Read and write considered harmful

ACCU Bristol, April 2018

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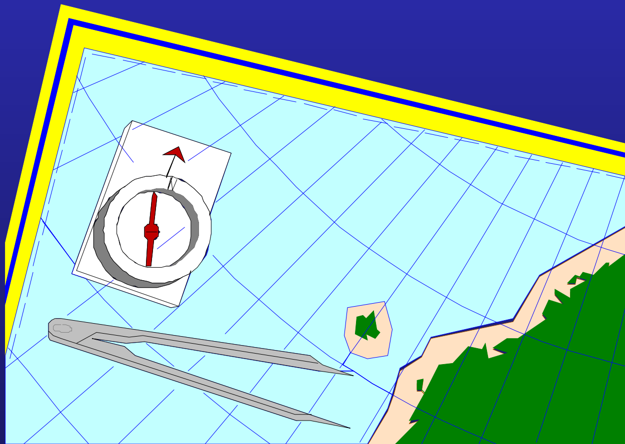
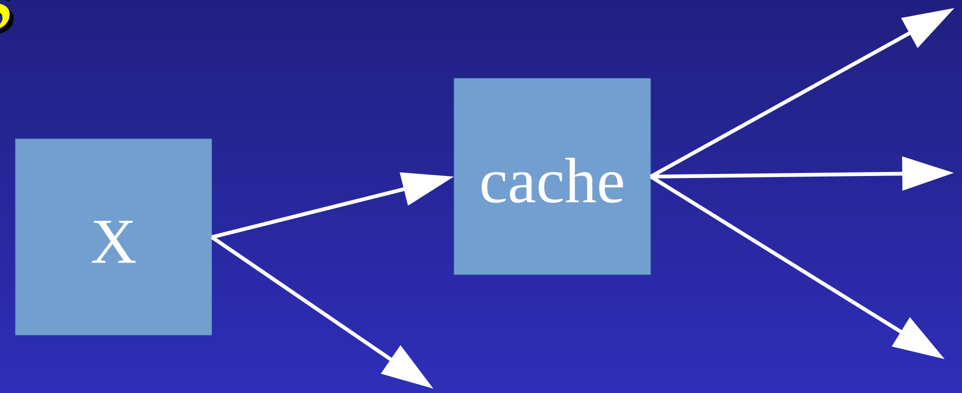


Why this talk?

Overview

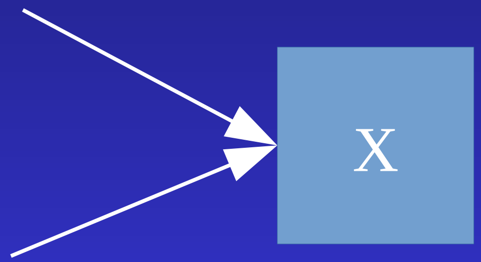
1) Basics of Read/Write
2) Business processes, rules and schemas
3) Performance, scaling, concurrency
4) Six questions about data
5) Asynchrony and queues
6) Structure changing
7) State management

Reads



- Can be cached, at multiple levels (e.g. CPU)
- Caching is transparent (mostly)
- Idempotent (can be retried without side-effects)
- Can be partitioned easily (routing)
- Access control rules only
- Synchronous and blocking
- Scalable bandwidth – fanout reduces contention

Writes

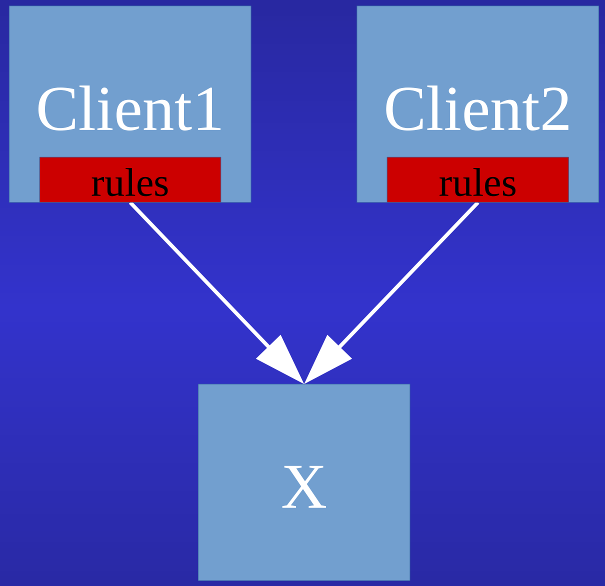


- Caching is horrible for writes
  - writeback/through, eviction policy, coherence,etc
- Scaling writes is horrible – fan-in creates contention
- Sharding works well only for primary key writes
- Access control rules plus update rules
- Can be delayed or asynchronous
- Idempotence is a design issue/choice

Dependencies

- Even simple code has dependencies caused by read and write
- Asymmetric – caller object doesn’t know who calls it
- Makes testing difficult
  - Substitution
  - Mocks, etc
- Introduces notion of push and pull

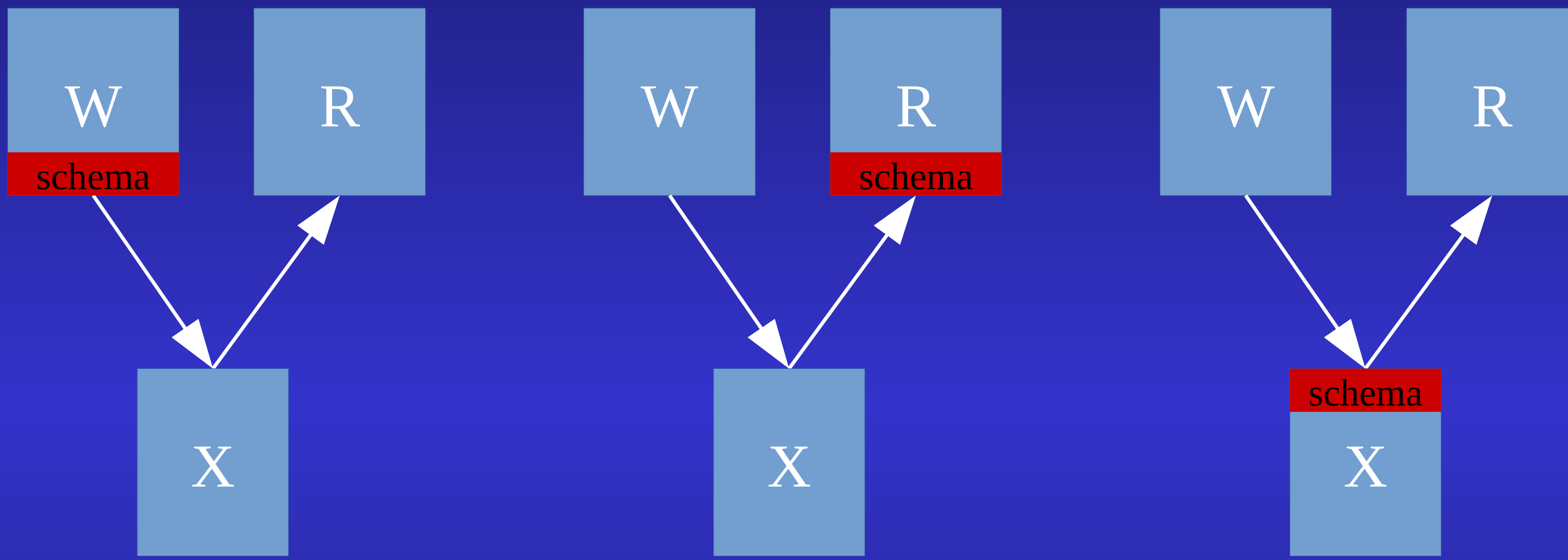
REST APIs and rules



REST = getters/setters on steroids

- Industrial-scale anti-pattern
- Separates code and data
- Opposite of encapsulation
- Very non-OO
- Duplicated logic/rules in every client
- Example: stock_level >= 0
- If rule is broken (stock_level == -1) where is the bug?

REST APIs and schemas



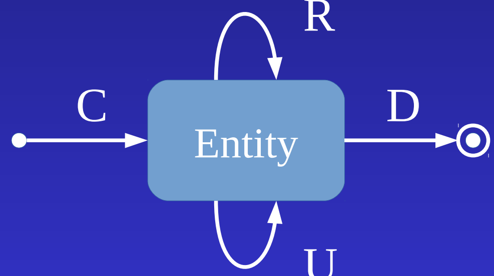
schema on write
(enforce valid data)

schema on read
(NoSQL)

schema with data
(SQL, OO)

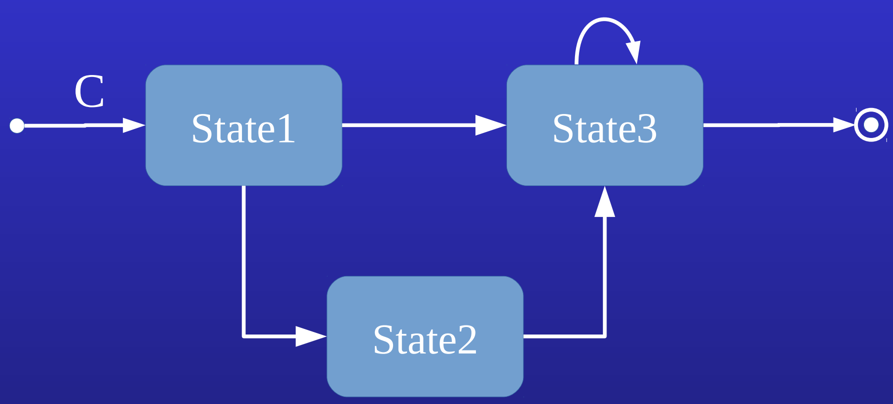
Tradeoffs: early/late validation failure, schema migration, versioning, code/rule duplication

REST APIs and processes



REST = CRUD

– Statechart has one state and four transitions
– OK for metadata



Real processes have multiple states

– Have different entities per state (possibly sub-entities)

Typical system scaling path

- Application is too slow
- Get more front-end boxes (scale R+W)

- Application is still too slow
- Get bigger DB box (scale R+W)

- Run out of read bandwidth
- Replicate or cache data (scale R)

- Run out of write bandwidth
- Shard/partition data on primary key (scale R+W)

- Create separate services per entity/component
- Cross-service joins done in client (scale entities)

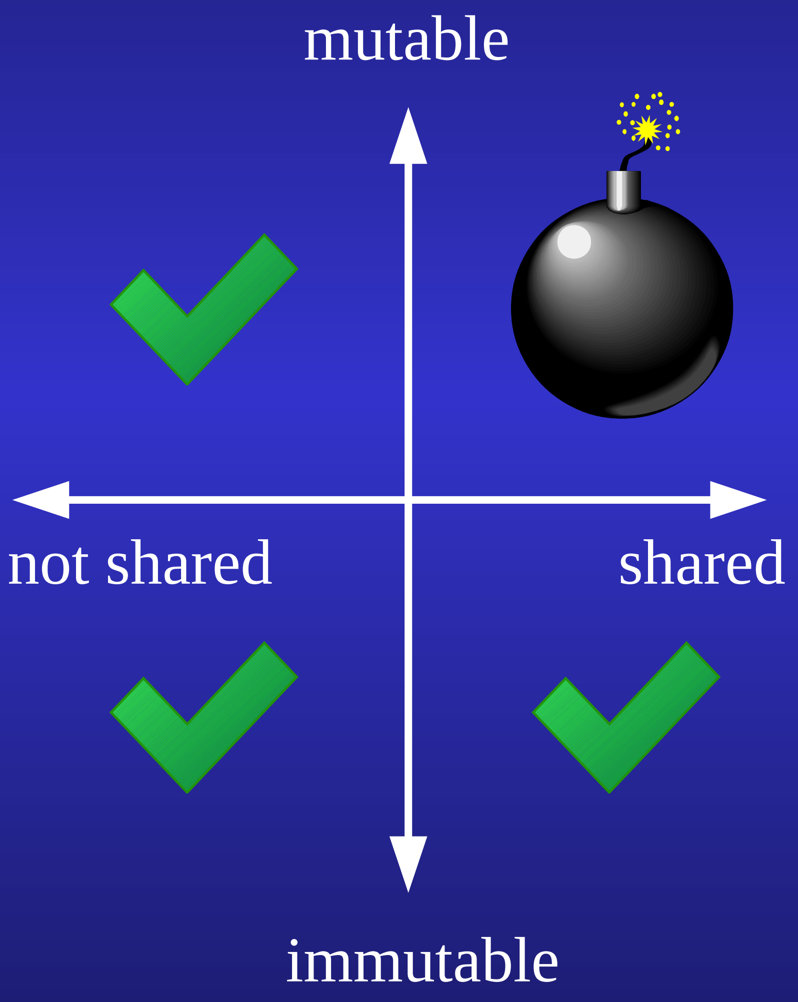
stop when it's fast enough

Scaling problems

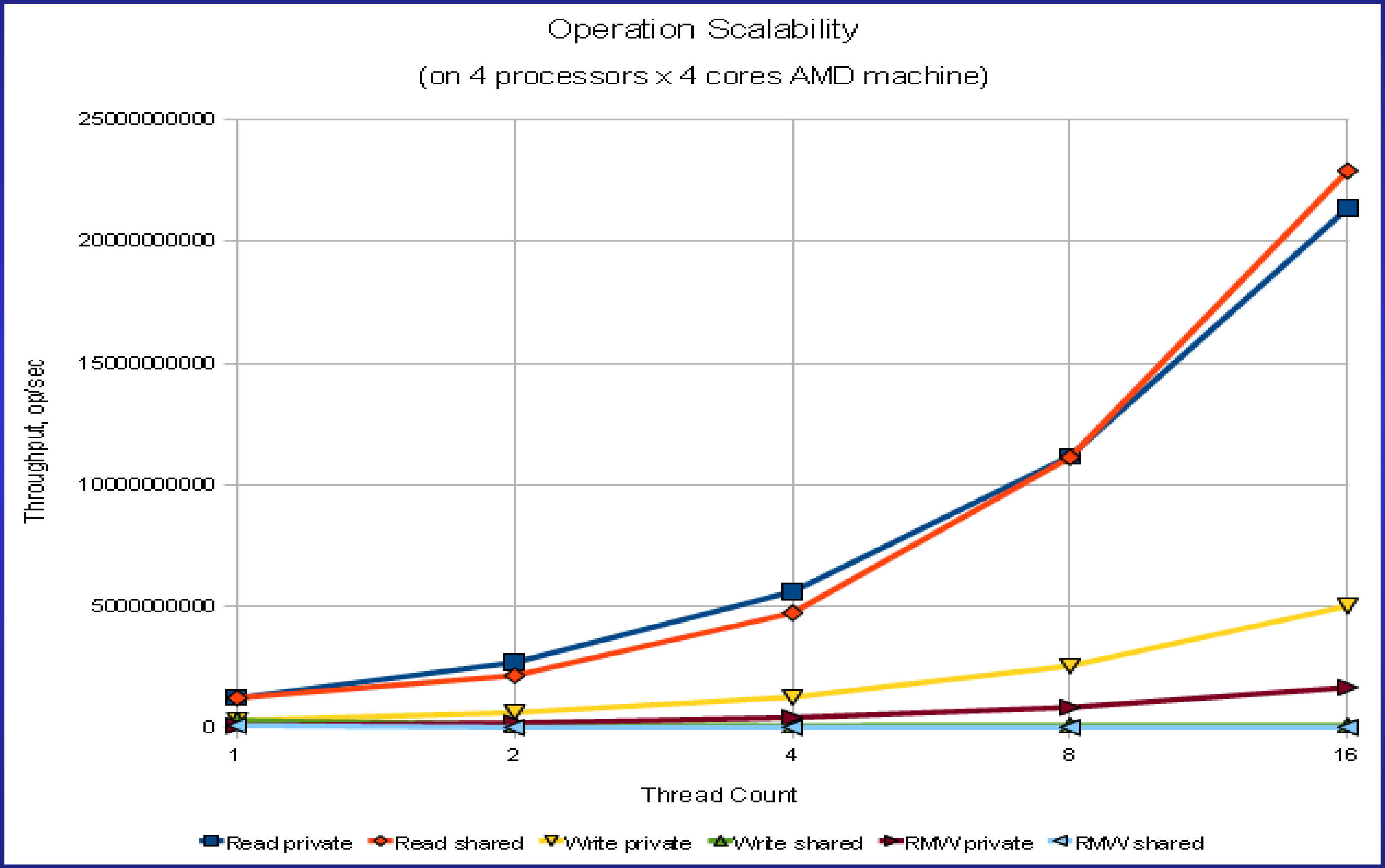
- Partitioning or sharding works to an extent
  - If access is strongly biased around primary key
- Nasty to scale cross-partition operations
  - Particularly for write (usually not idempotent)
  - Partial failure on write, cross-box transactions, concurrency, latency, etc (classic Waldo paper)
  - Service boundaries aligned with operation boundaries and failure boundaries
- Bulk access to multiple records can cause N+1 access problem (get primary keys then N single-row accesses – beware of REST and ORMs)

Avoid sharing mutable data

- Shared mutable data is the evil of all computing!
- Read-only data can be shared safely without locks
- Const is your friend
- Pure message-passing approach avoids this

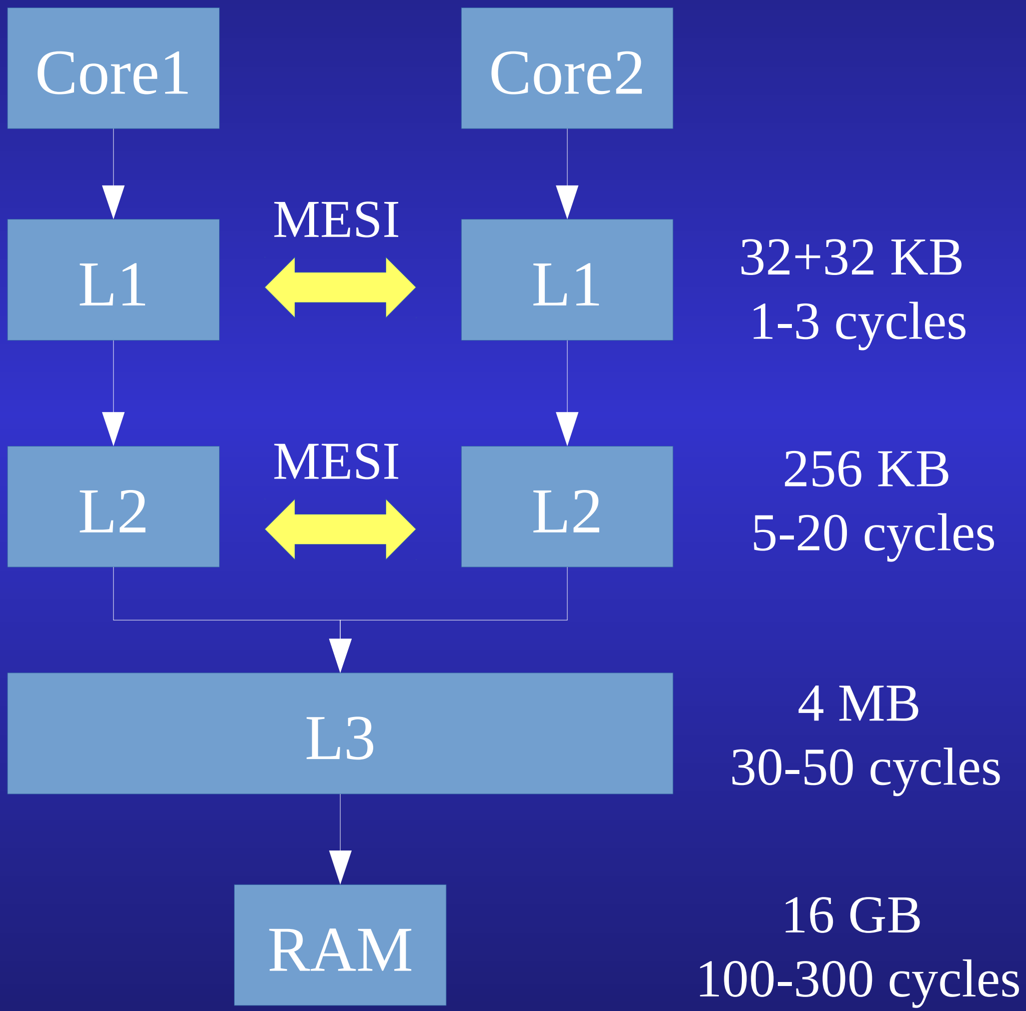


Shared writes don't scale



(graphic by Dmitry Vykov, http://www.1024cores.net, CC BY-NC-SA 3.0)

Why shared writes don't scale



- Caches have to communicate to ensure coherent view
- MESI protocol passes messages between caches
- Shared writes limited by MESI comms

6 questions about data access

PK	**hashing, partitioning, op==**
Non-PK	**search, secondary indexes, full-text search**
Range scans	**ordering, iteration, bulk vs. single values, op<**
R/W ratio	**caching, cost of lookups vs. cost of updates**
Working set	**how big is the commonly accessed set of data (RAM)**
Consistency	**exact results vs. fast approximations, eventual consistency, replication, batched updates**

Strongly related to the operational profile

1. Primary key access

- Most common form of access
  - Database primary key
  - std::map/unordered_map
- Can use hashing [O(1)], binary search [O(log N)] or linear search for small N [O(N)]
- Requires only operator==
- Partition on primary key into multiple parts that can operate in parallel or to avoid contention
- Examples: product catalogue, customer records, sticky web sessions, NoSQL, memcache, REST

2. Non-primary key access

- Finding items by value, not by key
- Need for secondary indexes (e.g. database indexes)
- Search on parts of a record
- Metadata search (date/time, etc)
- Full-text search
- May require substantially more work to build compared to PK-based access
- Usually slower than PK access for lookup

3. Range scans and sequential access

- Requires ordering, i.e. operator<, (ordering costs)
- Requires iterators/cursors/traversal state
- Seek then scan – first find is slow, then fast
- Dense linear access and prefetch
- Watch out for read/write amplification
- Bulk, not single record, access – may require bulk aggregate operations rather than N times single record operations for speed (DB N+1 problem)

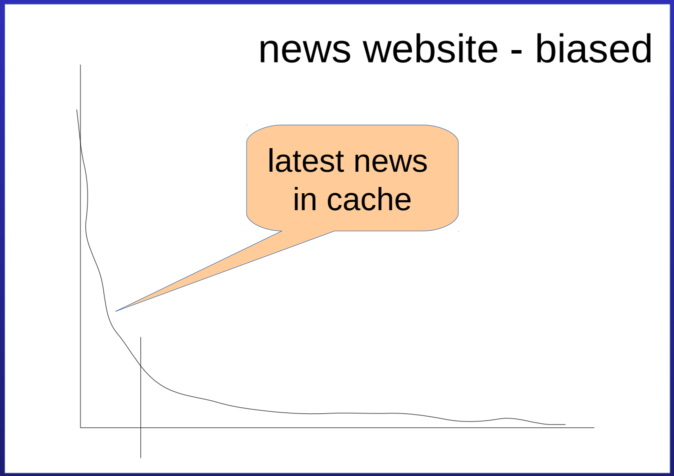
4. Read/write ratio

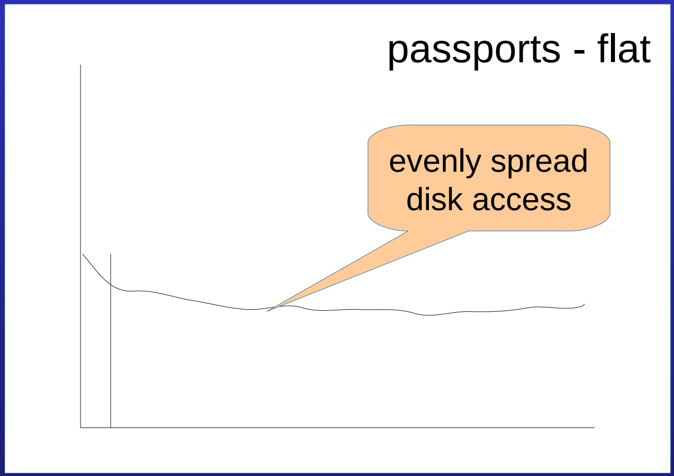
High reads	High writes
• Caches are effective • Cache writethrough/back • Cache eviction policy • Cache coherency • Index structures useful	• Caches don't help much (except for metadata) • Locking overhead • Index structures require updating

Not all data in a system has similar R/W ratios
e.g. metadata is often read-heavy

5. Working set size and skew

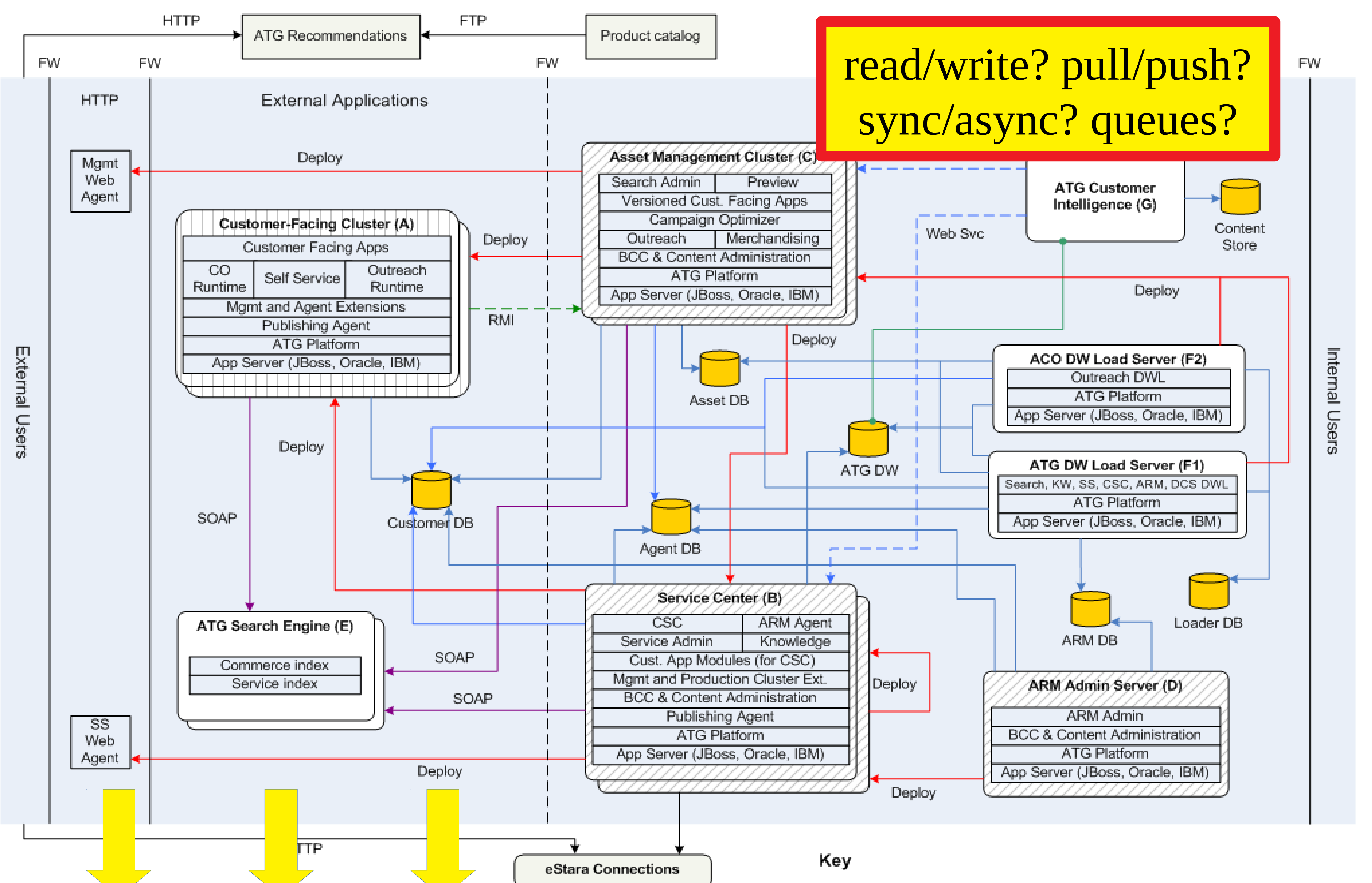
- How much of the common data will fit in main memory, the L1/L2/L3 cache
- Will the index structures fit but not the main data
  - Index data tends to be “hot”, main data may be “cold”
- Depends on data access patterns – 80/20 rule





6. Consistency

- Do all copies of the data need to be exactly up-to-date right now
  - ACID, 2-phase commit, centralised, locking, slow
- How often are copies updated
- Batch updates (e.g. overnight)
- Data vs. metadata (transactions vs. reference data)
- ACID vs. BASE (eventual consistency)
  - BASE allows for decoupled asynchronous systems



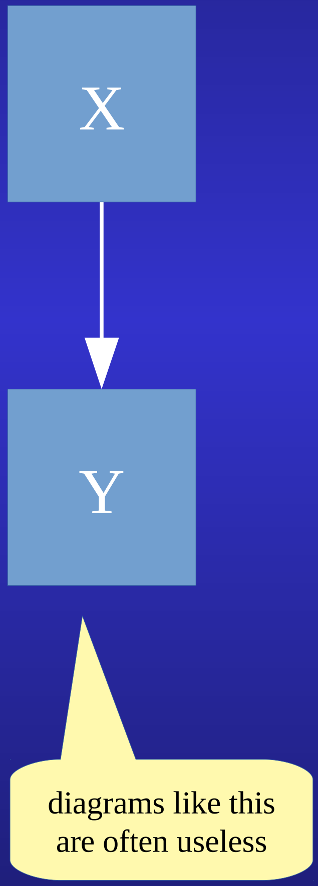
Notes

1. Arrows show connections; they do not indicate data flow.
2. Does not take into account the application usage patterns that impact scaling.
3. Does not show staging servers.
4. Letters A-G refer to descriptions of servers in ATG Multiple Application Integration Guide

Key

- Internal users
- External users
- Database
- **FW** Potential firewall
- Shows connections
- ODBC/Native connection
- JDBC connections
- **ATG DW** Data warehouse database

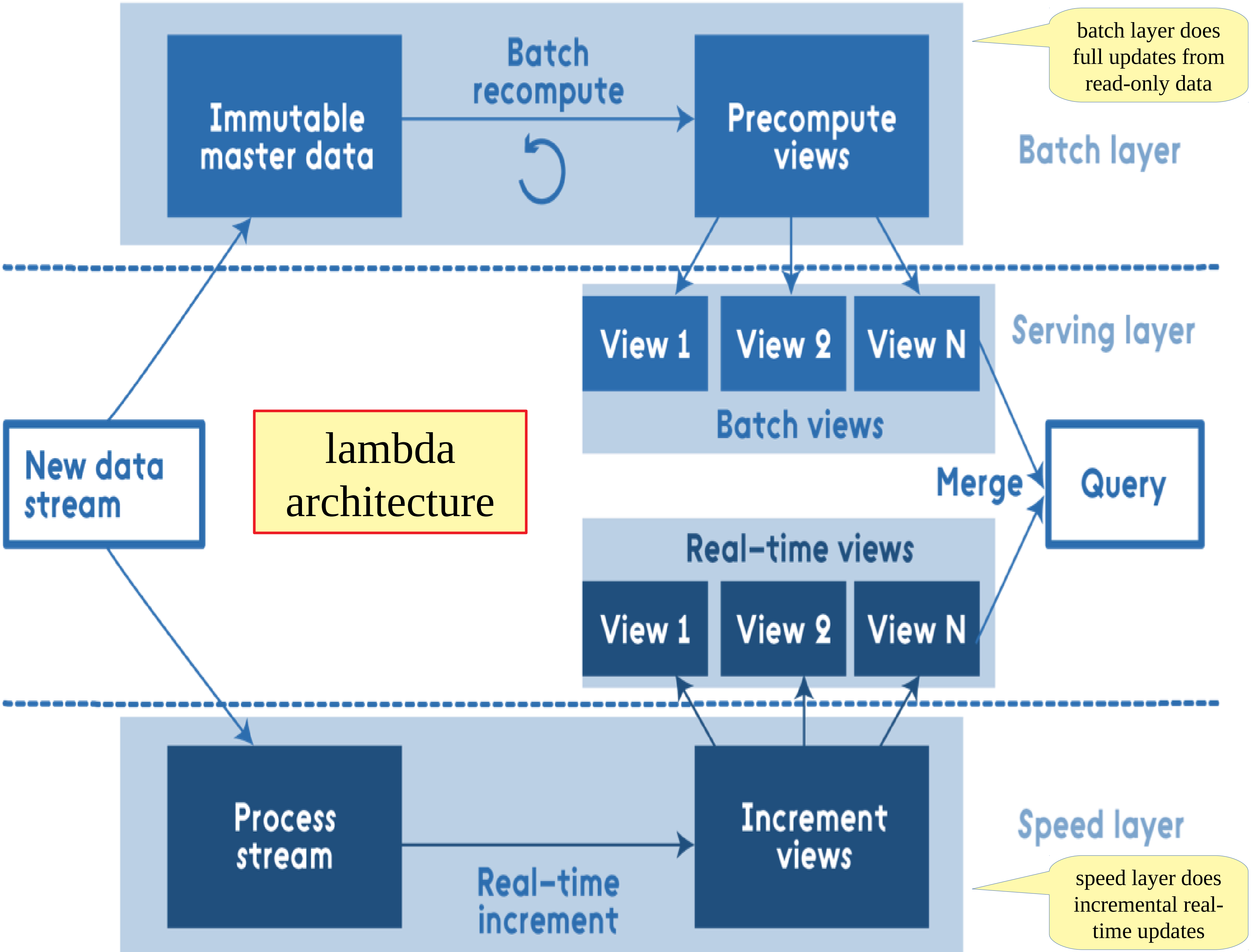
Read or write, pull or push?



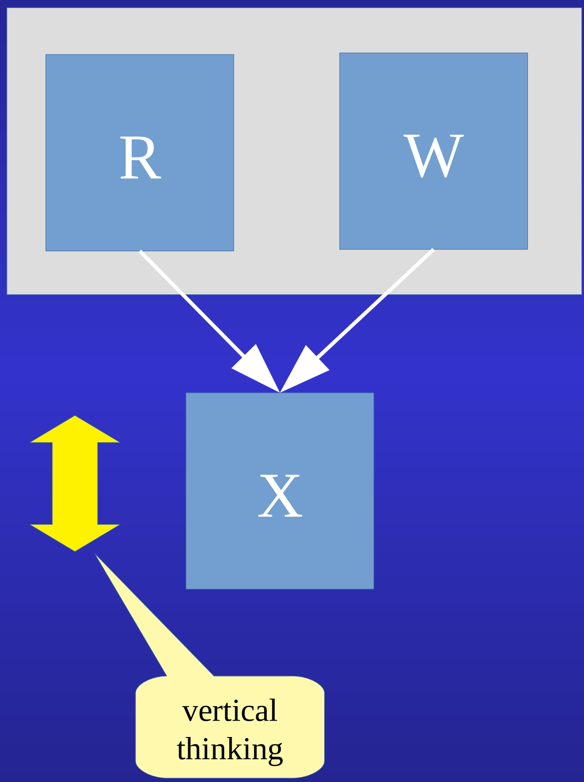
- Is X reading Y or writing to it?
- Or both at different times?
- Is X pushing or Y pulling?
- Where is the thread of control?
- Is this a full batch update or a partial incremental change?
- Is this an asynchronous push (fire-and-forget) or a synchronous blocking call?

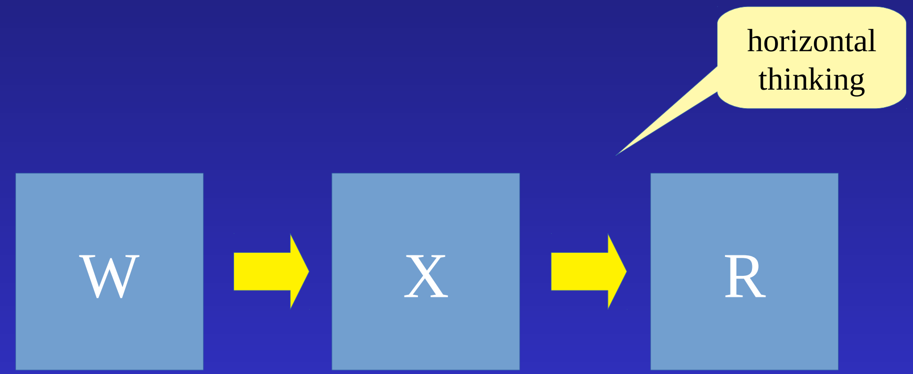
Full vs incremental

- Full changes allow the state to be reset on a regular basis
  - Prevents build-up of errors or divergence from base data
  - Slow, long latency, partial failure problems
  - One big transaction
- Incremental changes are fast but don't guarantee to keep state changes synchronised
  - Lost messages because of unavailability
  - Transactionality only on each update


Batch recompute
Immutable master data
Precompute views
batch layer does full updates from read-only data
Batch layer
View 1
View 2
View N
Batch views
Serving layer
New data stream
lambda architecture
Merge
Query
Real-time views
View 1
View 2
View N
Process stream
Real-time increment
Increment views
Speed layer
speed layer does incremental real-time updates

Reader/writer vs data flow

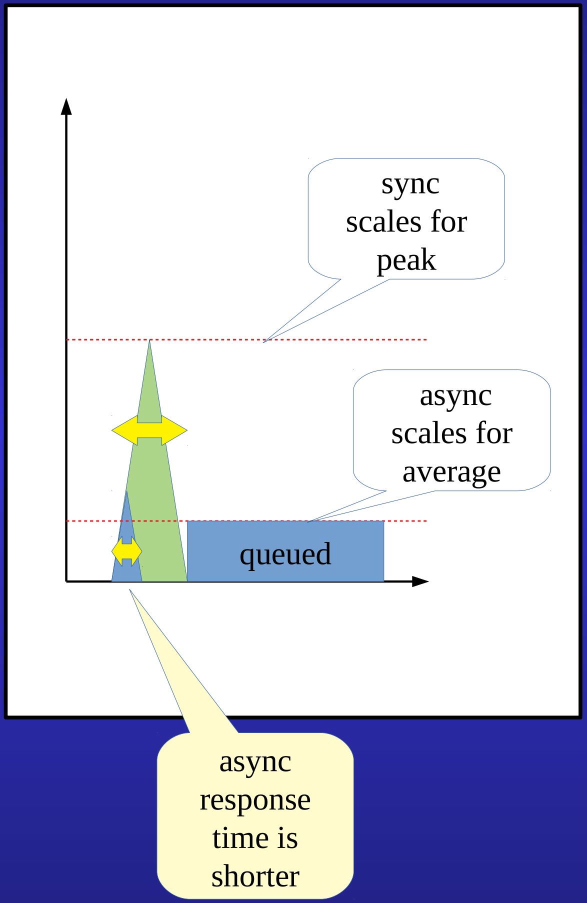




- Readers and writers view hides inherent data flow in systems
- Split R and W into microservices
  - Separates rules, performance, scaling, access control, etc
  - Often W and R are very different
  - W usually reads from somewhere

Sync vs async systems

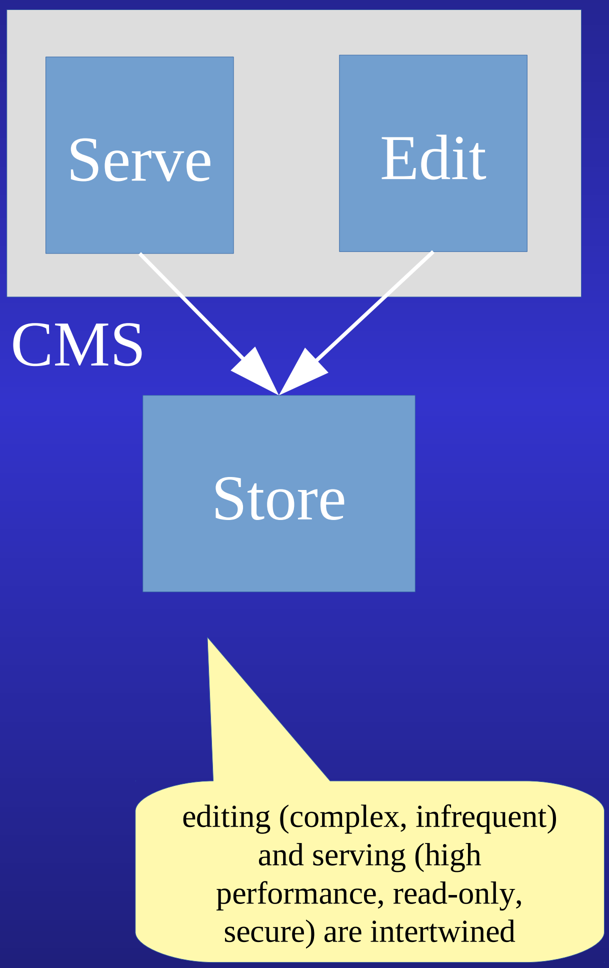
- ACID is hard to scale, partition, get right, can promote failures, makes for a more fragile system as everything has to be up all the time (brittle)
  - 10 sync systems with 99% uptime => 90% uptime
  - 10 async systems => 99% uptime for end system
- Can maybe delay writes or cover them up (lambda arch)
- Reads are sync but recent data may be sufficient, particularly for metadata (caching helps lots)

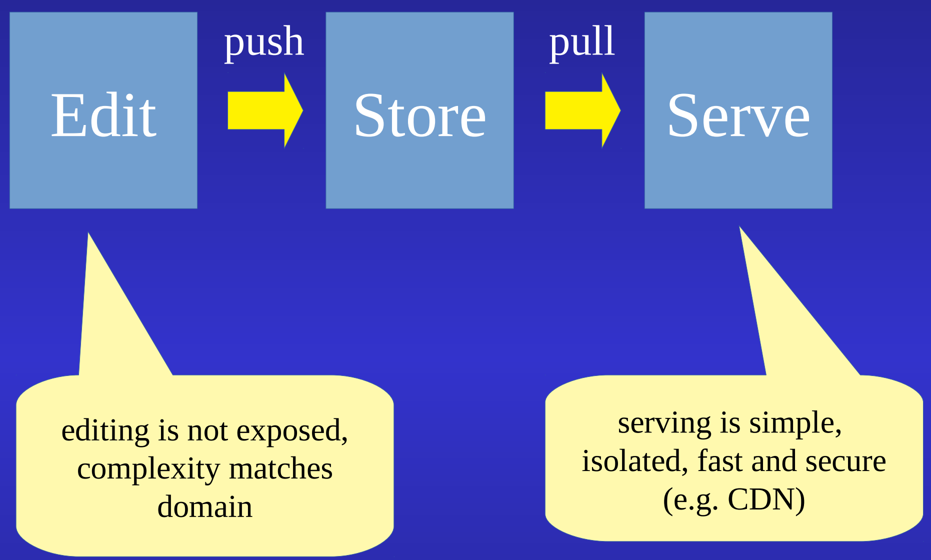


Data flow and sync/async

- Data flows can be point-to-point or broadcast
- Can be synchronous or asynchronous
  - Message queues provide simple sync intermediary
  - Flat file batch transfer is popular for a reason
- Queues can also be event stores with reread
  - c.f. Kafka => LinkedIn
  - Makes queue reads idempotent

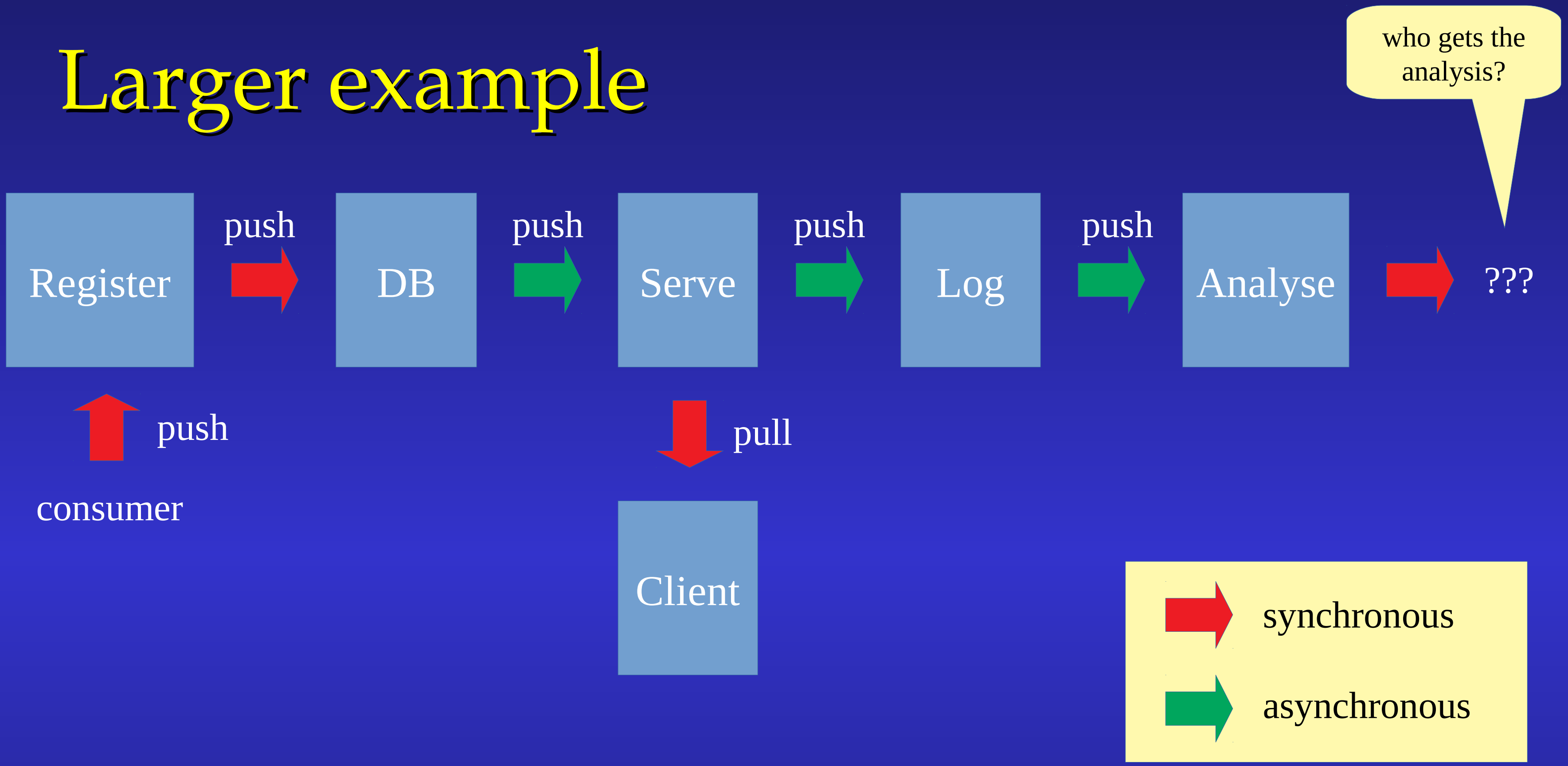
Content management example





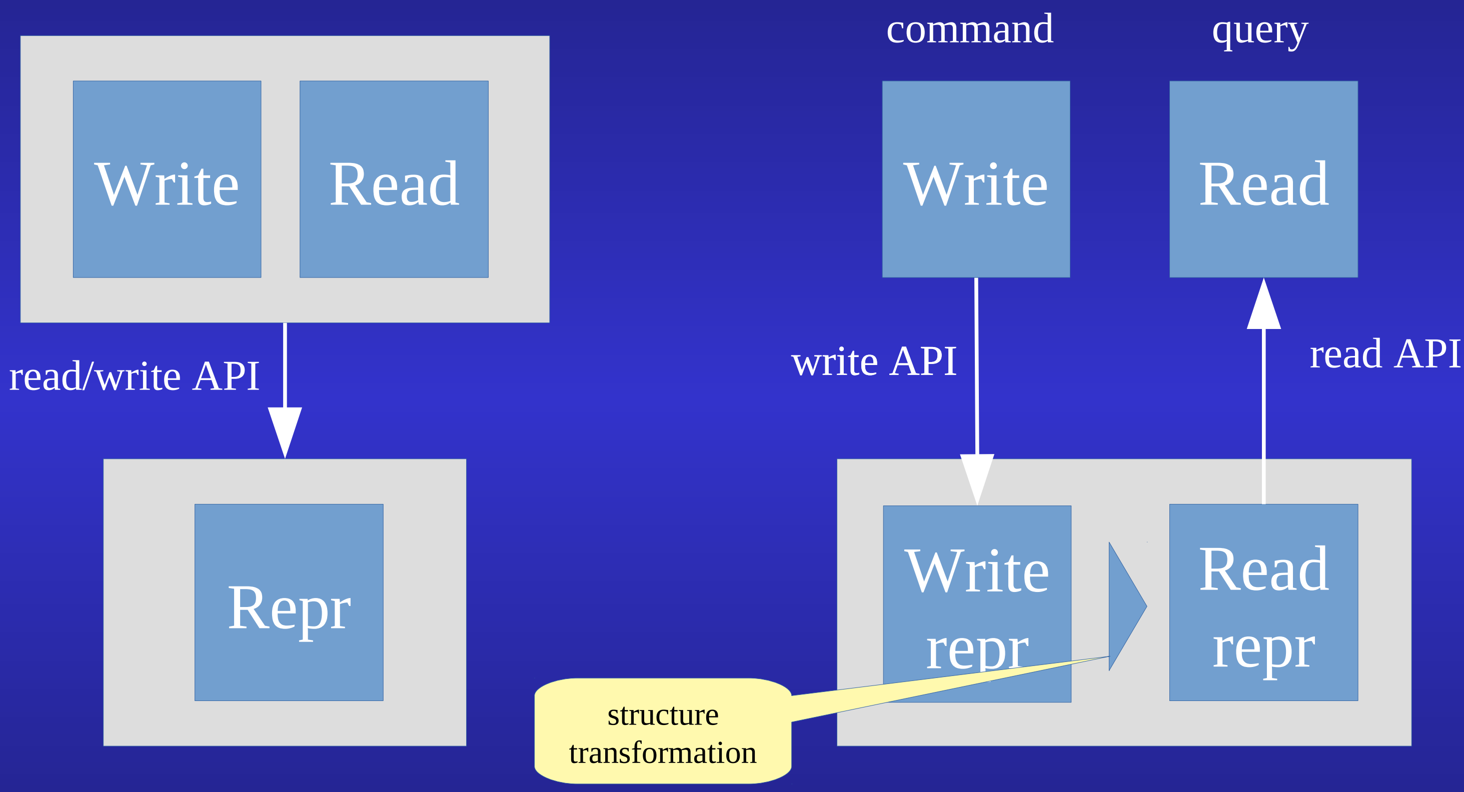
- Data flow approach keeps two APIs separate
  - Security, clarity of purpose
  - Separation of concerns
  - Horizontal not vertical thinking

Larger example



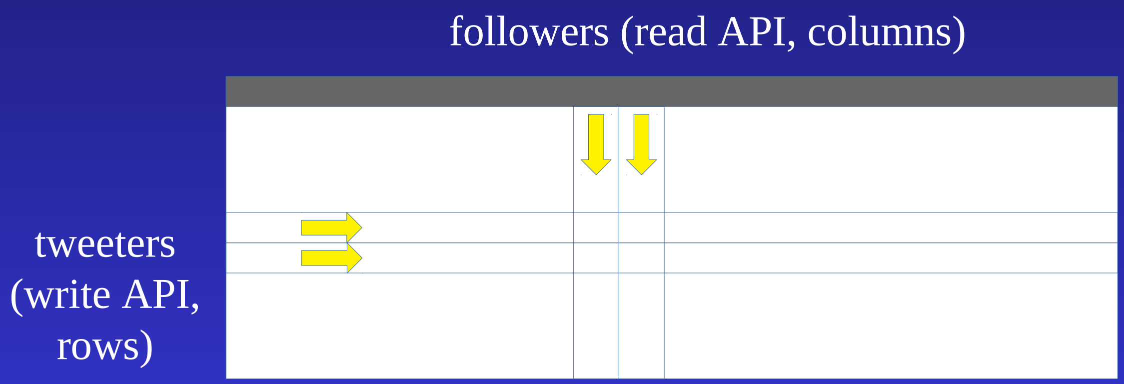
- Data flow makes you think about where data comes from and goes to
  - "Who is actually going to read the data I'm writing?"
- Microservices may have two APIs for sending and receiving
  - "Vertical" thinking may lead to trying to fit both into one API

Command Query Representation Separation (CQRS)



- Need to change the structure from the form that best suits the write API to the structure that best suits the read API
- Can be synchronous or asynchronous transformation

CQRS examples

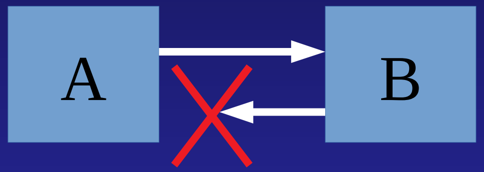


- Structure change can be on read or on write
  - Twitter does it on read for high-value users, not write
- Log-structured merge systems do this internally and asynchronously (e.g. HBase, RocksDB)
- Other examples
  - Time-series databases
  - Event sourcing
  - Struct-of-arrays vs array-of-structs (e.g. non-OO, data oriented)
  - Columnar analytics databases (e.g. Redshift, BigQuery)

State management

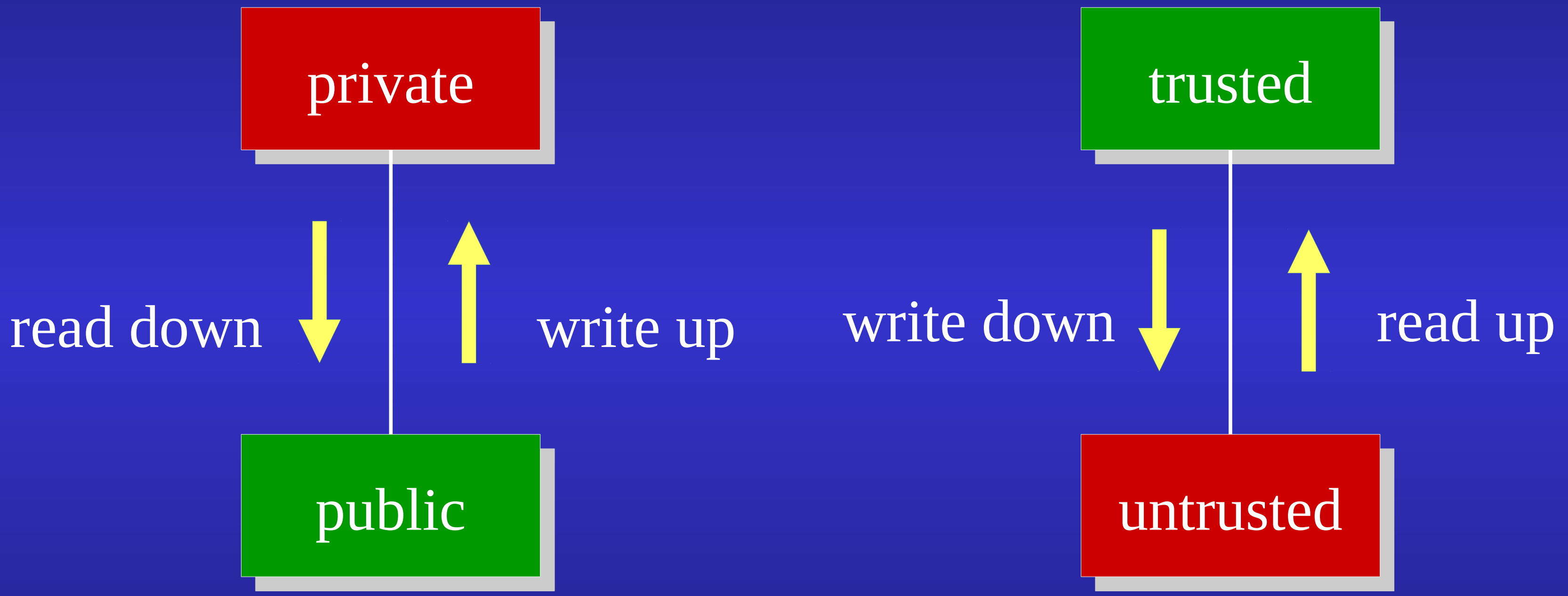
- Read and write focus doesn't help manage state across a complex system
- State management needs to address:
  - Transactions vs eventual consistency
  - Failure management
  - Availability and MTTR
  - Immutability
- Align txn boundaries with failure and aggregate boundaries
  - REST API: /resourceA/1/resourceB/2
  - Fragmentation and transactionality problems

Failure management



- Distributed systems can suffer from partial failures on writes
  - Writes in distributed are inherently concurrent
  - Recovery and resynchronising state is "fun"
- Idempotent writes allow for replay and deduping
  - Make deduping easy: serial number, timestamp, etc
  - Repeatable queues are useful (e.g. Kafka, flat files)
- Checkpointing of known good state
  - Point-in-time recovery
  - Full vs incremental update problem again

Bell-LaPadula and Biba models



Bell-LaPadula: confidentiality

Biba: integrity

diametrical opposites

Immutability

- Functional programming languages have immutable data
  - Make sharing and reasoning about data easier
- Russian Doll caching, MVCC
  - Change the key not the value
- Pets vs cattle – infrastructure
- SSA – compilers and CPU reservation stations
- Lambda architecture – immutable master data

Immutability makes things simpler

Availability

Availability = MTBF / (MTBF + MTTR)

(where MTBF = mean time between failures
MTTR = mean time to repair)

- Maximise MTBF by "normal" means:
  - Good software practices, hardware failover, reliable well-known technology choices
- Minimise MTTR by making systems easier to understand, debug and restart
  - Minimise state management (txn redo logs, fsck, etc)
  - Use immutability where possible

Read and write are too low level

- They don’t help you to design or analyse systems
  - They are the assembler-level of data (CRUD)
- They don’t relate to the larger picture
- It is too easy to deal with them in isolation
  - REST APIs are an all-too common example
- Looking at data flows, push vs. pull, sync/async, business processes, operational profiles, state management, etc are much more fruitful approaches