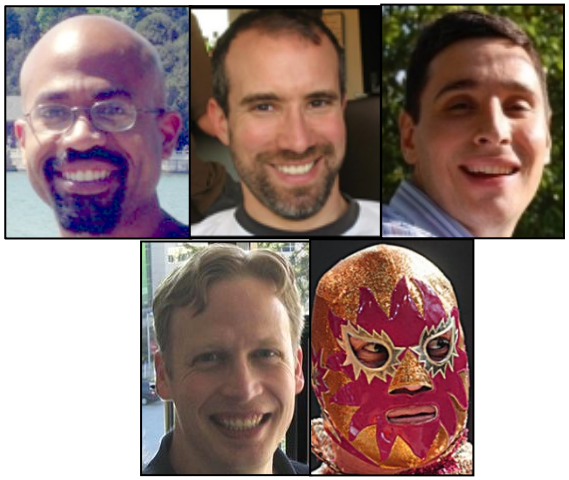
Blizzard: Fast, Cloud-scale Block Storage for Cloud-oblivious Applications

Microsoft Research



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THE UNIVERSITY of WISCONSIN MADISON

Asim Kadav
Vijay Chidambaram

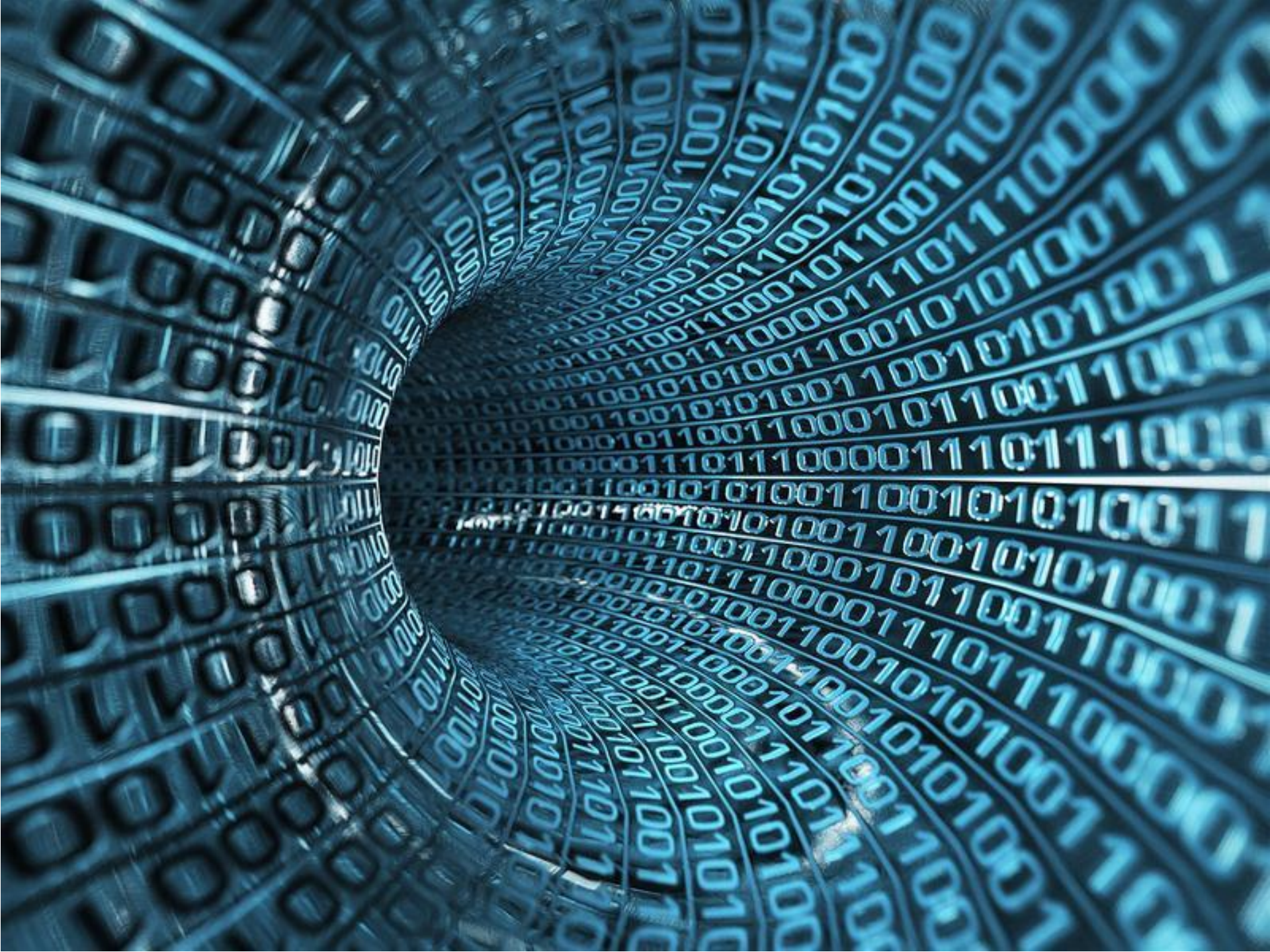
Carnegie Mellon University

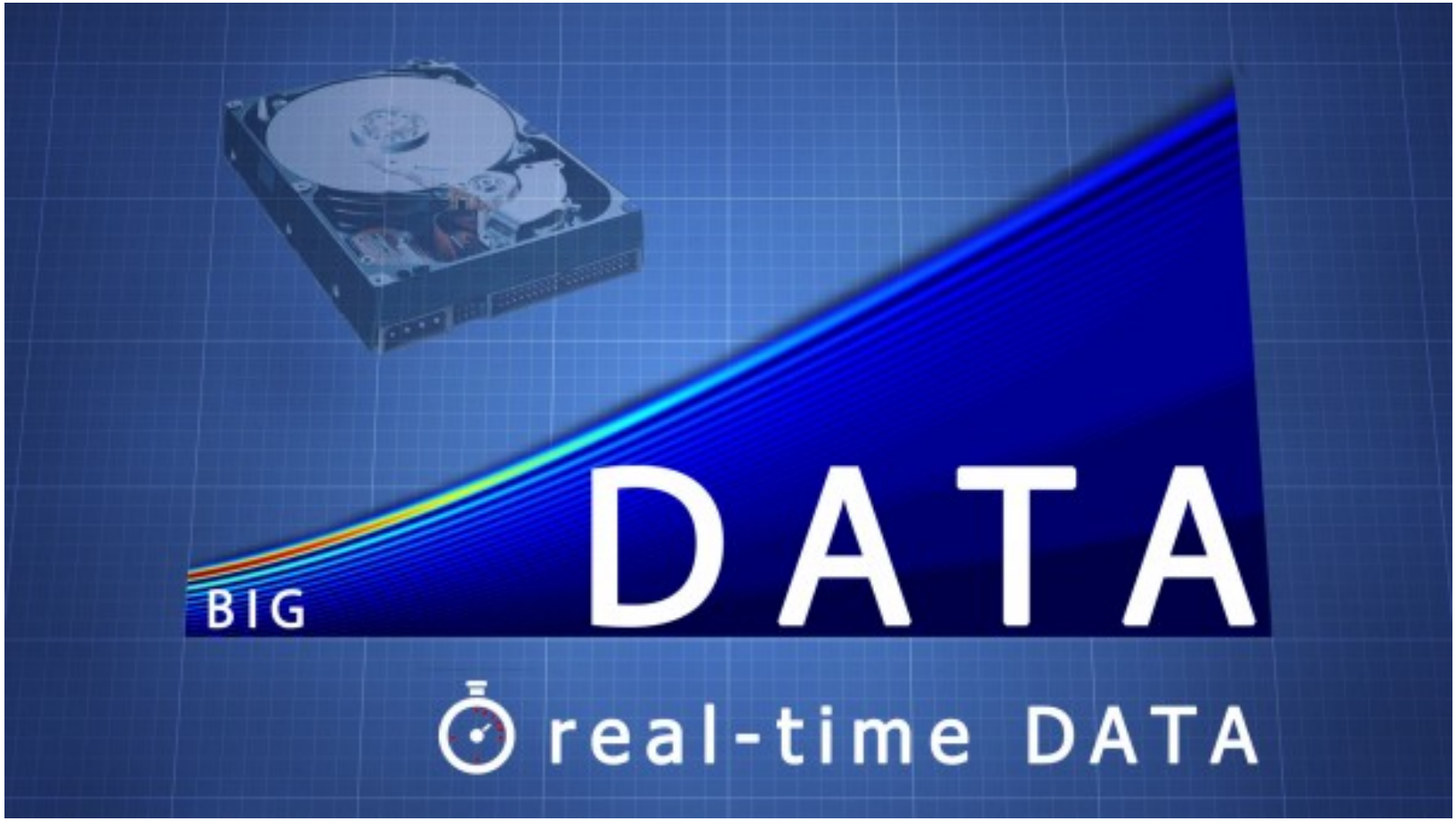
Bin Fan

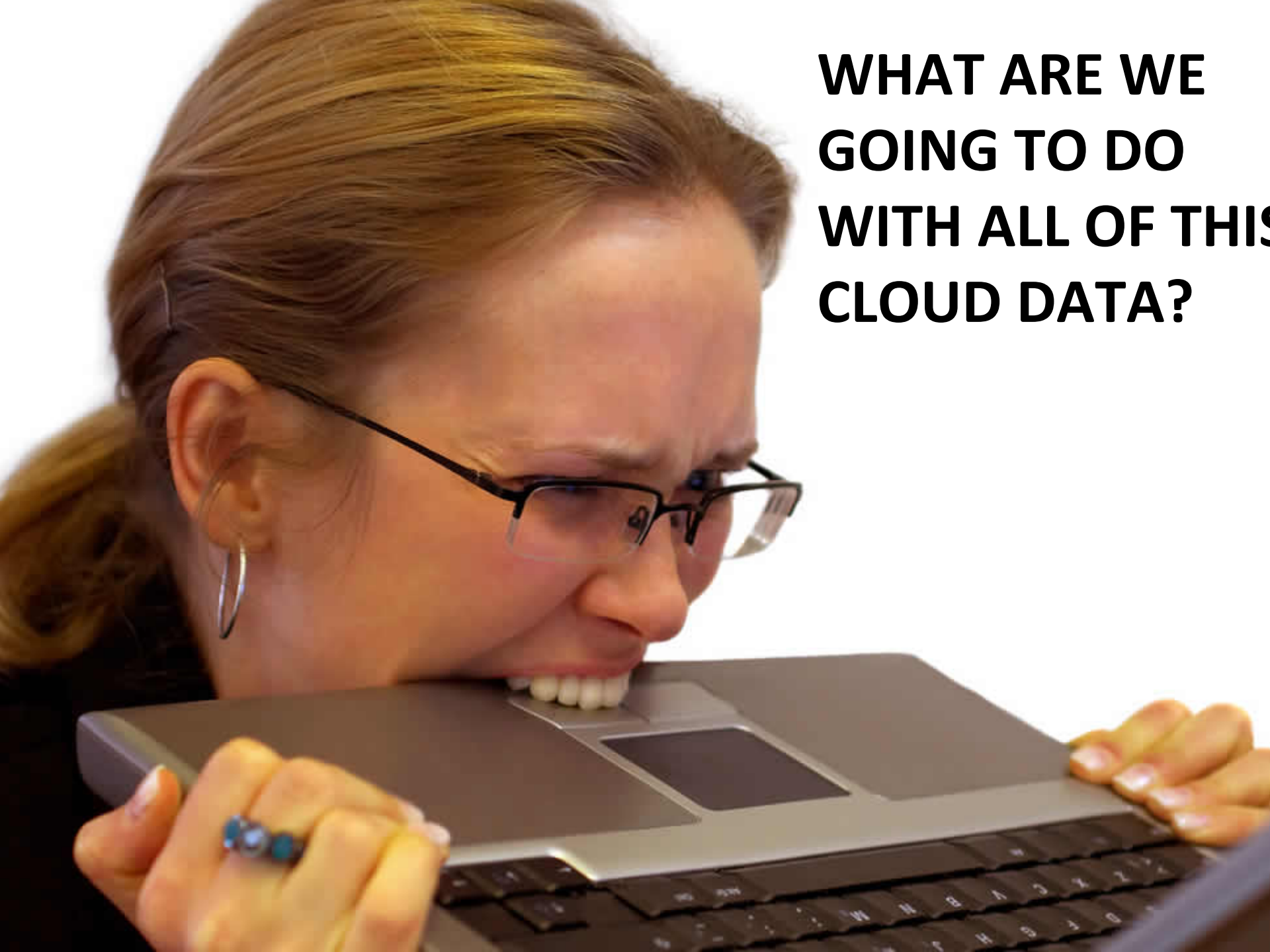
JOHNS HOPKINS

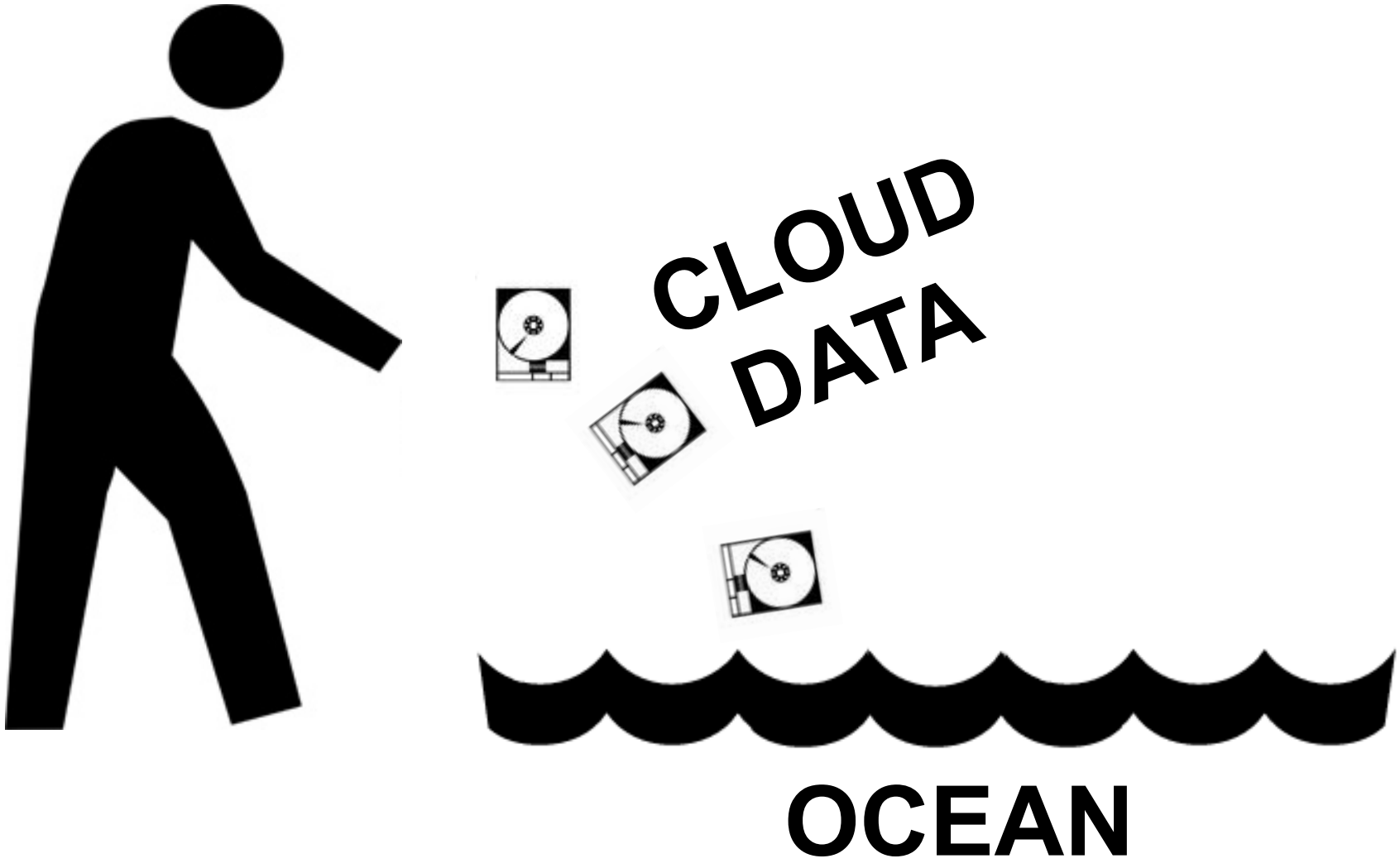
Osama Khan

IT'S, UH, THE FUTURE




BIG
DATA
real-time DATA


WHAT ARE WE
GOING TO DO
WITH ALL OF THIS
CLOUD DATA?


CLOUD
DATA
OCEAN

My Goal

- Take unmodified POSIX/Win32 applications . . .
- Run those applications in the cloud . . .
- On the same hardware used to run big-data apps . . .
- . . . and give them cloud-scale IO performance!

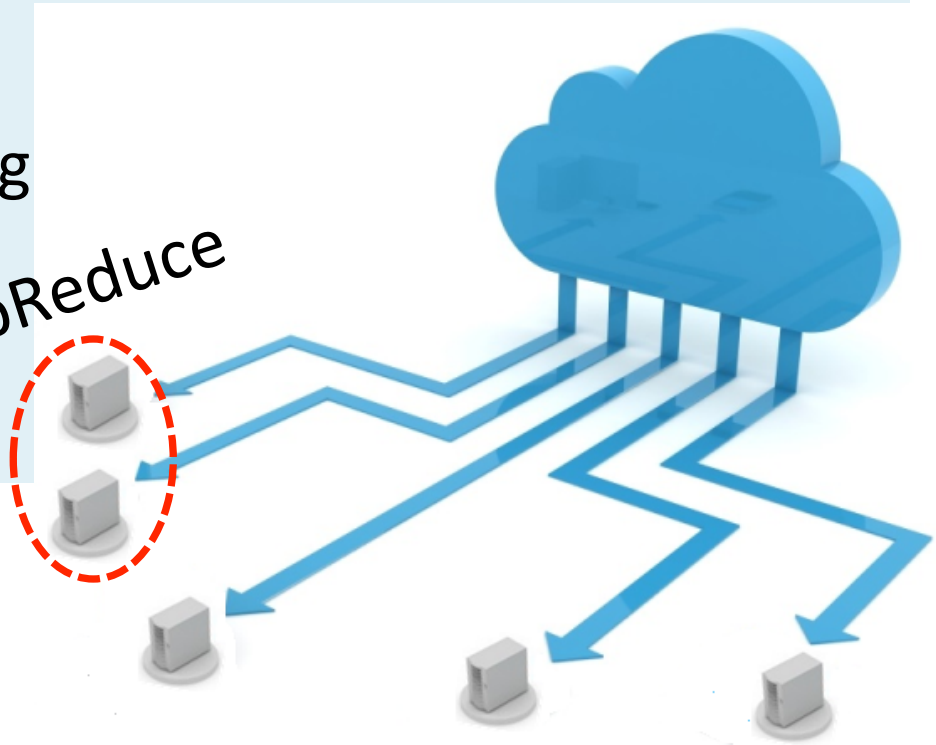
My Goal

- Take unmodified POSIX/Win32 applications . . .
- Run those applications in the cloud . . .
- On the same hardware used to run big-data apps . . .
- . . . and give them cloud-scale IO performance!
  - Throughput > 1000 MB/s
  - Scale-out architecture using commodity parts
  - Transparent failure recovery

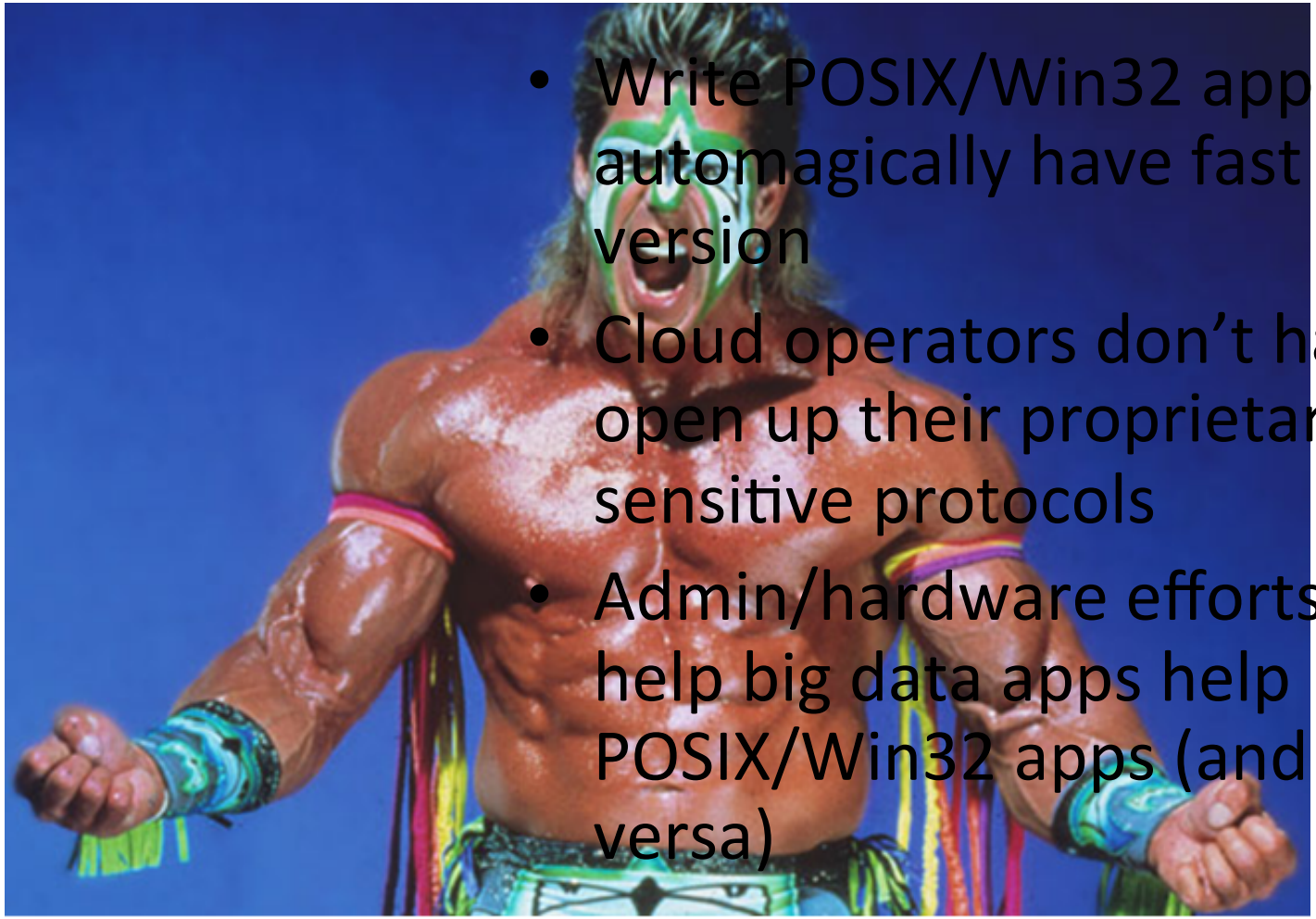
PostgreSQL

eclipse

Microsoft Exchange 2013



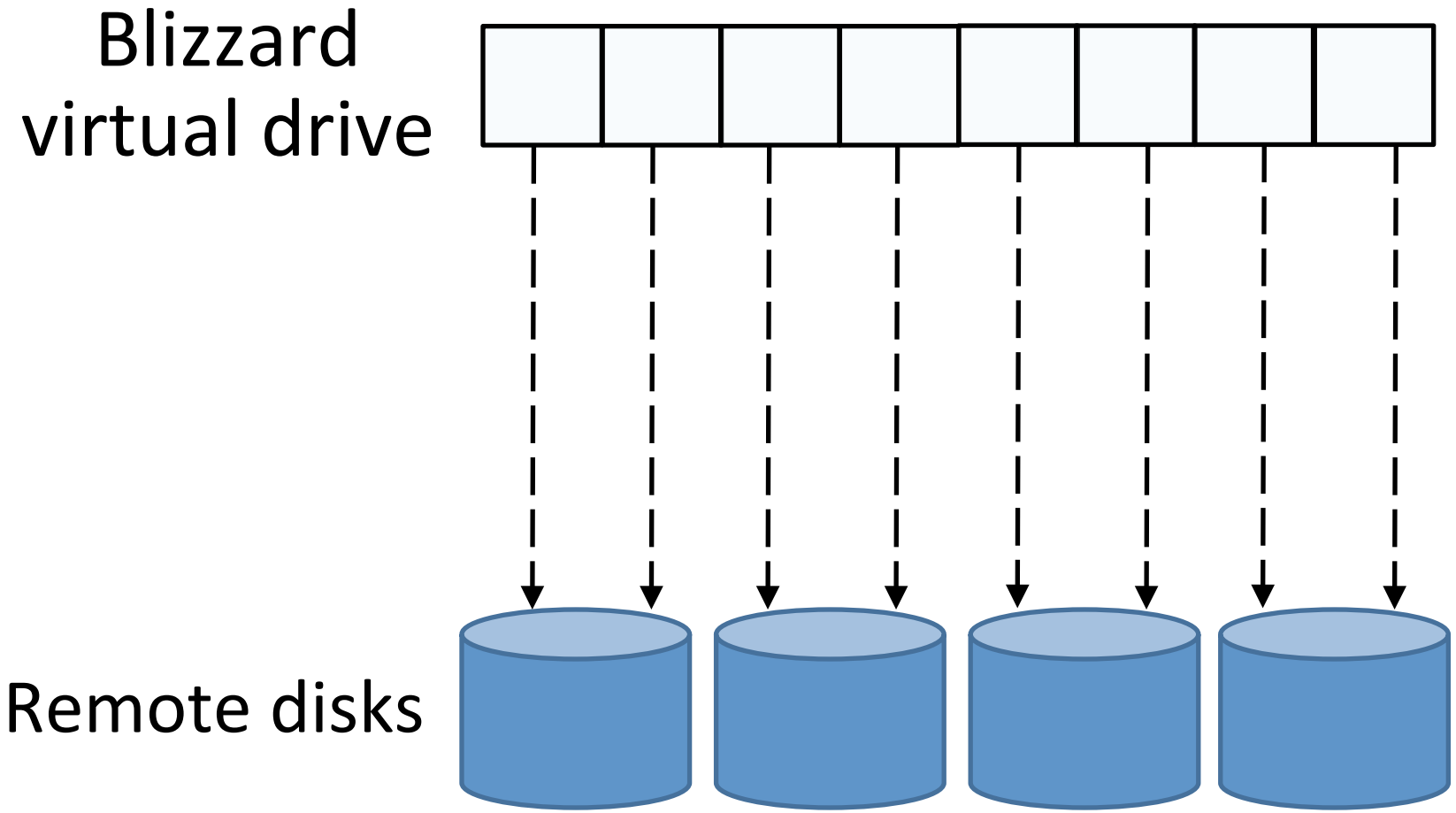
Why Do I Want To Do This?



- Write POSIX/Win32 app once, automagically have fast cloud version
- Cloud operators don't have to open up their proprietary or sensitive protocols
- Admin/hardware efforts that help big data apps help POSIX/Win32 apps (and vice versa)

BECAUSE THIS WOULD BE AMAZING

Our Solution: Blizzard



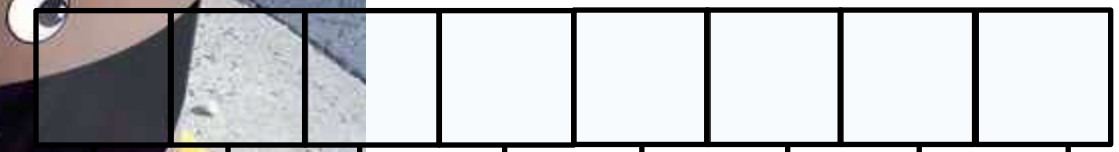
Our Solution: Blizzard

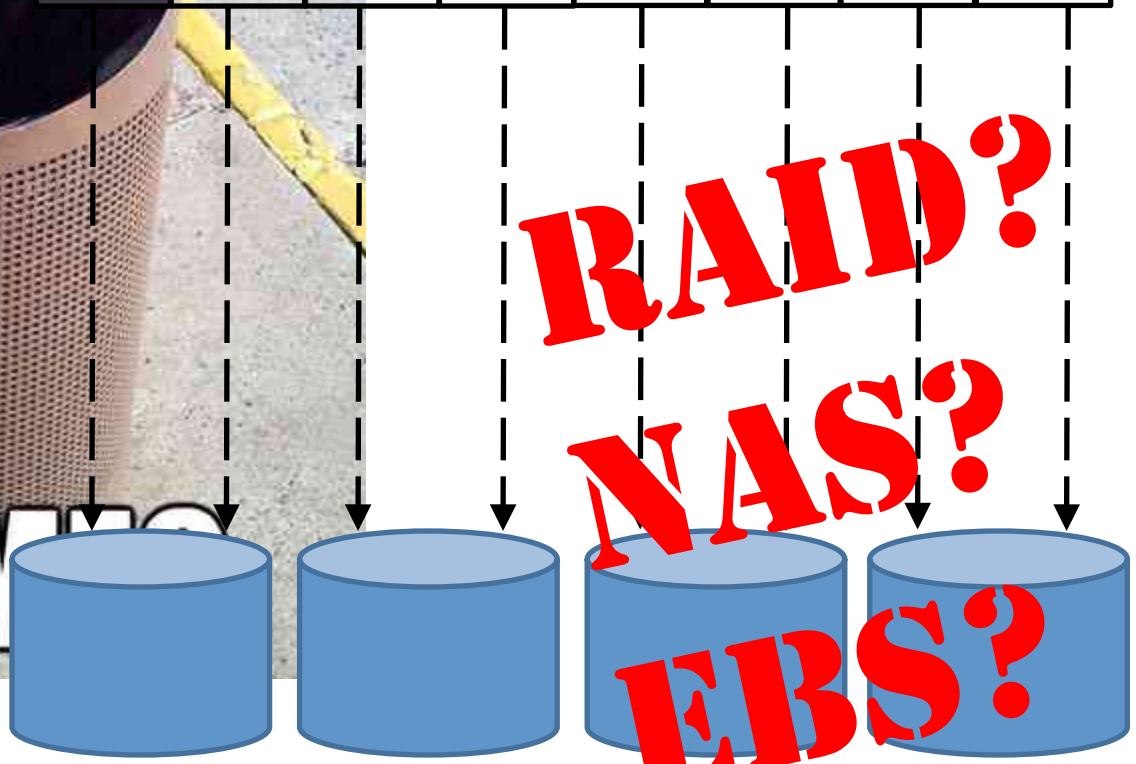
PostgreSQL

eclipse

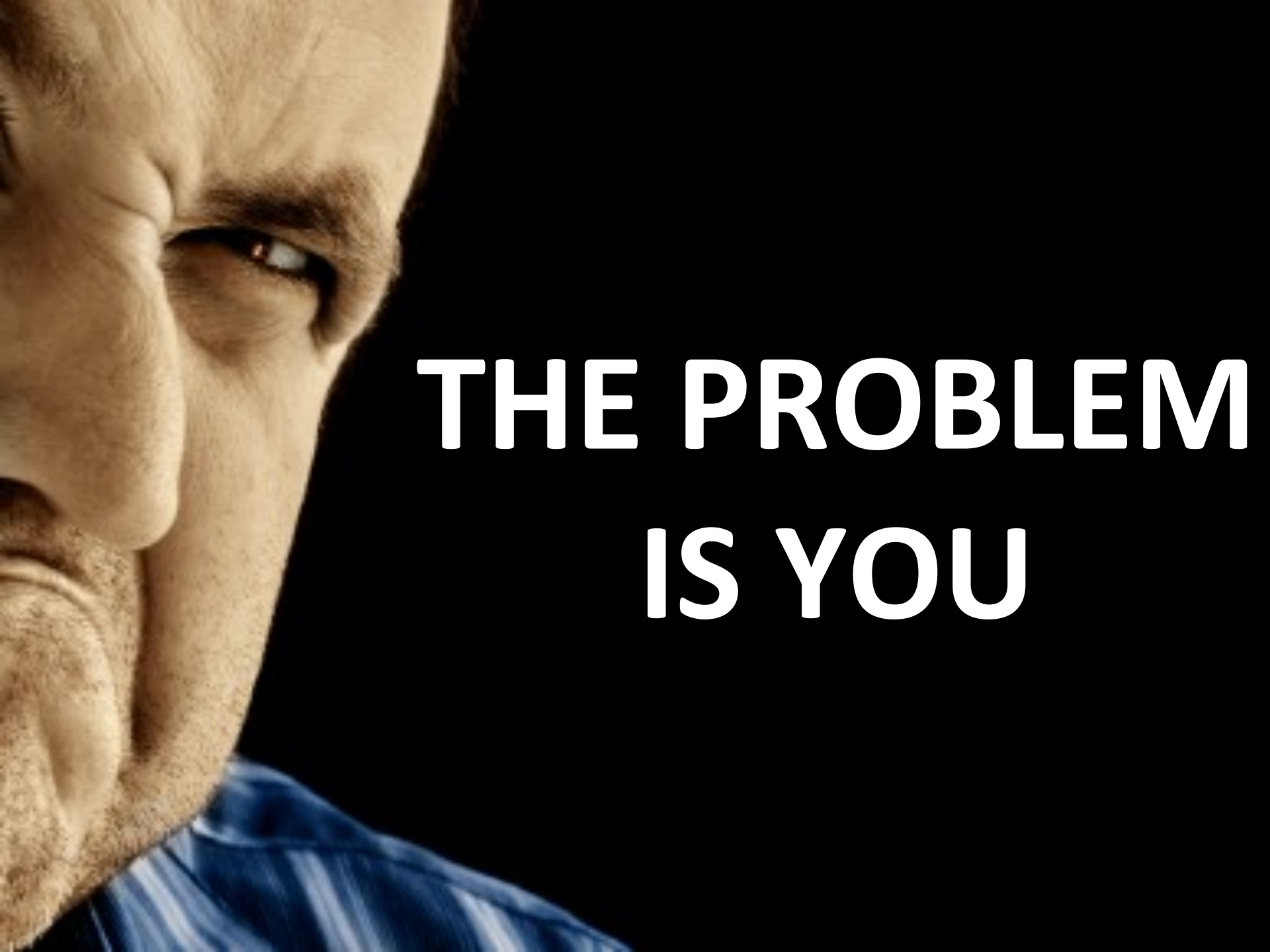
Microsoft® Exchange 2013

Blizzard virtual drive





Remote disks


THE PROBLEM
IS YOU

LISTEN

The naïve approach for implementing virtual disks does not **maximize spindle parallelism** for POSIX/Win32 applications which **frequently issue fsync() operations** to maintain consistency.

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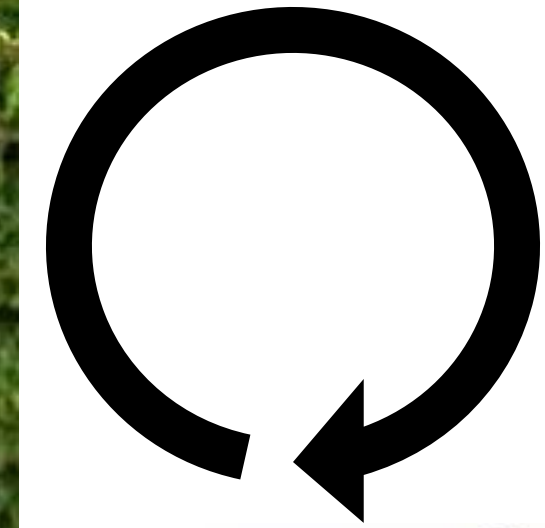
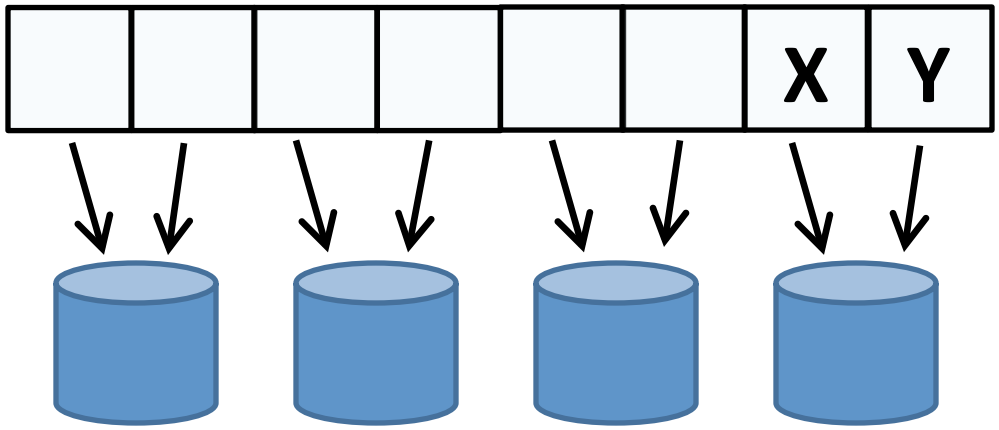
LISTEN

IOp dilation:
Nested striping

Rack locality:
Locality-oblivious
storage

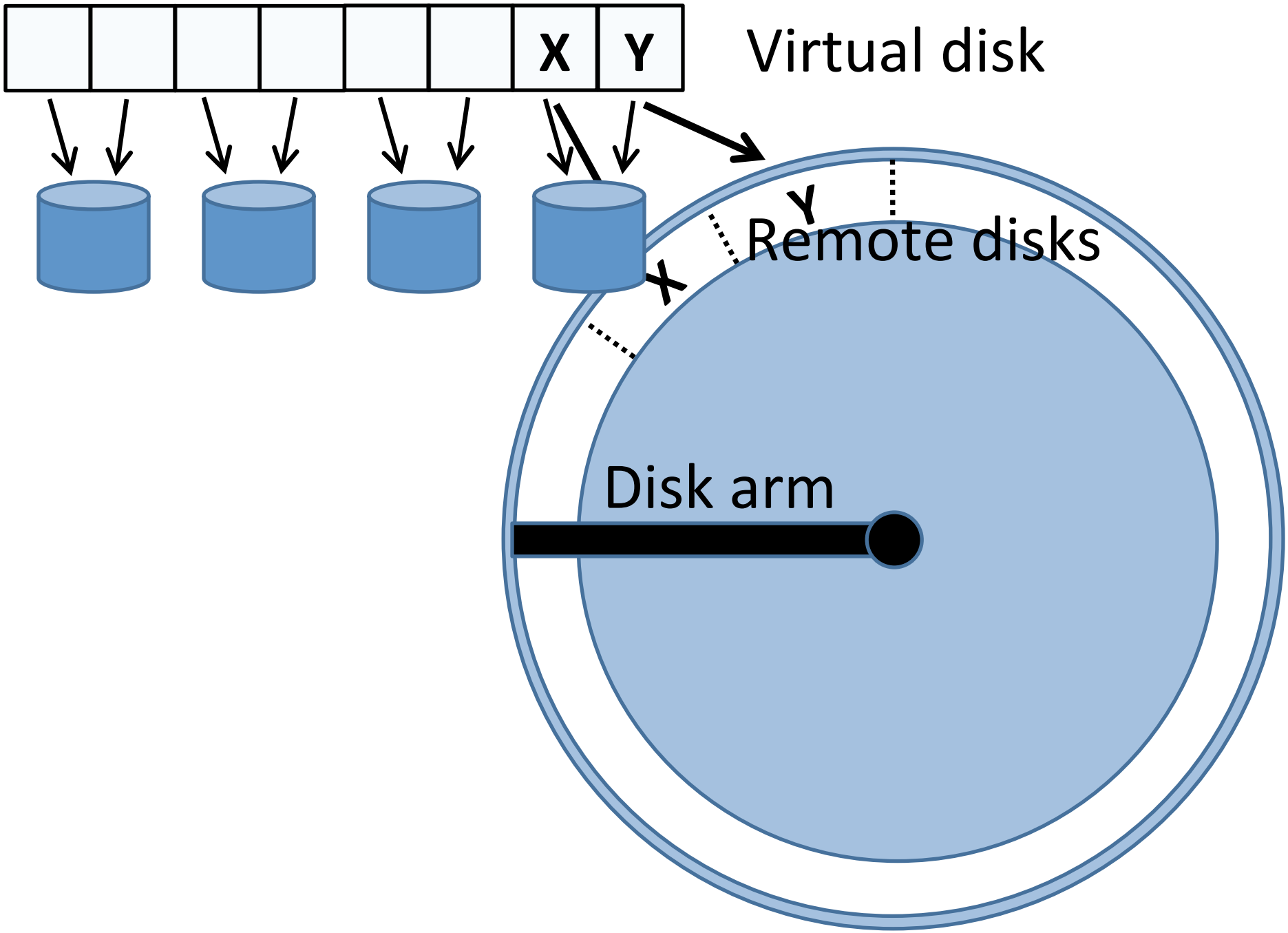
fsync() write barriers:
Delayed durability
semantics

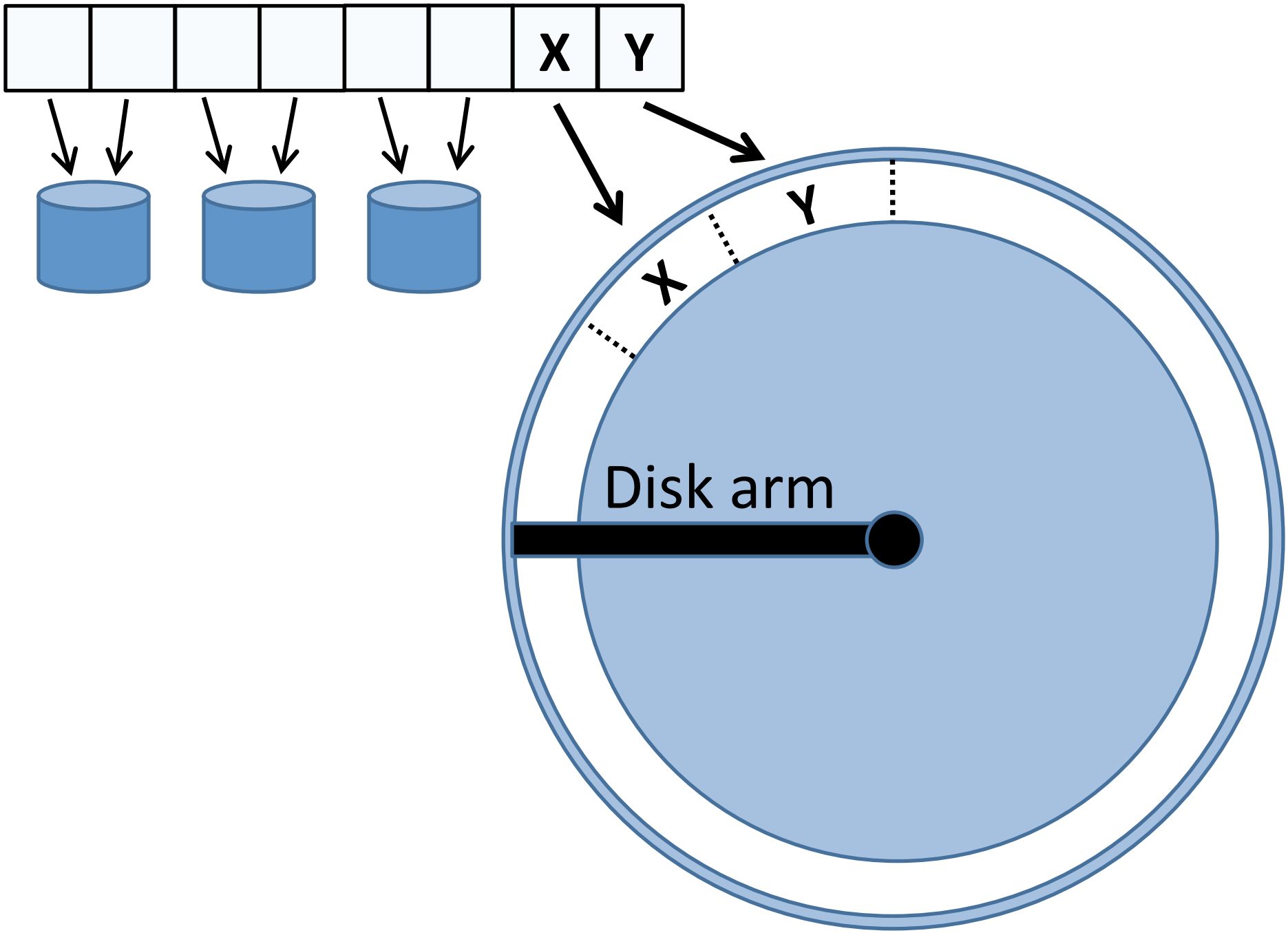


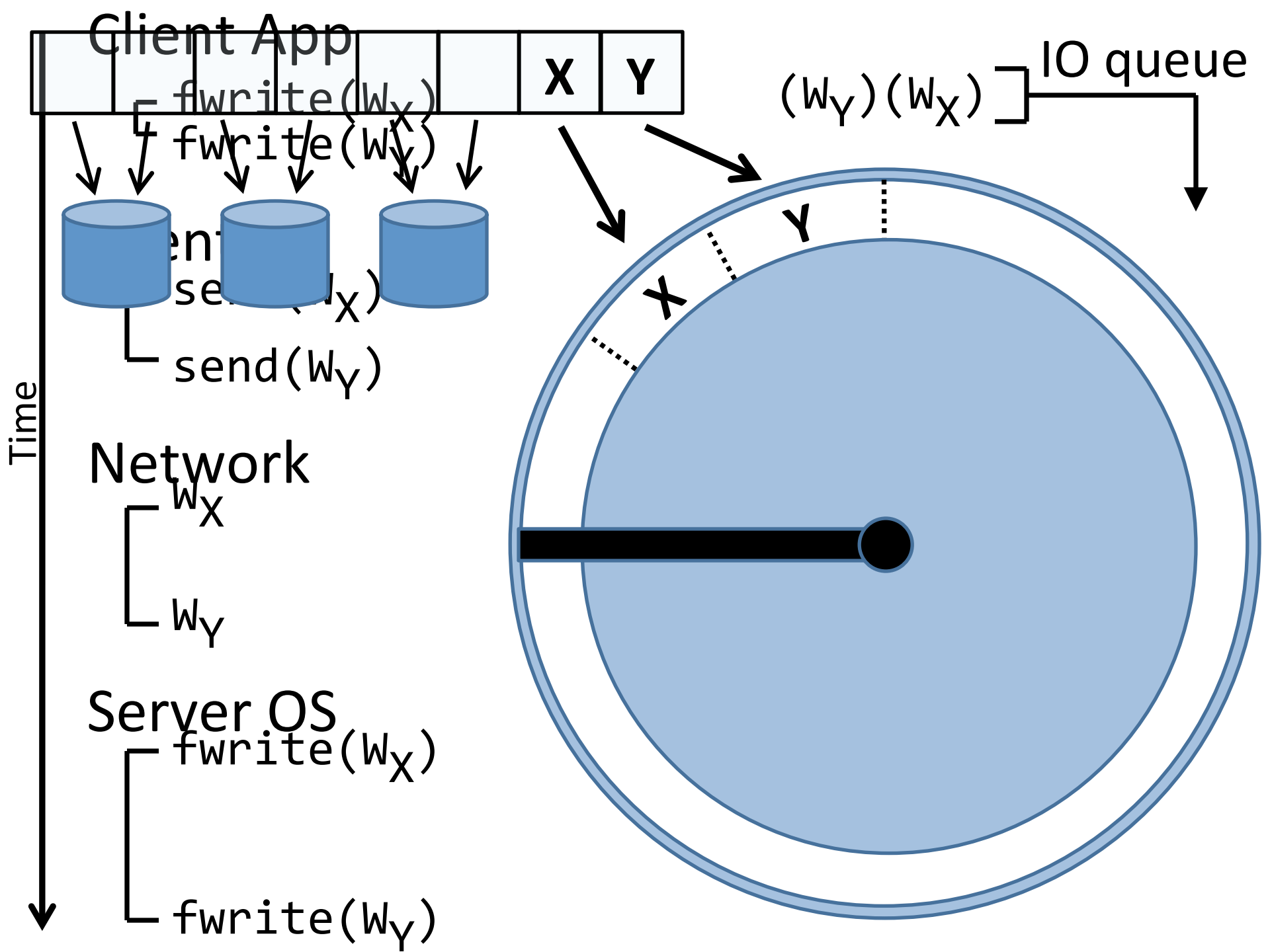


Virtual disk

Remote disks


X
Y
Virtual disk
Y
Remote disks
X
Disk arm


X
Y
Y
X
Disk arm


Client App
fwrite(W_X)
fwrite(W_Y)
X
Y
IO queue
(W_Y)(W_X)
send(W_X)
send(W_Y)
Time
Network
W_X
W_Y
Server OS
fwrite(W_X)
fwrite(W_Y)

IOp Convoy Dilation

Client App

fwrite(W_X)

fwrite(W_Y)

Client OS

fwrite(W_X)

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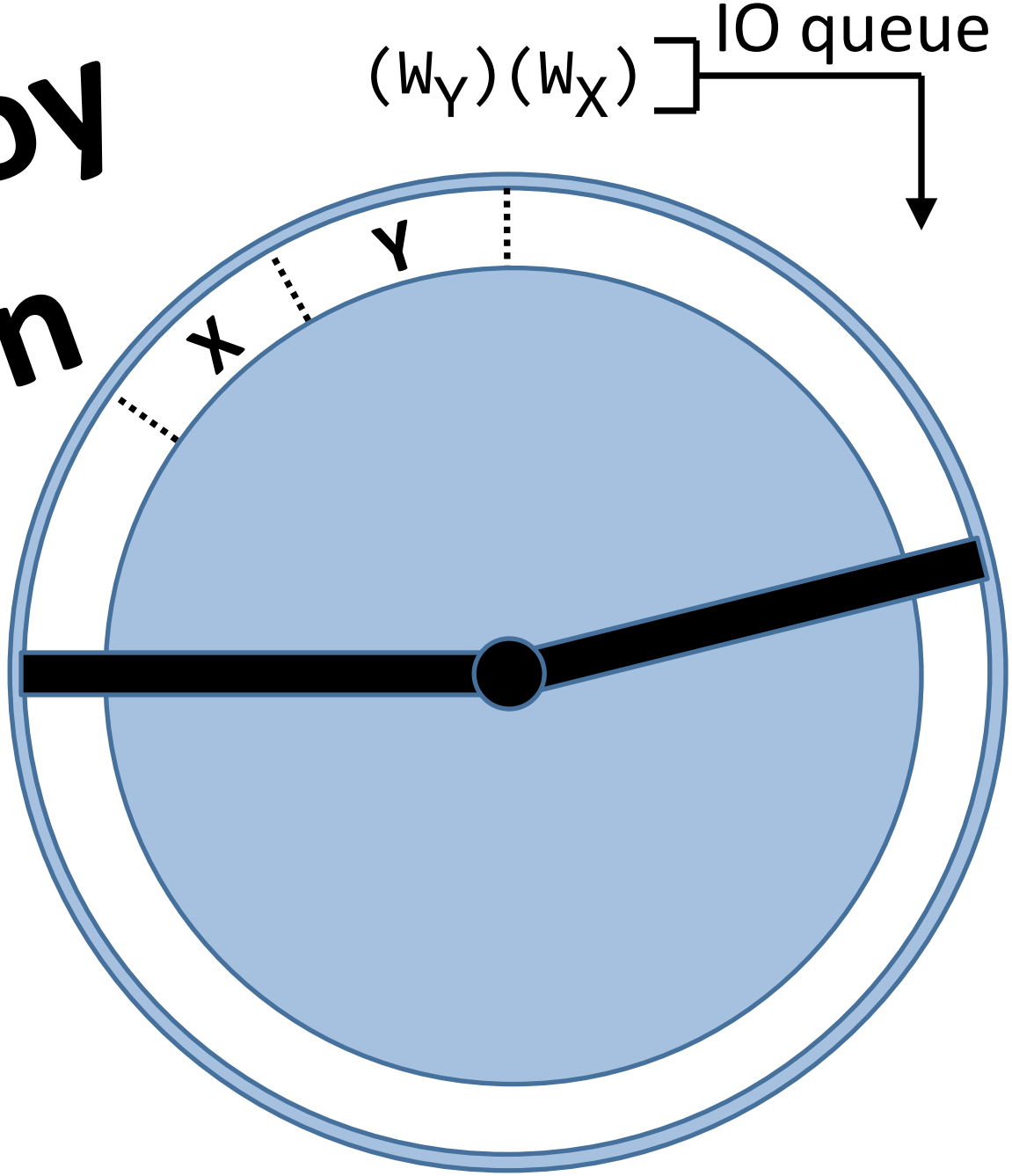
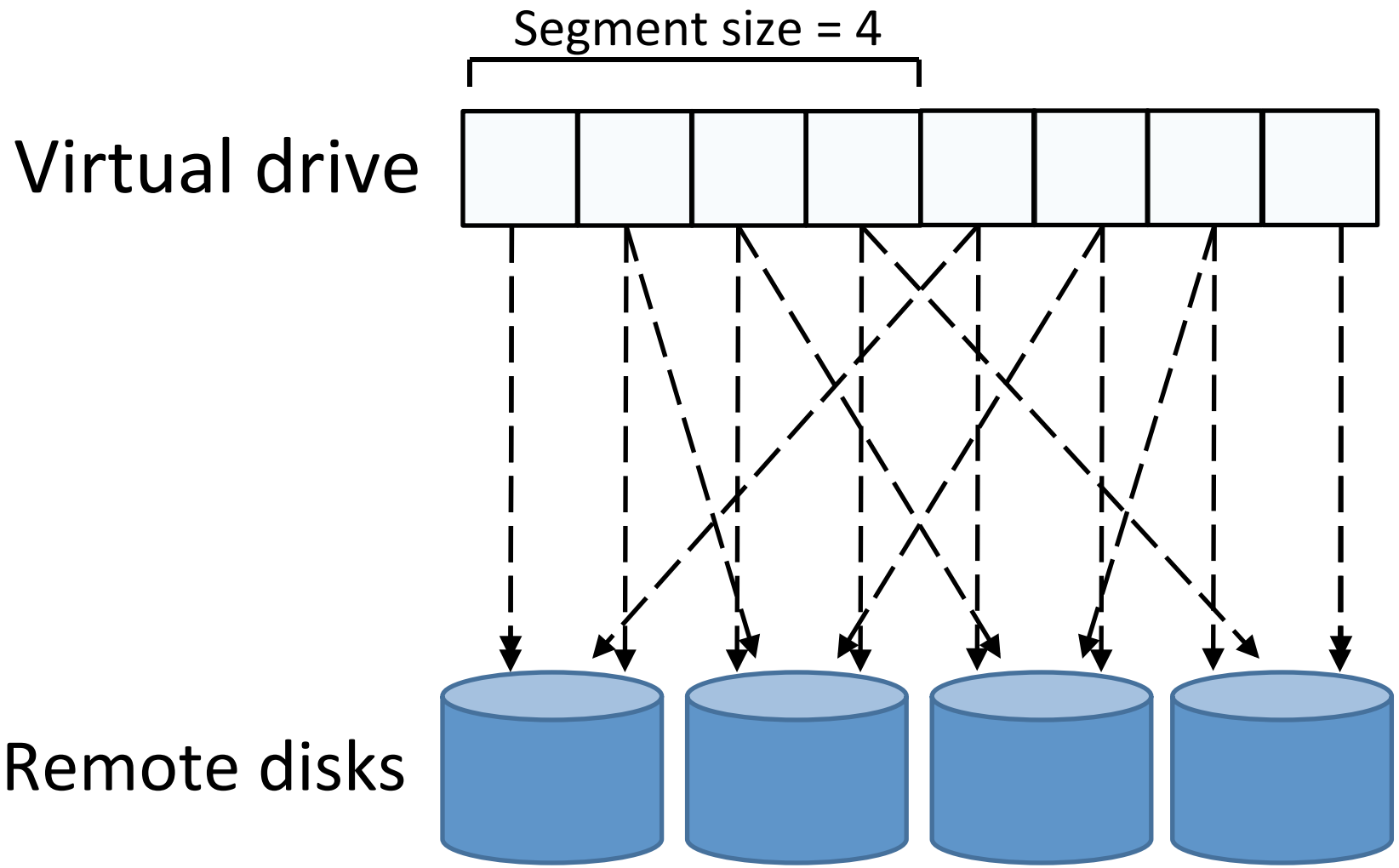


Fixing IOp Convoy Dilation



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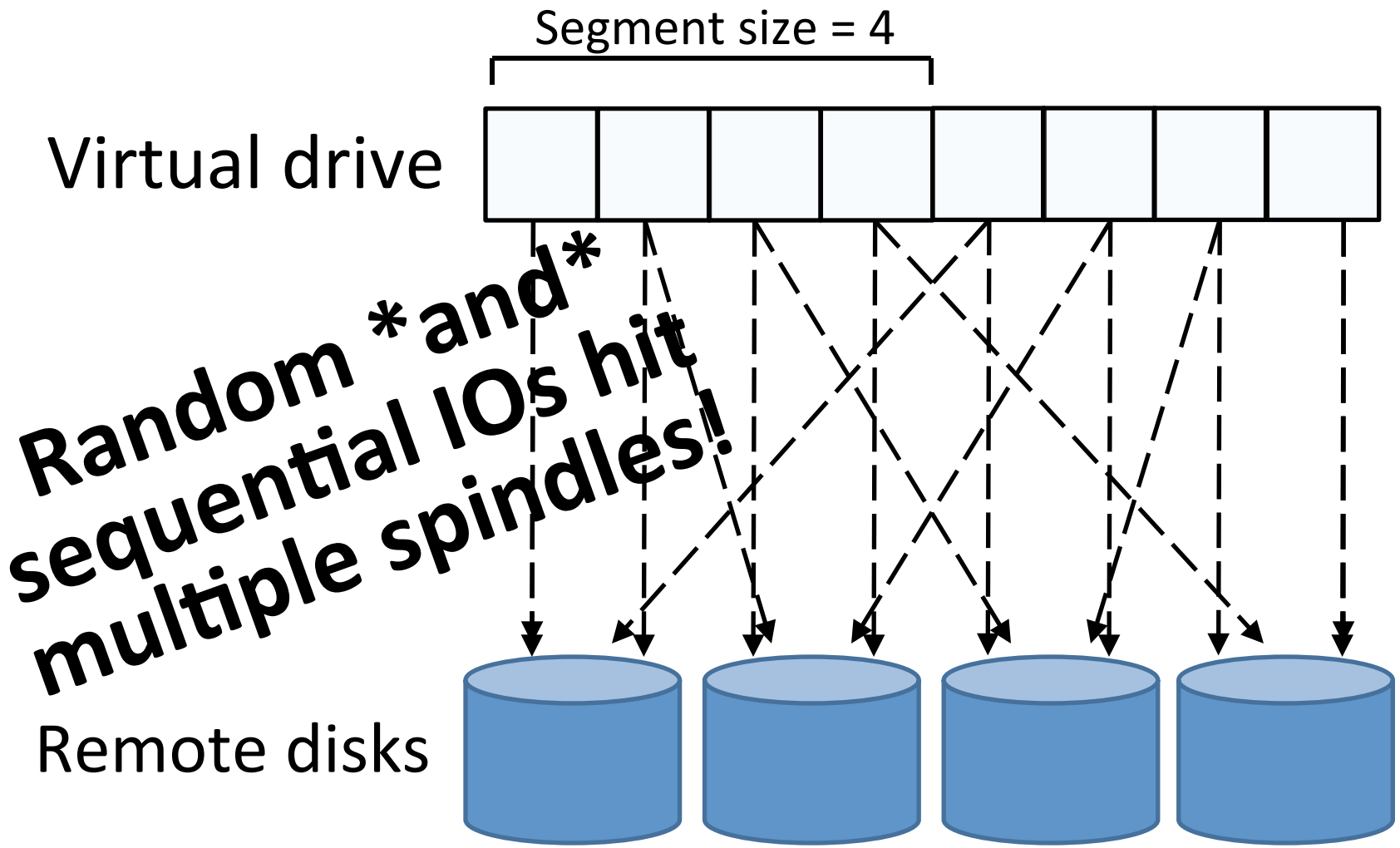
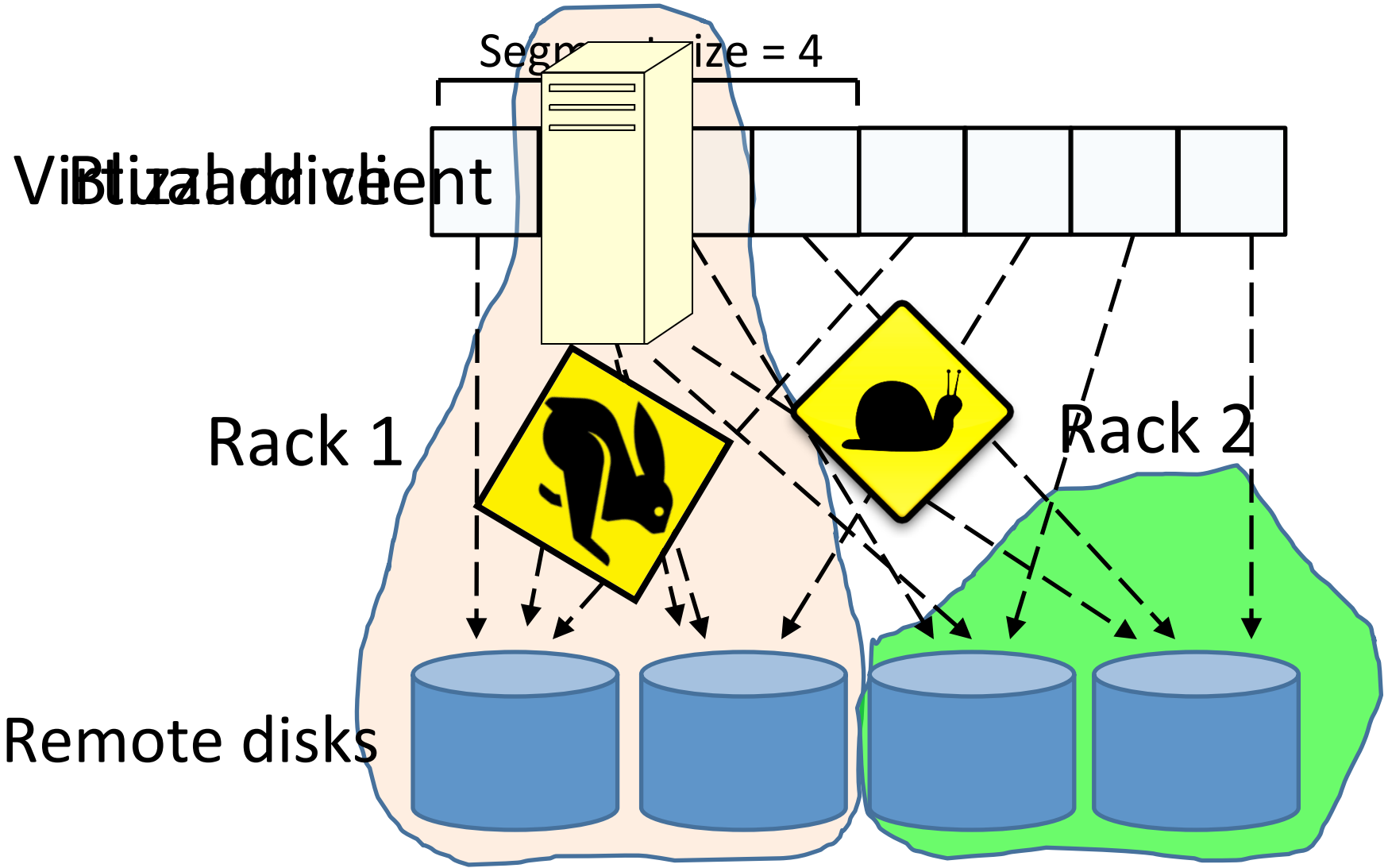



TOTAL
VICTORY

Rack Locality

Rack Locality

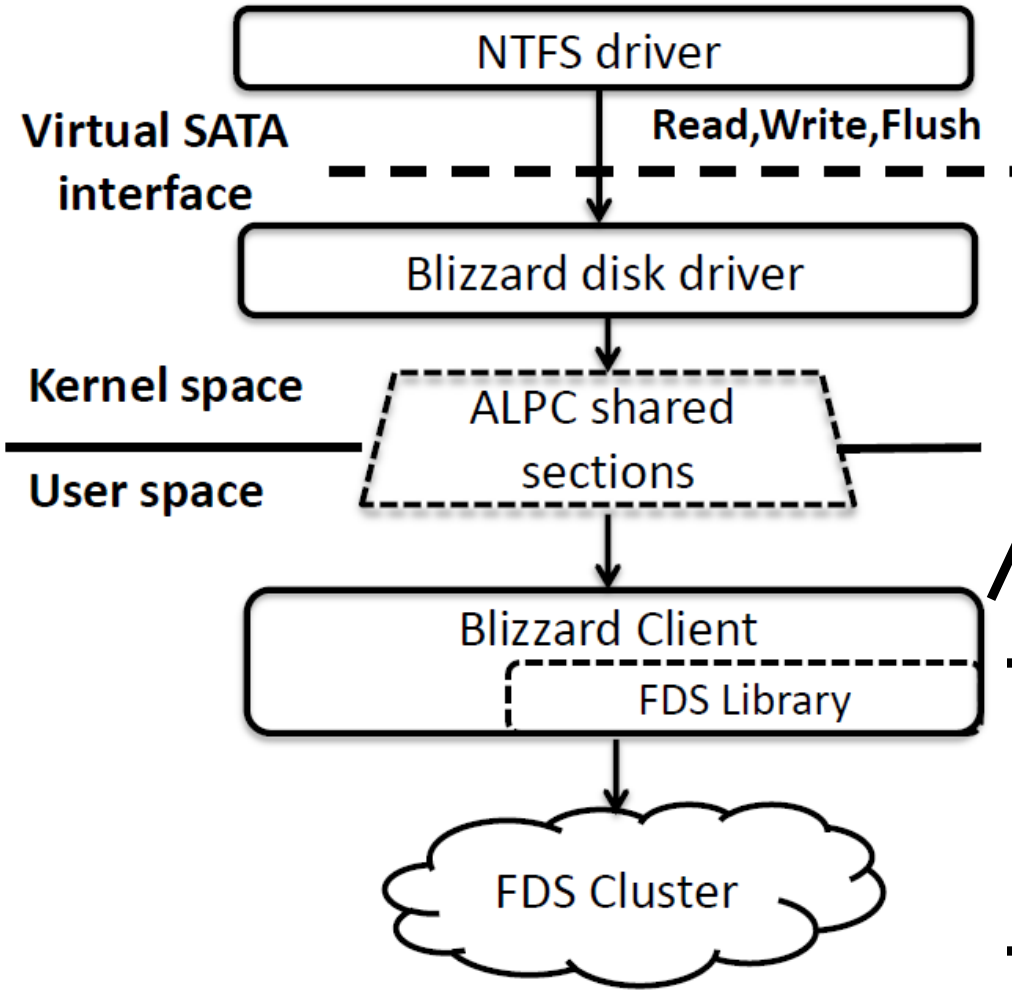


AIN’T NOBODY GOT TIME FOR THAT

FDS To The Rescue (OSDI 2012)

- Hardware architecture
  - Full bisection bandwidth network (no oversubscription)
  - Allocate each disk enough network bandwidth to drive disk at full sequential speed (1 disk ≈ 128 MB/s ≈ 1Gbps)
- Result: locality-oblivious storage
  - Any client can access any disk as fast as local
  - **Enables aggressive striping**

Blizzard as FDS Client



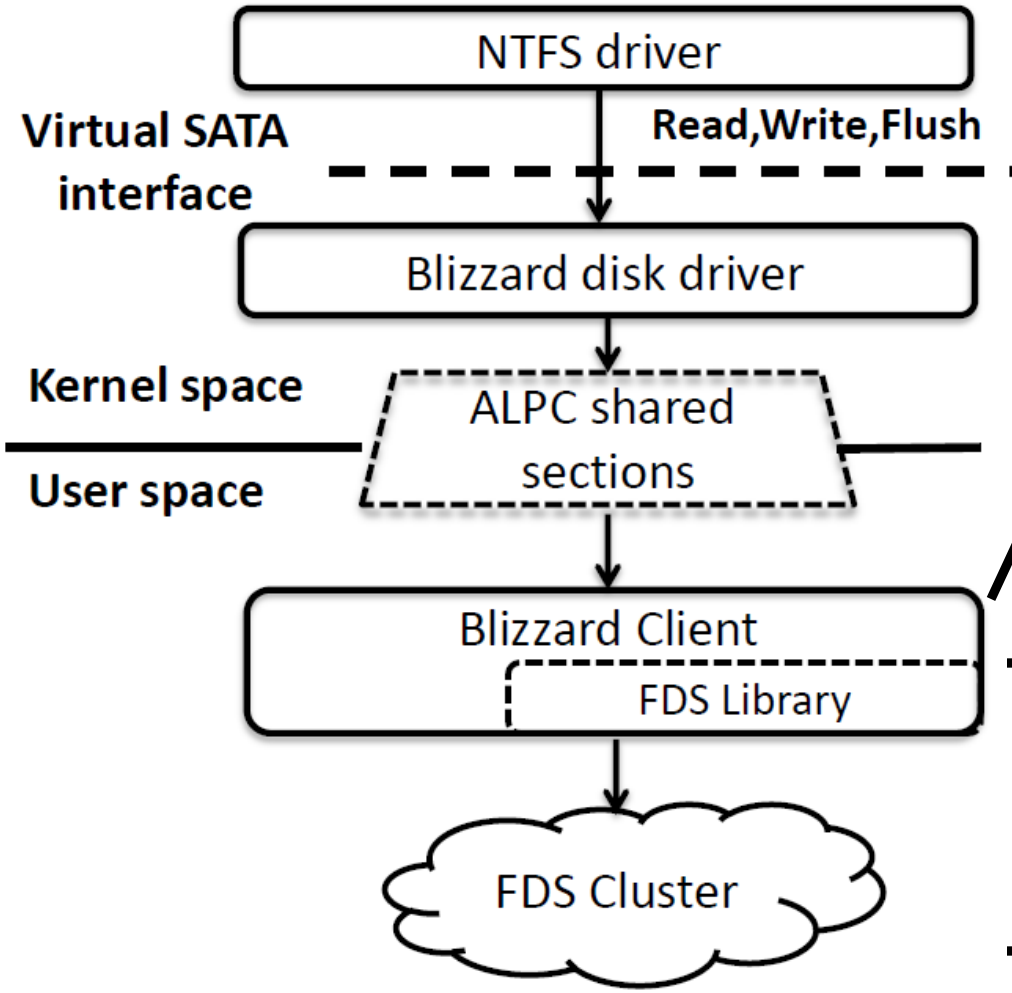
Blizzard client handles:

- Nested striping
- Delayed durability semantics

FDS provides:

- Locality-oblivious storage hardware
- Server-side failure recovery
- RTS/CTS to avoid edge congestion

Blizzard as FDS Client



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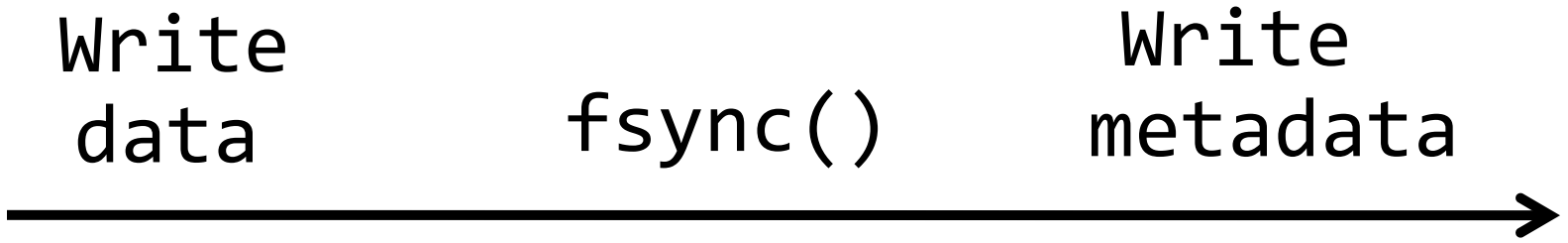
POSIX/Win32
apps
Traditional
big-data apps

ARE WE THERE YET?

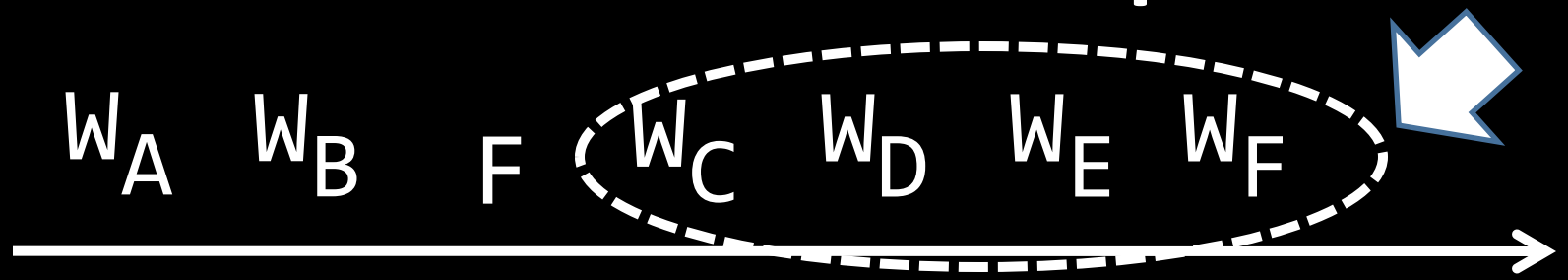
The problem with `fsync()`

- Used by POSIX/Win32 file systems and applications to implement crash consistency
  - Disk only returns from `fsync()` when all prior writes have become durable
  - Ex: ensure data is written before metadata



WRITE BARRIERS RUIN BIRTHDAYS

Stalled operations limit parallelism!



Delayed Durability

- Decouple durability from ordering
- Acknowledge `fsync()` immediately . . .
  - . . . but increment flush epoch
  - Tag writes with their epoch number, asynchronously retire writes in epoch order

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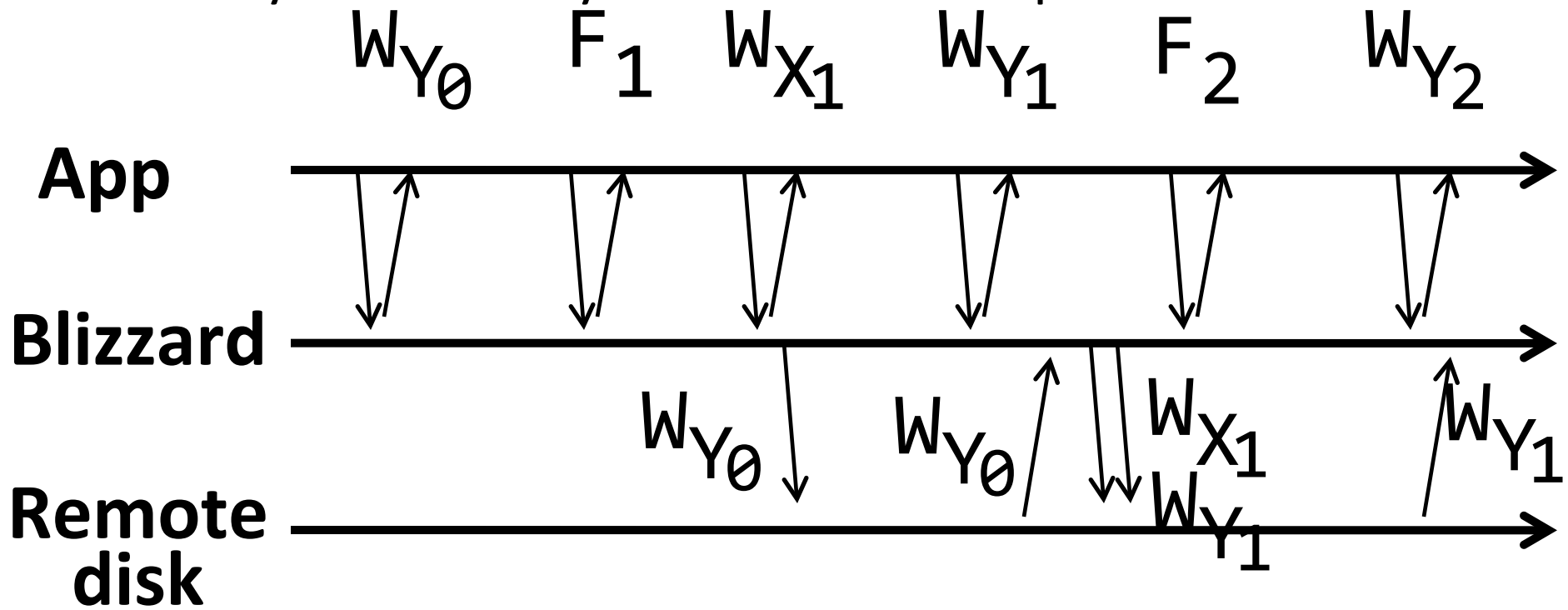
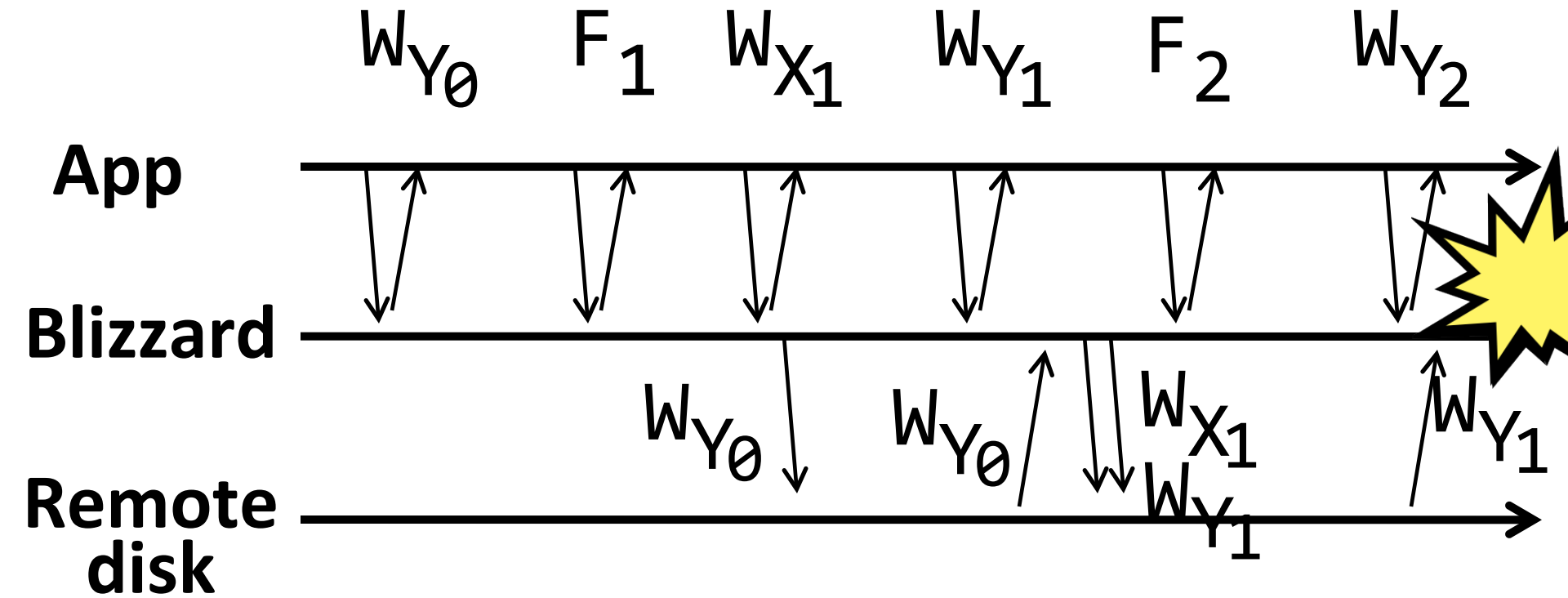
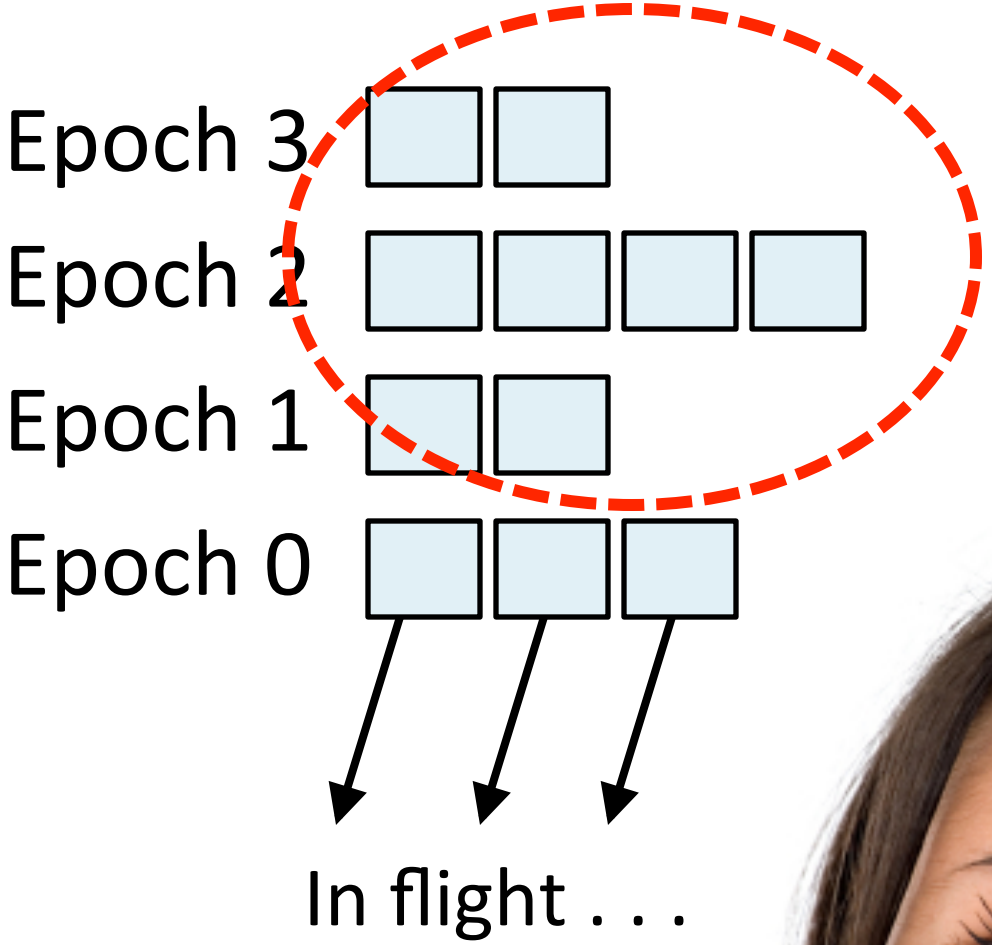


Delayed Durability

- All writes are acknowledged . . .
- . . . but only W_{Y_0} and W_{Y_1} are durable!
- Decouple durability from ordering
  - Acknowledge fsync() immediately . . .
  - . . . but tag writes with their epoch number
  - . . . and asynchronously retire writes in epoch order
- Prefix consistency good enough for most apps, provides much better performance!



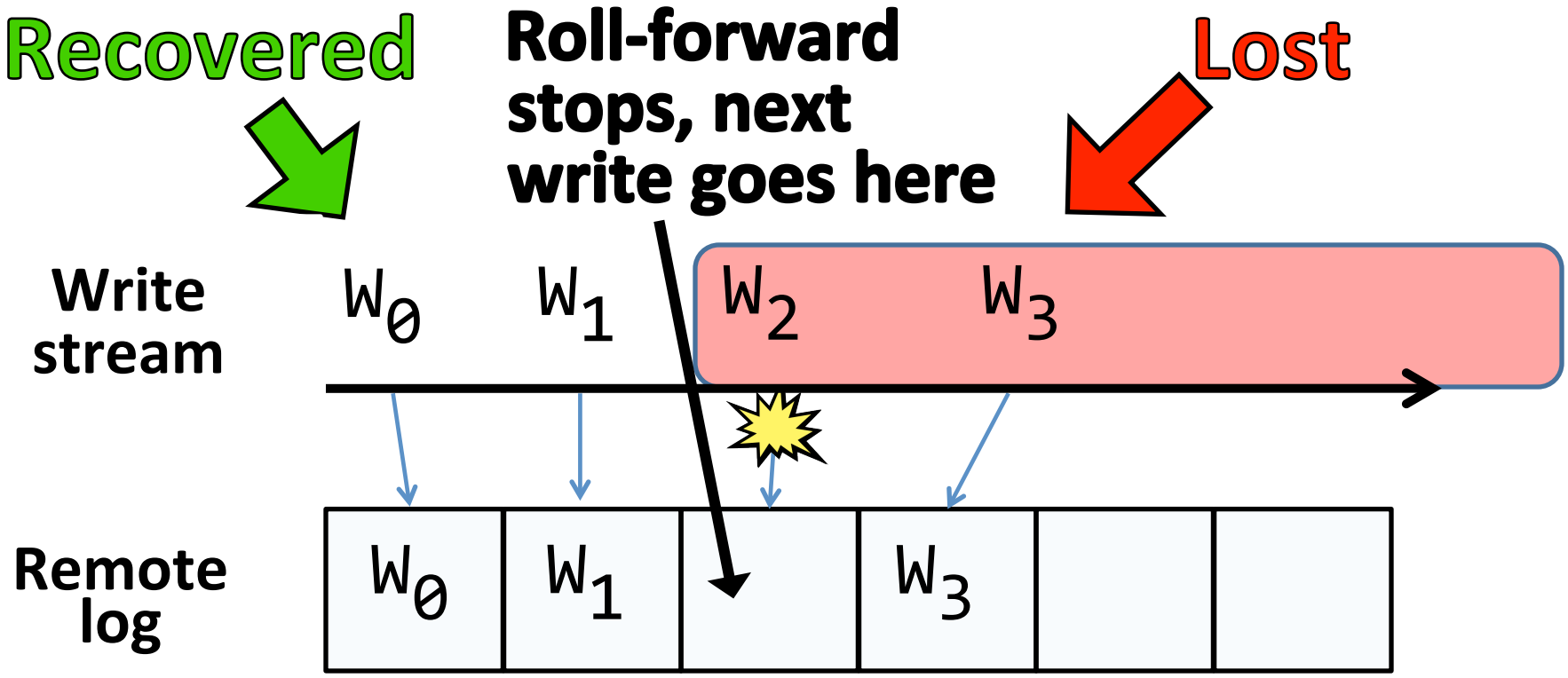
Isn’t Blizzard buffering a lot of data?



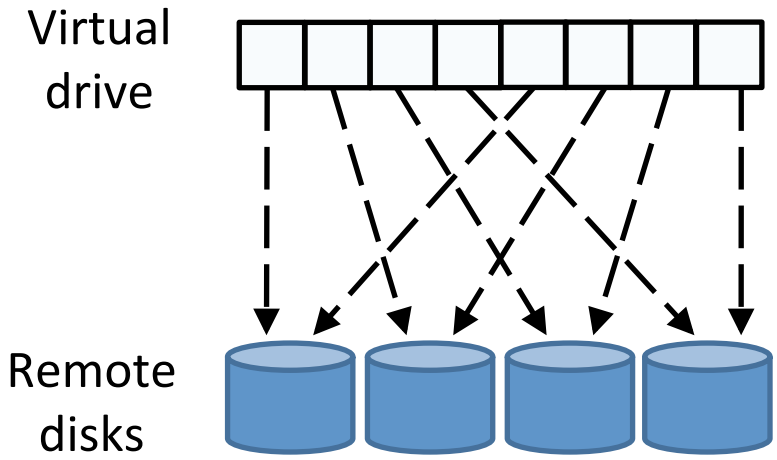

THERE ARE NO NEW TECHNIQUES
SPECULATIVE CACHING?
SPECULATIVE EXECUTION?

Log-based Writes

- Treat backing storage as a distributed log
  - Issue writes to log **immediately** and **in order**
  - On failure, roll forward from last checkpoint and stop when you find torn write, unallocated log block with old epoch number



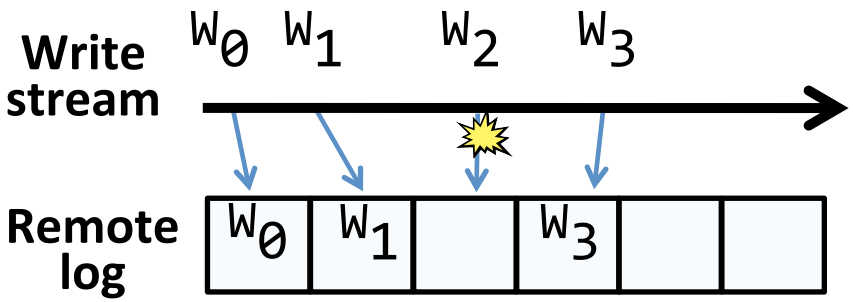
Summary of Blizzard's Design



- Problem: IOp Dilation
- Solution: Nested striping

FDS

- Problem: Rack locality constrains parallelism
- Solution: Full-bisection networks, match disk and network bandwidth

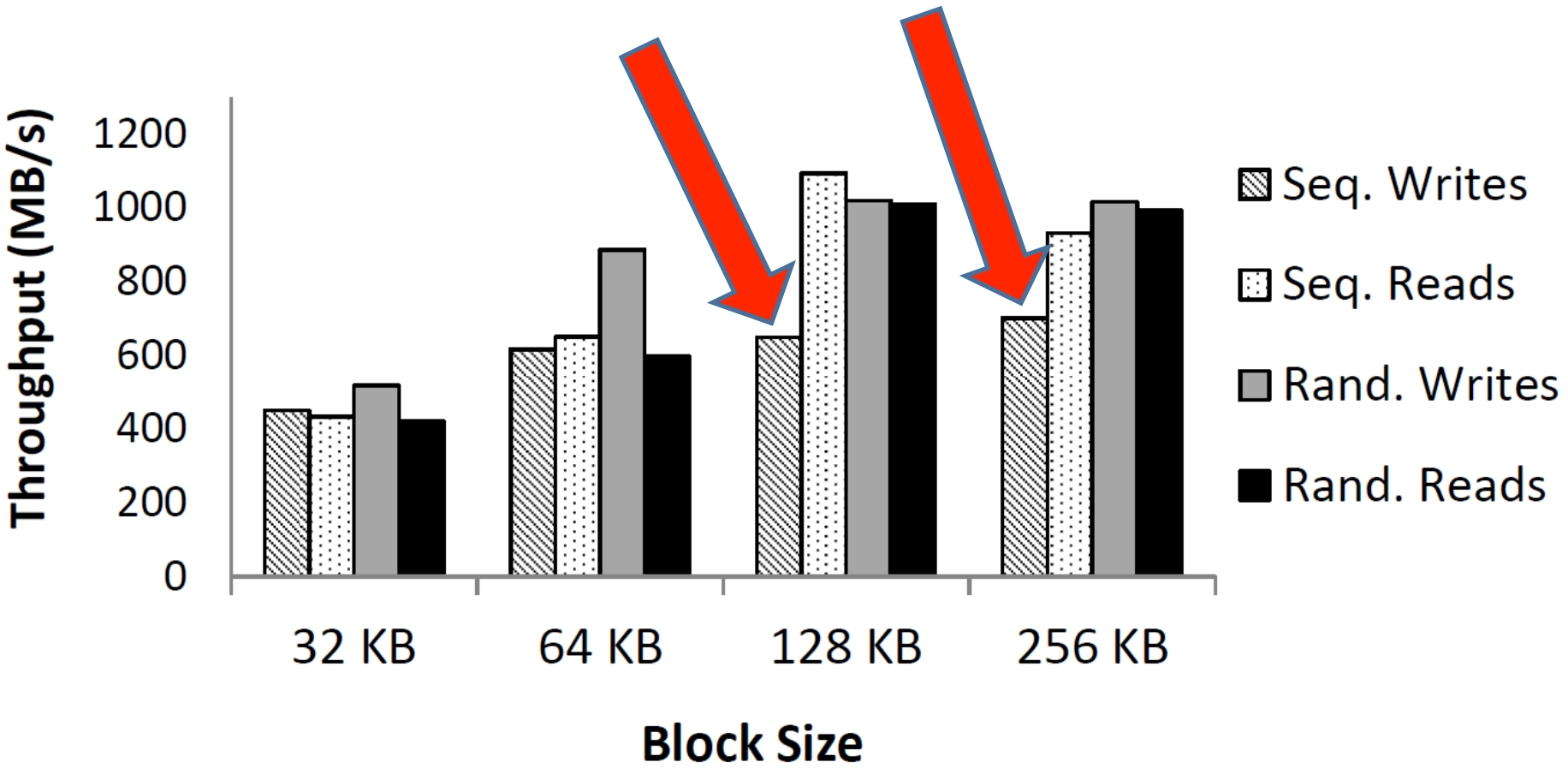


- Problem: Evil fsync()s
- Solution: Delayed durability

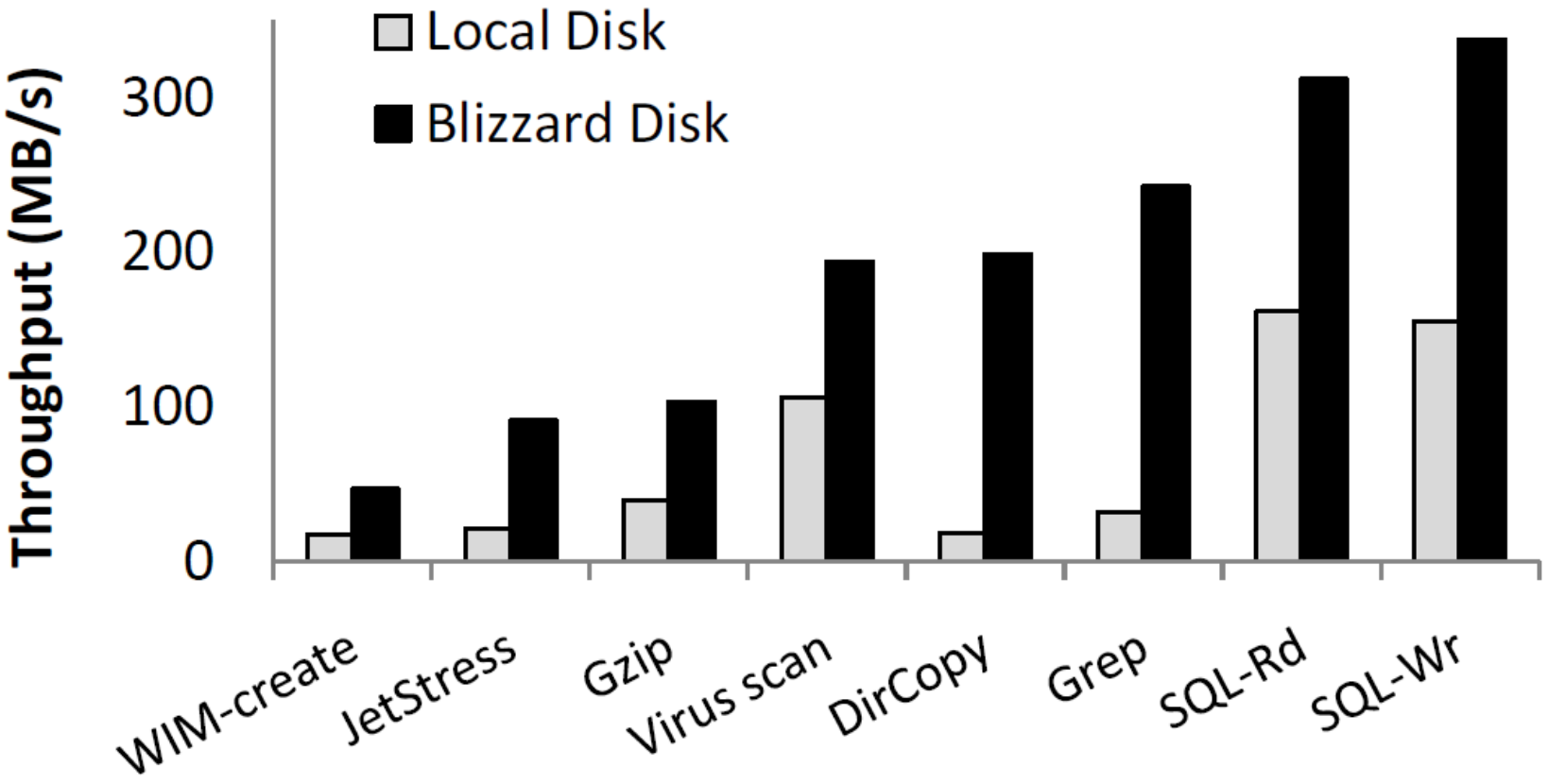
PROOF OF YOUR EXCELLENCE

I DO NOT SEE IT

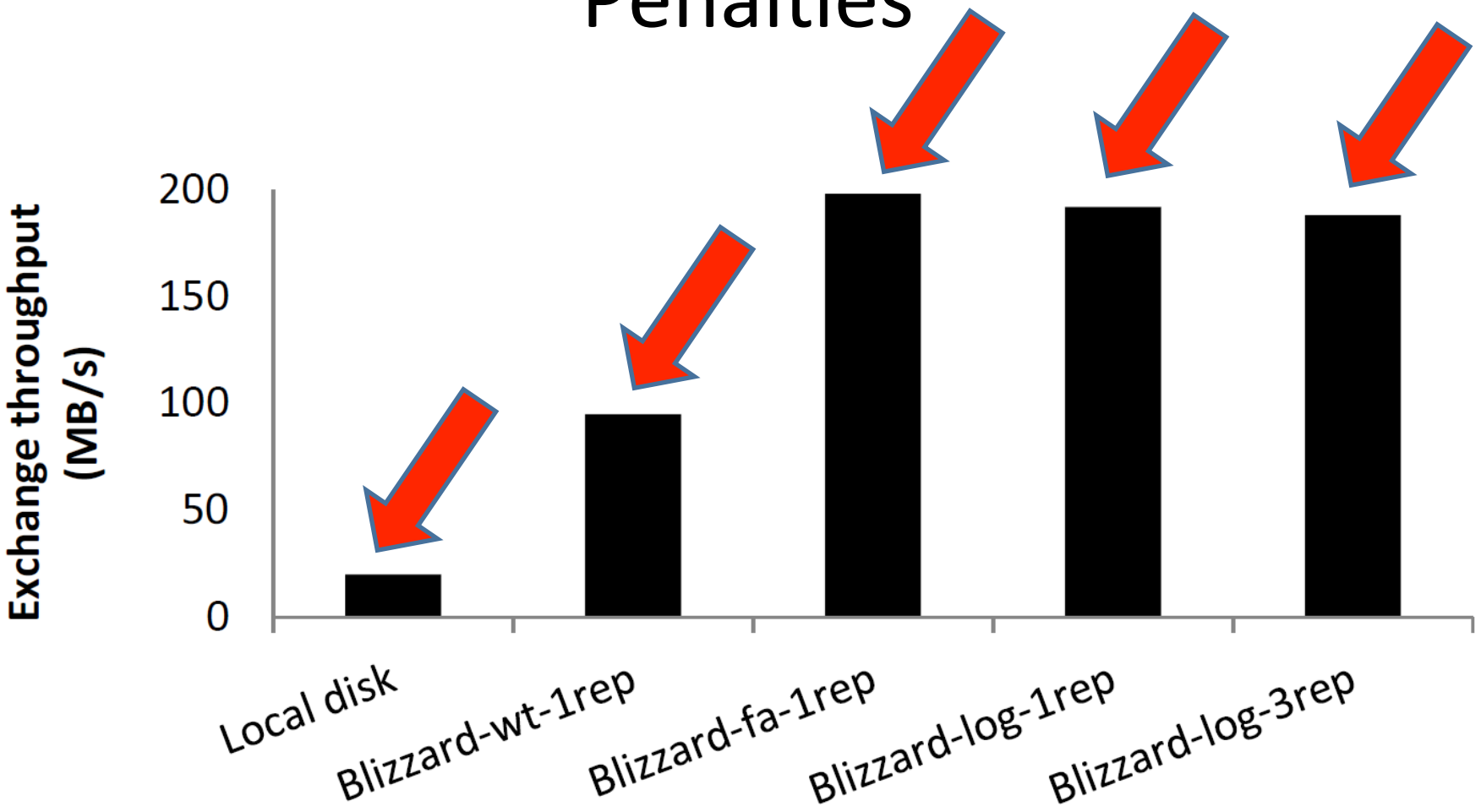
Throughput Microbenchmark



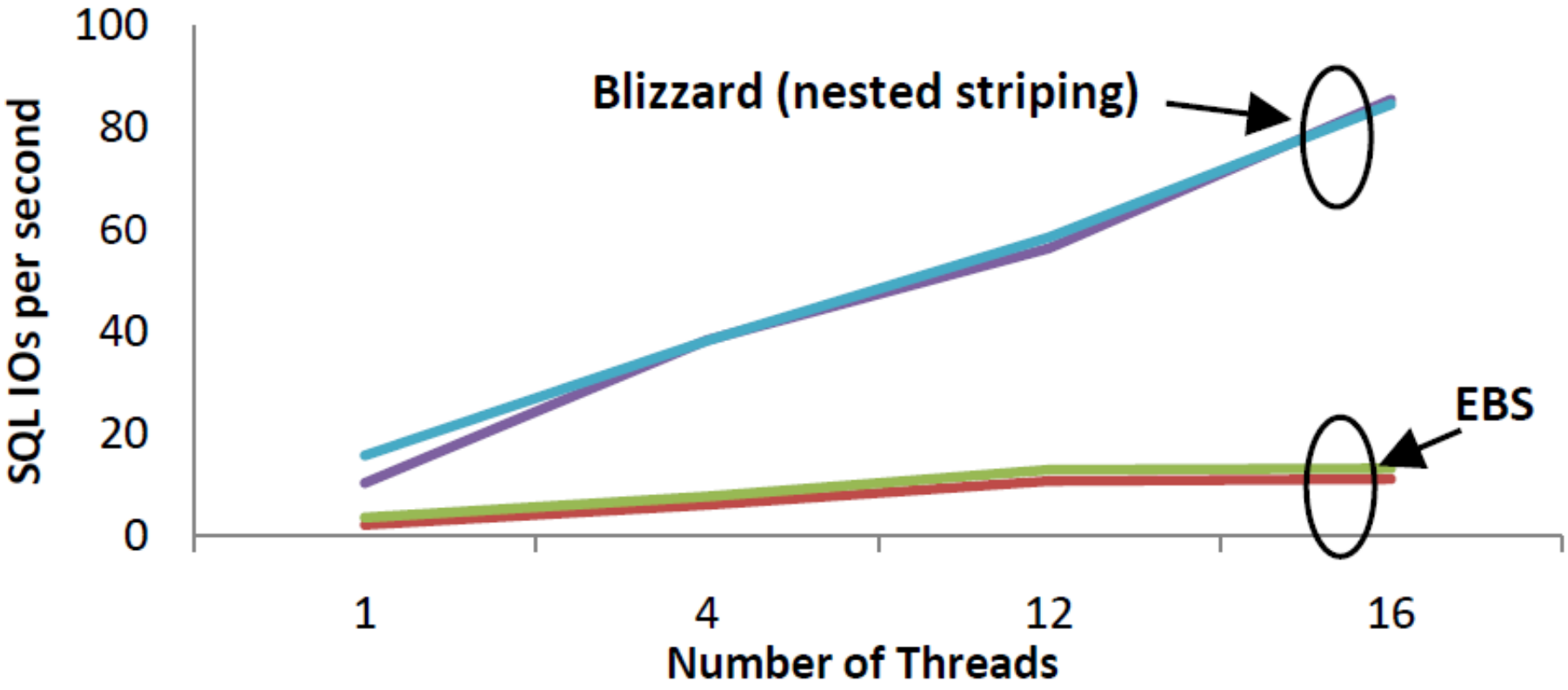
Application Macrobenchmarks



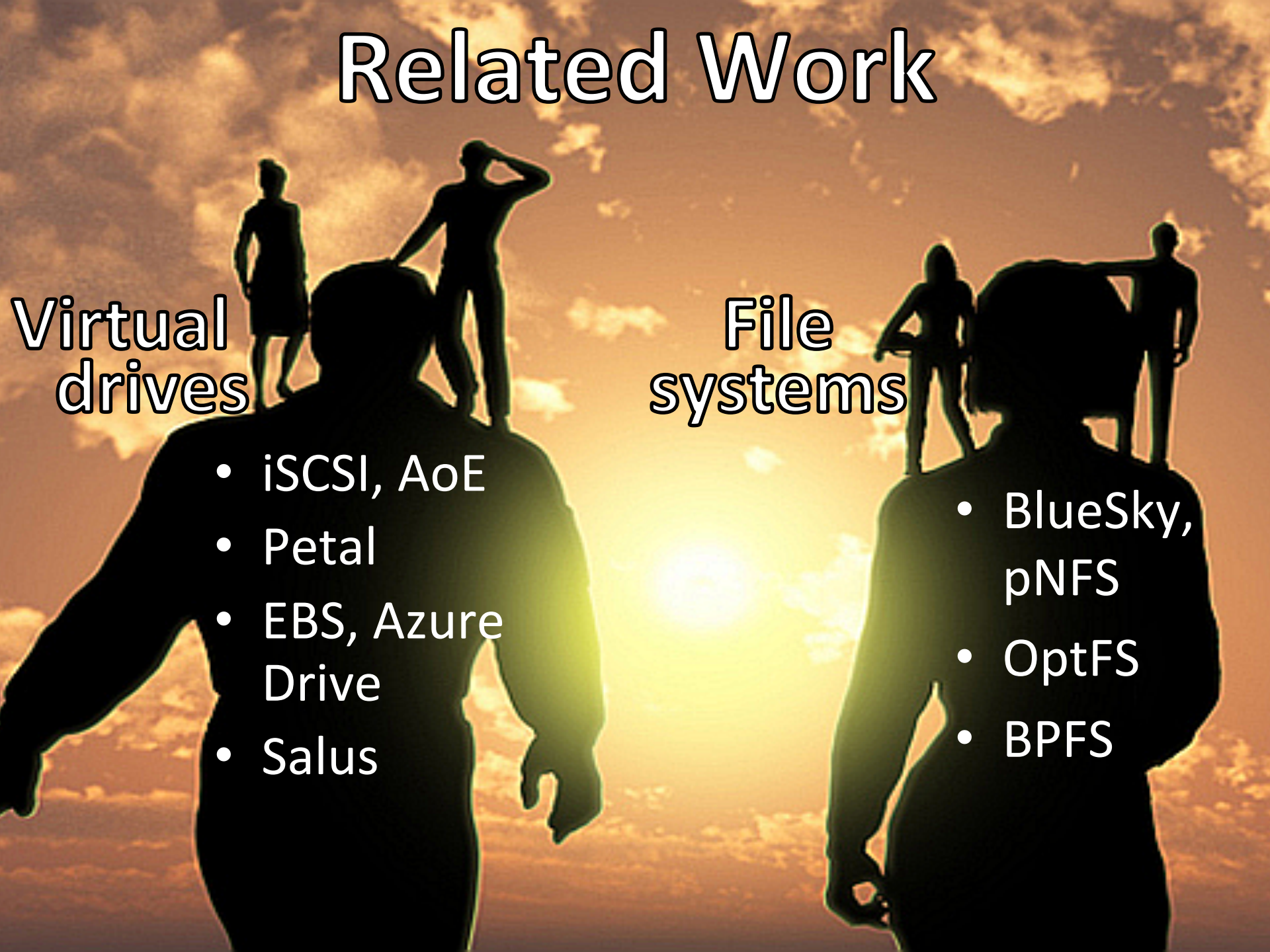
Delayed Durability: Hiding Replication Penalties



Blizzard vs EBS:
Write IOps and Read IOps



Related Work

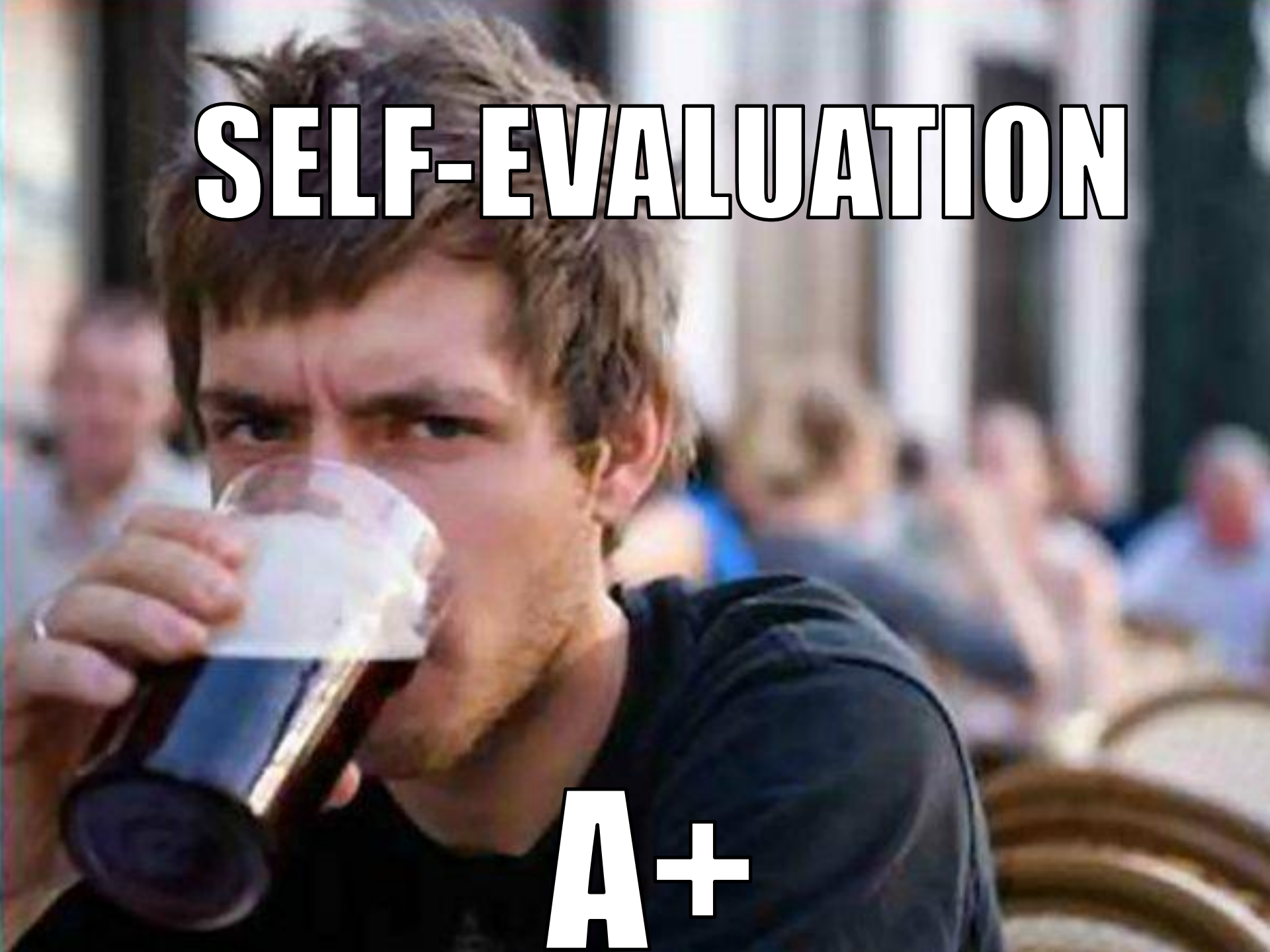


Virtual drives

- iSCSI, AoE
- Petal
- EBS, Azure Drive
- Salus

File systems

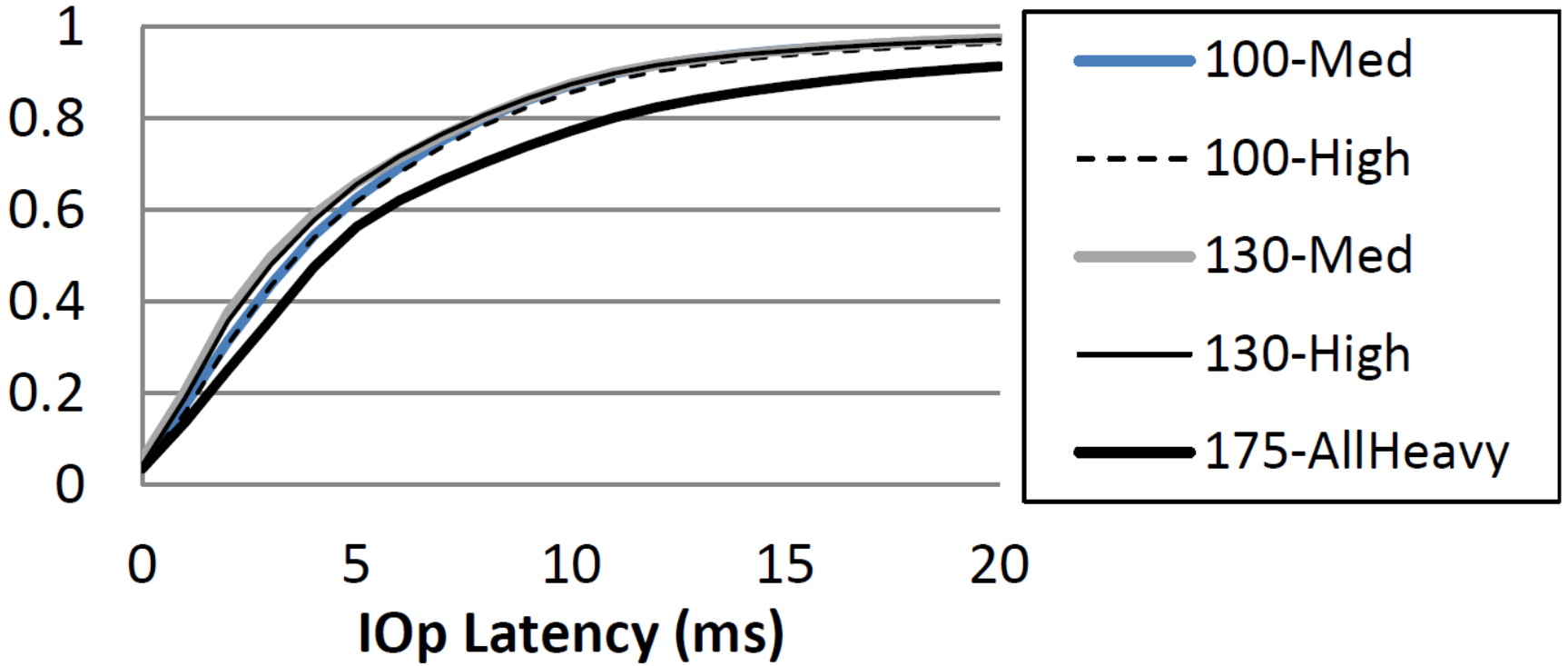
- BlueSky, pNFS
- OptFS
- BPFS


SELF-EVALUATION
A+

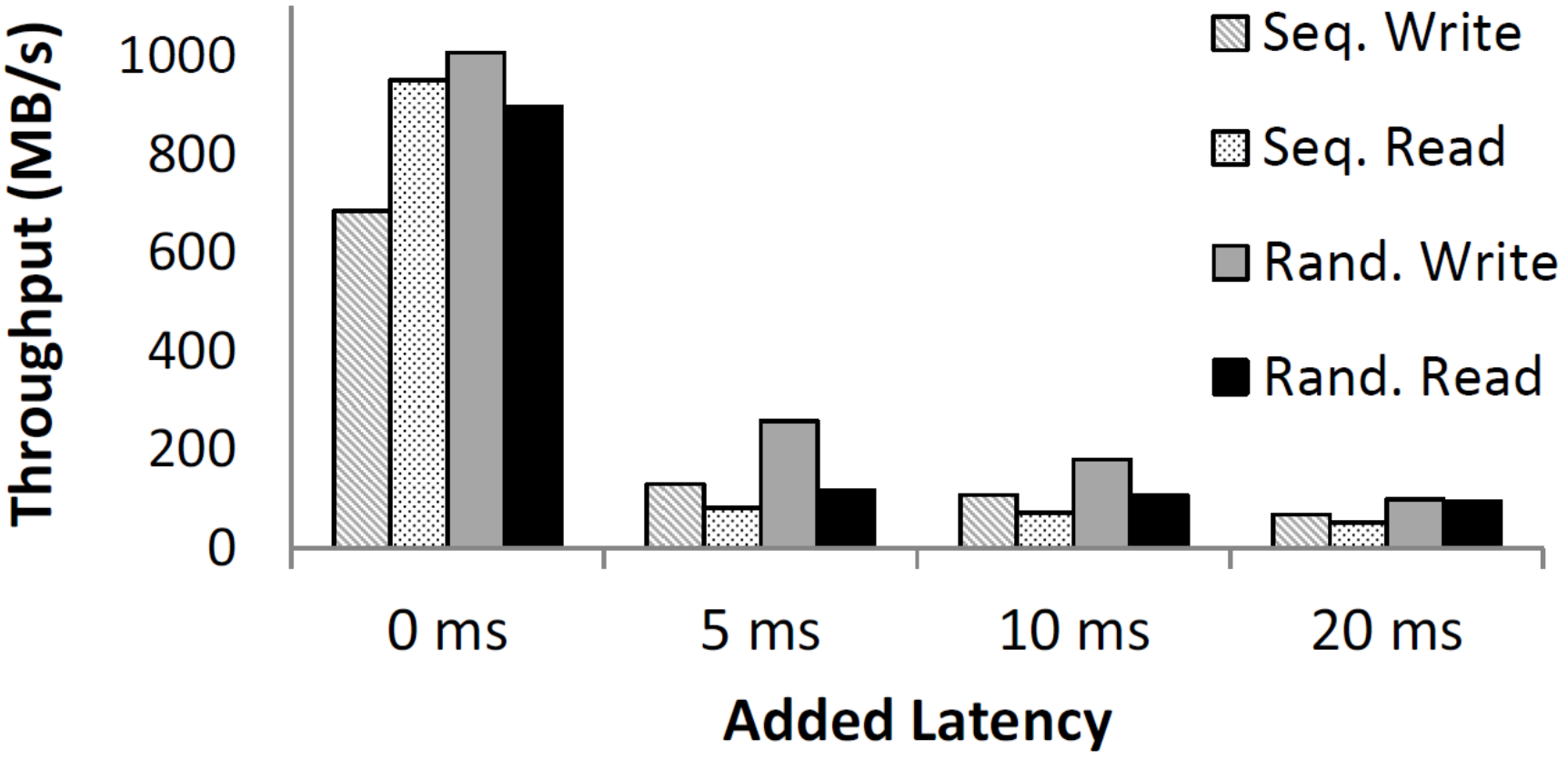
Conclusions

- Unmodified POSIX/Win32 apps can have cloud-scale IO!
  - Nested striping
  - FDS-style hardware substrate
  - Delayed durability semantics
- Raw perf: 1000+ MB/s
- 2x—10x app-level speedups

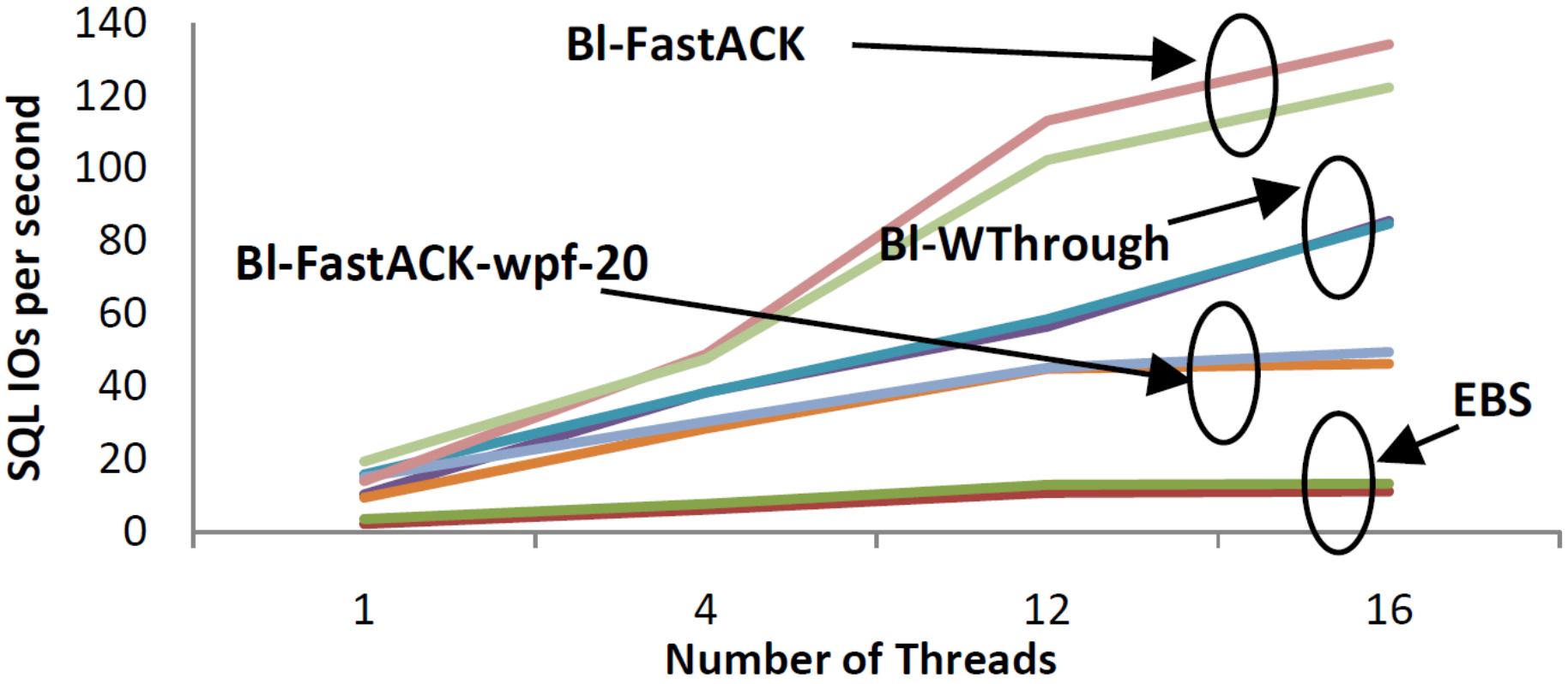
IOp Latency


1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
IOp Latency (ms)
100-Med
100-High
130-Med
130-High
175-AllHeavy

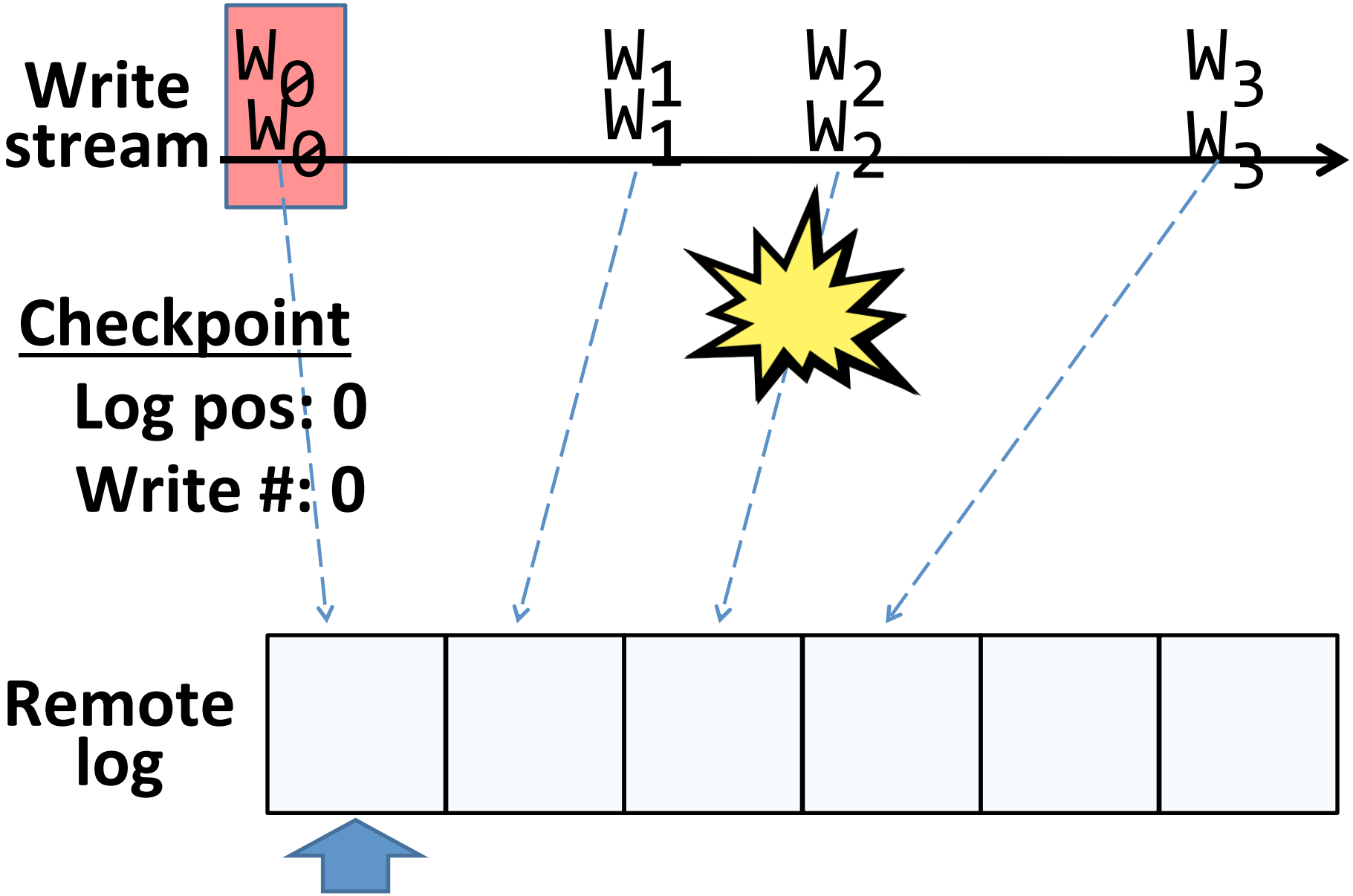
RTT Sensitivity



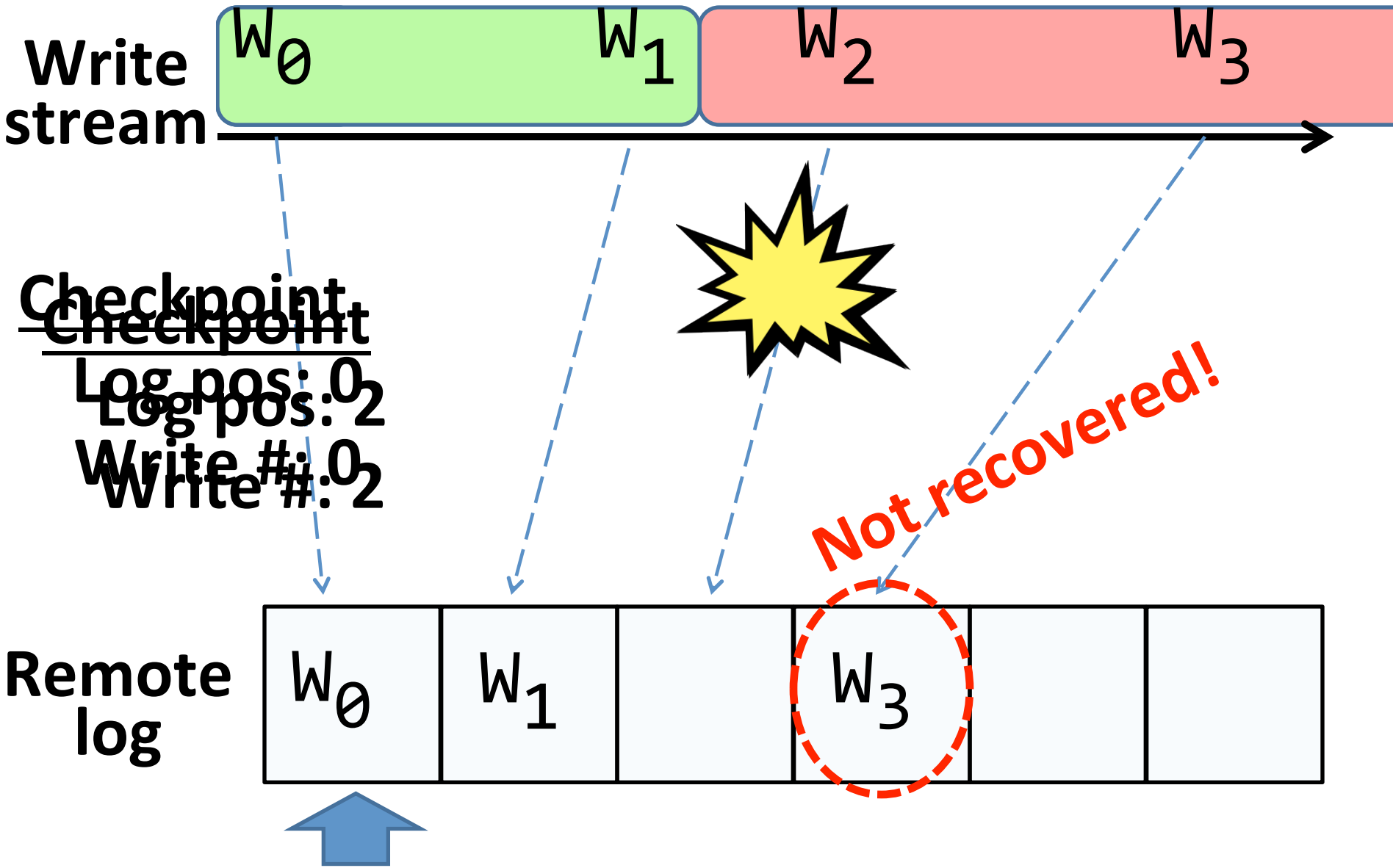
Blizzard vs. EBS



Log-Based Recovery Writes



Recovery


Write stream
W_0
W_1
W_2
W_3
Checkpoint
Log pos: 0
Write #: 0
Checkpoint
Log pos: 2
Write #: 2
Not recovered!
Remote log
W_0
W_1
W_3

Additional Details

- Blizzard maps each virtual block to backing physical block in the log
  - Allocation map included in checkpoints
- To avoid IOp dilation, use random permutation to determine next log position!

Prior example: 0, 1, 2, 3, 4, …

What Blizzard really does: $X_{n+1} = (aX_n + c) \bmod m$

(Checkpoint a, c, m, X_n)