Building a Flash Optimized Storage System

Software Approach

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Flash Memory Summit 2015
Santa Clara, CA

Flash : The change agent in Storage Software Design

- Performance
  - Enables 4-5 times improvement in throughput at low latency
  - Sustained read and write rate
  - Scale up vs. Scale out
- Physical Limits and Goals of Media
  - Finite life span of the media
    - Every potential reuse of the block result in media life loss
  - Better power usage
  - Smaller Form Factor and Weight
- Cost
  - Higher upfront cost
  - Should integrate seamlessly with lower endurance Flash
  - Offset with better TCO

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Performance: Reads

Techniques:

- IO path with few delay centers
- Use all the channels on the SSD
- Different priority for
  - Data being read by host vs. system
  - Data being read vs. written
- Software needs to be able to take advantage of all the CPU
  - MP safe data structures

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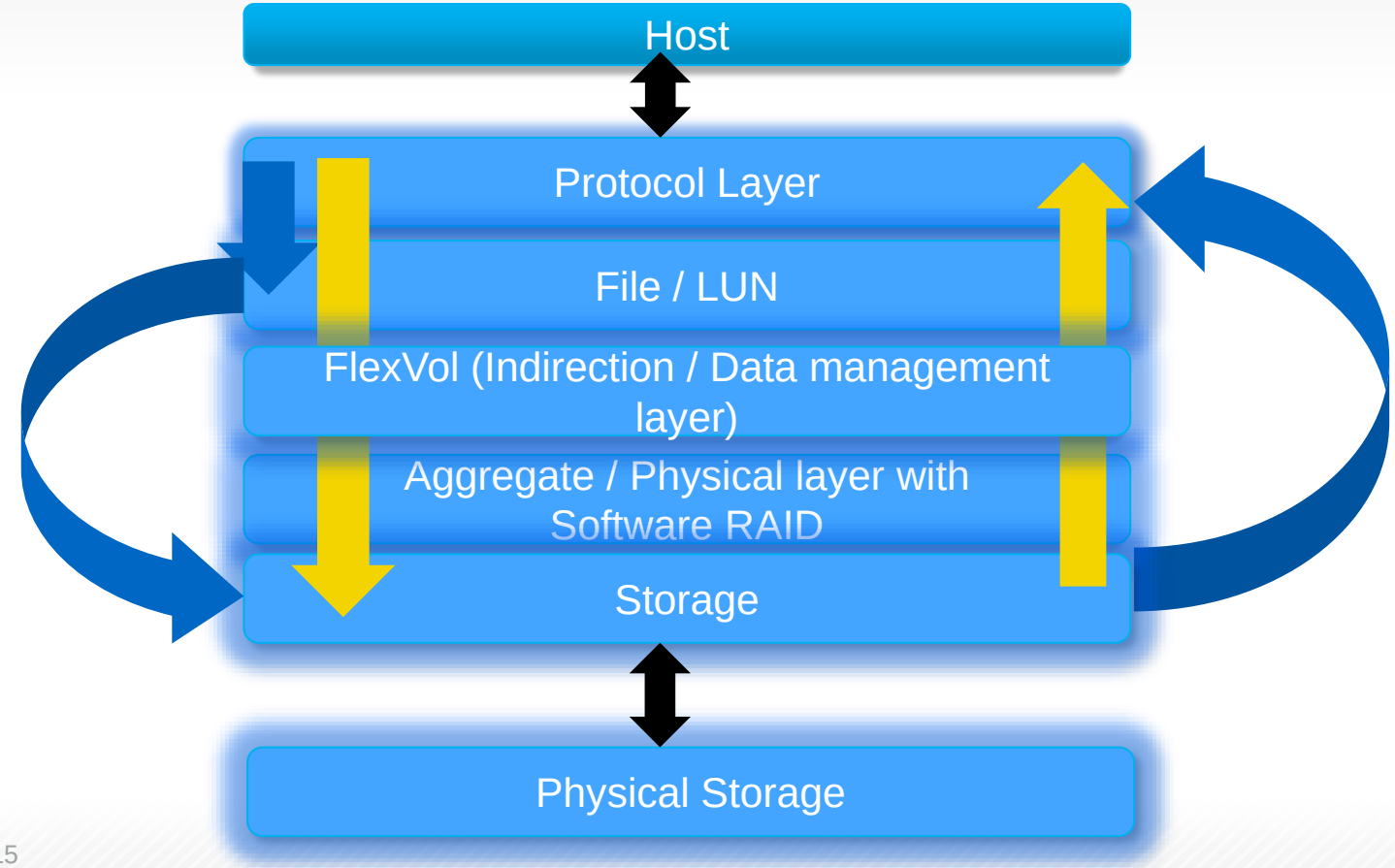
Data ONTAP IO Path: Reads

Optimized read path to take advantage of device latencies.



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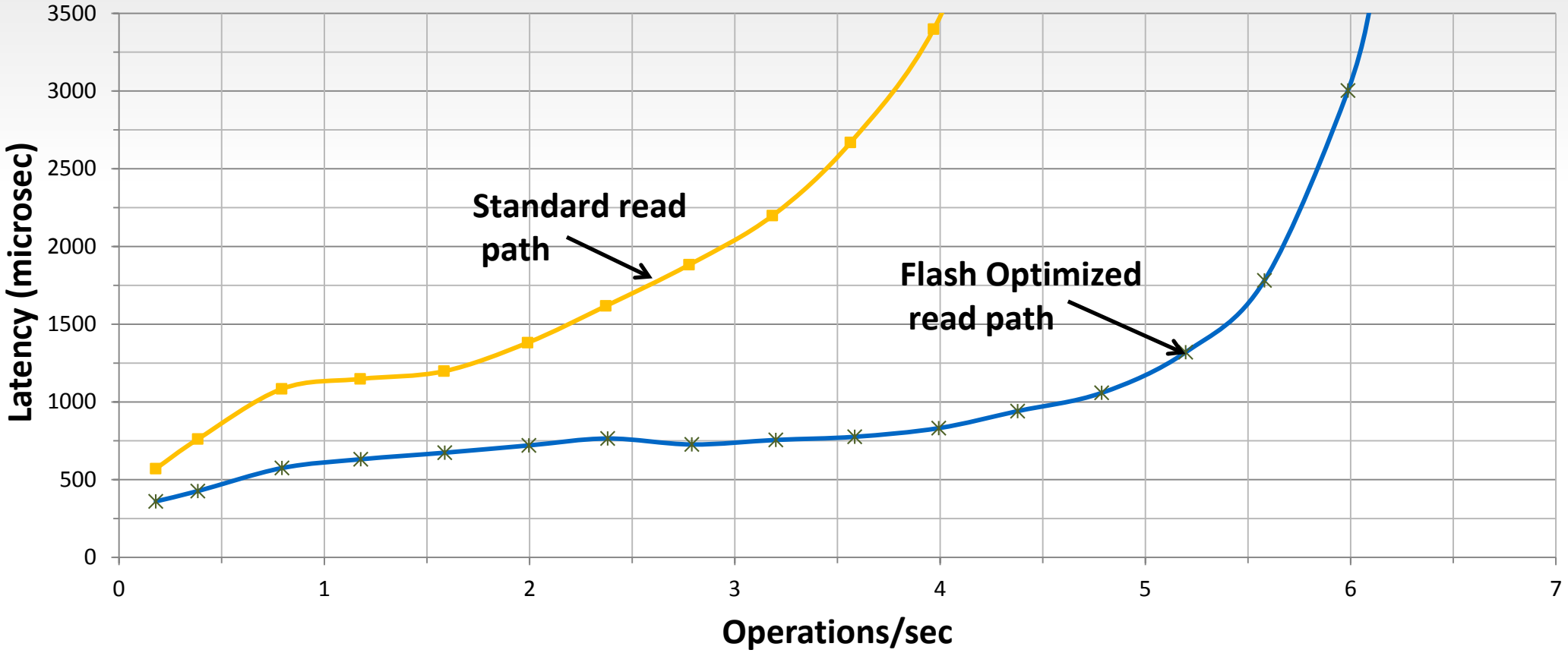
Data ONTAP Read Path for Flash: Impact on performance



4x Improvement on Random Read Operations for the same latency

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Performance: Writes

Techniques:

- Journal changes or log the operation to persistent lowest latency media
  - NVRAM/NVMem or battery backed DRAM
- Perform CPU intensive operations and metadata updates in the background instead of the IO path
- Writes to flash batched and sequential to reduce WAF
- Frees / overwrites batched to reduce random metadata updates

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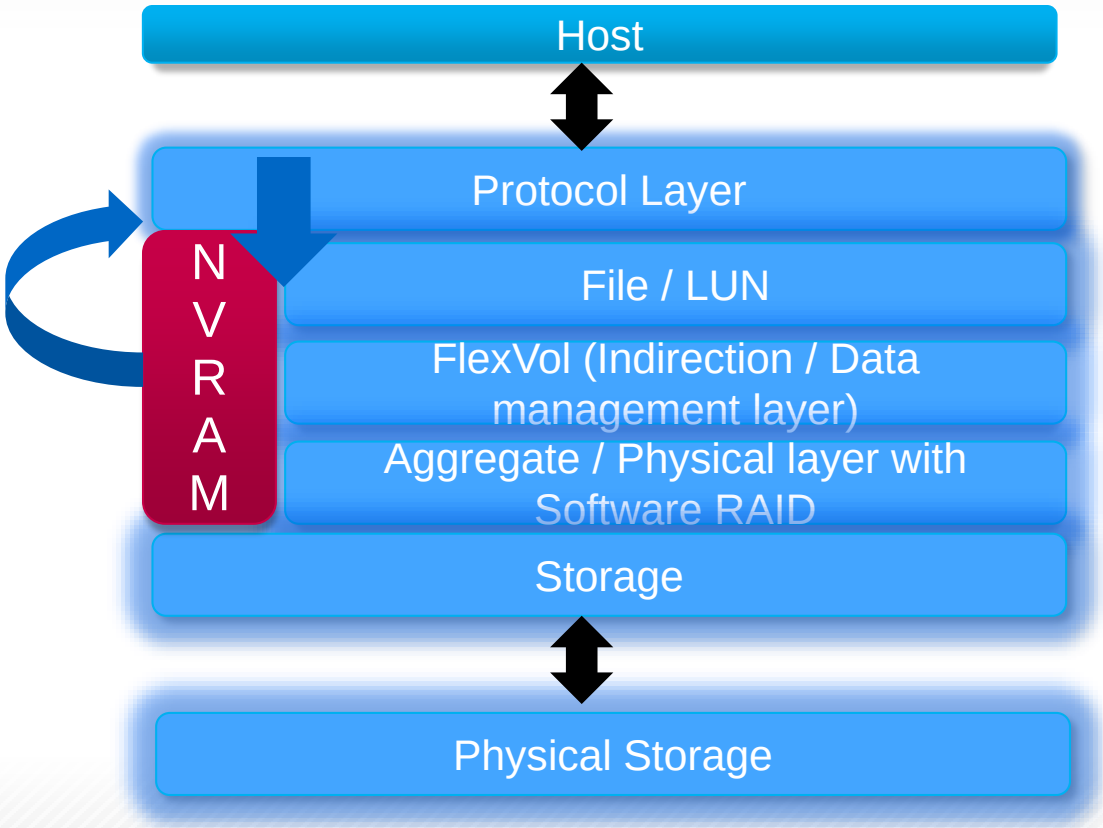
Data ONTAP IO Path: Writes

- Writes logged to NVRAM
- Data pushed to persistent storage periodically in the background



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Performance Trade Off: Scale out vs. Scale up

Performance / Application requirements dictate architecture trade off

Scale Up

- No fixed Storage to DRAM and CPU ratio
- Metadata must be searchable on disk for performance
- Applications with Small working sets but large storage footprint

Scale Out

- Fixed Storage to DRAM and CPU ratio
- Metadata normally in memory
- Performance scales with nodes
- Performance sensitive applications

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Data ONTAP: Scale Up and Scale out

- We need both
- Cost, performance and data center footprint dictate scale up vs. scale out
- Ideal performance when DRAM to Storage ratio around 1%
  - Not every workload / Application requires the same level of performance
- Scale up
  - Metadata for the working set fits in DRAM
  - Applications can tolerate occasional latency spikes during workload shifts
- Scale out
  - Consistent latency
  - Performance scales with storage
  - Large working sets

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Flash Physical limits: Layout

- Log structured layout
  - No writes in place
  - Results in fragmentation – addressed using other means
- Indirection layer to address physical blocks
  - Ability to defrag & create clean segments
  - Reduces random overwrite, which in turn reduces WA
  - Allows for additional functionality that reduces the overall TCO
    - deduplication
    - cloning
    - thin provisioning
- Log On Log
  - Mitigated by writing sequentially to large segments using a single stream
  - Data segregation with multi-stream capabilities on next version SSD firmware

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Data ONTAP – Layout Engine

- Write Anywhere File Layout (WAFL)
  - Log structured file system
  - Already optimized for write
  - NVRAM for staging writes
- Metadata searchable both in-memory as well as persistent storage
- Metadata updates optimized by batching updates
- FlexVols provide an indirection layer
- Generic File system instead of optimized for SAN
- Format that supports Storage Efficiency features
- Media aware physical layout engine – allows for support of different types of persistent media

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Cost

Reduce the TCO by enabling Storage efficiency features

- Log structured file layout
  - Create space efficient snapshots with very little overhead
- Indirection layer allows for Storage efficiency features like
  - Deduplication
  - Clones
  - Thin provisioning
  - Writeable snapshots
  - Segment cleaning / Defrag – which reduces the Write Amp on the SSDs
    - Allowing for reduction of Overprovisioning on the SSDs
- Format that supports compression at various levels

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Conclusion

- Software design requires efficient use of CPU and fewer delay centers
- Software needs to customized for media writes
- Layout and format is important to reduce TCO by enabling storage efficiency features
- Application performance requirements dictate architecture

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