Panache: A Parallel Filesystem Cache for Global file Access

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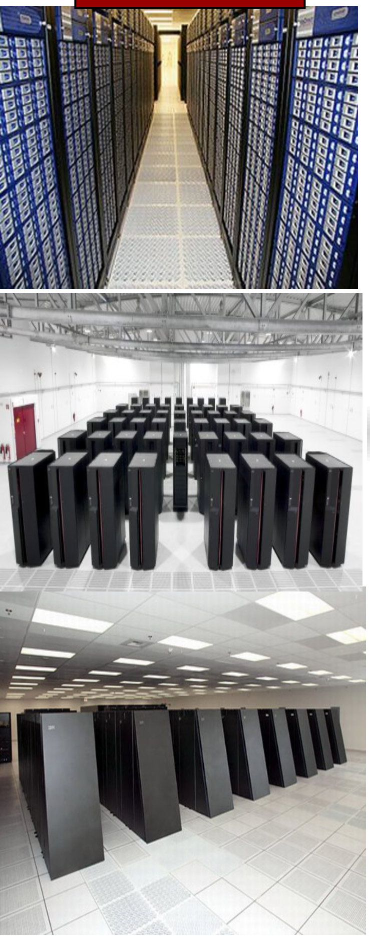
IBM Almaden

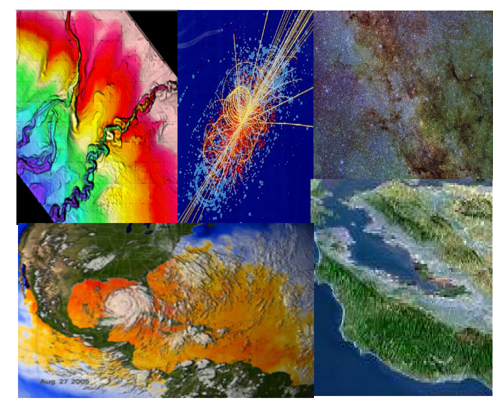
Compute Farms



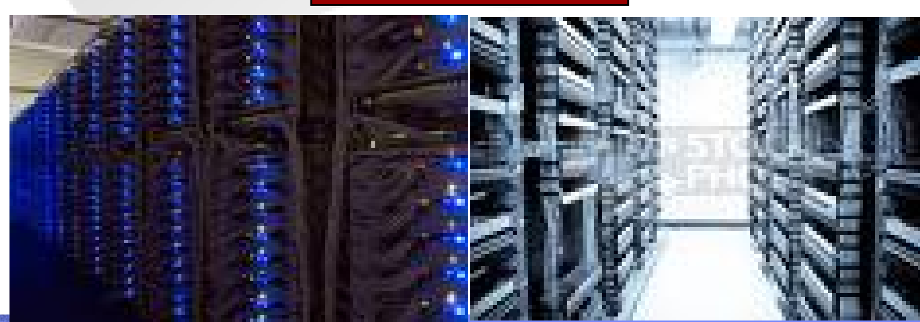
Data Source

Global File Access

Clients



Data Centers



Characteristics

- **High latency links**
  - ~150 ms.
- **Bandwidth across data centers is decent**
  - Across data centers OC-48/192
  - Teragrid 10-30Gb/s
- **WAN Network is not reliable**
  - Multiple exchange points, outages, packet loss
- **Predominantly large files**
  - Virtual machine images, application virtual disks
  - Large satellite images
  - Youtube videos
- **Global access but local speeds**

Global performance to match local?

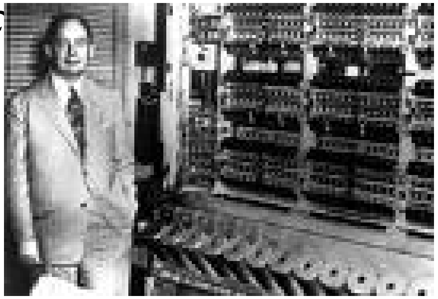
With 25 years of Internet experience,
we've learned exactly one way to deal with exponential growth:

... Caching.

Data has to find 'local' sources near consumers
rather than always coming from the place it was originally
produced -- Van Jacobson, 1995

A. W. Burks, H. Goldstine, John von Neumann "Preliminary Discussion of the Logical Design of an Electronic Computing Instrument", 1946.

> *"Ideally one would desire an indefinitely large memory capacity such that any particular word would be immediately available.*
>
> *We are forced to recognize the possibility of constructing a hierarchy of memories, each of which has greater capacity than the preceding but which is less quickly acc*

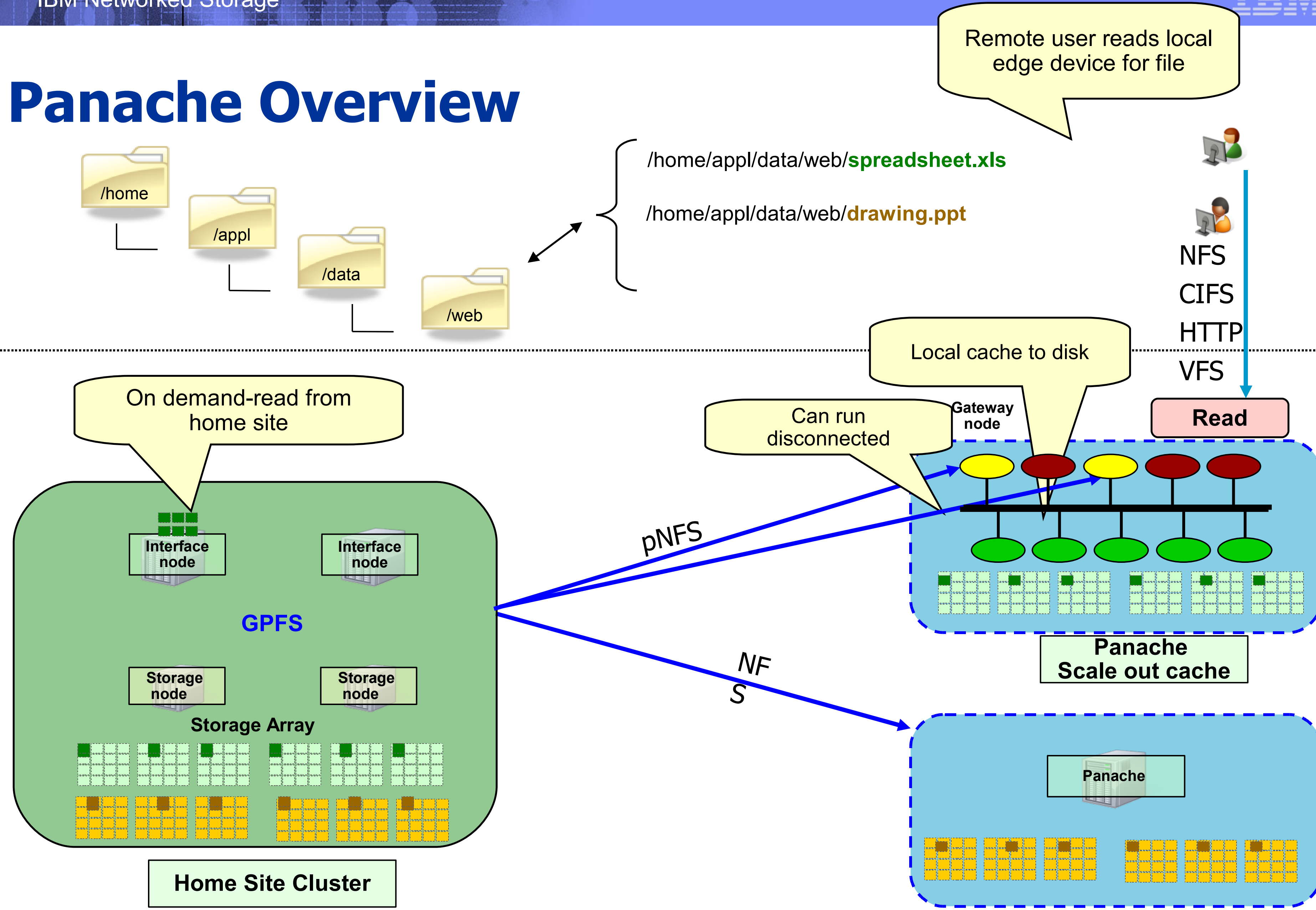


Cache is not only 'local' but also scalable

Outline

1	Panache Architecture
2	pNFS and parallel Reads
3	Asynchronous updates
4	Dependent Metadata operations
5	Namespace Caching
6	Summary and Conclusions

Panache Overview



How did that work

- Independent filesystems
- Separate inode space
- Home FS is unchanged
- Cache is a standalone clustered FS

Inode: 100

Inode attrs:

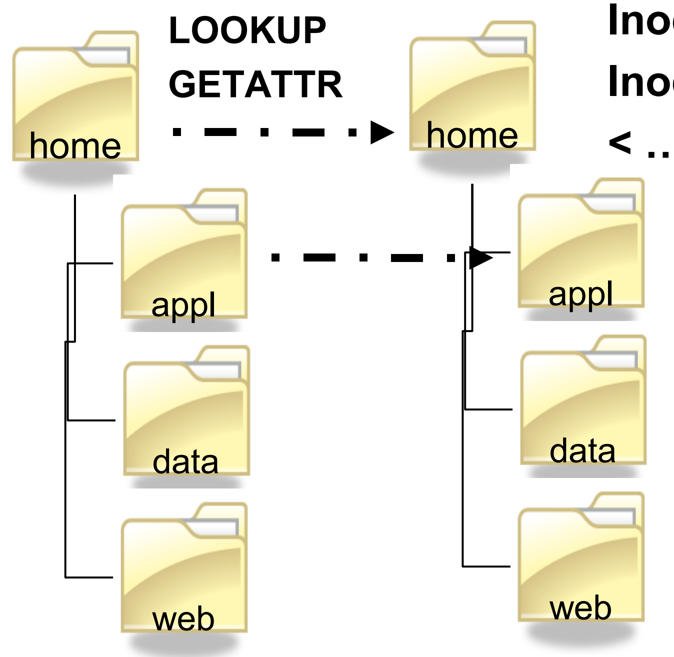
< … >

Remote state:

<id: 1024

attrs: mtime, ctime

>



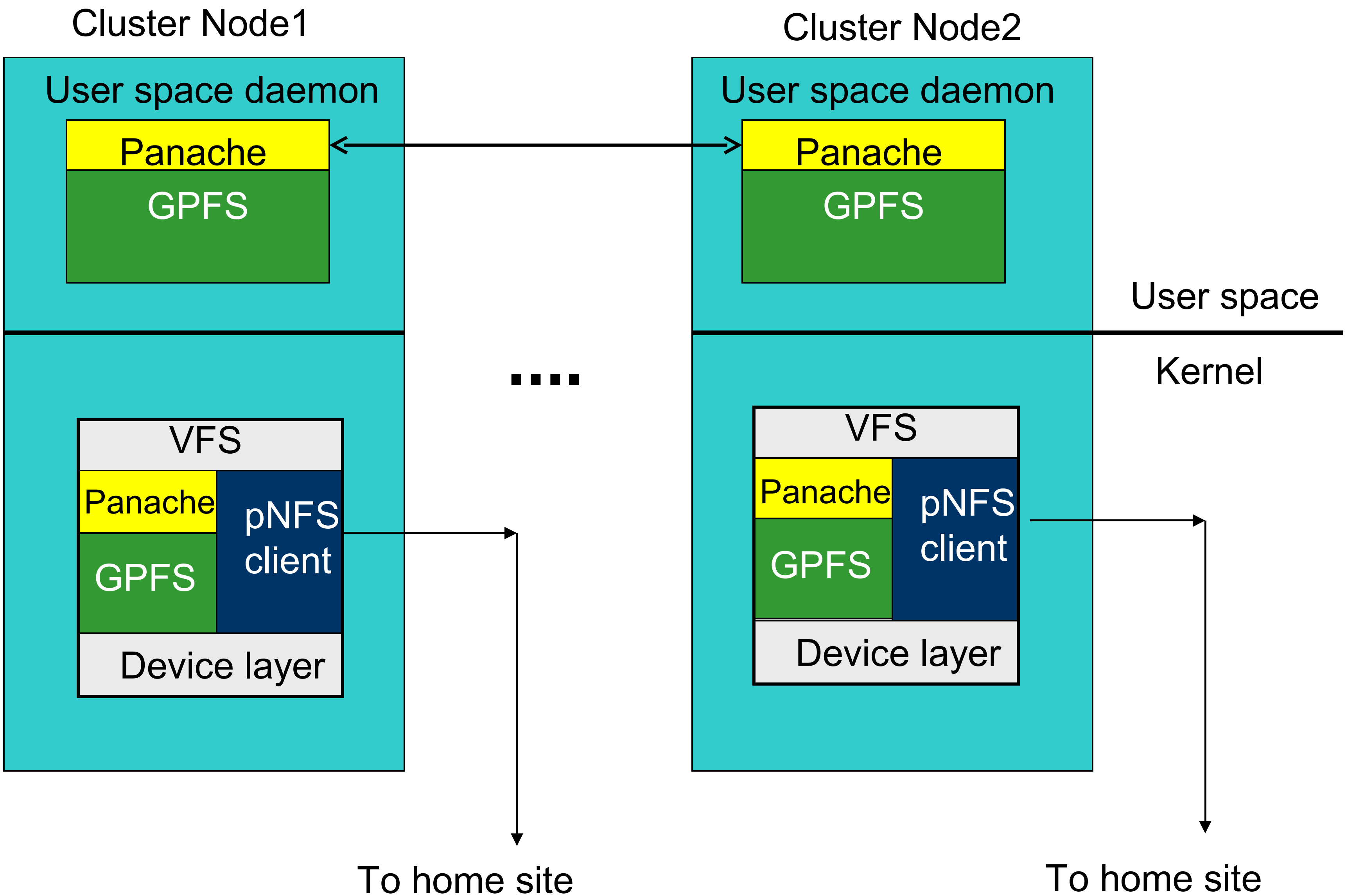
Inode 1024

Inode attrs:

< … >

Cache directory tree **Home directory tree**

Panache Internal Architecture



Key Features

- **Miss throughput at WAN bandwidth**
- **Hit throughput matches local access**
- **Writes and metadata updates match local speeds**
  - Asynchronous write back
  - Assume high latency to disconnected network by design
- **All operations are parallel**
  - Parallel ingest
  - Parallel access
  - Parallel update
  - Parallel data write-back
  - Parallel metadata write-back (non dependent operations)

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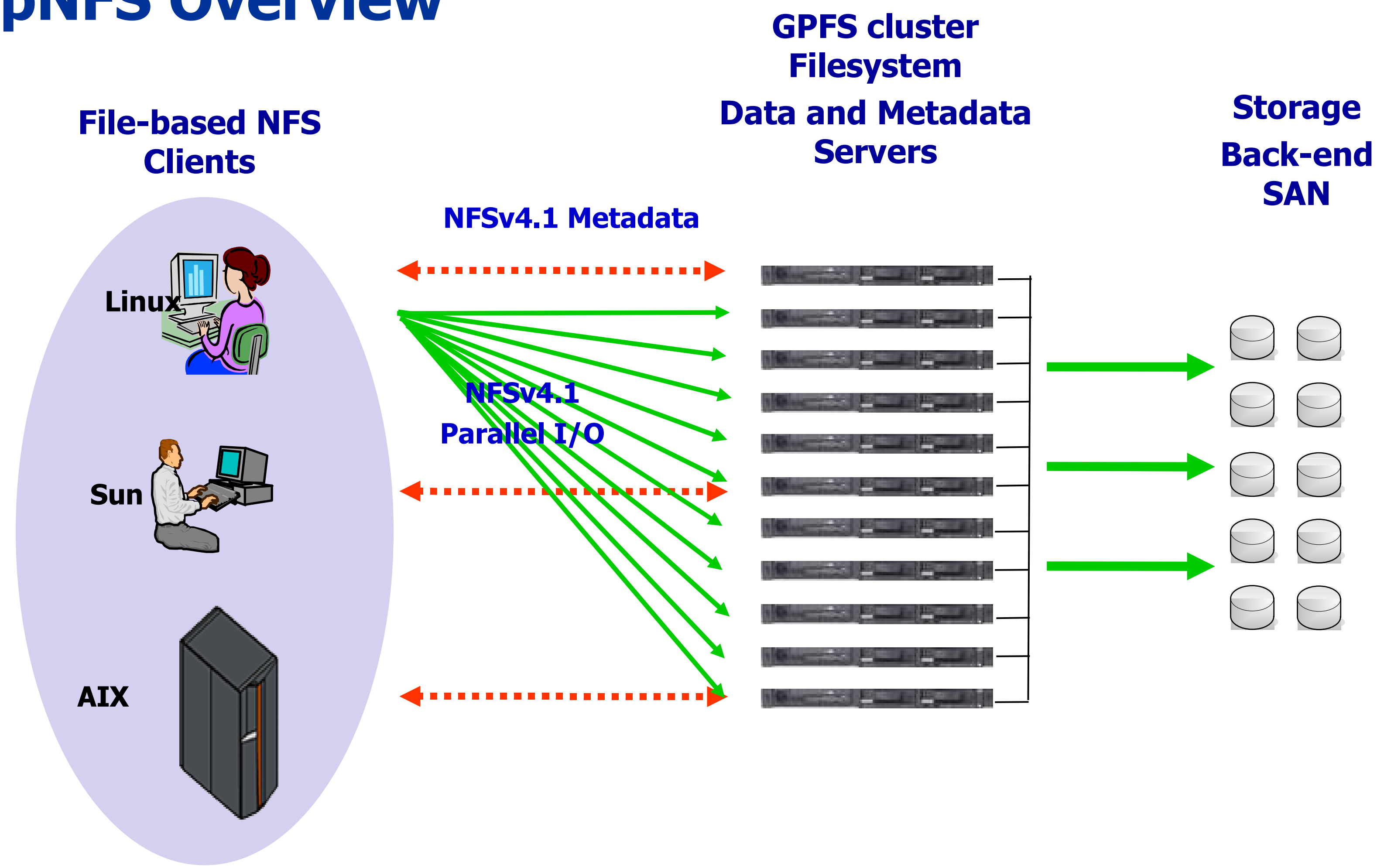
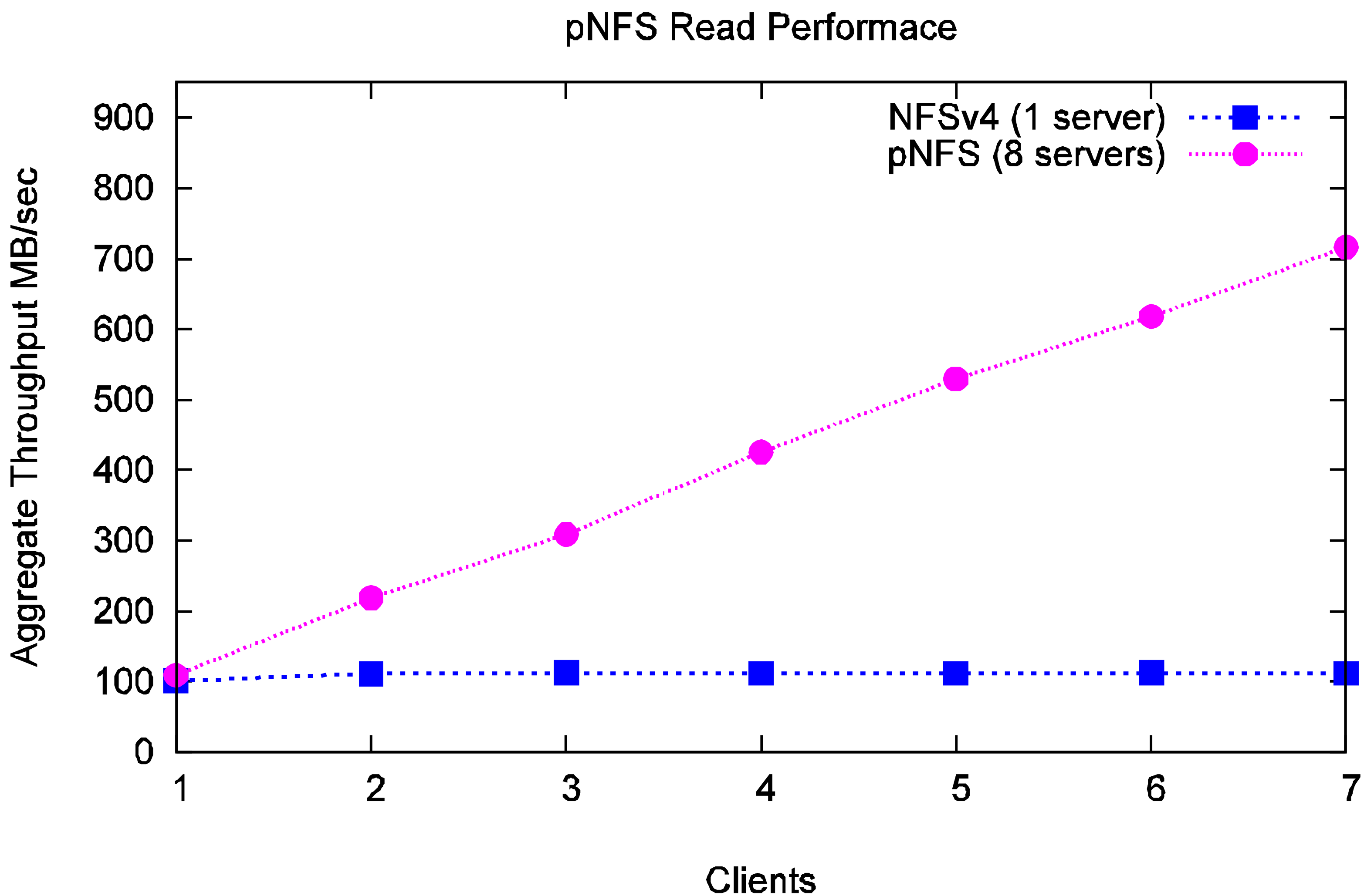
pNFS Overview

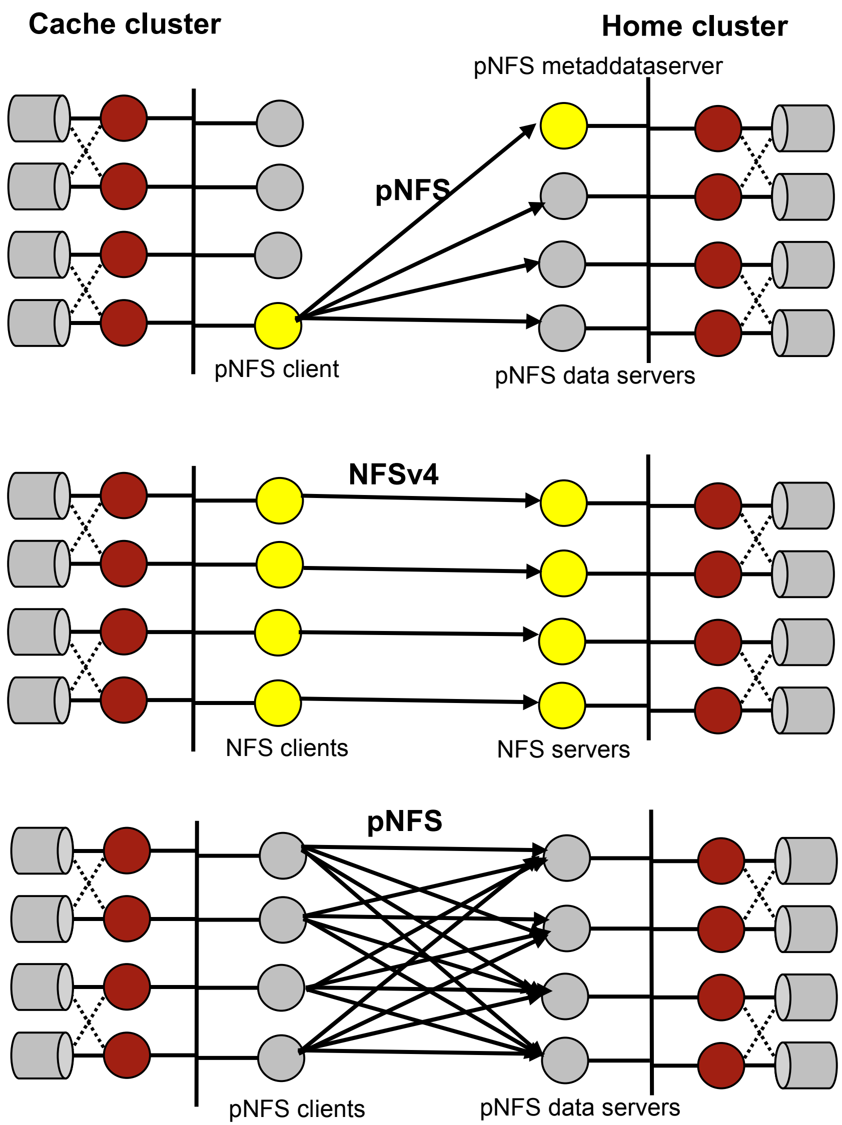


Why use pNFS for Data Transfer

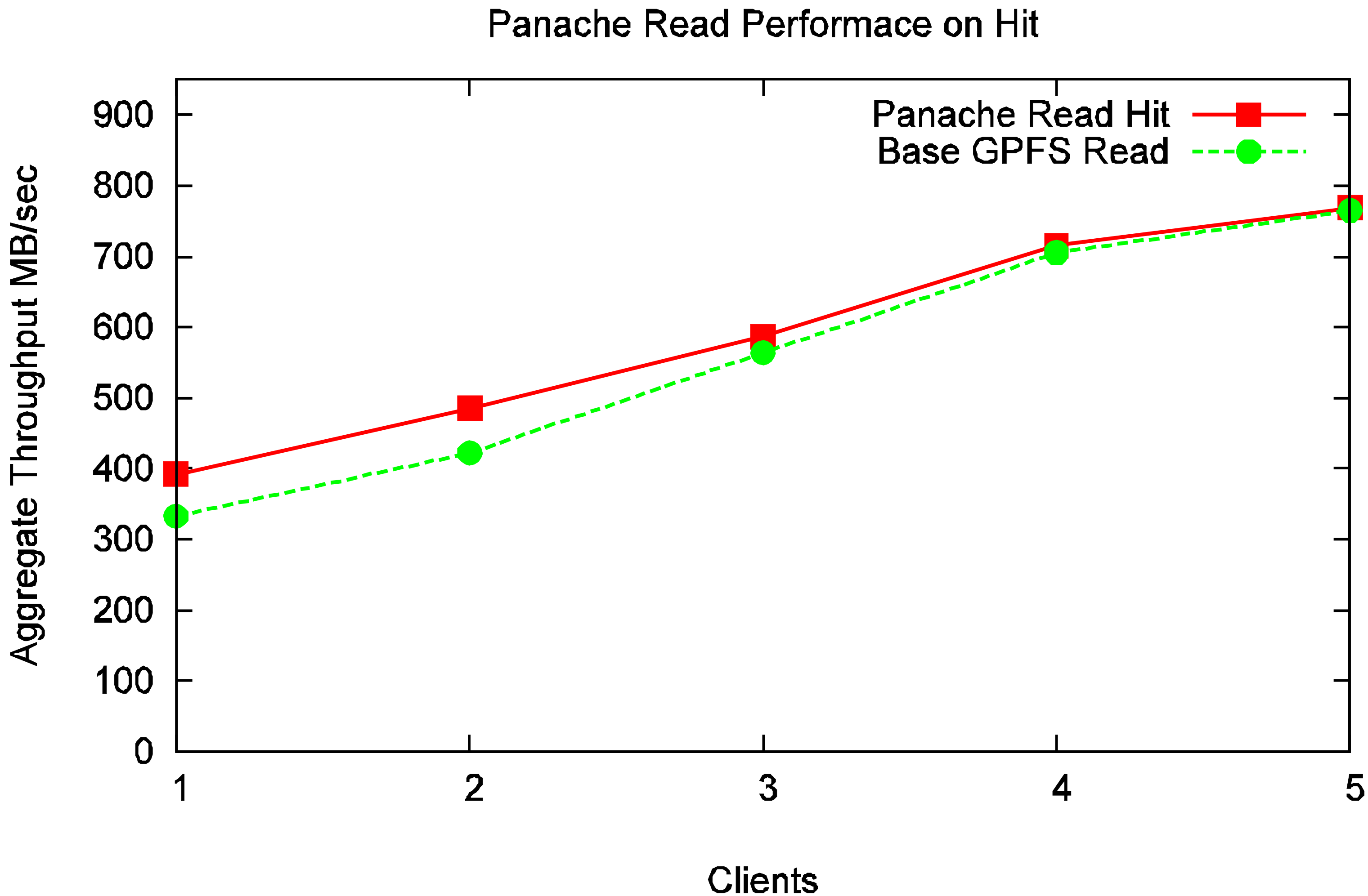


ior reads 8GB files, 8 node server cluster completely saturates the network

Parallel Ingest Options

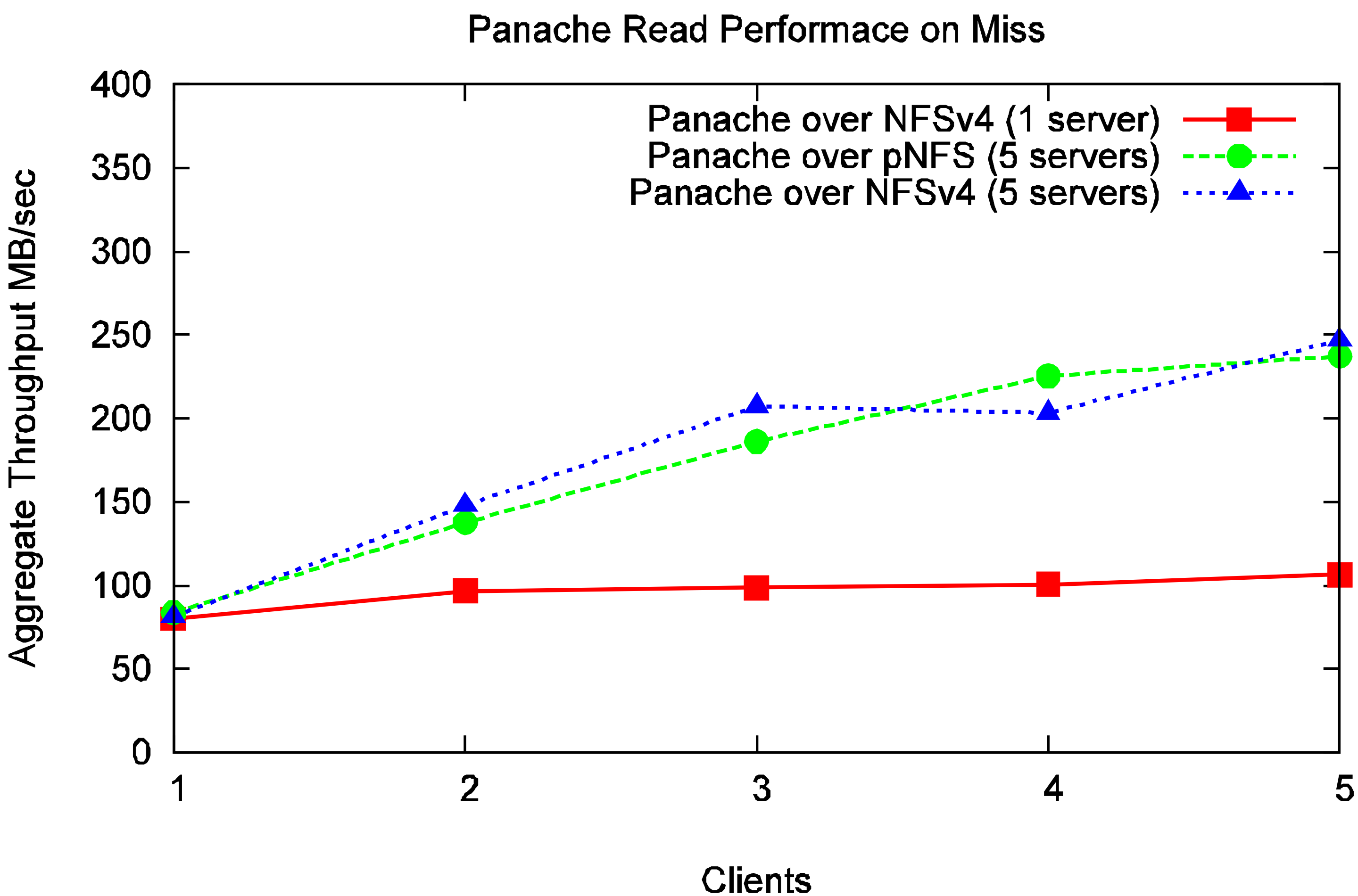


Cache Hit Performance



ior reads 8GB files, 10 node cache cluster (5 app + 5 gw), hits match local access

Cache Miss Performance



ior reads 8GB files, 10 node cache cluster (5 app + 5 gw), 5 node remote cluster
miss limited by network bandwidth

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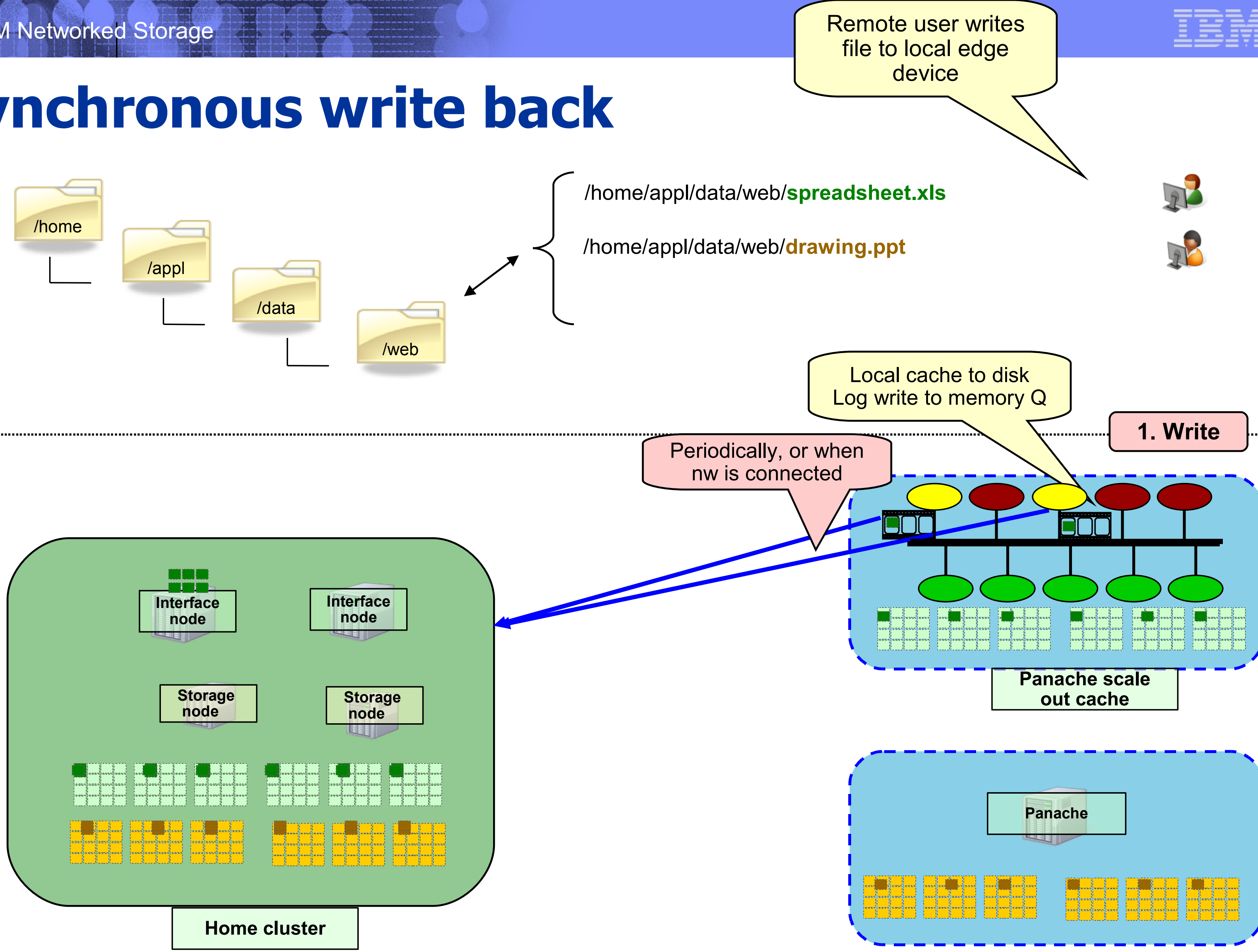
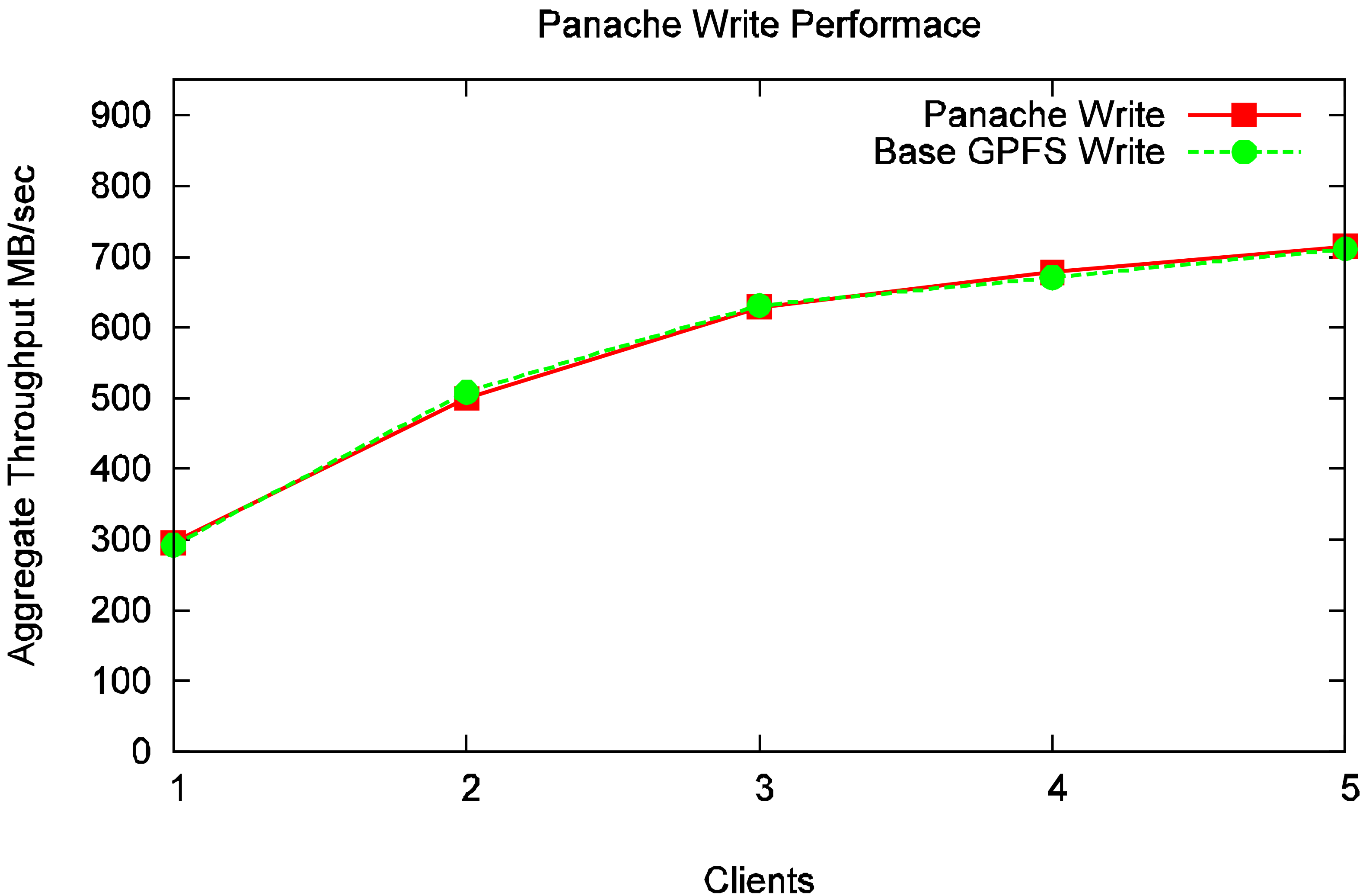
Asynchronous write back



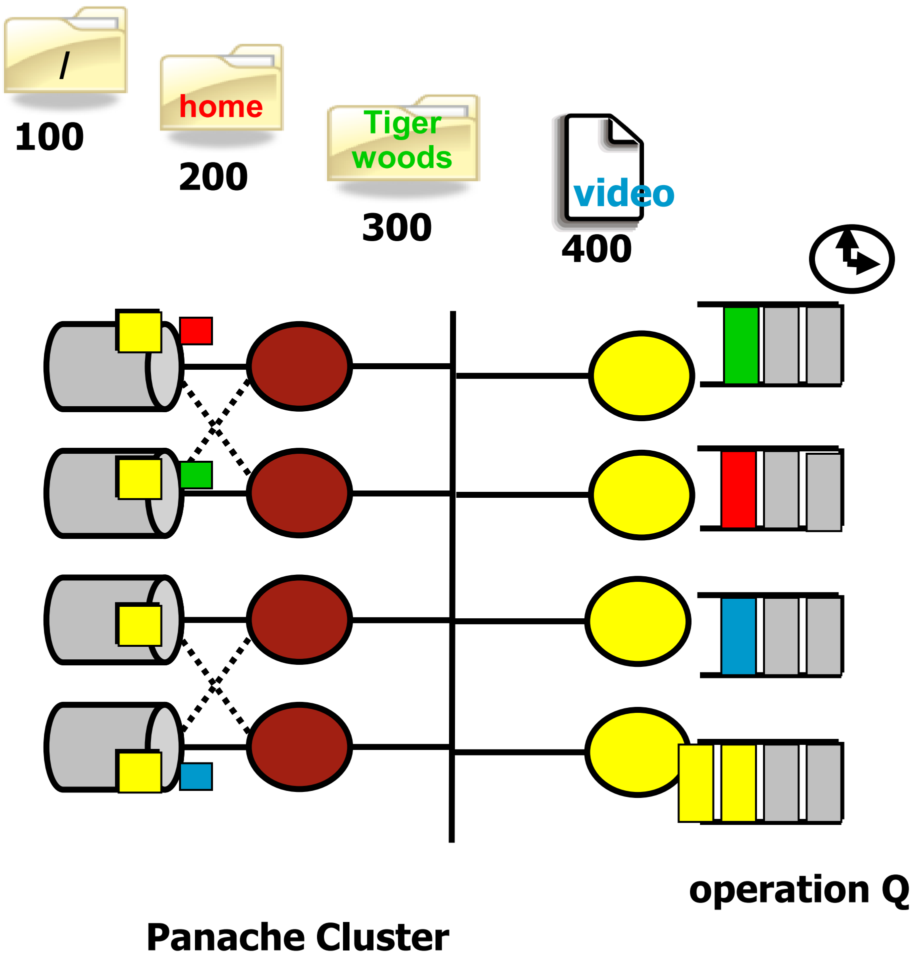
Cache Write Performance

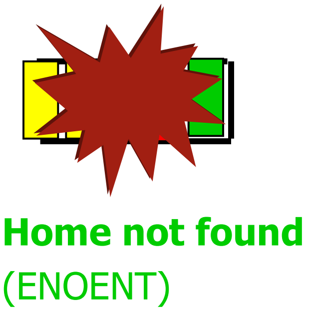


ior writes 8GB files, 10 node cache cluster (5app+5gw), writes match local access

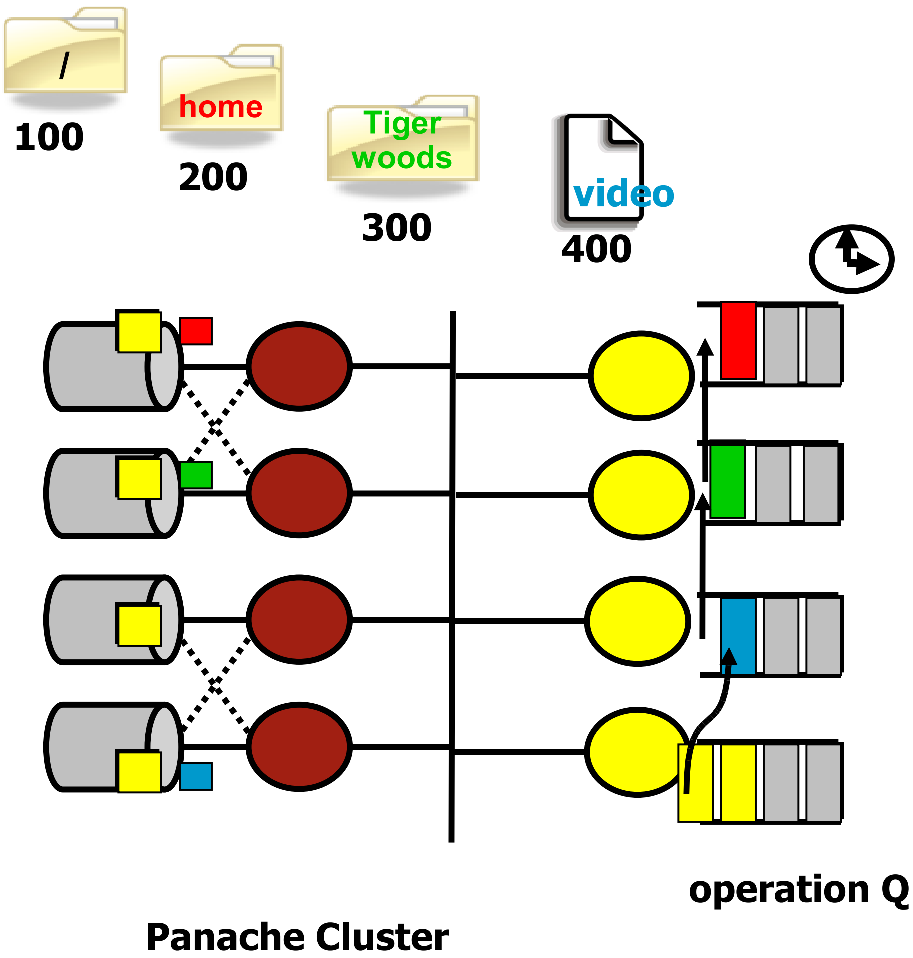
Dependent Metadata Operations

1	mkdir 100, home
2	mkdir 200, Tigerwoods
3	create 300, video
4	write 400, 0, 4M





Dependent Metadata Operations with Token Chaining



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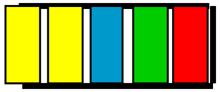
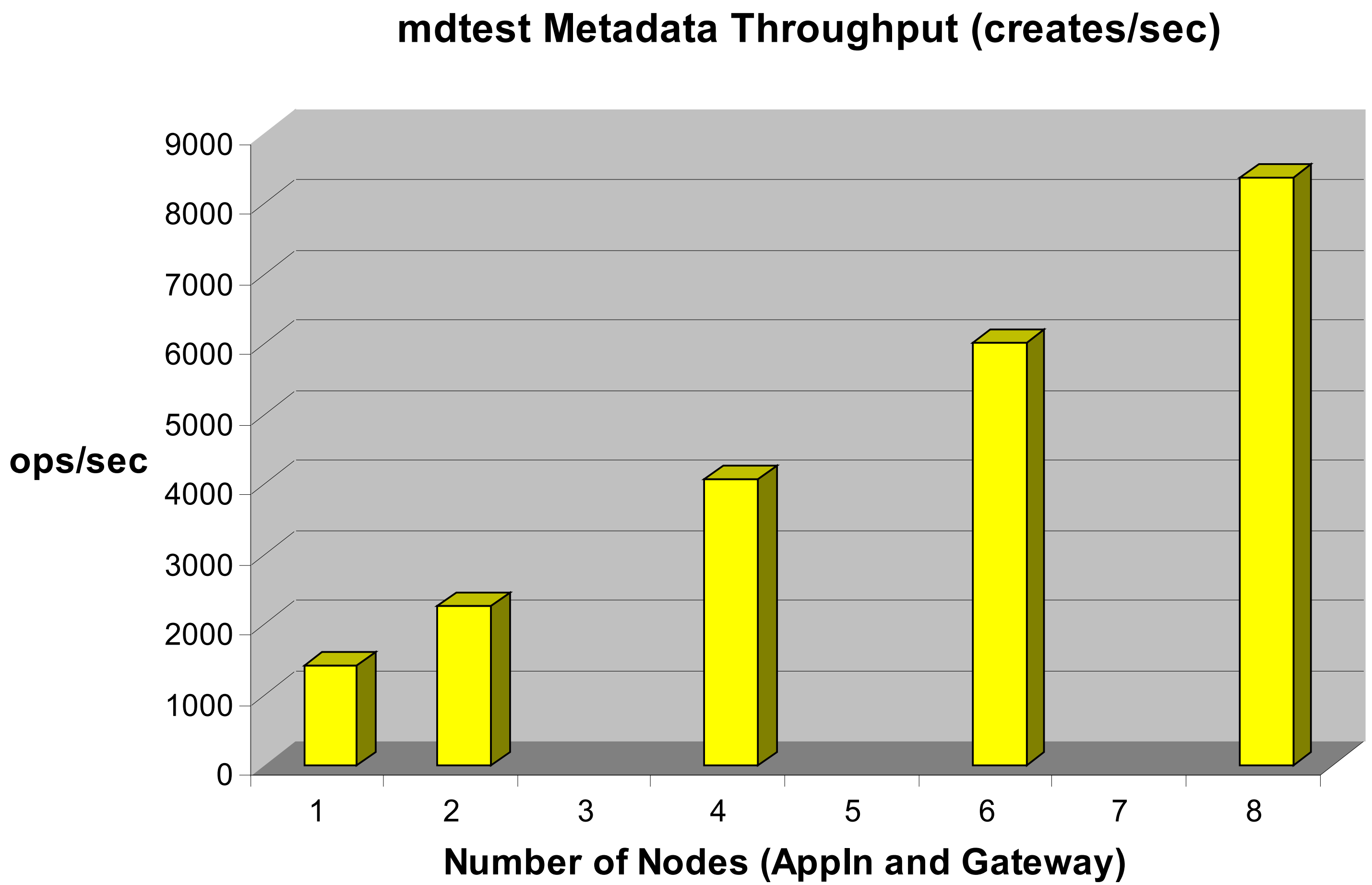


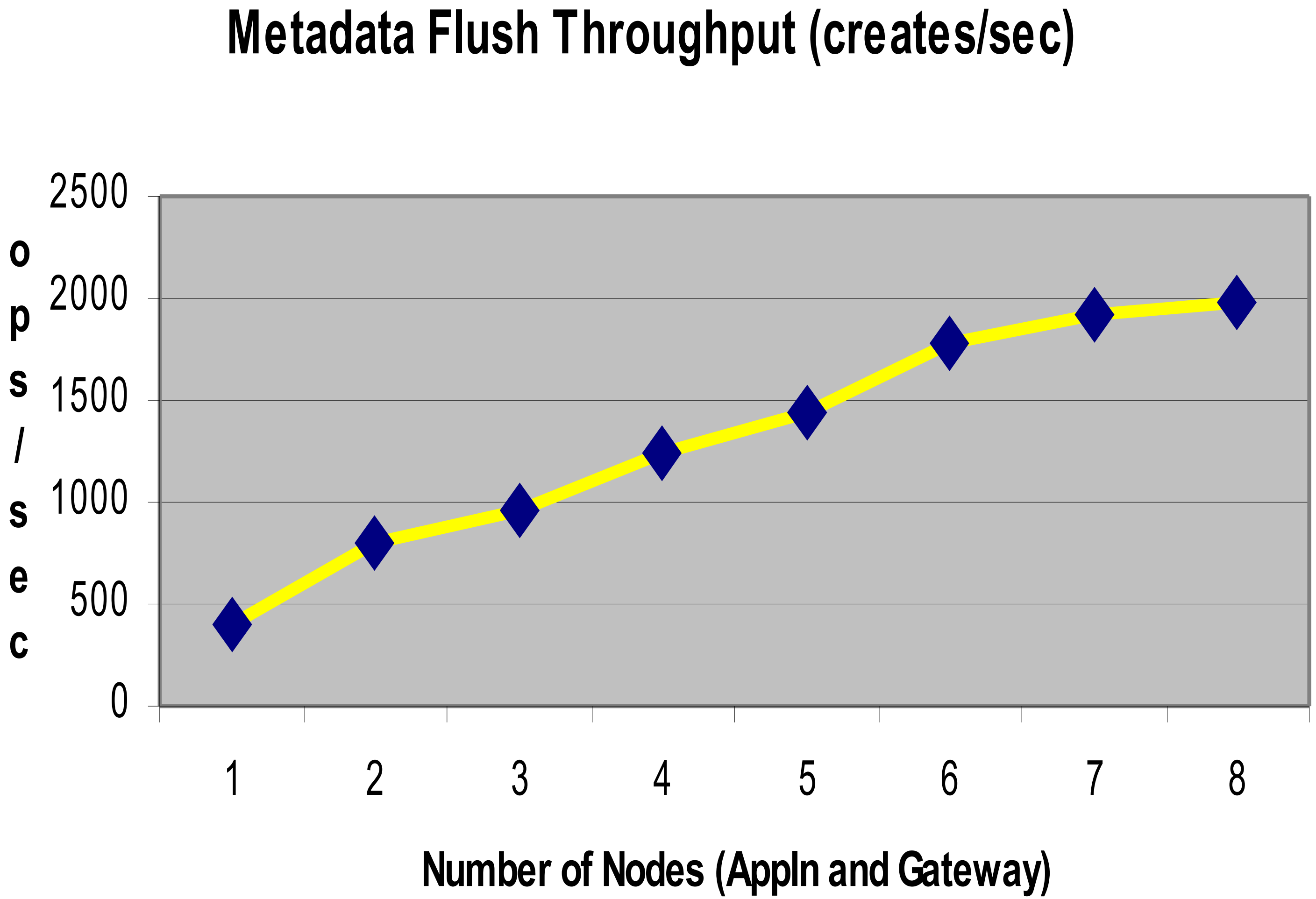
Rename, hard links cross multiple inodes

Parallel Metadata Throughput



mdtest 1000 creates/node, remote cluster size grows in tandem with gw nodes of cache cluster

Metadata Flush Throughput



mdtest 1000 creates/node, remote cluster size grows in tandem with gw nodes of cache cluster

Consistency Definitions

- **Local consistency**
  - Read from a node of the cache cluster returns the last write from any node of the cache cluster
- **Validity Lag** δ
  - Time delay between a read at the cache site reflecting the last write at the remote site
- **Synchronization Lag** μ
  - Time delay between a read at the remote site reflecting the last write at the cache site.
- **Close-to-open consistency**
  - For Open $\delta = 0$
  - For Close $\mu = 0$
- **When disconnected for time T**
  - $\delta \rightarrow$ T
  - $\mu \rightarrow$ T

Conflicts

- **In the absence of cross-site locking**
- **… In the presence of concurrent updates**
- **… Conflicts will happen**
- **Conflict detection**
  - Based on <ctime, mtime, inode#>
- **Conflict resolution**
  - Policy driven per dir tree
  - No data loss …copy to .conflicts dir

Caching Large Namespaces

- **Directory Tree “created” on demand**
- **Readdir (e.g., ls)**
  - <name, inode number>…
- **Readdir plus attrs (e.g., ls –l)**
  - < inode attrs> for each dir entry
- **Inodes allocated but not “created”**
  - Directory entry contains “orphan” inode
  - “create” the inode on a later lookup

Namespace Caching Results

Files per dir	Readdir w/ creates	Readdir w/ orphan inodes	Readdir from cache
100	1.9 s	0.7 s	0.03 s
1000	3.1	1.2	0.09
10000	7.5	2.8	0.15
100000	451.7	25.4	1.2

Summary

- For global file access across data centers
- …cache should be scalable
- Parallel data fetching from/to multiple nodes
  - Miss throughput limited by WAN bandwidth
- Hit throughput matches local data access
- Update throughput matches local access
- All data/metadata updates are asynchronous
  - Handle intermittent network connectivity by design

Questions?