Cold Storage

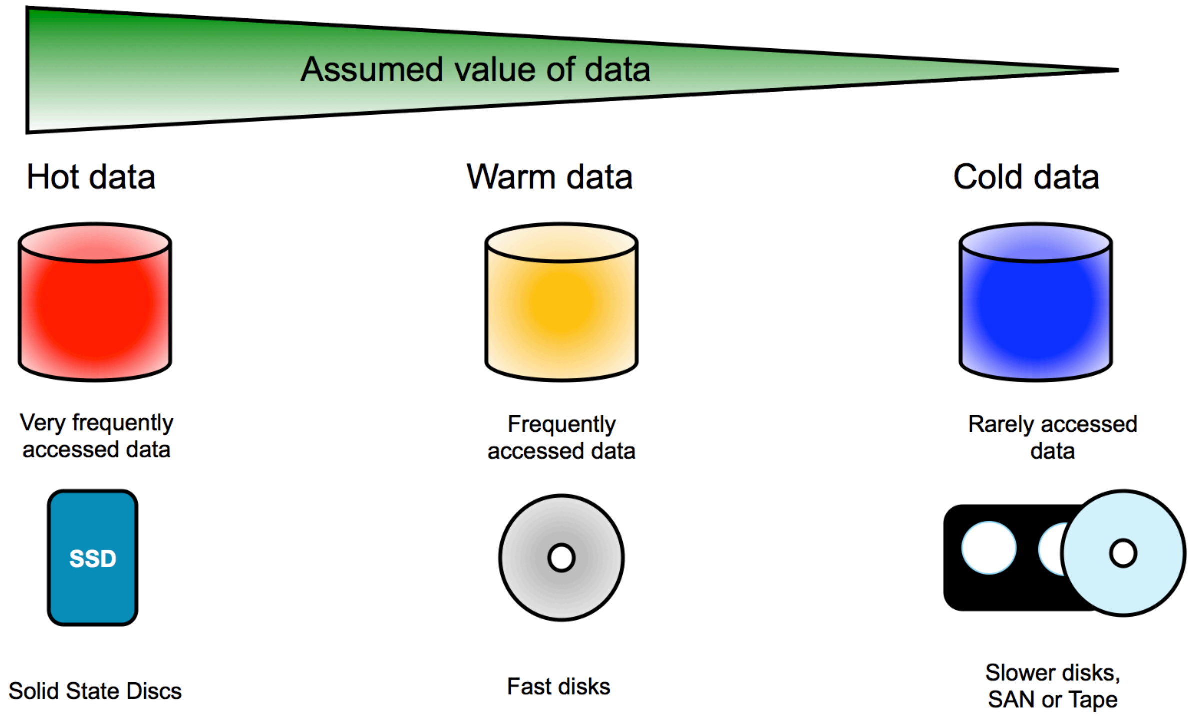
Imperial College London

SCALE LAB

Data – Size and temperature!

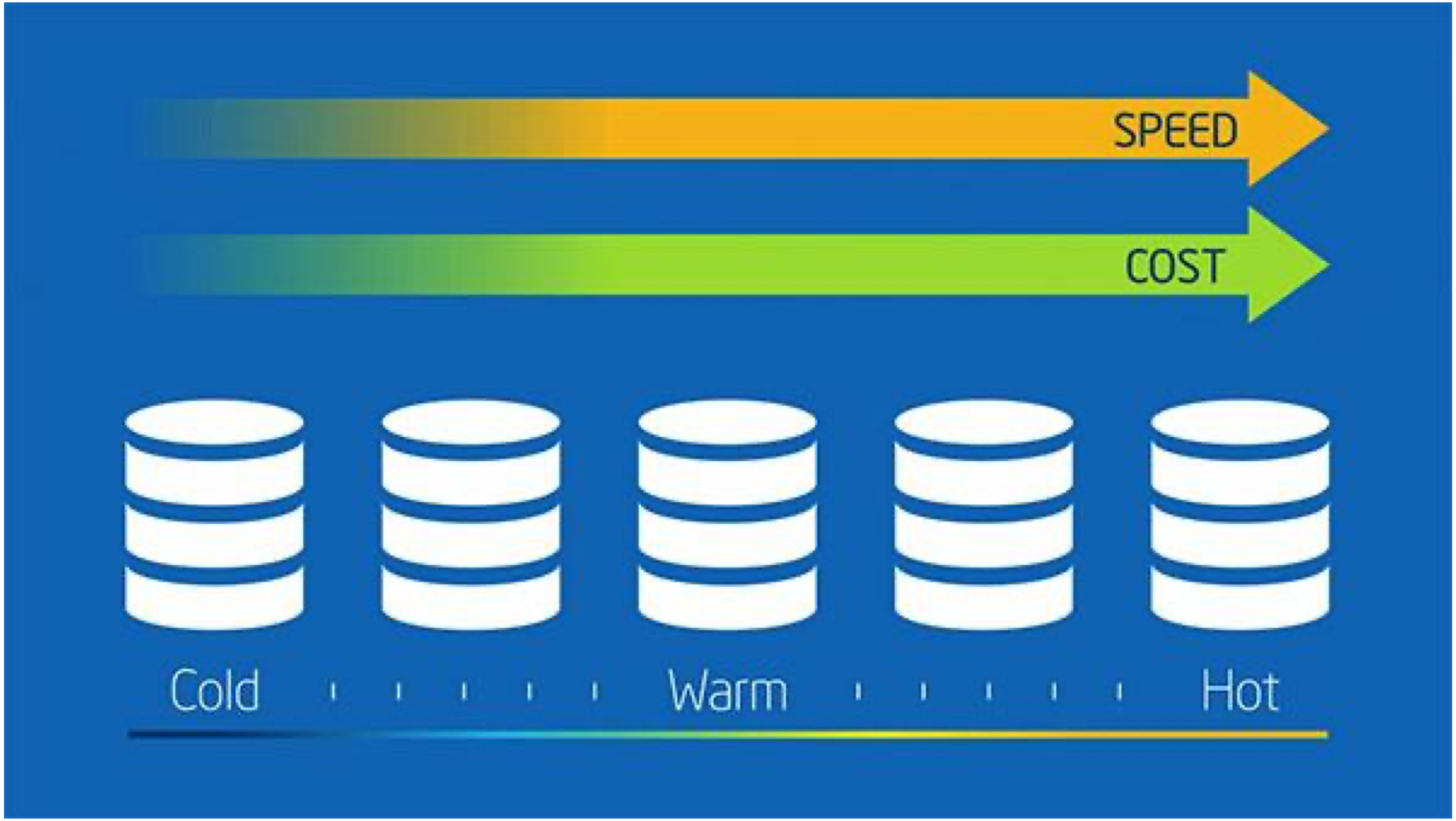
- Data grows in size
- Most of the data gets COLD
  - Infrequently accessed
- Objective:
  - High Performance
  - Low Cost

➔ Price/Performance tradeoff

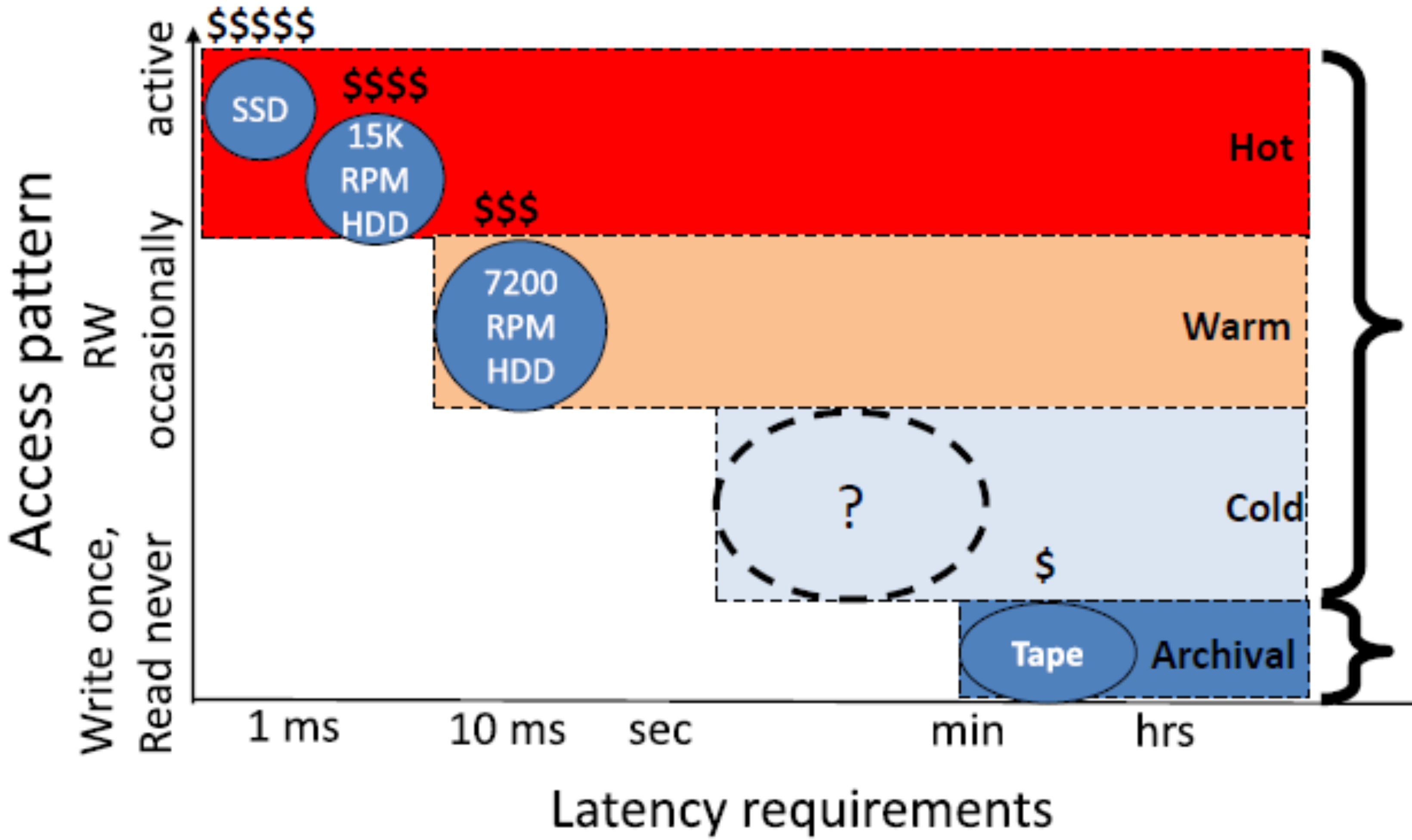


* Image retrieved from: https://goo.gl/o7GGcp

Data in the cloud



Price versus Latency



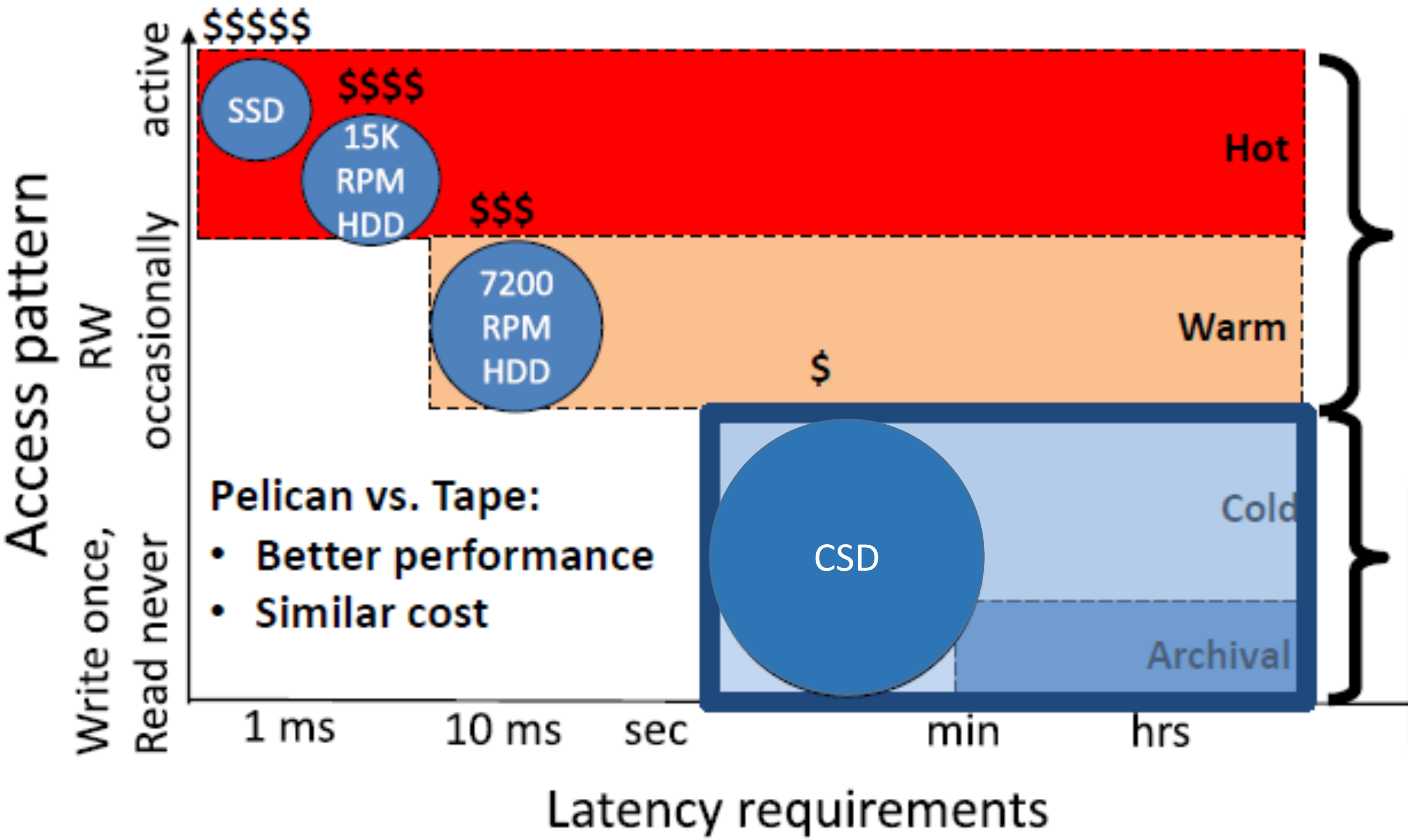
Hot tier

- Provisioned for peak
- High throughput
- Low latency
- High cost

Archive tier

- Low cost
- High latency (hours)

Price versus Latency



Hot tier

- Provisioned for peak
- High throughput
- Low latency
- High cost

Cold tier:

- High density
- Low hardware cost
- Low operating cost
- Latency lower than tape

Adequate Provisioning

Provision resources **just** for the cold data workload:

- Disks:
  - Archival and SMR instead of commodity drives

- Power
- Cooling
- Bandwidth

→ Enough for the required workload
Not to keep all disks spinning

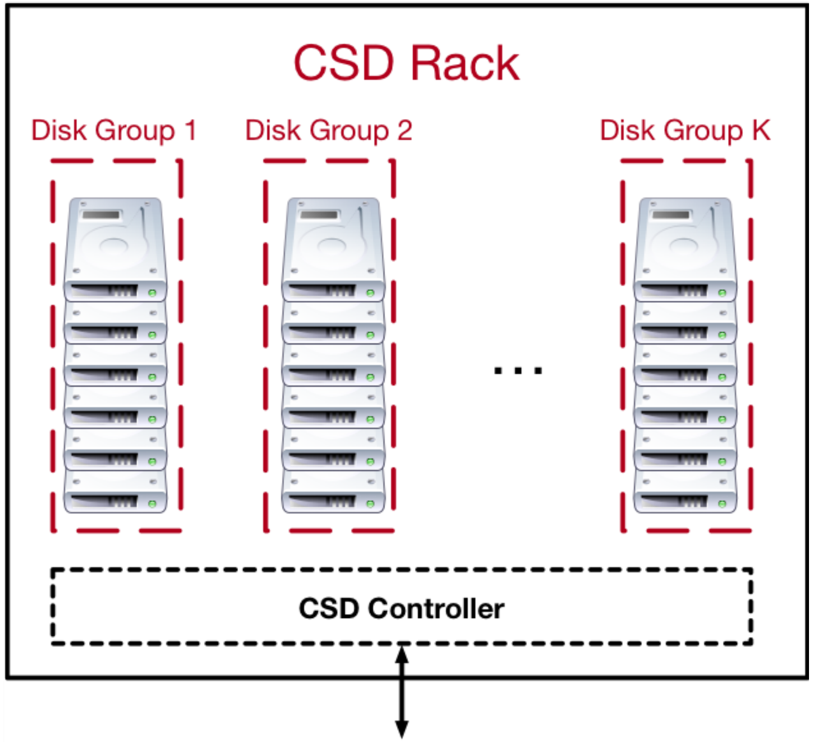
Advantages

Benefits of removing unnecessary resources:

- High density of storage
- Low hardware cost
- Low operating cost (capped performance)

Cold Storage Device

- Limited power & cooling facilities
  - Only one disk group is spun up
    - E.g. in Pelican: $1/K^{th}$ = 8% of disks are active
  - Disk switch latency: 10-30 seconds
- Example Systems:
  - Microsoft Pelican
  - OpenVault's Knox storage
  - Facebook Cold Storage
  - Amazon Glacier



- Workload: Write Once – Read Occasionally (WORO)

Pelican

The Pelican Rack

- Mechanical, hardware and storage software stack co-designed.
- Right-provisioned for cold data workload:
- 52U rack with 1152 archival class 3.5” SATA disks.
- Average size of 4.55 TB to provide a total of 5 PB of storage
- It uses 2 servers and no top of the rack switch
- Only 8% of the disks are spinning concurrently.
- Designed to store blobs which are infrequently accessed.

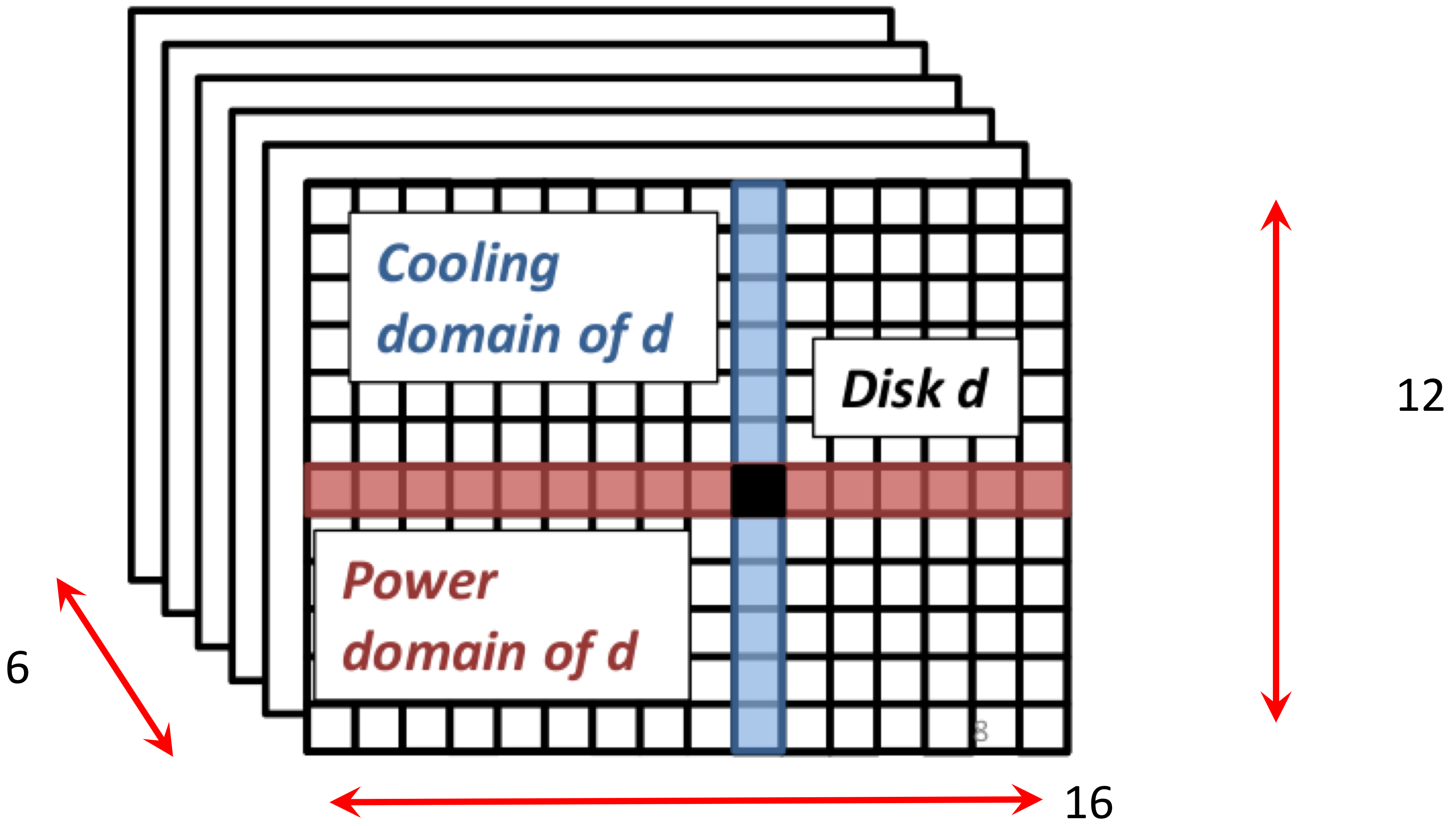
Resource Domain

- Each domain is only provisioned to supply its resource to a subset of disks
- Each disk uses resources from a set of resource domains

- ***Domain-conflicting*** - Disks that are in the same resource domain.
- ***Domain-disjoint*** - Disks that share no common resource domains.

- Pelican domains
  - Cooling, Power, Bandwidth

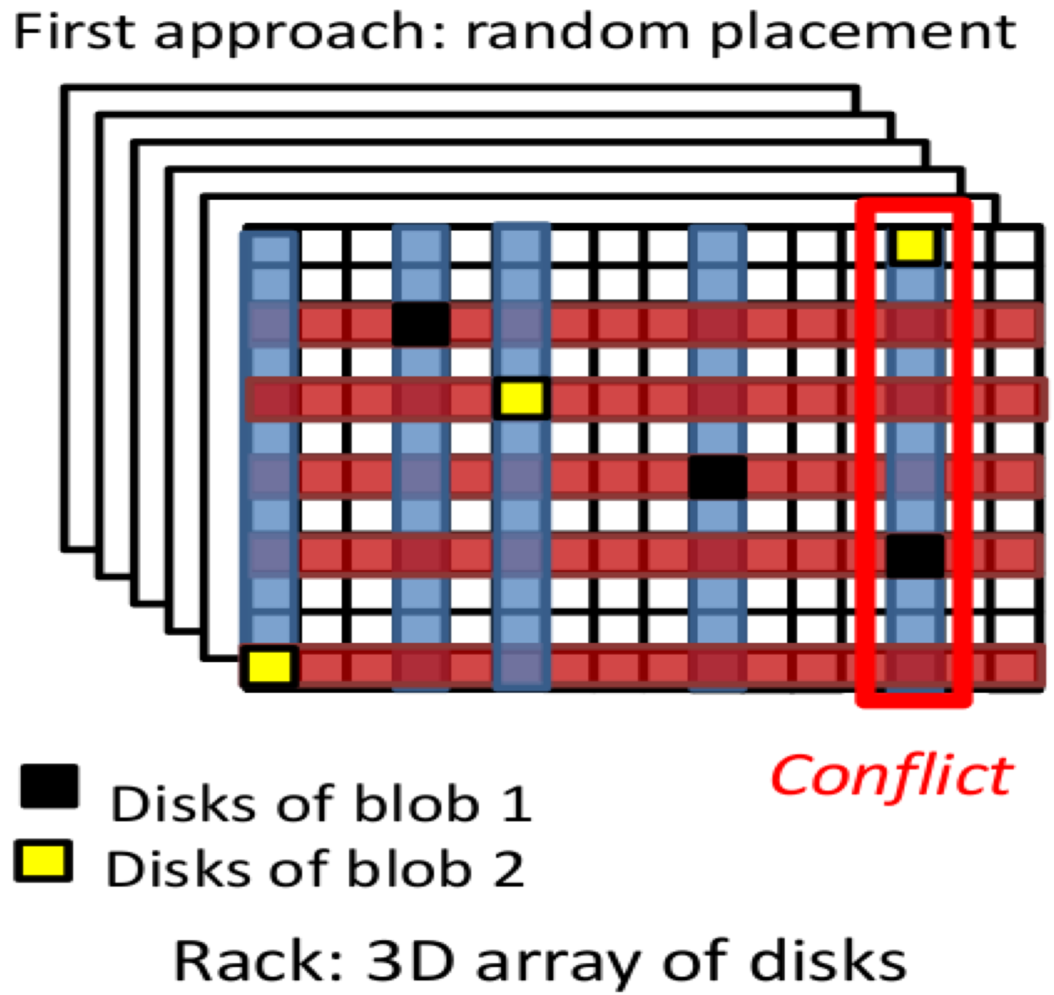
Schematic representation



Data Layout

- Objective - maximize number of requests that can be concurrently serviced while operating within constraints.
- Each blob is stored over a set of disks.
- It is split into a sequence of 128kB fragments. For each “k” fragments, additional “r” fragments are generated.
- The k+r fragments form a stripe
- In Pelican they statically partition disks into groups and disks within a group can be concurrently active. Thus they concentrate all conflicts over a few sets of disks.

Data Placement



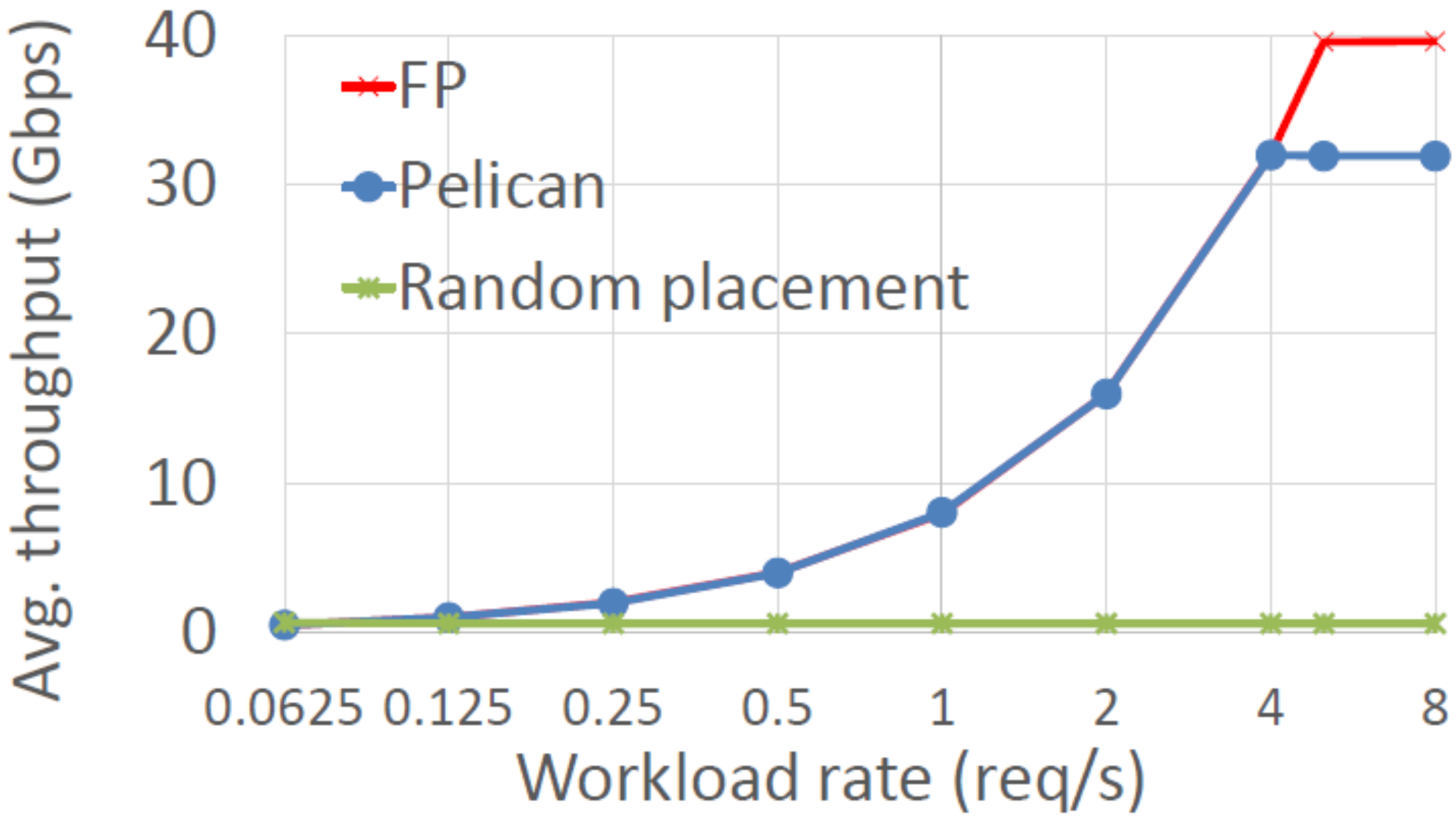
IO Scheduler

- Traditional disks are optimized to reorder IOs to minimize seek latency.
- Pelican - reorder requests in order to minimize the impact of spin up latency.
- Four independent schedulers. Each scheduler services requests for its class and reordering happens at a class level.
- Each Scheduler uses two queues – one for rebuild operations and one for other operations.
- Reordering is done to amortize the group spin up latency over the set of operations.
- Rate limiting is done to manage the interference between rebuild and other operations.

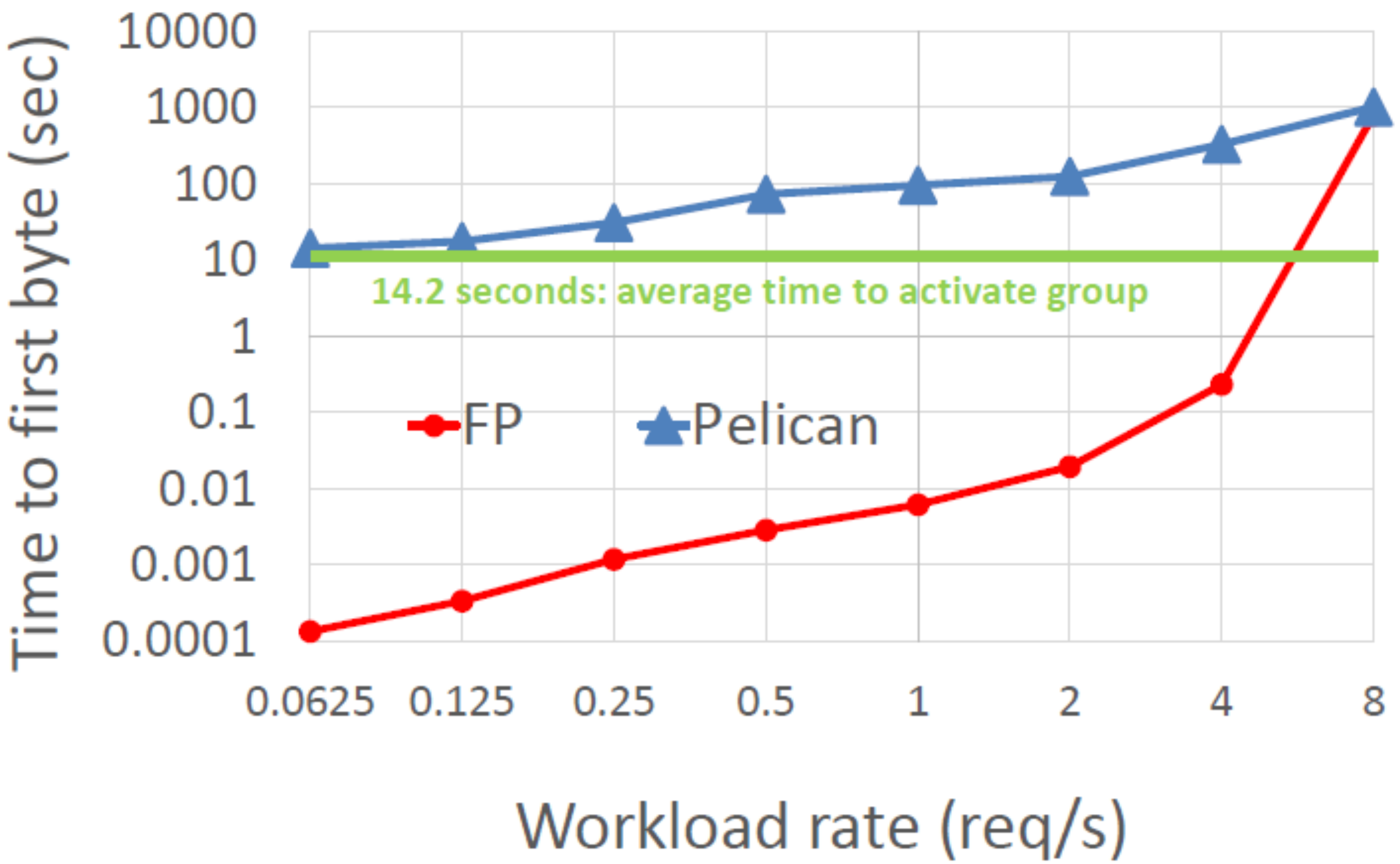
Evaluation

- Comparison against a system organized like Pelican but with full provisioning for power and cooling.
- The FP uses the same physical internal topology but disks are *never spun down*.

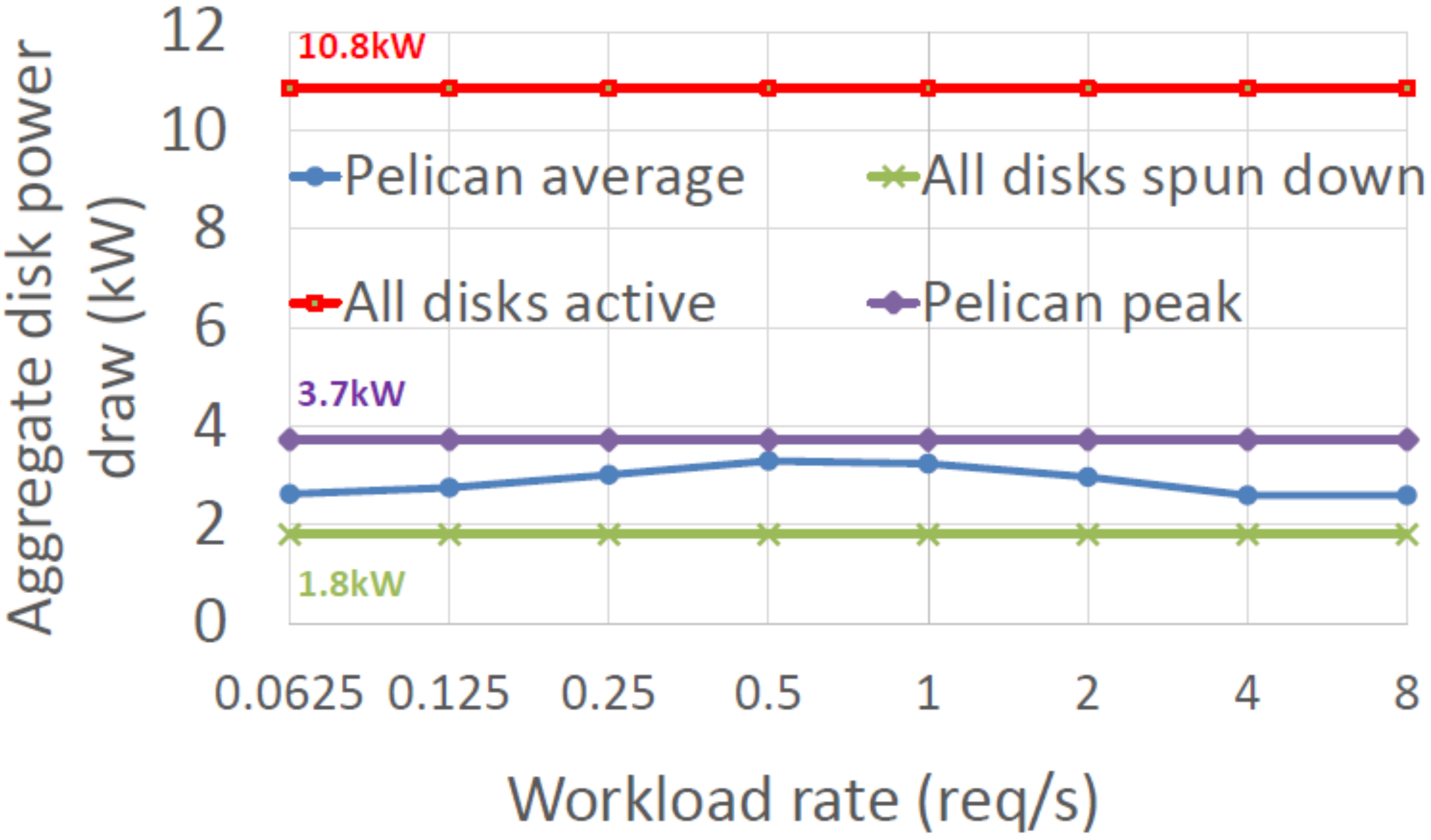
Performance – Rack Throughput



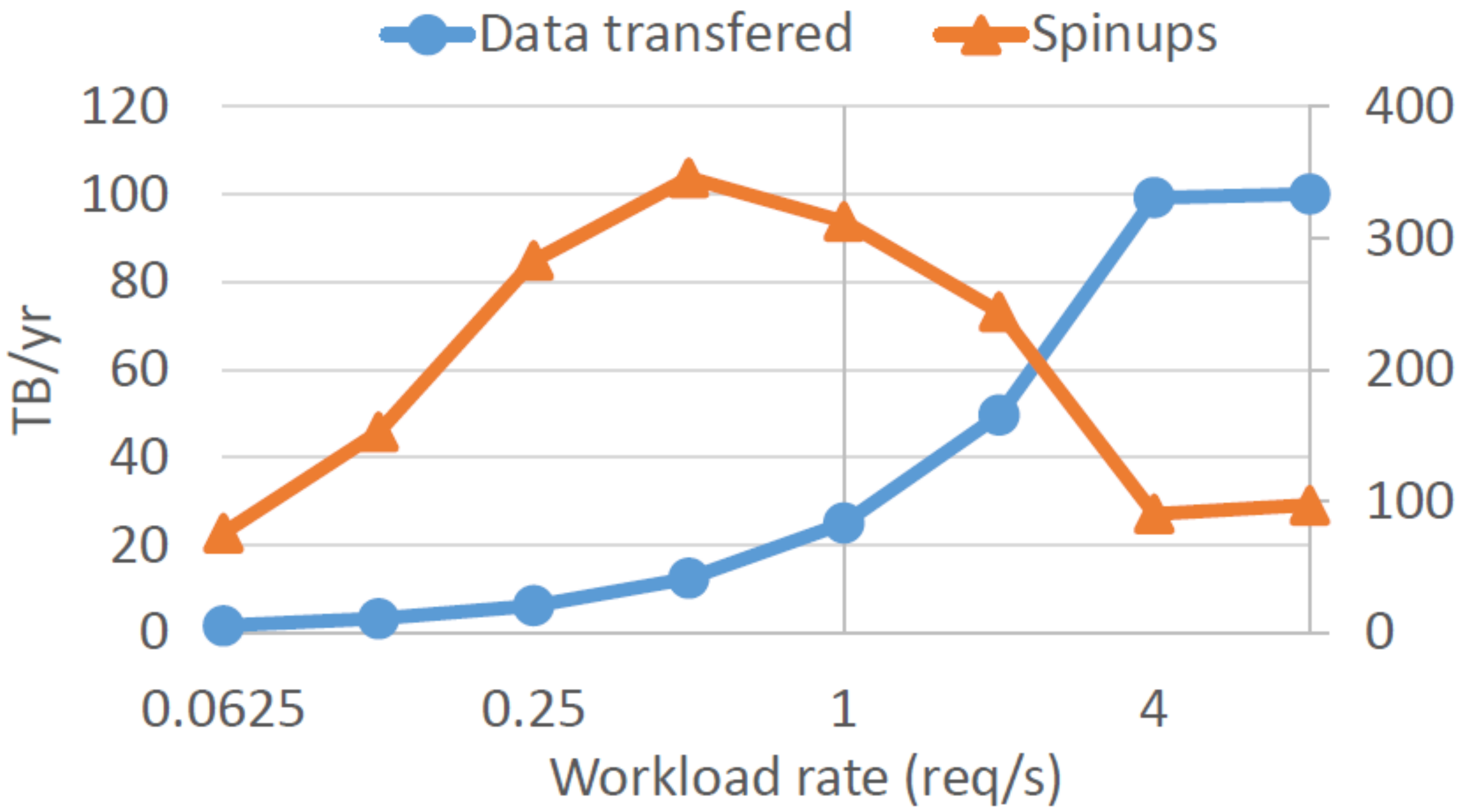
Time to first byte



Power Consumption



Disk Lifetime



Disk statistics as a function of the workload

Pros

- Reduced
  - Cost
  - Power Consumption
- Erasure codes for fault tolerance
- Hardware abstraction simplifies IO schedulers work.

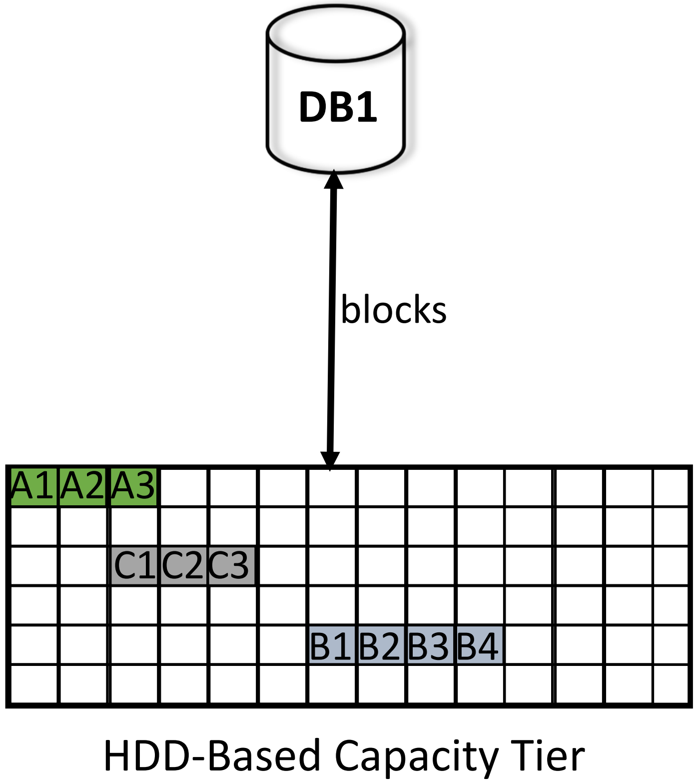
Cons

- Tight constraints – less flexible to changes
- Sensitive to hardware changes
- No justification to some of the configuration decisions made.
- Not sure if it is an optimal design

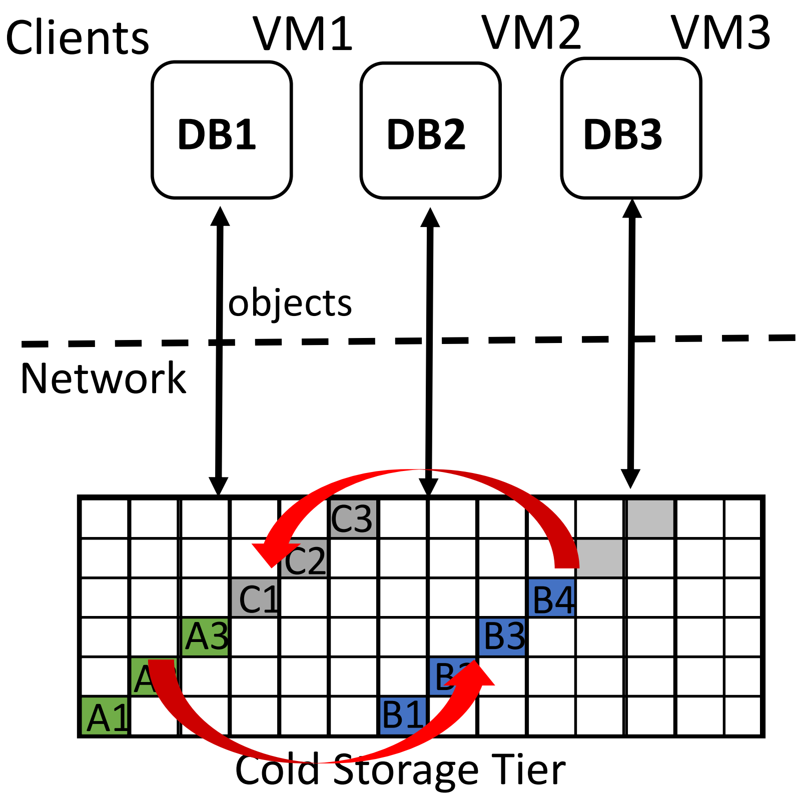
Data Processing

Query execution over CSD

Traditional setting



Virtualized enterprise data center



Uniform access ✓ **Control layout** ✓

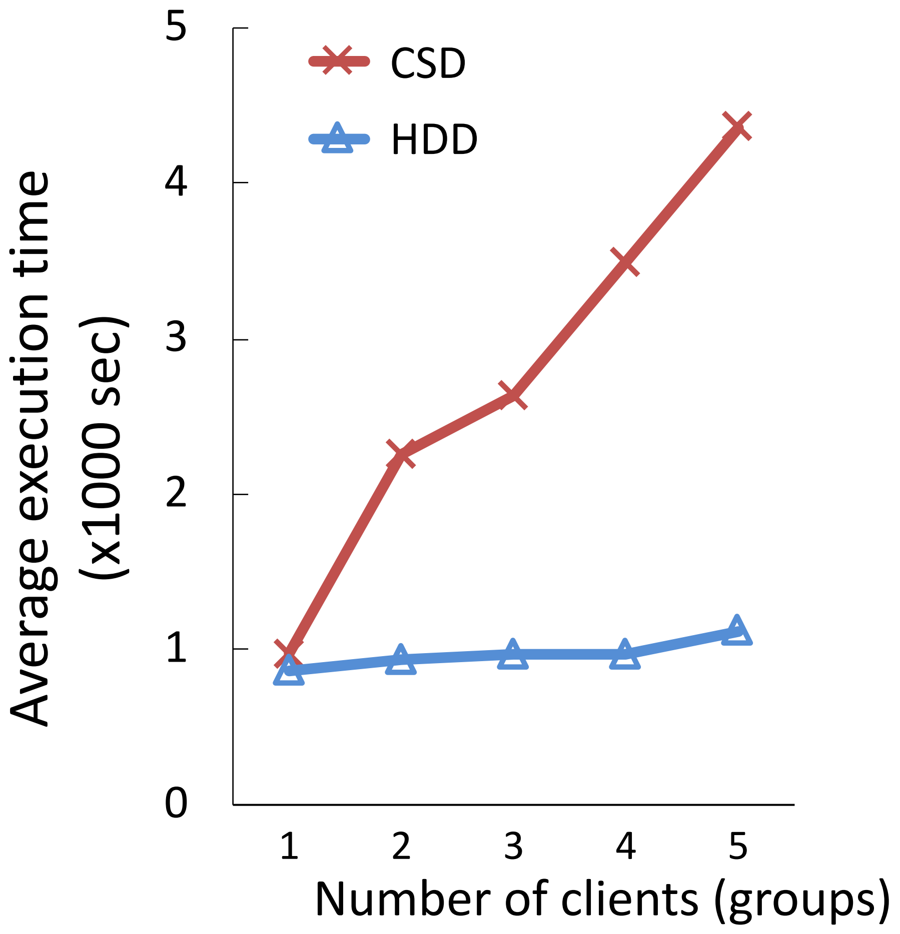
Static (pull-based) execution ✓

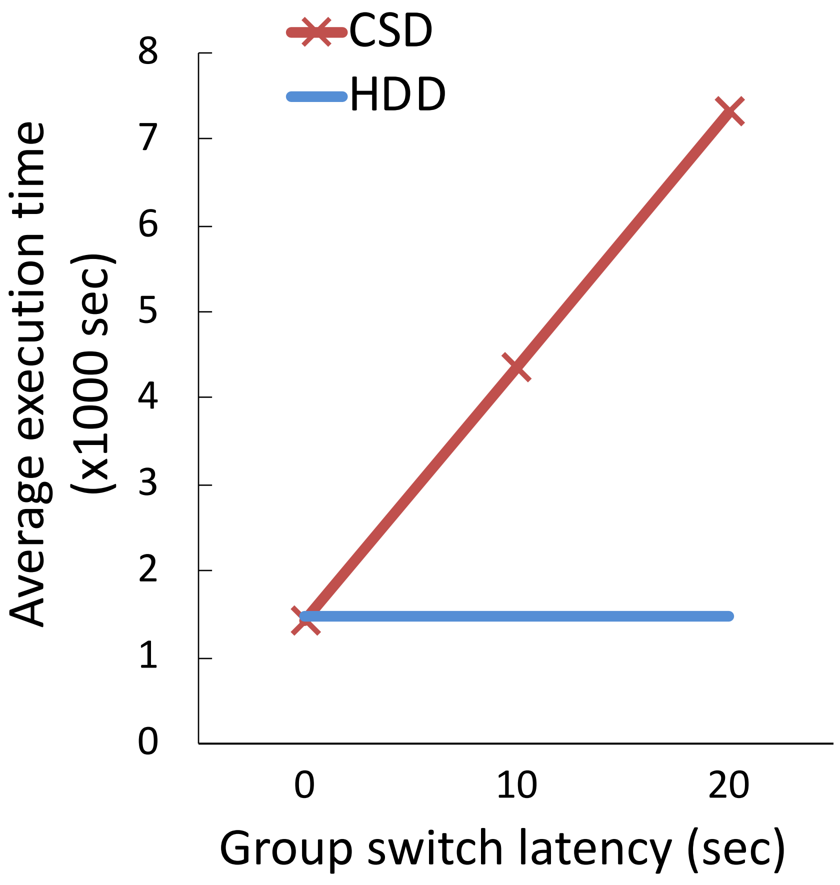
Uniform access ✗ **Control layout** ✗

Pull-based execution will trigger unwarranted group switches

What this means for an enterprise datacenter…

Setting: multitenant enterprise datacenter, clients: PostgreSQL , TPCH 50, Q12, CSD: shared, layout: one client per group





Need hardware-software codesign

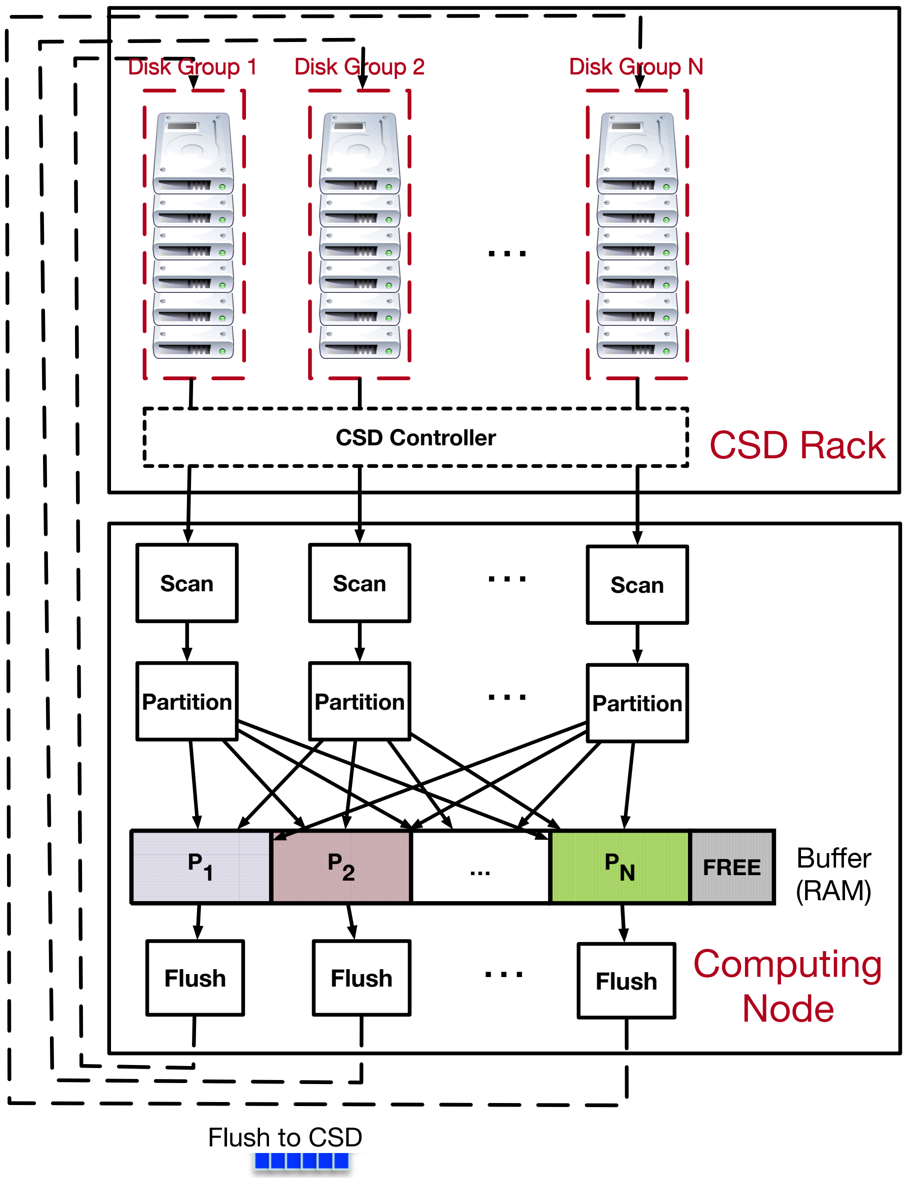
1. Data access has to be **hardware-driven** to minimize group switches

2. Query execution engine has to process data pushed from storage in **out-of-order** (unpredictable) manner

3. Reduce data round-trips to cold storage by **smart** data **caching**

Batch Processing on CSD

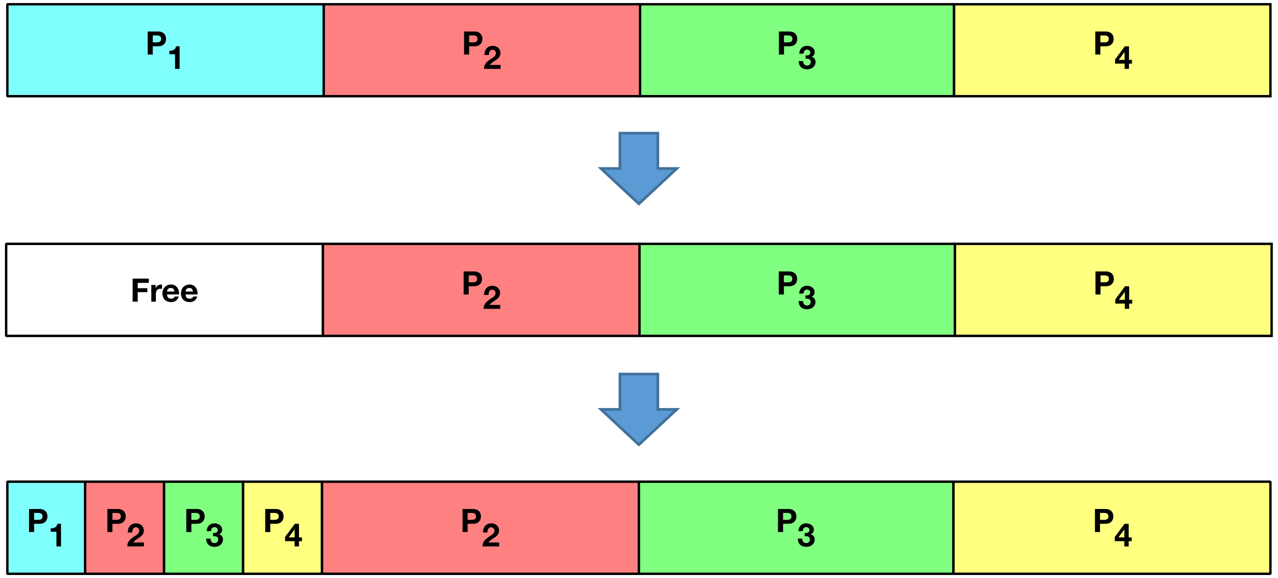
- Common batch processes on cold data:
  - Massive-scale Group-by / Join
  - [Near]-duplicate detection
  - Data Localization
  - In-place Map-Reduce
- Data Partitioning
  - Partition items into K groups
    - Distribute between K disk groups
  - **group_ID = *Partitioner*(element)**
  - Various Partitioners:
    - Hash, Range, map(), etc.



How do we flush the data?

Flushing

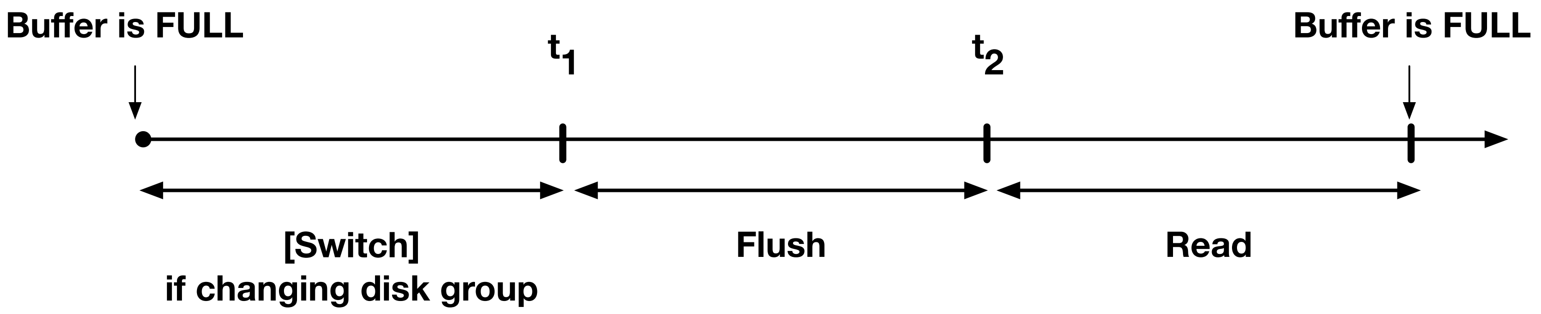
- Buffer is full → flush → into which disk group?



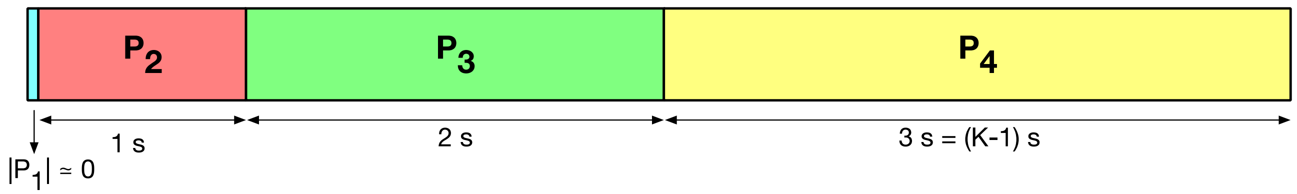
- Naïve approach: Many switches

Buff-Pack

- Greedy approach:



  - Try to maximize throughput (GB/sec) in the next step(s)
- Intuition:
  - Flush into the current disk group to avoid switching, if possible.
  - Otherwise: switch to disk group with the largest buffer



Off-Pack

- Intuition:
  - Available buffer plays a key role
    - Flush the entire buffer
    - Write-Offloading: Write data to the `wrong` disk group → then transfer.
  - When buffer is full (active partition = i):
    - Flush **`buffer[i]`** into the active disk group
    - For all. $j \neq i$ flush **`buffer[i]`** into **`offload_buffer_i_j`**
  - Post processing: move all **`offload_buffer_i_j`** to disk group j

Which algorithm? - Analytical Model

- Estimates for the number of disk group switches and computation time of each algorithm

$$T_{total} = T_{switch} + T_{seek} + T_{read} + T_{write}$$

- Intuition:
  - Off-Pack: Fewer switches, more read/write
  - Off-Pack is better for a
    - Smaller buffer ↓
    - Higher # disk groups ↑
    - Higher throughput ↑

Experiments – CSD Spec.

Configuration

Parameter	Value
Buffer size	8 GB
# Disk groups	12
Dataset size	100 TB
Throughput	1 GB/sec
Group switch latency	10 sec