A light-weight, cooperative temporary file system (CTFS) for cluster-based Web servers

Jun Wang

Computer Science and Engineering Dept.

University of Nebraska Lincoln

Outline

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- CTFS design
- Experimental methodology
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- Related work
- Conclusion

Introduction

- A commodity cluster-based Web server becomes more popular
- Disk I/O is an important performance bottleneck in non-content aware cluster-based Web servers
- Content-aware cluster-based Web servers can alleviate I/O overhead but with complicated implementation; more importantly, they are not helpful for data-intensive Web loads
- Pai et al. (ASPLOS'98) concluded that cluster-based Web servers have disk-bound problems rather than CPU-bound
- CDN and reverse proxy server can not eliminate I/O problem

Current solutions

- The general-purpose native file system (FFS, UFS, etc.) where cluster-based Web servers are designed to run has following problems
  – Local file systems on host server nodes do not share and exchange files, and result in repeated I/Os
  – Specialized distributed file systems have poor portability
  – Multiple buffering or data copies for intra-cluster communications
  – Small docs dominate Web server access pattern but FFS is not good
  – Read requests dominate Web server access pattern
  – Associated access locality is not exploited (Ex., a HTML file with hyper linked files)
  – Meta-data overhead (Ex., frequent access time update)

Our new solution

- A light-weight, cooperative temporary file system (CTFS)
  - Deploy a TFS (temporal file system published in Wang et al's MASCOTS'03) on each server node
    - Manage own data and meta-data on raw disk, bypass native file system (NaFS, for example, FFS, UFS) and adopt customized optimization cache replacement algorithm for Web server workload
    - Work in front of NaFS
    - Store secondary copies and optimize data layout
    - Transparent to users
  - Each TFS peer works cooperatively together with other TFS peers and construct a peer-to-peer TFS software architecture

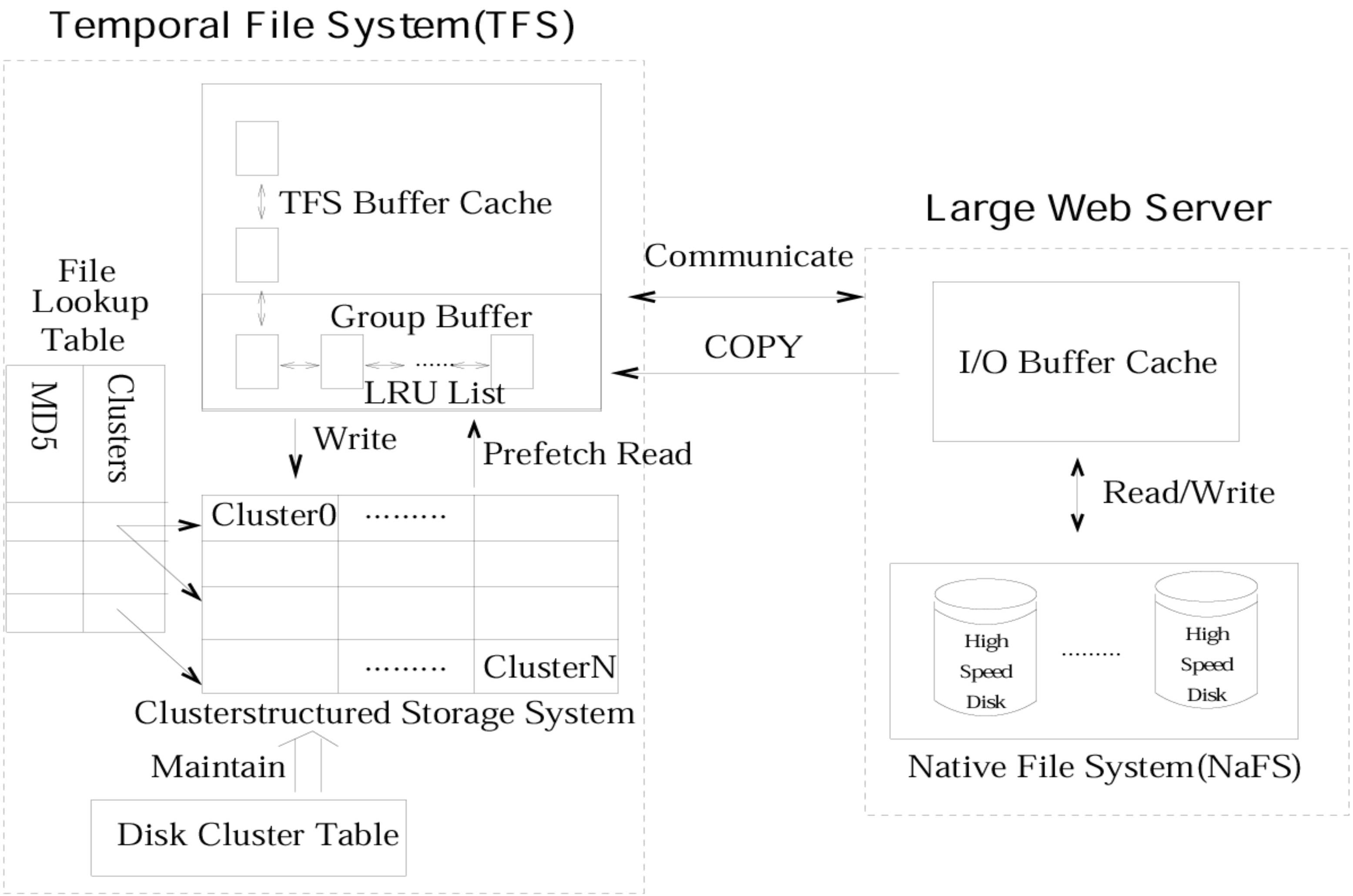
Our new solution (cont.)

- Intra-cluster communication technique adopts remote direct memory access (RDMA)
  - Advantages: low CPU overhead, zero copy, fast transfer and follow user-level implementation
    - Transferring 32 KB data by RDMA takes 0.29 ms while local disk access needs 8 ms. Compared to TCP, RDMA improves performance as much as 29% (Carrera et al. HPCA8)
  - Several successful implementations such as Myrinet-VI, Giganet VIA, M-VIA, ServerNet VIA, Firm VIA
  - Direct Access File System (DAFS) employs VIA/RDMA as network communication technique

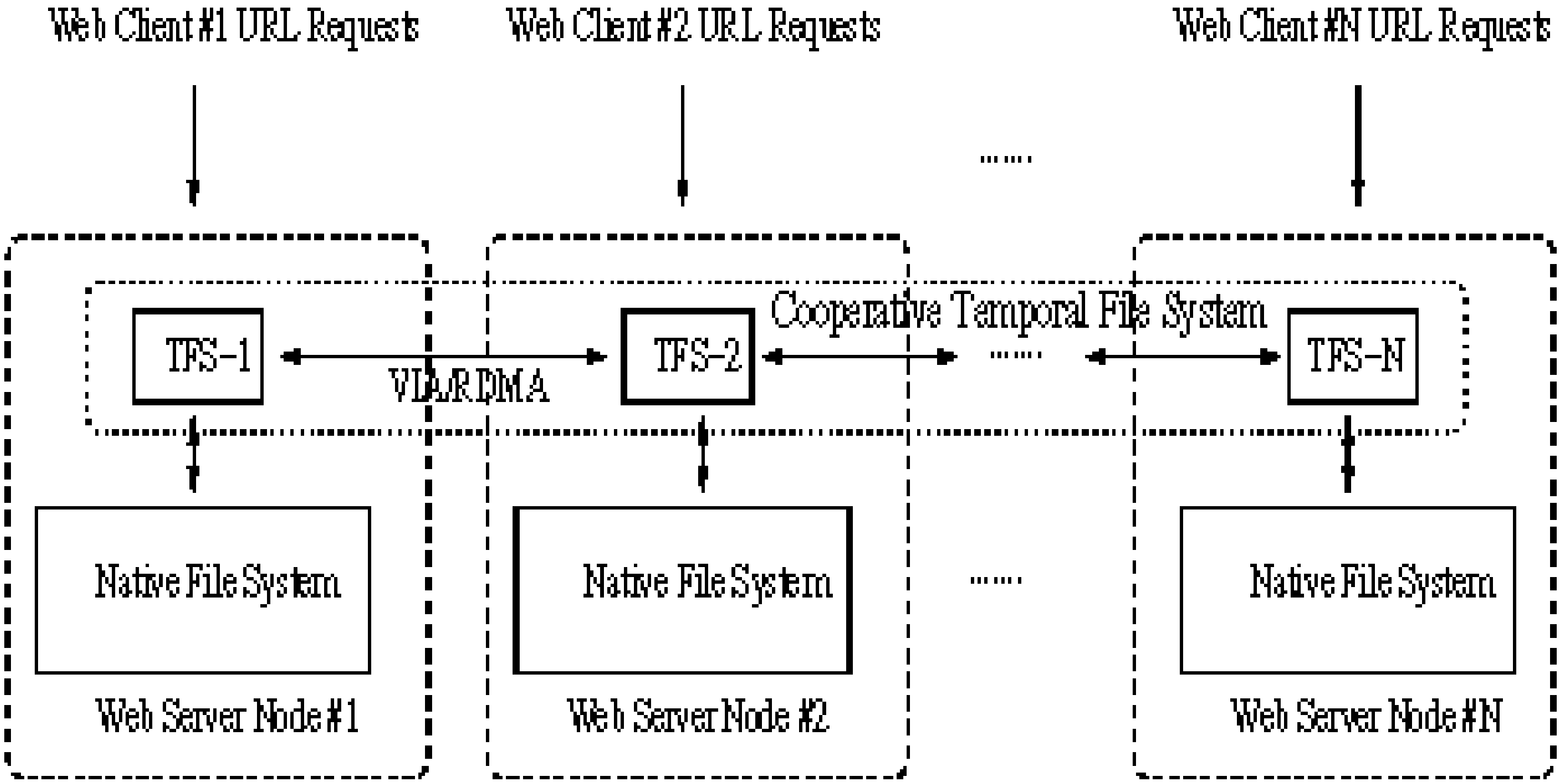
Our new solution (cont.)

- Disadvantages
  - Additional space for second copy, but disk space is too cheap and such a trend will continue. Moreover, CTFS controls the size of its partition by managing only frequently-accessed files

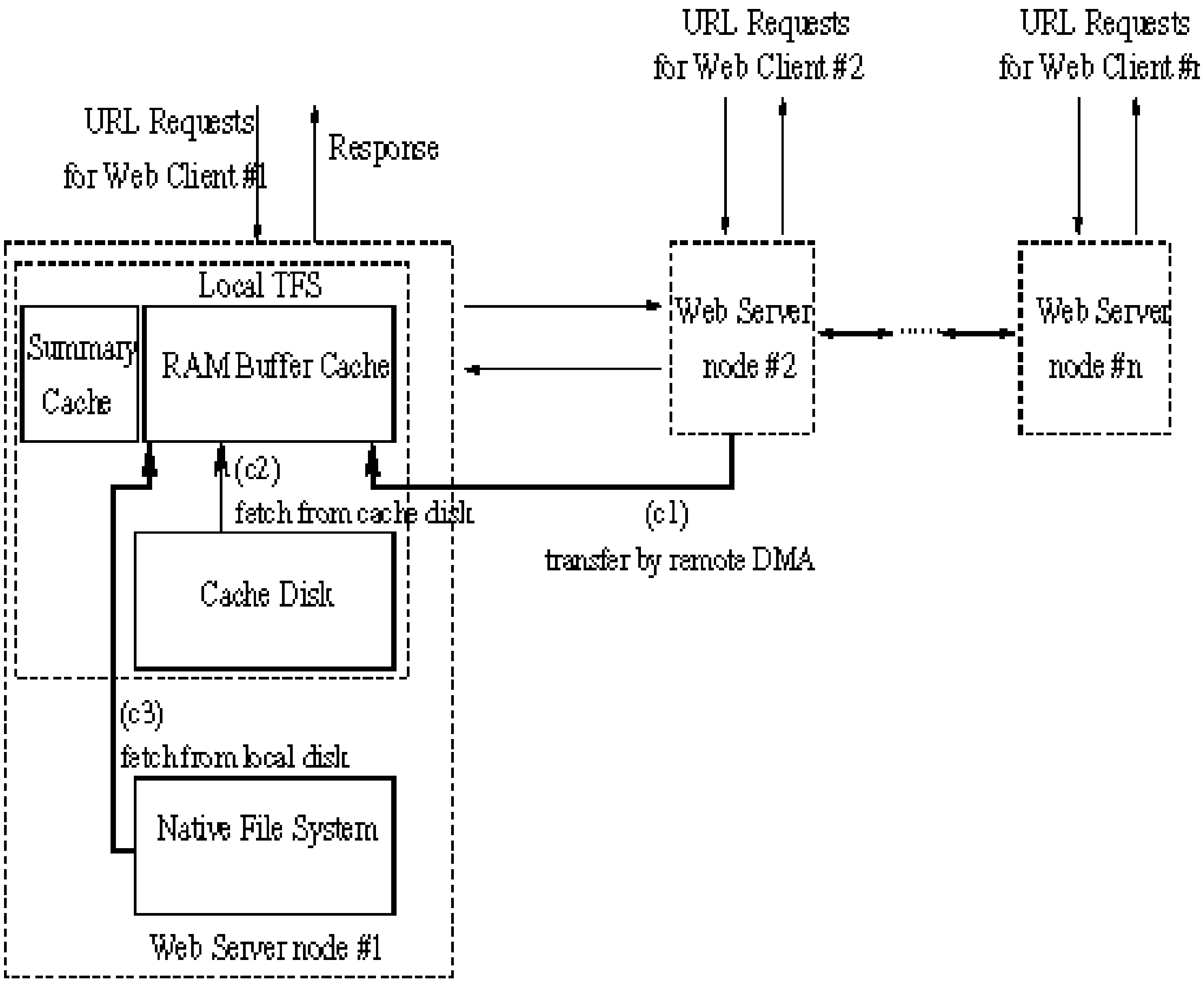
TFS system architecture on a single server node



CTFS for cluster-based Web server architecture



CTFS Cooperative Caching Architecture



Summary Cache Design

- Each TFS peer adopts a bloom filter representing all CTFS files as an in-memory file lookup table
- Similar to summary cache project (Li, Cao and Almeida’s SIGCOMM'98)
- CTFS can support 64 peer TFS with each containing 10 K files, and 1.4 MB memory space for 640 K files in total

Advantageous Prefetch

- Do prefetch simultaneously when reading the target file from remote buffer cache or local CTFS cache disk
- Capture associative locality in Web access load for both local and remote nodes

Consistency Control

- Multiple copies of the same file may be cached on different TFS
- Native file system informs CTFS a stale file, every related TFS invalidate the entire disk cluster that contains the stale file
- Associate access locality indicates the files reside on a cluster may be invalidated together

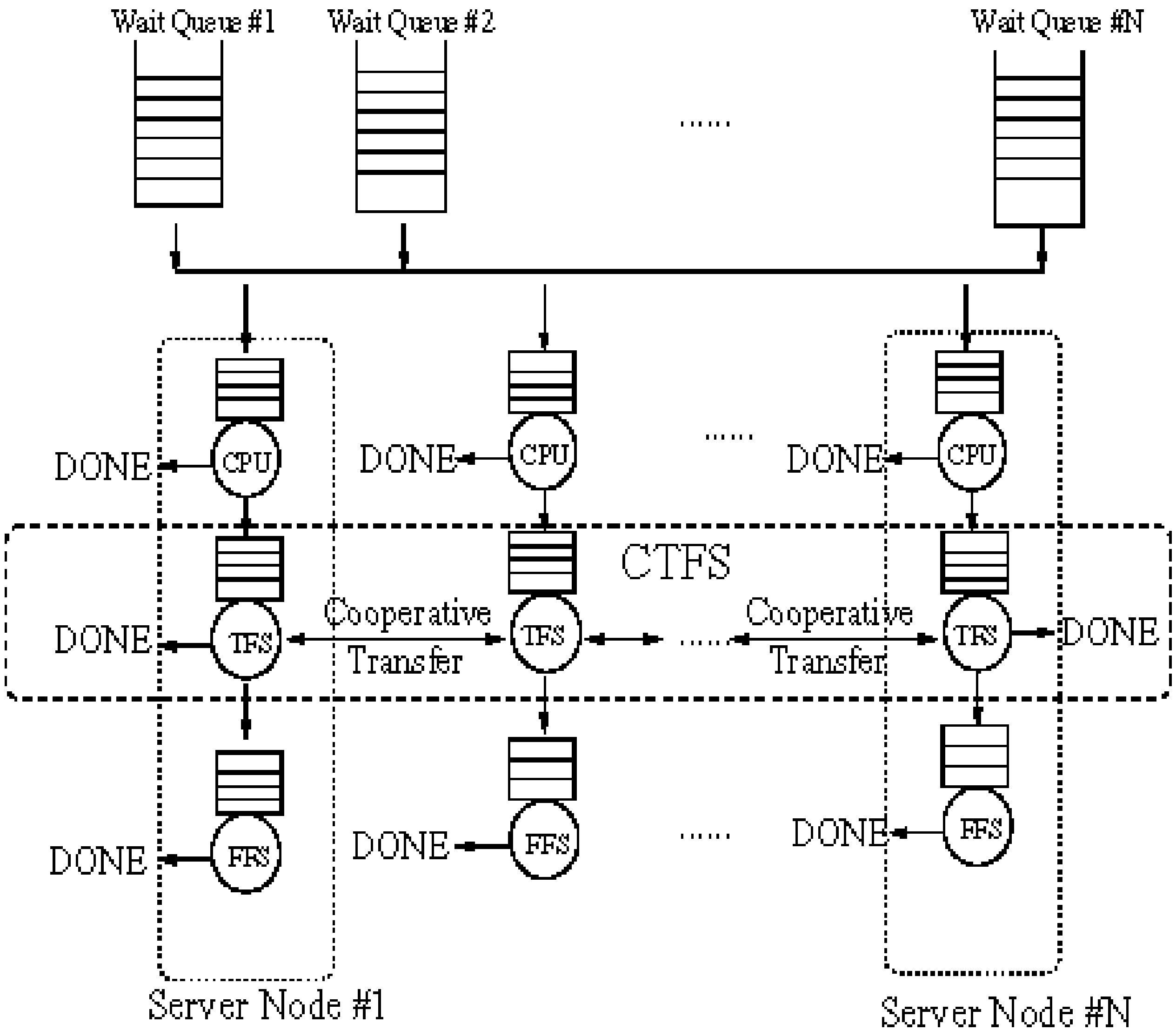
Crash Recovery

- Not a major issue since CTFS is a temporary, read-only file system
- Can implement a journaling file that will log the most-recently-accessed cluster Ids
- After a crash, the clusters on such a log will be used to initialize CTFS buffer cache. Therefore CTFS can achieve a hit rate close to that before the crash

Experimental methodology

- CTFS is a HTTP trace-driven simulator ported from distributed Web server simulator by University of Saskatchewan
- CTFS contains
  - A cluster-based Web server component
  - CTFS together with FFS-async component
  - Disk simulation slaver
- Baseline system: UNIX FFS mounted on asynchronous mode (FFS –async)

CTFS Simulation Model



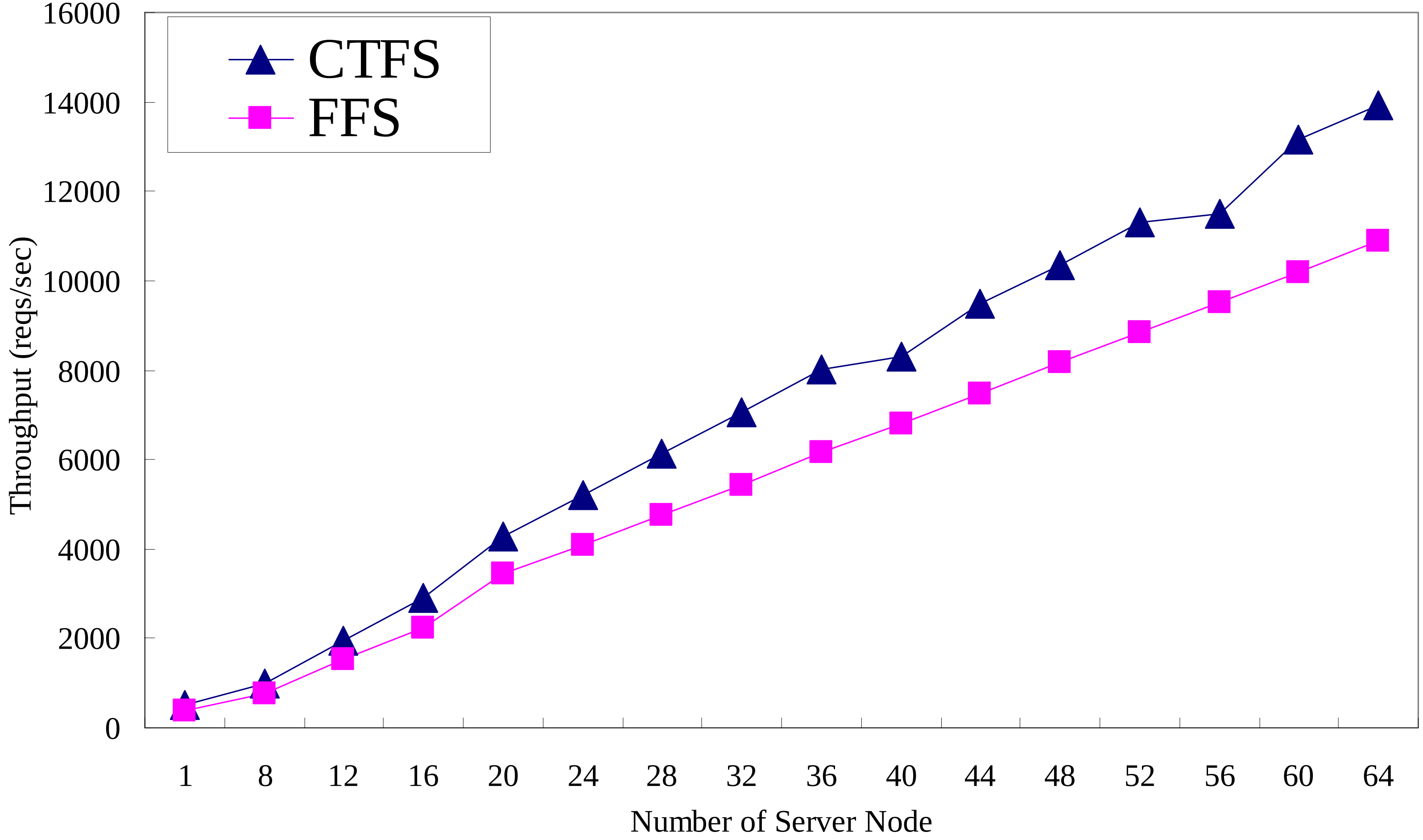
Configure Simulation

- RDMA-based intra cluster communication:
  - 4 byte message takes 9 microseconds, 32 KB message takes 0.29 ms
- Connection establishment and shut down costs are 40 us
- I/O buffer cache replacement policy are Greedy-dual-size
- A weighted round-robin request distribution strategy
- I/O buffer cache size is 512 MB

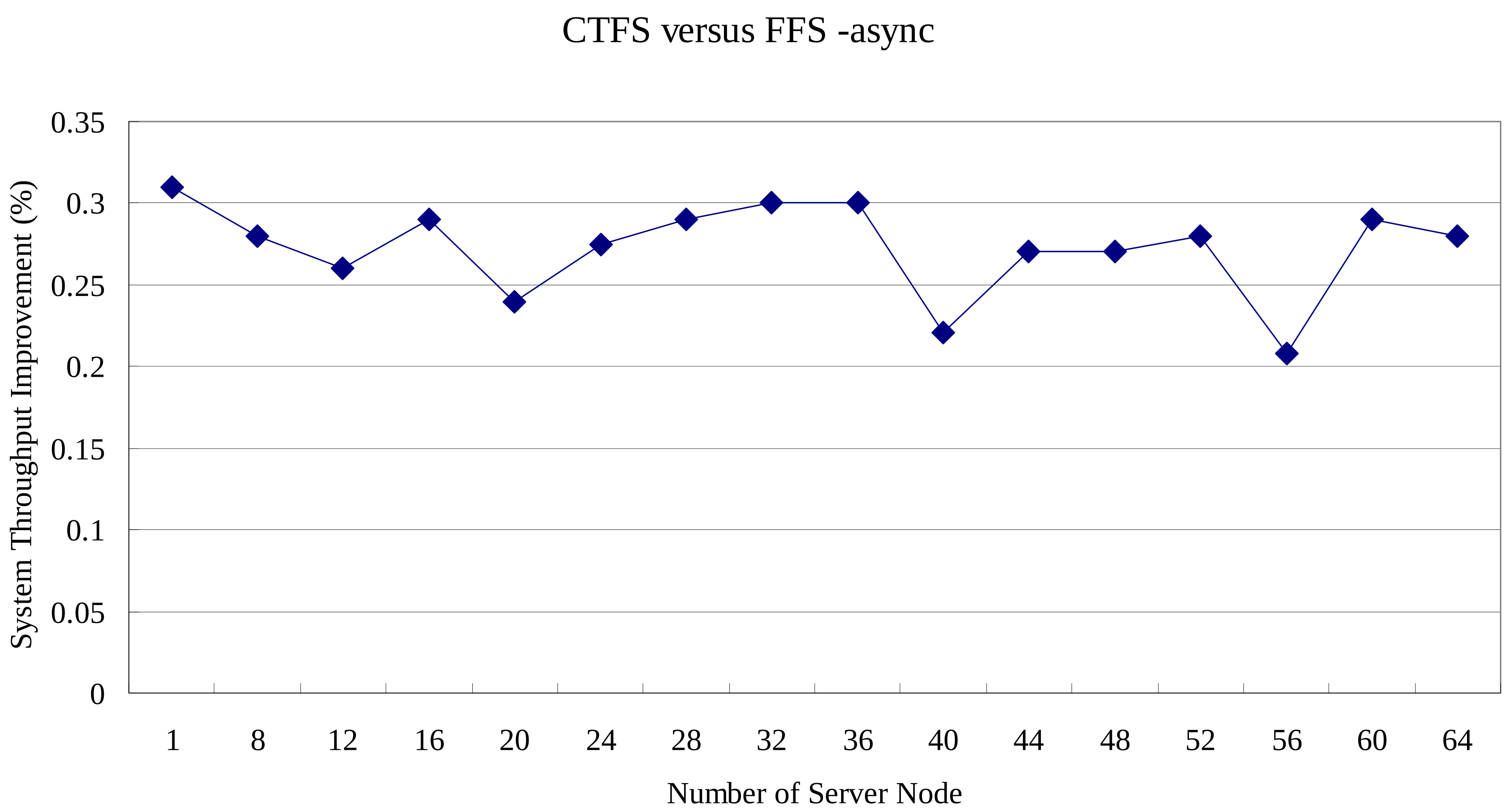
Real-world Workloads

Properties	UCBSep01	SpecWeb99
Location	U. of California Berkeley	U. of Nebraska Lincoln
Duration	Sep.1-Dec.1, 2001	Sep.7-Sep.8 2002
Requests	14,413,271	40,000,000
Bytes Xerred(MB)	320,056	350,000
Unique Bytes(MB)	14,605	25,000
Mean File(B)	26,040	18,584
Median File(B)	6,912	5,094

Experimental Results with Berkeley Trace



Experimental Results with Berkeley Trace



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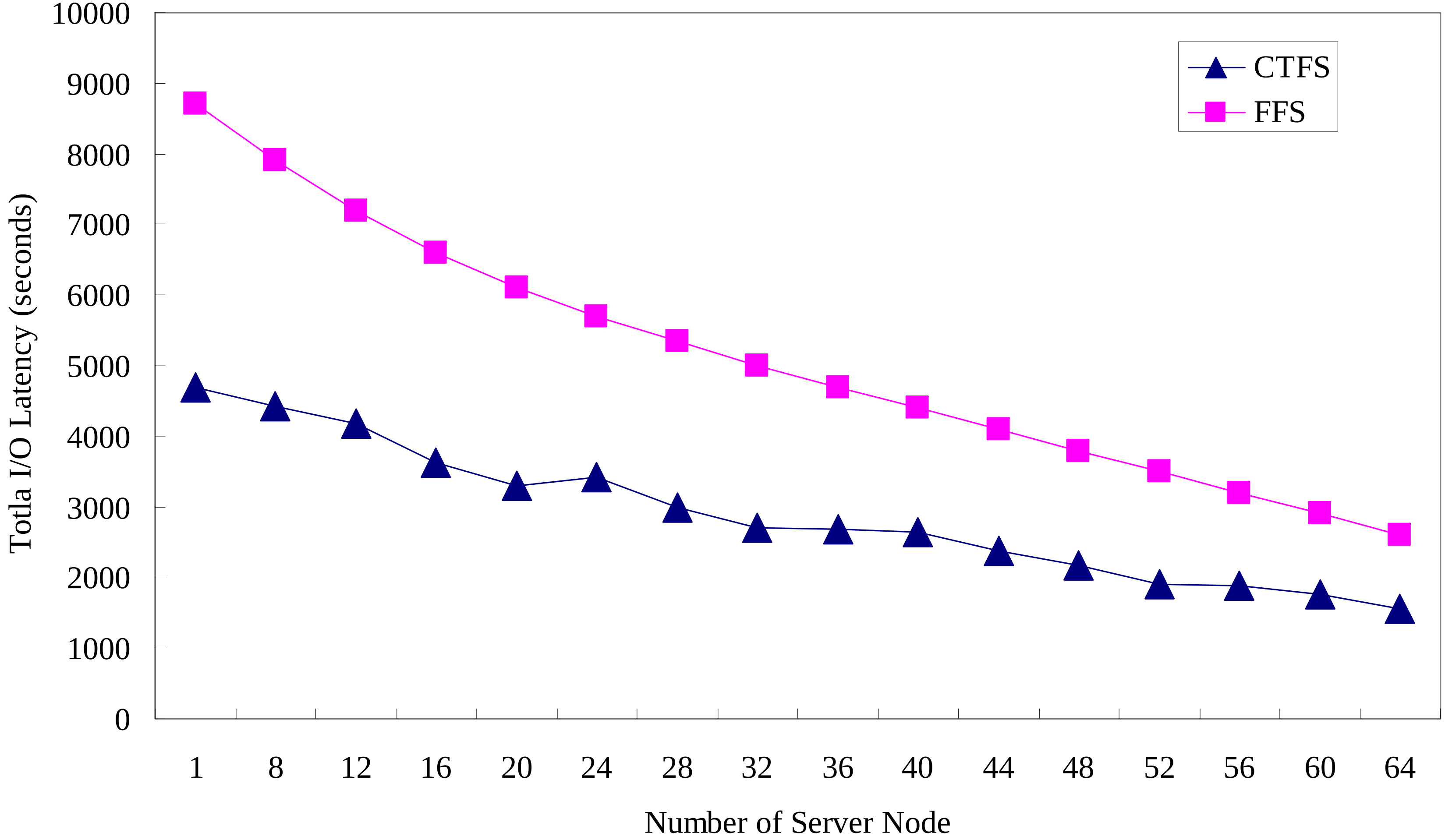
Experimental Results with Berkeley Trace



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Related work

- UCFS (Wang & Hu, IEEE TC 2002)
  - UCFS for Web proxy server, both read and write intensive
- TFS for Web server, read intensive (Wang & Li, IEEE MASCOTS 2003)
- Hummingbird (Shriver USENIX'01)
  - TFS no garbage collection overhead
- Other temporary file systems work in kernel space, rather than user space

Conclusions

- CTFS is a new light-weight, cooperative temporary file system for cluster-based Web servers
- Advantages are good portability, scalability, improved system throughput, much less I/O traffic and deliver a sustained high I/O performance
- CTFS improves system throughput from 24% to 37% compared to FFS-async when the cluster size varies up to 64