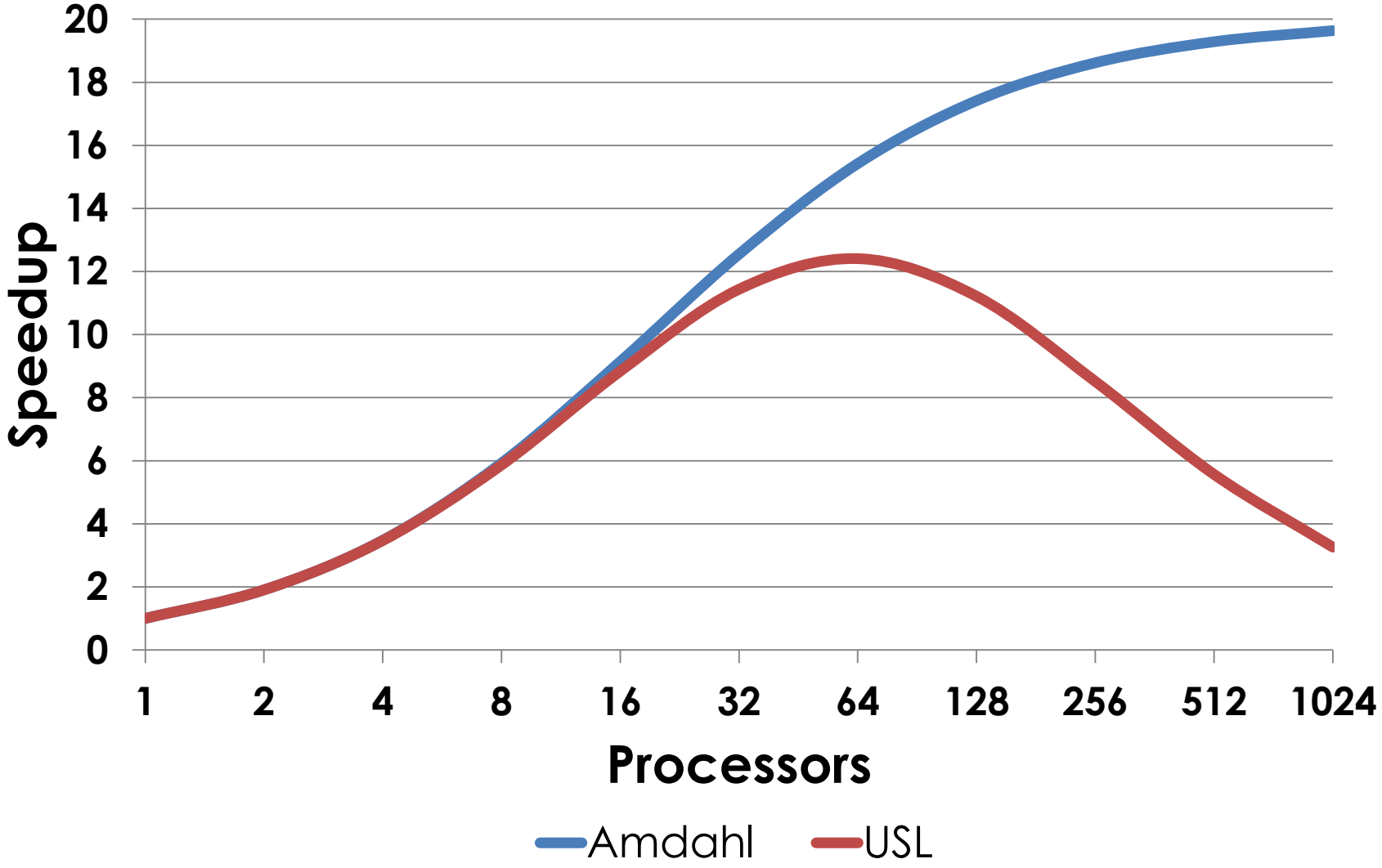


# Amdahl's & Universal Scalability Laws



# 3. *Adventures with Locks and Queues?*

***Some queue implementations spend more time queueing to be enqueued than in queue time!!!***

# *The evils of* Blocking

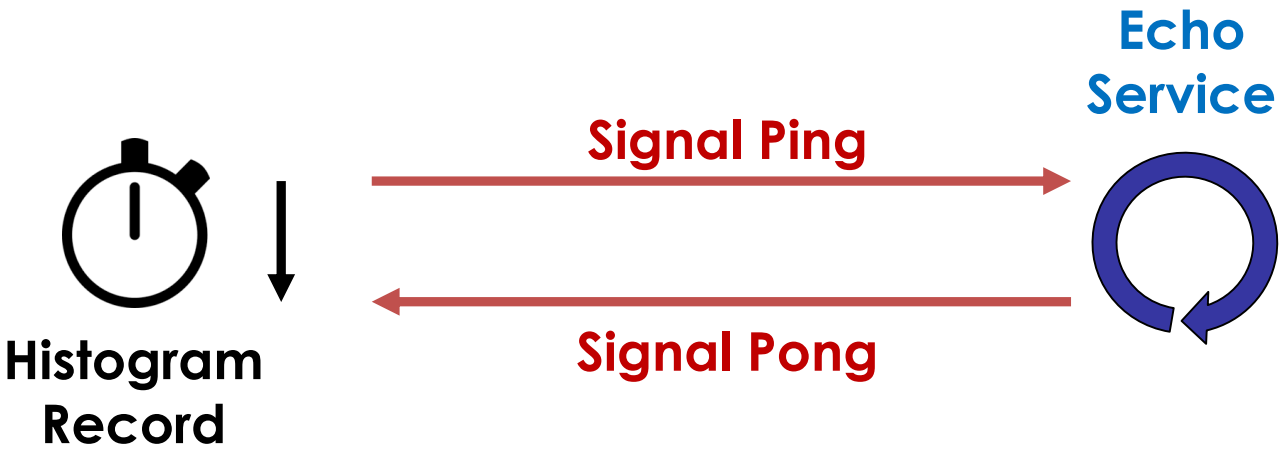
`Queue.put()`

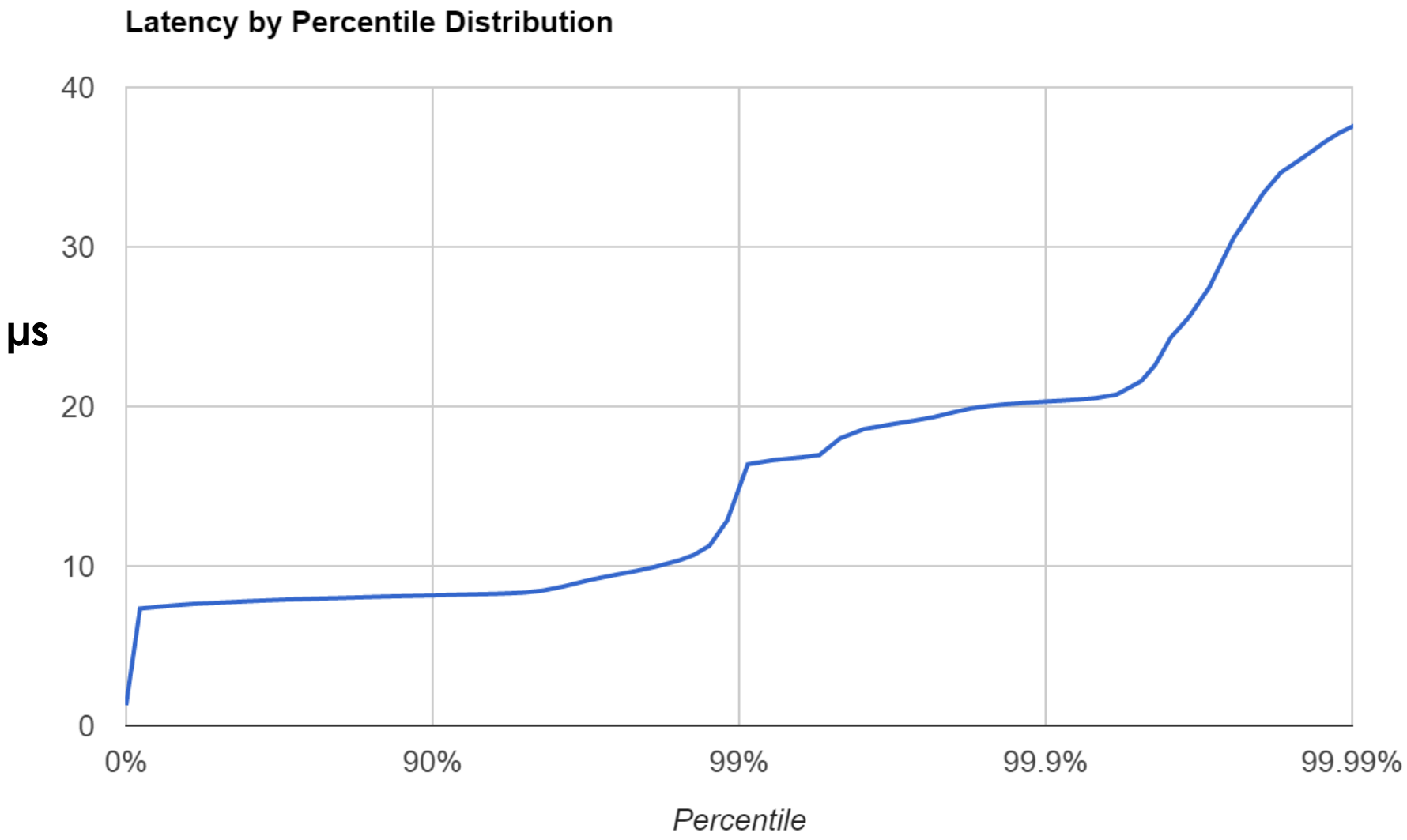
`&&`

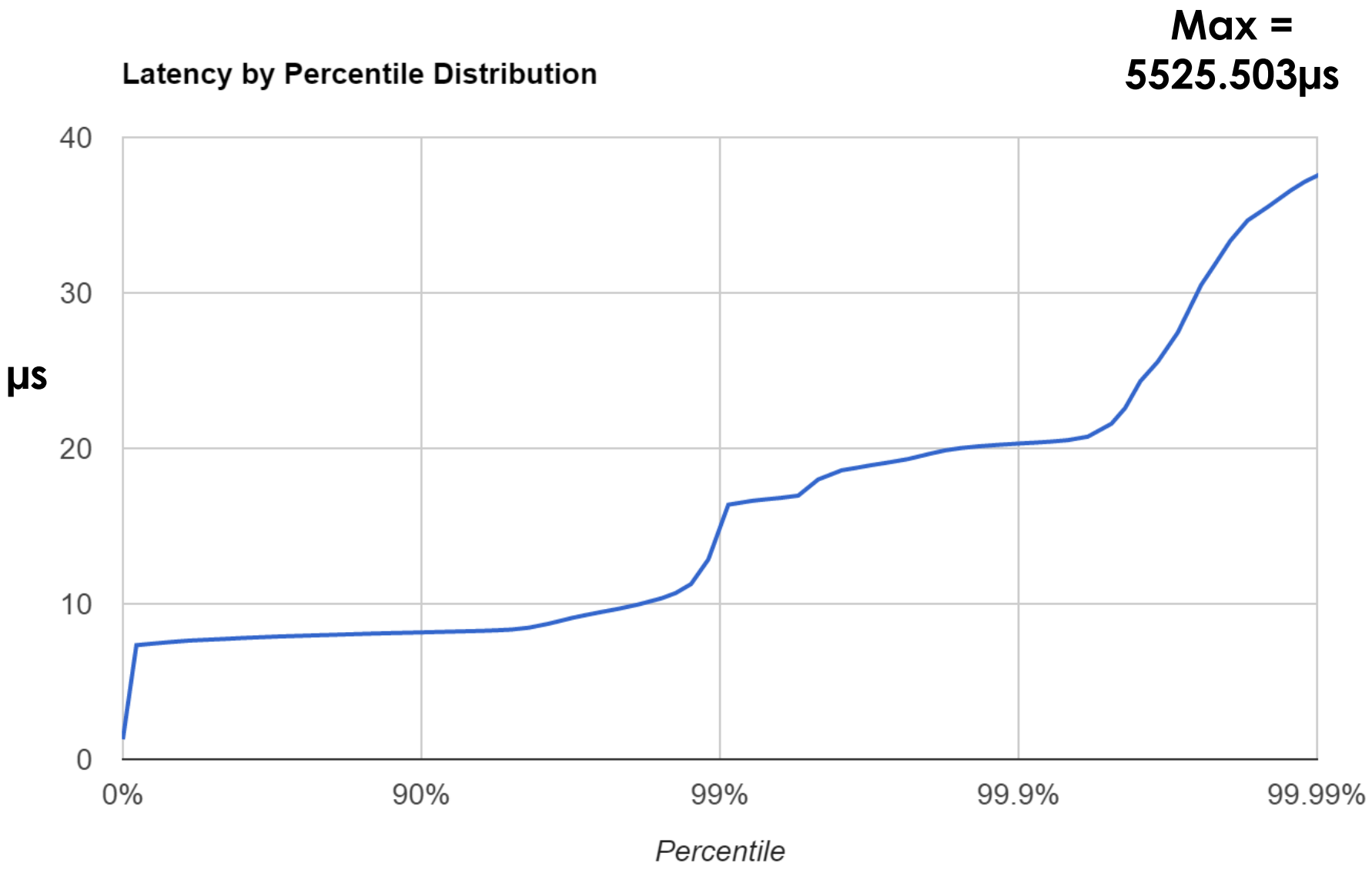
`Queue.take()`

# *Condition Variables*

# Condition Variable RTT




Latency by Percentile Distribution
40
30
20
10
0
µs
0%
90%
99%
99.9%
99.99%
Percentile


Latency by Percentile Distribution
Max = 5525.503µs
µs
40
30
20
10
0
0%
90%
99%
99.9%
99.99%
Percentile

***Bad News***

***That's the best case scenario!***

*Are non-blocking APIs any better?*

```
Queue.offer()
&&
Queue.poll()
```

# Context for the Benchmarks

***https://github.com/real-logic/benchmarks***

***Java 8u60***
***Ubuntu 15.04 – "performance" mode***
***Intel i7-3632QM – 2.2 GHz (Ivy Bridge)***

# Burst Length = 1: RTT (ns)

| | Prod # | Mean | 99% |
|---|---|---|---|
| `Baseline (Wait-free)` | 1 | 167 | 189 |
| `ArrayBlockingQueue` | 1 | 645 | 1,210 |
| | 2 | 1,984 | 11,648 |
| | 3 | 5,257 | 19,680 |
| `LinkedBlockingQueue` | 1 | 461 | 740 |
| | 2 | 1,197 | 7,320 |
| | 3 | 2,010 | 15,152 |
| `ConcurrentLinkedQueue` | 1 | 281 | 361 |
| | 2 | 381 | 559 |
| | 3 | 444 | 705 |

# Burst Length = 100: RTT (ns)

| | Prod # | Mean | 99% |
|---|---|---|---|
| `Baseline (Wait-free)` | 1 | 721 | 982 |
| `ArrayBlockingQueue` | 1 | 30,346 | 41,728 |
| | 2 | 35,631 | 65,008 |
| | 3 | 50,271 | 90,240 |
| `LinkedBlockingQueue` | 1 | 31,422 | 41,600 |
| | 2 | 45,096 | 94,208 |
| | 3 | 89,820 | 180,224 |
| `ConcurrentLinkedQueue` | 1 | 12,916 | 15,792 |
| | 2 | 25,132 | 35,136 |
| | 3 | 39,462 | 56,768 |

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*Backpressure?*

*Size methods?*

*Flow Rates?*

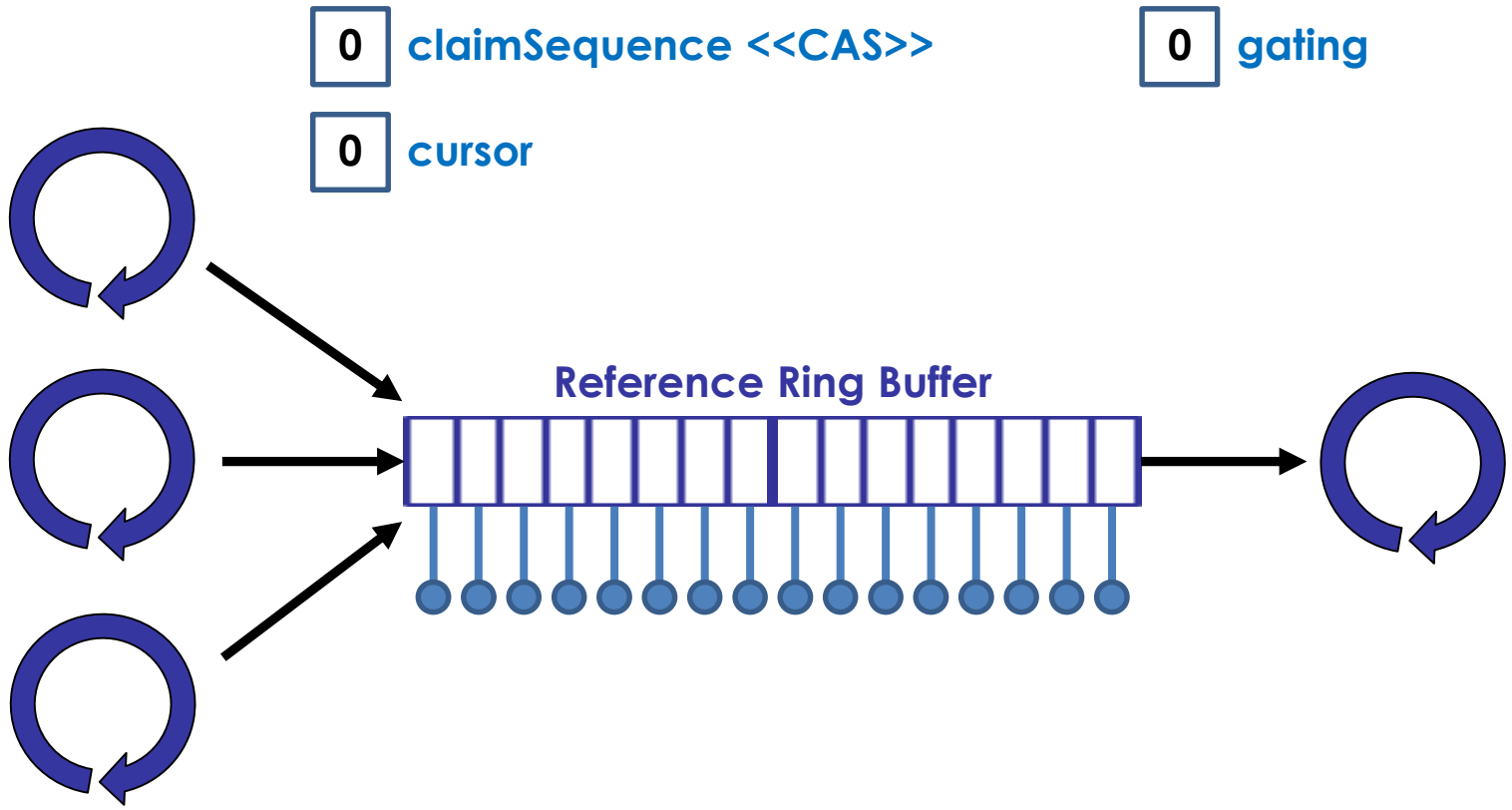
*Garbage?*

*Fan out?*

# 5. Some alternative FIFOs

# Inter-Thread FIFOs

# Disruptor 1.0 – 2.0




*Influences: Lamport + Network Cards*

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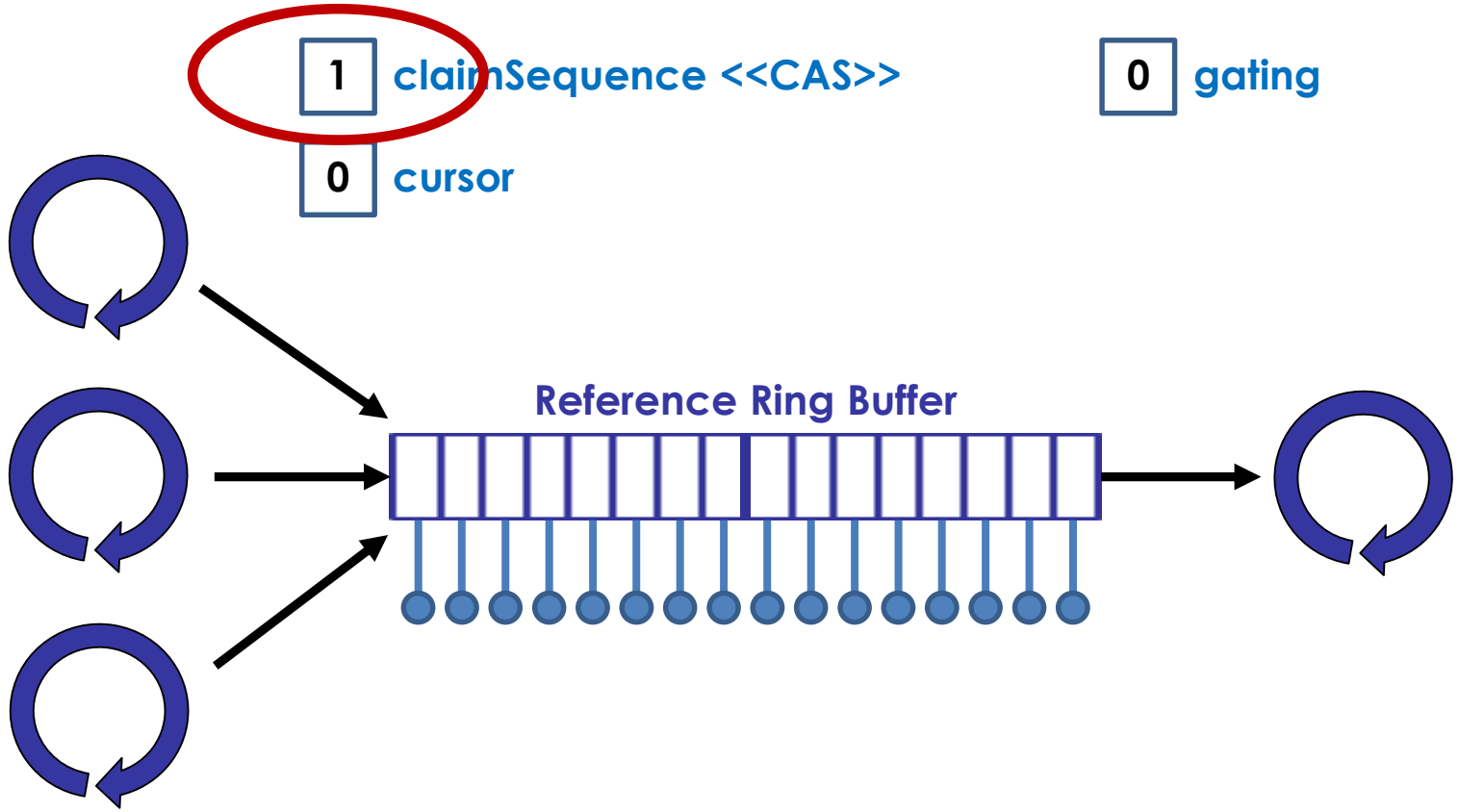


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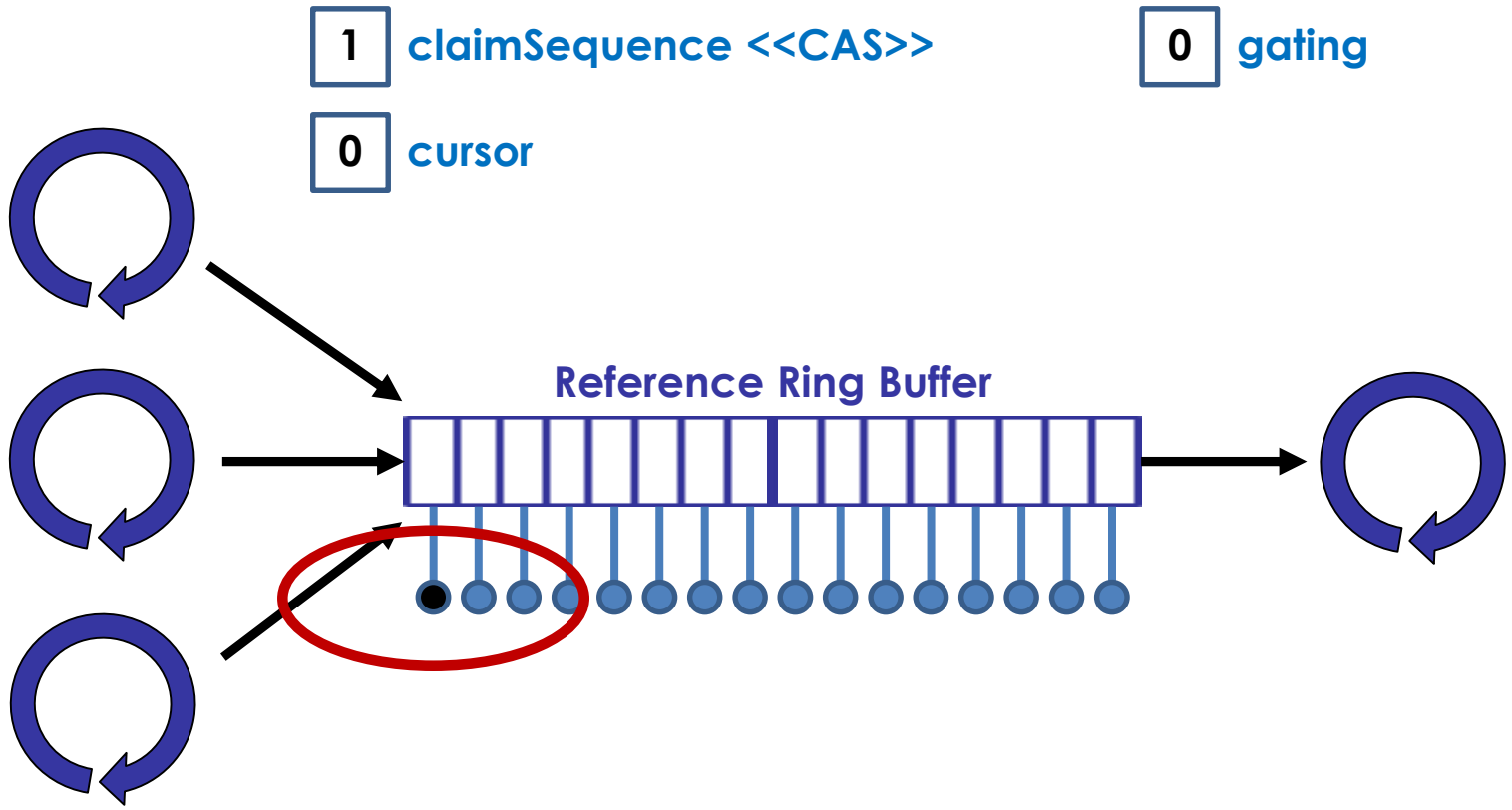


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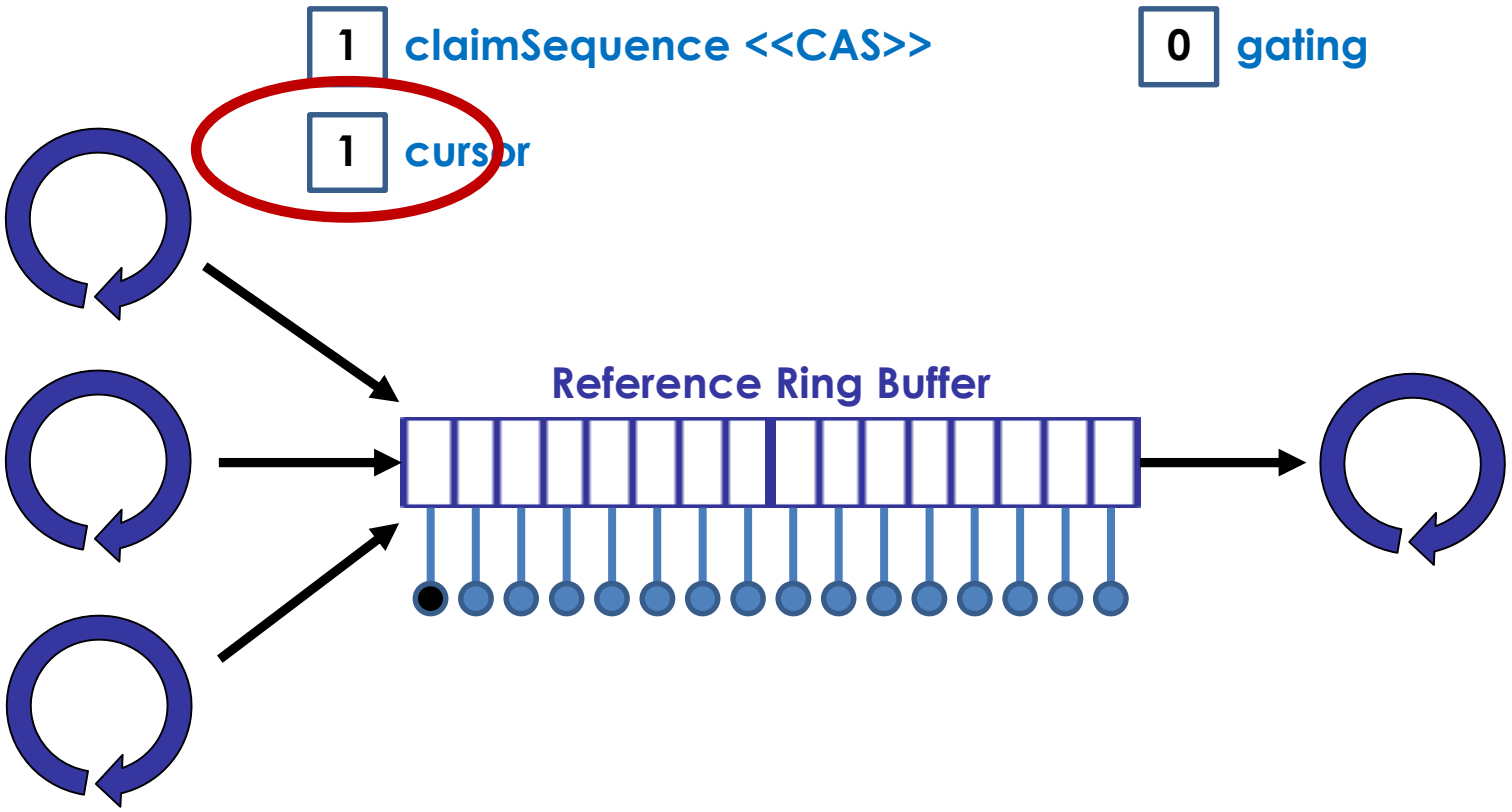


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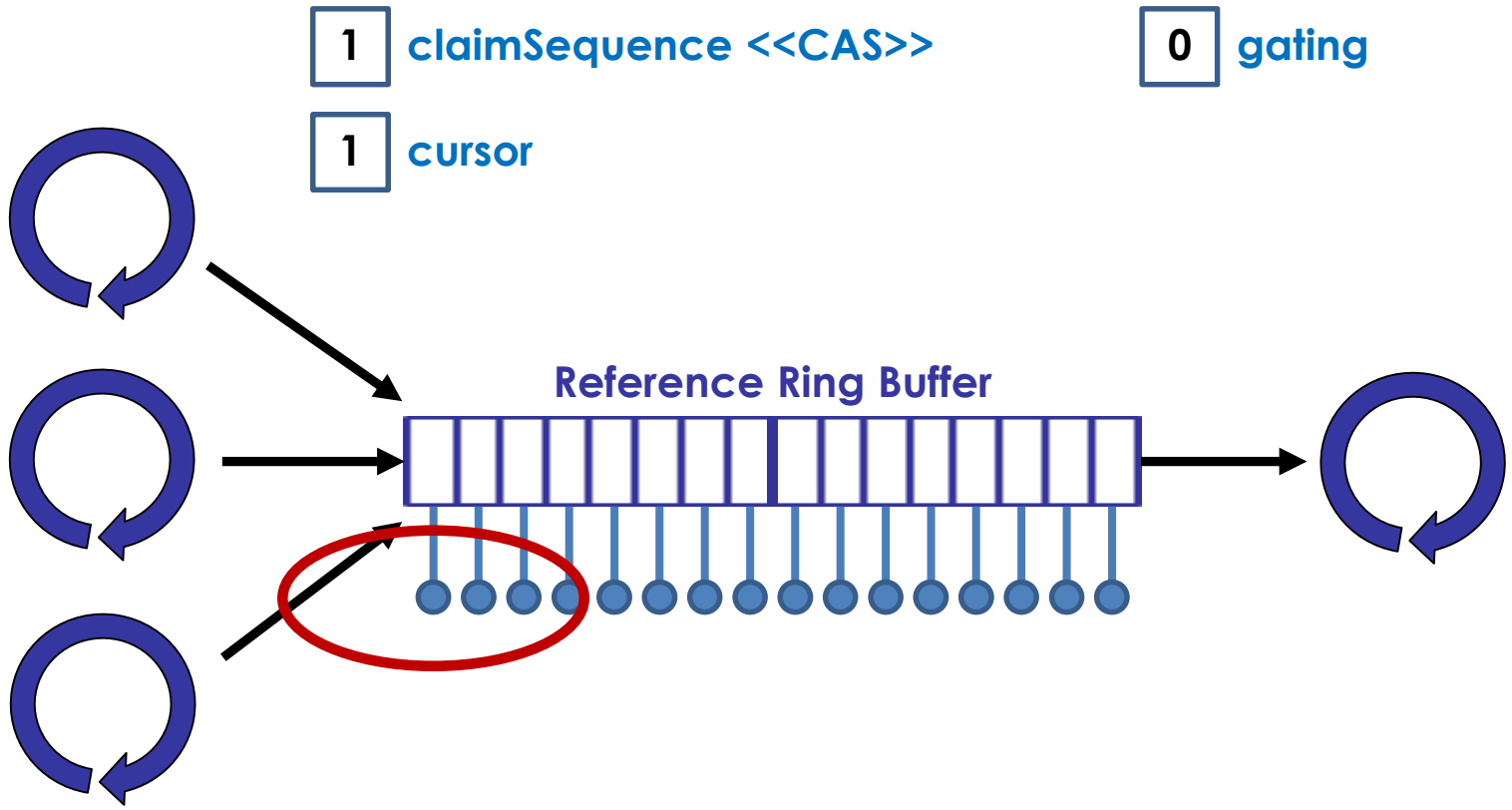


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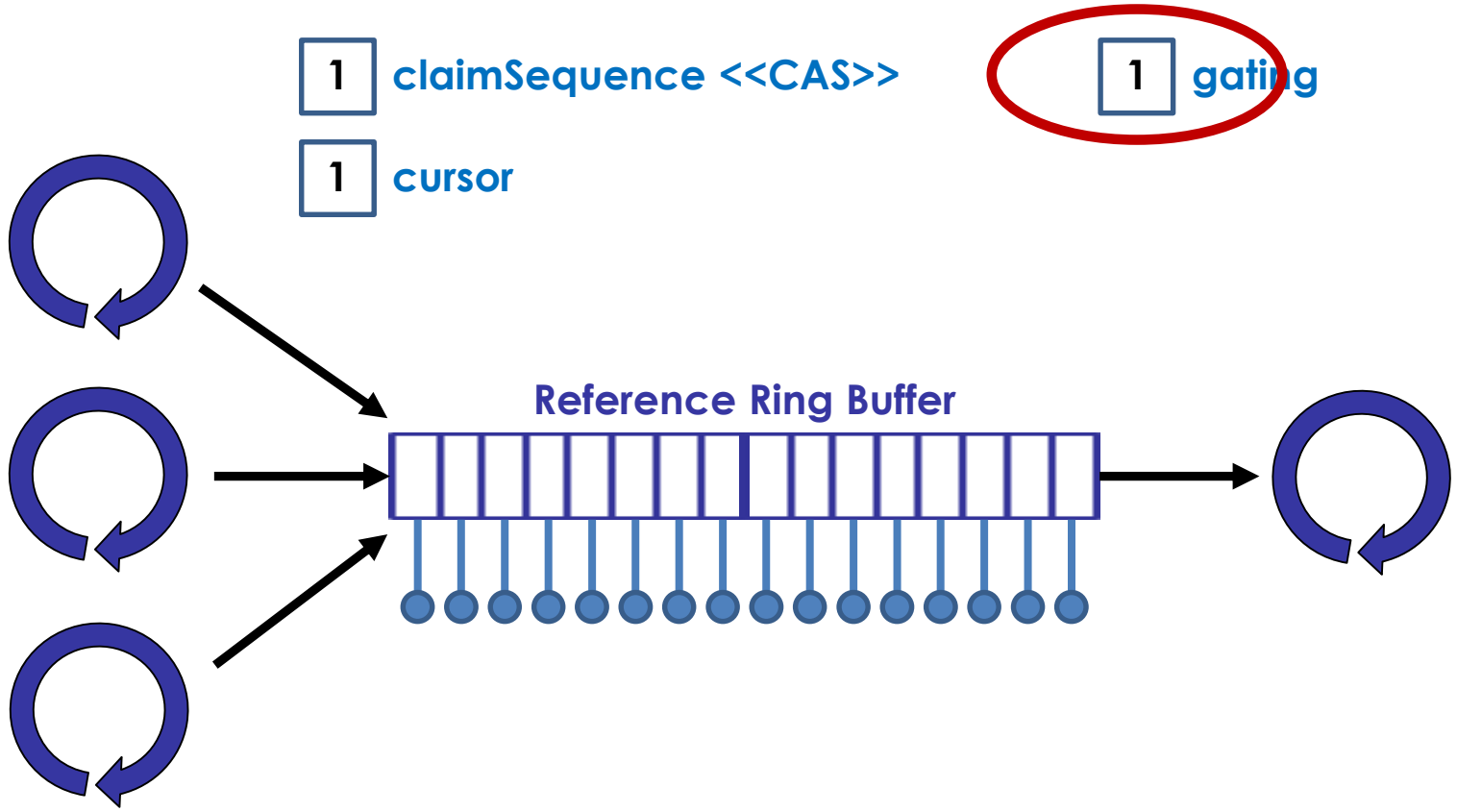


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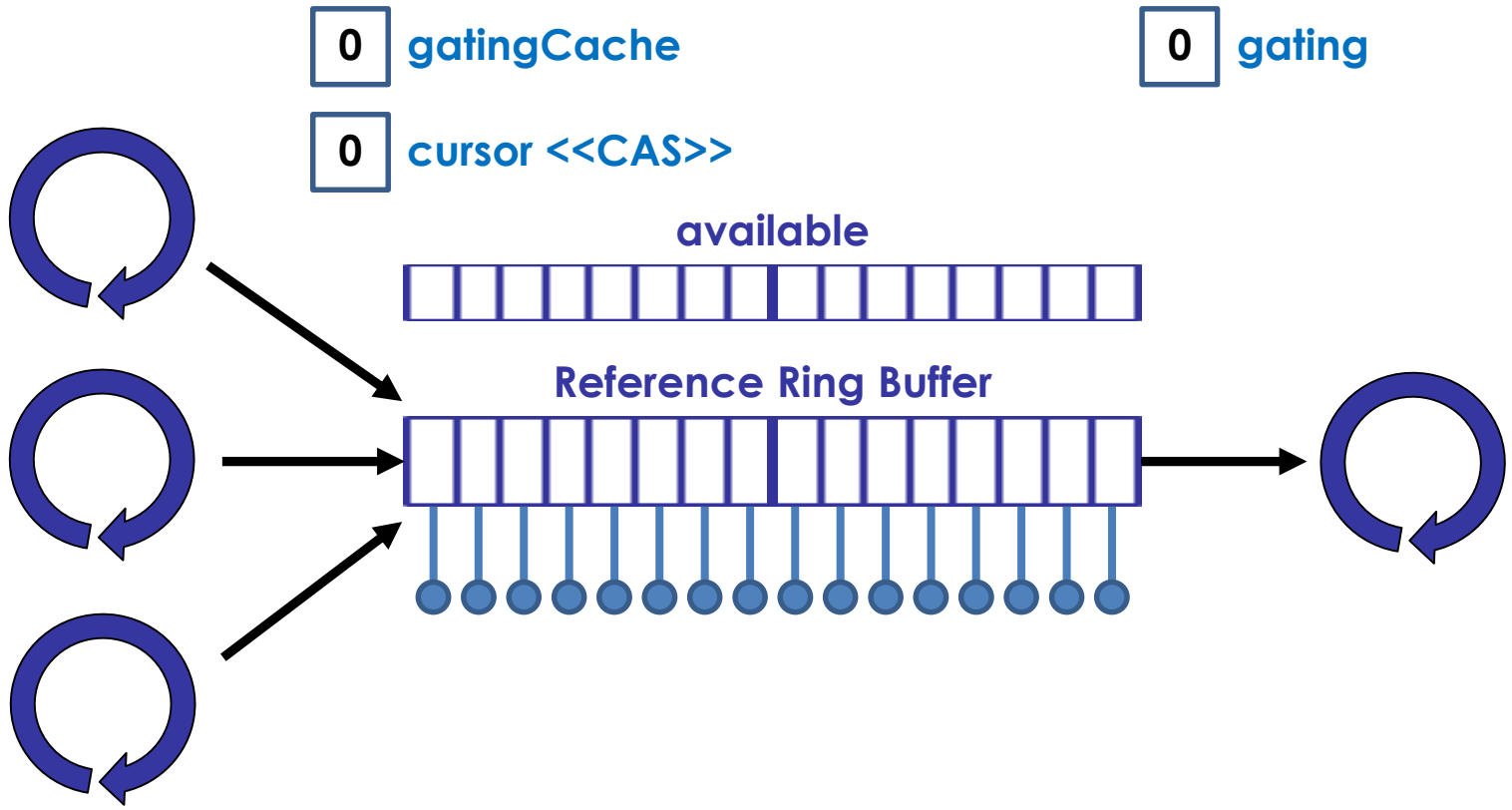
```
long expectedSequence = claimedSequence - 1;

while (cursor != expectedSequence)
{
    // busy spin
}

cursor = claimedSequence;
```

# Disruptor 3.0

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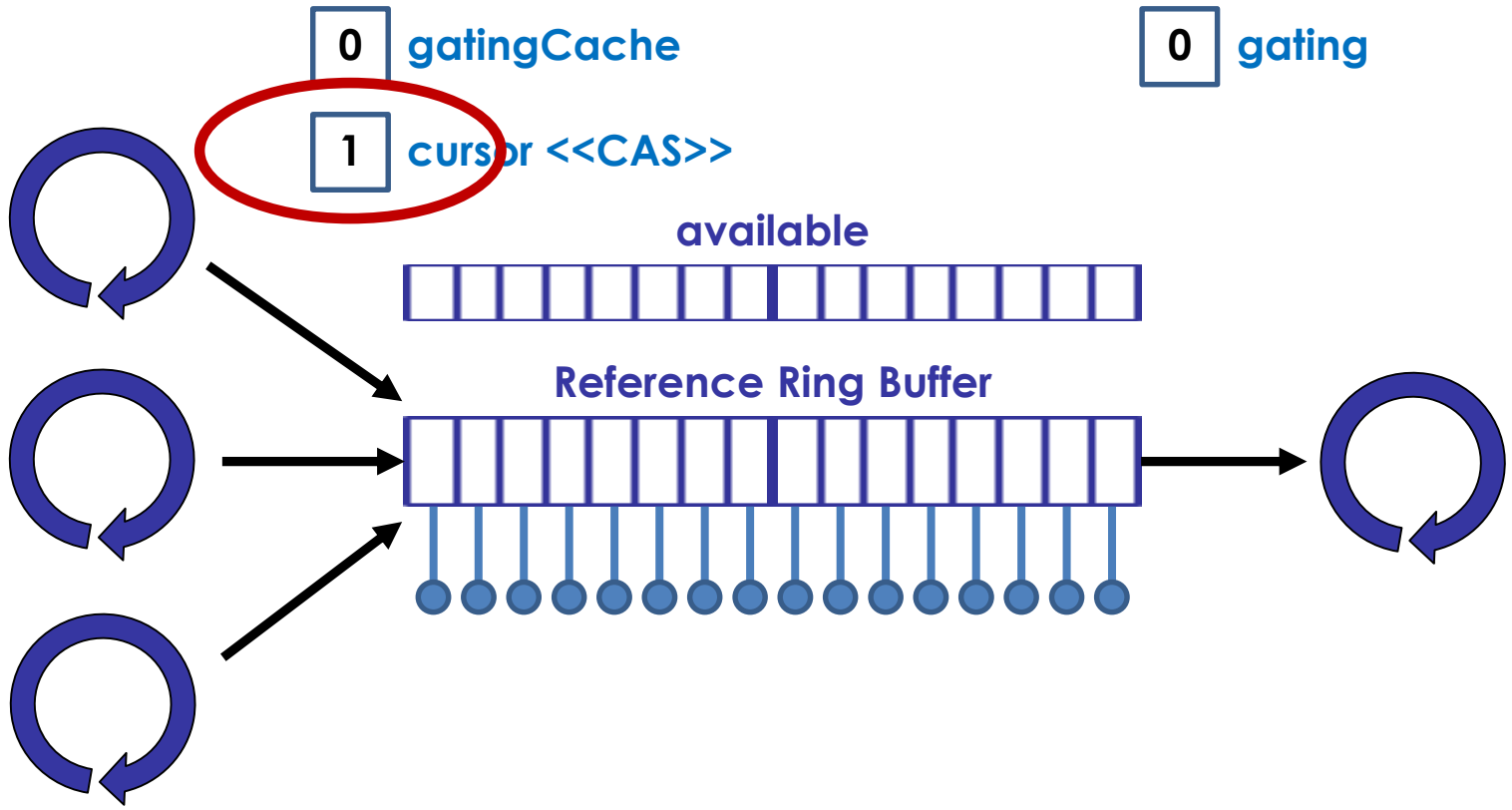


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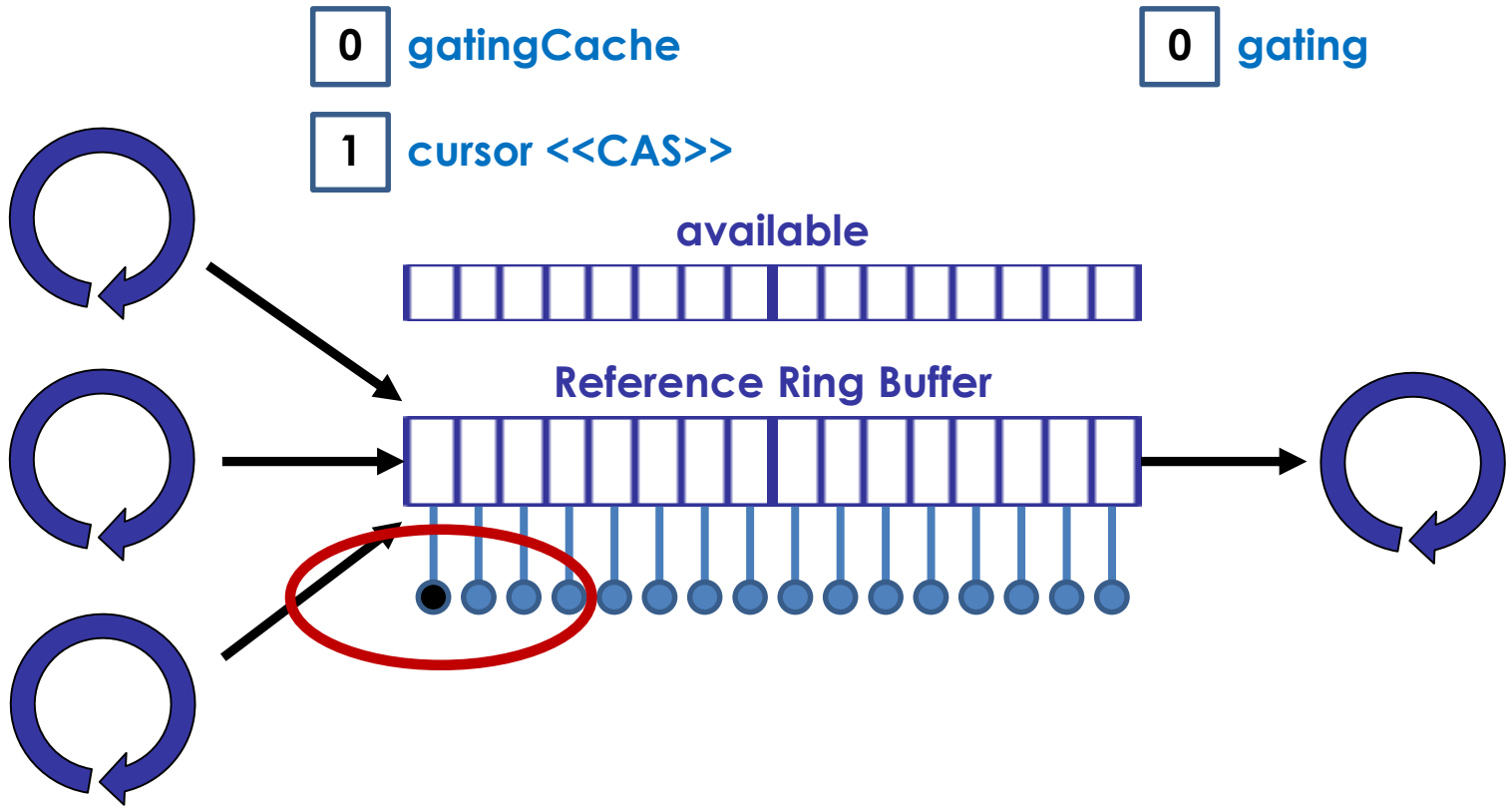


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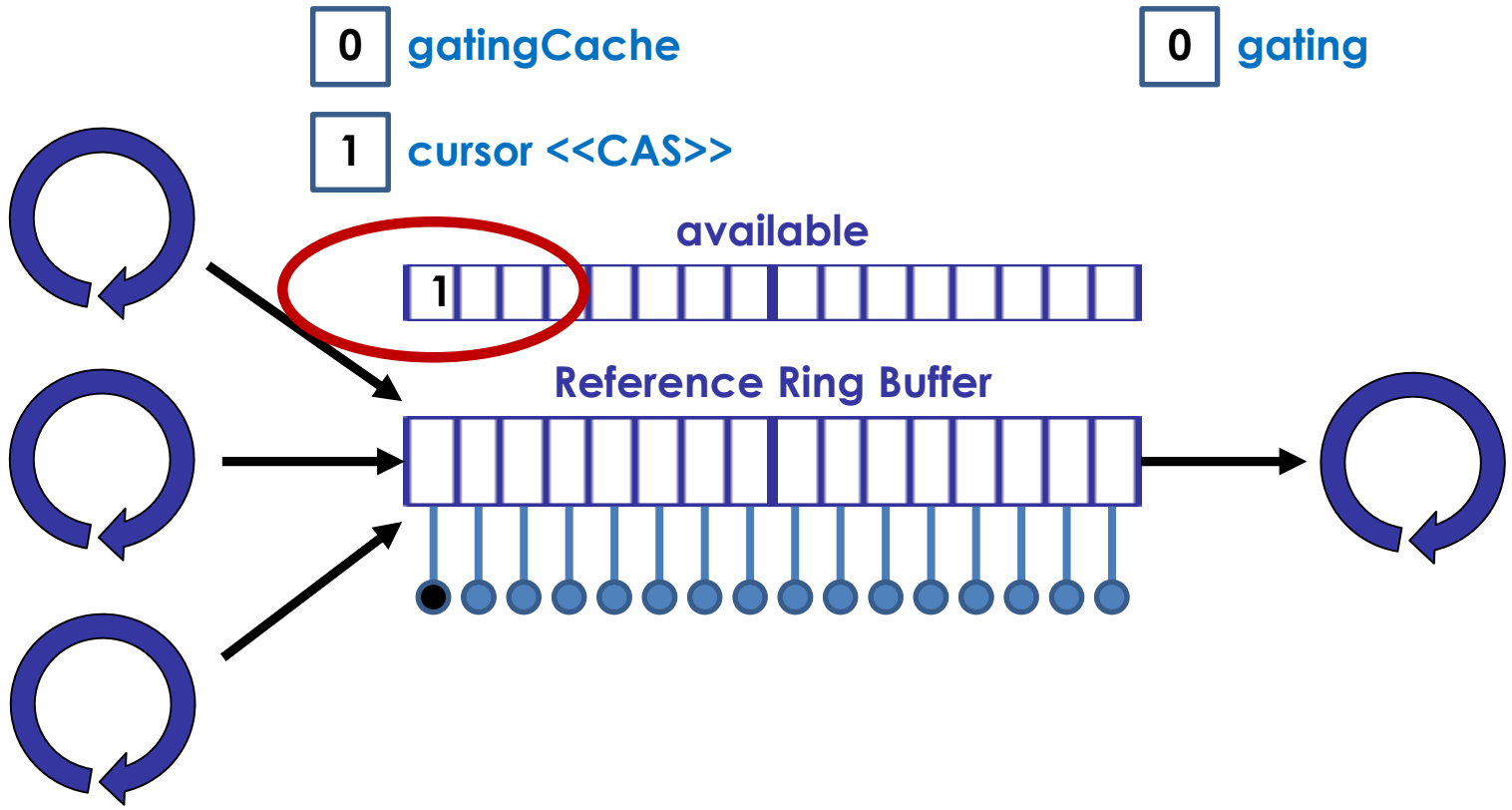


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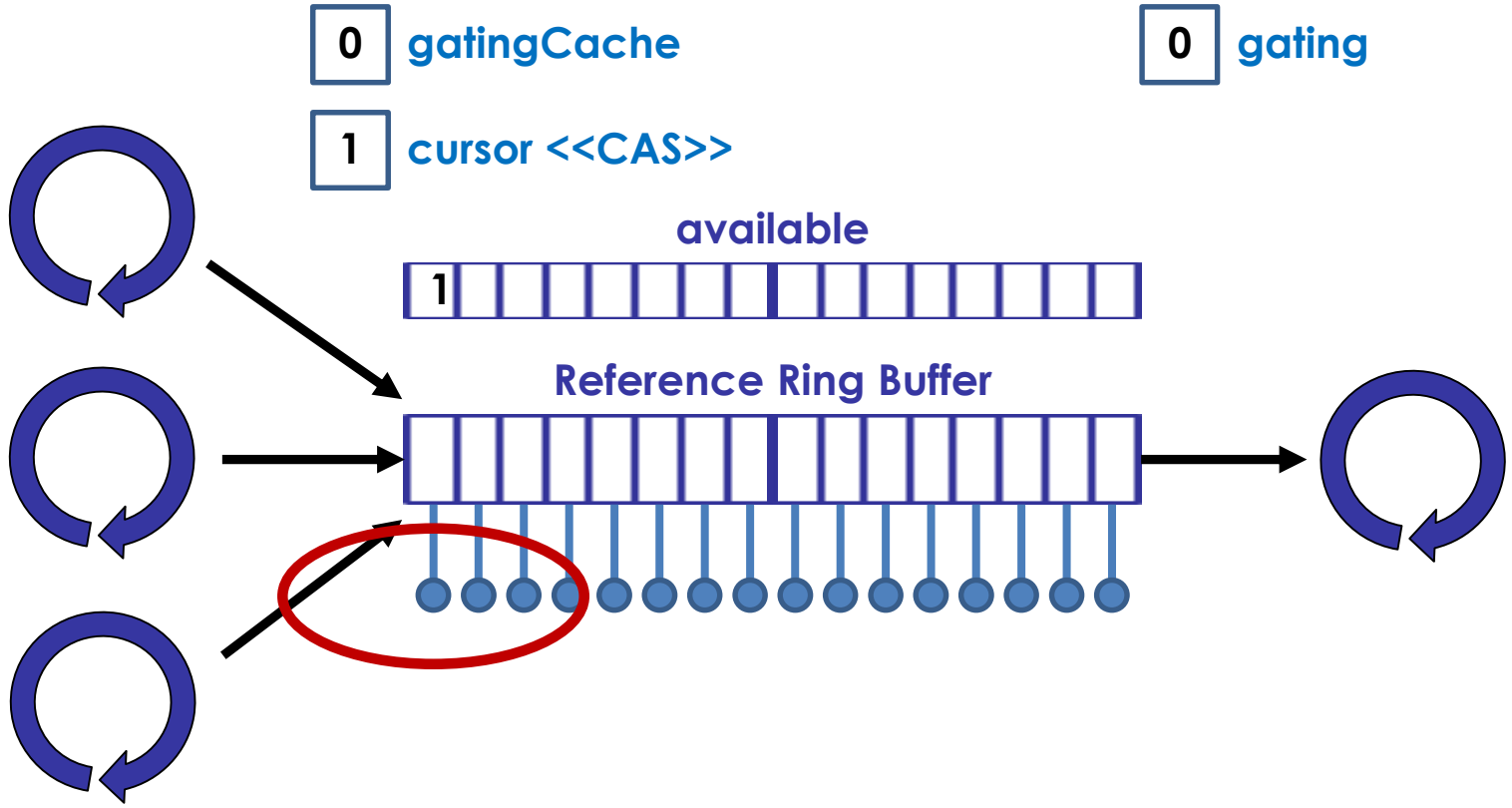


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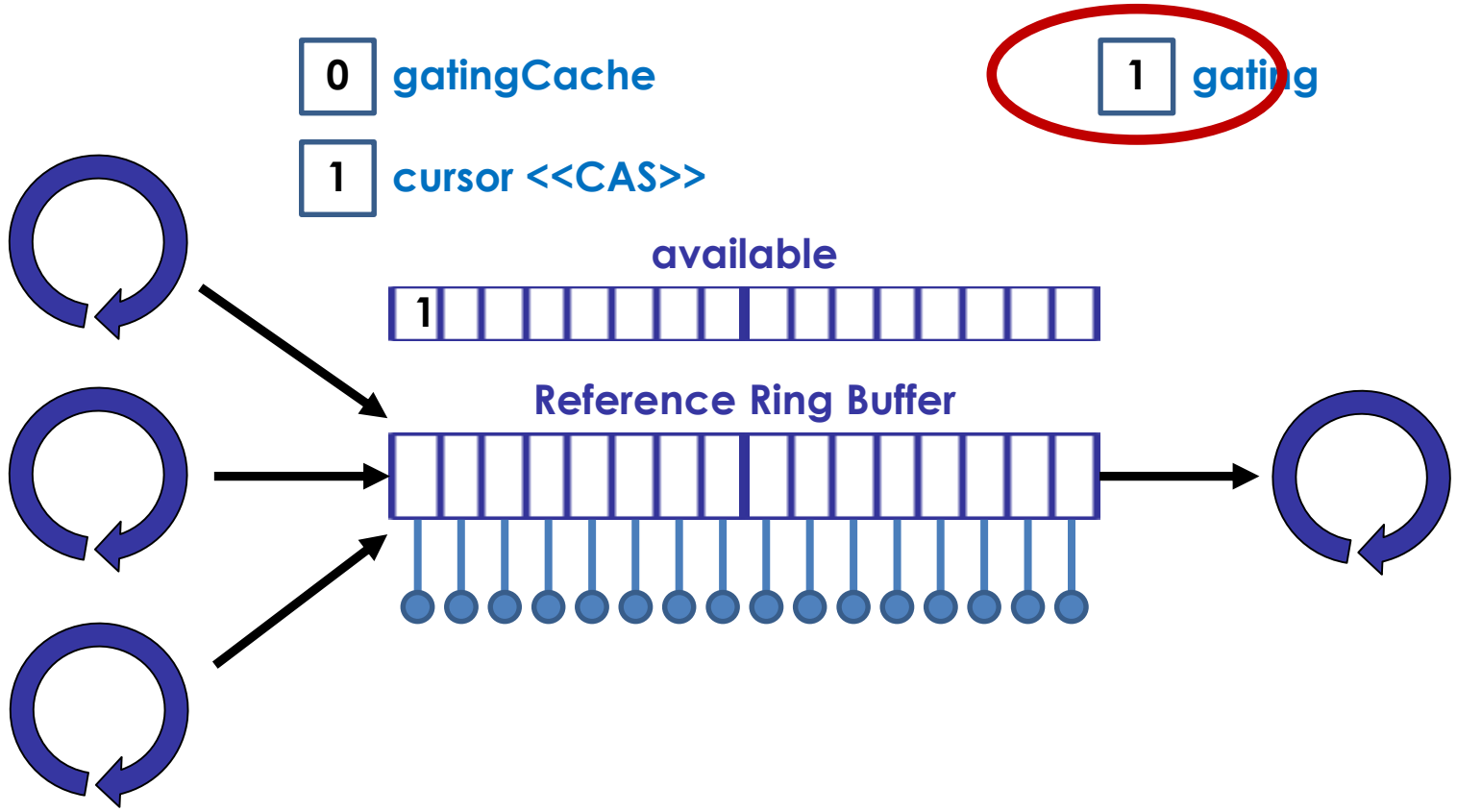
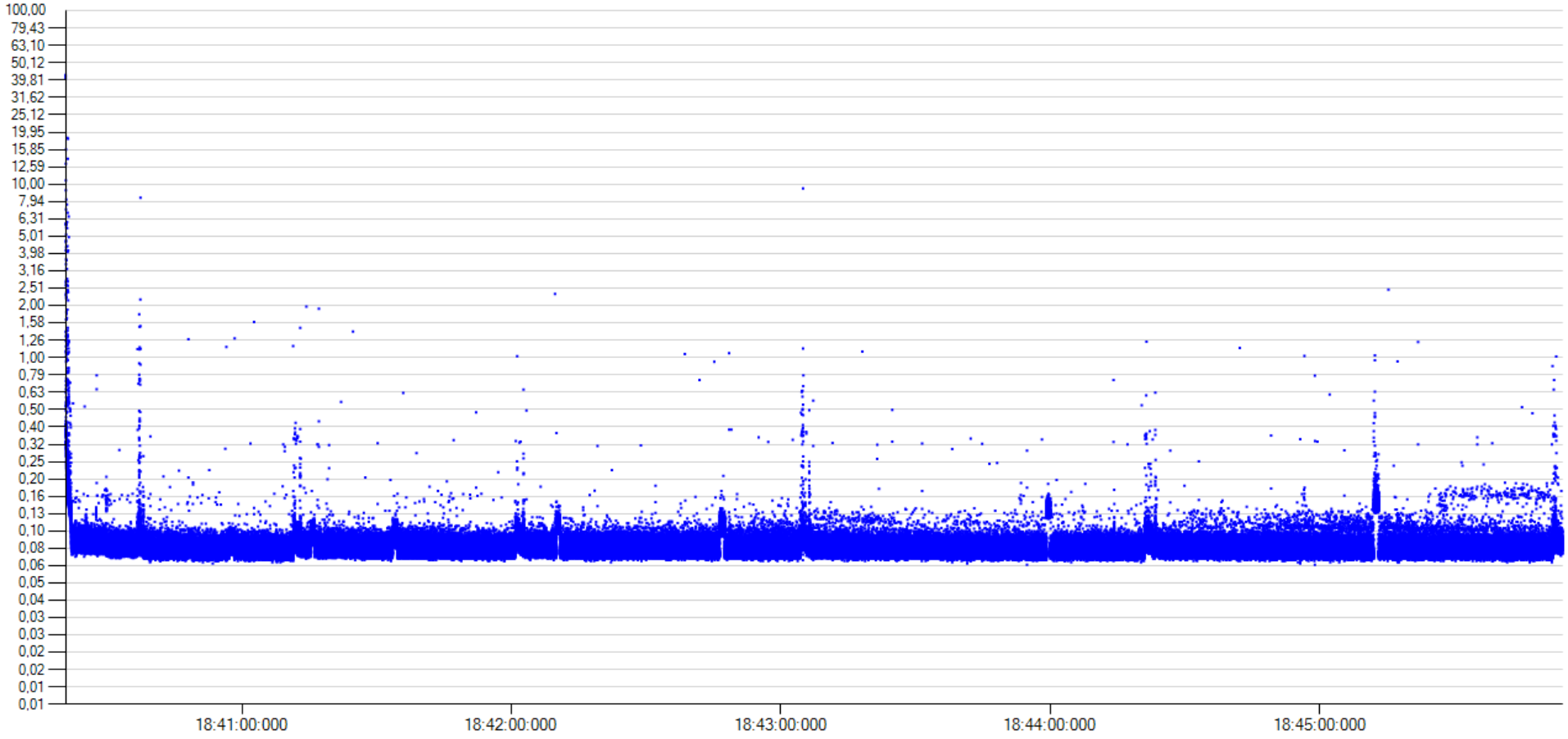



*Influences: Lamport + Network Cards + Fast Flow*

# Disruptor 2.0



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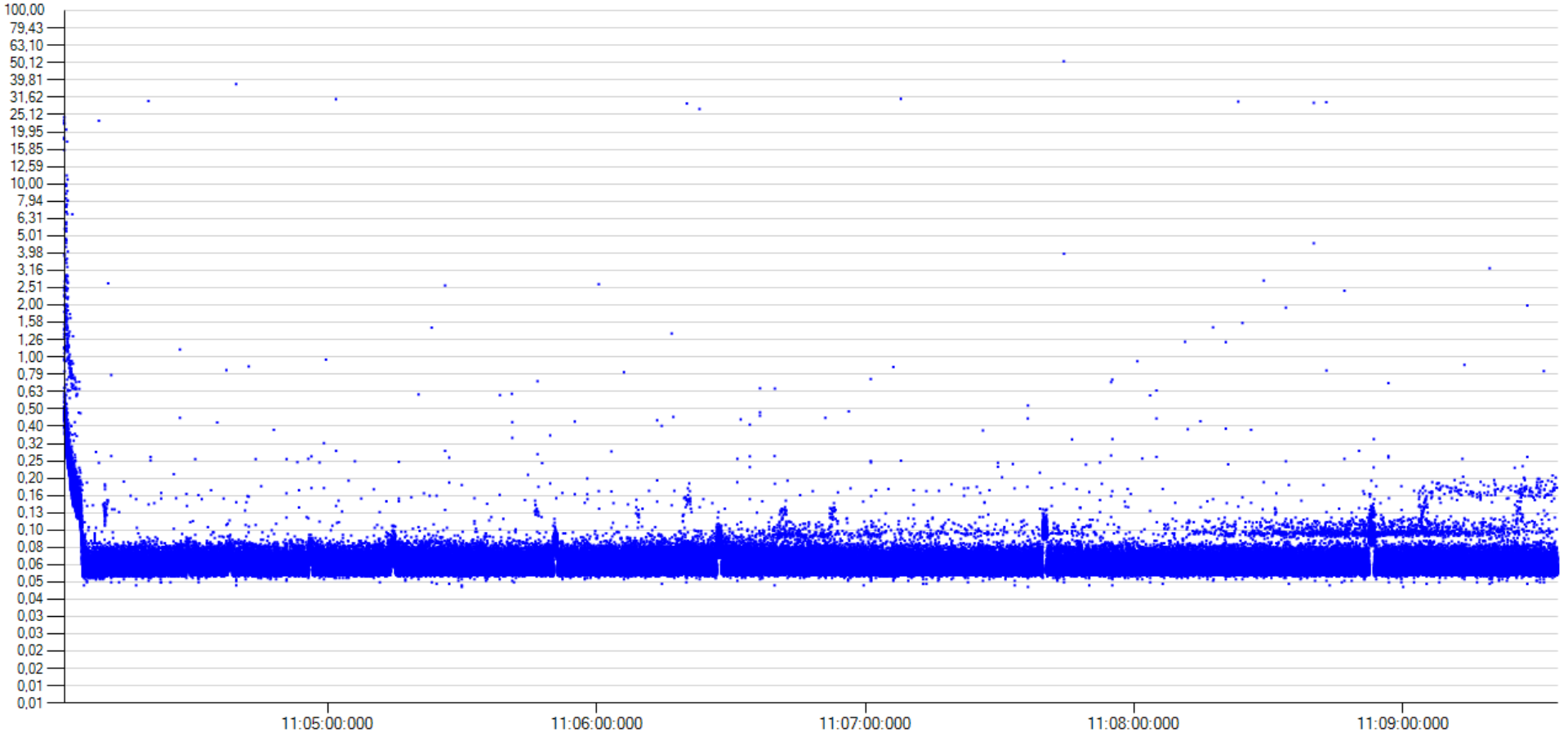
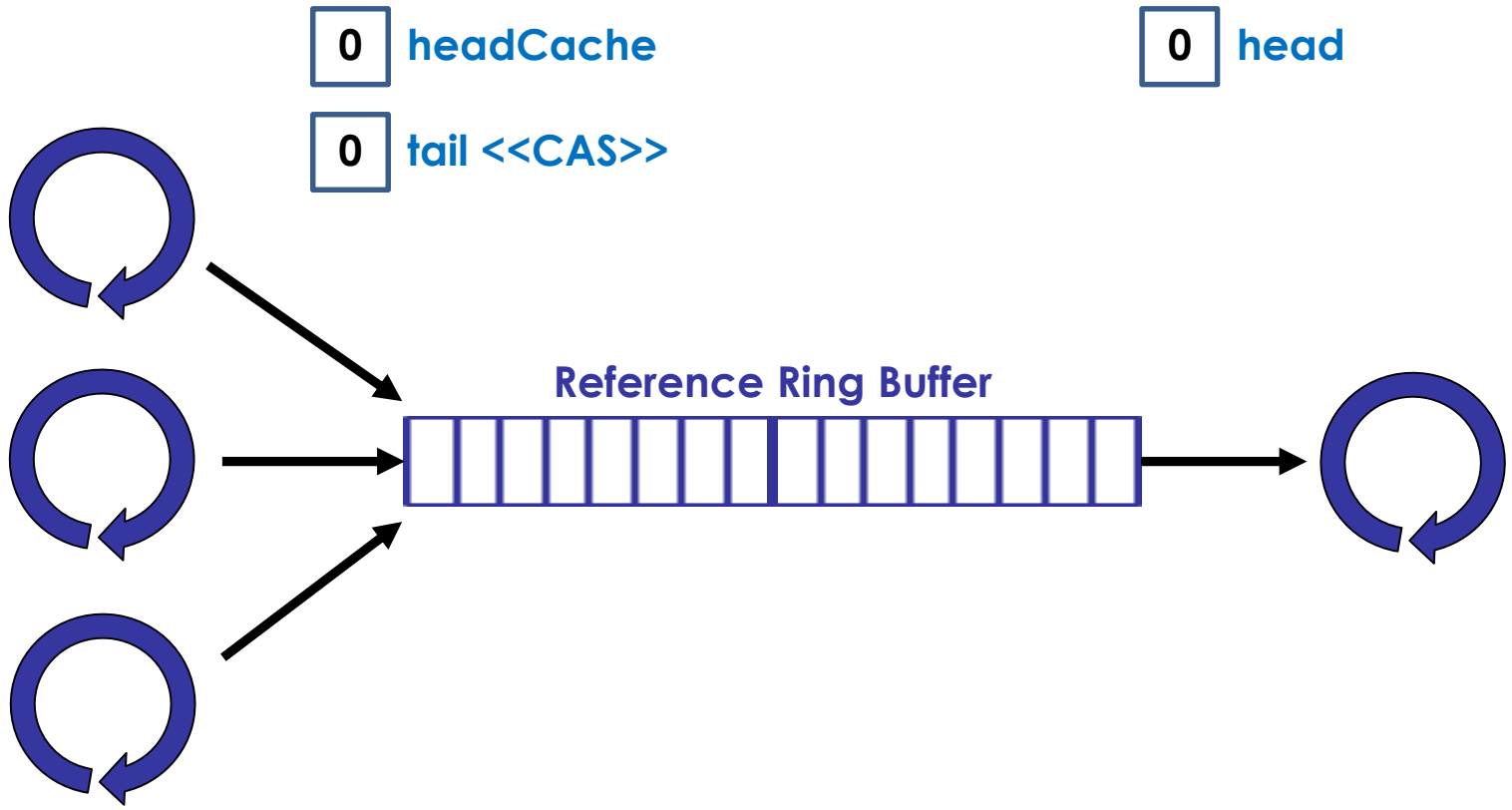


***What if I need something with a Queue interface?***

# ManyToOneConcurrentArrayQueue

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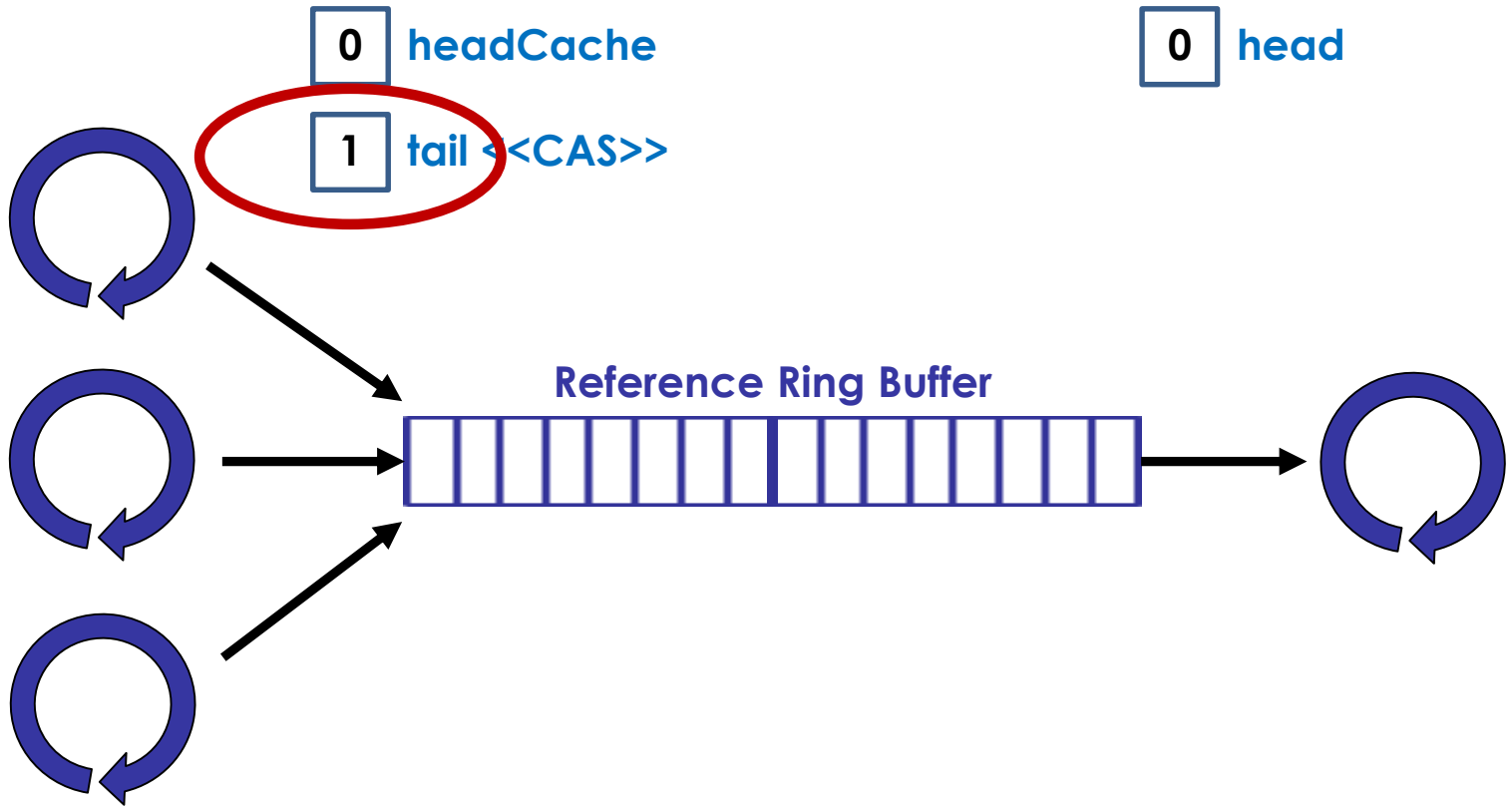


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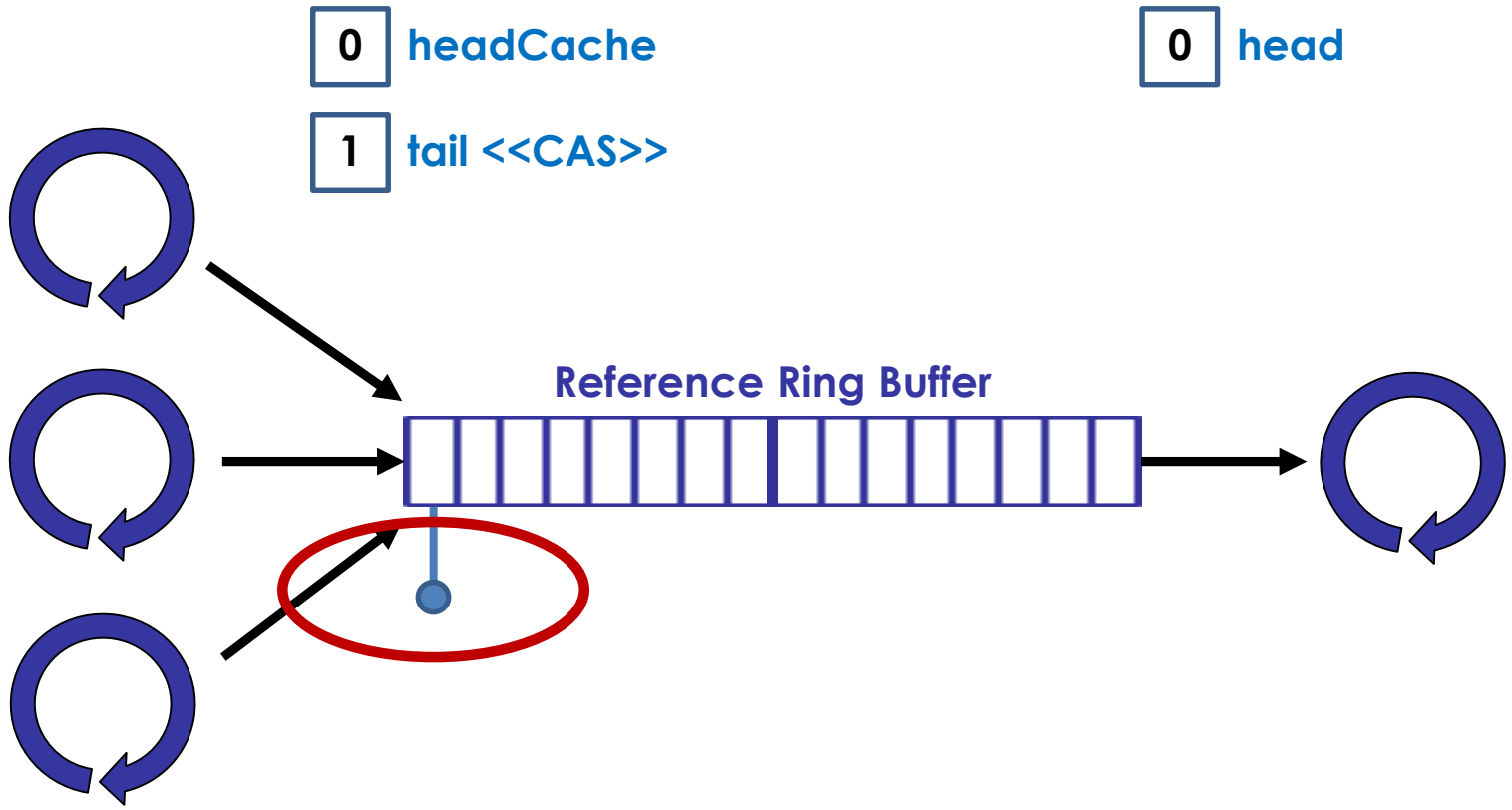


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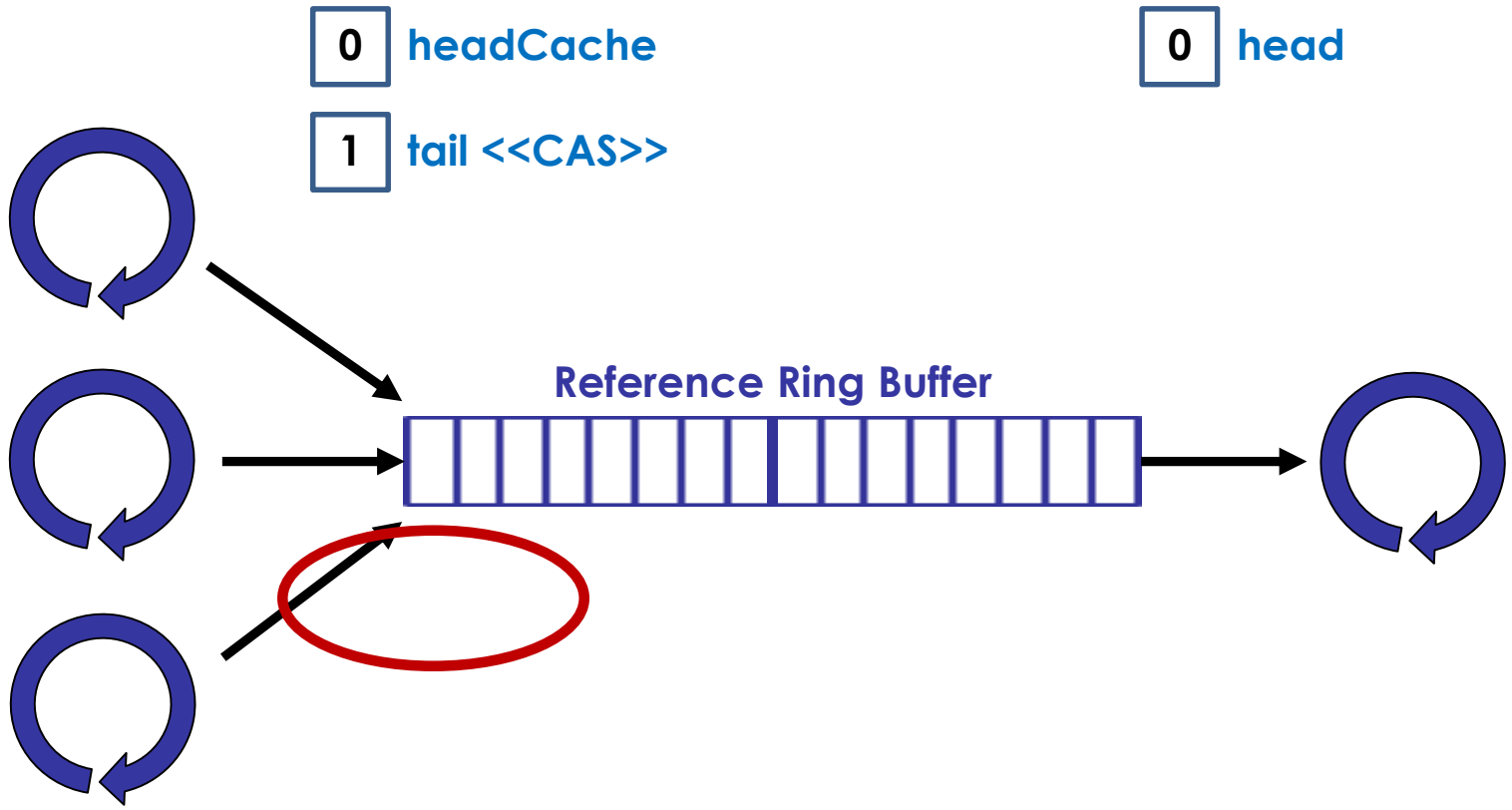


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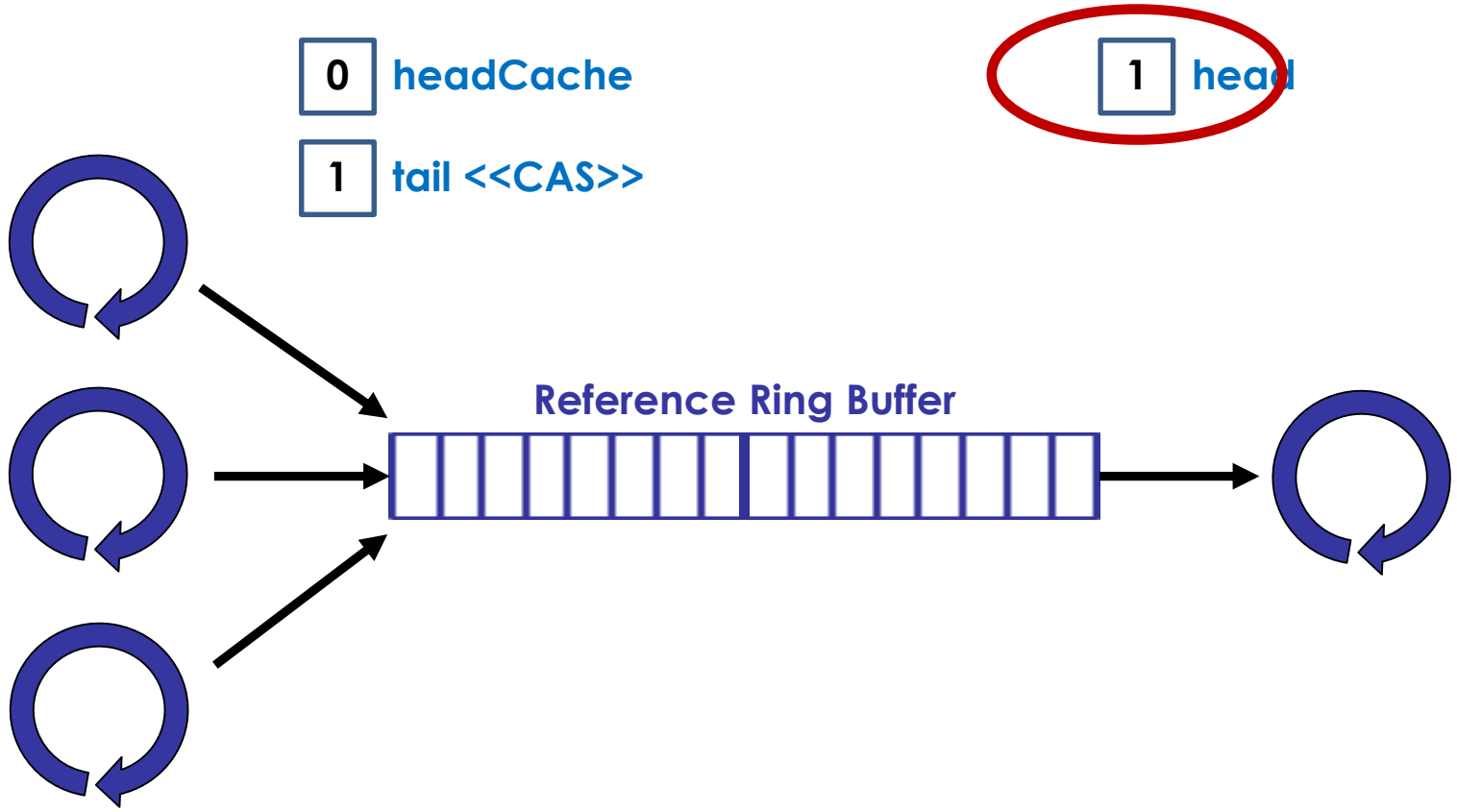


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| `Disruptor 3.3.2` | 1 | 201 | 263 |
| | 2 | 256 | 373 |
| | 3 | 282 | 459 |
| `ManyToOneConcurrentArrayQueue` | 1 | 173 | 198 |
| | 2 | 238 | 319 |
| | 3 | 259 | 392 |

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| | 2 | 15,159 | 21,184 |
| | 3 | 31,597 | 54,976 |
| ManyToOneConcurrentArrayQueue | 1 | 3,570 | 3,932 |
| | 2 | 12,926 | 16,480 |
| | 3 | 26,685 | 51,072 |

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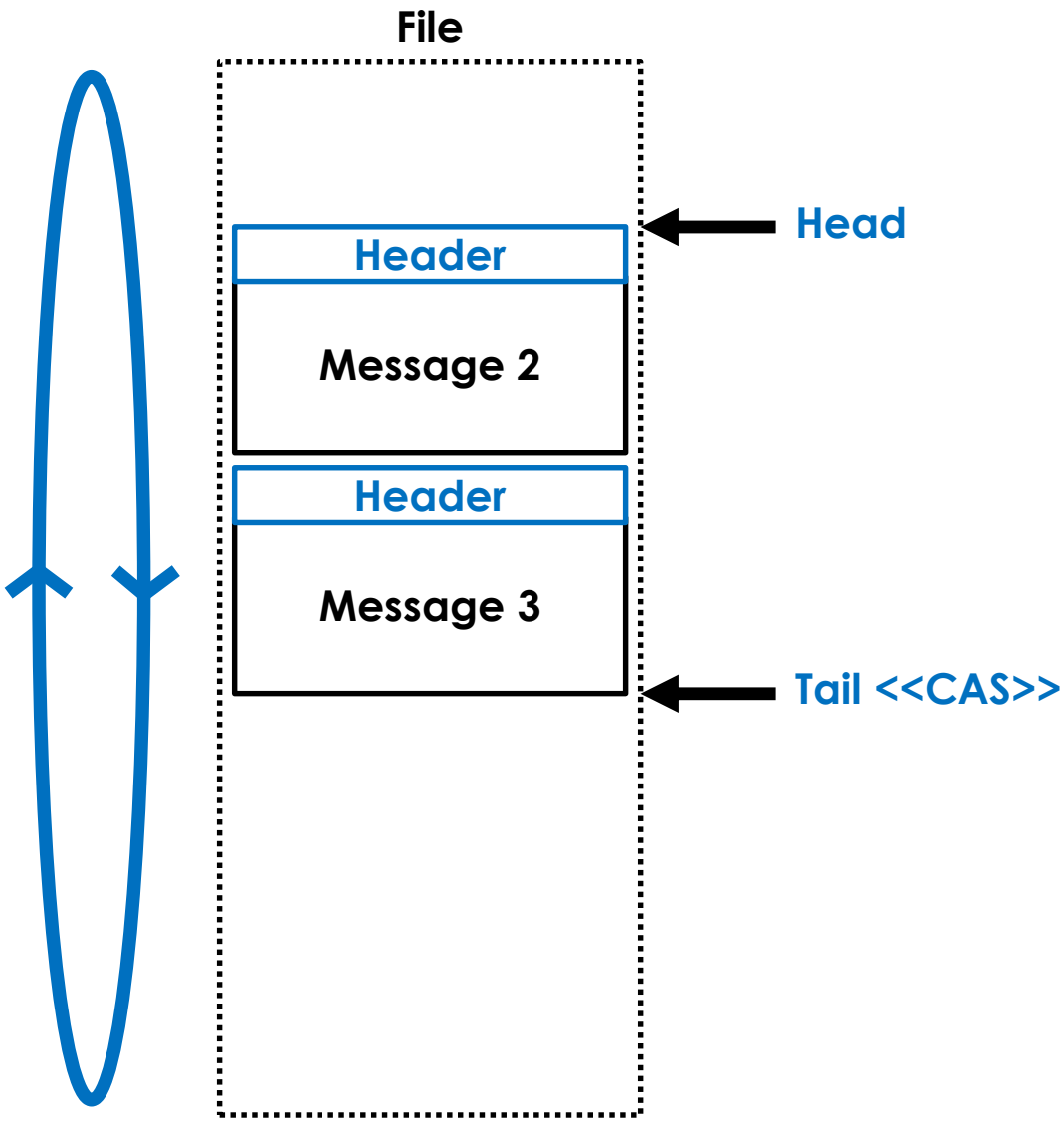
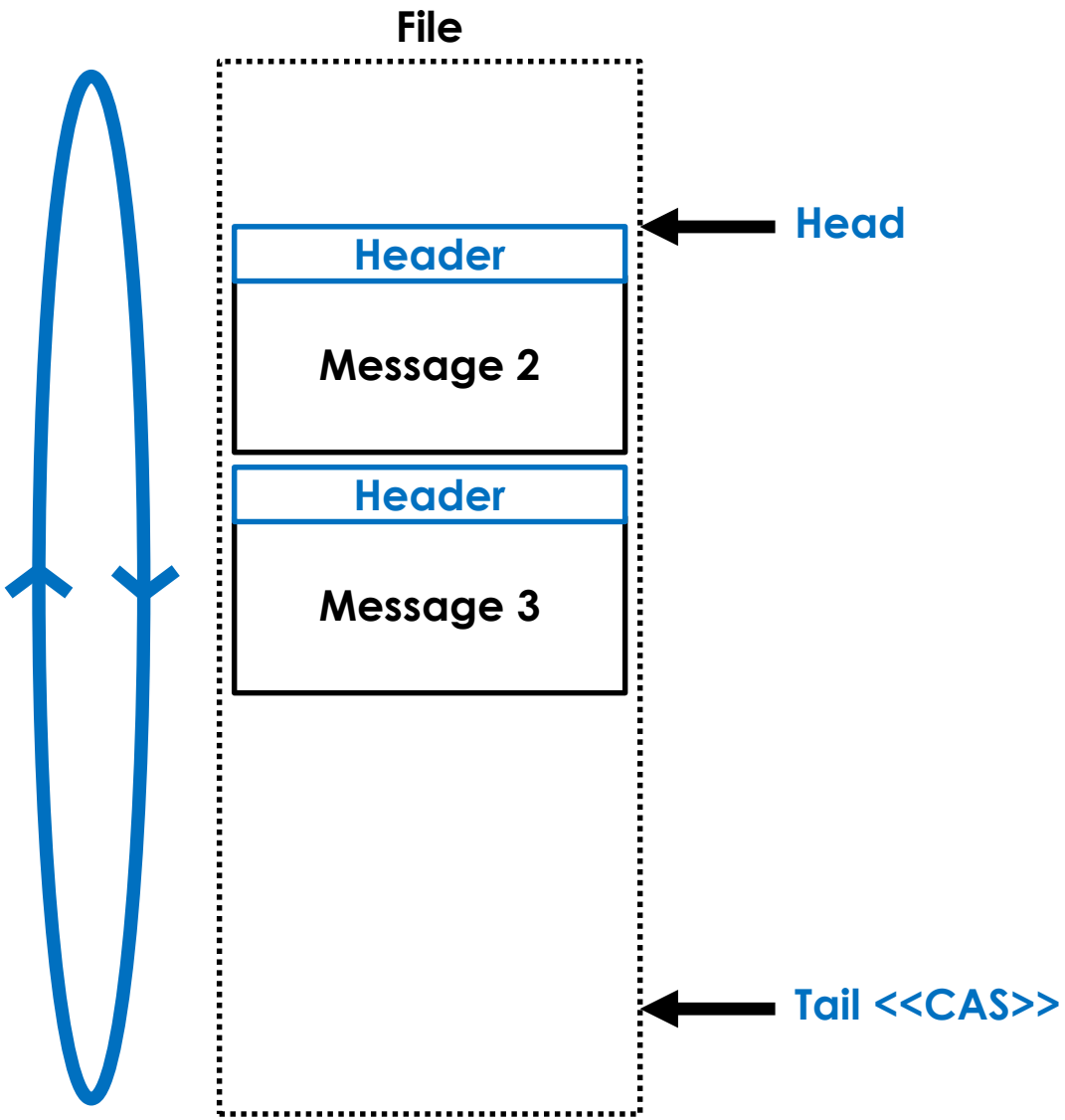
***BUT!!!***

***Disruptor has single producer and batch methods***

# Inter-Process FIFOs

# *ManyToOneRingBuffer*


File
Header
Message 2
Header
Message 3
Head
Tail <<CAS>>


File
Header
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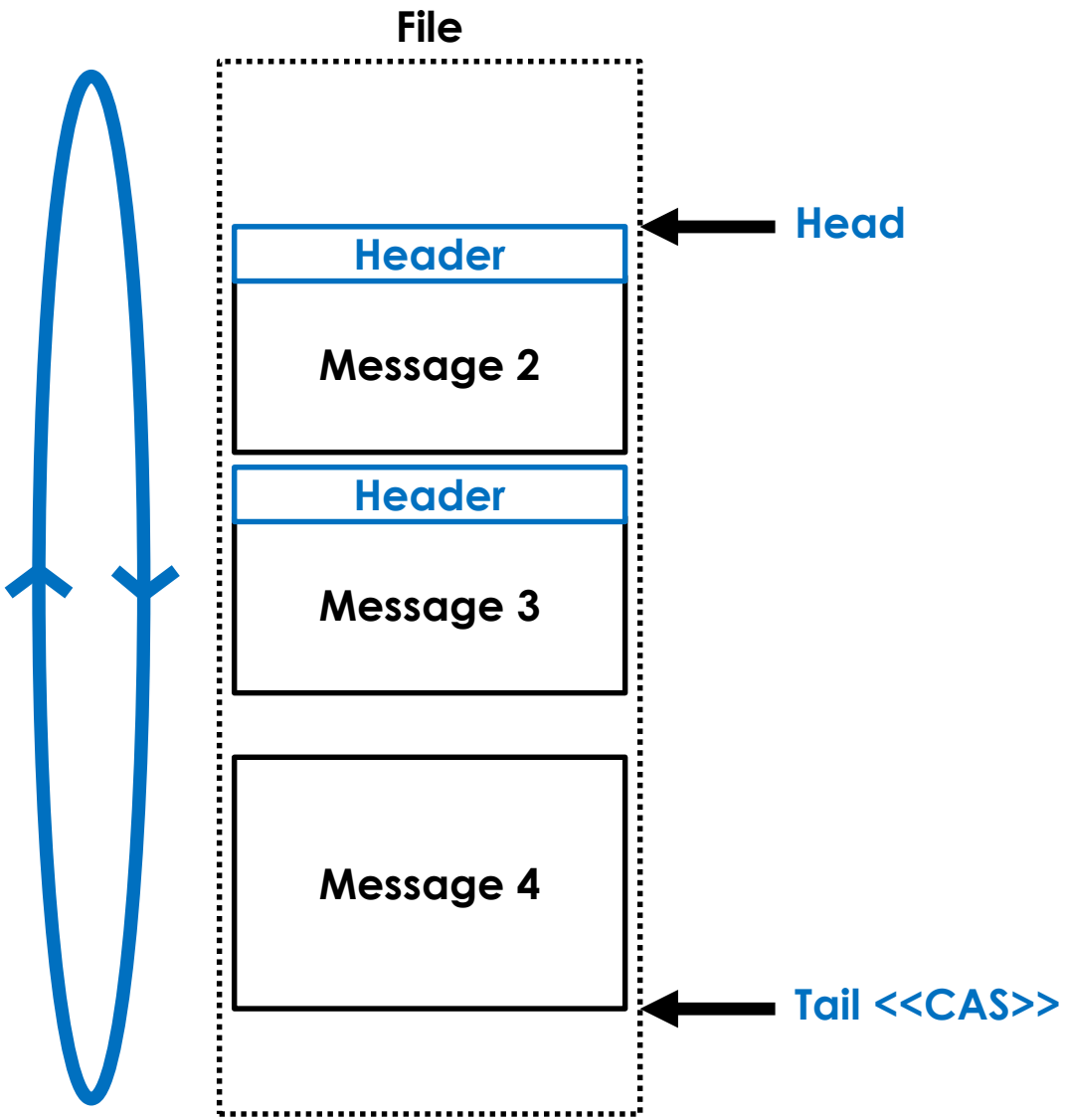
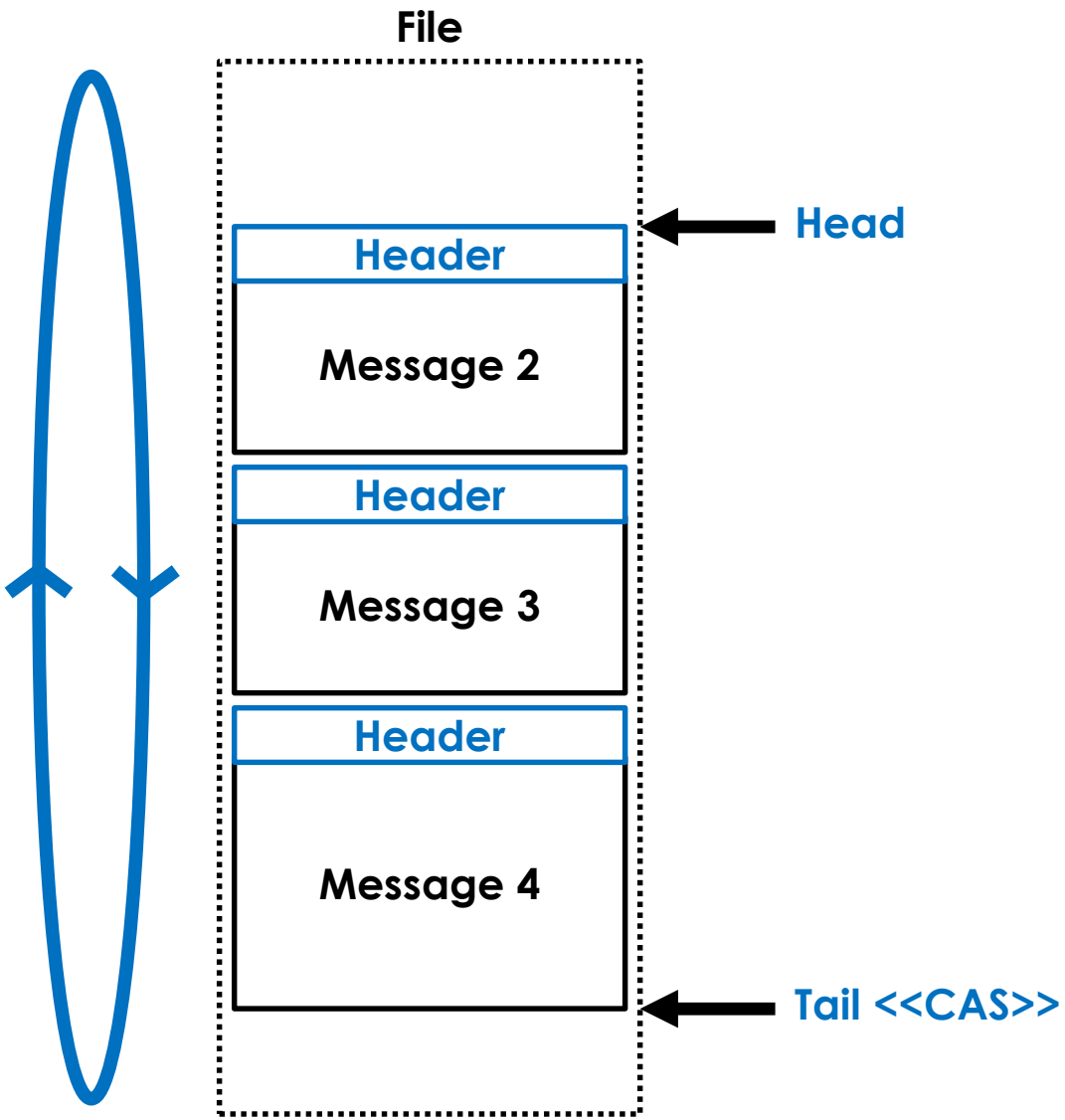
Header
Message 3
Head
Tail <<CAS>>


File
Header
Message 2
Header
Message 3
Message 4
Head
Tail <<CAS>>


File
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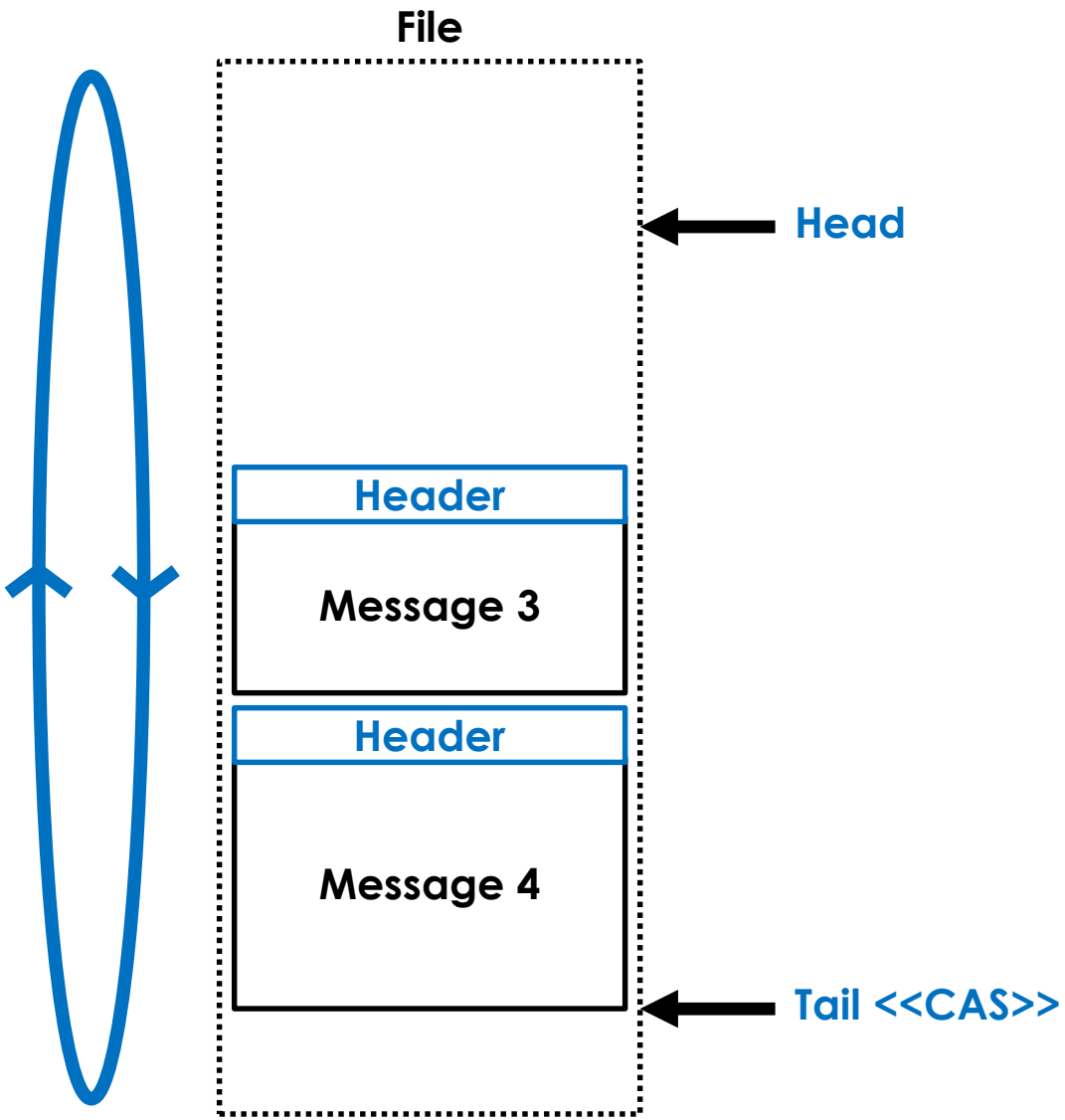
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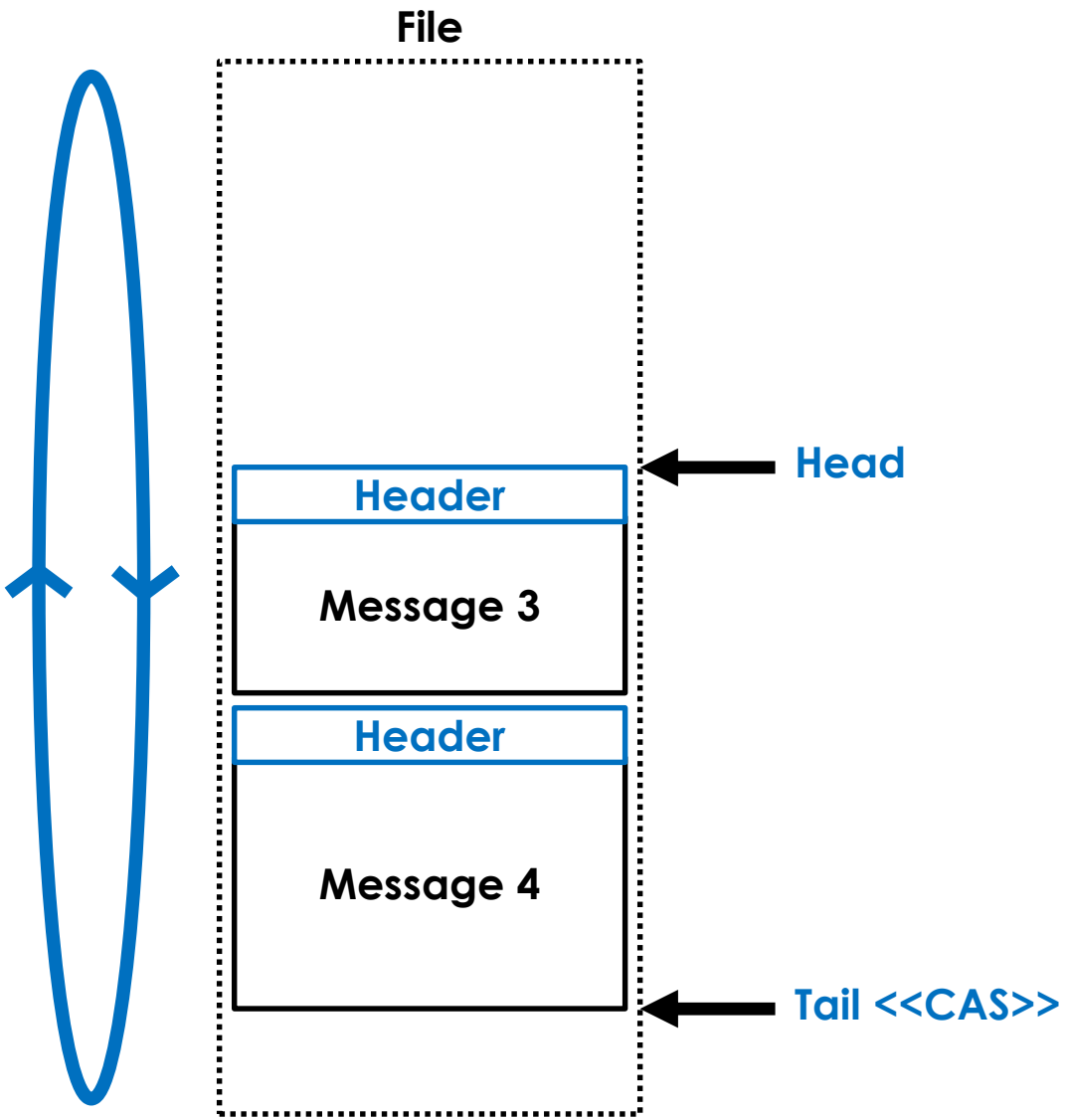
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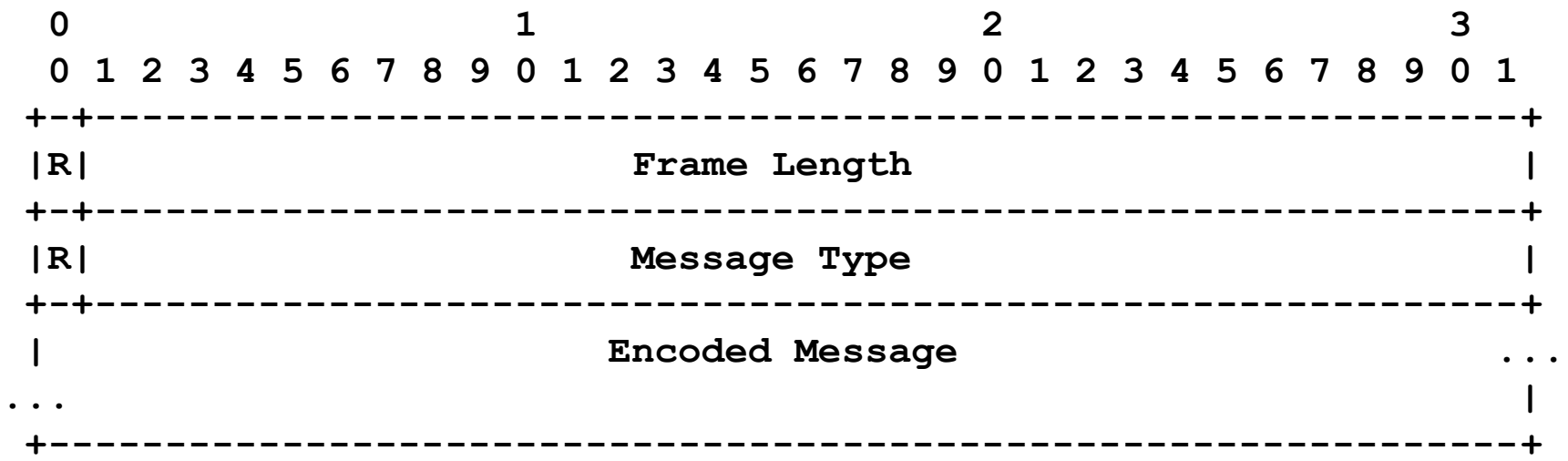
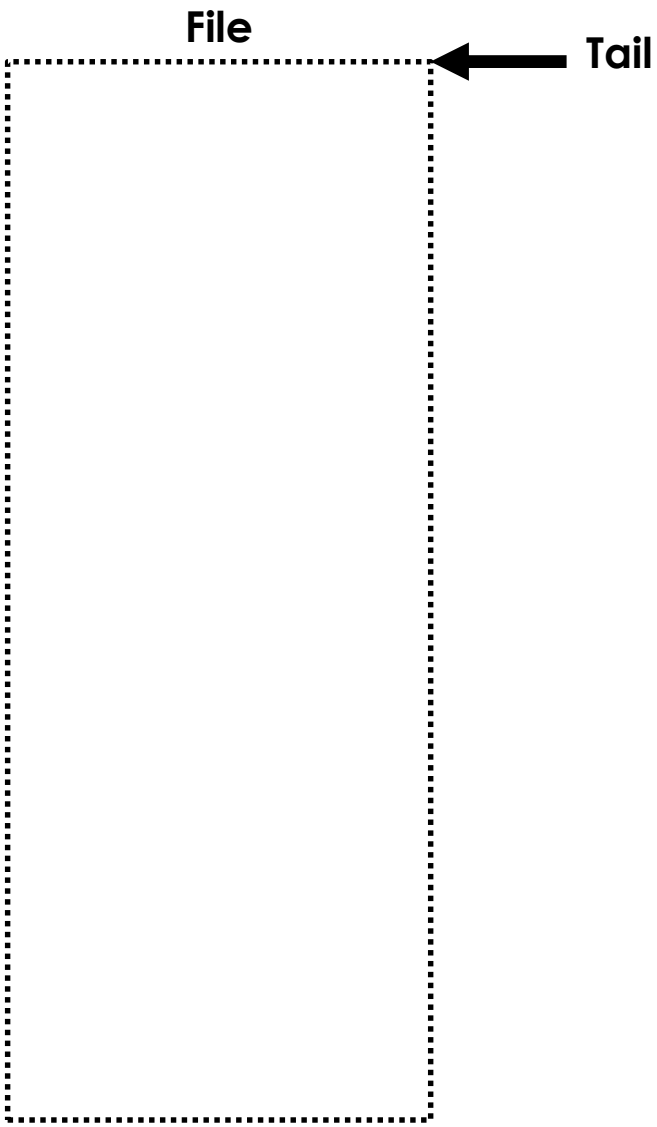
Message 3
Header
Message 4
Head
Tail <<CAS>>

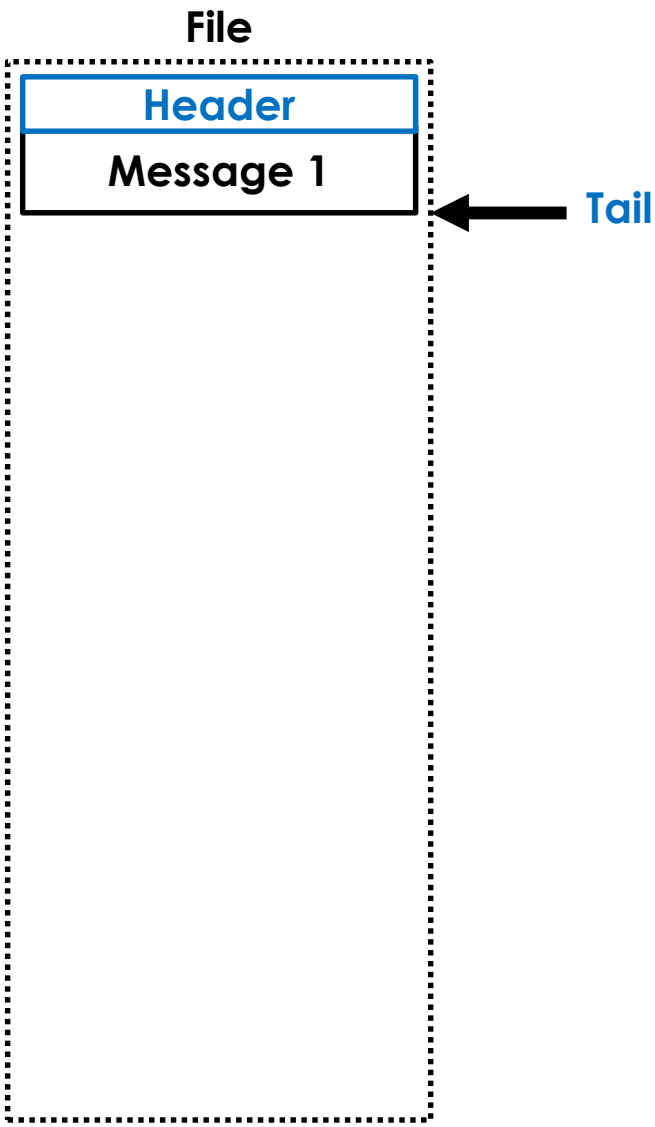
# MPSC Ring Buffer Message Header

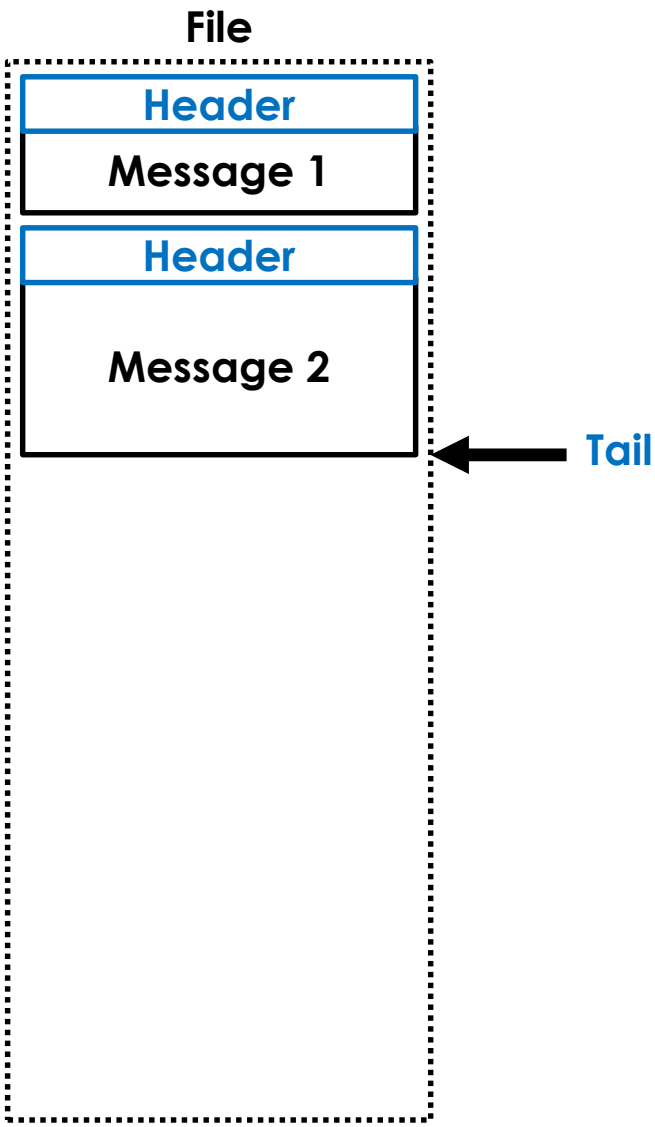


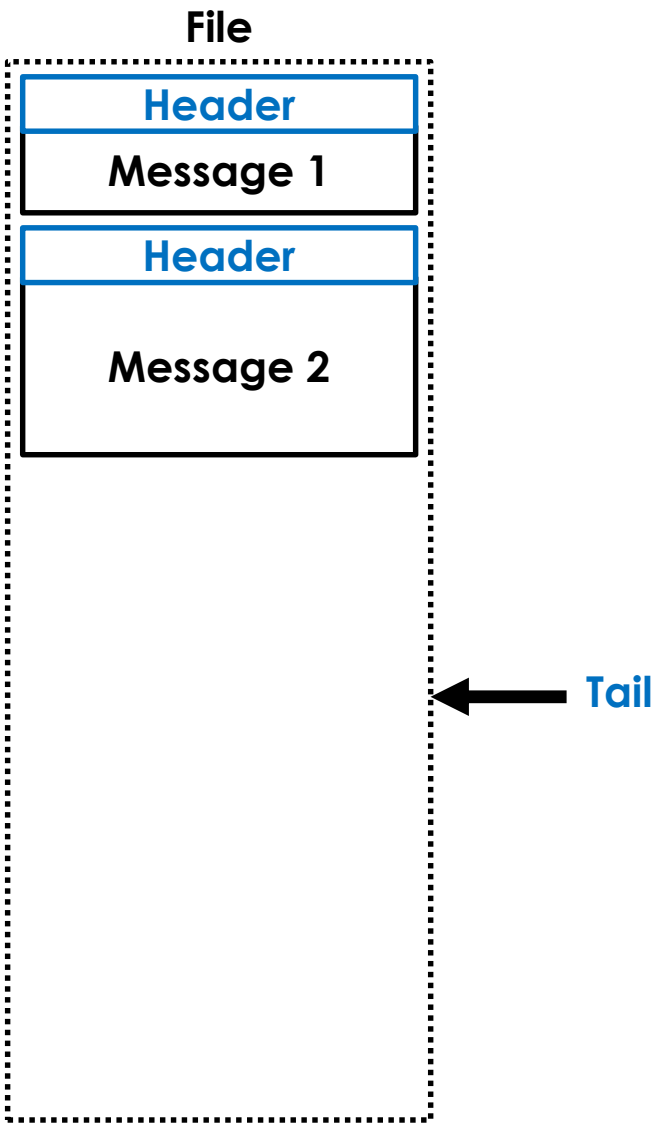
*Takes a throughput hit on zero'ing memory but latency is good*

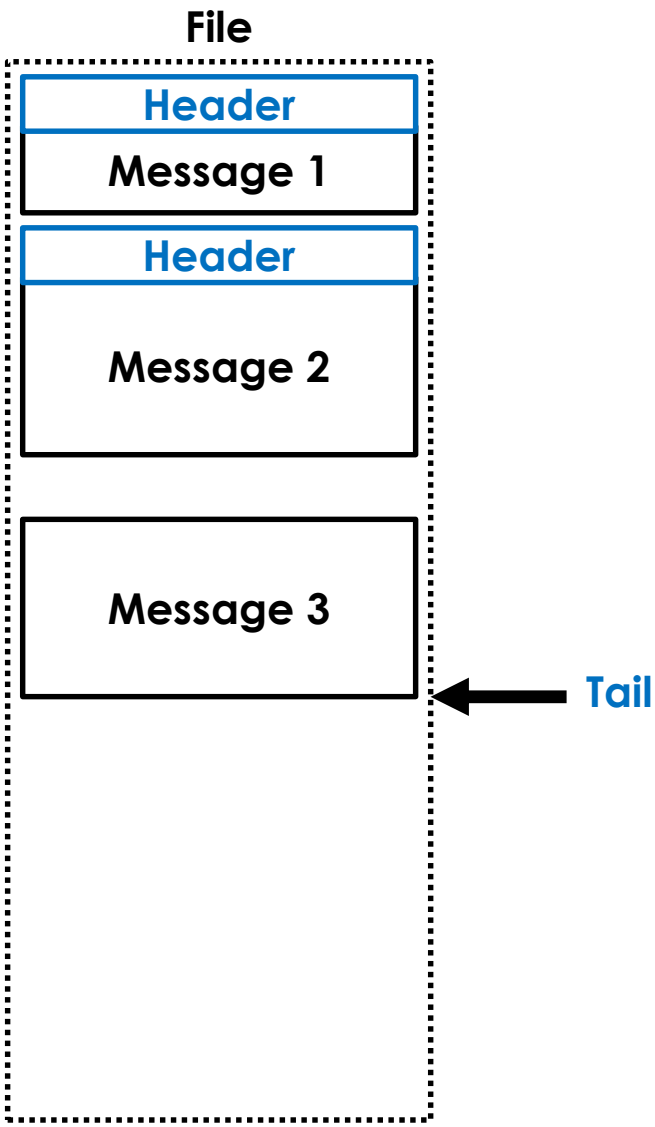
# *Aeron IPC*

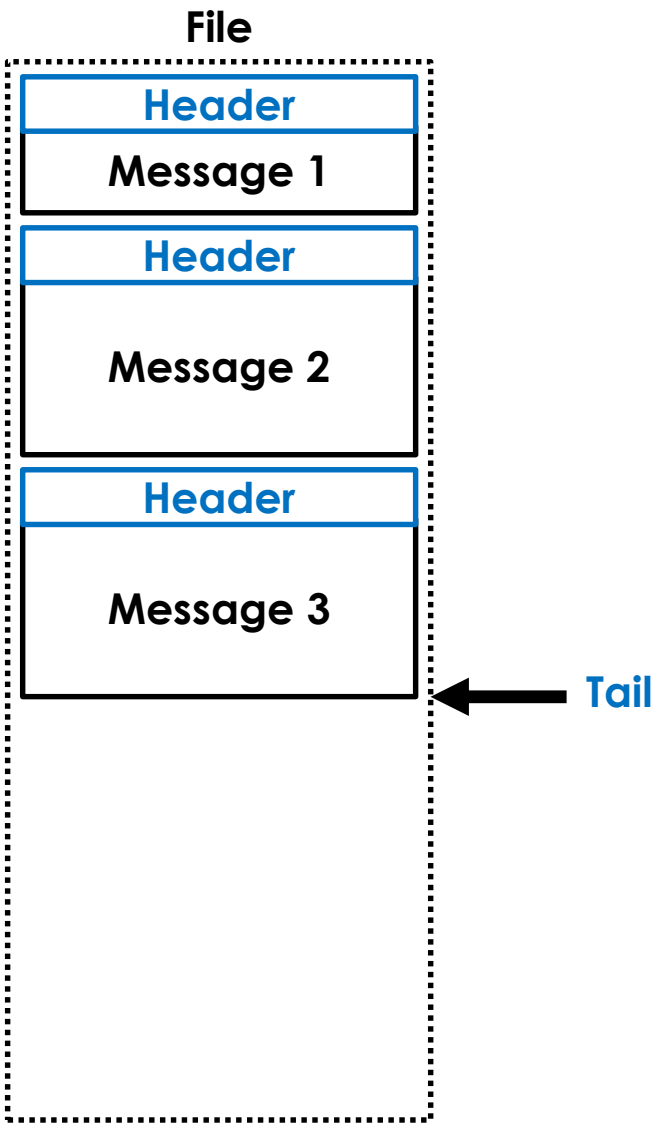

File
Tail


File
Header
Message 1
Tail


File
Header
Message 1
Header
Message 2
Tail


File
Header
Message 1
Header
Message 2
Tail

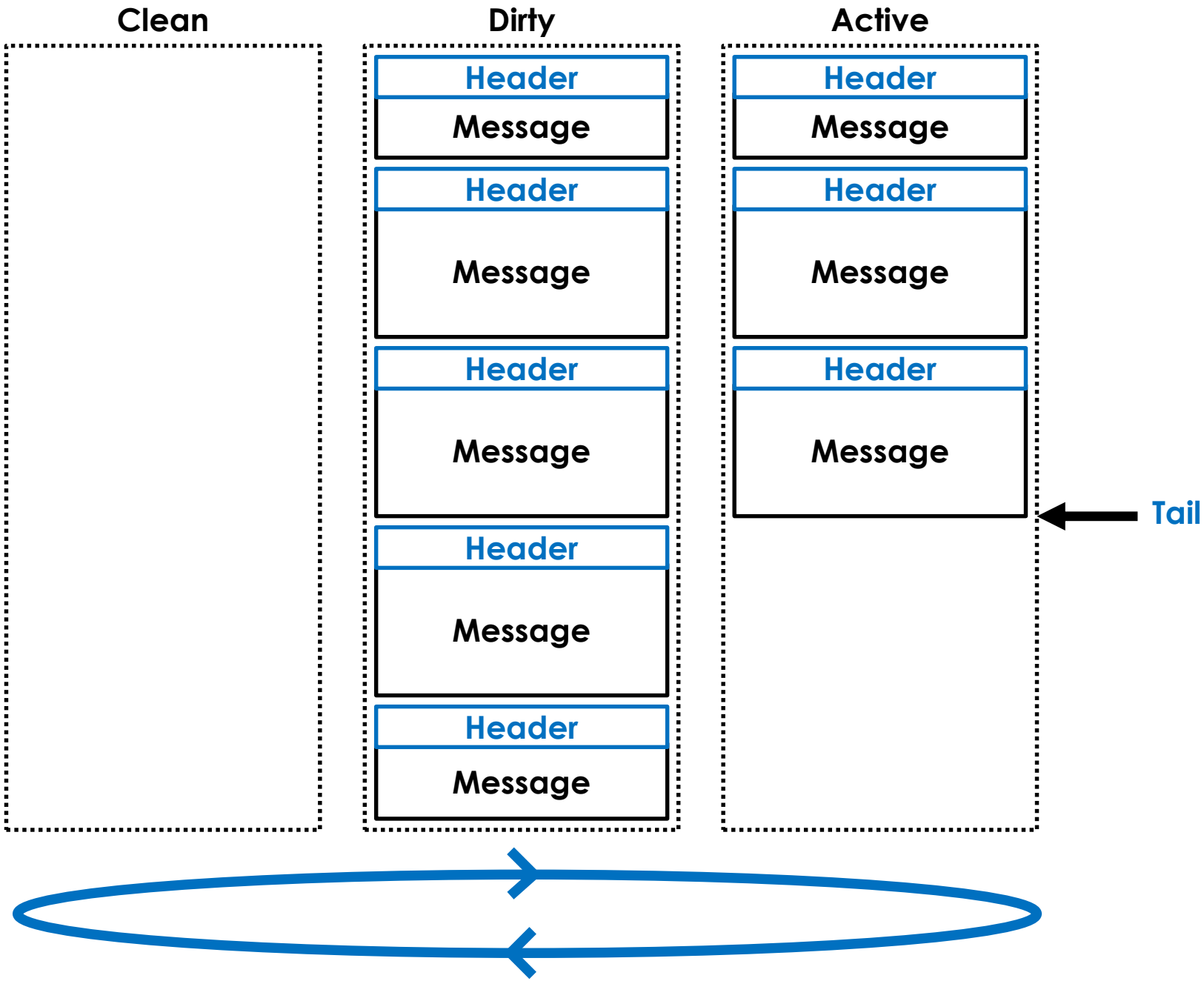

File
Header
Message 1
Header
Message 2
Message 3
Tail


File
Header
Message 1
Header
Message 2
Header
Message 3
Tail

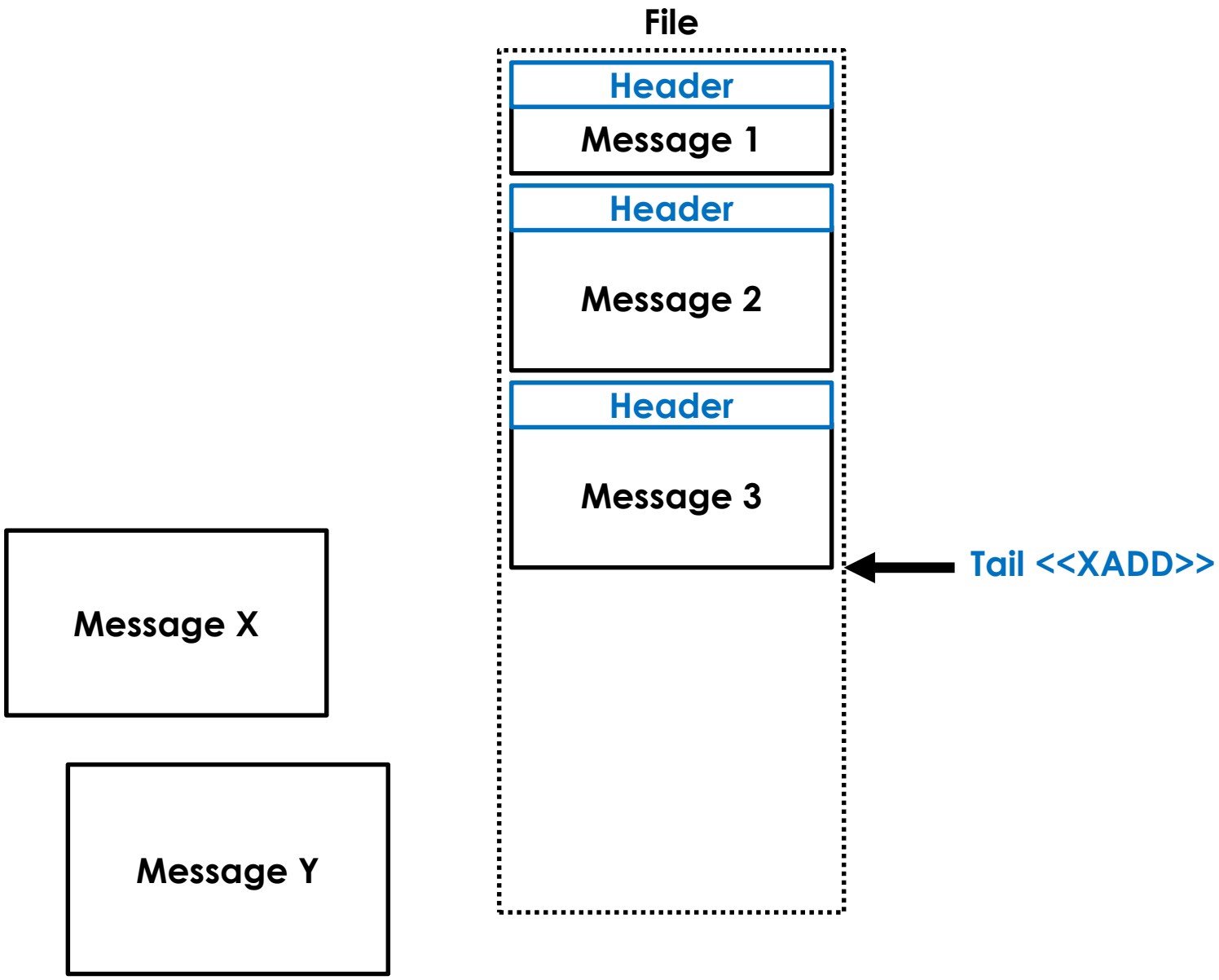
*One big file that goes on forever?*

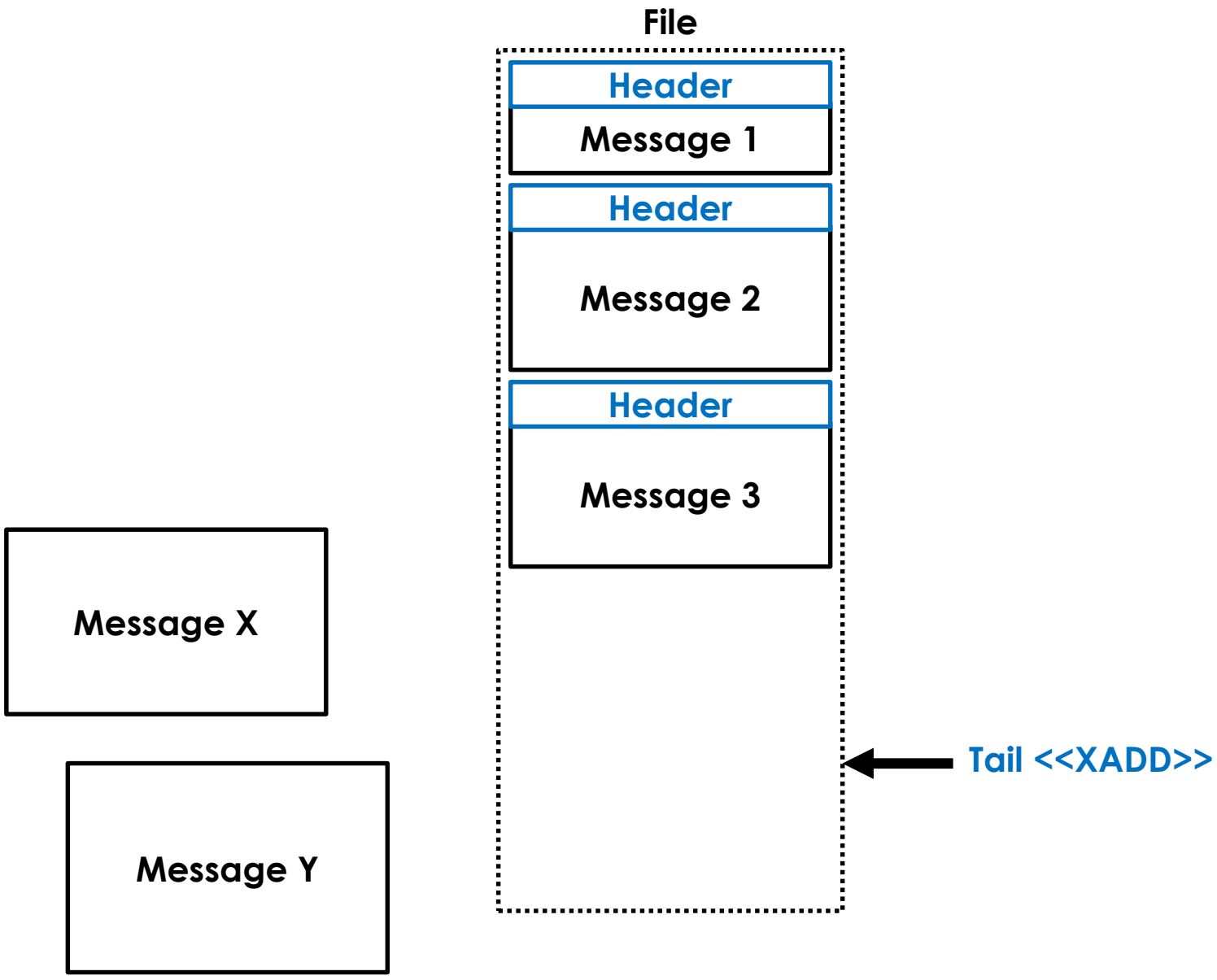
# *No!!!*

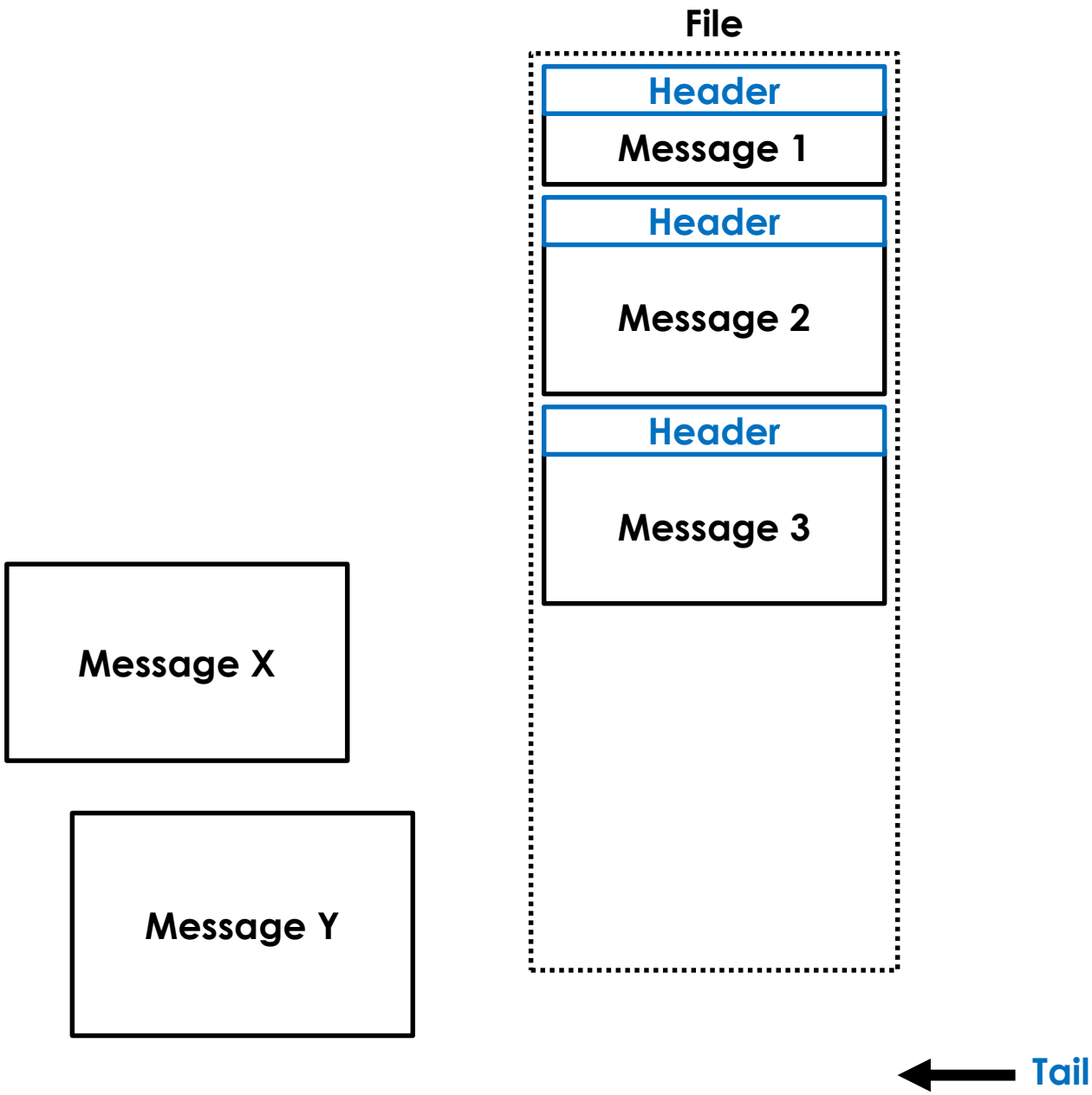
*Page faults, page cache churn, VM pressure, ...*

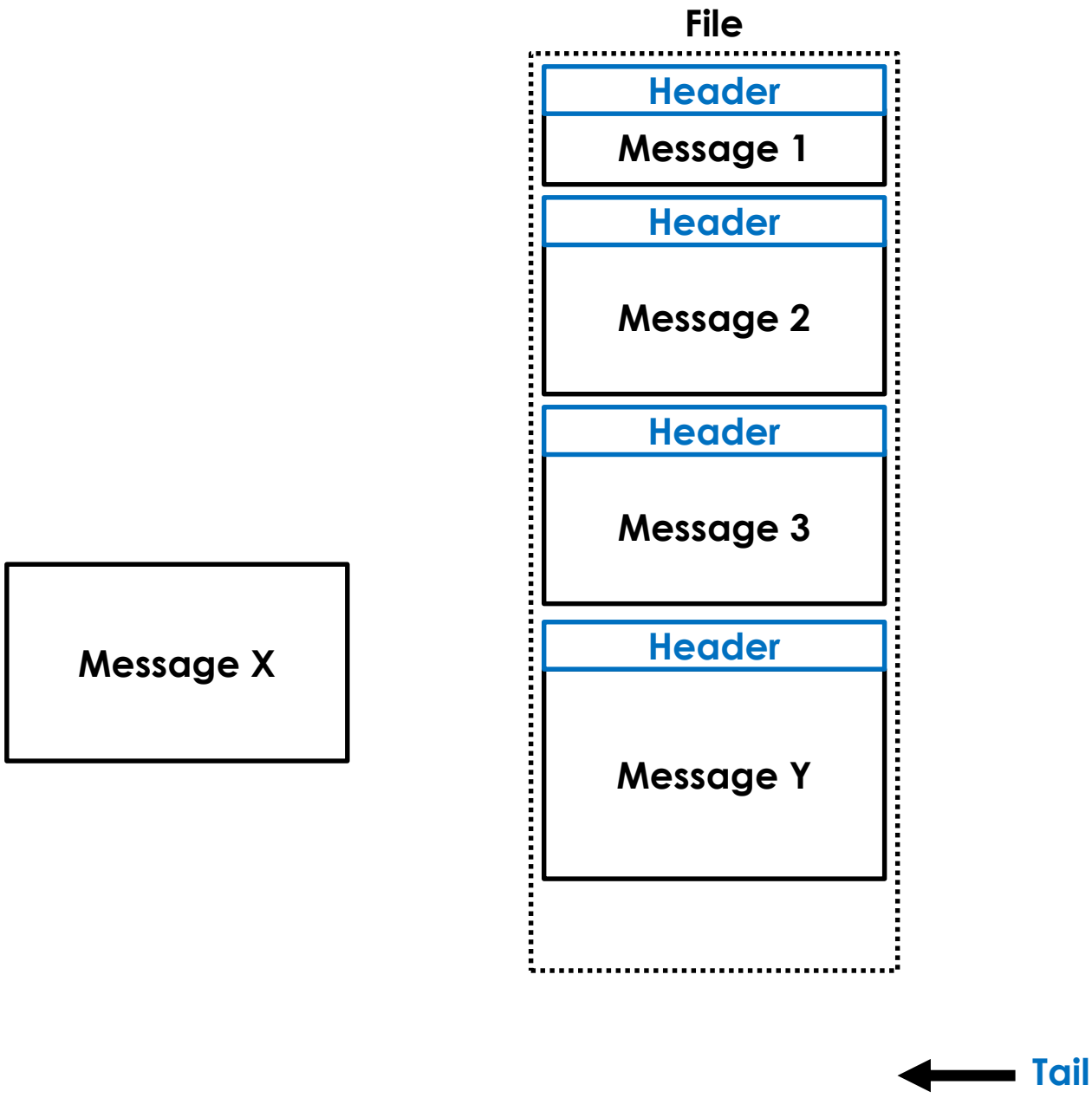

Clean
Dirty
Active
Header
Message
Header
Message
Header
Message
Header
Message
Header
Message
Header
Message
Header
Message
Tail

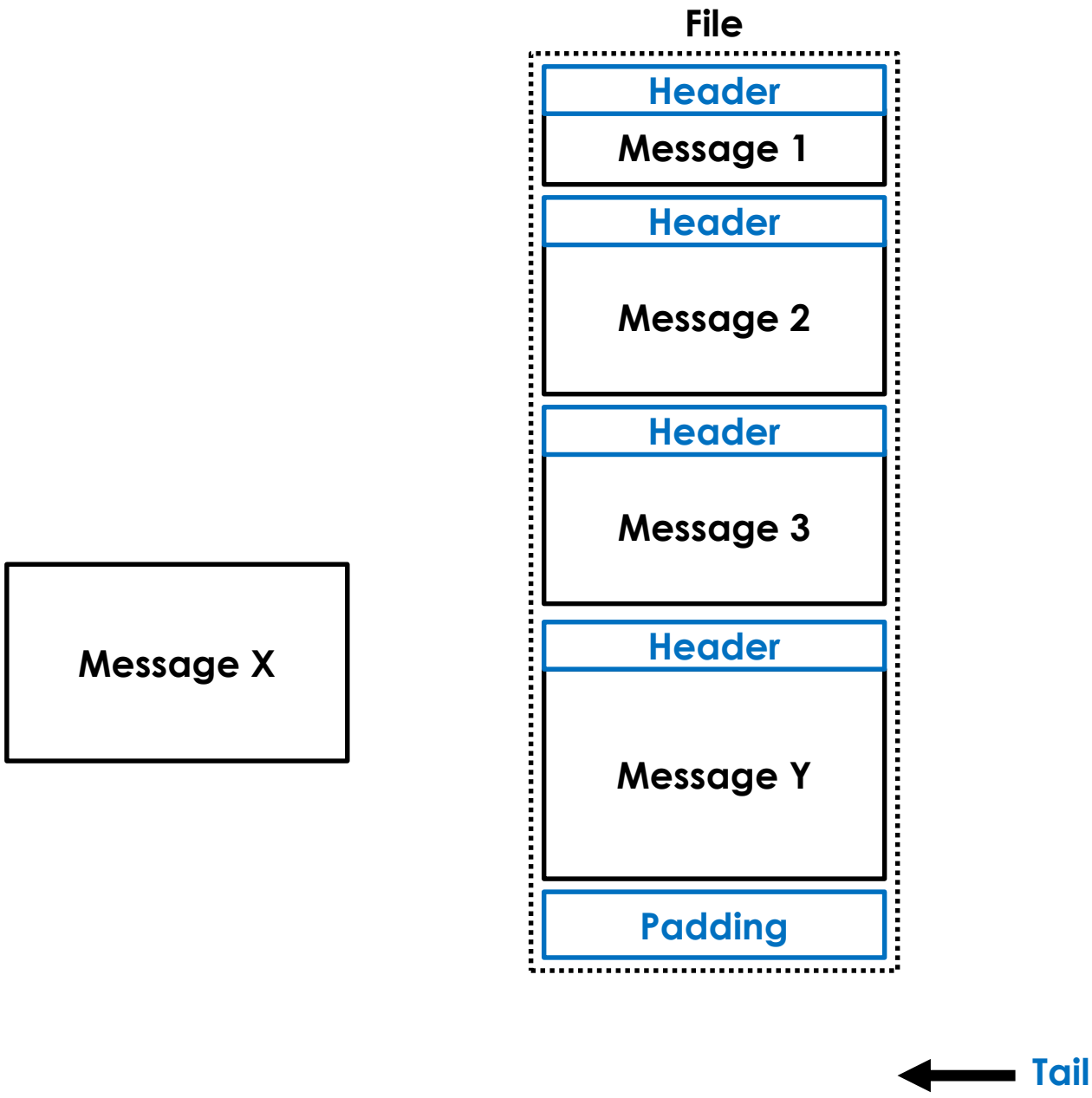
*Do publishers need a CAS?*

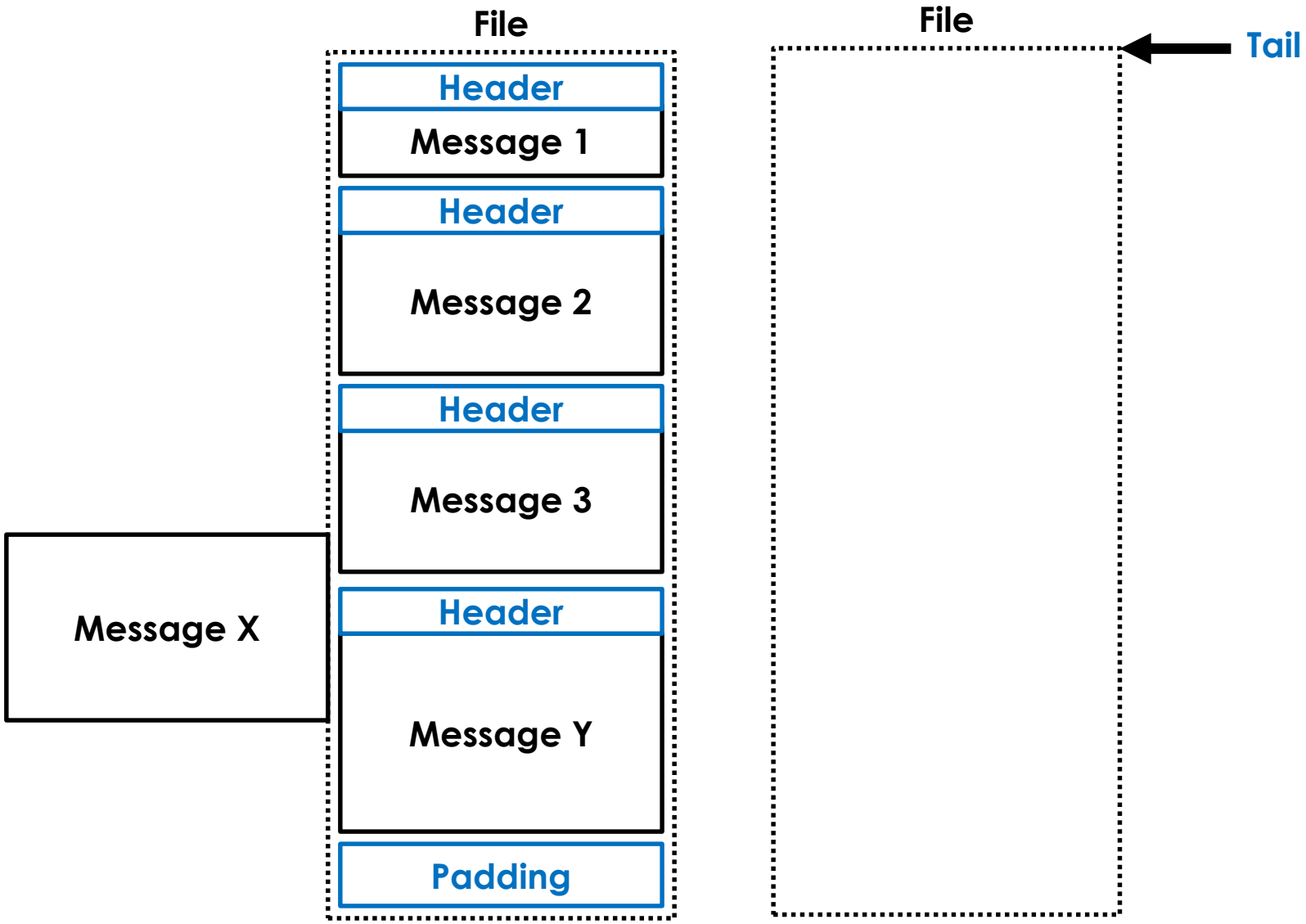

File
Header
Message 1
Header
Message 2
Header
Message 3
Tail <<XADD>>
Message X
Message Y

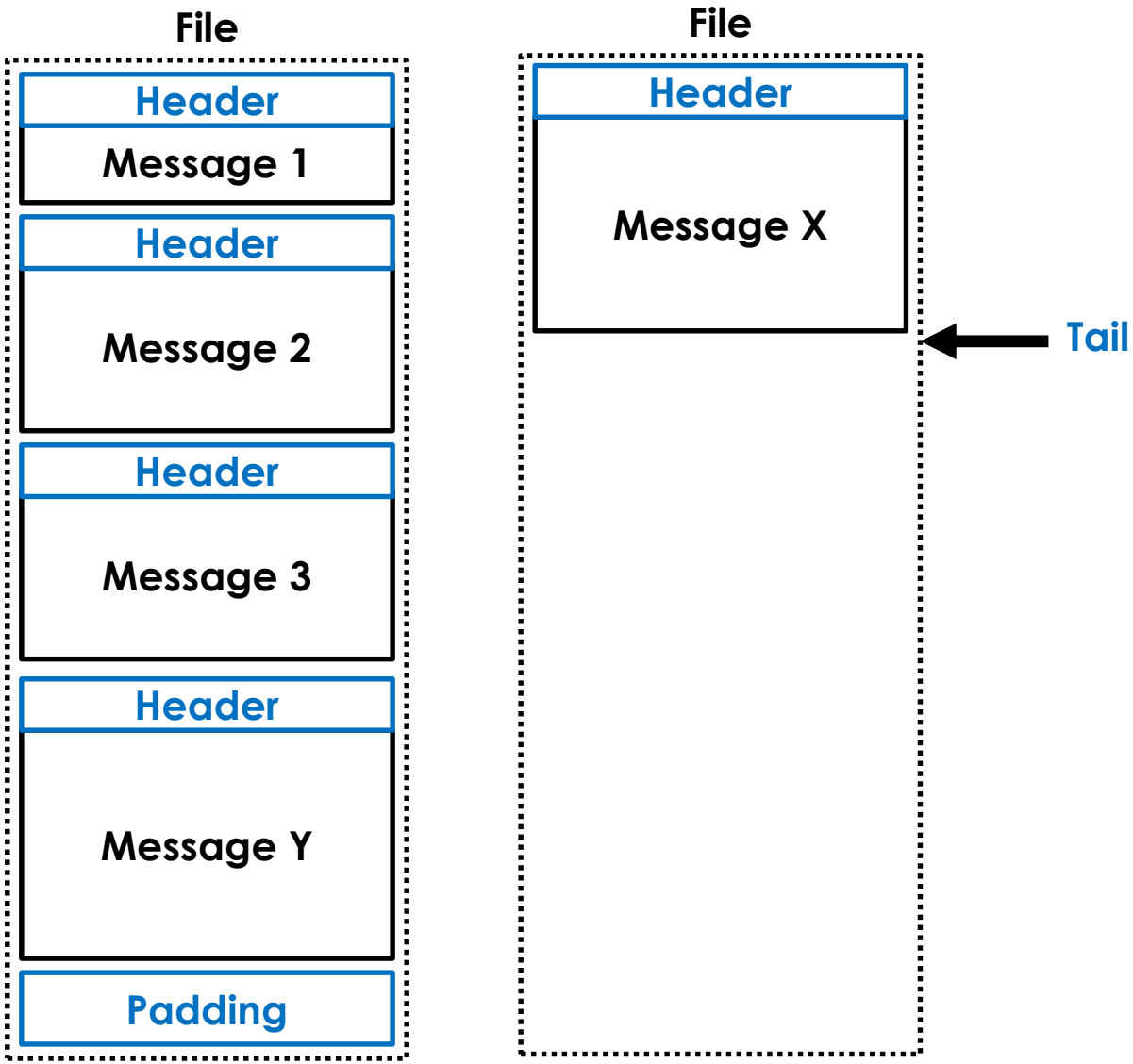

File
Header
Message 1
Header
Message 2
Header
Message 3
Message X
Message Y
Tail <<XADD>>


File
Header
Message 1
Header
Message 2
Header
Message 3
Message X
Message Y
Tail


File
Header
Message 1
Header
Message 2
Header
Message 3
Header
Message Y
Message X
Tail


File
Header
Message 1
Header
Message 2
Header
Message 3
Header
Message Y
Padding
Message X
Tail


File
Header
Message 1
Header
Message 2
Header
Message 3
Message X
Header
Message Y
Padding
File
Tail


File
Header
Message 1
Header
Message 2
Header
Message 3
Header
Message Y
Padding
File
Header
Message X
Tail

***Have a background thread do zero'ing and flow control***

# Burst Length = 1: RTT (ns)

| | Prod # | Mean | 99% |
|---|---|---|---|
| Baseline (Wait-free) | 1 | 167 | 189 |
| ConcurrentLinkedQueue | 1 | 281 | 361 |
| | 2 | 381 | 559 |
| | 3 | 444 | 705 |
| ManyToOneRingBuffer | 1 | 170 | 194 |
| | 2 | 256 | 279 |
| | 3 | 283 | 340 |
| Aeron IPC | 1 | 192 | 210 |
| | 2 | 251 | 286 |
| | 3 | 290 | 342 |

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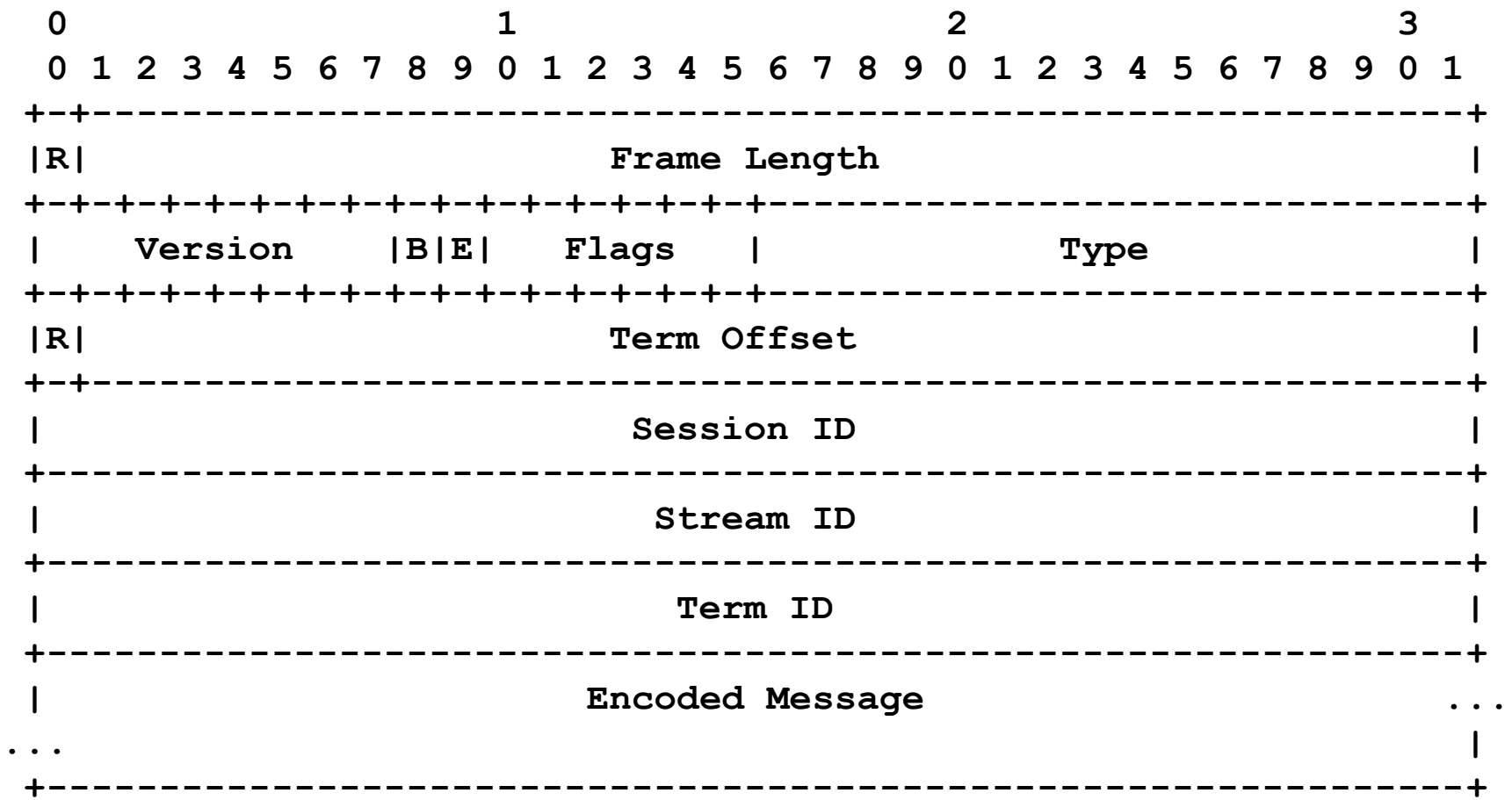
| | 2 | 251 | 286 |
| | 3 | 290 | 342 |

# Aeron Data Message Header



# Burst Length = 100: RTT (ns)

| | Prod # | Mean | 99% |
|---|---|---|---|
| Baseline (Wait-free) | 1 | 721 | 982 |
| ConcurrentLinkedQueue | 1 | 12,916 | 15,792 |
| | 2 | 25,132 | 35,136 |
| | 3 | 39,462 | 56,768 |
| ManyToOneRingBuffer | 1 | 3,773 | 3,992 |
| | 2 | 11,286 | 13,200 |
| | 3 | 27,255 | 34,432 |
| Aeron IPC | 1 | 4,436 | 4,632 |
| | 2 | 7,623 | 8,224 |
| | 3 | 10,825 | 13,872 |

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| Aeron IPC | 1 | 4,436 | 4,632 |
| | 2 | 7,623 | 8,224 |
| | 3 | 10,825 | 13,872 |

*Less “False Sharing”*

*-*

*Inlined data vs Reference Array*

*Less “Card Marking”*

*Is avoiding the spinning "CAS" loop is a major step forward?*

# Burst Length = 100: RTT (ns)

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| Baseline (Wait-free) | 1 | 721 | 982 |
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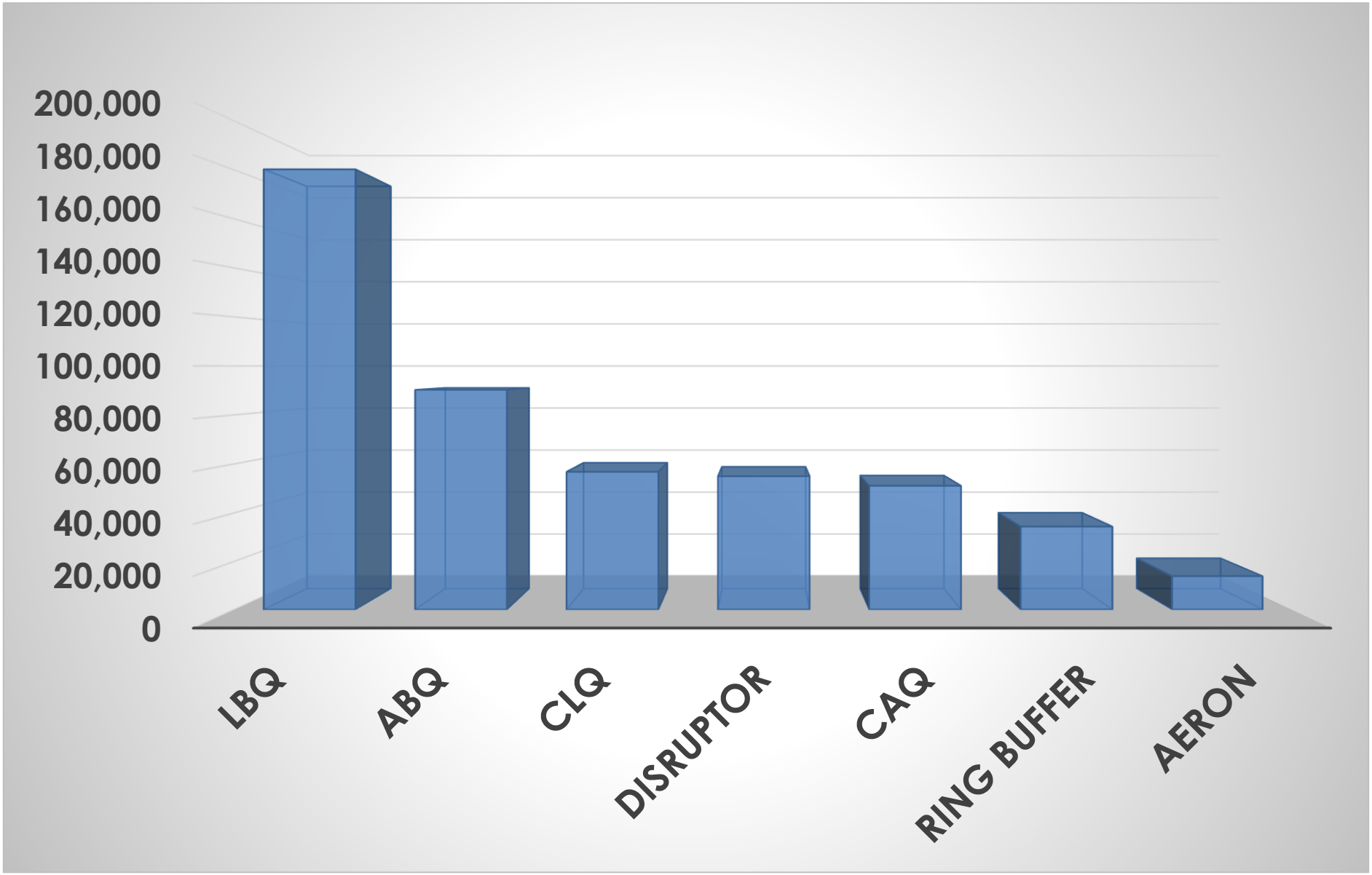
# Burst Length = 100: 99% RTT (ns)



*Logging is a*
*Messaging Problem*

*What design should we use?*

# *5. Where can we go Next?*

# C vs Java

# C vs Java

- **Spin Wait Loops**
  - `Thread.onSpinWait()`

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  - **Heap Aggregates - ObjectLayout**
  - **Stack Allocation – Value Types**

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- **Spin Wait Loops**
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  - Baseline against `memcpy()` for differing alignment

# C vs Java

- Spin Wait Loops
  - `Thread.onSpinWait()`
- Data Dependent Loads
  - Heap Aggregates - ObjectLayout
  - Stack Allocation – Value Types
- Memory Copying
  - Baseline against `memcpy()` for differing alignment
- Queue Interface
  - Break conflated concerns to reduce blocking actions

# *In closing…*

# 2TB RAM and 100+ vcores!!!

# Where can I find the code?

*https://github.com/real-logic/benchmarks*

*https://github.com/real-logic/Agrona*

*https://github.com/real-logic/Aeron*

# Questions?

Blog: http://mechanical-sympathy.blogspot.com/

Twitter: @mjpt777

***"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."***

**- Albert Einstein**