The Last Day

CS 161: Lecture 19

4/25/17

Goals

- 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!

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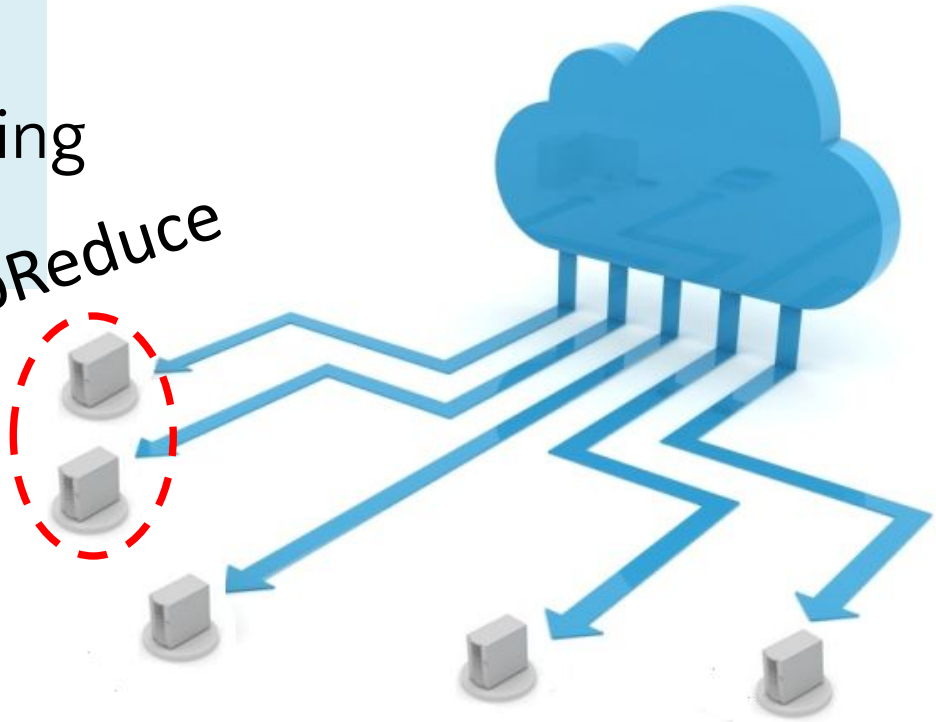
PostgreSQL

eclipse

Microsoft Exchange 2013

- Throughput > 1000 MB/s
- Scale-out architecture using commodity parts

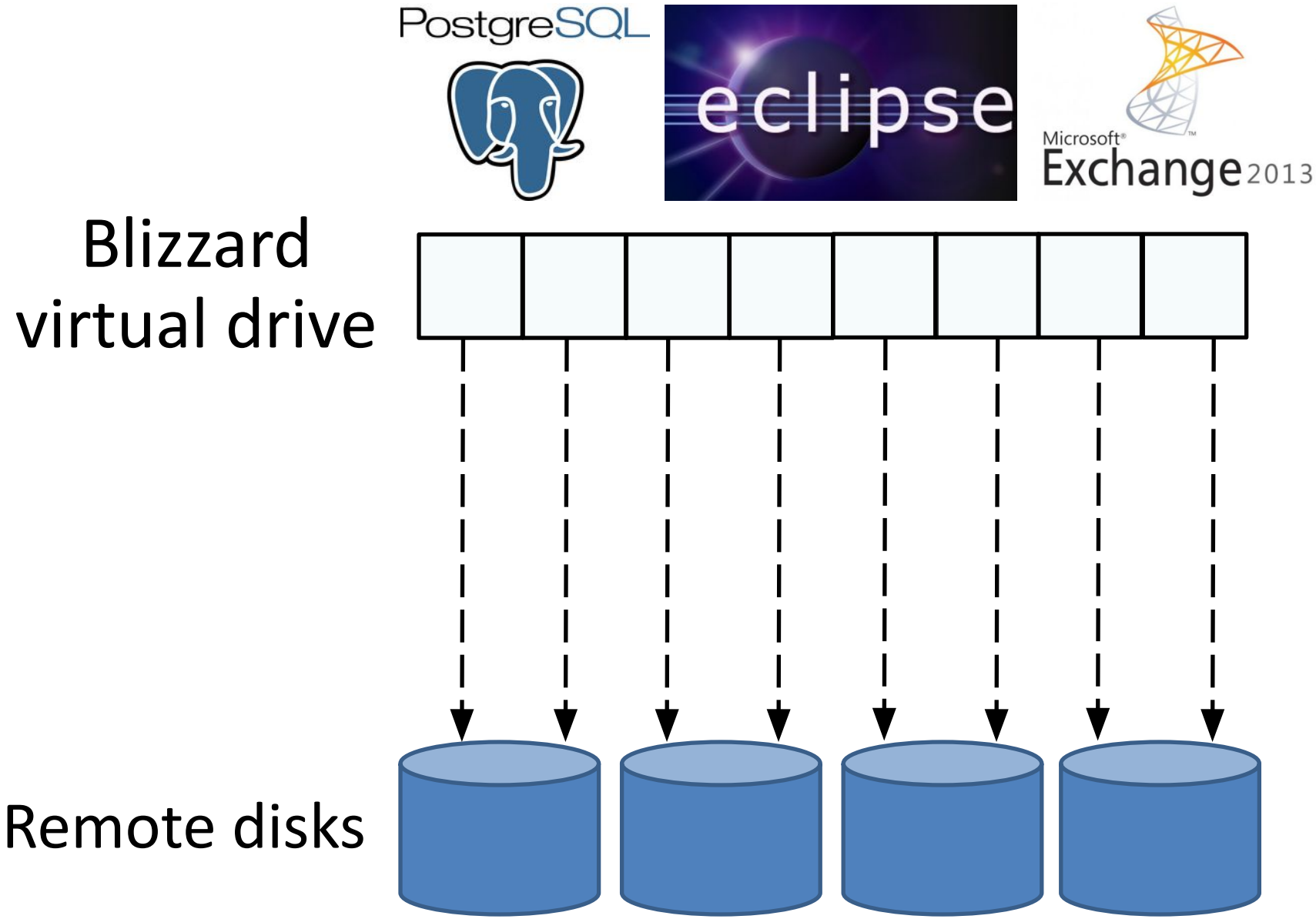
MapReduce



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)

Naïve Solution: Network RAID



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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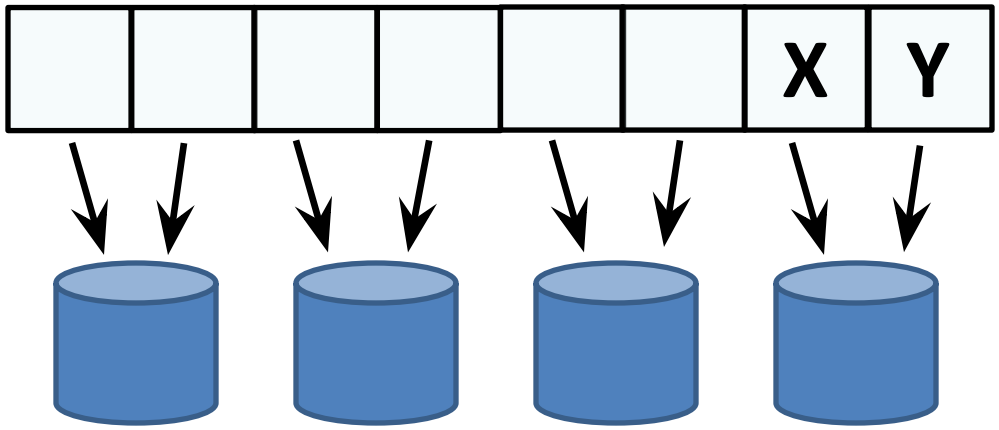
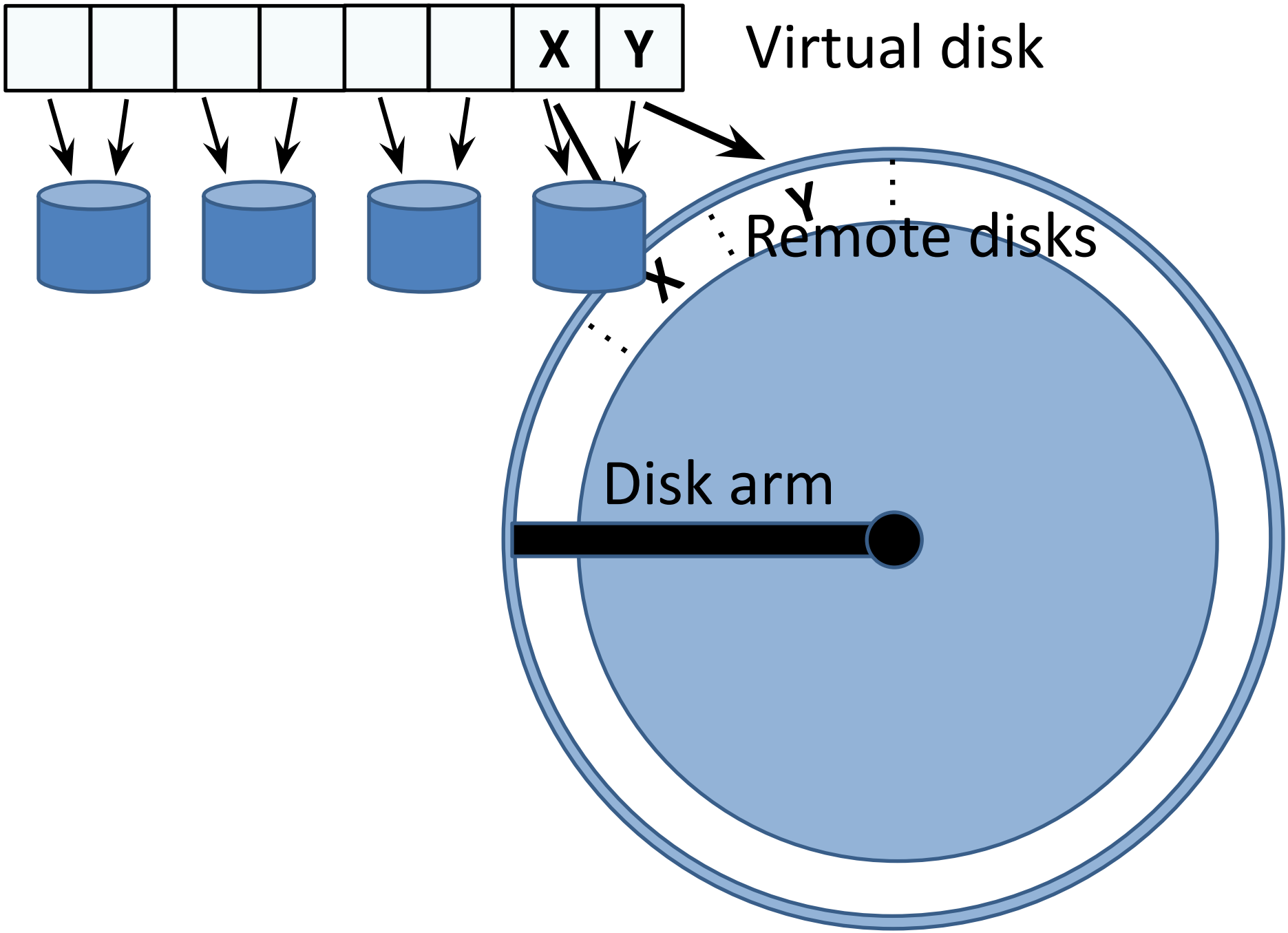
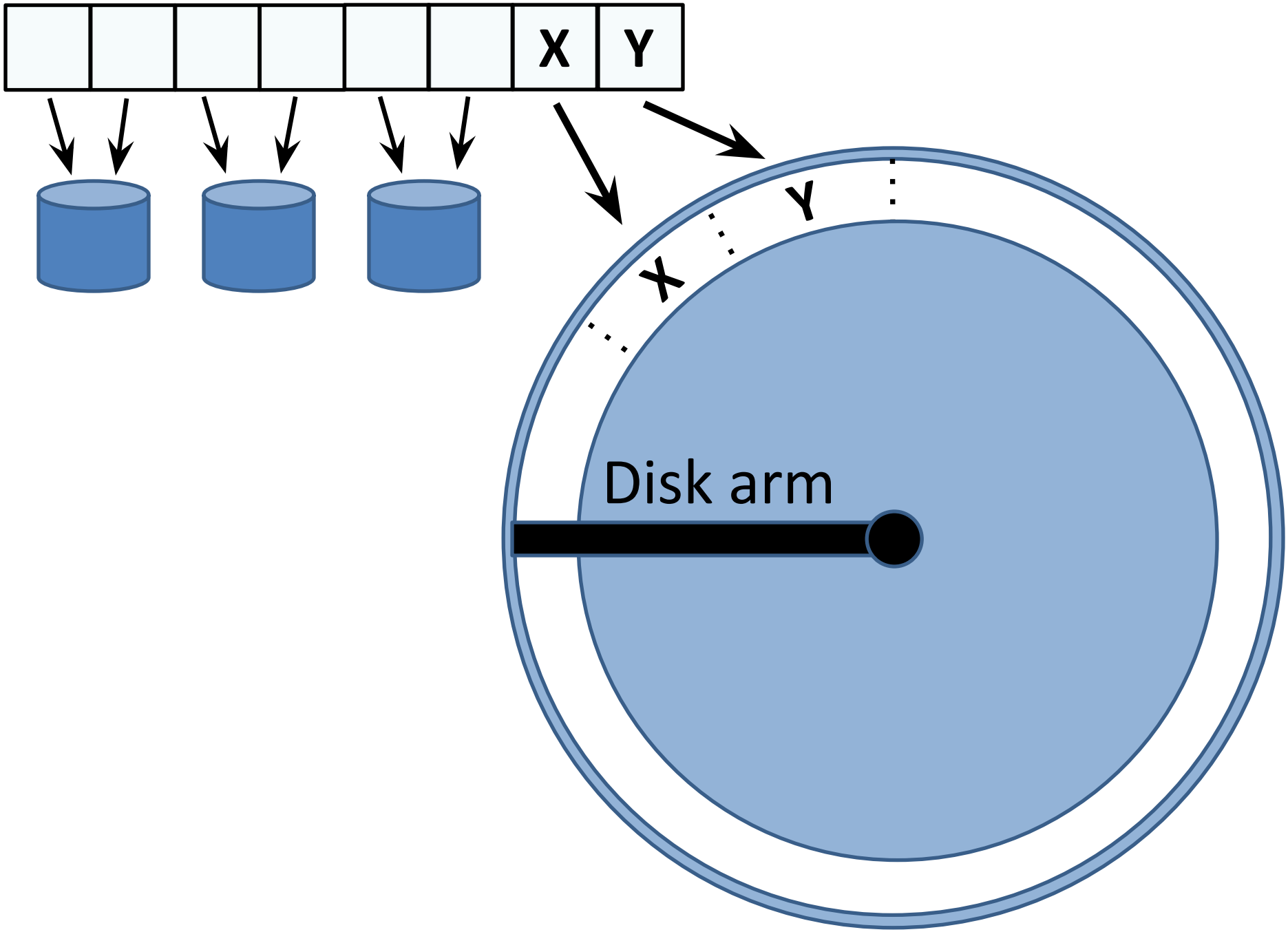


Virtual disk

Remote disks


X
Y
Virtual disk
Y
Remote disks
X
Disk arm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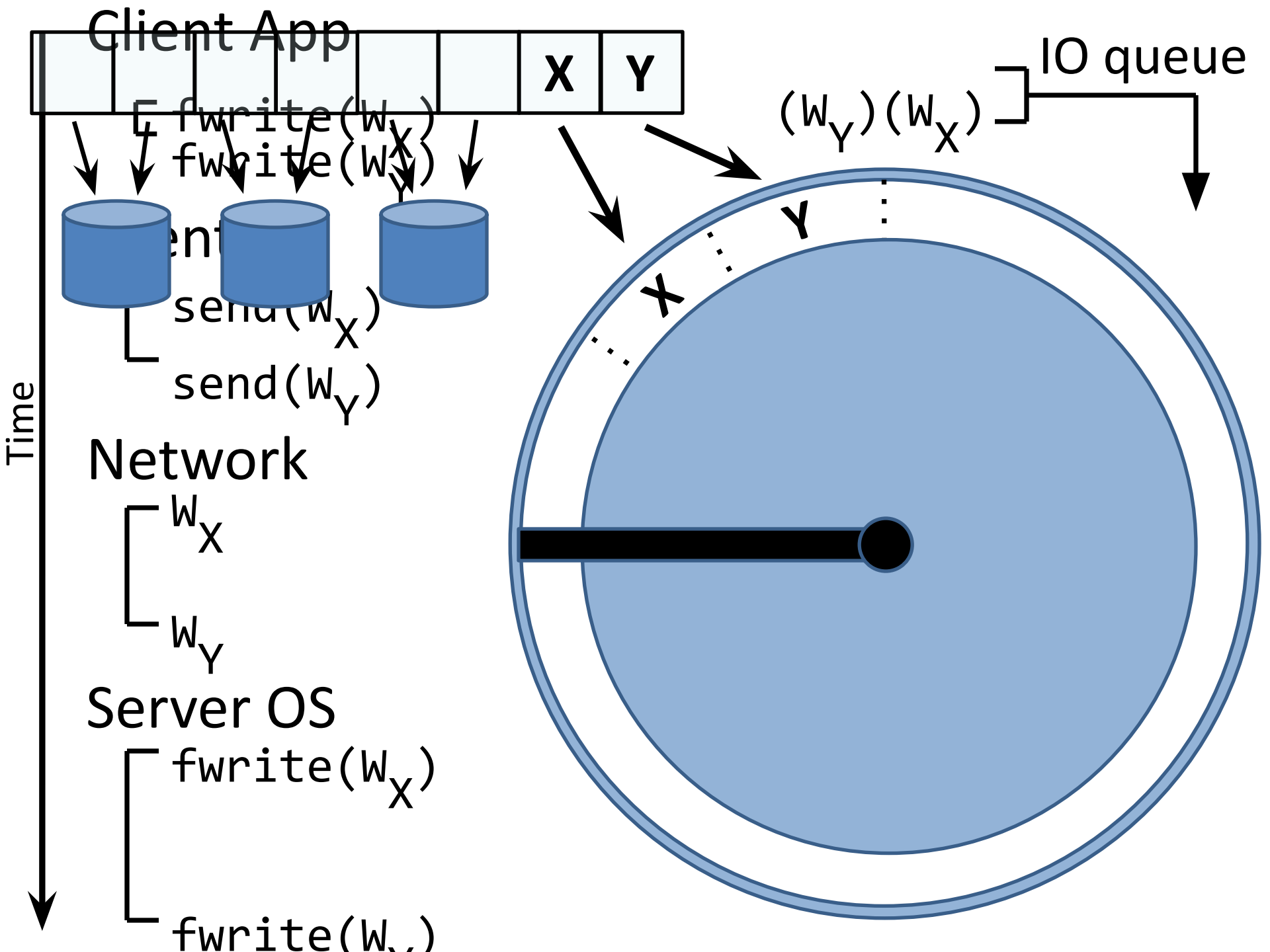

Client App
X
Y
fwrite(W_X)
fwrite(W_Y)
send(W_X)
send(W_Y)
Time
Network
W_X
W_Y
Server OS
fwrite(W_X)
fwrite(W_Y)
IO queue
(W_Y)(W_X)
Y
X

IOp Convoy Dilation

Client App

fwrite(W_X)

fwrite(W_Y)

Client OS

fwrite(W_X)

fwrite(W_Y)

Network

fwrite(W_X)

fwrite(W_Y)

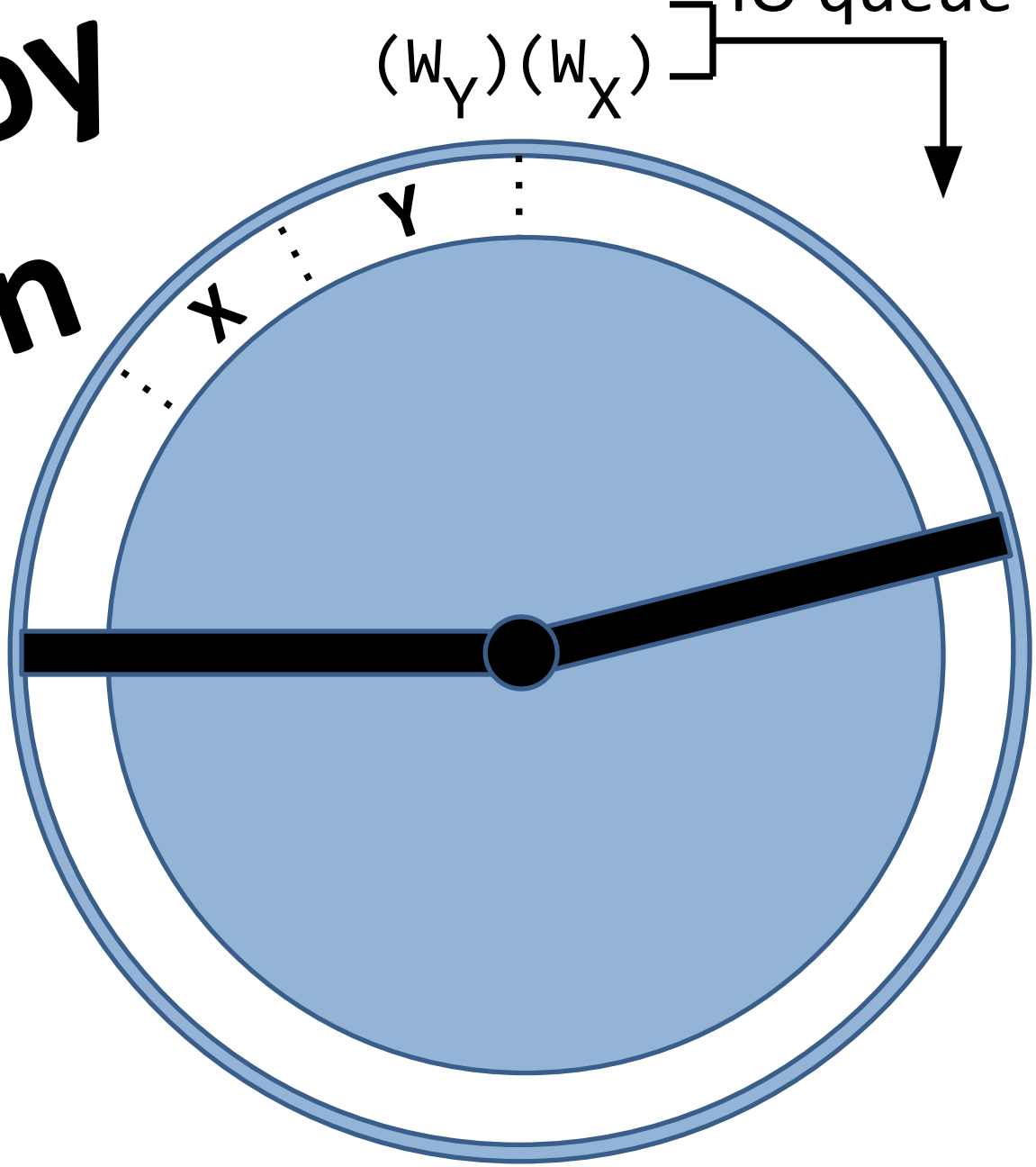
Server OS

fwrite(W_X)

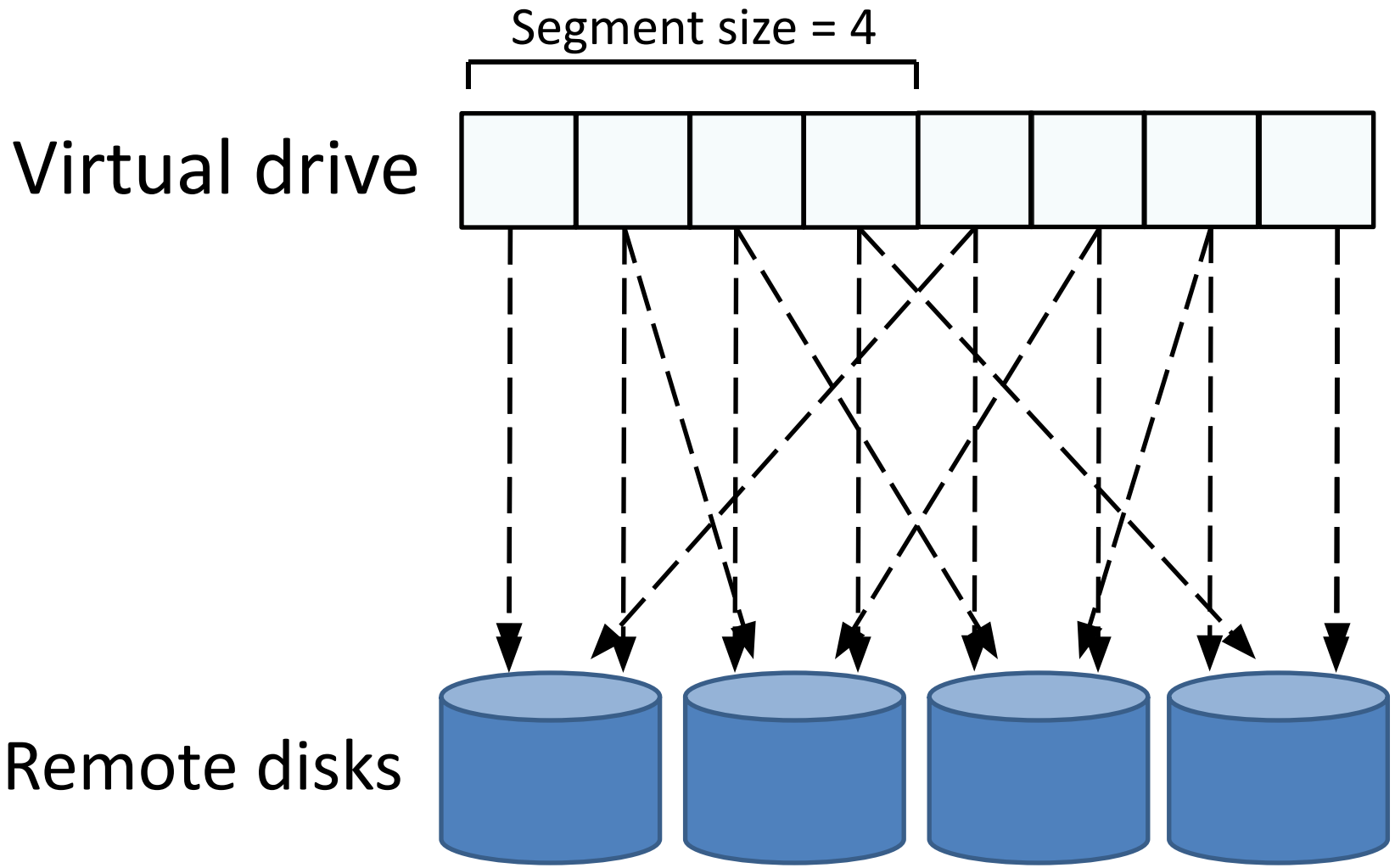
fwrite(W_Y)

Time

The two writes may have to pay two rotational latencies



Fixing IOp Convoy Dilation



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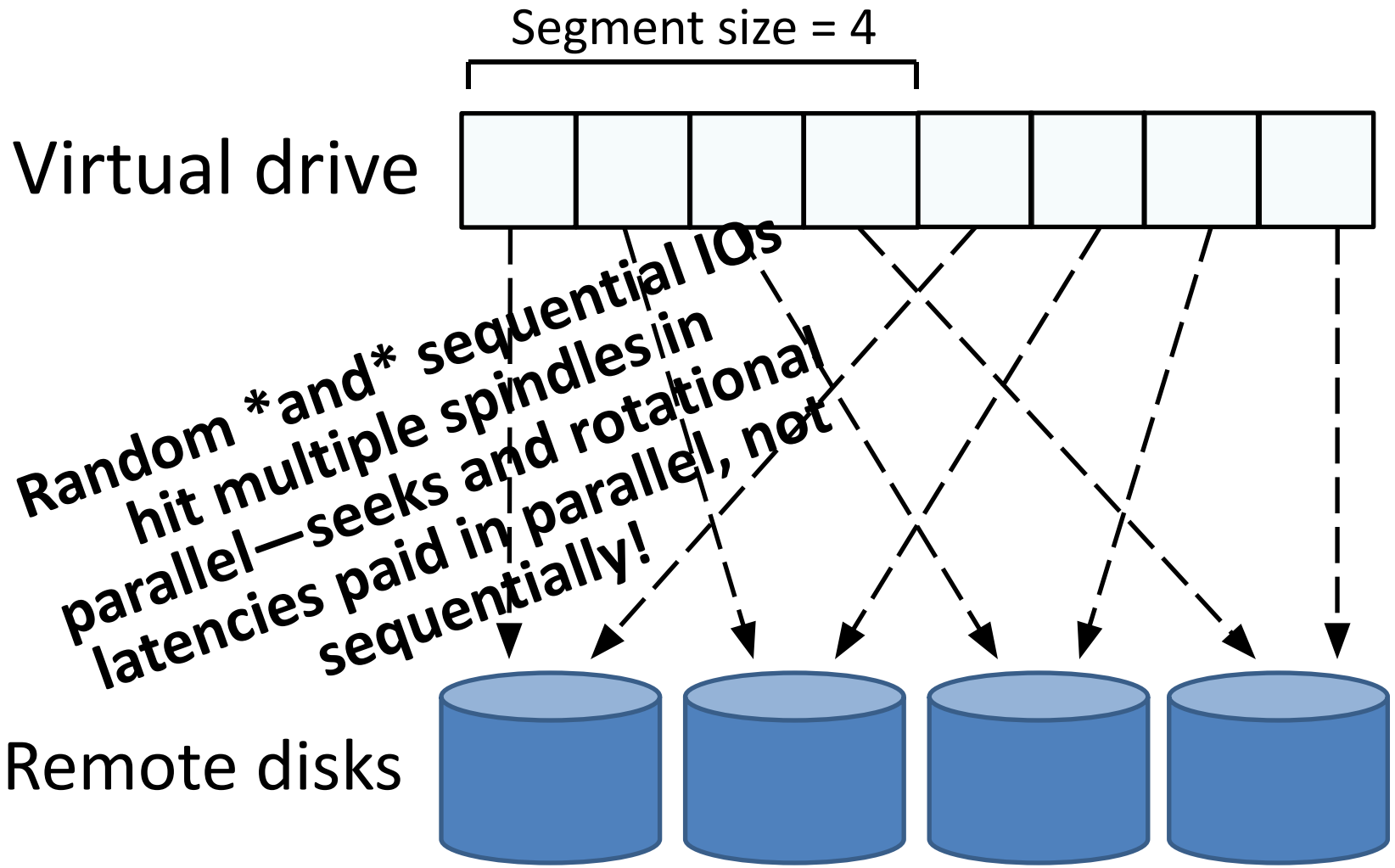
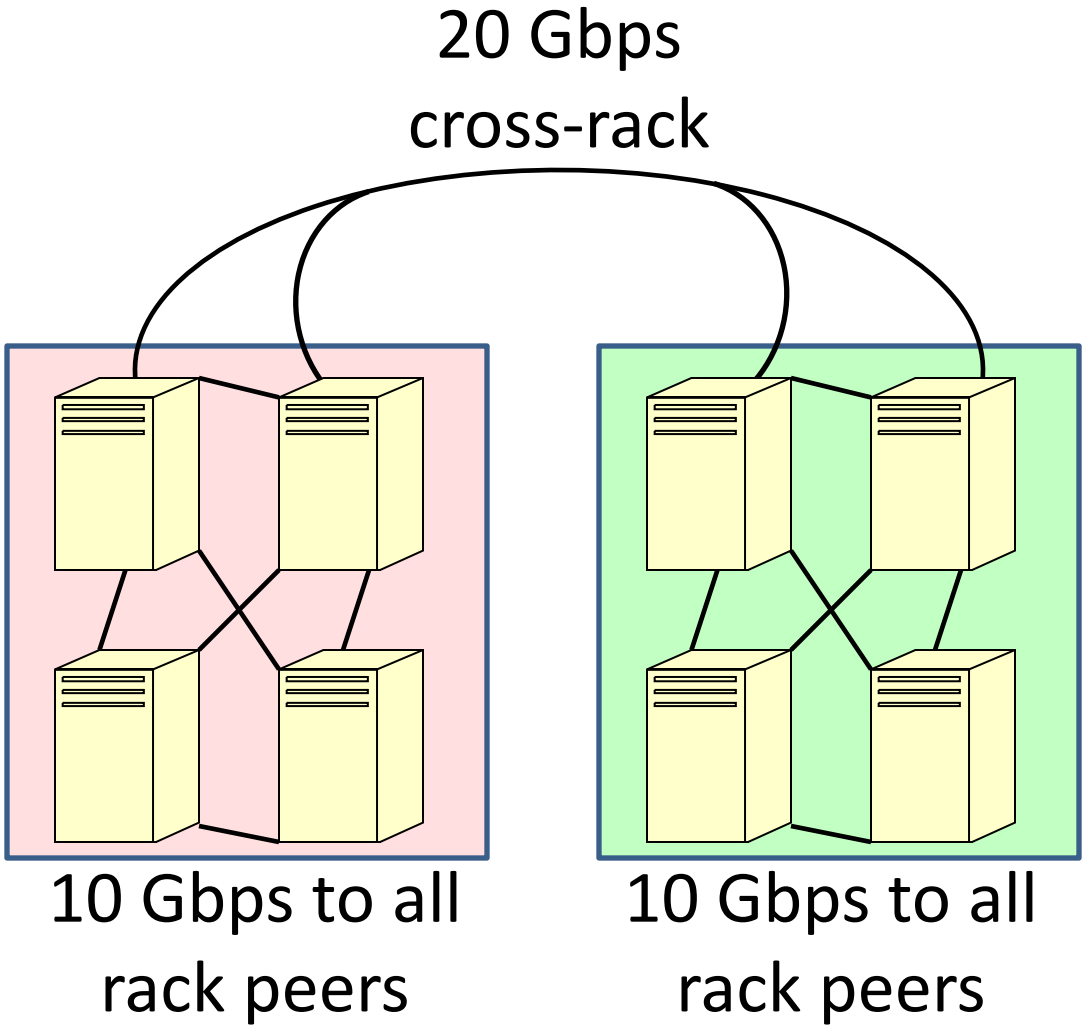
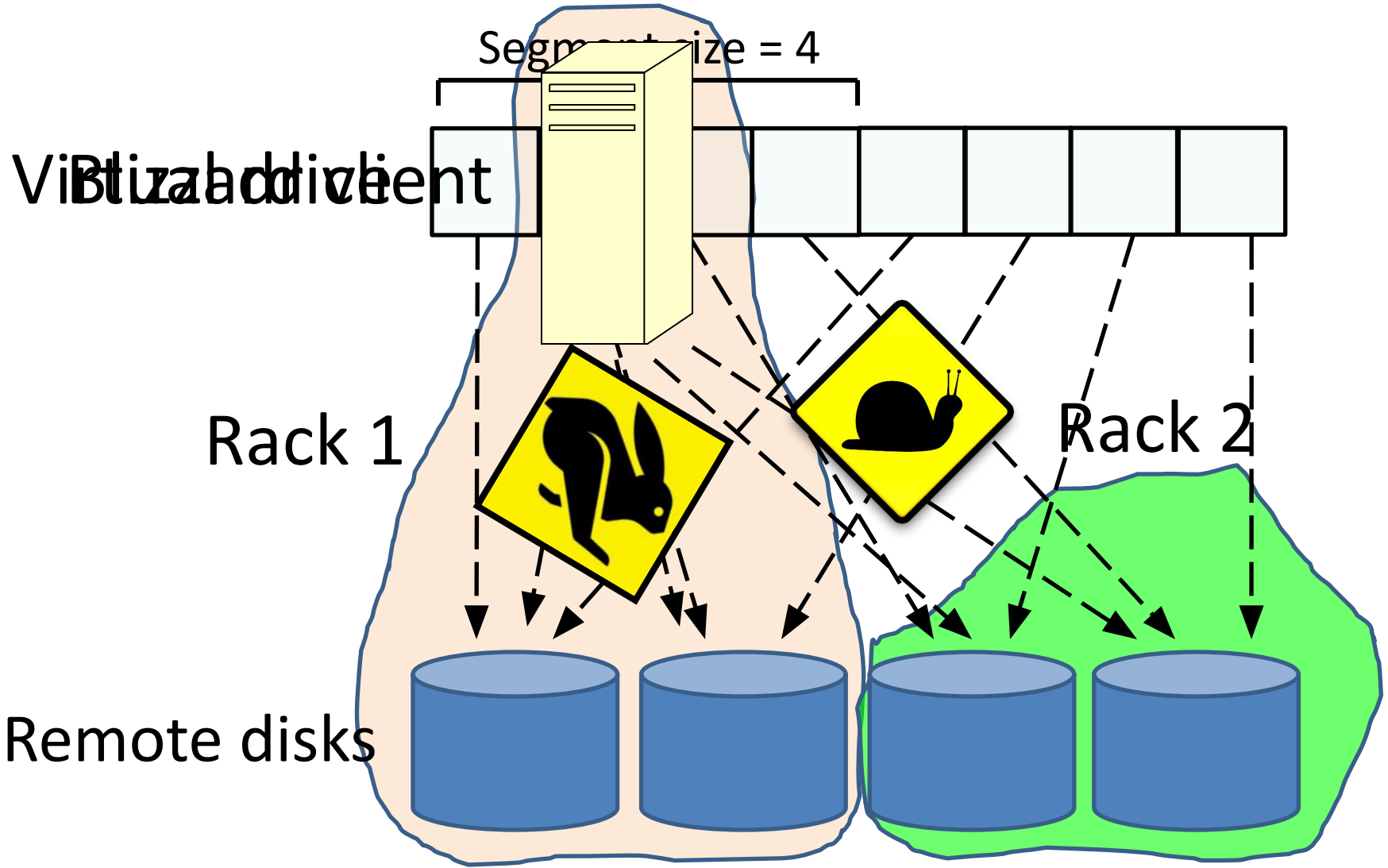


Rack Locality



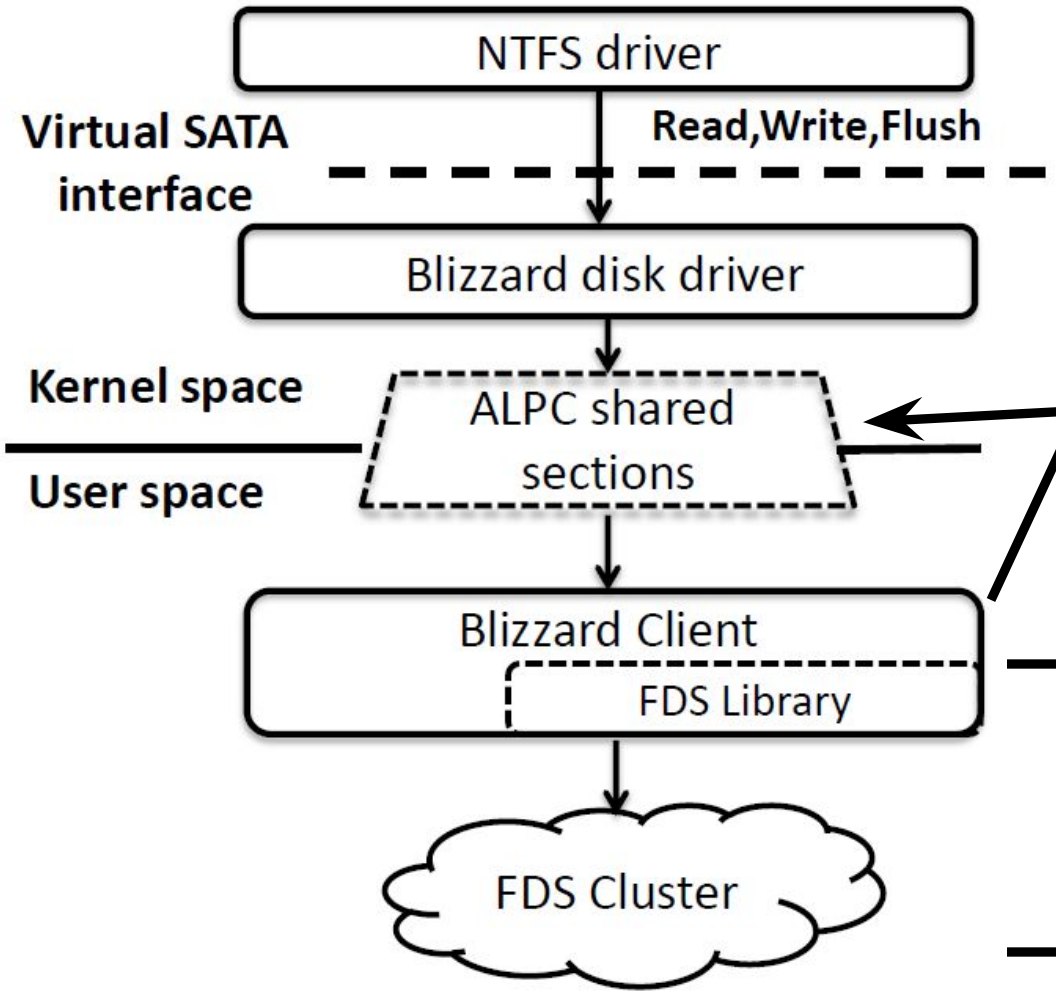
Rack Locality In A Datacenter



Flat Datacenter Storage (FDS)

- Idea 1: Build a datacenter network with full-bisection bandwidth (i.e., no oversubscription)
  - Half of the servers can simultaneously communicate with the other half, and the network won't melt
  - In other words, the core of the network has enough bandwidth to handle ½ the sum of the servers' NIC speeds
- Idea 2: Give each server enough NICs to be able to read/write the server's disks at full sequential speeds
  - Ex: If one disk has sequential r/w bandwidth of 128 MB, and a server has 10 disks, give the server 10 x 128 MB = 10 Gbps NIC
- Result: Locality-oblivious remote storage
  - Any server can access any disk as fast as if the disk were local (assuming datacenter RTTs << than seek+rotational delays)
  - FDS is useful for big data applications like MapReduce too!

Blizzard as FDS Client



Blizzard client handles:

- Nested striping
- Delayed durability semantics

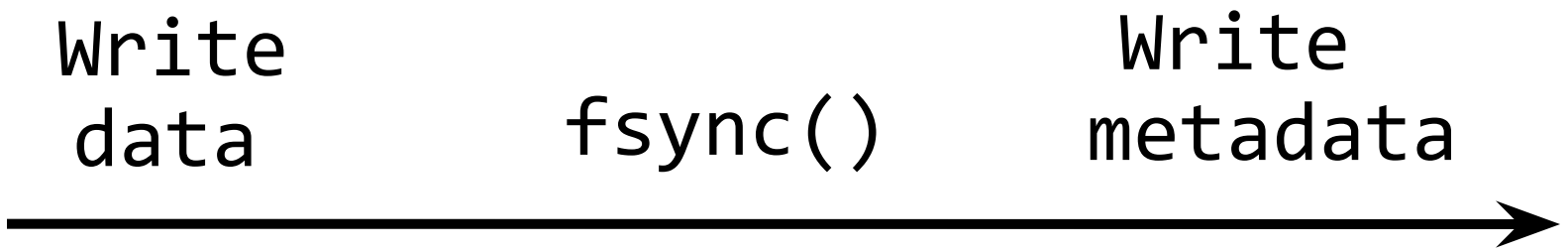
Zero-copy buffer shared by kernel and user-level code!

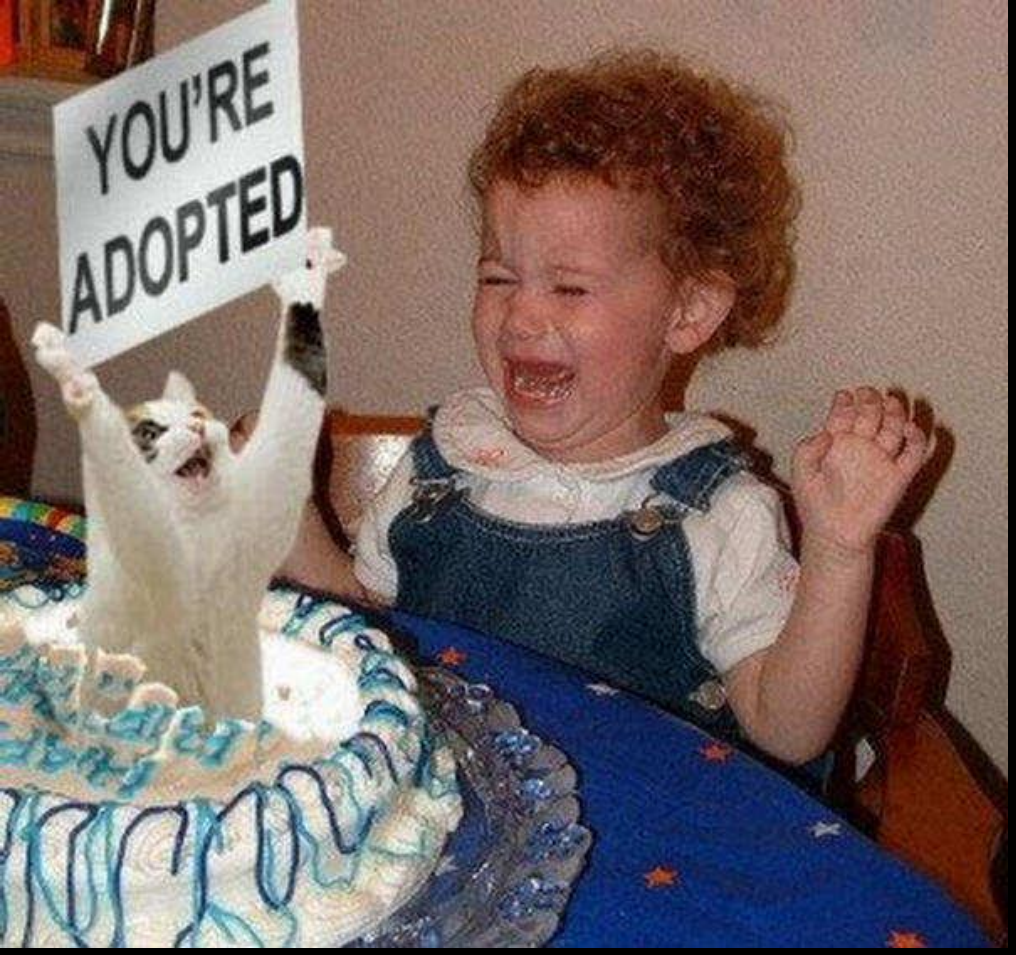
FDS provides:

- Locality-oblivious storage
- RTS/CTS to avoid edge congestion

The problem with fsync()

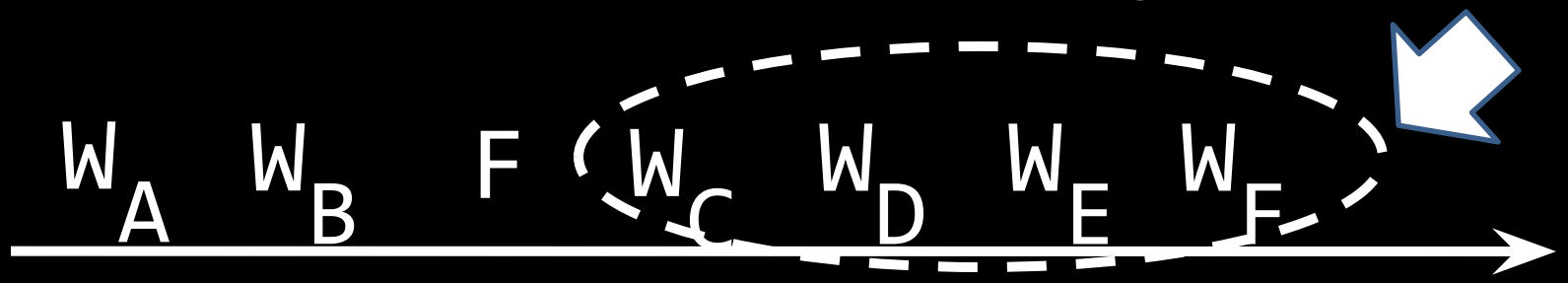
- Used by POSIX/Win32 file systems and applications to implement crash consistency
  - On-disk write buffers let the disk acknowledge a write quickly, even if the write data has not been written to a platter!
  - In addition to supporting read() and write(), the disk also implements flush()
    - The flush() command only finishes when all writes issued prior to the flush() have hit a platter
  - fsync() system call allows user-level code to ask the OS to issue a flush()
  - Ex: ensure data is written before metadata





WRITE BARRIERS RUIN BIRTHDAYS

Stalled operations limit parallelism!



Delayed Durability in Blizzard's Virtual Drive

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

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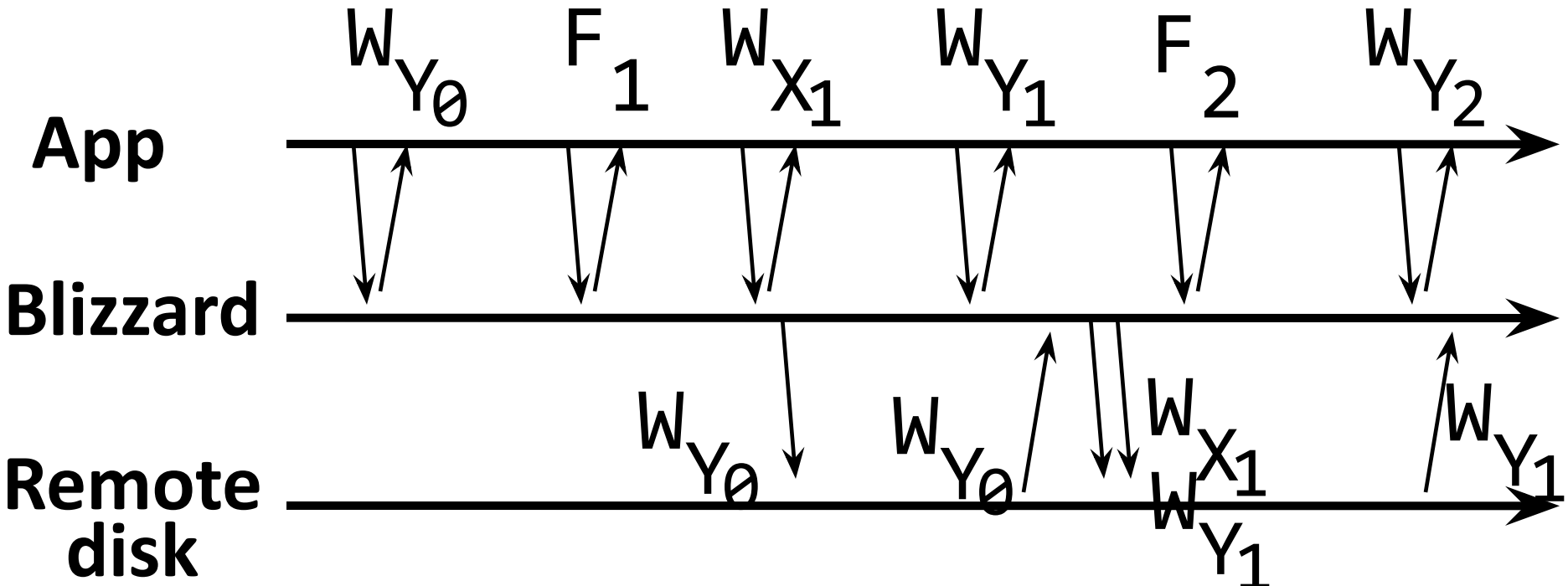
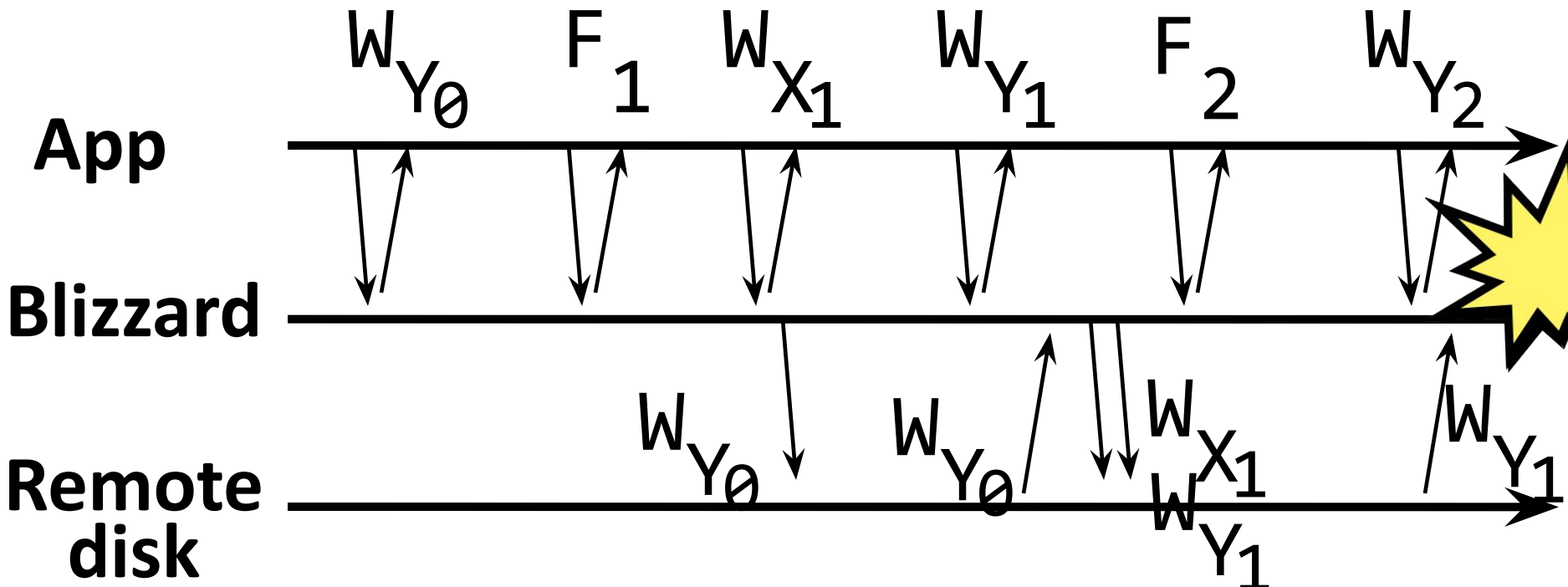
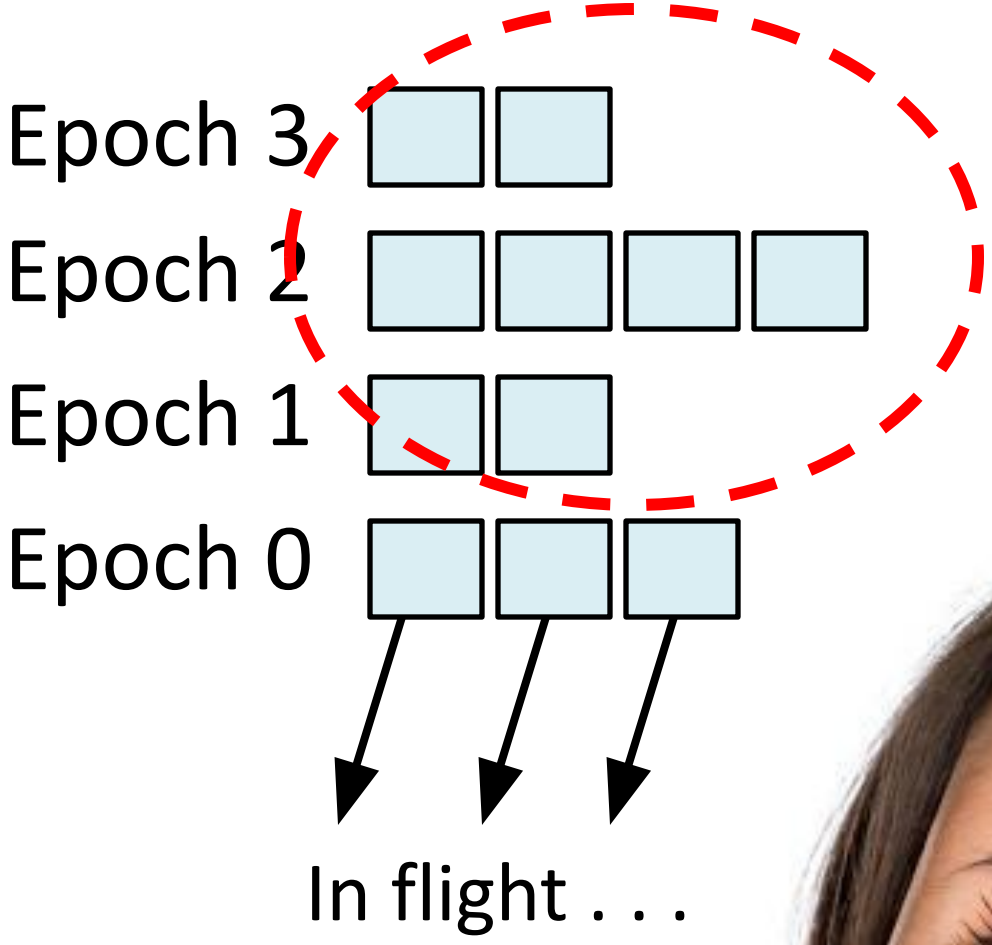


Delayed Durability in Blizzard's Virtual Drive

- All writes are acknowledged . . .
- . . . but only W_{Y0} and W_{Y1} are durable!
- Satisfies prefix consistency
- Decouple durability from ordering
  - All epochs up to N–1 are durable
  - Some, all, or no writes from epoch N are durable
  - No writes from later epochs are durable
- Acknowledge flush() immediately . . .
  - but in-memory flush epoch
  - Tag writes with their epoch number
  - Asynchronously retire writes in epoch order
- Prefix consistency is good enough for most apps, provides much better performance!

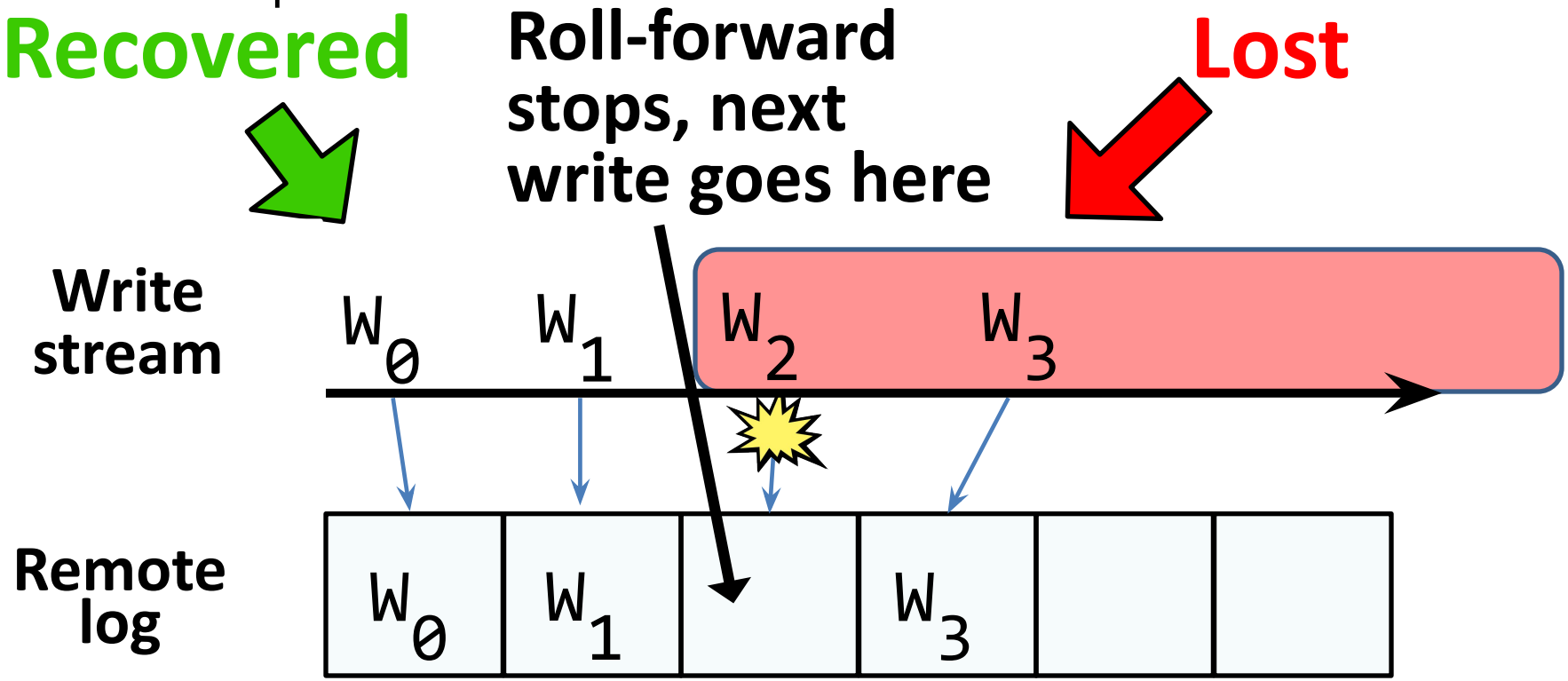


Isn't Blizzard buffering a lot of data?

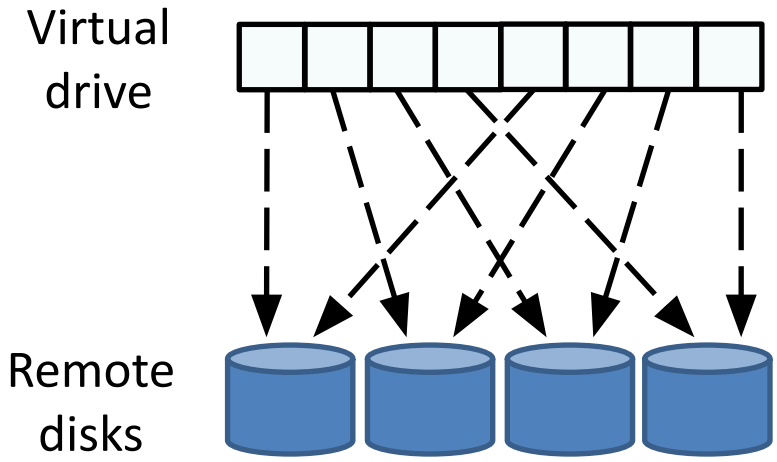


Log-based Writes

- Treat backing FDS storage as a distributed log
  - Issue block writes to log immediately and in order
  - Blizzard maintains a mapping from logical virtual disk blocks to their physical location in the log
  - On failure, roll forward from last checkpoint and stop when you find torn write, unallocated log block with old epoch number



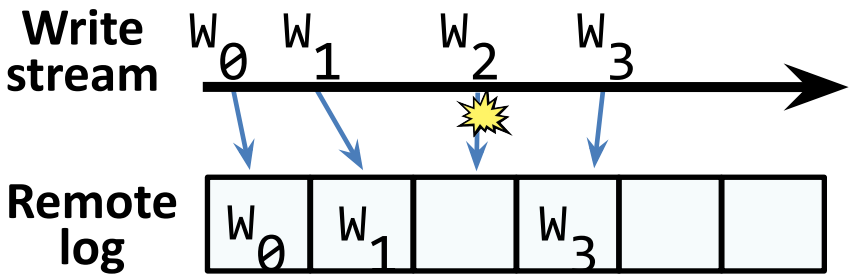
Summary of Blizzard's Design



- Problem: IOp Dilation
- Solution: Nested striping

FDS

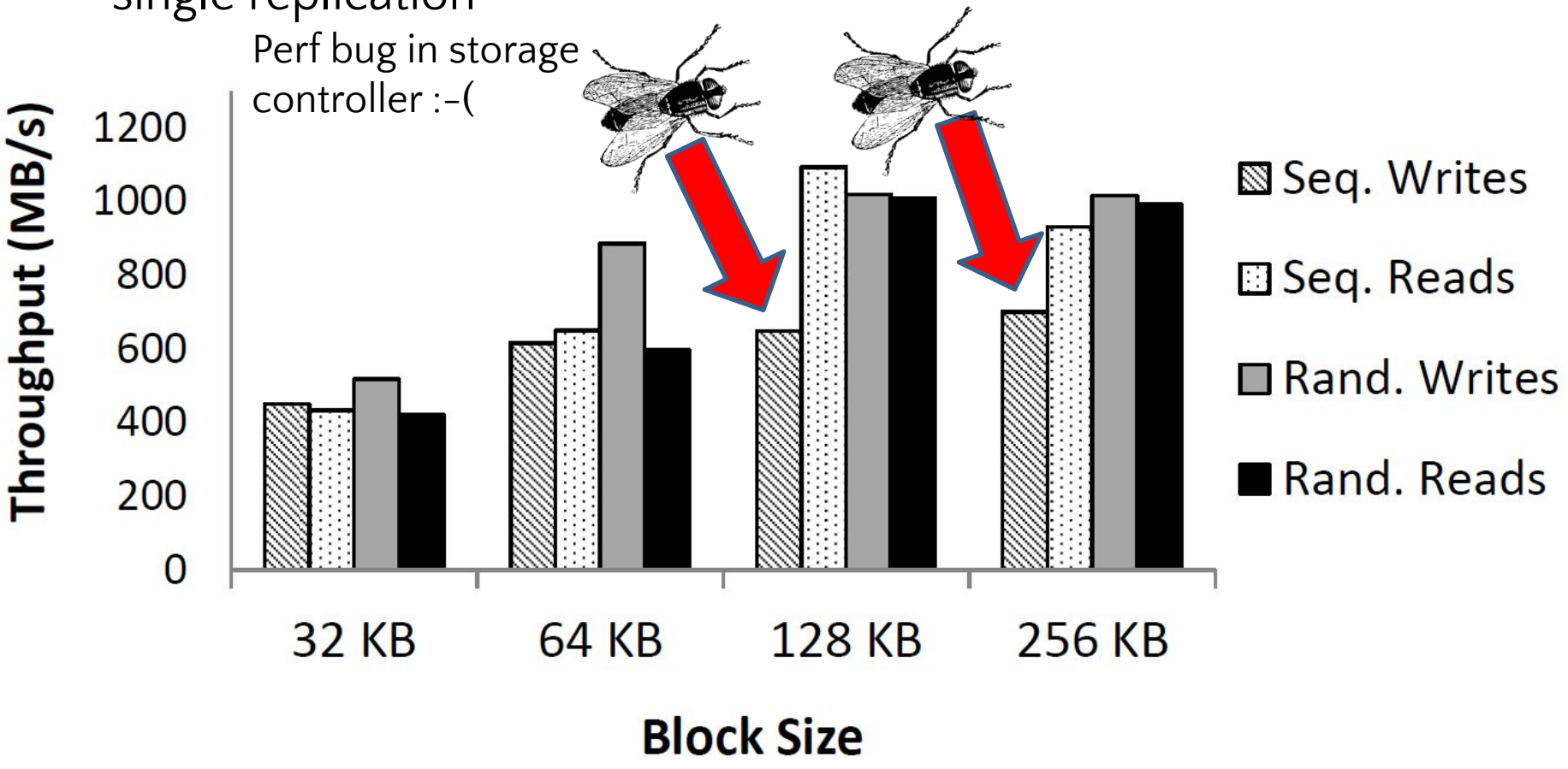
- Problem: Rack locality constrains parallelism
- Solution: Full-bisection networks, match disk and network bandwidth



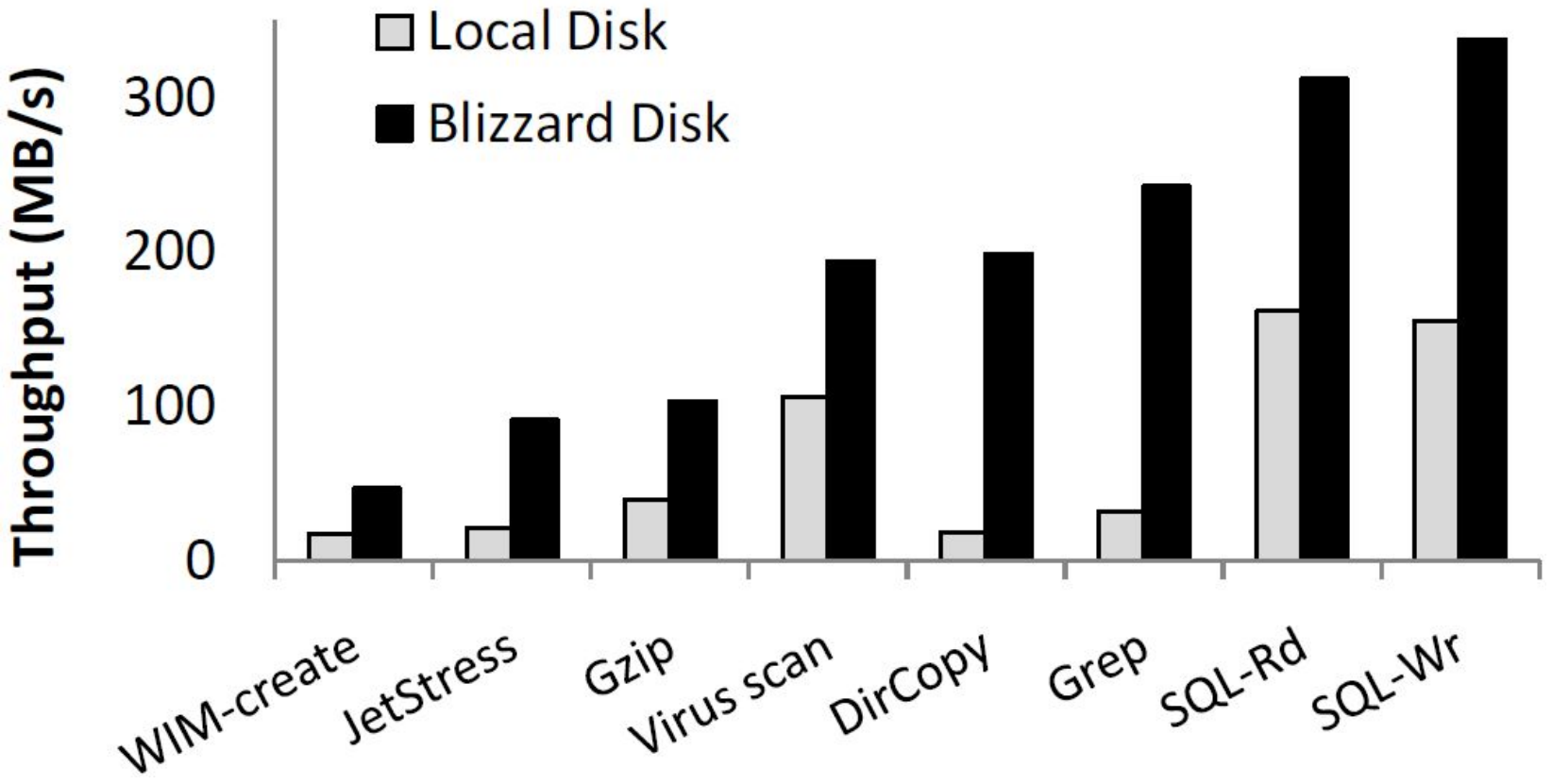
- Problem: Evil fsync()s
- Solution: Delayed durability (note that the log is nested-striped)

Throughput Microbenchmark

- Application issues a bunch of parallel reads or writes
  - In this experiment, we use nested striping but synchronous write-through (i.e., no delayed durability tricks—a write does not complete until it is persistent)
  - Blizzard virtual disk backed by 128 remote physical disks, and used single replication



Application Macrobenchmarks (Write-through, Single Replication)



Delayed Durability: Hiding Replication Penalties

fa="fast acknowledgment" (i.e., delayed durability but no log-based writes)

Just as fast as fast ack, but has to buffer less data (and thus loses less data after crash)