# Nswap2L: Transparently Managing Heterogeneous Cluster Storage Resources for Fast Swapping

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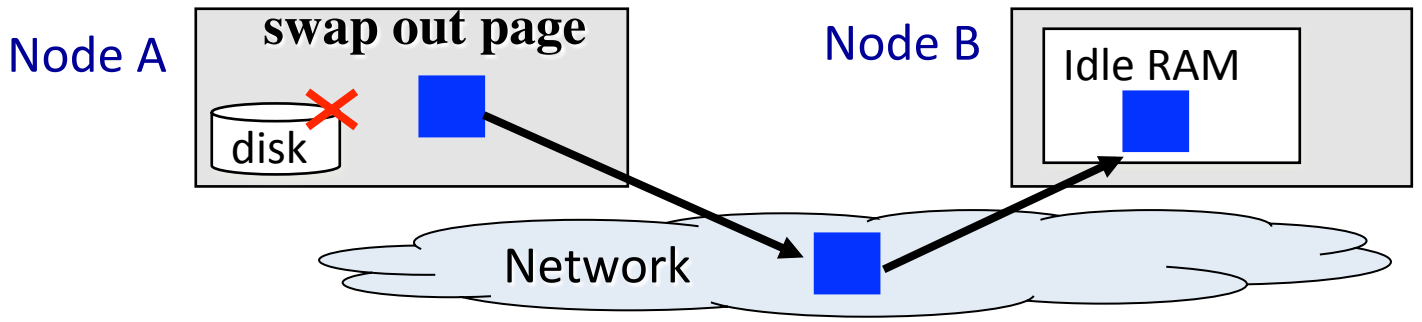
# Data Intensive Computing

"The next 10 years will be shaped primarily by new algorithms that make sense of massive and diverse datasets and discover hidden value" Genevieve Bell, Intel Fellow, from SC'13 Keynote

- Require significant resources for good performance (or even feasibility)
- Stress the memory hierarchy
  - WS too large to fit in RAM → swapping
  - Out-of-core algorithms → temporary files

# General Purpose Clusters

- Variable WL lead to resource usage imbalances
  - Some nodes swapping, others have idle RAM
- Network RAM Storage is an option:
  - Use idle RAM of remote nodes for swap space



# Cluster Storage Devices

Heterogeneous:

- HDD, Flash SSD, PCM(?), Network RAM, local and remote

Different Strengths:

- Network RAM: fast, volatile, variable capacity
- PCM: fast, expensive, capacity issues
- Flash SSD: faster R than W, erasure blocks, wear-out
- HDD: slow, cheap, still widely used

➔ Cluster Storage likely to remain heterogeneous

# Storage and Performance

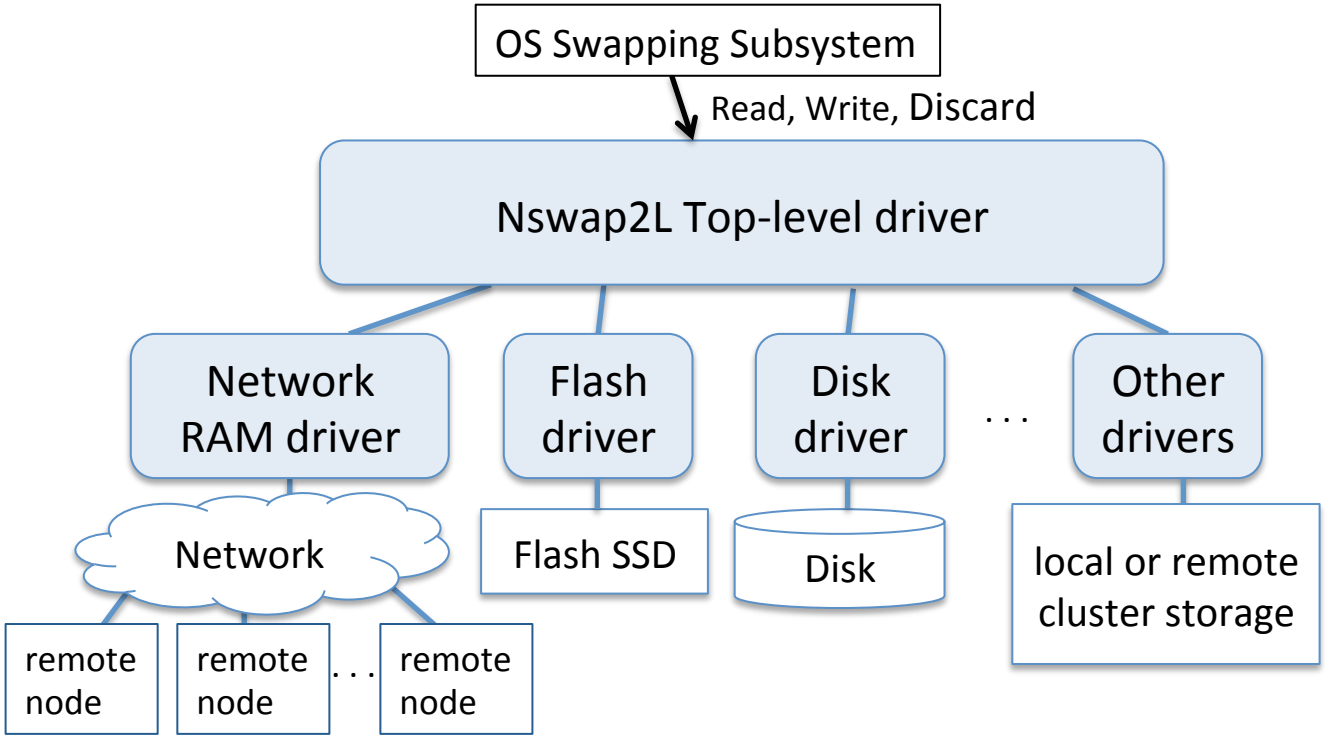
- Making best use of heterogeneous storage will have significant impact on application performance
- Problem: Tuning node OS's swapping subsystem for every possible combination of underlying storage is not possible
  - Still mostly optimized for disk
  - Some SSD support (TRIM/Discard)

# Our Solution: Nswap2L

## 2 Level Device Driver Design:

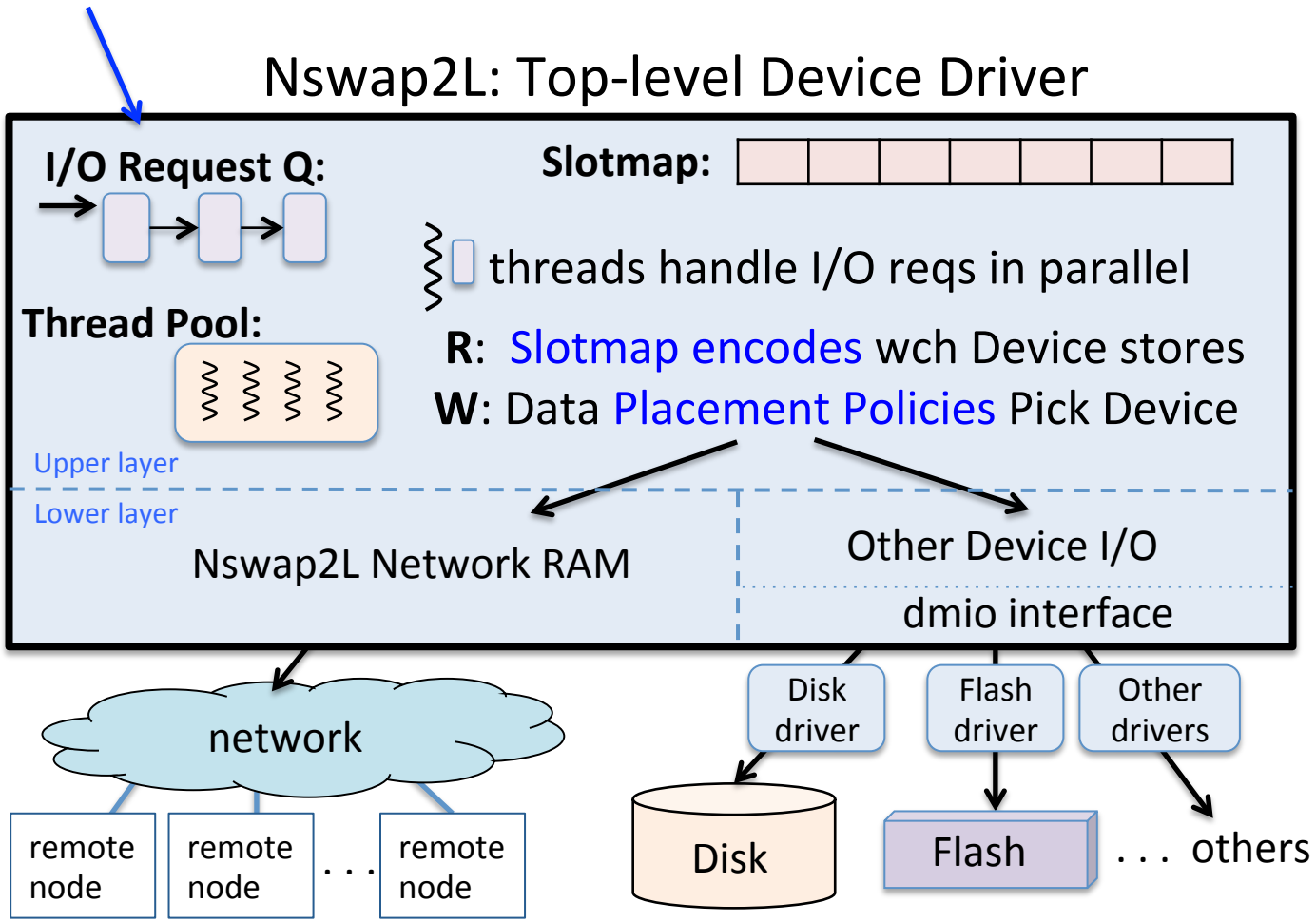
- Transparent: to OS a single, fast, random access device
- Manages underlying heterogeneous storage devices

  Adaptable/Tunable Policies for Data Placement & Prefetching



# System Architecture

- Linux 4.0 driver, added as swap partition on nodes
  - Underlying devices at load & added later (via `/sys`)
- OS sends Read/Write/Discard to swap in/out/free



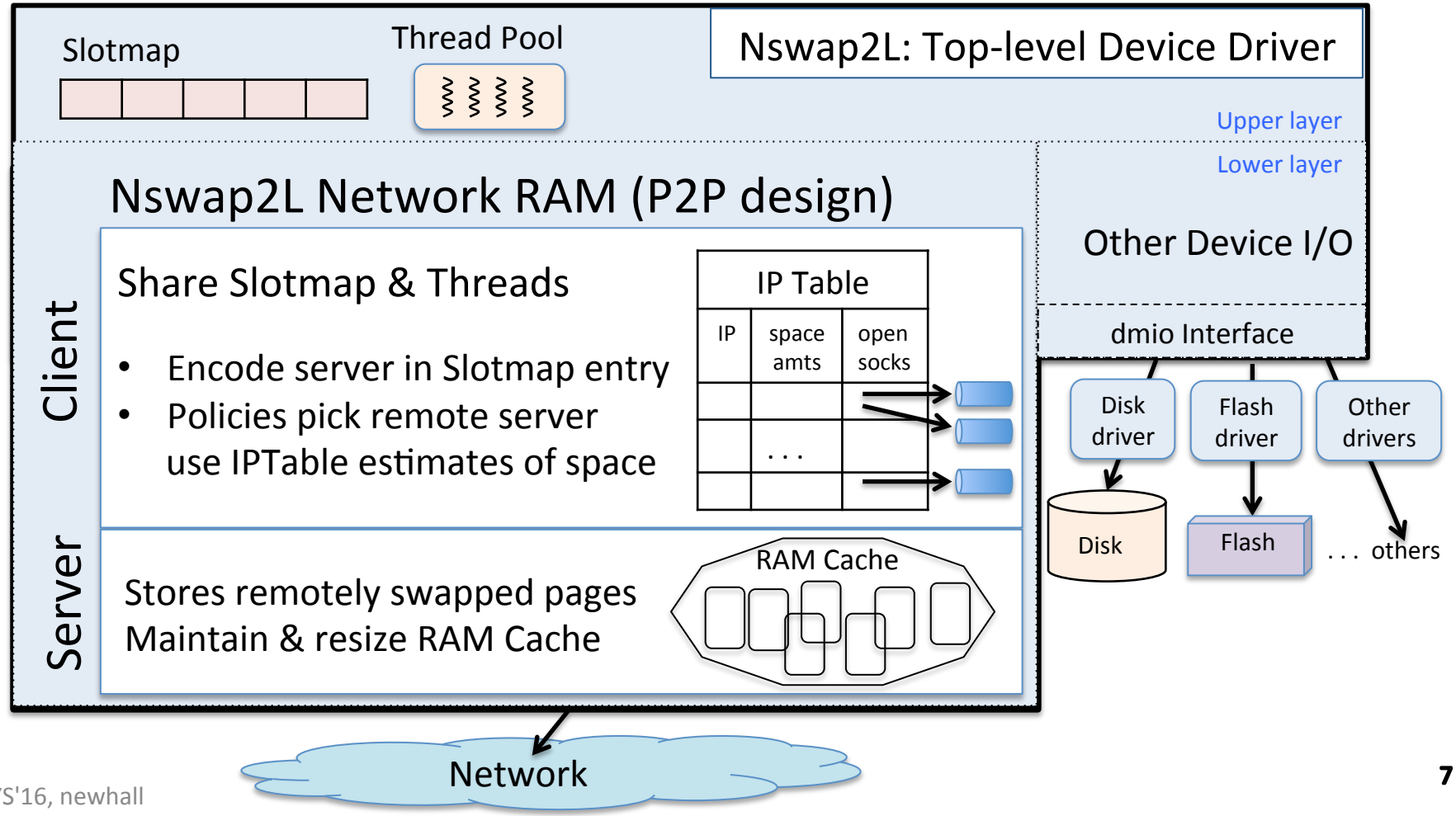

- Multi-threaded
- Slotmap
- Placement Polices on W

- dmio to most bottom-level devices
- Nework RAM part of Nswap2L

# Nswap2L Network RAM

Scalable: P2P design, local estimate available Network RAM

Adaptable: Amount of RAM available for Network RAM grows & shrinks w/cluster workload RAM usage



# Prefetching

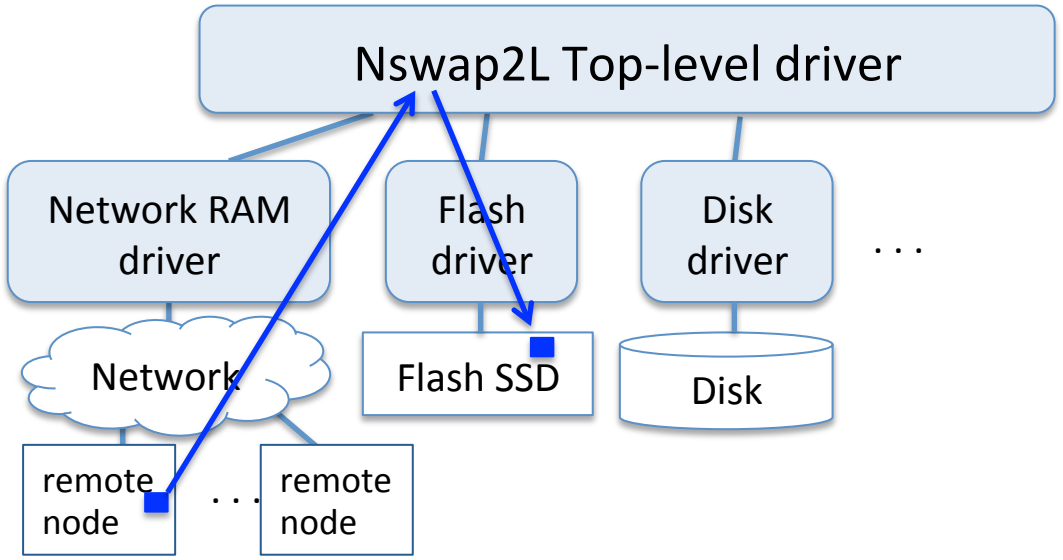
- Moving page data between underlying devices
  - Transparent to OS: I/O internal to Nswap2L
- Take advantage of strengths of different devices

  (ex) Prefetching from Network RAM to Flash:
  - free up NW RAM for future fast Writes
  - increase Read parallelism over Flash and NW RAM

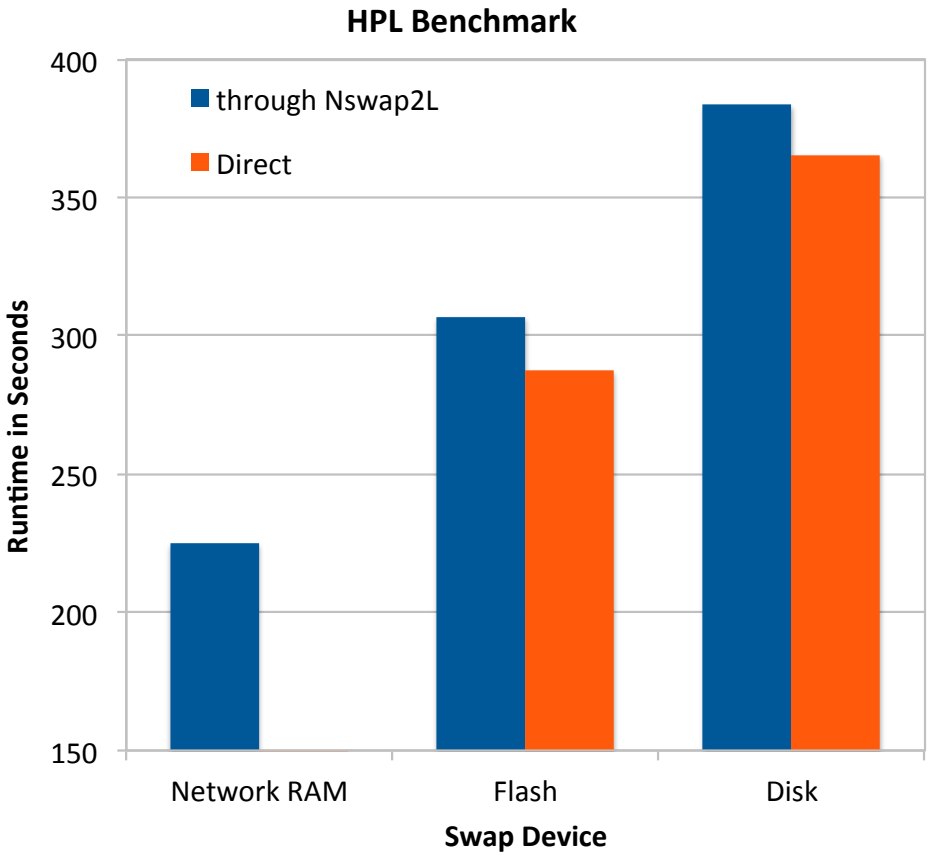
**Tunable Policies**

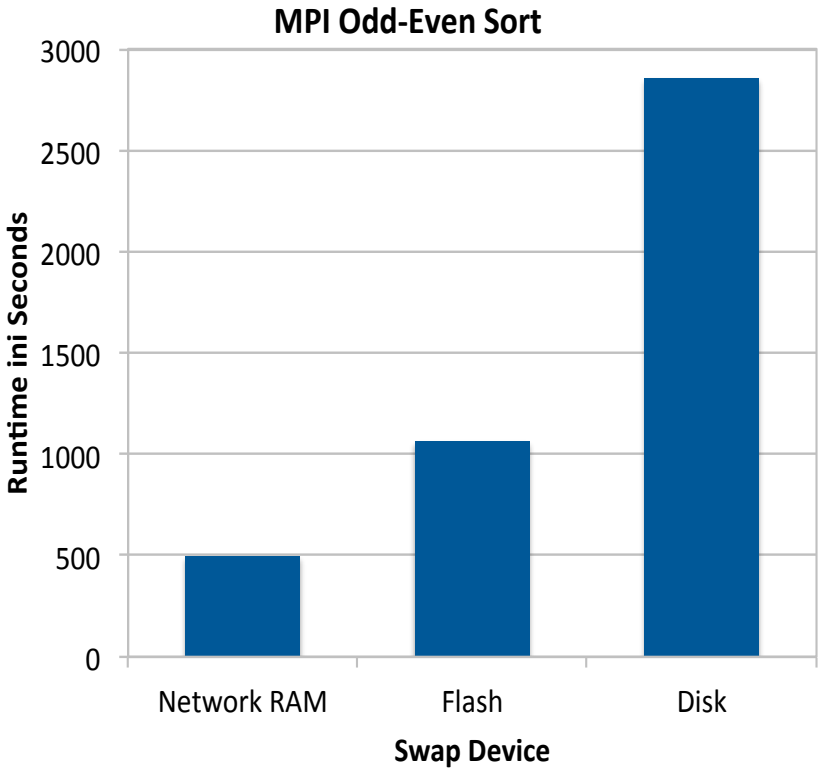
via `/sys` interface

How much?
How often?
Which pages?
To/From?



# Nswap2L Performance

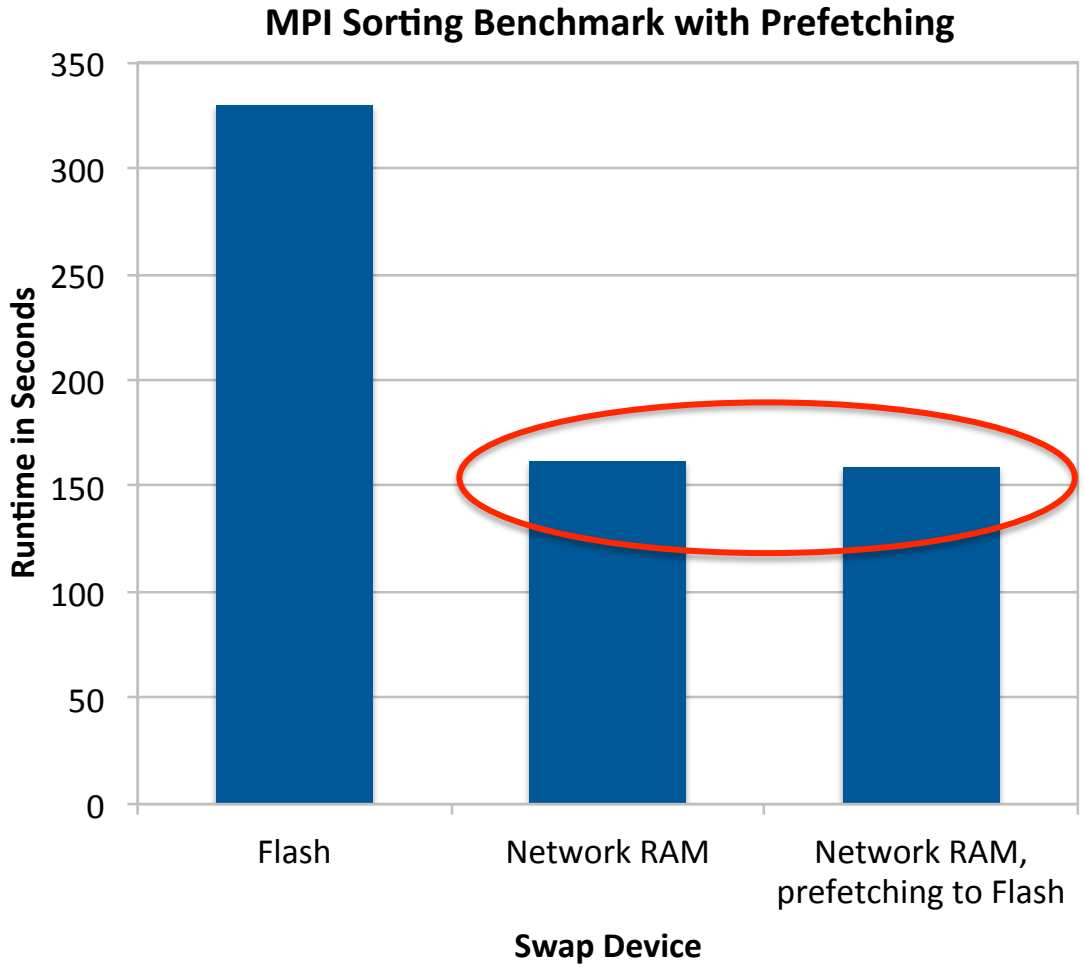



Nswap2L loaded as Linux 4.0.4 device driver, and added as swap partition on 16 node cluster, 10 Gbit Ethernet. Underlying Network RAM, Flash SSD & HDD.

# Benefit of Prefetching

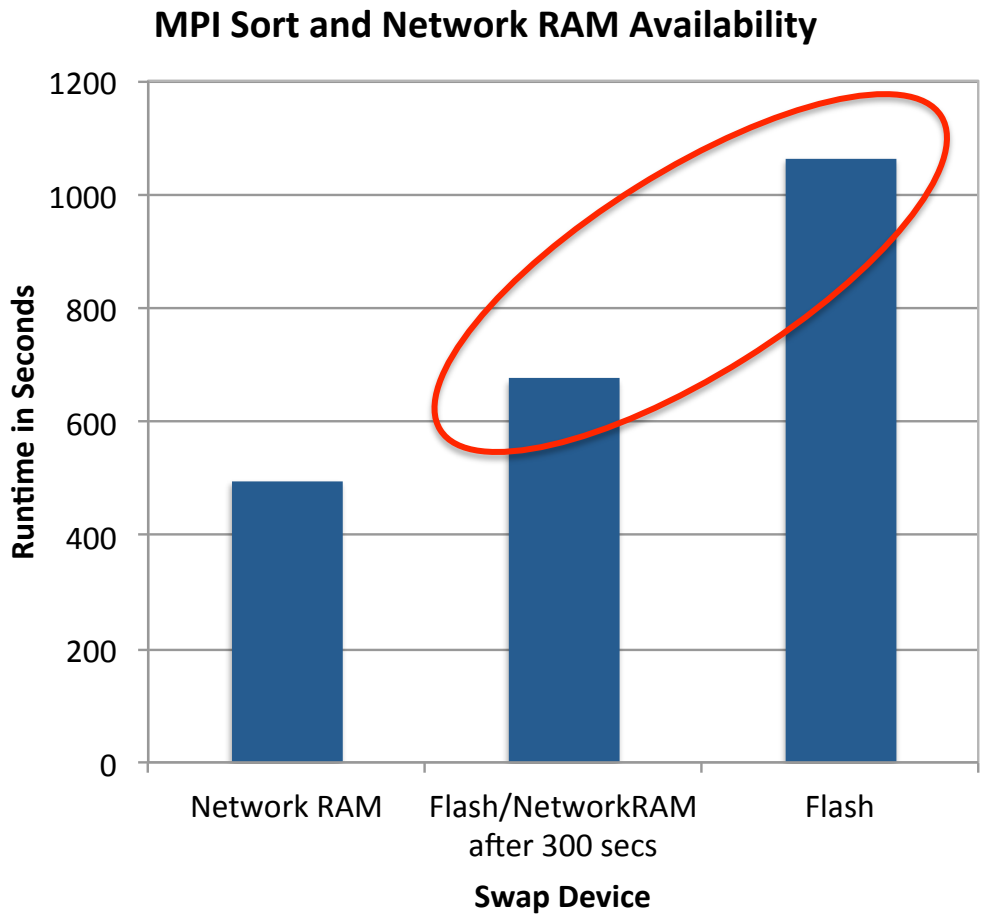
- Swapping out to faster Network RAM with prefetching some pages from Network RAM to slower Flash




- *Increase degree of Read parallelism over Flash and Network RAM*
- *Get slightly faster runtime than swapping to faster Network RAM alone*

# Benefit of Adaptable Policies

- Flash available for entire run, Network RAM becomes available after about 5 minutes of runtime




- *Adaptable Data Placement Polices allow Nswap2L to discover faster underlying storage and make use of it as it becomes available*
- *Significantly faster runtime than statically swapping to Flash alone*

# Nswap2L:

- Fast Backing Store for Swap in Clusters
- Transparently Manages Heterogeneous Cluster Storage Devices, including its own Network RAM
  - Presents as single, fast swap device to node OSs
- Adaptable polices result in performance improvements over fastest single swap device

# Current and Future Directions

- Expand Nswap2L to be used for other types of backing storage
  - File data, particularly targeting temporary files
- Further investigating adaptive policies
  - Data placement
  - Prefetching
  - Network RAM growing/shrinking
  - Implementing a more Extensible Policy interface
    - adding in new policy on the fly
- Evaluate on Larger Systems, Scalability

# Thank You

# Questions?

www.cs.swarthmore.edu/~newhall/nswap2L.html