Principles of High Load

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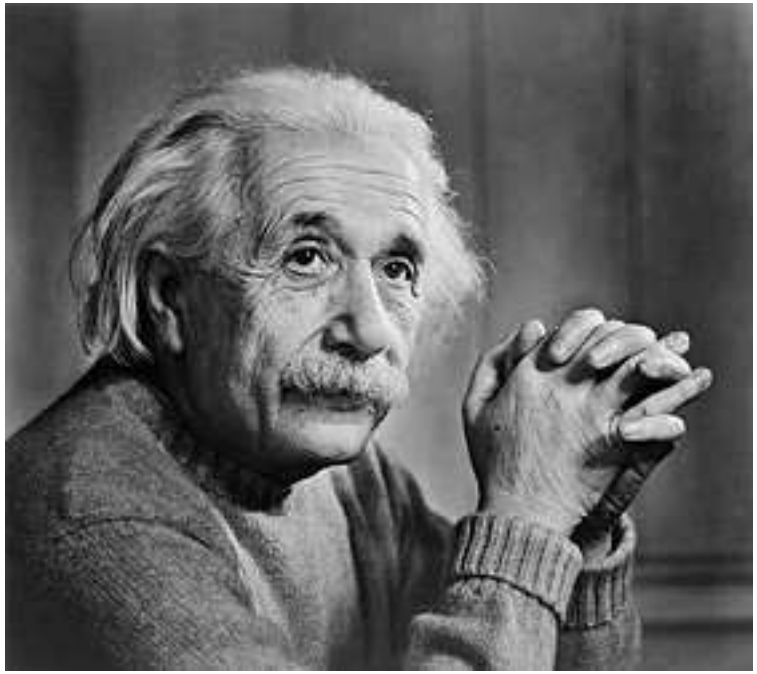
AEROSPIKE

Wisdom vs Guessing



“Insanity is doing the same thing over & over again expecting different results”
– Albert Einstein

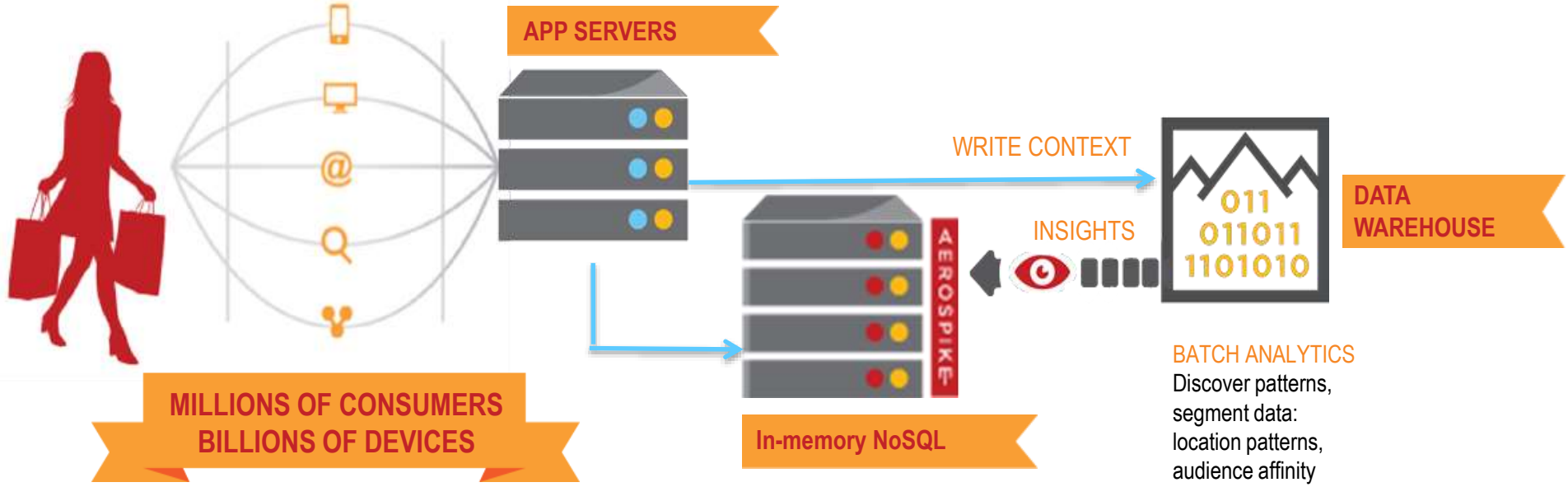
"Everything that can be invented has been invented.” - Charles Holland Duell – US Patent Office 1899

High load

Shinagawa Railway Station - Tokyo, Japan

12 December 2014 08:22 AM

Advertising Technology Stack



BATCH ANALYTICS
Discover patterns, segment data: location patterns, audience affinity

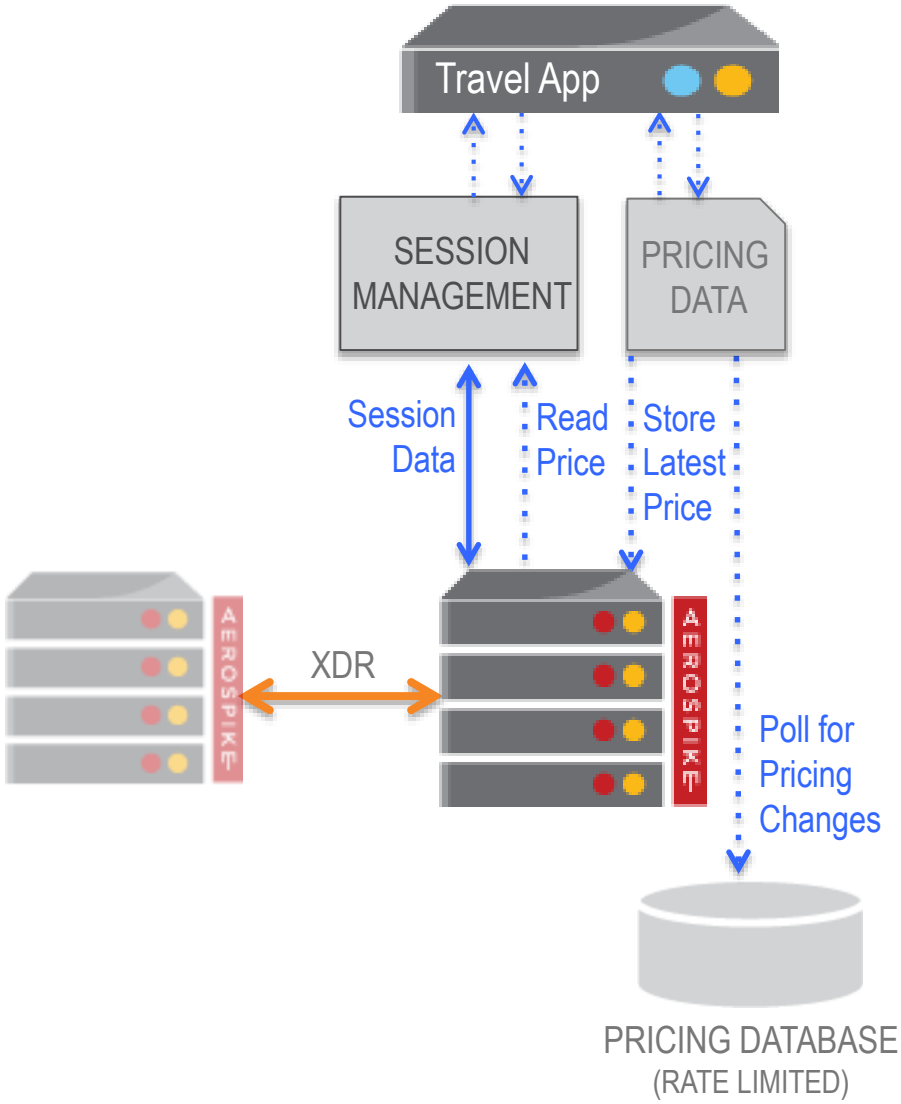
WRITE REAL-TIME CONTEXT
READ RECENT CONTENT

PROFILE STORE
Cookies, email, deviceID, IP address, location, segments, clicks, likes, tweets, search terms...

REAL-TIME ANALYTICS
Best sellers, top scores, trending tweets

Currently about 3.0M / sec in North American

Travel Portal



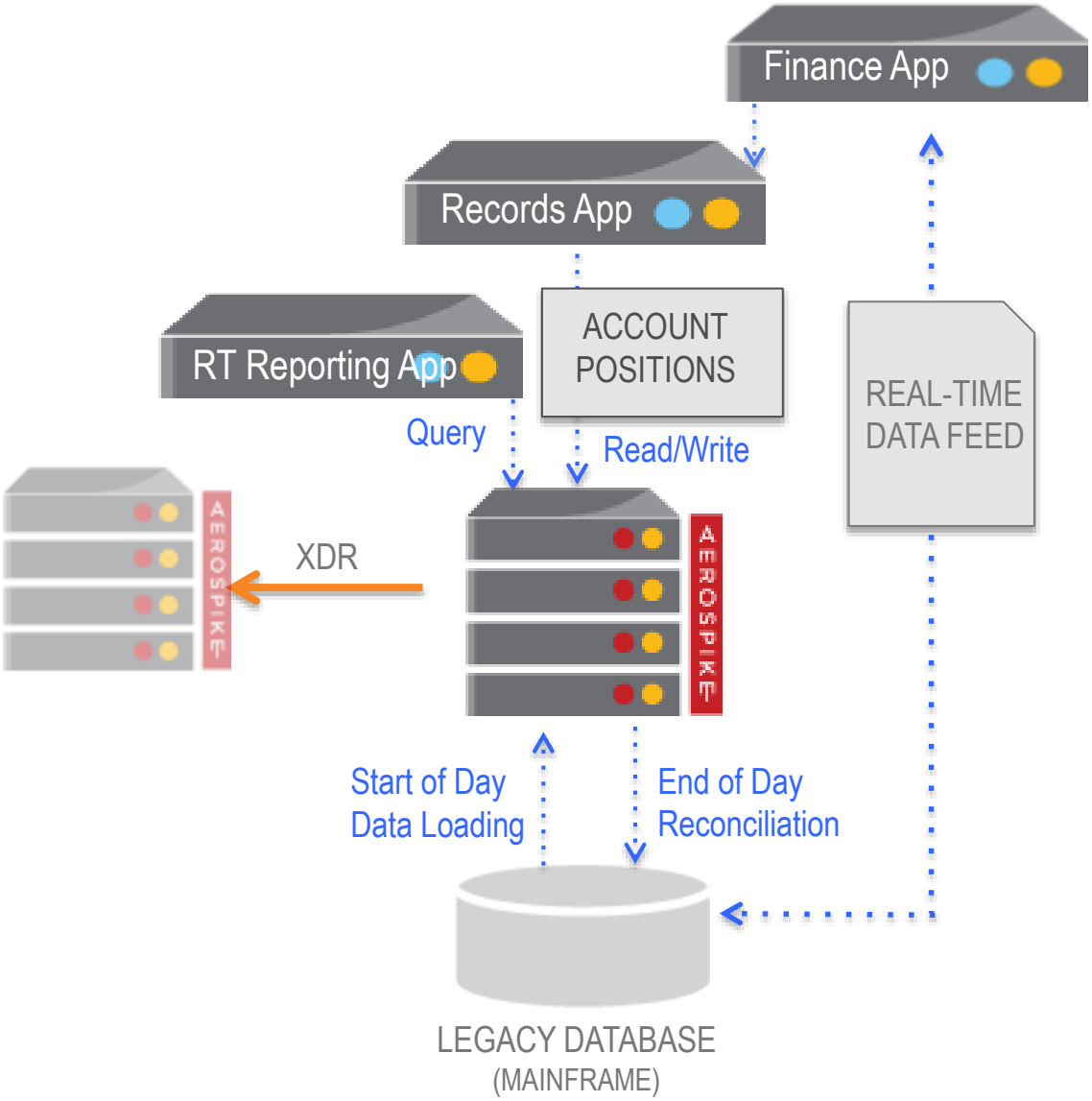
Airlines forced interstate banking

Legacy mainframe technology

Multi-company reservation and pricing

Requirement: **1M TPS** allowing overhead

Financial Services – Intraday Positions



10M+ user records

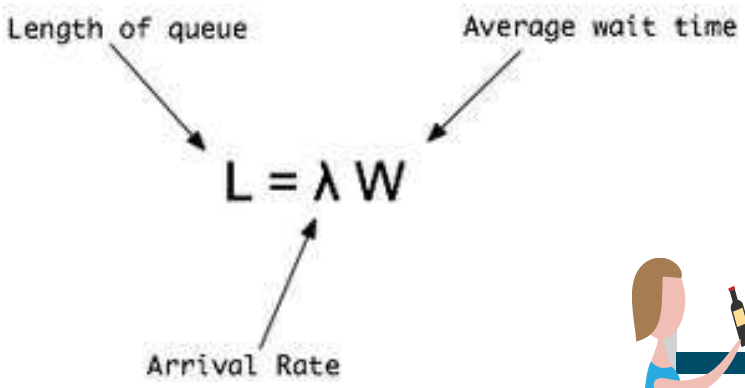
Primary key access

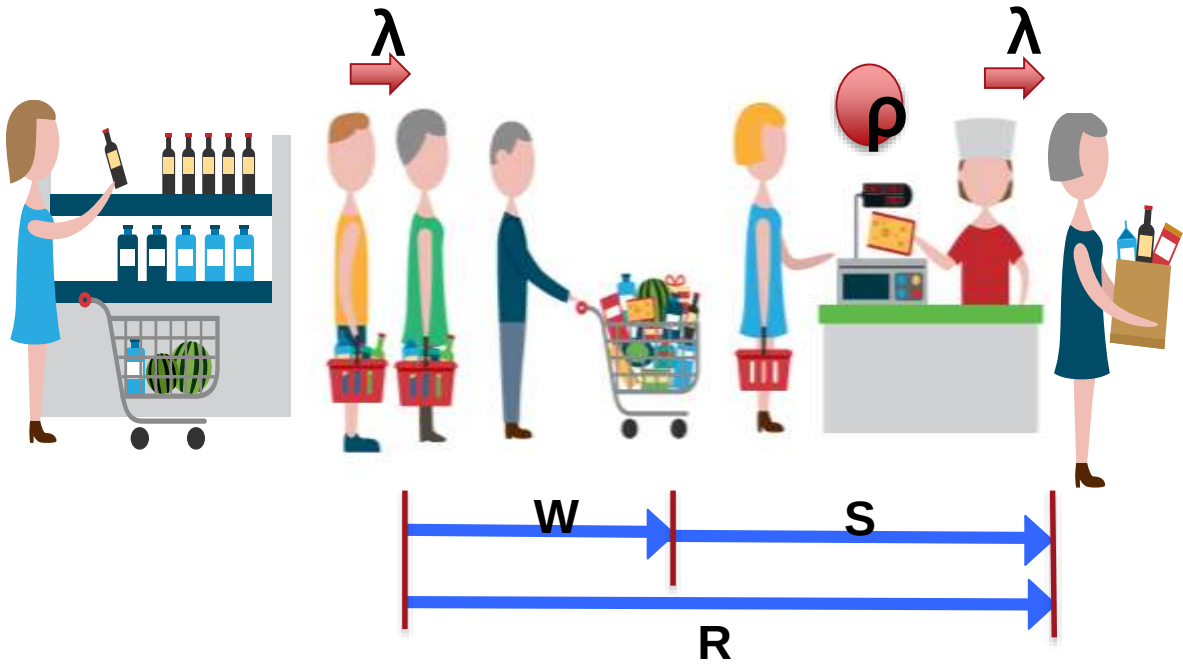
1M+ TPS

Principles

Little's Law

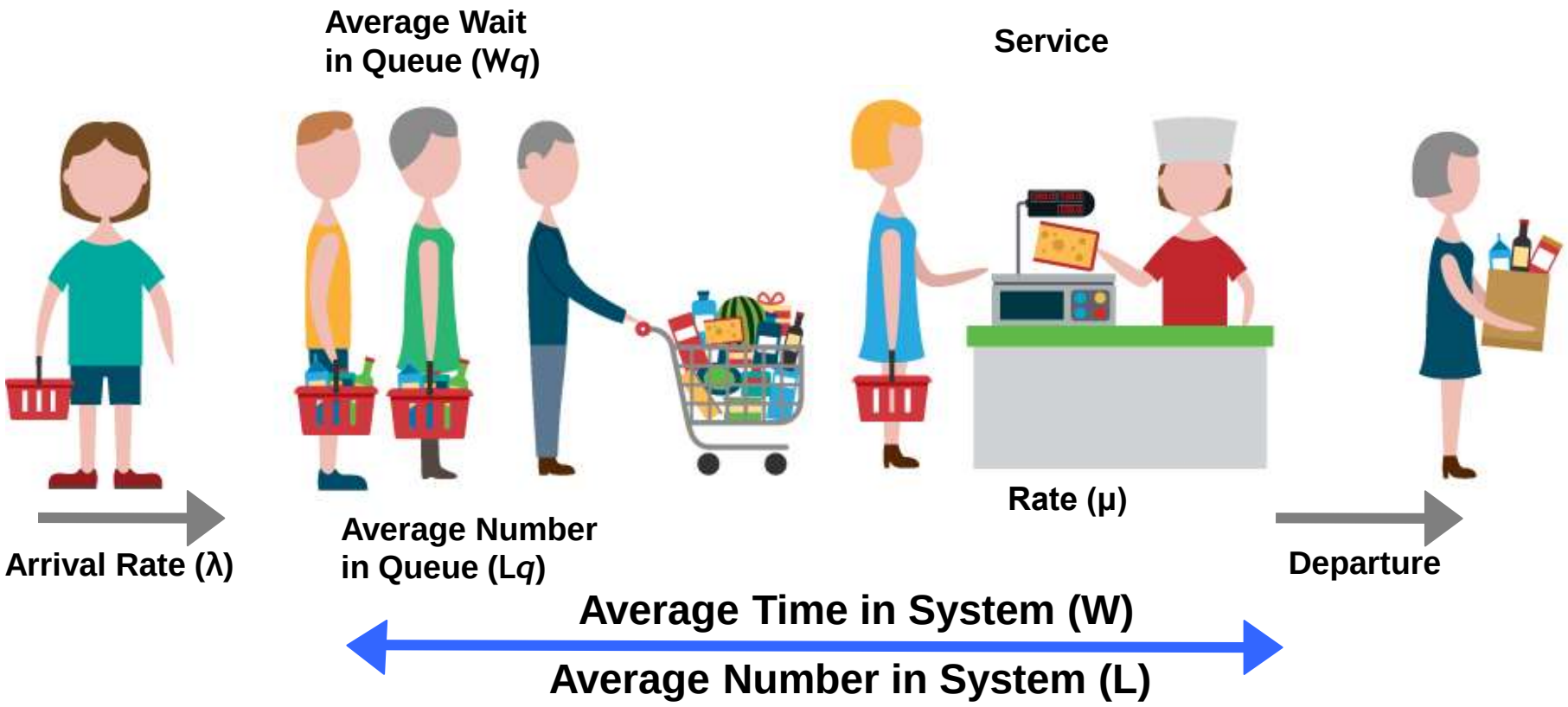
The long-term average number of customers **L** in a stable system is equal to the long-term average effective **arrival rate λ**, multiplied by **the average time W** a customer spends in the system





Queuing Theory

- **Queuing theory** is the mathematical study of waiting lines, or queues.



Throughput

Throughput is the **rate of production** or the rate at which something can be processed

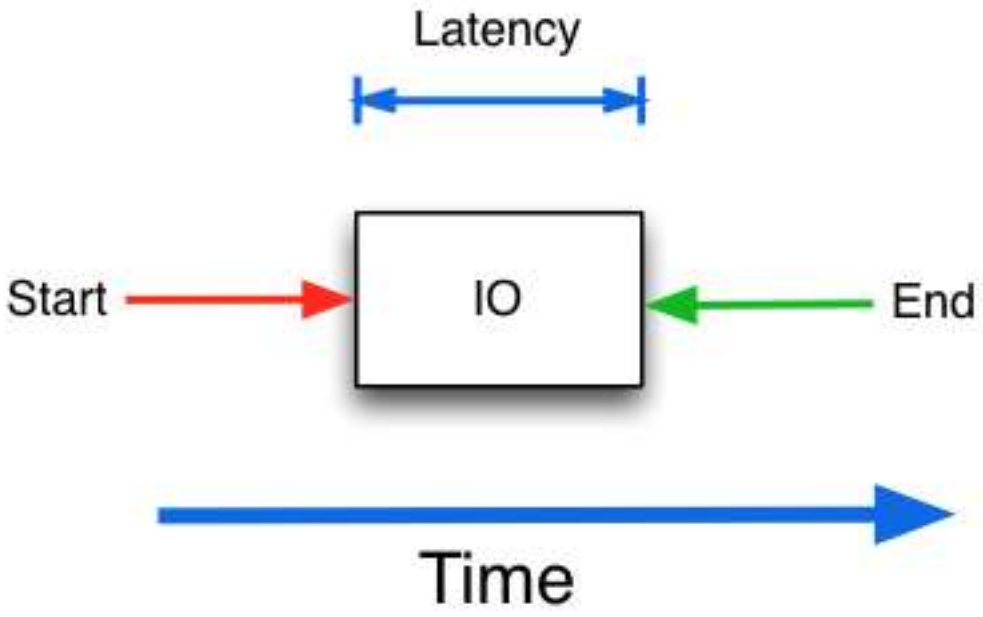
Similar to: “work done / time taken”

$$P = \frac{W}{\Delta t}$$

The power of a system is proportional to its throughput

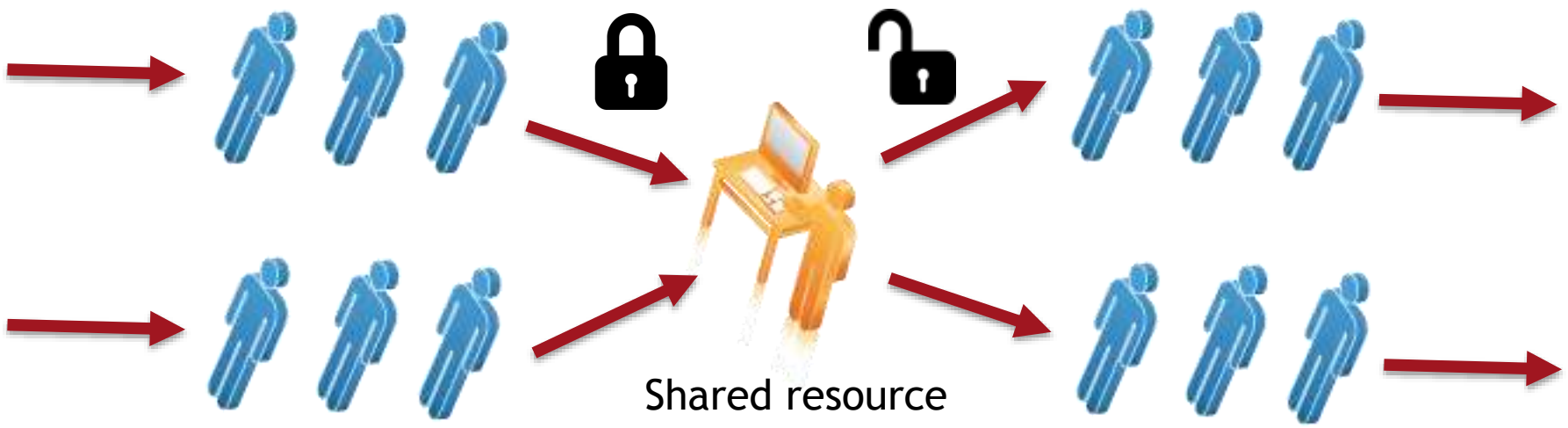
Latency

Latency is a **time interval** between the stimulation and response, or, from a more general point of view, as a time delay between the cause and the effect of some physical change in the system being observed.



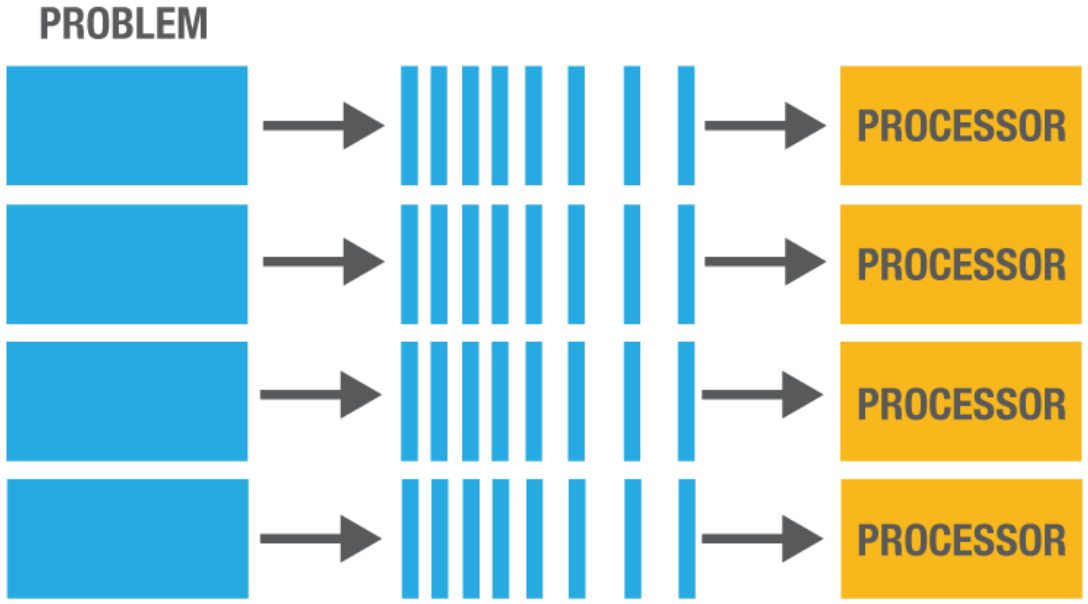
Concurrency

- **Concurrency** is a property of systems in which several computations are executing **simultaneously**, and potentially **interacting** with each other.

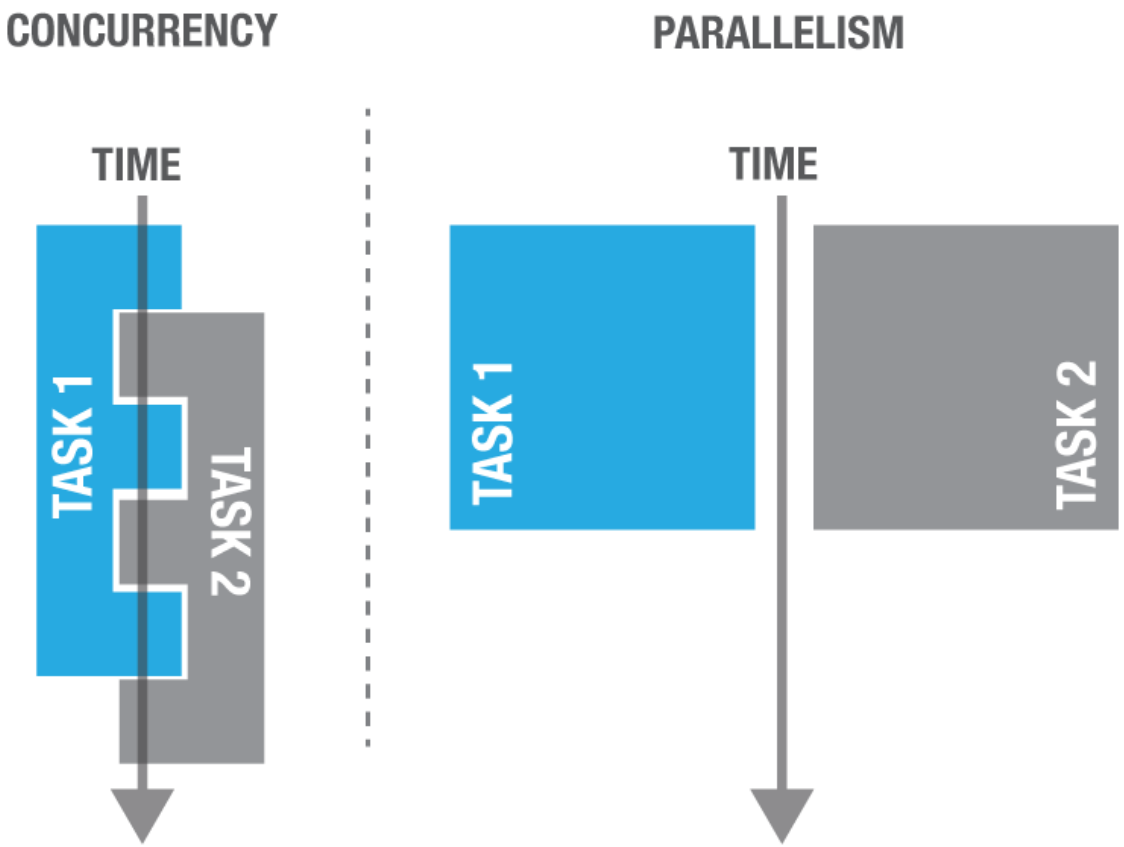


Division of labor – Parallel processing

Parallel processing is the **simultaneous use of more than one CPU** or processor core to execute a program or multiple computational threads. Ideally, parallel processing makes programs run faster because there are more engines (CPUs or cores) running it. In practice, it is often difficult to divide a program in such a way that separate CPUs or cores can execute different portions without interfering with each other.

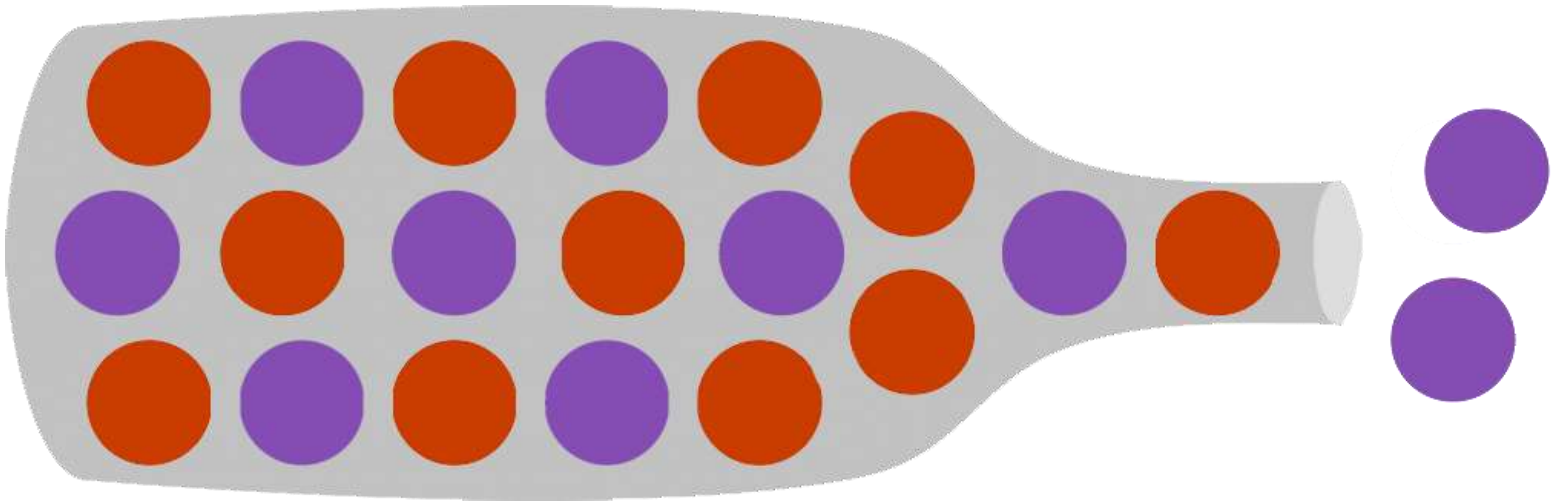


Concurrency vs Parallelism



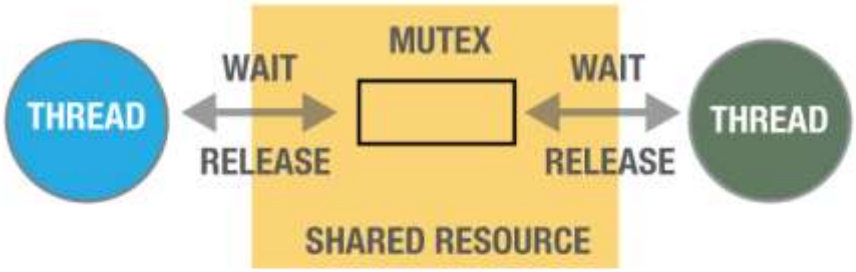
Bottle necks

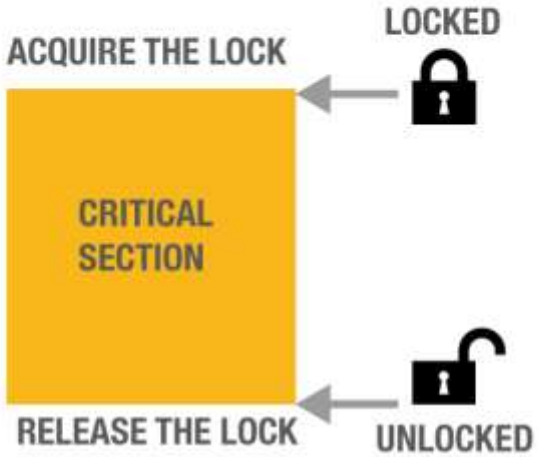
Bottleneck is a phenomenon where the performance or capacity of an entire system is limited by a single or small number of components or resources



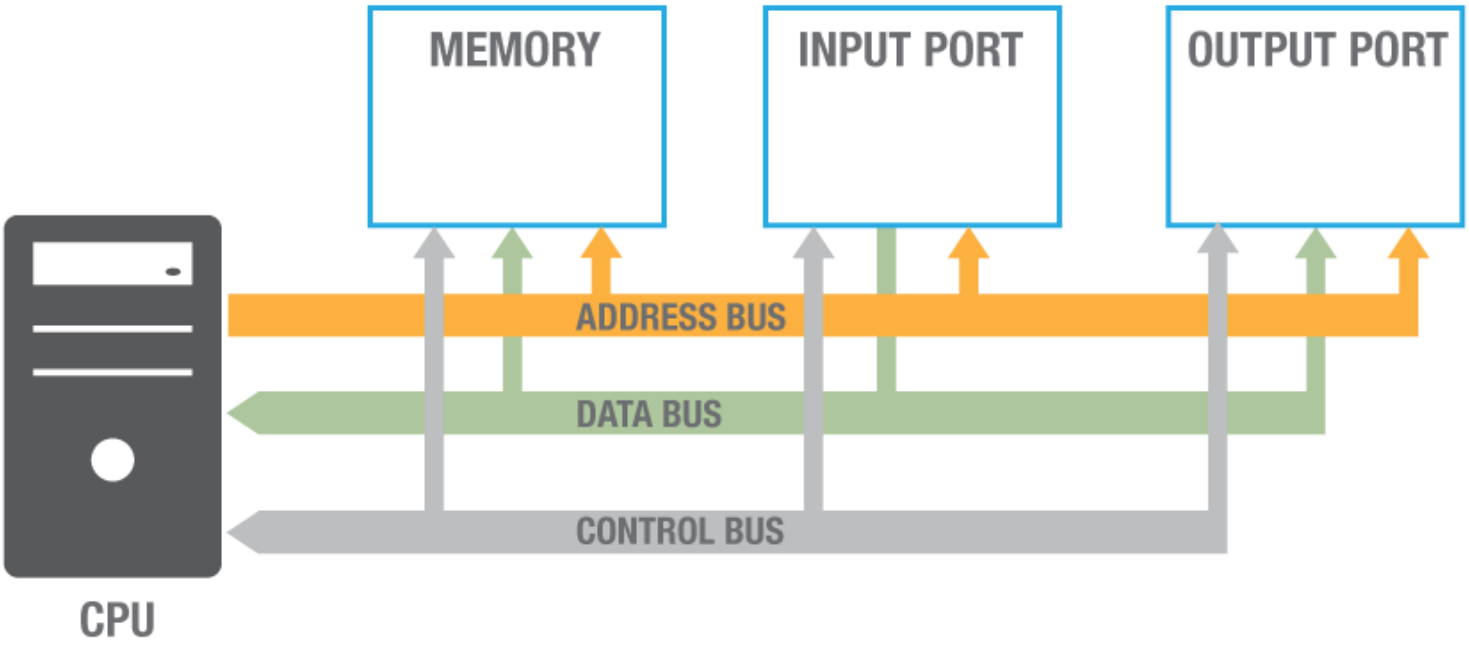
Locks, Mutexes and Critical Regions

- **Lock**
  - Atomic Latch
  - Hardware implementation
    - 1 machine instruction
  - OS system routine
- **Mutex**
  - Mutual exclusion
  - Combination of a Lock and a Semaphore
- **Critical section**
  - Region of code allowing 1 thread only.
  - Bounded by Lock/Mutex



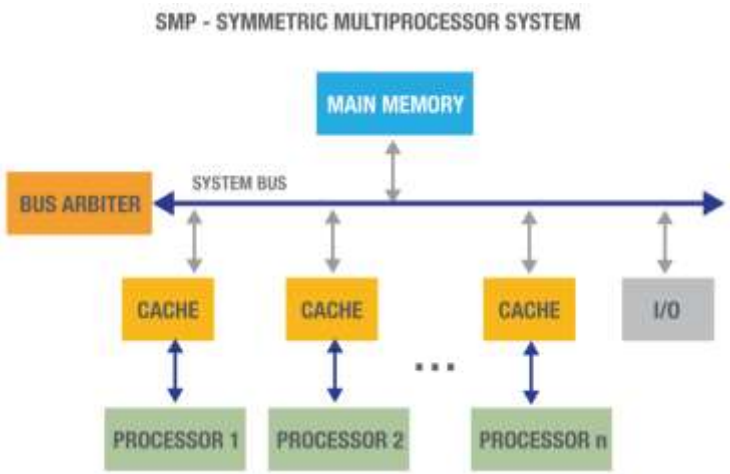


Basic computer architecture

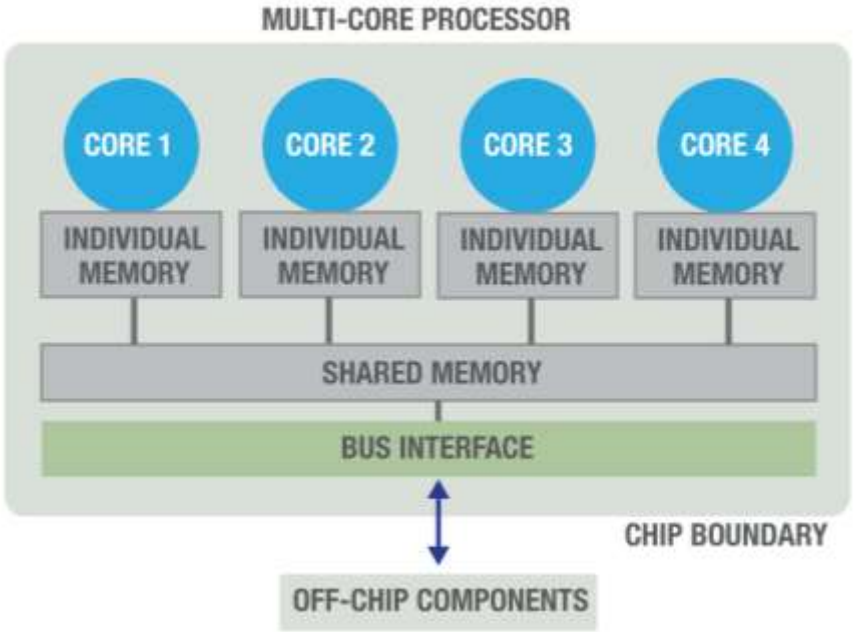


Multi-processor, Multi-core, NUMA

- **Multi-processor**
  - > 1 processor sharing Bus and Memory

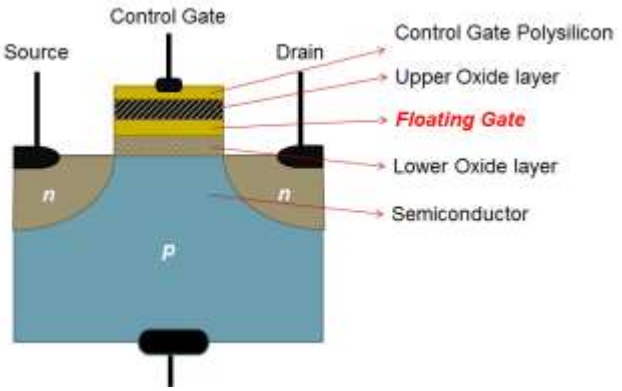


- **Multi-core**
  - > 1 processor in a chip
  - Each with local Memory
  - Access to shared memory
- **N**on **U**niform **M**emory **A**llocation
  - Local memory faster to access than shared memory
- **Multi-channel** Bus

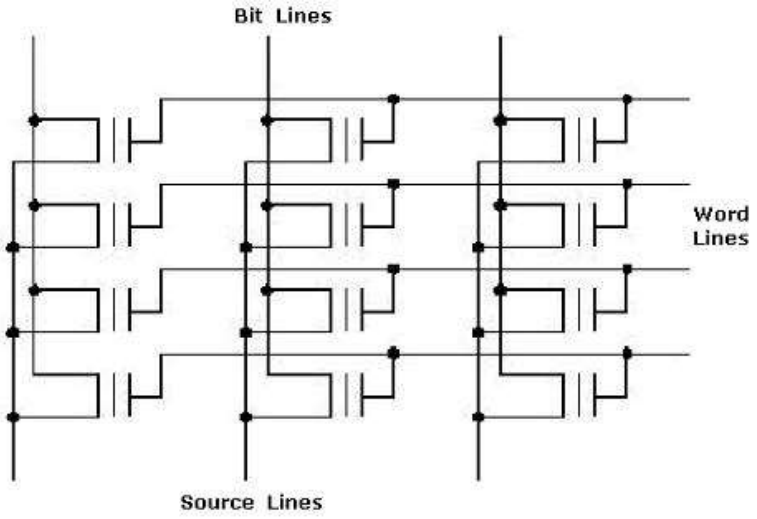


Flash - SSDs

- Uses Floating Gate MOSFET



- Arranged into circuits “similar” to RAM

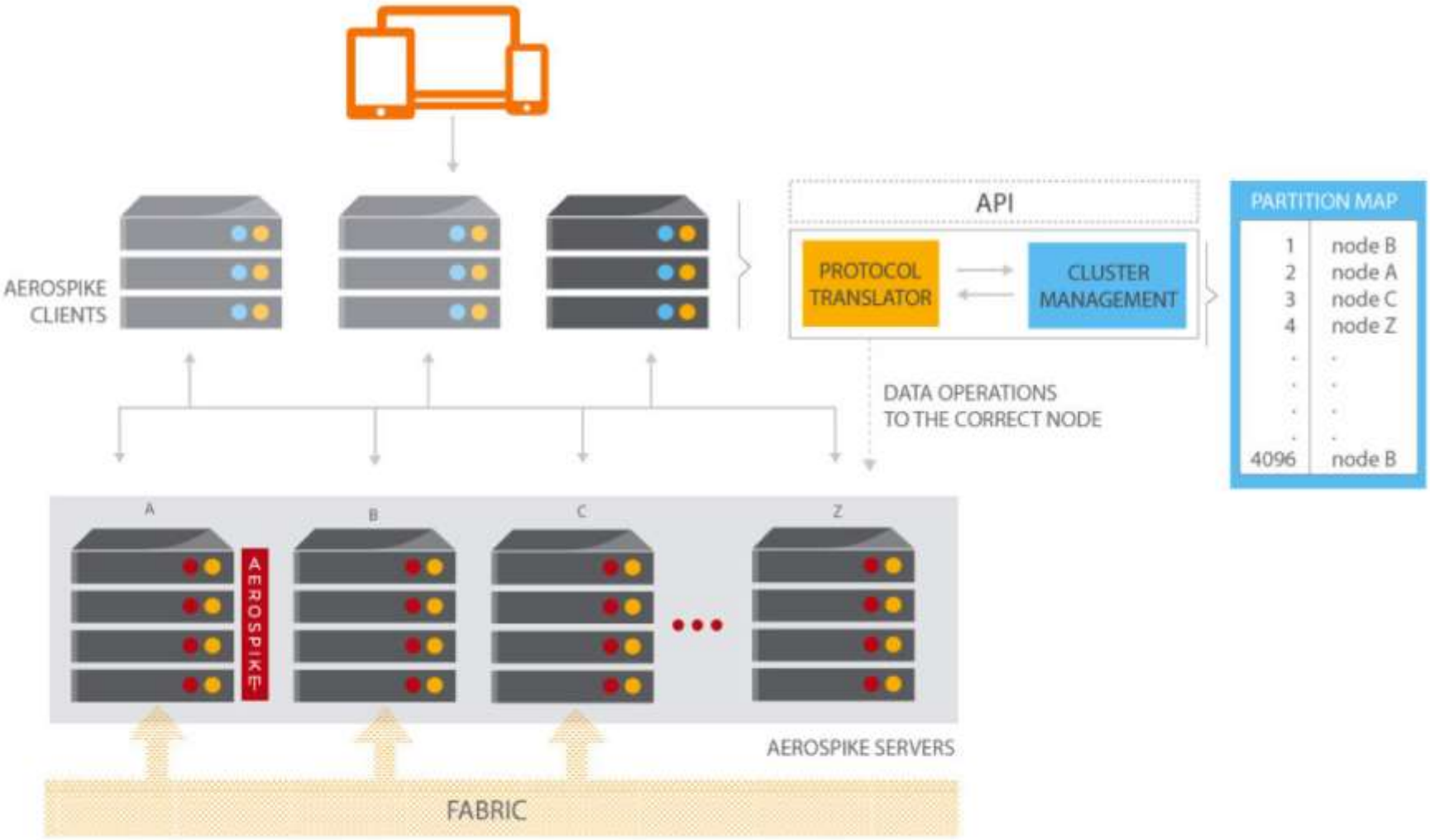


- Packaged as PCIe or SATA devices

- **No seek or rotational latencies**

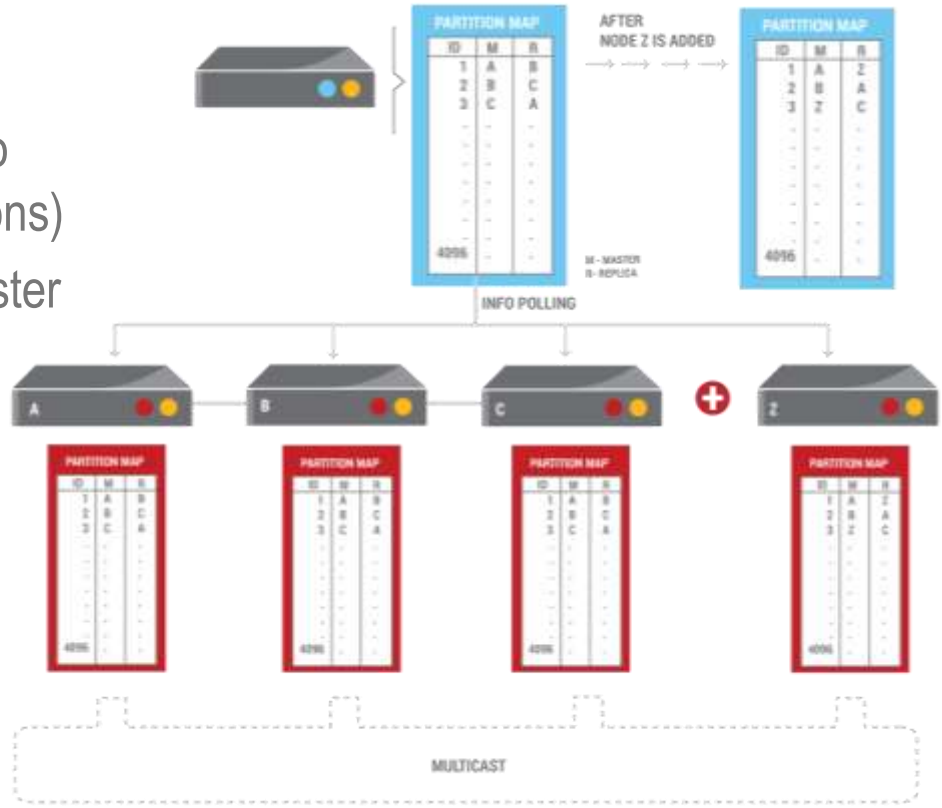
How Aerospike does it

The Big Picture



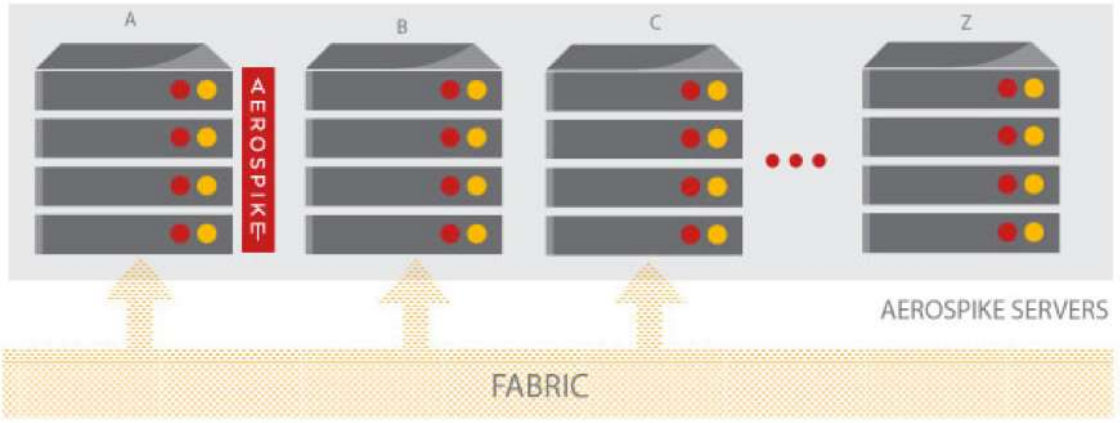
Smart Client -Distributed Hash table

- Distributed Hash Table with No Hotspots
  - Every key **hashed** with RIPEMD160 into an ultra efficient 20 byte (fixed length) string
  - Hash + additional (fixed 64 bytes) data forms **index entry** in RAM
  - **Some bits** from hash value are used to calculate the **Partition ID** (4096 partitions)
  - Partition ID maps to Node ID in the cluster
- **1 Hop** to data
  - Smart Client simply calculates Partition ID to determine Node ID
  - No Load Balancers required



The Cluster (servers)

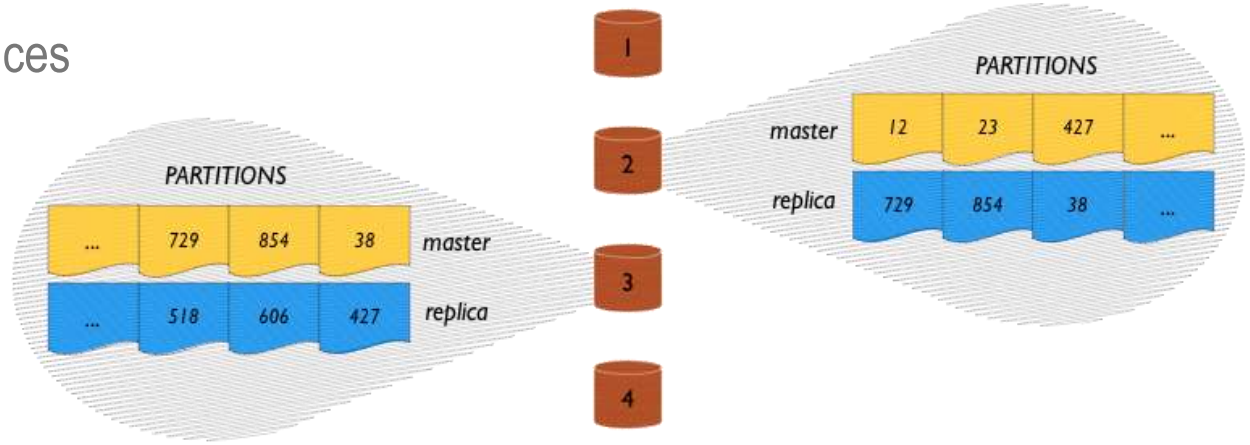
- Federation of **local servers**
  - XDR to remote cluster
- Automatic **load balancing**
- Automatic **fail over**
- Detects **new nodes** (multicast)
- **Rebalances** data (measured rate)
- Adds nodes **under load**
- **Rack awareness**
- **Locally attached** storage



Data Distribution

Data is **distributed evenly** across nodes in a cluster using the Aerospike Smart Partitions™ algorithm.

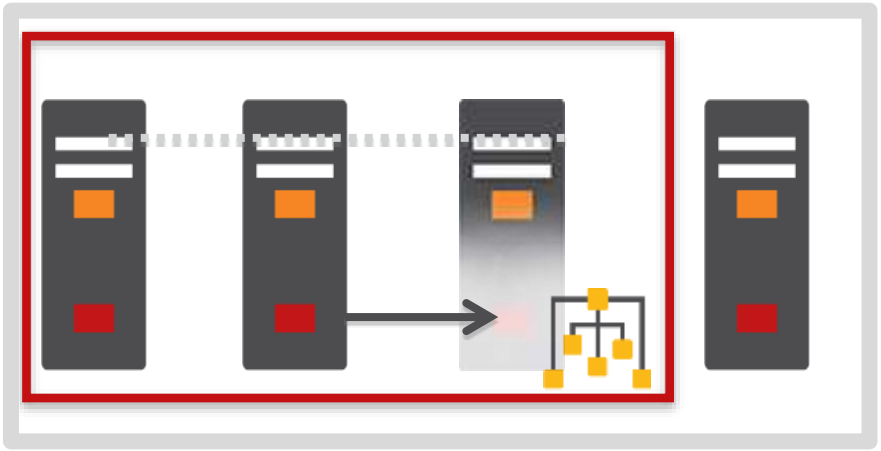
- RIPEMD160 (no collisions yet found)
- 4096 Data Partitions
- Even distribution of
  - Partitions across nodes
  - Records across Partitions
  - Data across Flash devices
- Primary and Replica Partitions



Automatic rebalancing

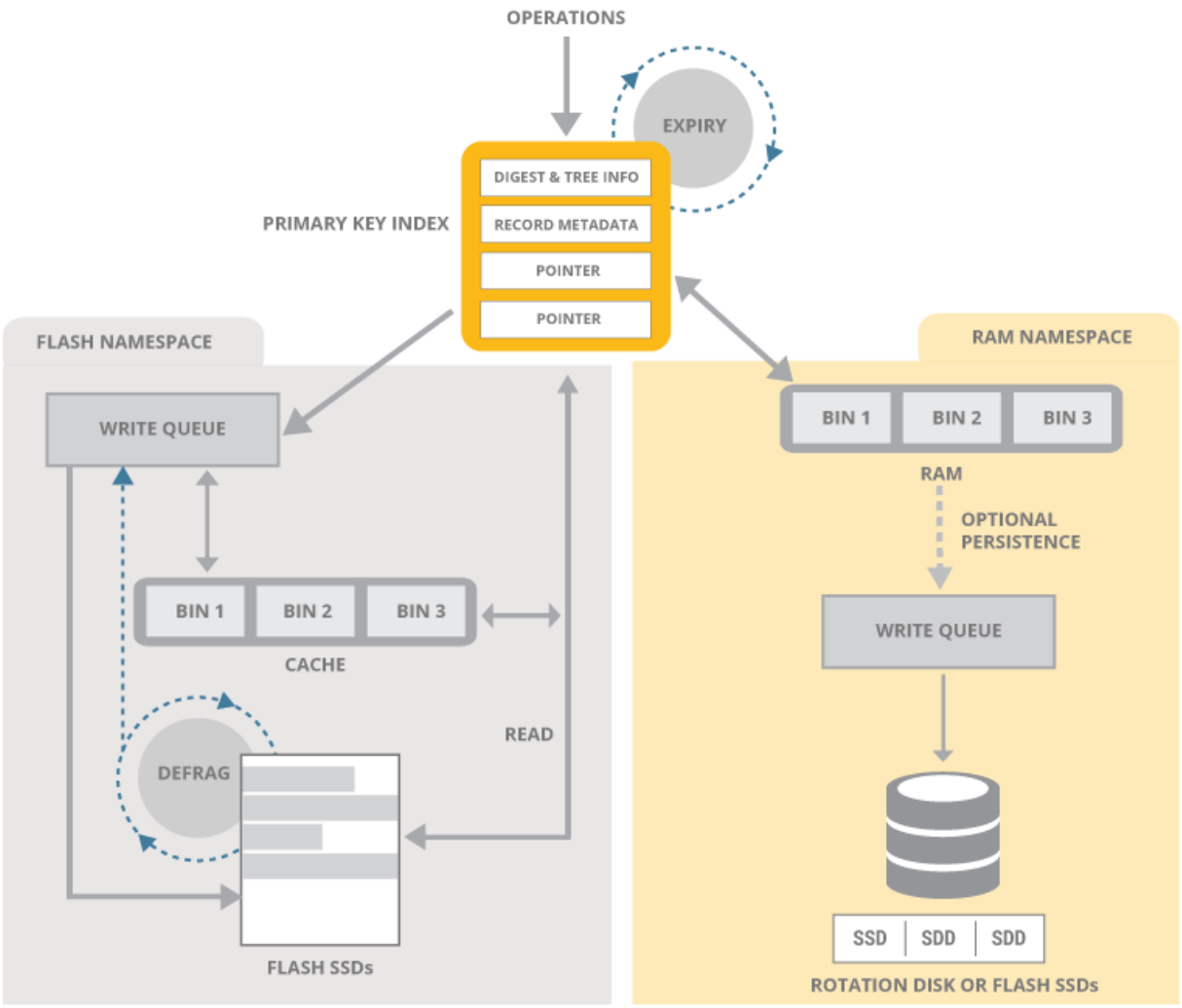
Adding, or Removing a node, the Cluster **automatically rebalances**

1. Cluster discovers new node via gossip protocol
2. Paxos vote determines new data organization
3. Partition migrations scheduled
4. When a partition migration starts, write journal starts on destination
5. Partition moves atomically
6. Journal is applied and source data deleted



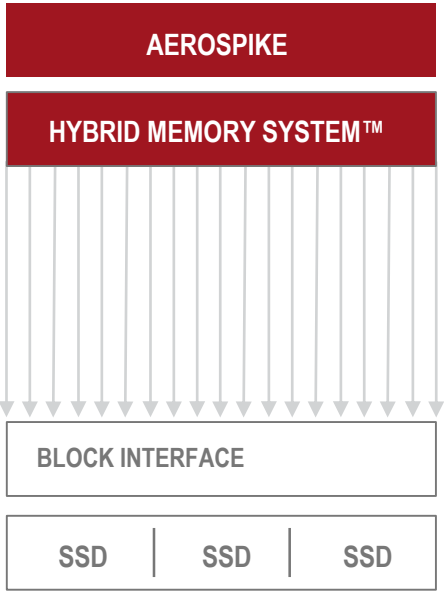
After migration is complete, the Cluster is **evenly** balanced.

Data Storage Layer



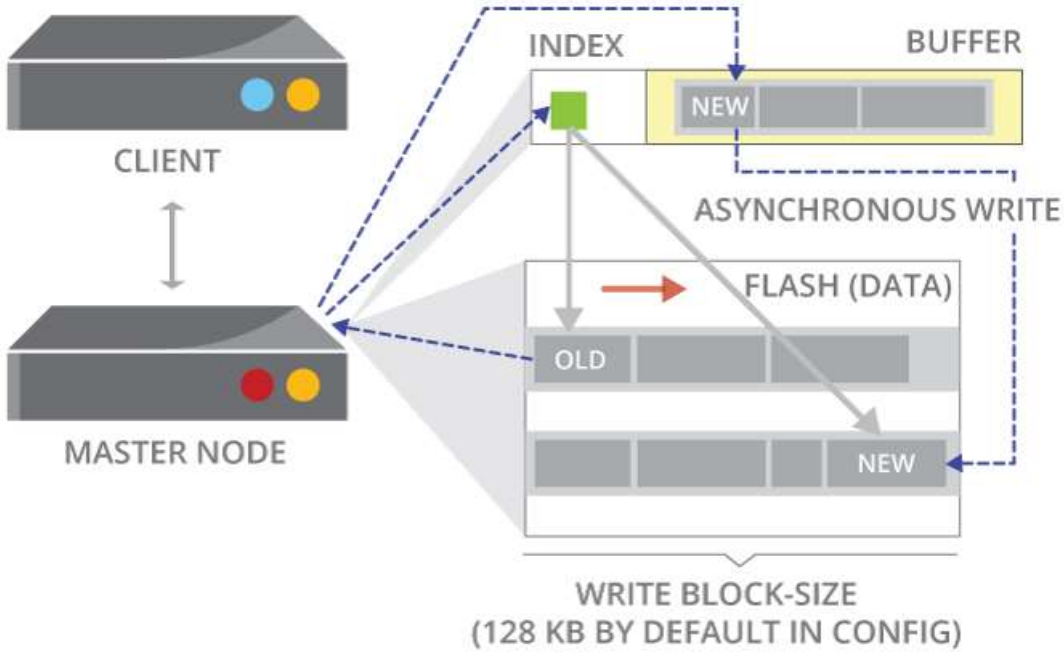
Data on Flash / SSD

- Indexes in RAM (64 bytes per)
  - Low wear
- Data in Flash (SSD)
  - Record data stored contiguously
    - 1 read per record (multithreaded)
  - Automatic **continuous defragment**
  - Log structured file system, “copy on write”
    - O_DIRECT, O_SYNC
  - Data written in **flash optimal blocks**
  - Automatic distribution (no RAID)
  - Writes cached

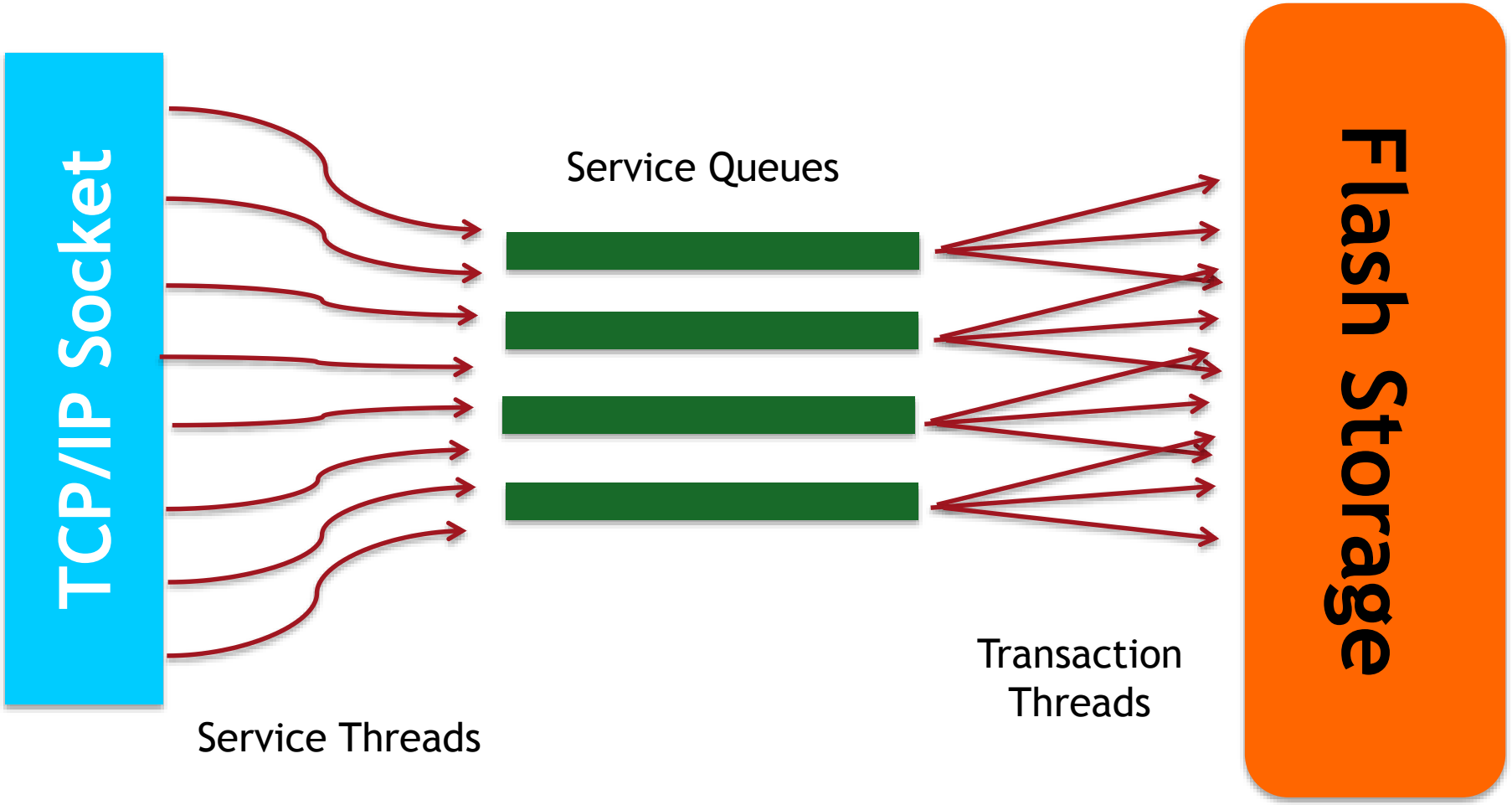


Copy on write – Log structured writes

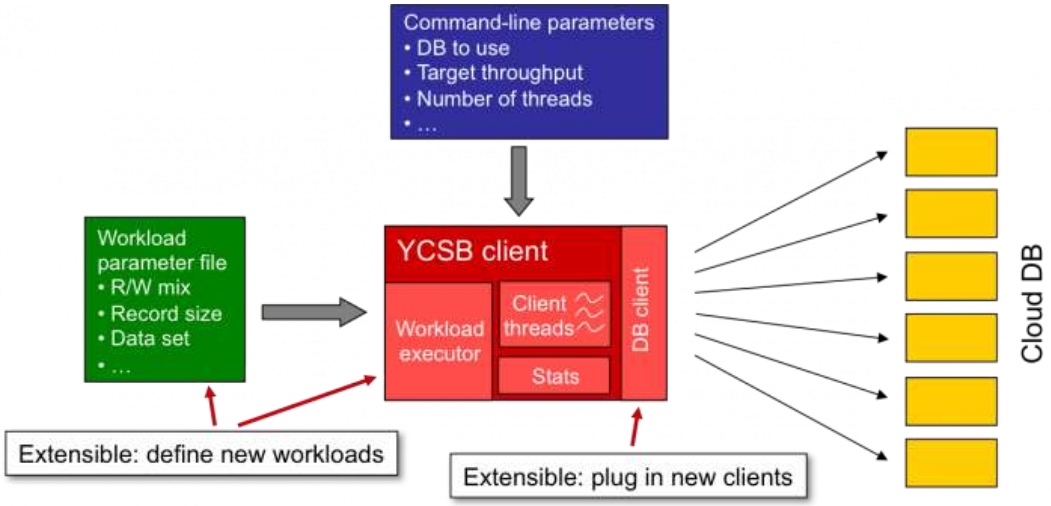
- Record is written to new block
  - Not written in place
  - Much faster
- Even wearing of Flash



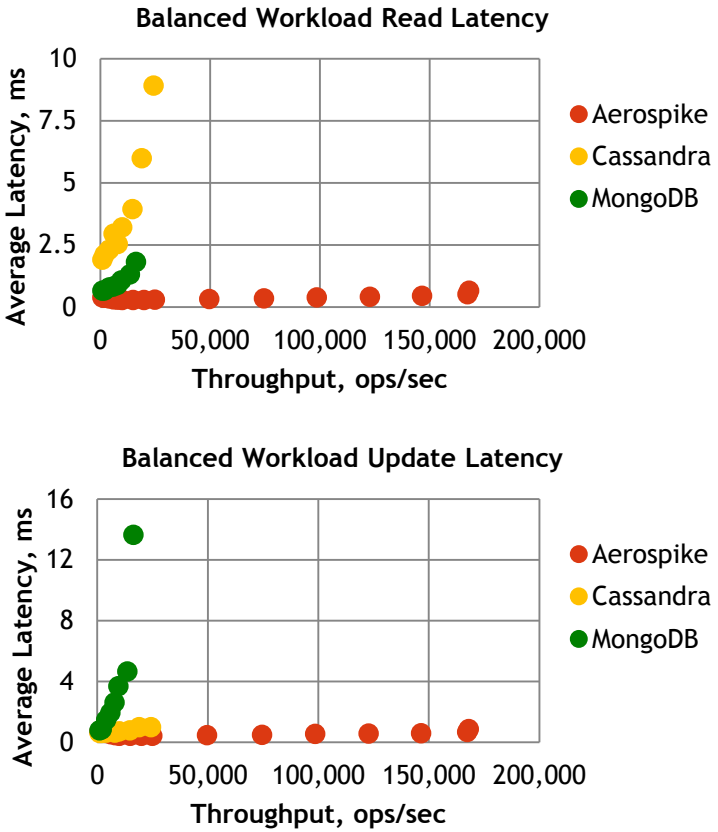
Service threads, Queues, Transaction threads



YCSB – Yahoo Cloud Serving Benchmark



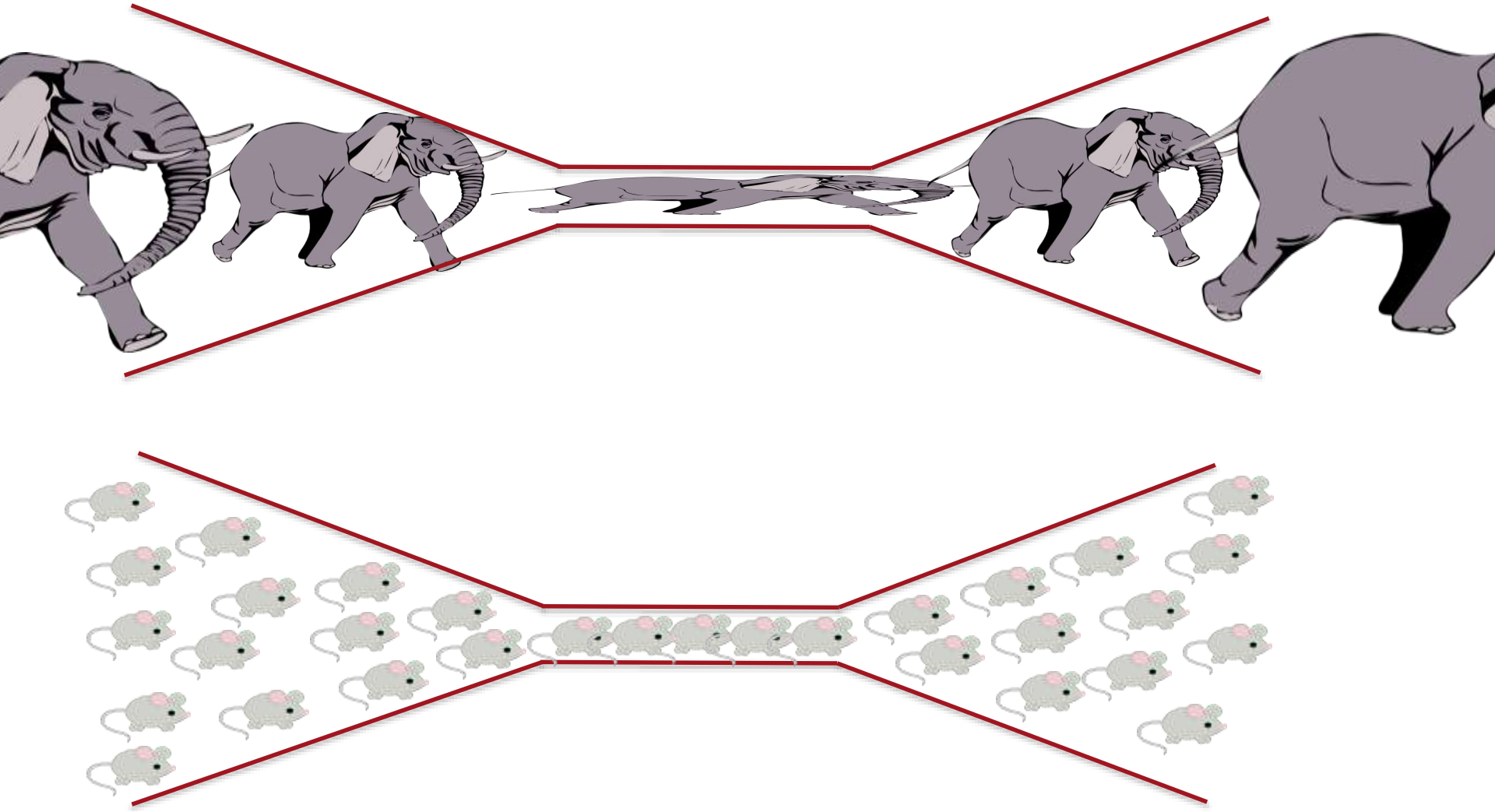
Throughput vs Latency



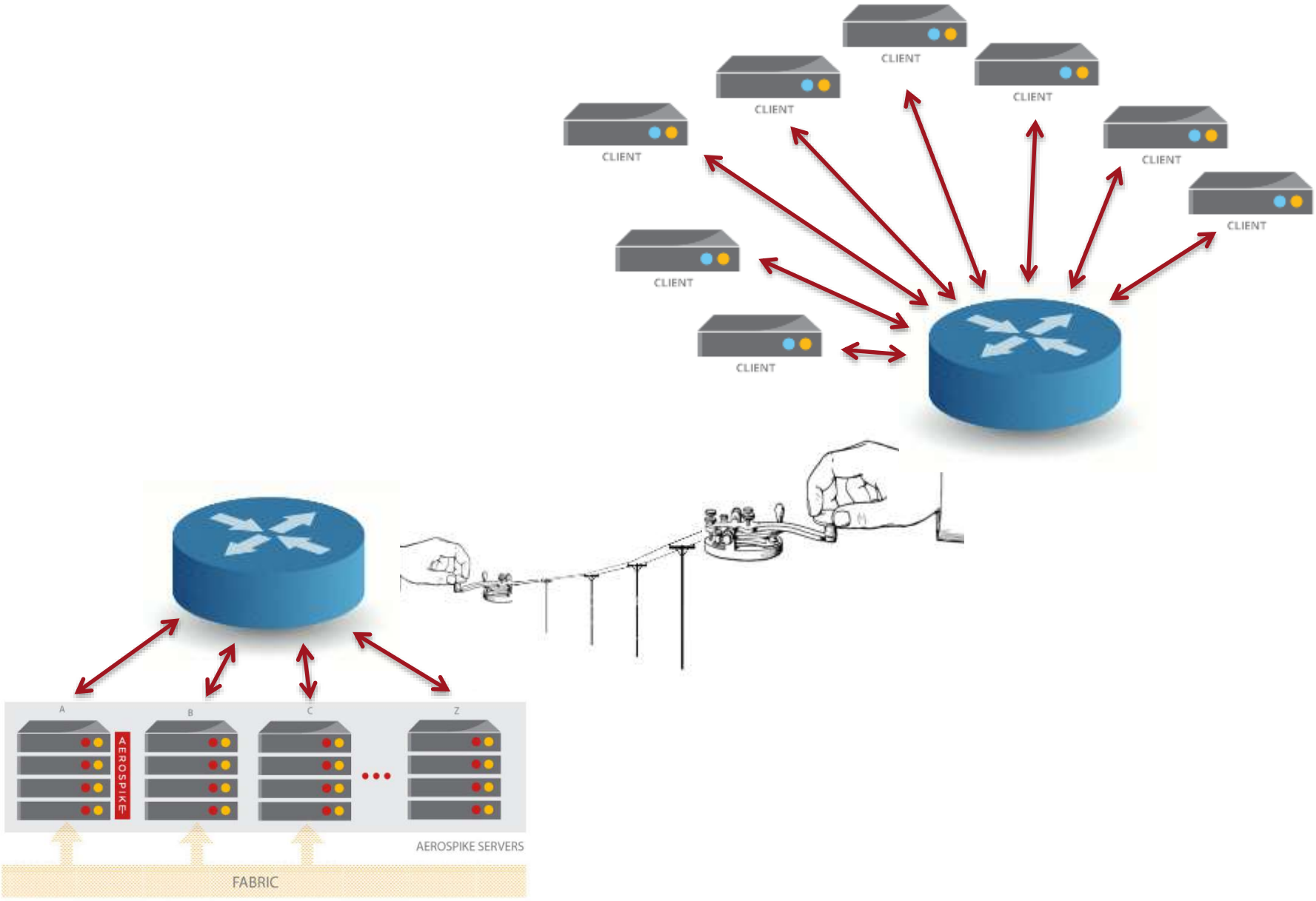
thumbtack TECHNOLOGY

High load failures

Networking – Message size and frequency

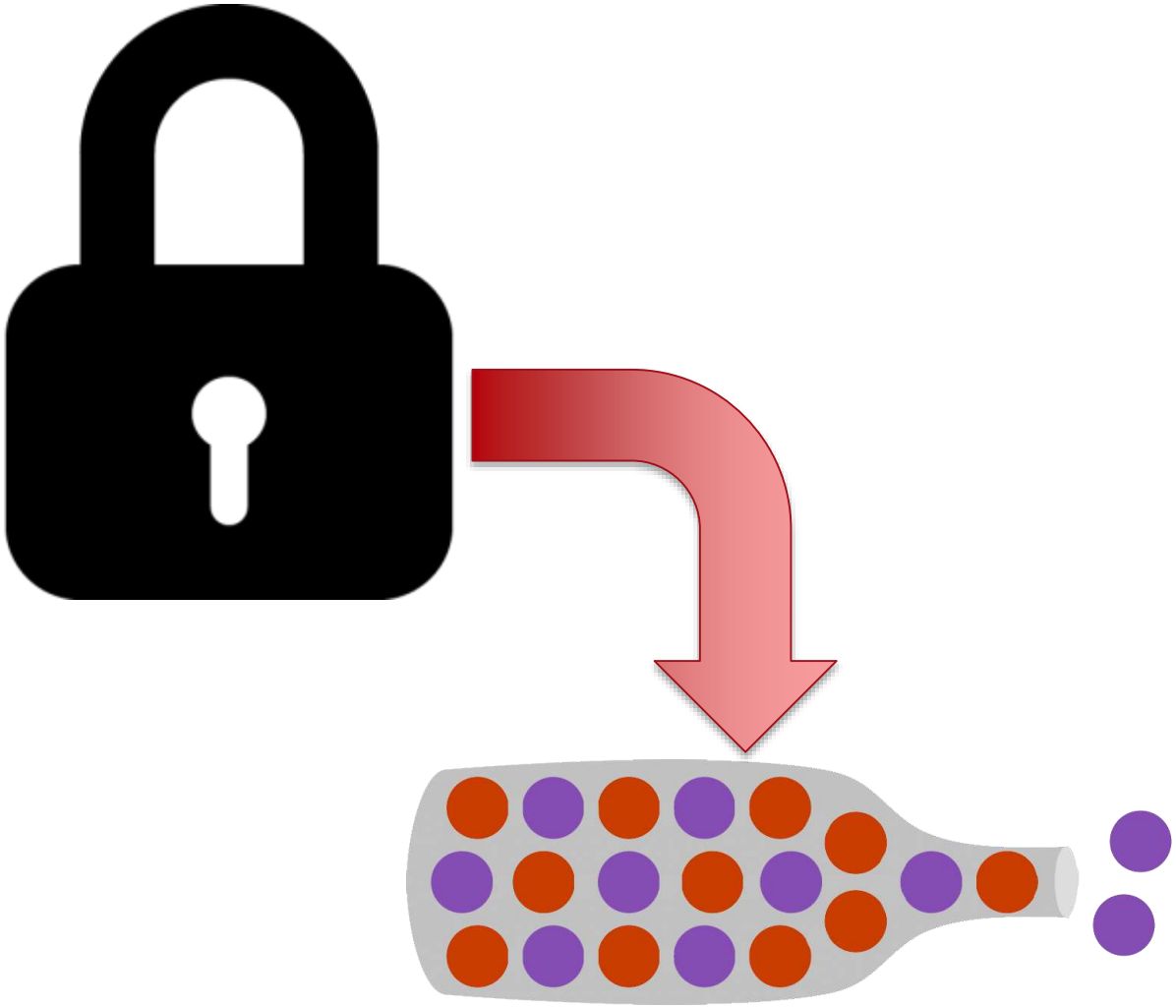


Networking - design



Big Locks

- Locks held for **too long**
- Increases latency
- Decreases concurrency
- Results in a **bottleneck**



Computing power not used

- **Network IRQ** not balanced across all Cores
  - 1 core does all the I/O
- Code does not use **multiple cores**
  - Single threaded
  - 1 core does all the processing
- **Uneven workload** on Cores
  - 1 core 90%, others 10%
- Code not **NUMA aware**
  - Using shared memory

Stupid code

- **1980's programmers** worried about
  - Memory, CPU cycles, I/Os
- **1990's programmers** worried about
  - Frameworks, Dogma, Style, Fashion

- **Stupid code**
  - Unneeded I/Os
  - Unneeded object creation/destruction
  - Poor memory management
    - Overworked GC
    - Malloc/Free
  - Loops within loops within loops
  - Unnecessary recursion
  - Single threaded/tasked
  - Big locks

Poor load testing

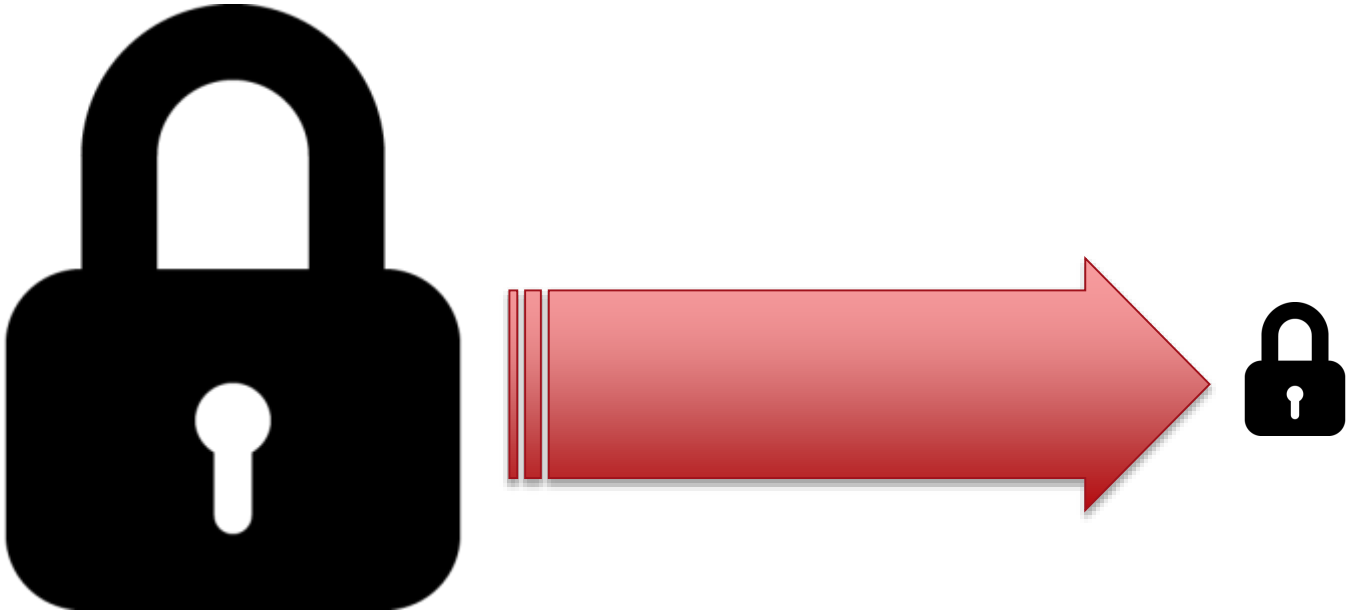
- BAA opened Heathrow's fifth terminal at a cost **of £4.3 billion**.
- Passengers had been promised a "**calmer, smoother, simpler airport experience**".
- The baggage system failed, **23,205** bags required manual sorting before being returned to their owners.

Uncle Pete's advice

Lock size

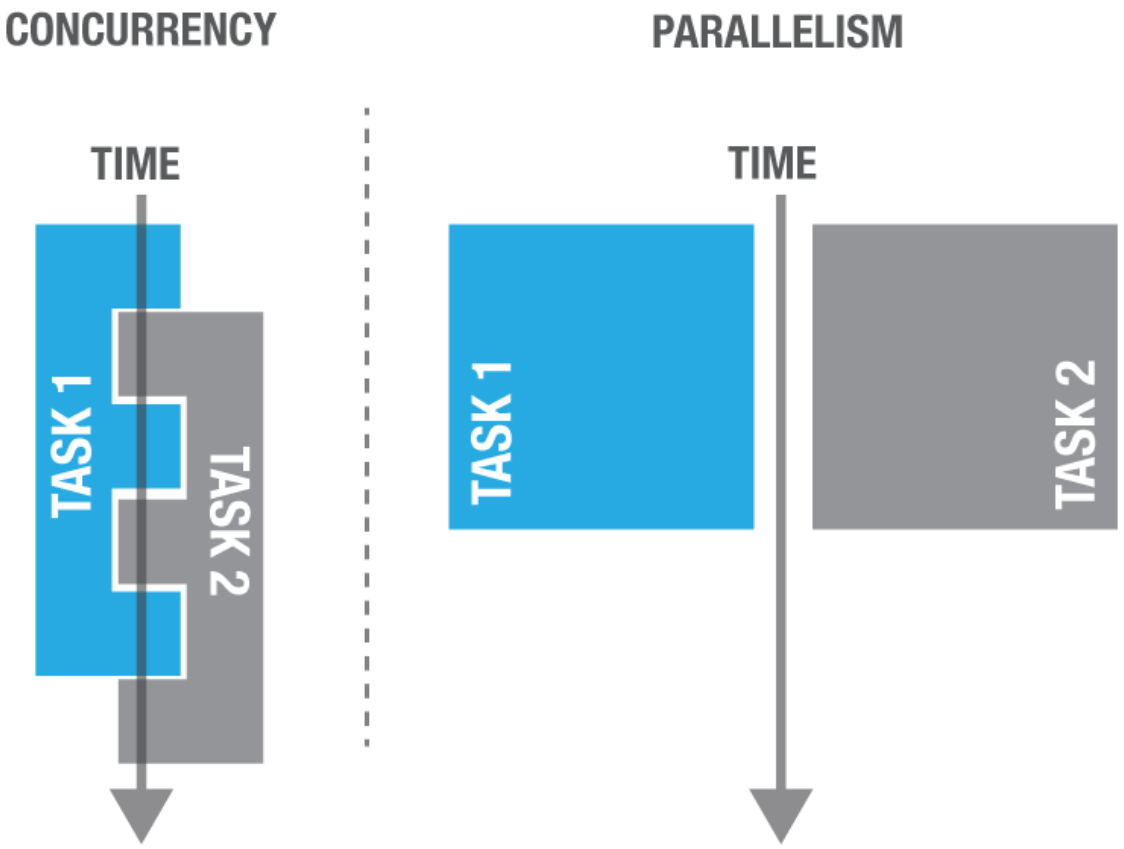
Make locks small

- Increase concurrency
- Reduce latency



Parallelism at every step

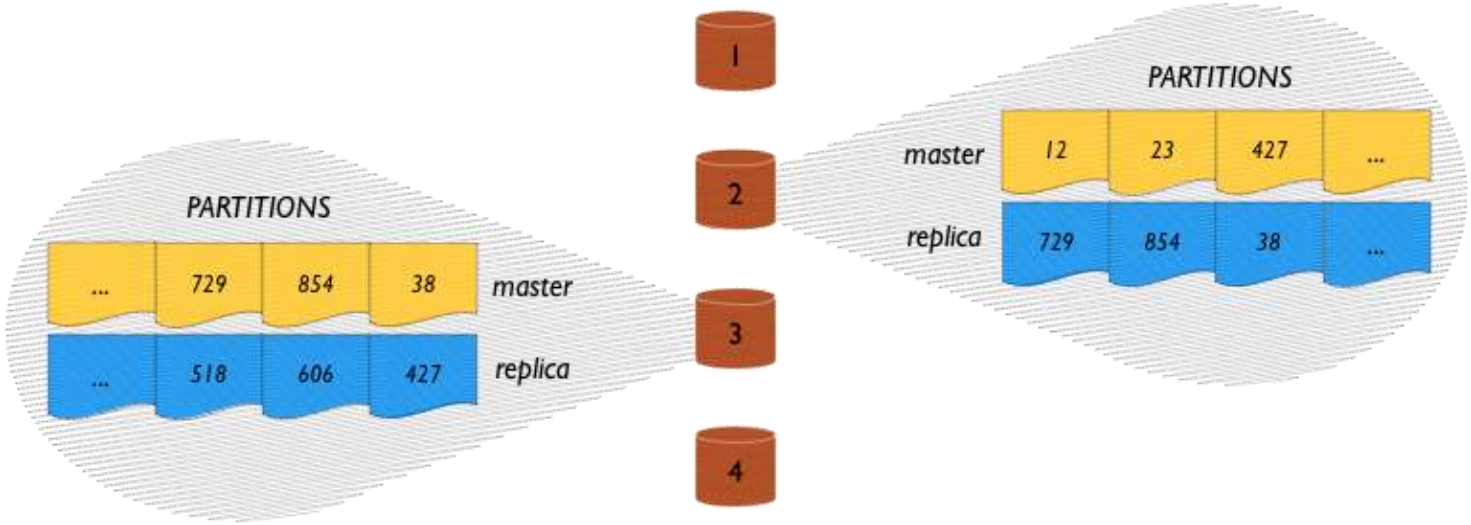
- Multiple machines
- Multiple cores
- Multiple Threads,
- Multiple IRQs
  - IRQ balancing
- Multi-channel Bus



Efficient and robust partitioning

Partition your workload (Application) with

- Reliable, proven Algorithm
  - No collisions
  - No corner cases



Latency of your application

Latency = Sum(L_D) + Sum(L_S)

- L_D = Device latency
- L_S = Stupidity latency

- **Minimise** stupidity

Load test

- Simulation
  - Simulate real load
- Nothing is better than **real data**
  - Record live data and playback in testing

Finally..

A well designed and build application should

- Deliver the **correct** result
- **Perform** adequately
- Be **maintainable** by the average Guy or Girl

Questions?

Dúvidas?

Klausimai?

Fragen?

質問がありますか？