
A GLIMPSE INTO
DISTRIBUTED SYSTEMS
briefly, slowly, humbly
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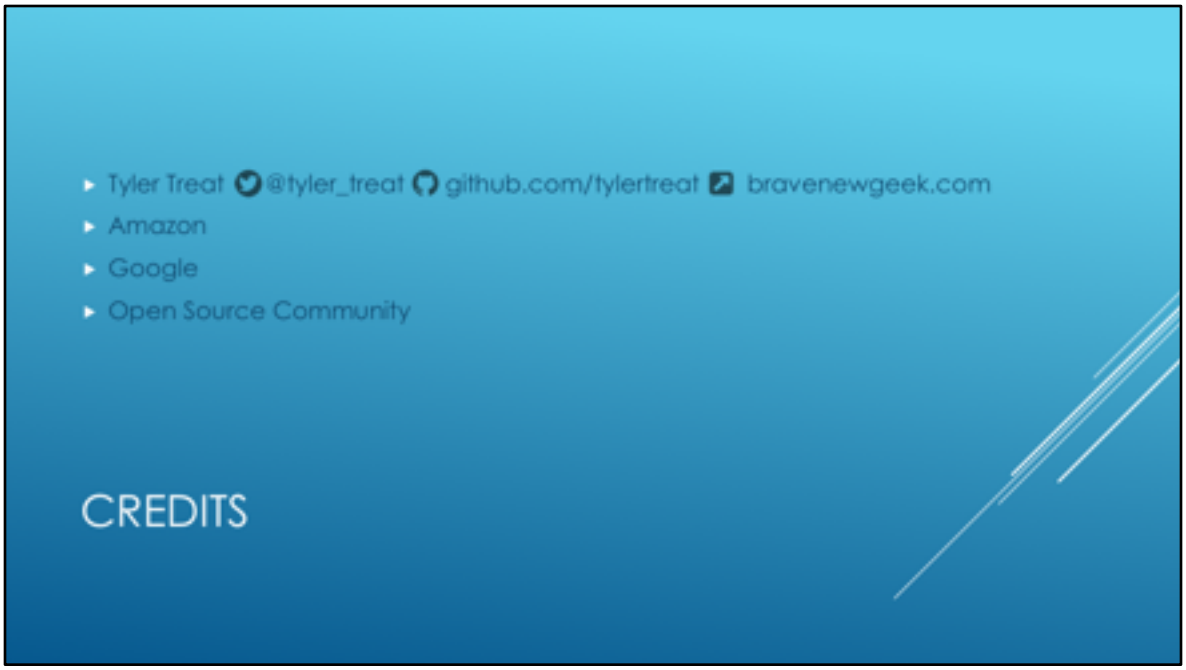
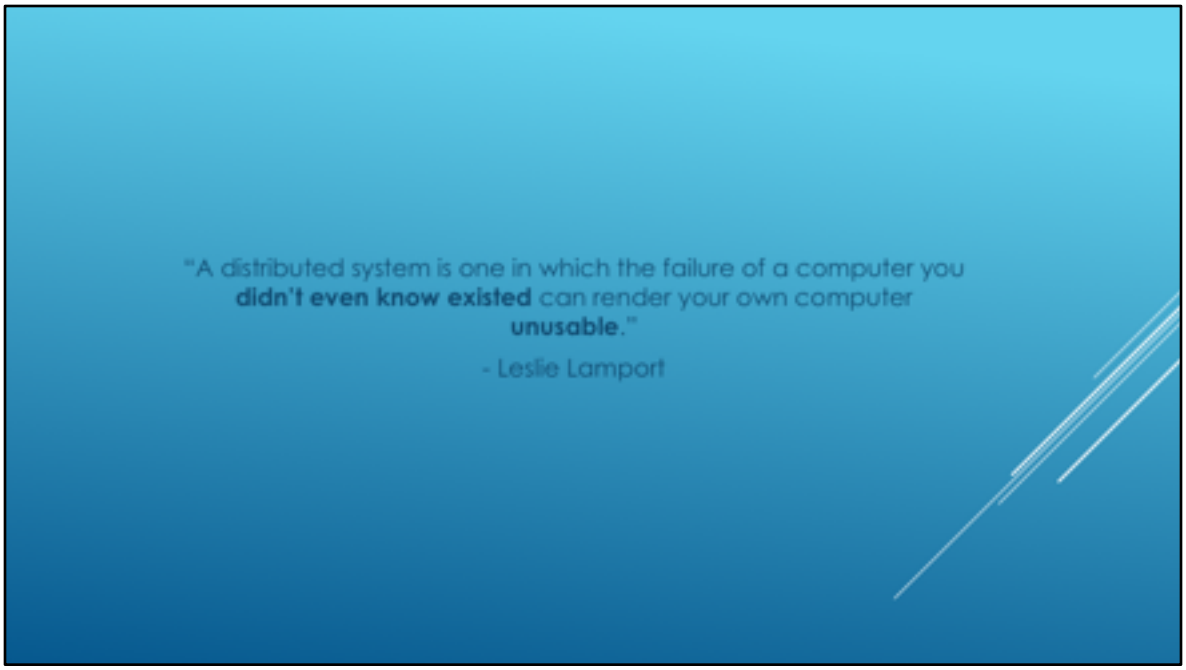
Moca Team, Hoolai Games Ltd.



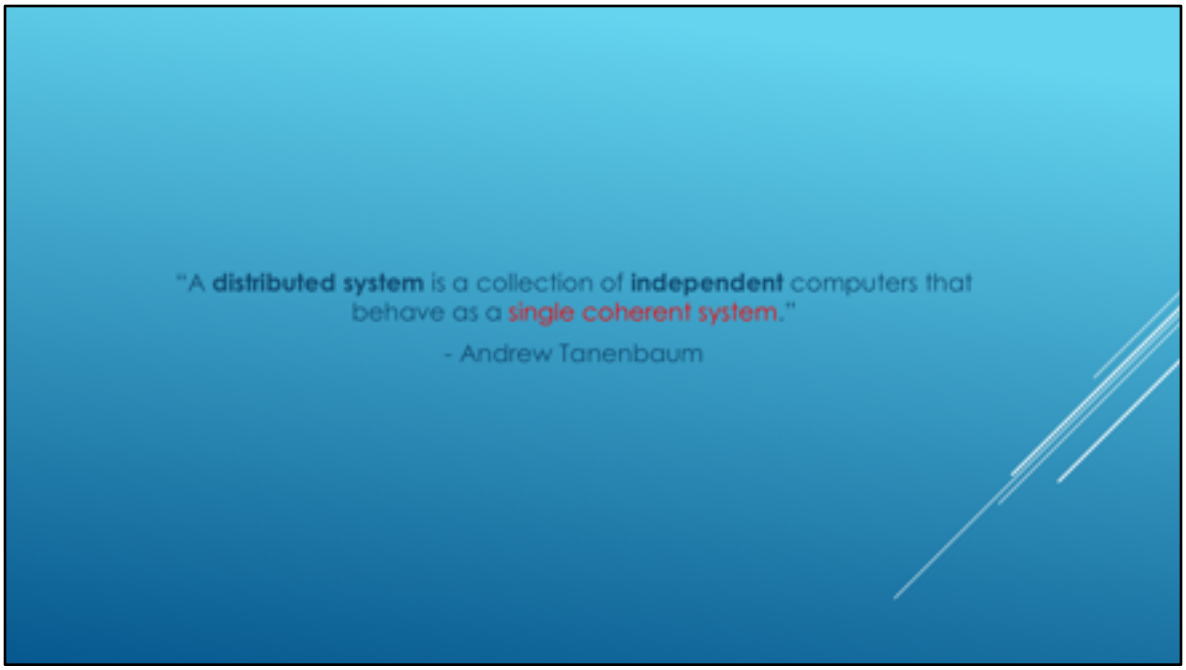
Over 50% of content come from Tyler Treat's Introduction to Distributed System presentation, many thanks to his work, greatly reduced my load to prepare the tech talk.


Thirty thousand foot view
Why
Fallacies
Characteristics
Pitfalls
Above the sea
Byzantine Generals and Consensus
Brain split
Consistency
Scaling
Fancy world
Dynamo/GFS/BigTable
Map Reduce/MPP/Streaming Processing
TOPICS

What you are seeing and hearing these days, mostly derived from fundamental works other people have done decades ago.
Paxos: 1989
Lamport timestamps: 1978
Vector clock: 1988

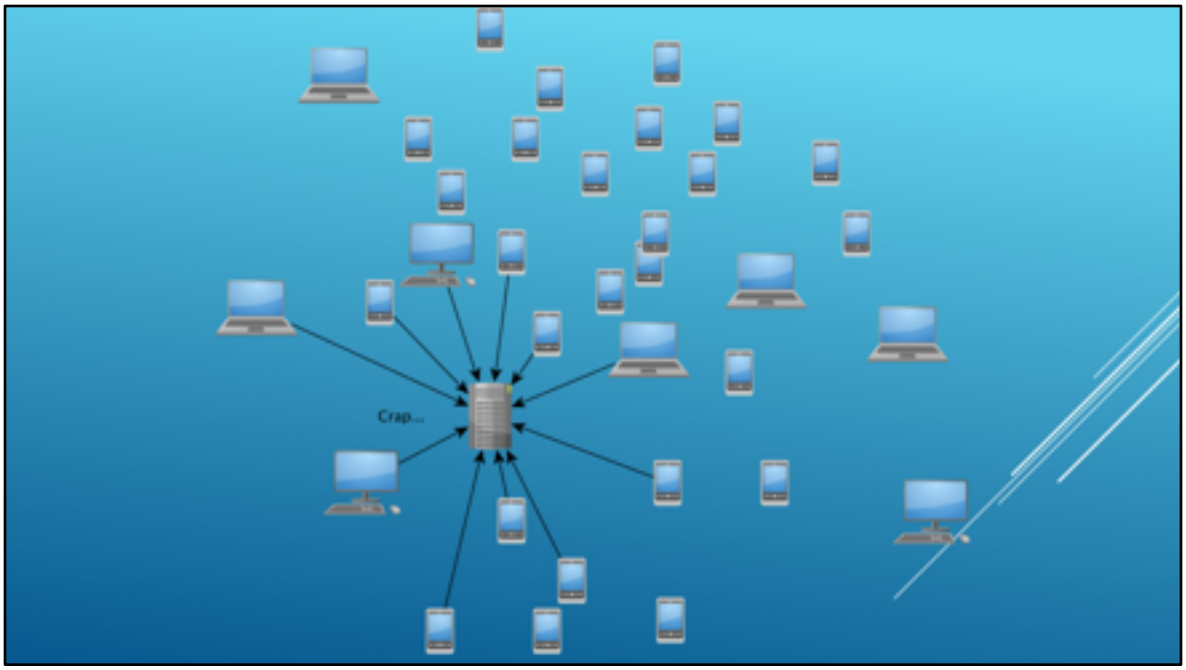


For example, alipay system outage makes you impossible to make a purchase on your computer or other connected devices.



Tanenbaum was the professor when Linus was studying operating system.


Availability serve every single request
Fault Tolerance resilient to failures
Throughput parallel computation
Architecture decoupled, focused service
Economics scale-out is manageable and cost-effective
WHY



This is why

Shit happens, So

Now, let's see what common issues could be which you might not realize their existence at all.

We can only try our best to deliver, no guarantee from network itself.

Distance from China to USA is 11640 KM, a round trip is 23280 KM. Light travels about 213000 KM per second within optical fiber. So it takes about 0.1 second for light to travel. TCP 3 way handshake itself already take 0.15 second.

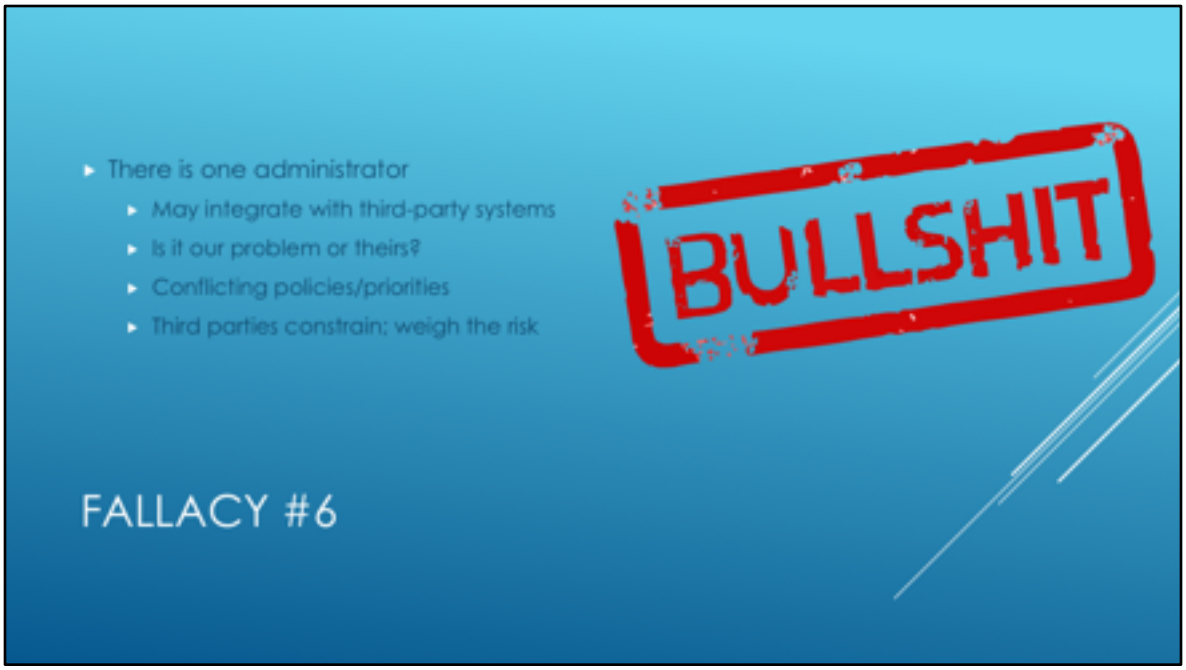
What we can do?
Minimize network calls
Design asynchronous systems that do not block. But remember, latency doesn't go away, these can only improve overall throughput not making a single request perform beyond limits.

What we can do?
Limit message size, more compact protocol, e.g. binary protocol instead of text based. Compression. Design protocol to help compression algorithm.
Use message queueing, decouple producer and consumer, so burst traffic doesn't blow the whole system off.

Security precaution at every layer

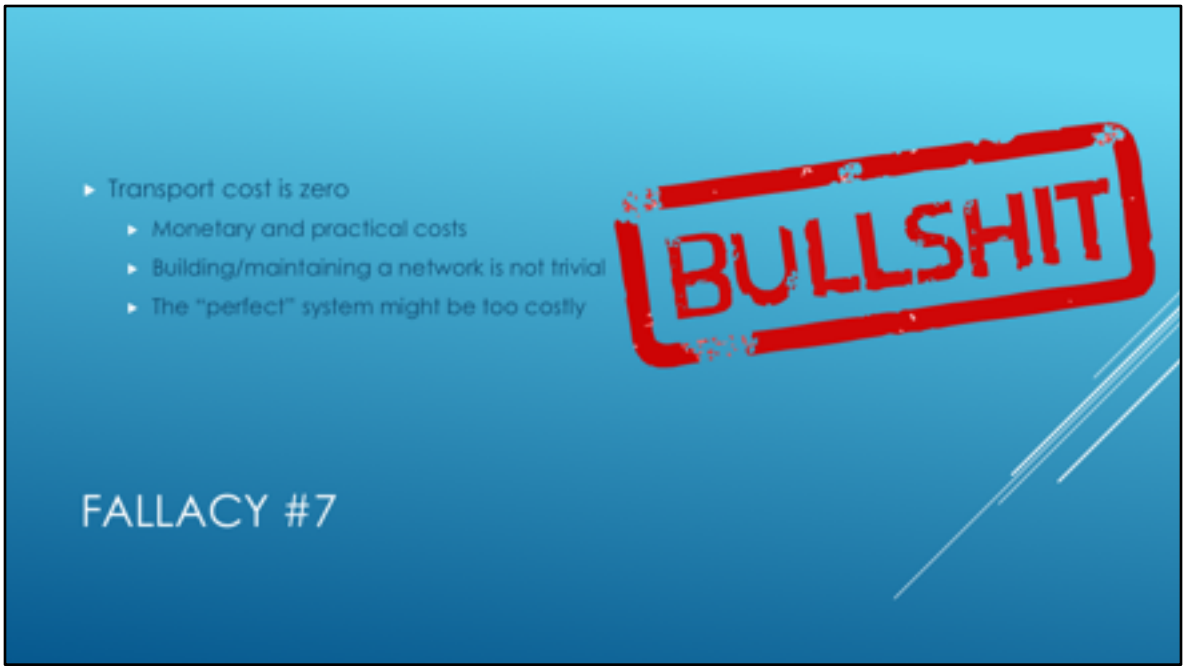
1. IPSec at IP layer
2. SSL at transportation layer
3. Multifactor authentication
4. Single sign-on
5. Fraud detection
6. Transaction signing and encryption

Packets of a single TCP connection might go through completely different route to get you. TCP stack does the heavy lifting for you.
People who have developed udp, mcast which under the hood is also udp, applications know.



One administrator knows everything

Never true



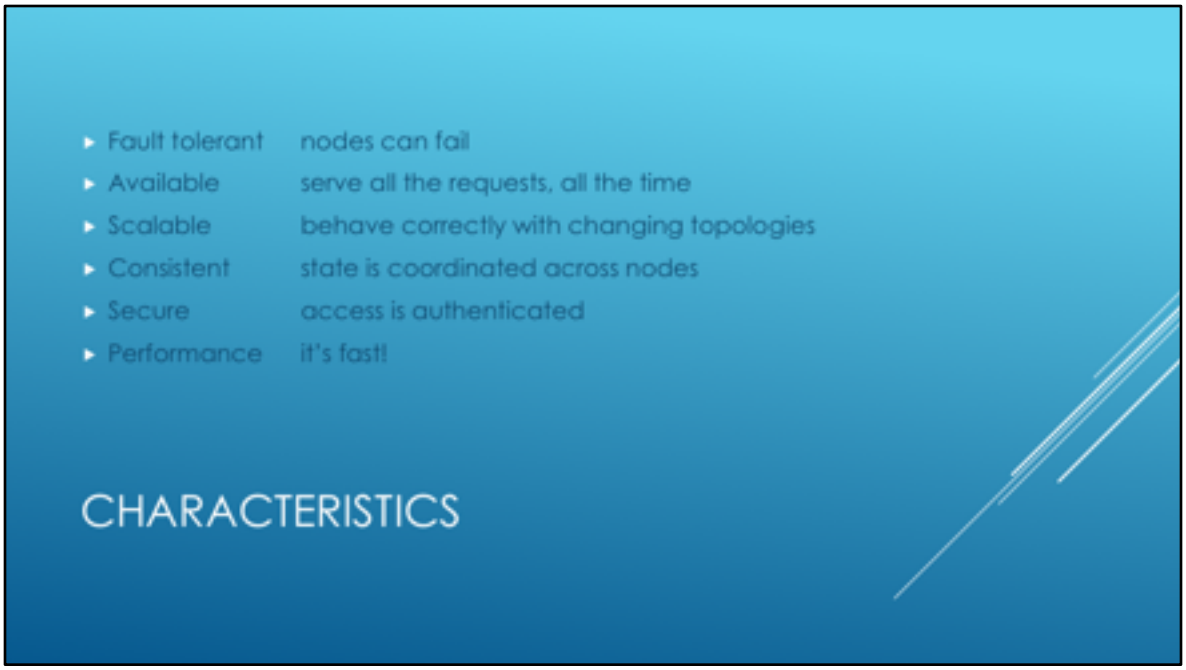
No one is rich --- enough --- to ignore the cost.

Remember starcraft back to college? It uses IPX/SPX.
Heard of infiniband? It infiniband! Though you can still use TCP over it, performance wise sucks. Like driving Maserati on sideway

Application layers? Chaos!


These problems apply to LAN and WAN systems
(Single data center and cross data center)
No one is safe.


"Anything that can go wrong **will go wrong**"
- Murphy's law



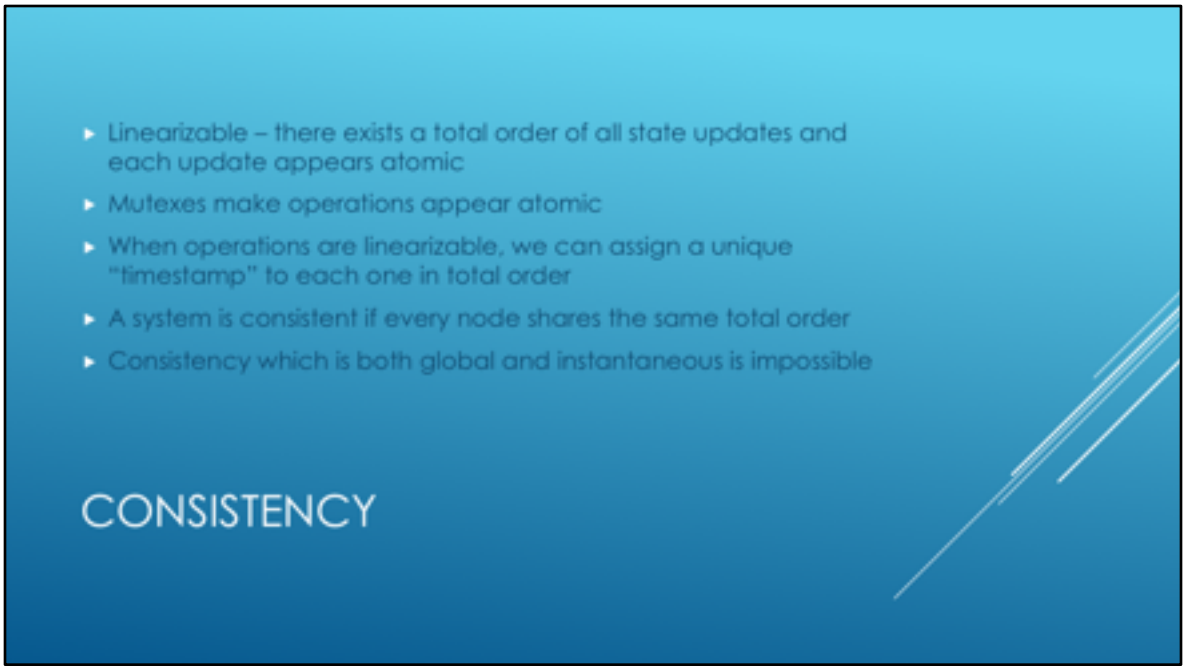
Why fault tolerant? nodes can fail
Why available? We want to serve all the requests, all the time
Why scalable? We want system behave correctly with changing topologies
Why consistent? We what the state to be coordinated across nodes
Why secure? We want every access to be authenticated
Why performance? We like fast

Hunting for buzzwords

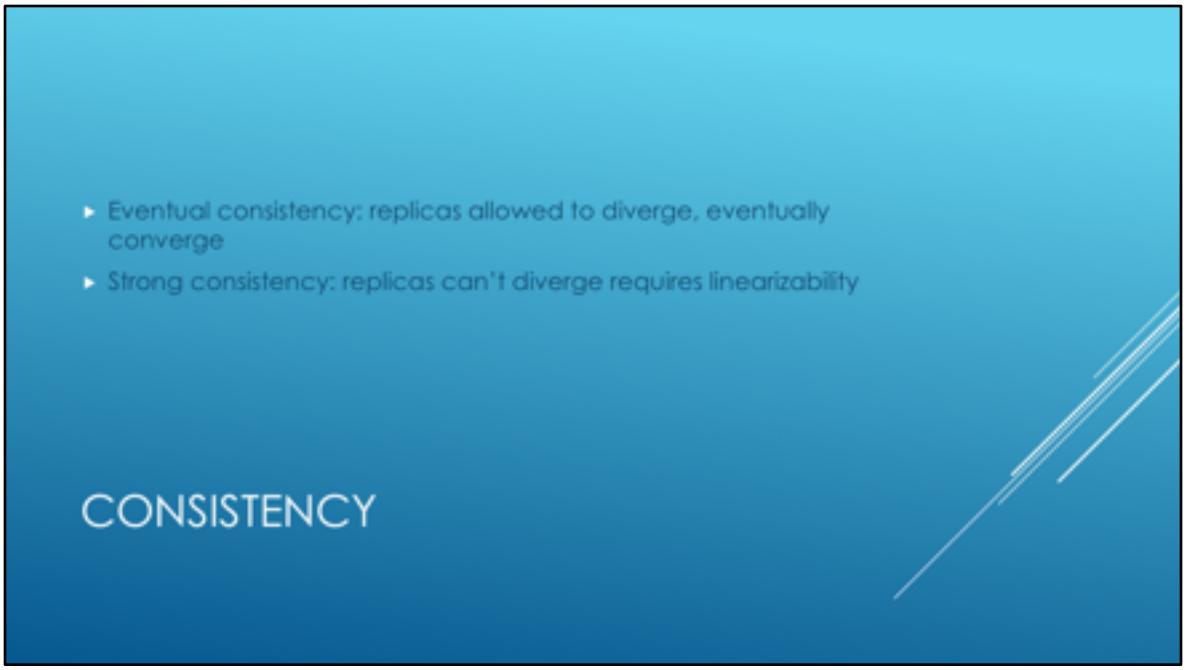
Before we start, please remember, tradeoff, tradeoff and tradeoff

CAP THEOREM

- Presented in 1998 by Eric Brewer
- Impossible to guarantee all the three:
  - Consistency
  - Availability
  - Partition tolerance



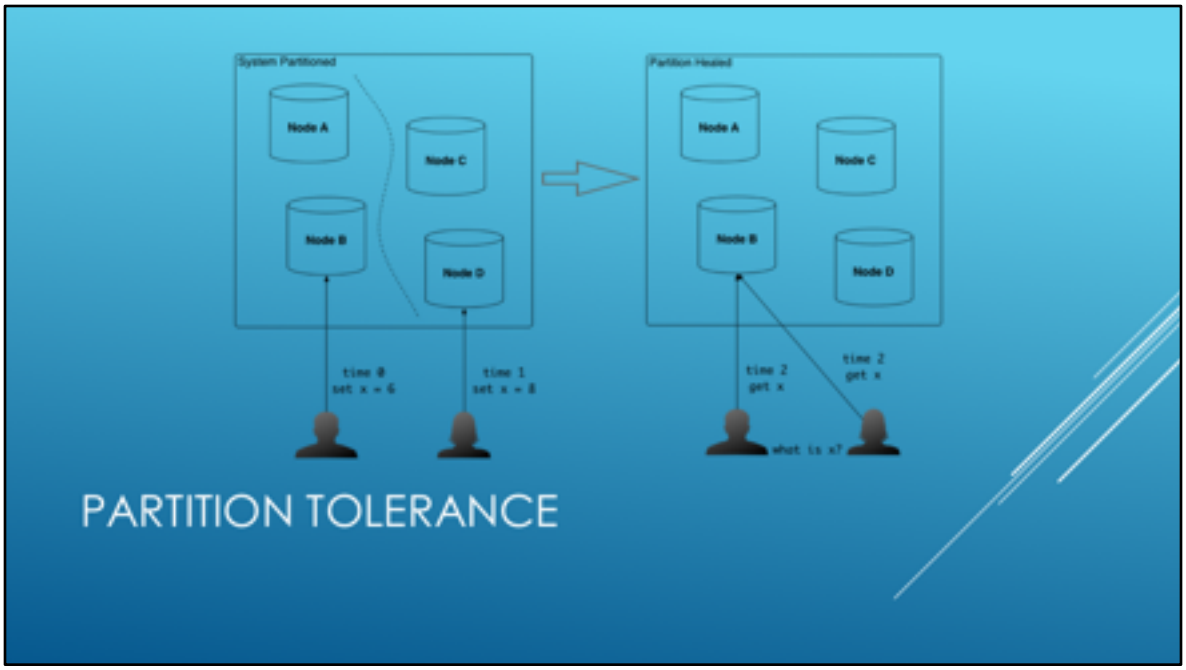
Way to consistency.
The truth is, instantaneous global consistency is impossible. Write takes time



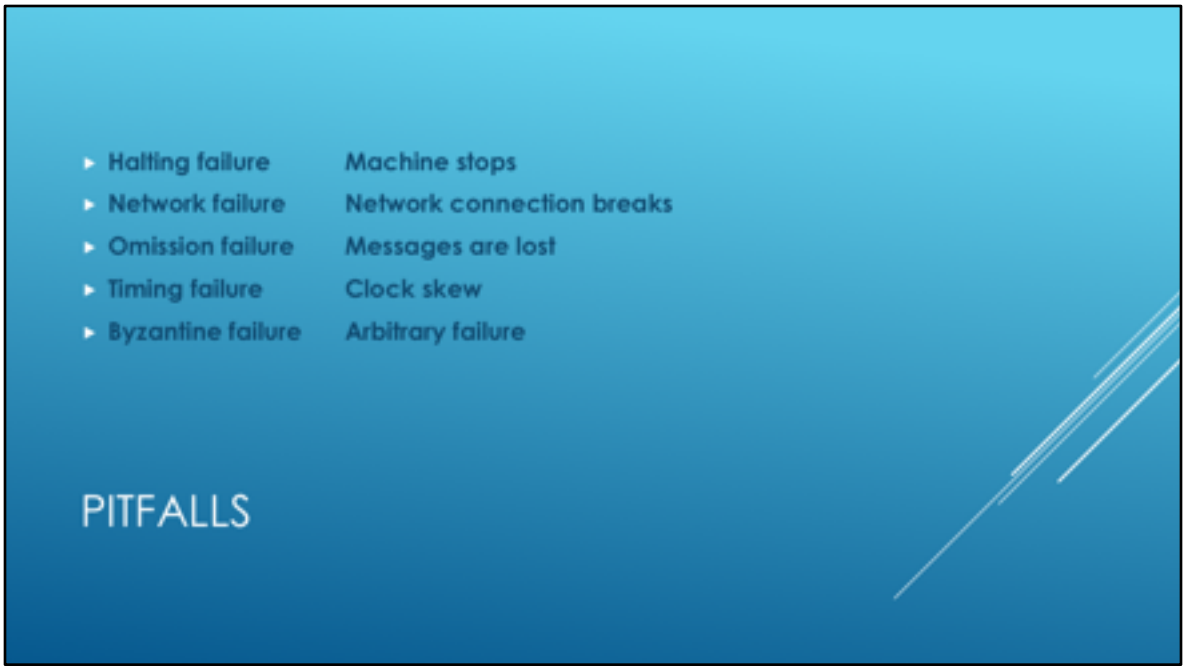
So what we can get.
Eventual consistency, replicas of an object could diverge at some point, but converge eventually is going to happen. Dynamo is an example.
Strong consistency, replicas can't diverge if linearizability is guaranteed. Distributed Transaction is one example.

Basically, serve every single request

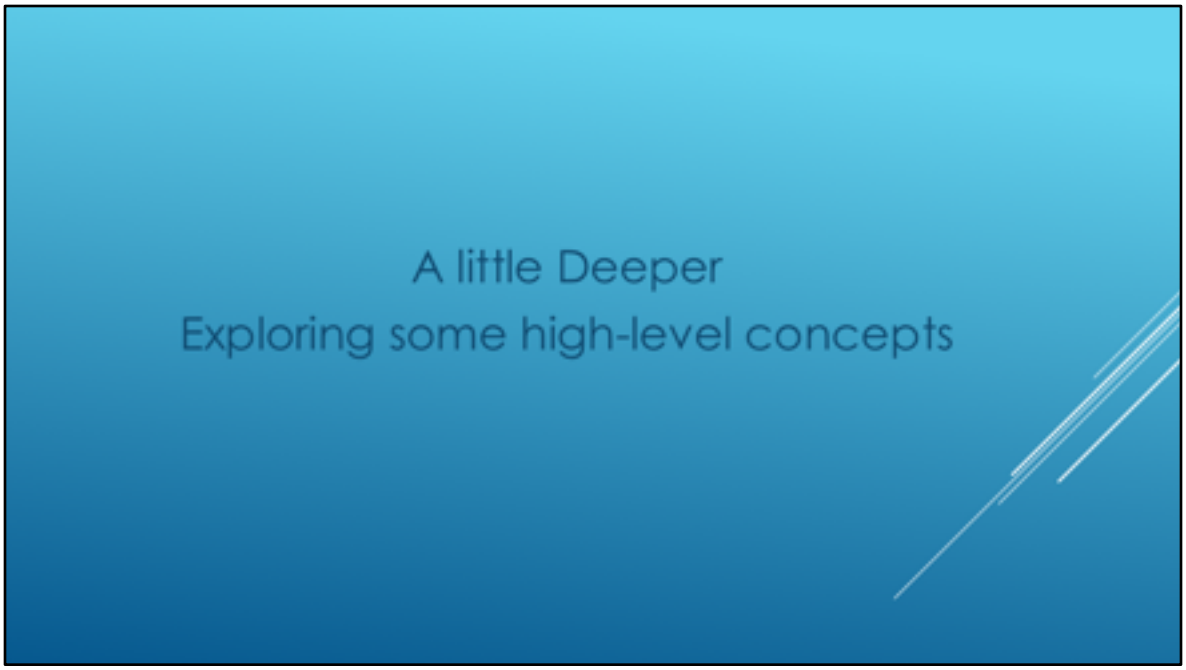
CAP is only possible when your are in dream so your network is 100% reliable.



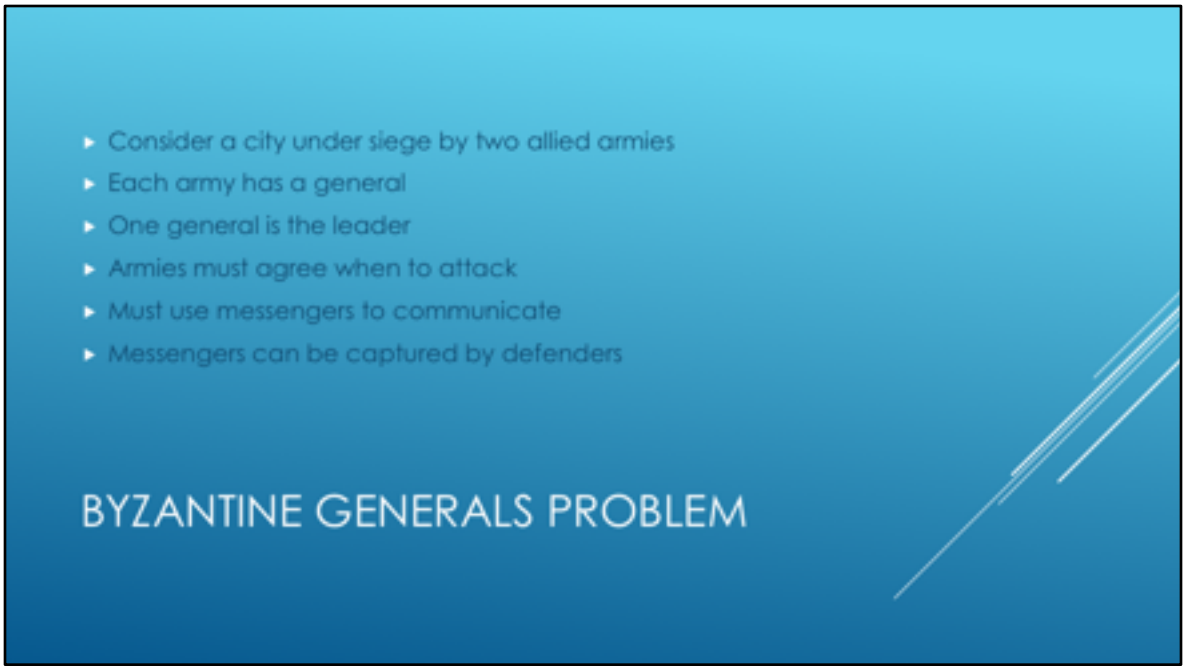
What will happen if we choose to sacrifice consistency and choose to continue serve requests when partition happens.



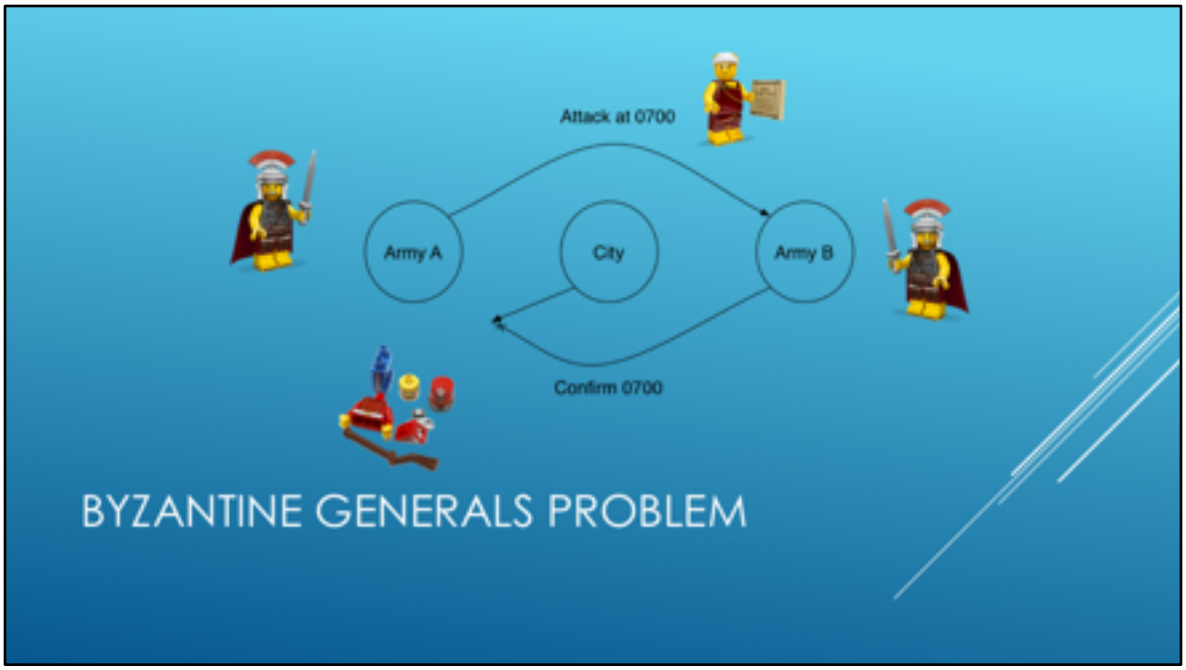
Literally every single thing you could ever imagine and be afraid of, will happen.
Machine could stop running cause service to halt
Network could break cause service to be unreachable.
Messages could get lost
Time skew could make timeout based failure detection shaky
Arbitrary failure, yes, it's called byzantine failure



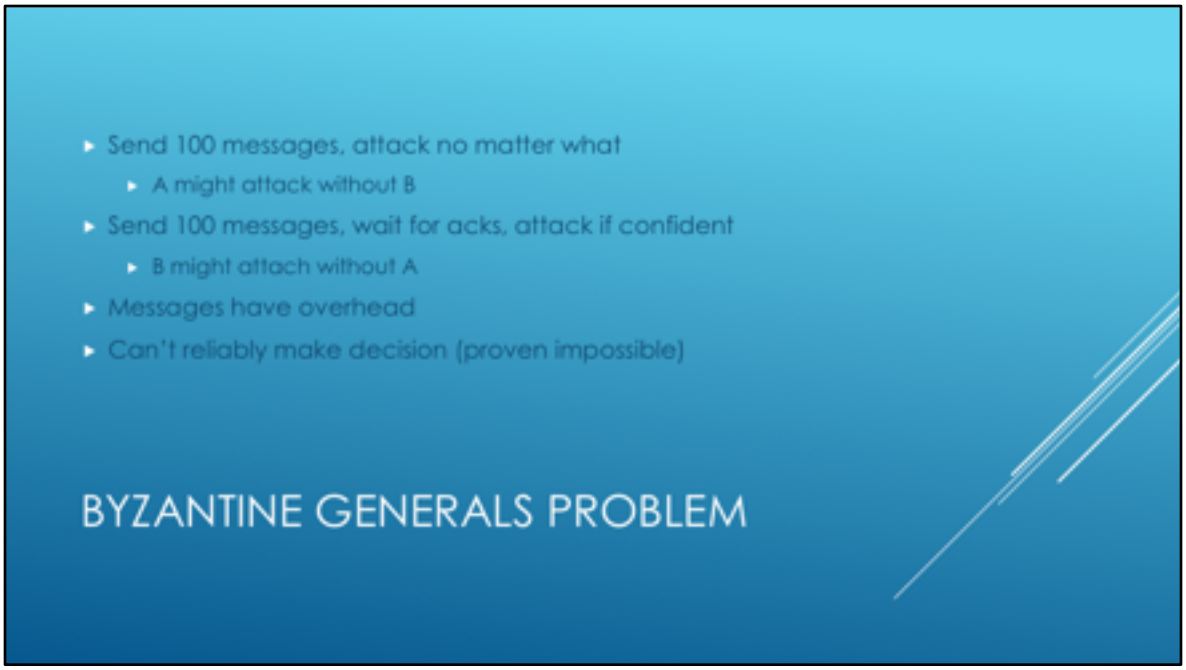
Wow, concepts.



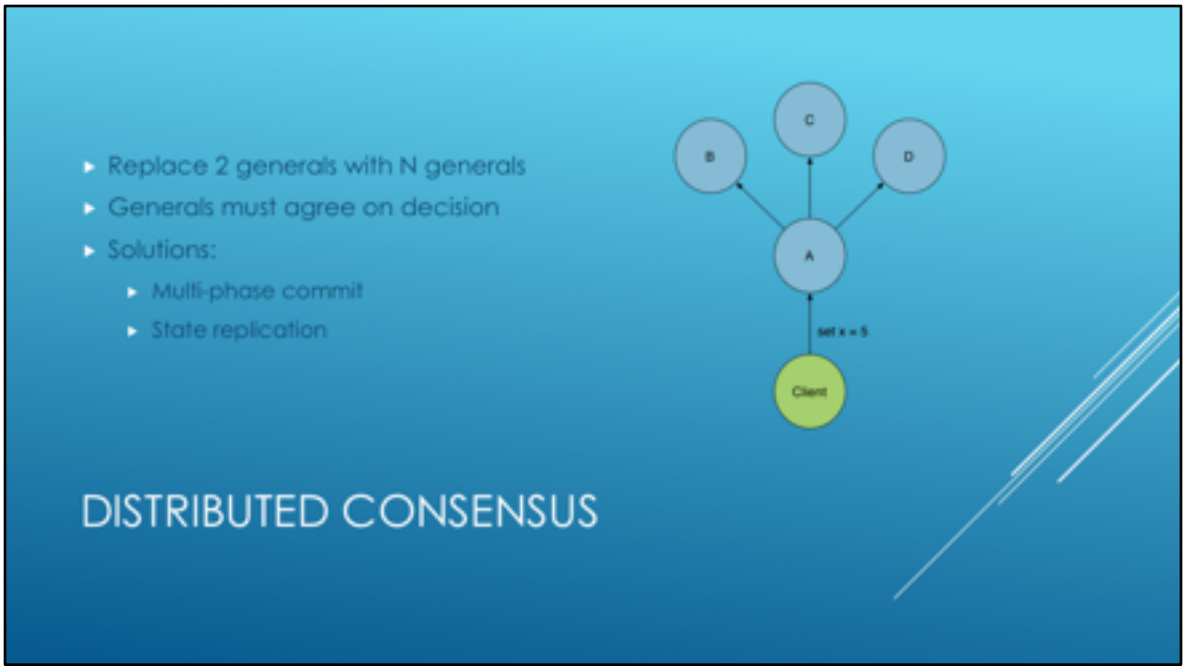
Let's have a day dream



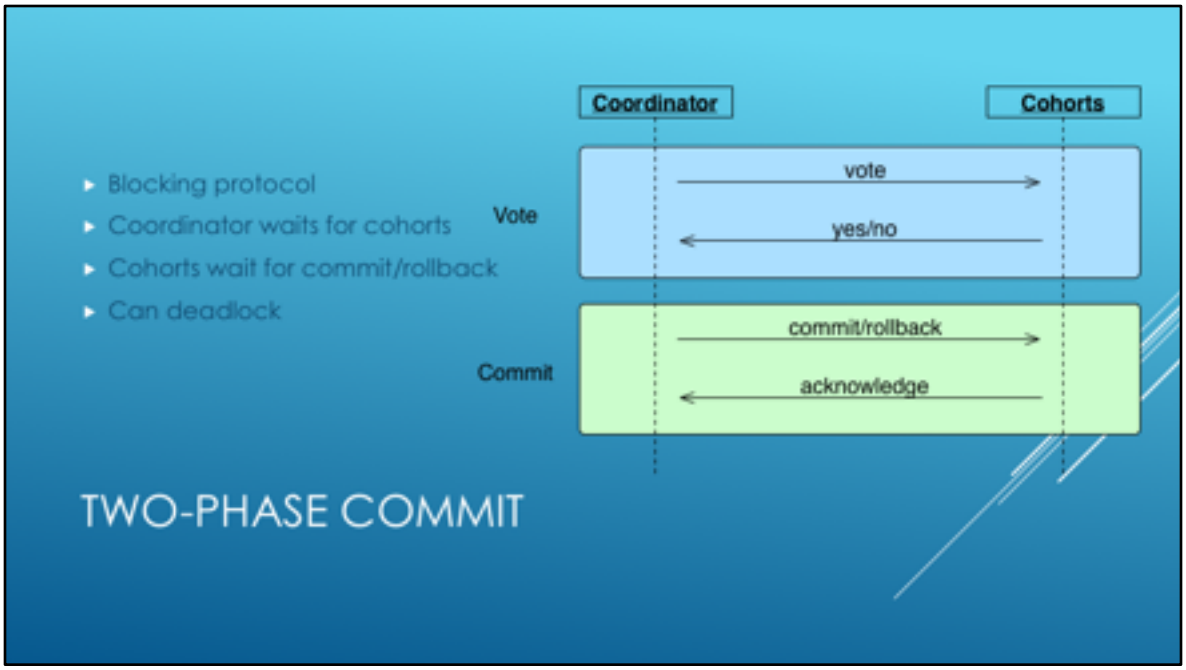
So what can we do


Send 100 messages, attack no matter what
A might attack without B
Send 100 messages, wait for acks, attack if confident
B might attach without A
Messages have overhead
Can't reliably make decision (proven impossible)
BYZANTINE GENERALS PROBLEM

Not so much

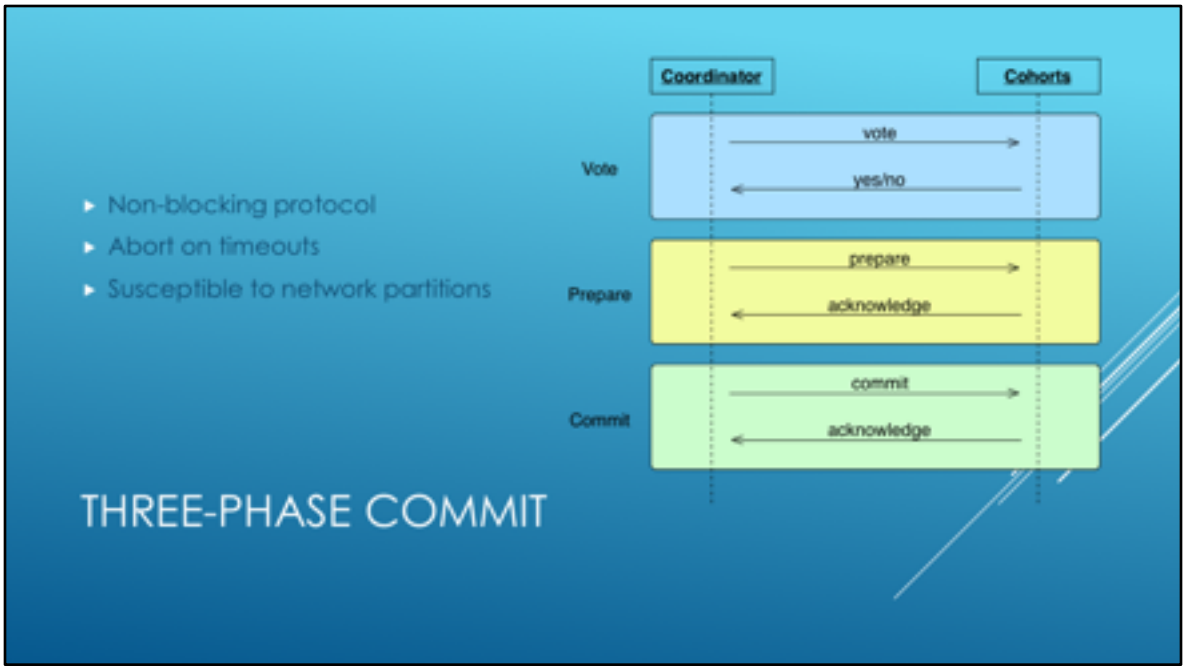


Technology perspective



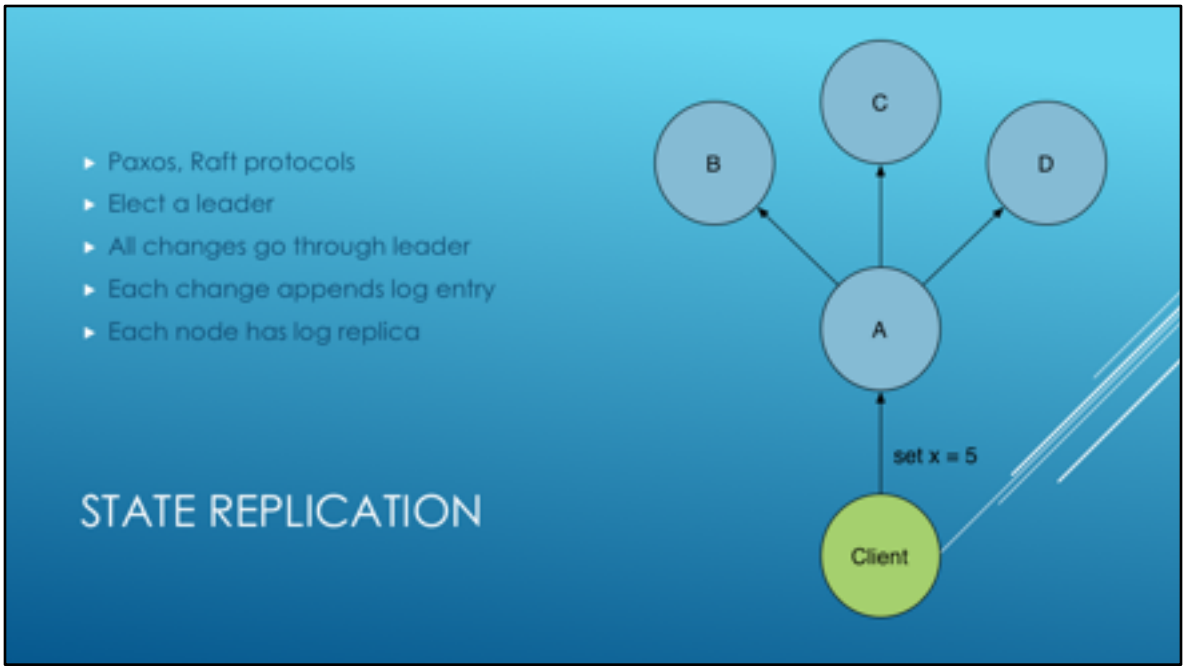
If coordinator dies in middle, cohorts wait.
Any cohort dies, coordinator waits forever.

In the case ack loses, the state of the particular cohort is in doubt. Cohorts or coordinator keep sending recover messages to each other



Vote state: timeout causes abort
Prepare state: timeout causes state changing to commit on cohorts side as everyone would have made the commitment in vote state
Commit state: coordinator timeout lead to cohorts commit, cohorts timeout result in doubtable transaction and requires recovery protocol to clear the state

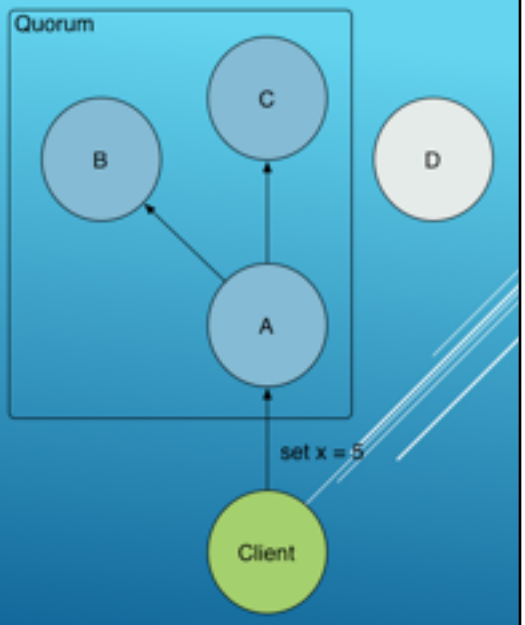
There is a enhanced three phase commit that can survive from network partitions or quorum lost

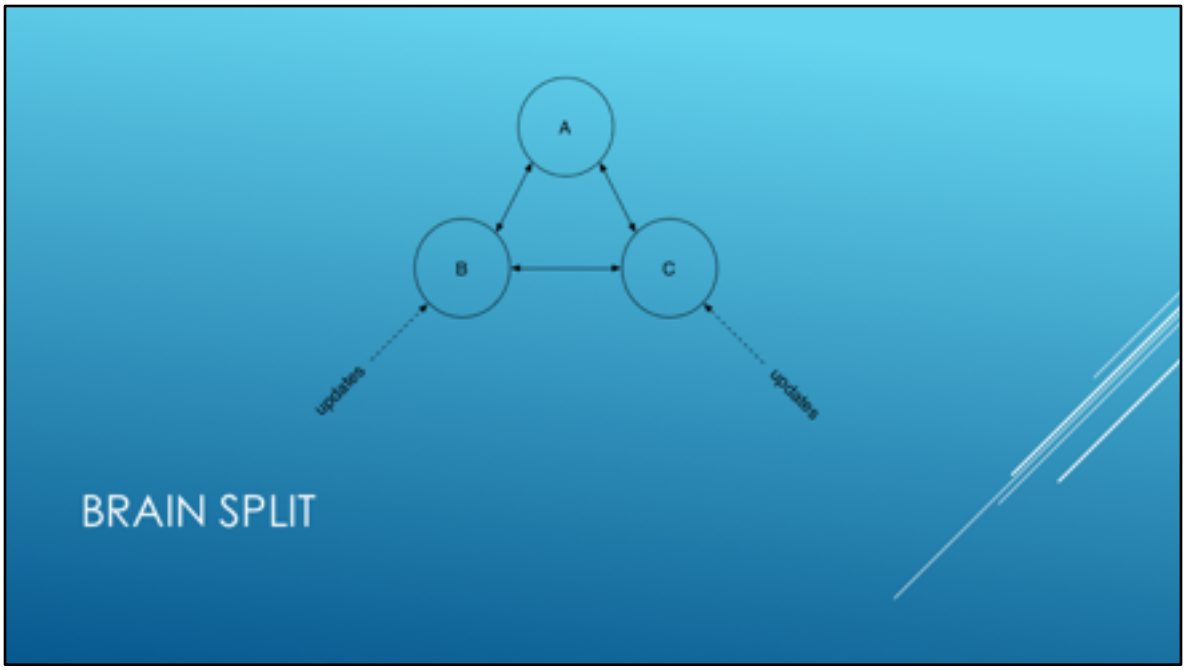


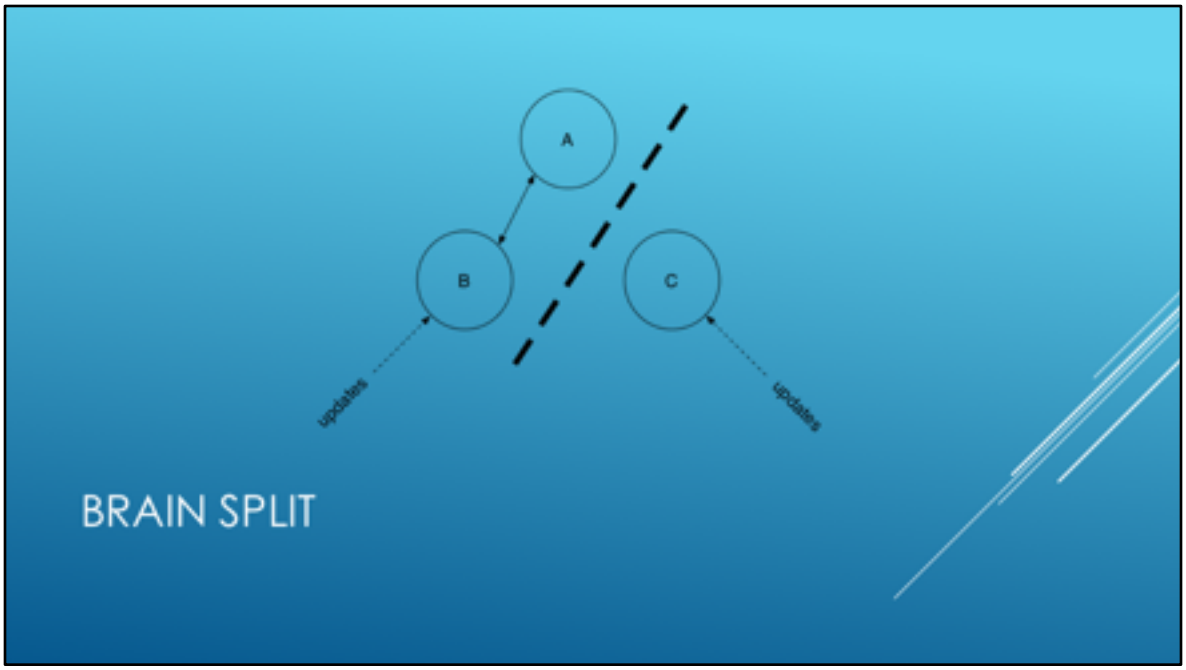
Yes, there are more.

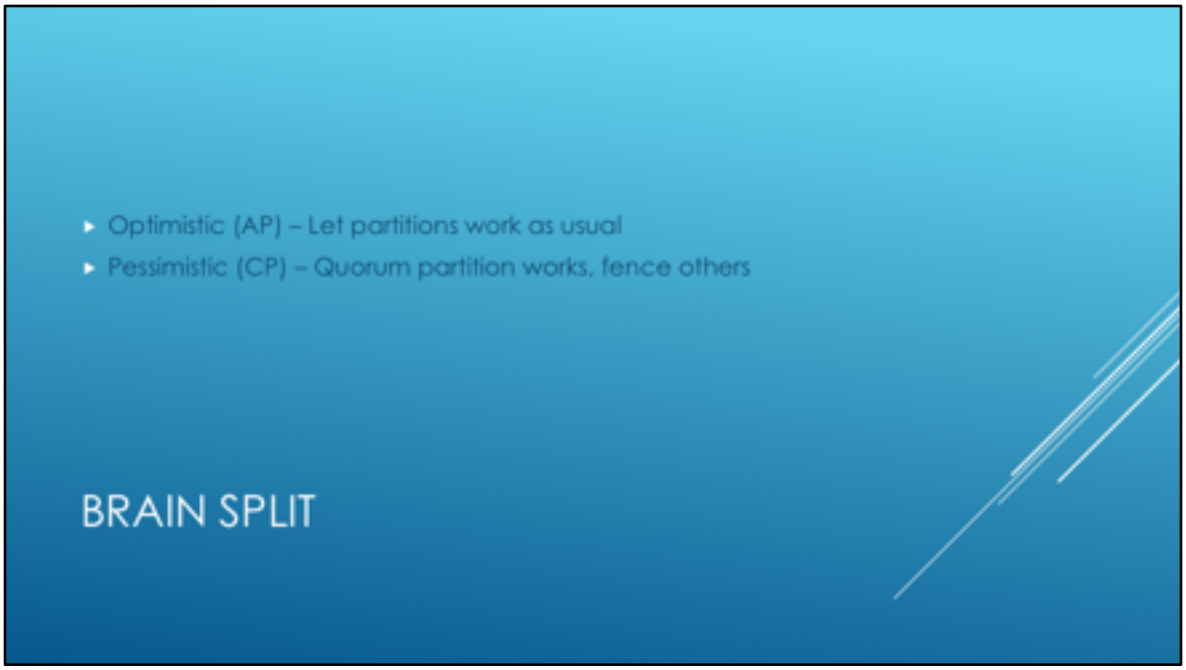
STATE REPLICATION

- Must have quorum to proceed
- Commit once quorum acks
- Quorums mitigate partitions
- Logs allow state to be rebuilt

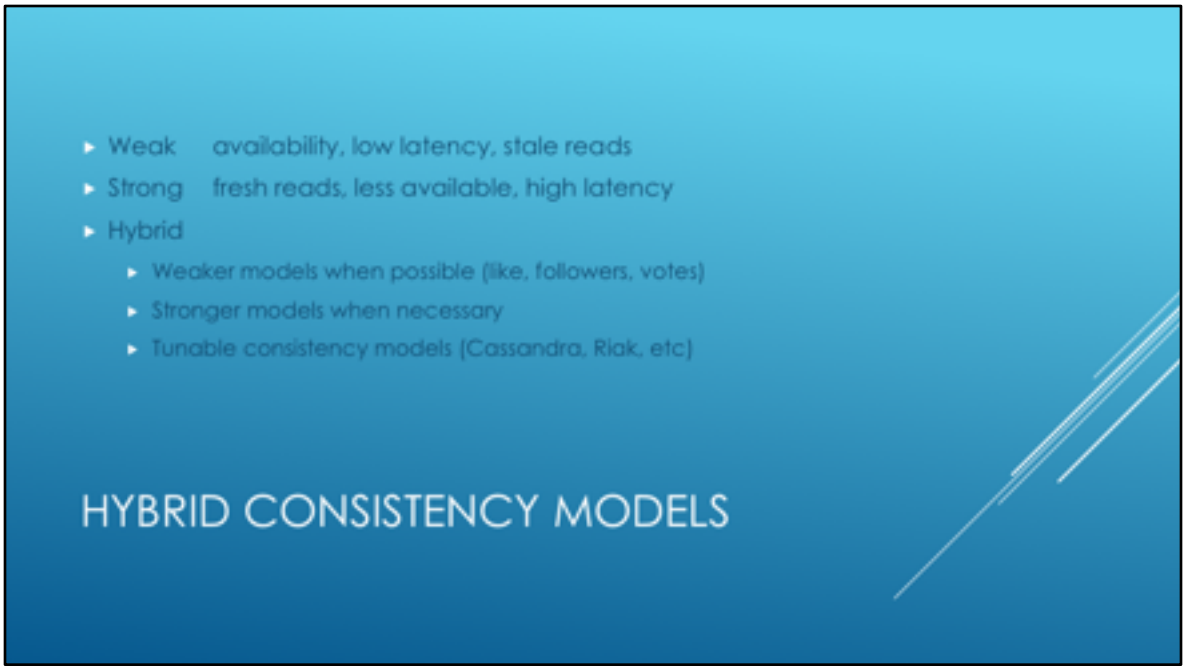



A
B
C
updates
updates
BRAIN SPLIT


A
B
C
updates
updates
BRAIN SPLIT



Tradeoff, tradeoff, tradeoff
Remember CAP theorem
Choose Availability + Partition Tolerance yields inconsistency
Choose Consistency + Partition Tolerance renders system unavailable for certain cases depends on reliability requirement.

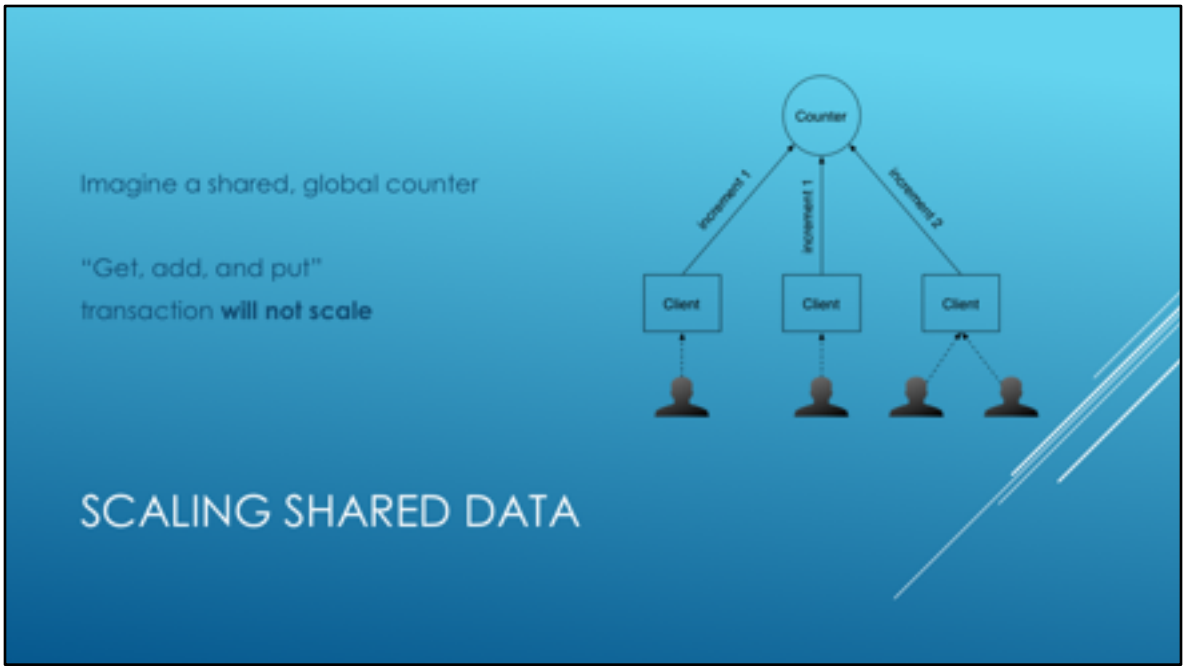


Consistency Models:
Weak means better availability because you don't need to wait at least two or quorum to reply, but you could read old version of data
Strong requires at least quorum number of reads which means at least two for three replicas system. More roundtrips means higher latency, also means there must be at least quorum available replicas.

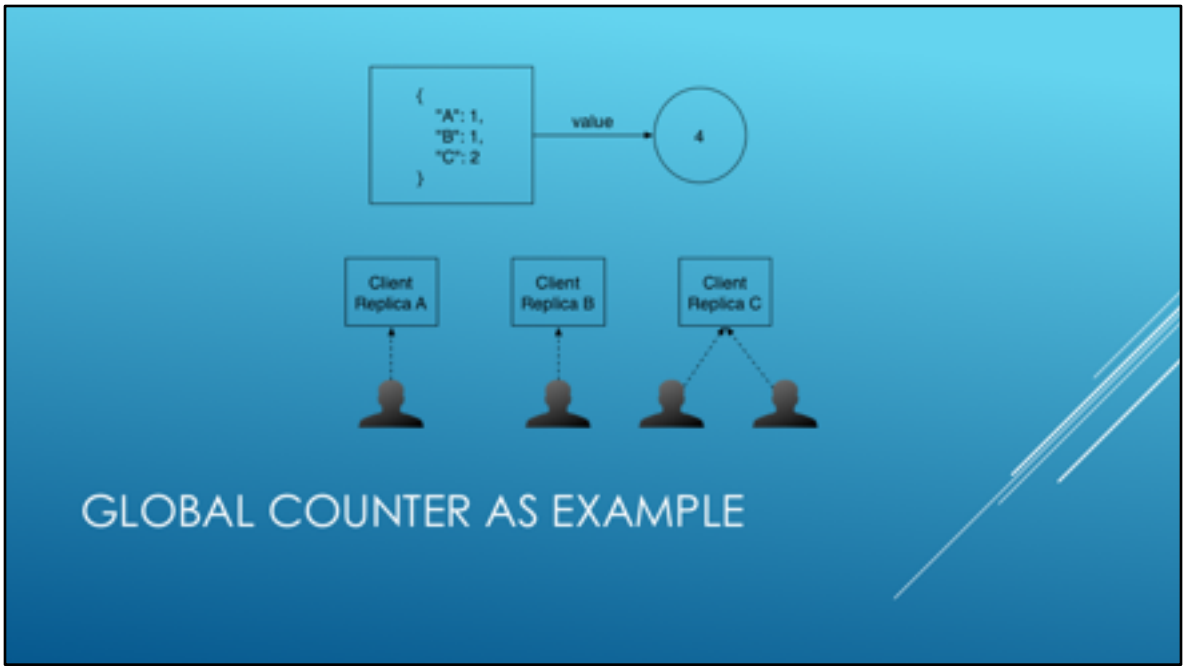
Of cause, tradeoffs exist.

SCALING SHARED DATA

- Sharing **mutable data** at large scale is difficult
- Solutions
  - Immutable data
  - Last write wins
  - Application level conflict resolution
  - Causal ordering (e.g. vector clocks)
  - Distributed data types (CRDTs)



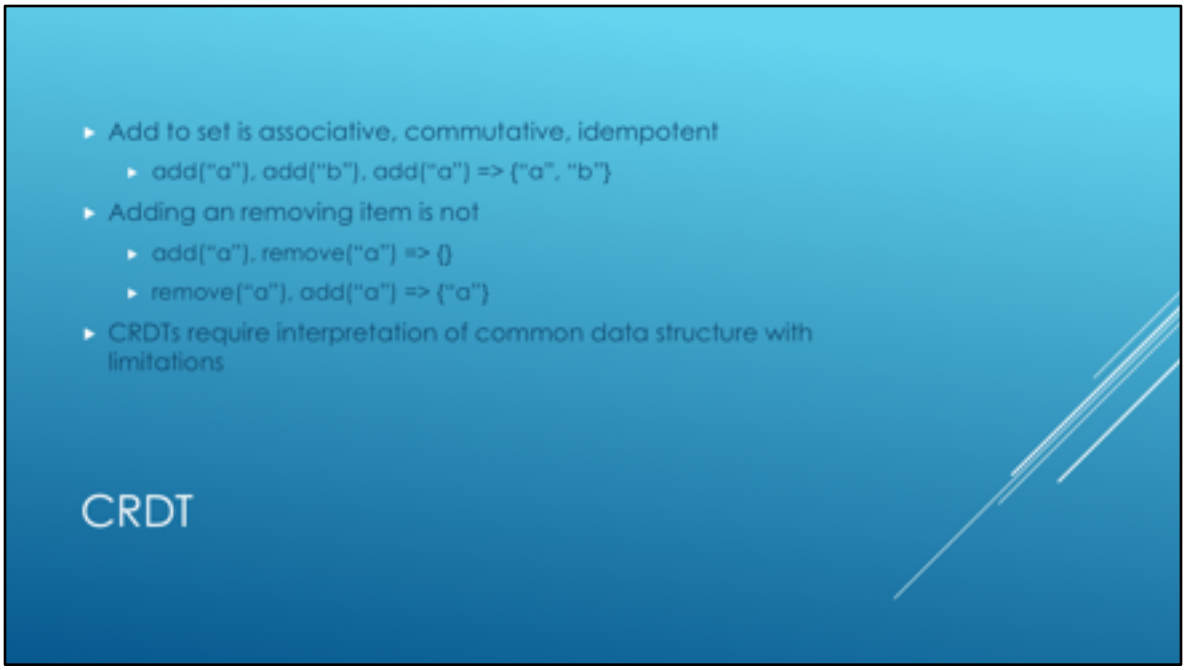
Mutex required



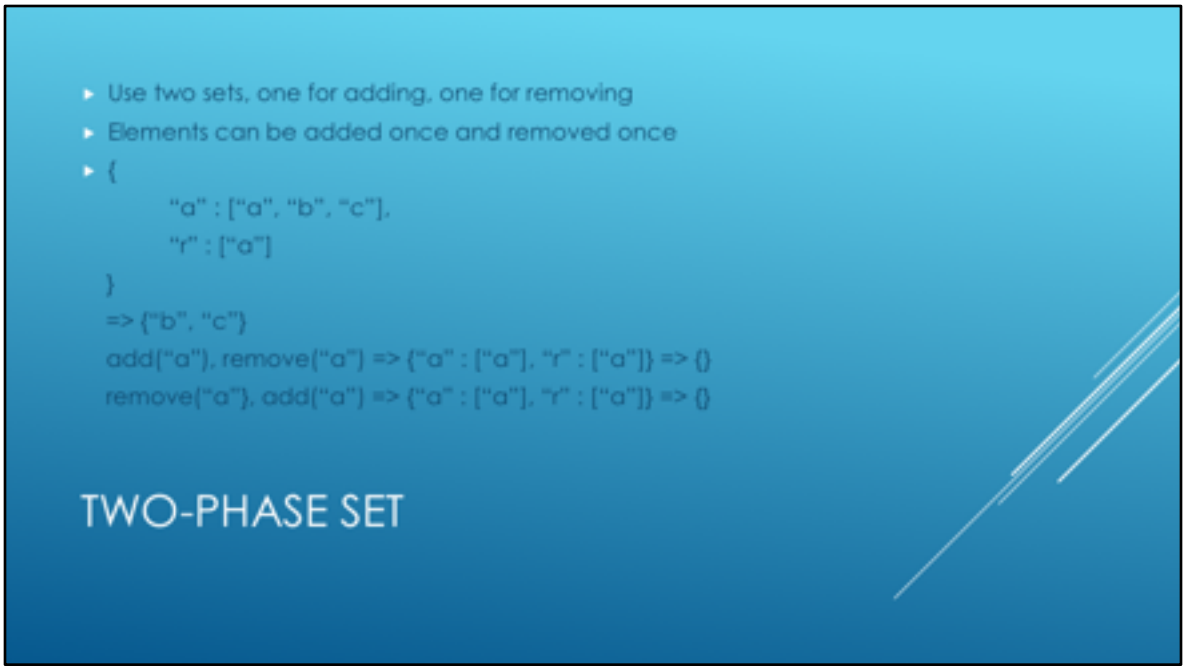
Set of operations being applied on the counter sequentially.

Required properties: Convergence, commutation


CRDTs always converge (provably)
Operations commute
Highly available, eventually consistent
Always reach consistent state
Requires knowledge of all clients
Must be associative, commutative, and idempotent
CRDT



Why regular set as it is, is not conflict free in replicated environment.



Make it CRDT. Remember, it has limitation, not regular set in our mind.


Fancy world
Looks a lot like heaven,
tastes much like hell


Object store
Amazon Dynamo
Riak
File system
Google GFS
HDFS
Structured store
Google BigTable
Hbase
Block store
Amazon EBS
Ceph
A LOT OF STORES
WHERE A LOT MEANS A LOT MORE

DYNAMO

- Bring to public at SOSP 2007
- Always writable at first place, can be tuned by N/W/R
- Decentralized
- Data partitioned using consistent hashing
- Flat namespace

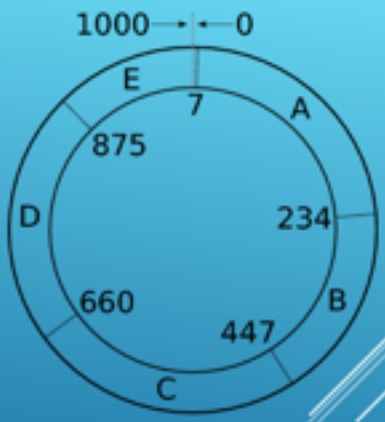
CONSISTENT HASHING

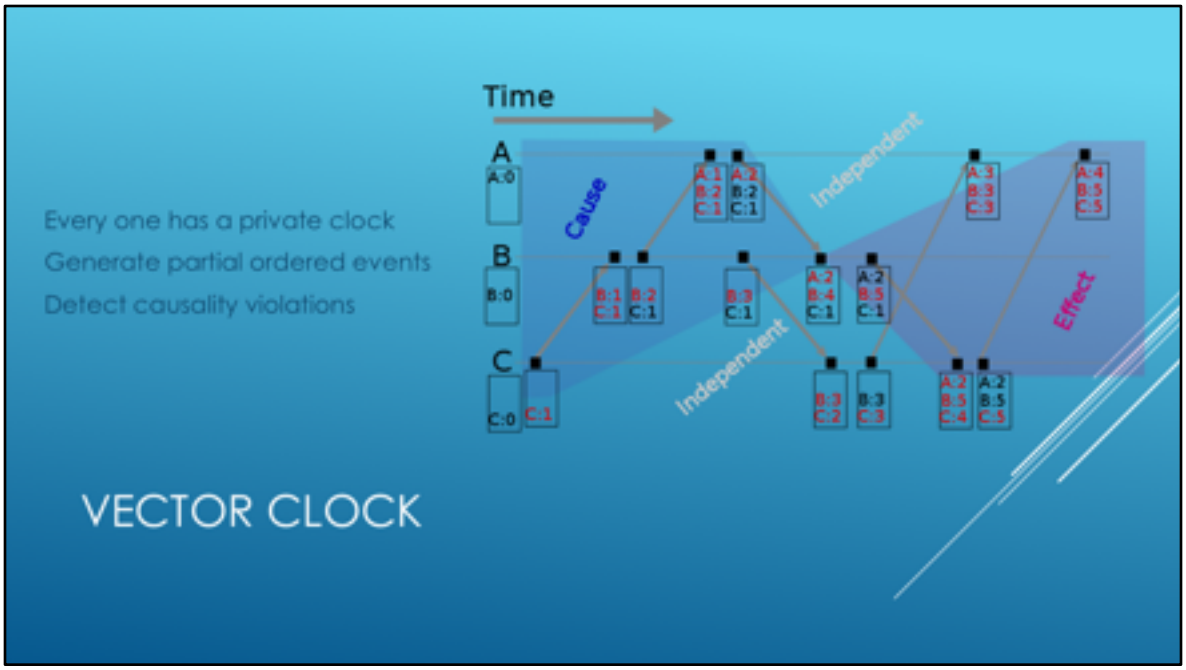
Resize of hash table causes K/N keys to be relocated on average.

K: size of key space

N: number of partitions

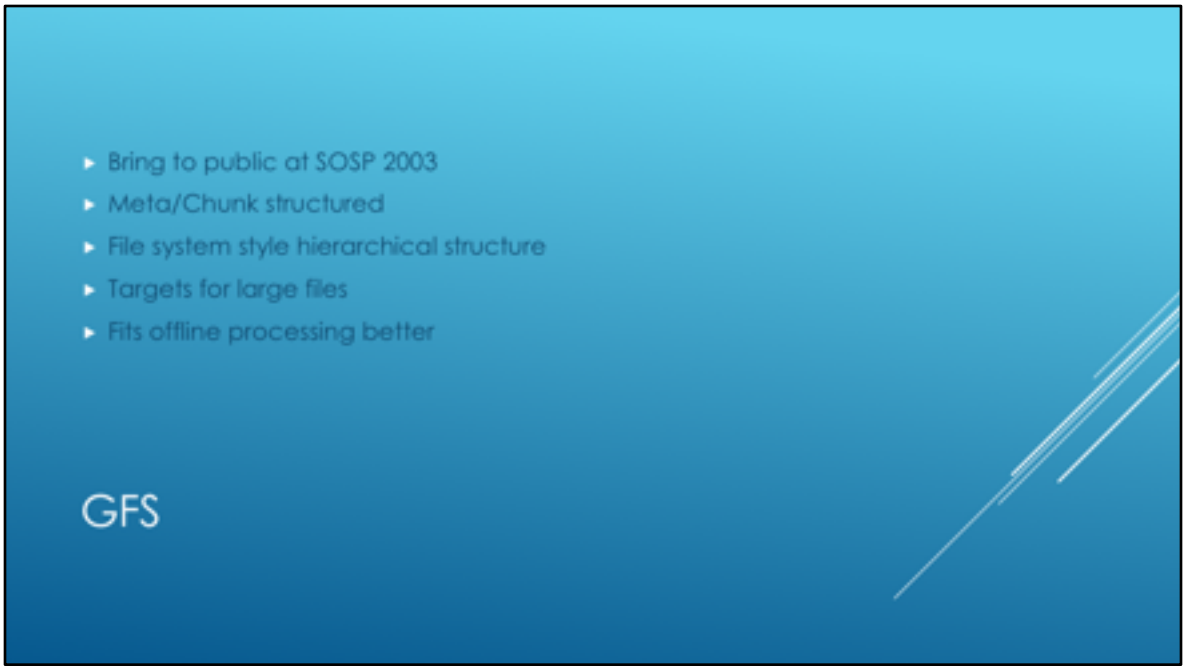
key' = F(key)

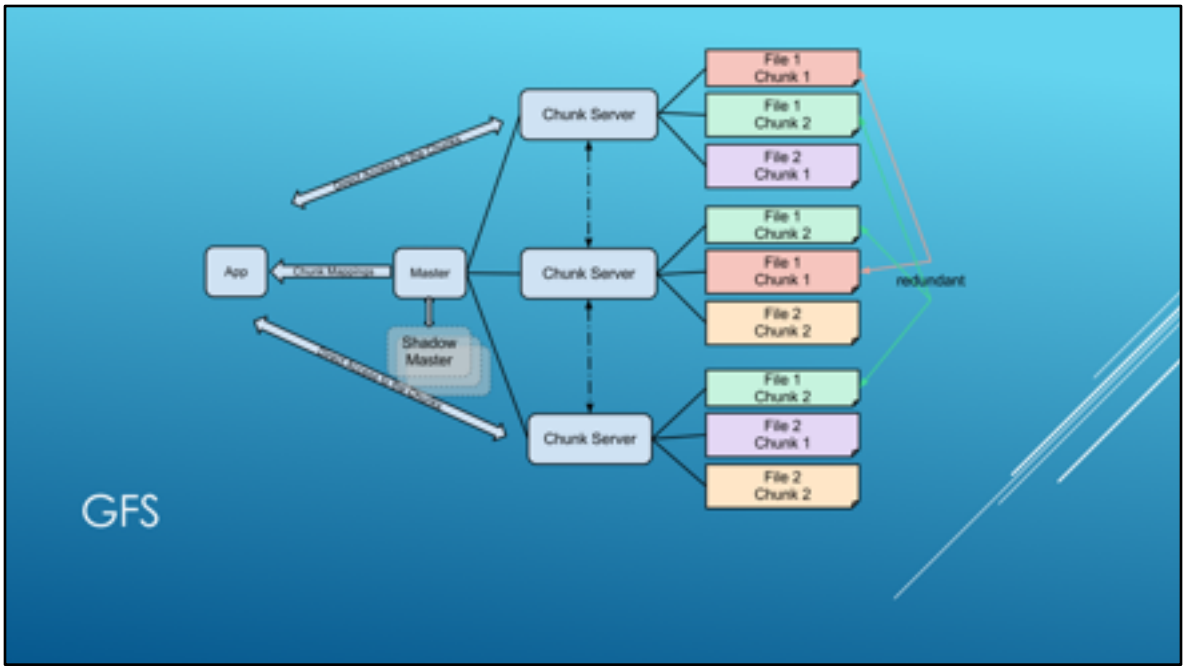




e.g.

Event 1->{B:1, C:1} is older than event 2->{A:2, B:5, C:1} because for each process in {A, B, C}.
A:0 < A:2
B:1 < B:5
C:1 <= C:1

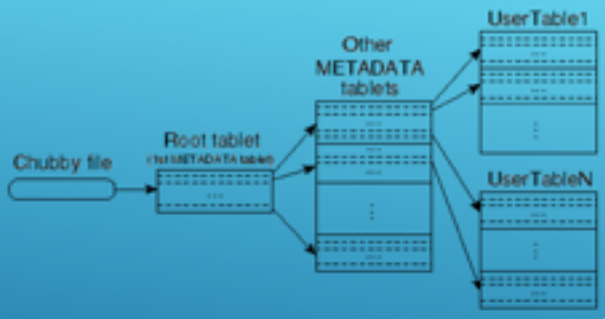

Bring to public at SOSP 2003
Meta/Chunk structured
File system style hierarchical structure
Targets for large files
Fits offline processing better
GFS

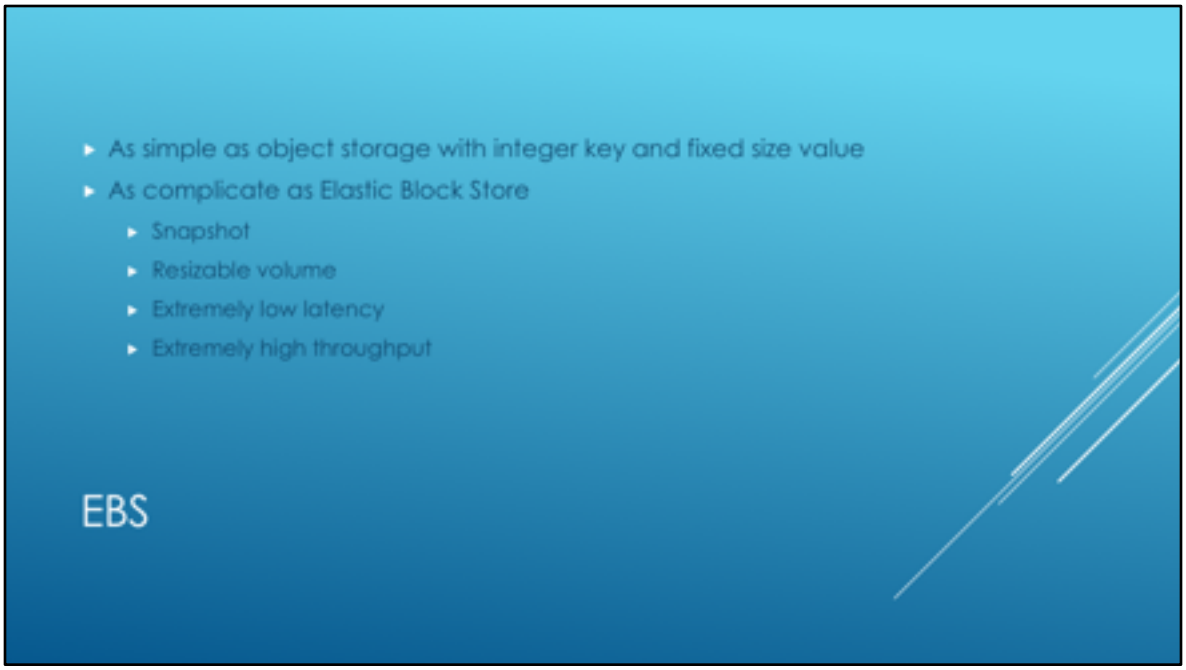

GFS
App
Master
Shadow Master
Chunk Server
Chunk Server
Chunk Server
File 1 Chunk 1
File 1 Chunk 2
File 2 Chunk 1
File 1 Chunk 2
File 1 Chunk 1
File 2 Chunk 2
File 1 Chunk 2
File 2 Chunk 1
File 2 Chunk 2
redundant


Bring to public at OSDI 2006
Structured but schema free
Serves both throughput oriented and latency sensitive tasks well
BIGTABLE

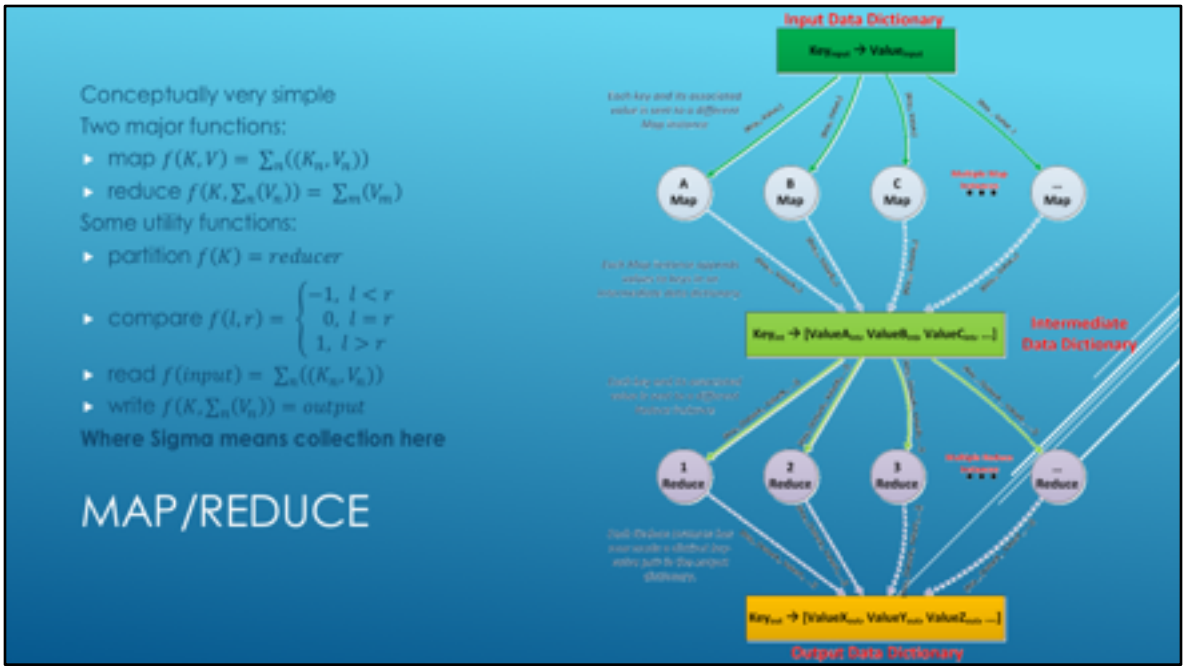
BIGTABLE

- Layered on top of chubby, GFS
- Memtables and SSTables as storage engine

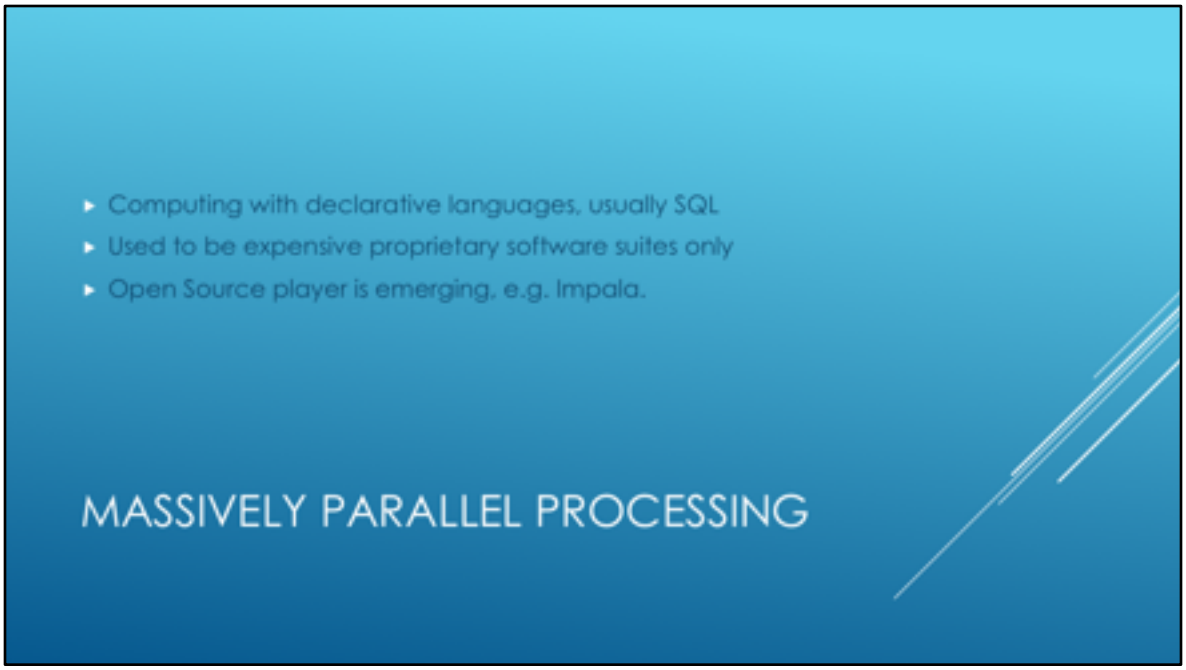



As simple as object storage with integer key and fixed size value
As complicate as Elastic Block Store
Snapshot
Resizable volume
Extremely low latency
Extremely high throughput
EBS

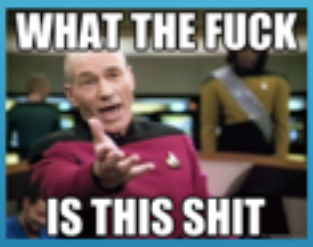

Map Reduce
MPP
Of course, there are more. Different models, different implementations and different tradeoffs.
IT'S ALL ABOUT COMPUTING



Attention: Where sigma doesn't mean sigma as it is in mathematic. It means collection here.

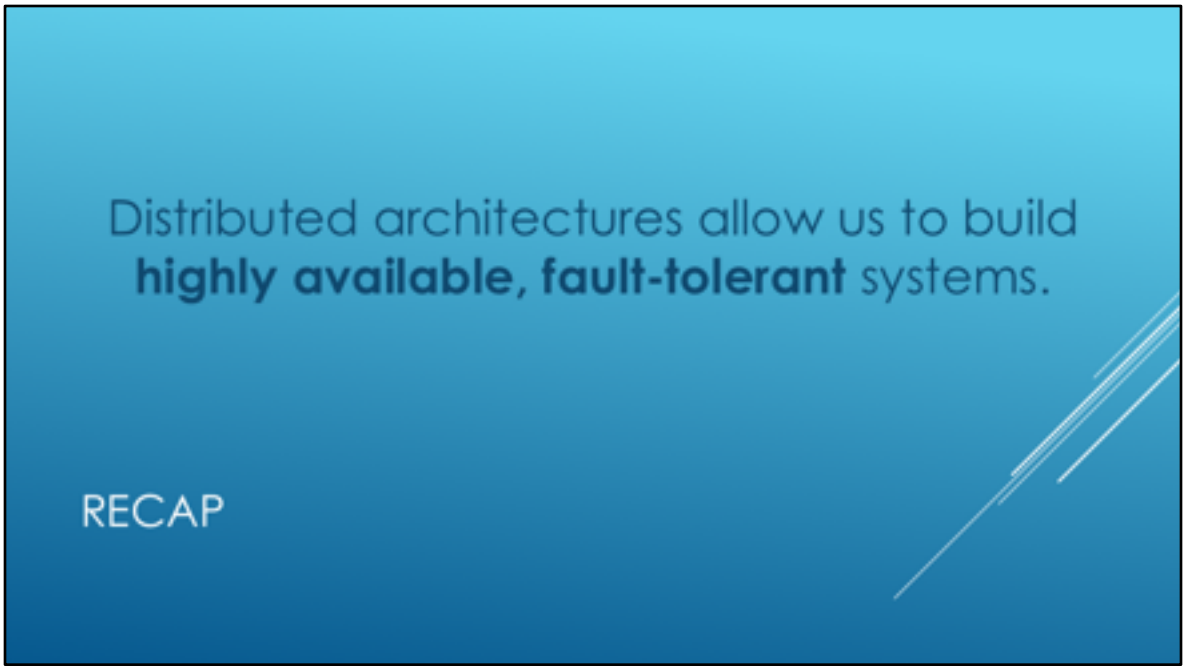

Computing with declarative languages, usually SQL
Used to be expensive proprietary software suites only
Open Source player is emerging, e.g. Impala.
MASSIVELY PARALLEL PROCESSING

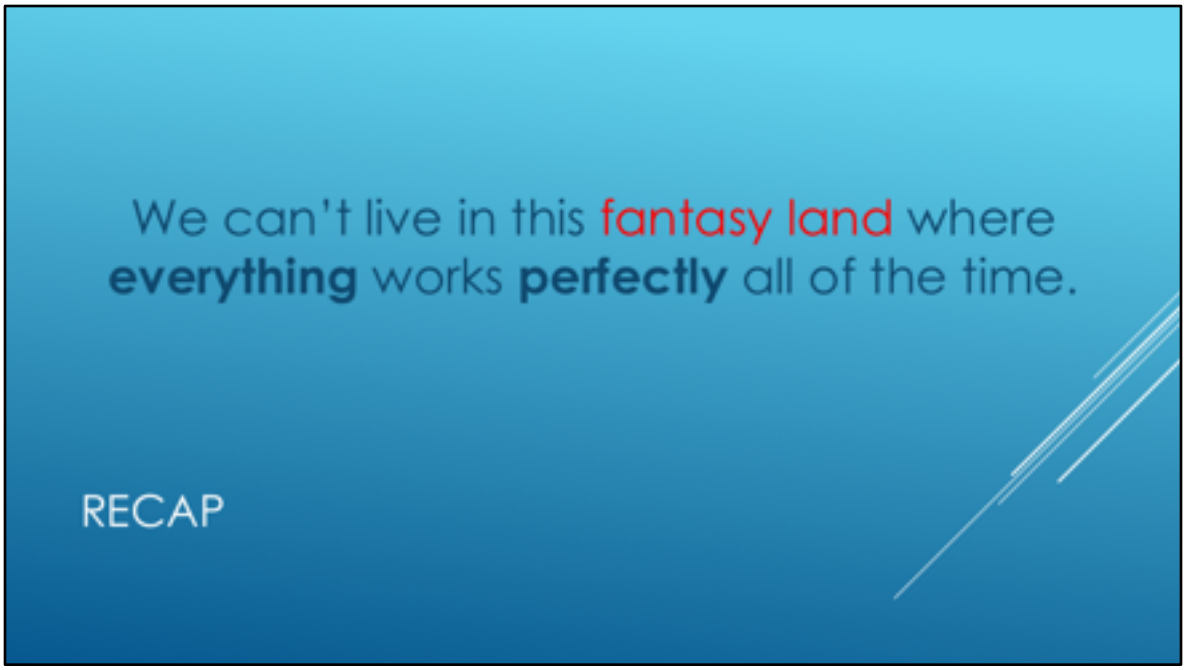
- Everything sounds beautiful, looks terrific, smells like teen spirit
- However, tastes bitter than bitter
- Deemed life long journey

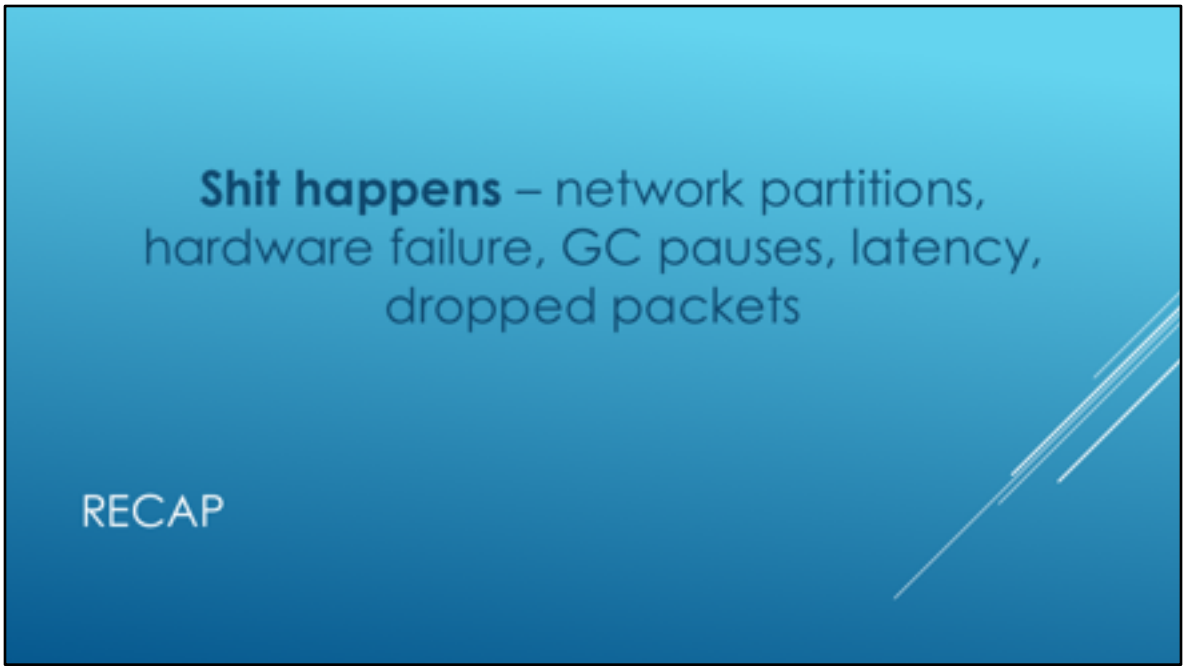


A JOURNEY FOREVER

CONFIDENTIAL


Distributed architectures allow us to build
highly available, fault-tolerant systems.
RECAP


We can't live in this fantasy land where
everything works perfectly all of the time.
RECAP

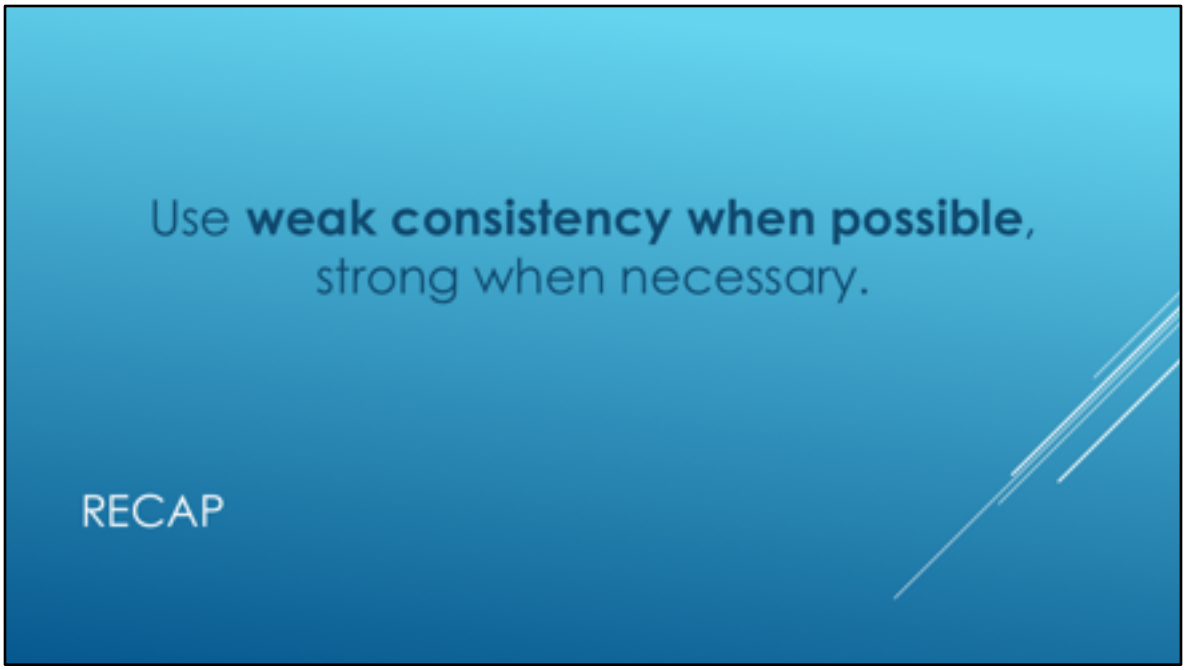

Shit happens – network partitions, hardware failure, GC pauses, latency, dropped packets
RECAP


Build **resilient** systems.
RECAP


Design for failure.
RECAP


Consider the trade-off between
consistency and availability.
RECAP


Partition tolerance is not an option, it's required.
RECAP

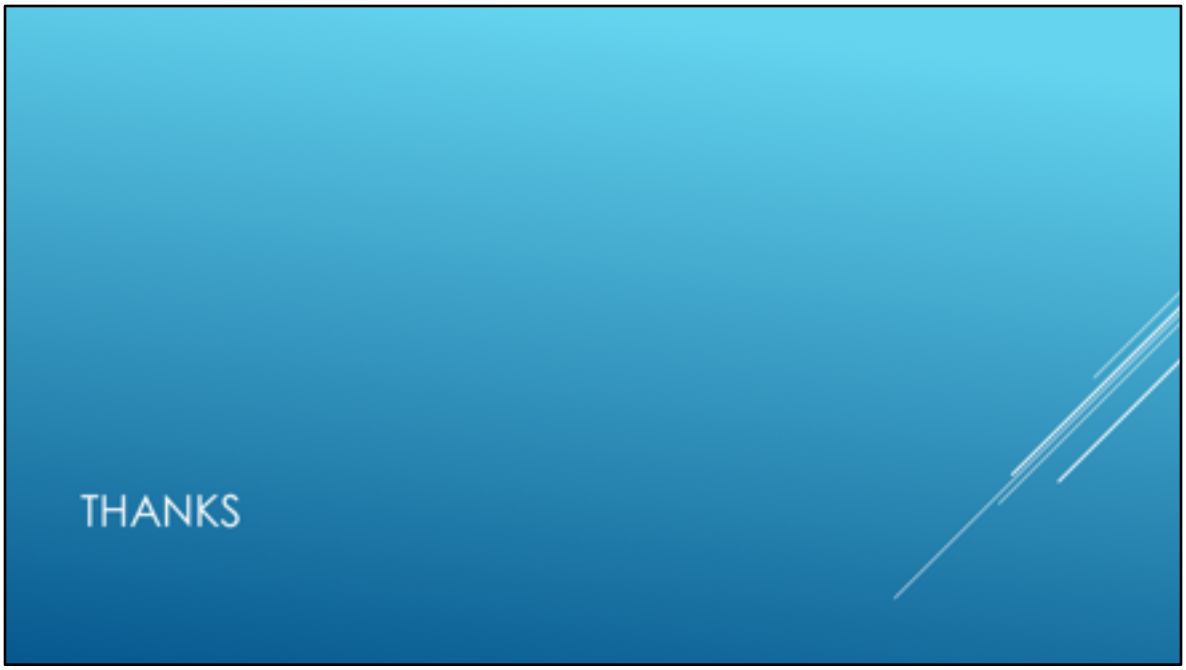

Use **weak consistency when possible**,
strong when necessary.
RECAP


Sharing data at scale is hard, let's go shopping.
RECAP


State is hell.
RECAP

FURTHER READINGS

- Reliable Distributed Systems: Technologies, Web Services and Applications
- Paxos Made Simple
- Dynamo: Amazon's Highly available Key-value store.
- MapReduce: Simplified Data Processing on Large Clusters
- BigTable: A Distributed Storage System for Structured Data
- Many more…
- There is one more thing


THANKS