User Level Techniques for Improvement of Disk I/O in WWW Caching

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Overview

Goal, target and challenge

Bottle necks

Our techniques at user land

Evaluation

Background

Current trends of WWW Cache

- Network appliance
- Kernel side techniques

However, these means...

- No or poor portability
- Vendor depend
- Expensive

Goal

Fast WWW caching system upon **GENERIC** system

For work-group and/or department cache service

up to 100Mbps

We want

More portable

Vendor independent

and cheap...

What is Generic System ?

Don’t use special something

- super computer (e.g, GS-xxx, Origin-xxxx)
- physical devices (e.g., silicon disk)
- logical devices (e.g., /dev/poll)
- filesystem architectures (e.g., raw I/O)
- system-calls (e.g., sendfile())

Targets & Challenges

Targets

- UNIX
- BSD sockets and related
- UFS interfaces
- POSIX threads

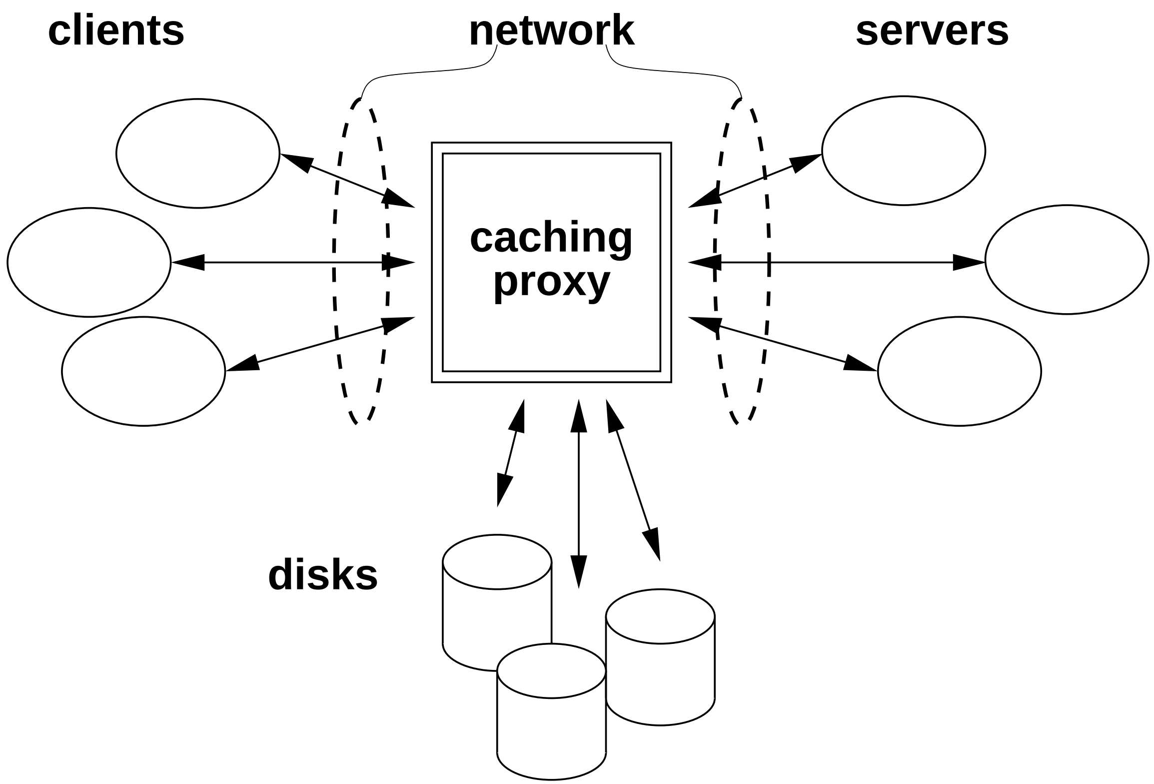
Challenges

- Fast disk I/O w/o kernel change
- User level storage mechanism like filesystem

Where is Bottle-Neck(s) ?

Caching Proxy is I/O multiplexing system

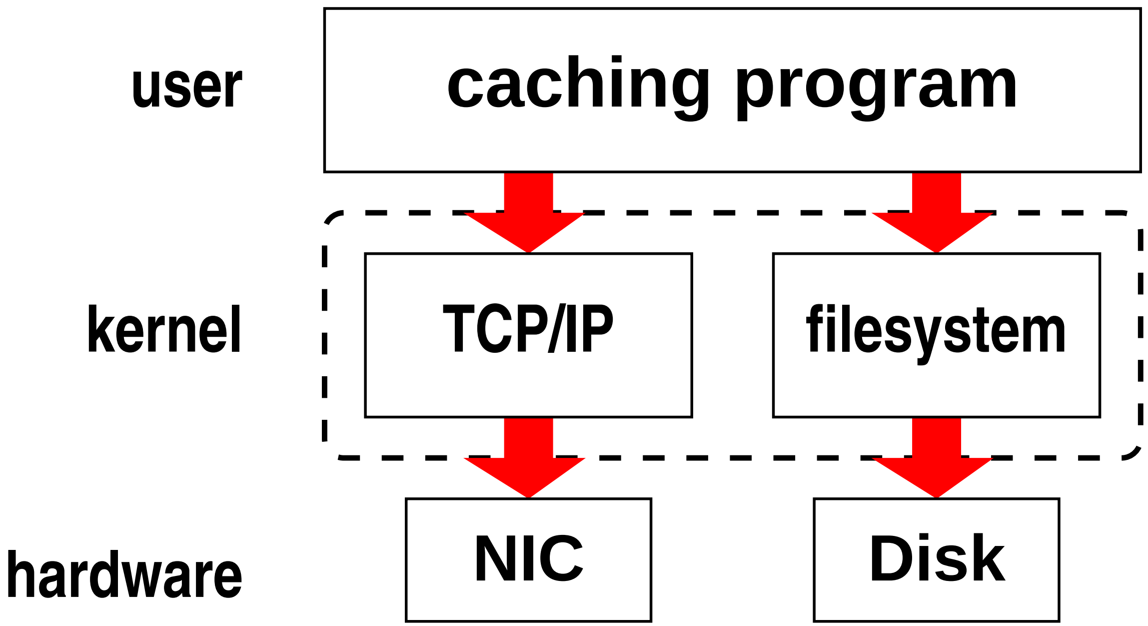
Most of time is I/O waiting



Network v.s. Disk

Network is controlled via TCP/IP stack.

Disk is controlled via filesystem.



Network v.s. Disk (*cont*.)

Network

Typical: FastEthernet, Gigabit Ethernet

Max: Gigabit Ethernet

Boundary: PCI bus; thru-put is cutted under few 100Mbps

Disk

Typical: Ultra 2 Wide SCSI, SCSI 160m, ATA 100

Max: SCSI 160m, FC 2Gbps

Boundary: filesystem; few MB/s (several 10Mbps)

Filesystem is bottle-neck

- Network is enough to satisfy our requirement (under 100Mbps)
- Filesystem is not satisfy our requirement

Remarks:

- RAID is not perfect solution
  - RAID improves raw disk performance
  - But bottle-neck is file system...

Why filesystem takes long time ?

- Designed for generic purpose
- Resource management
  - i-node
  - directories
  - free block bitmaps
- System calls
  - open/creat
  - read/write

Characteristics of WWW Caching

- Small size
  - most several KBs, max few MBs
- Poor locality
  - typical hit ratio is 20% - 40%
  - smaller than memory or disk caching
- Long term stress
  - writing/reading several hours

Typical Approach

Many vendor/organization employ **special solution**

- Special filesystems
- Special scheduling for I/O
- Special systemcall for I/O
- and others

These approachs depend paticular OSes and/or vendors

Our Approach — KOTETU

Reduce filesystem overheads w/ user level techniques

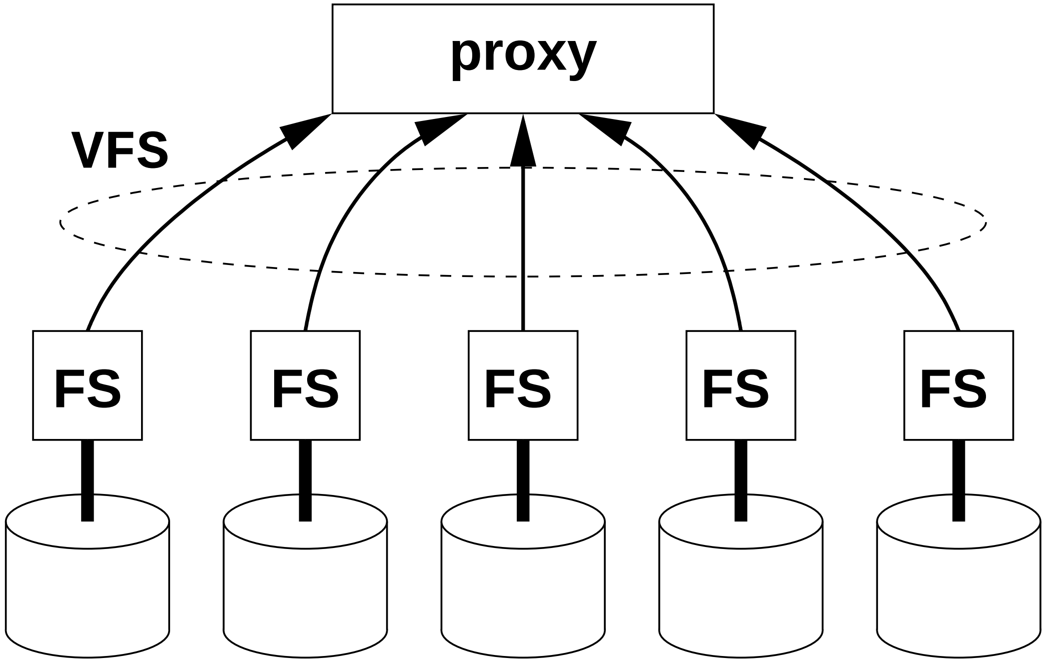
- Disk Splicing
- Object Packing
- Signature/Bitmaps

...Following pages show you these techniques

Disk Splicing

Gathering multi disks (filesystem)

Transparency access w/o symlink or other tricks

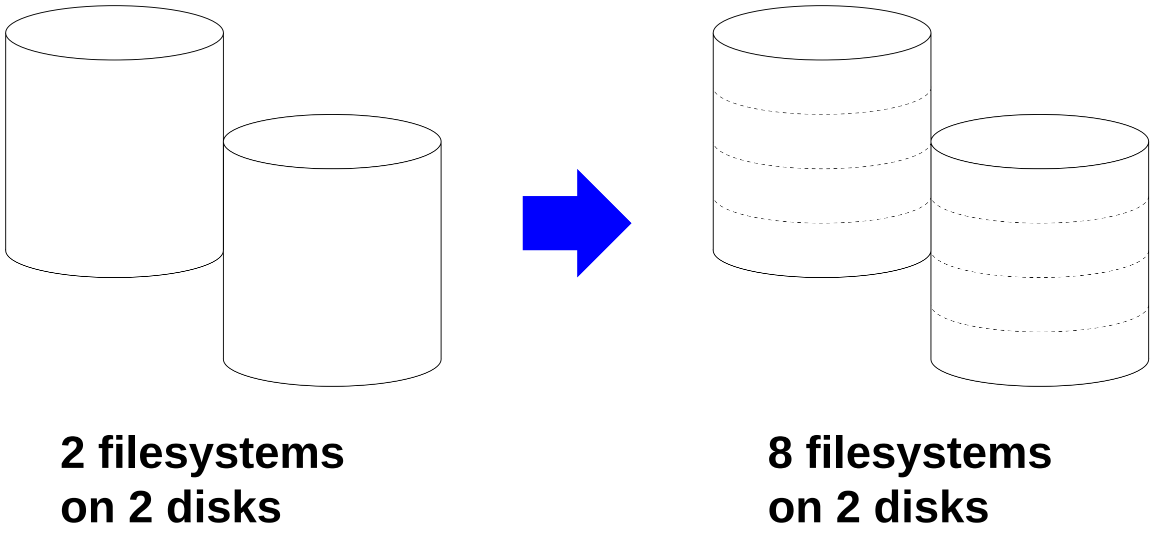


Disk Splicing — Splitting

The performance of filesystem is depend on its size

Small filesystem is faster than large one

Split disk(s) into a set of small filesystems



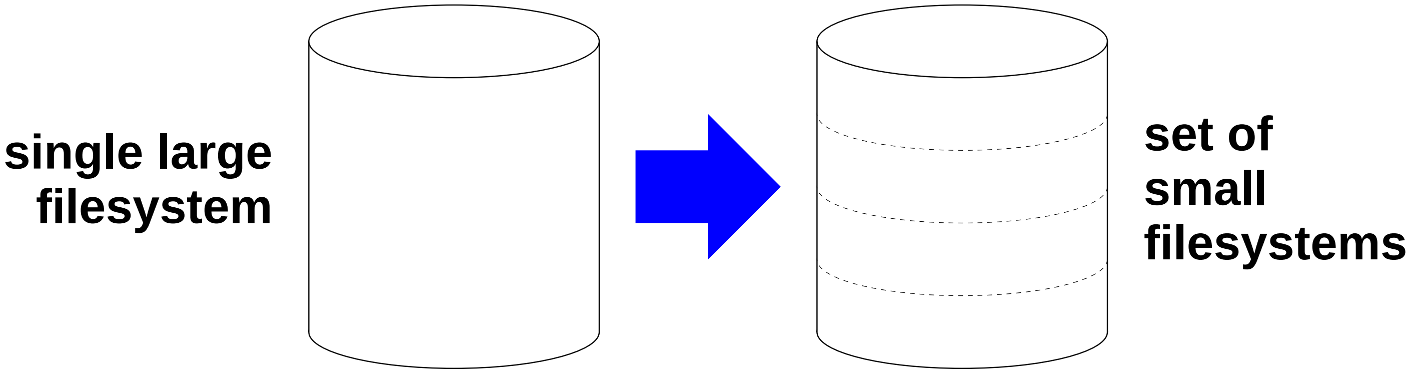
Disk Splicing — Splitting (*cont.*)

Striped disk array (RAID0) has same characteristic, also

Disk splitting brings more better performance

You can use following ways for splitting

- Partitions
- Logical drives, if possible



Object Packing

Store many objects in single file

Reduce the number of files

Reduce open/close overhead (included directory traces in kernel side)

Remarks:

Traditional systems store an object in single file

CERN httpd, Squid

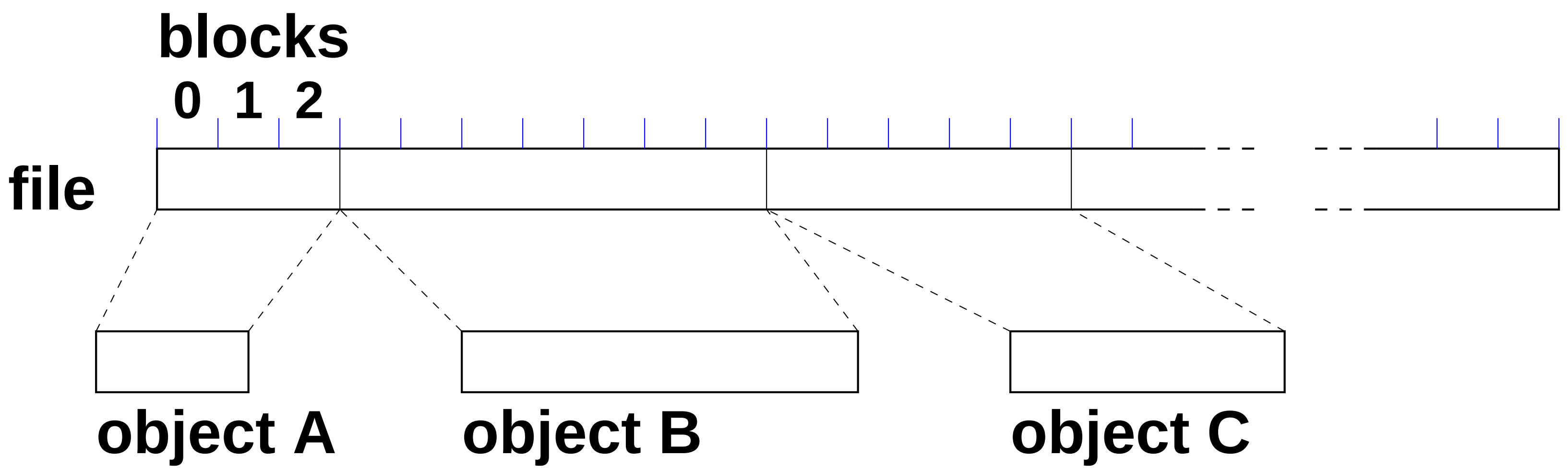
Don’t complain, it is historical reason

Object Packing (*cont.*)

File consists 1000-1500 blocks

Block size is 8-20Kbytes

Objects are stored with several blocks

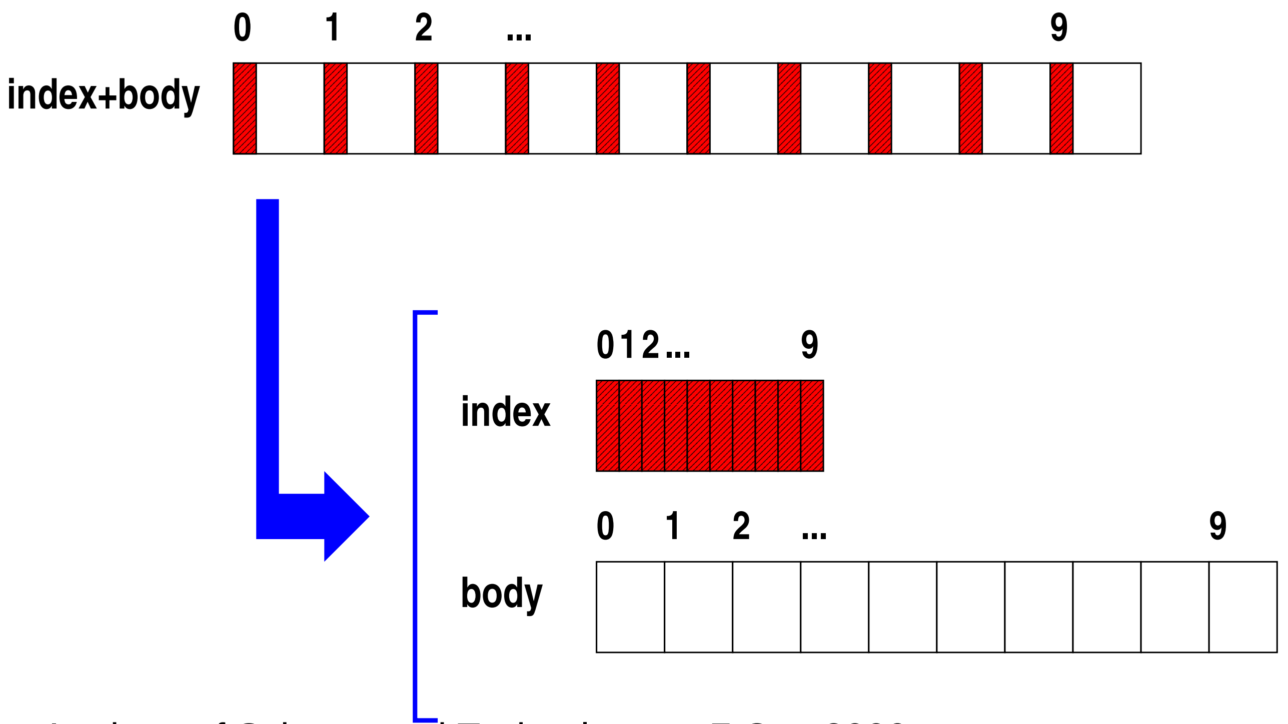


Split file into index and body

index – control block (attributes) // body – response

Decrease distance between control blocks

Improve seeking time



Object Packing - Example

Cache capacity = 30GB

Average object size = 10KB

Block size = 8K

The number of blocks in file = 1500

case 1: Store to single file $\Rightarrow$ 3M files

case 2: Store to packed file $\Rightarrow$ 2621 files

file size = 8K x 1500 = 12.3M

Packing reduce the number of files and overheads

Signature/Bitmaps

Hints for decision w/o disk access

Signature: Is the object stored ?

Reduces seeking for checking object existence

Makes fast swapin

Bitmap: where is empty block ?

Reduces seeking to resolve object position

Makes fast swapout

Signature/Bitmaps – Example

How much size is spend by such maps ?

1block = 8KBytes

map type	ratio	1MB map covers
bit (bitmap)	1:8192*8	64GB
integer (4byte)	4:8192	2GB

Swap

Swapping memory to disk is not eliminate

Because main memory is very smaller than traffic

Size of main memory is up to few GB

WWW traffic is several tens GB/day

Example: fill 1GB memory with 100Mbps (12.8MB/s)

All miss → 80 seconds

50% hit → upto 160 seconds

Swap (*cont*.)

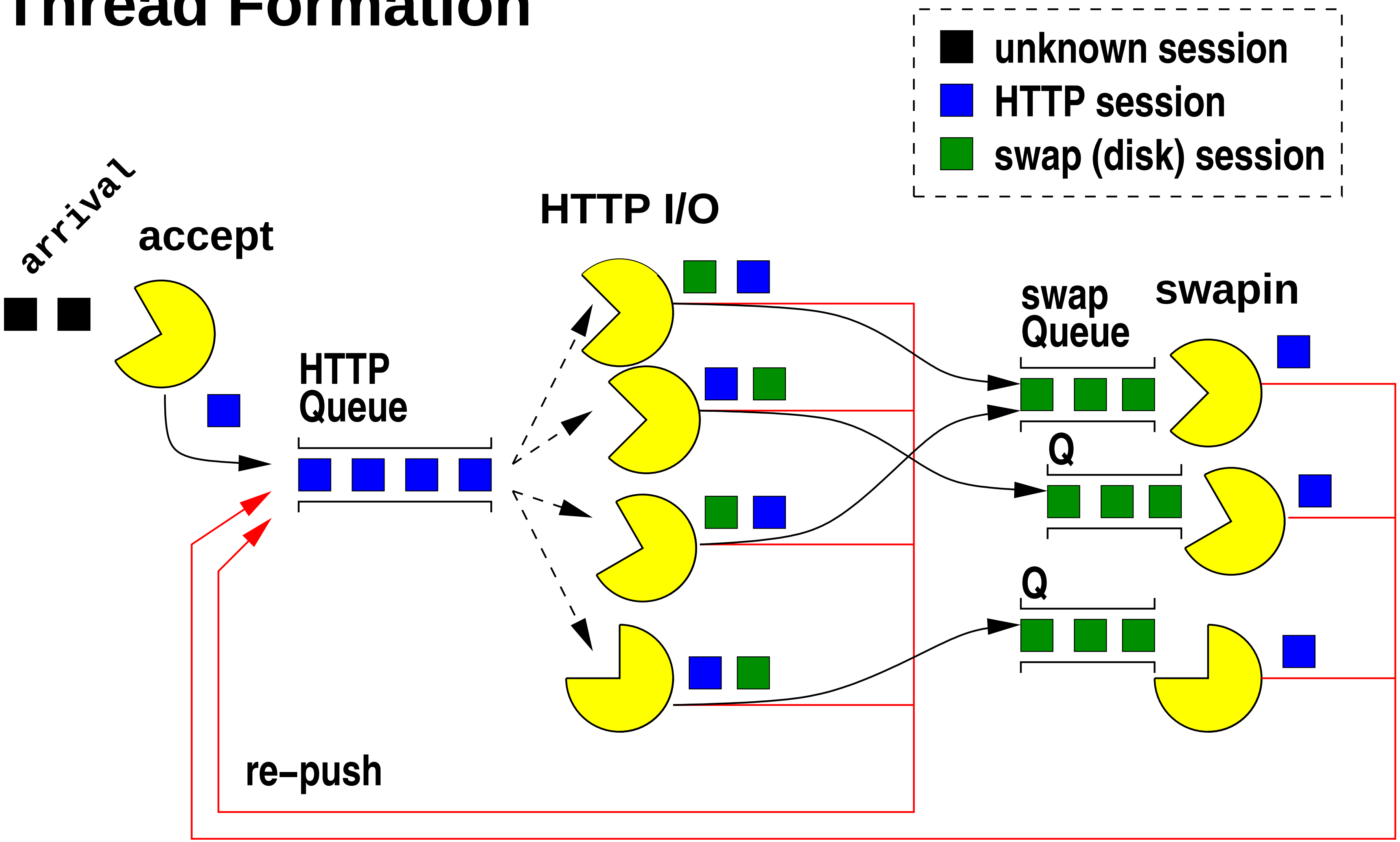
Swapin is depend on client requests

- Swapin is proccessed in foreground

Swapout is independent from client requests

- Swapout is processed in background

Thread Formation



Evaluation – Facts

Hardware

CPU: dual Pentium 3 866MHz

disk: six 10krpm SCSI disk w/ hardware RAID

memory: four 256MB SDRAM w/ registered ECC

Software

OS: Linux 2.2.17

FS: ReiserFS

Proxy: KOTETU 1.5b

Using 35 logical drives on single disk array

Evaluation

- Our system achives 300 request/sec
- It means about 25Mbps
- Enough for workgroup service
- Workload // polygraph with Polymix-3
  - Cache Size = 31.3GB
  - Peak Rate = 300rps
  - Fill ratio = 75% (default)

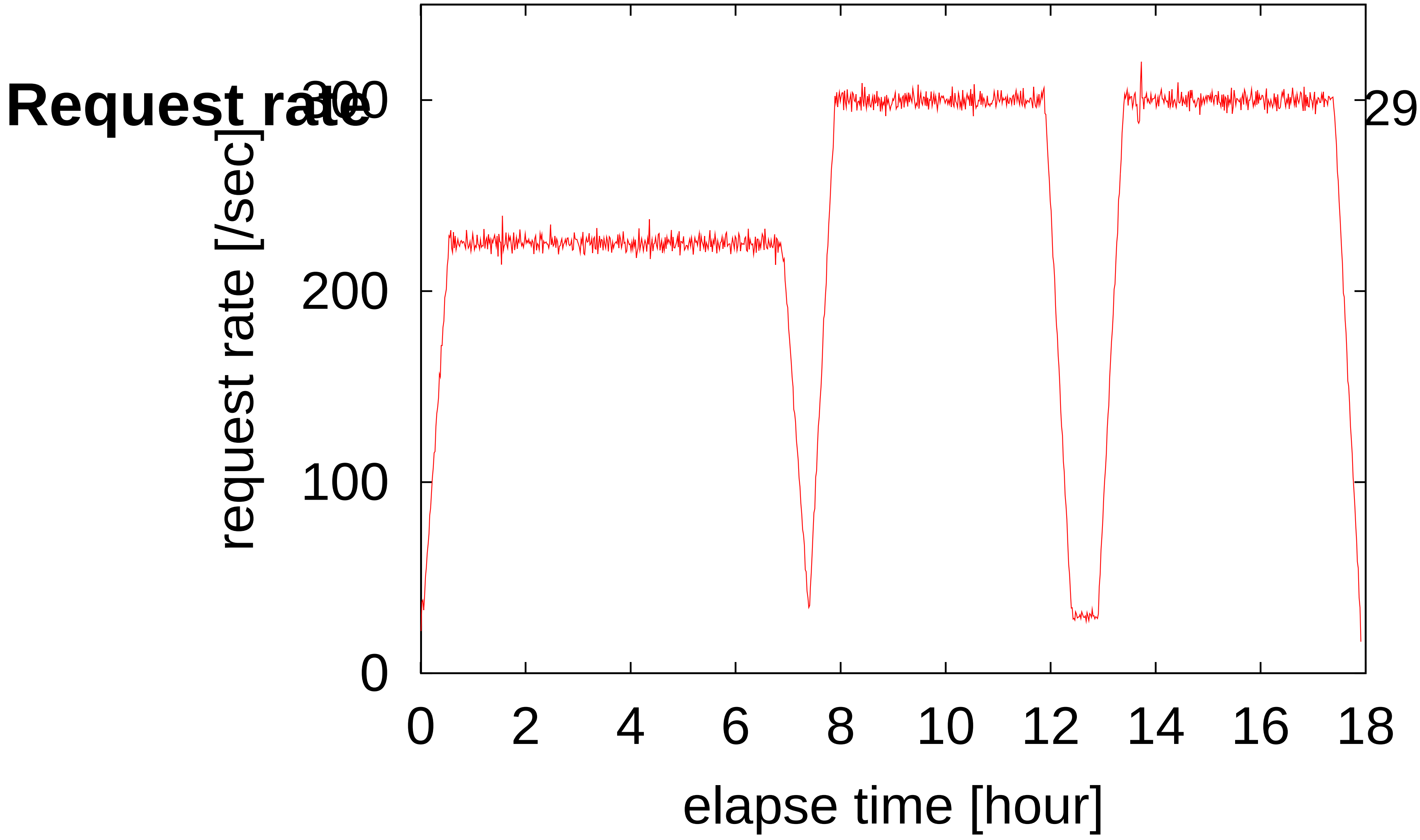
Evaluation – Workload & Result

Polymix-3

- Cache Size = 31.3GB
- Peak Rate = 300rps
- Fill ratio = 75% (default)

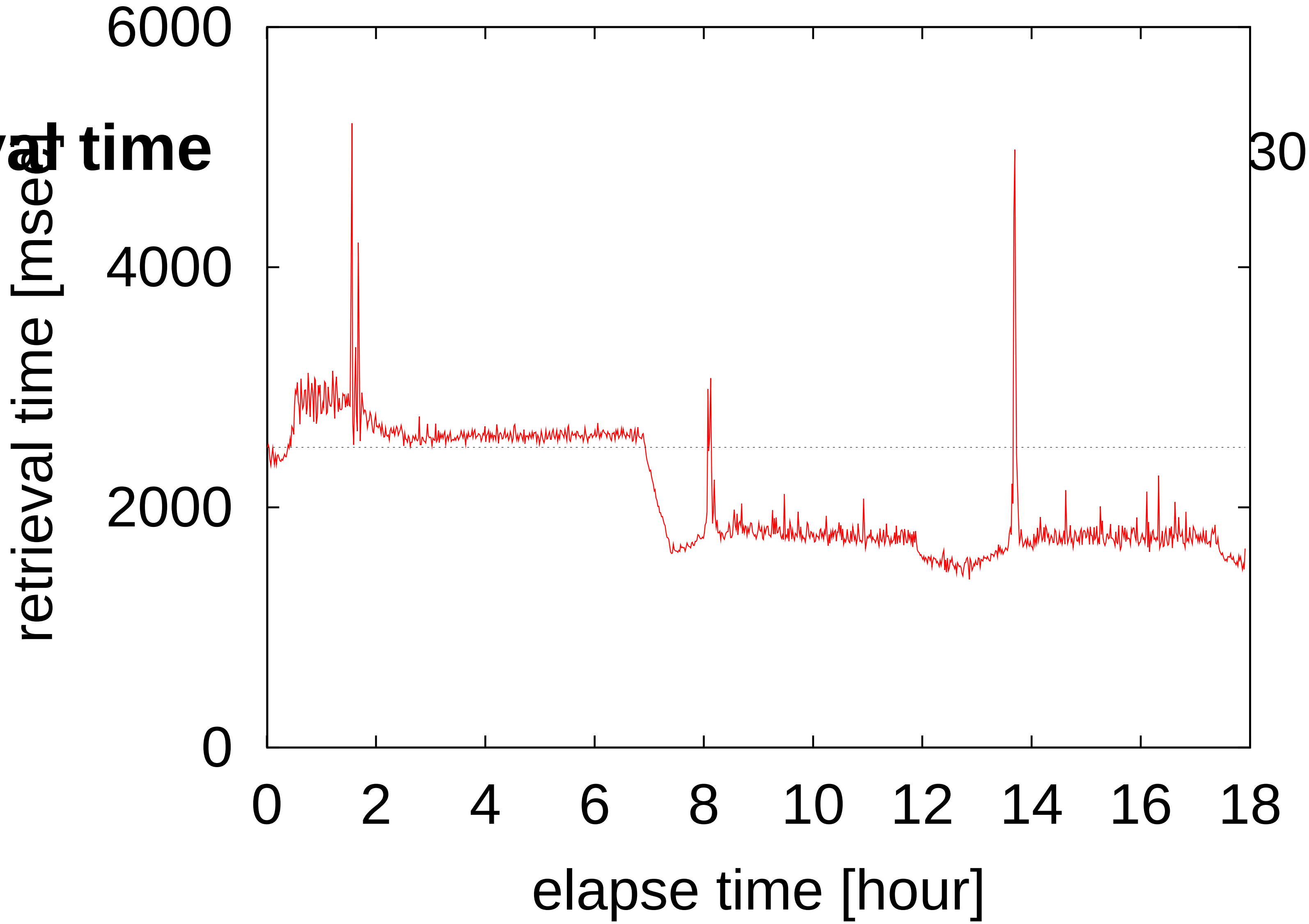
Result

- Response time = 1.792 sec (server reply = 2.5sec)
- Hit ratio = 42.91 %
- Error = 0.10 %

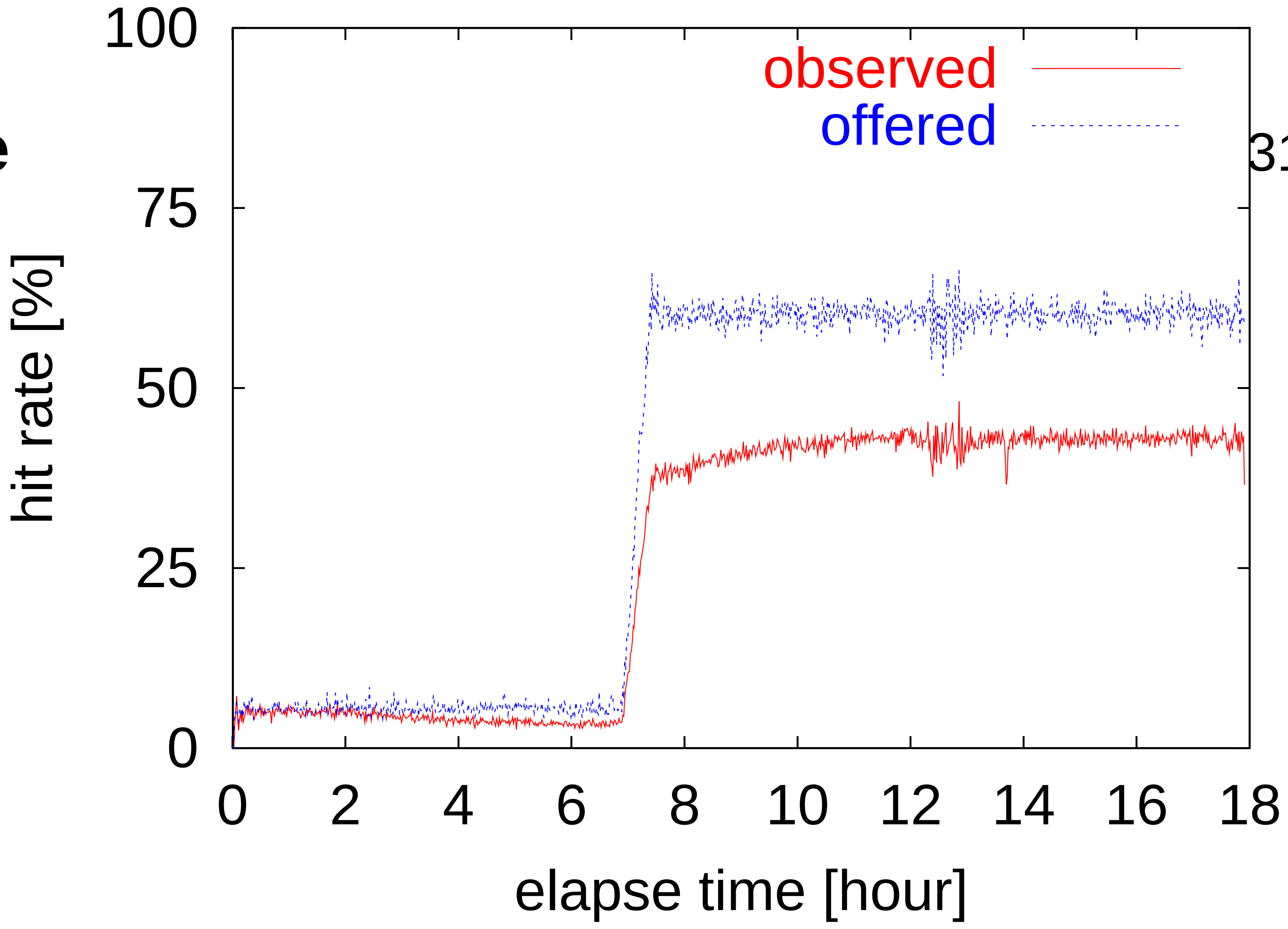


Request rate
300
200
100
0
29
0
2
4
6
8
10
12
14
16
18
request rate [/sec]
elapse time [hour]

Retrieval time 30



Hit rate



100
75
50
25
0
hit rate [%]
observed
offered
0
2
4
6
8
10
12
14
16
18
elapse time [hour]

Summary

- Design and implementation of WWW cache
  - Using general OS
  - Using typical filesystem interface
- Bottle-neck in WWW $\Rightarrow$ filesystem
- Our techniques to optimize disk I/O
- Evaluation

$\Rightarrow$ Achieves 300rps in benchmark

Future Works

Operation in actual environments

More public/authorized results

$\longrightarrow$ we register TMF's 4th Cache-Off

Tunning

Contact Points

Our system is available at following page

```
http://infonet.aist-nara.ac.jp/products/kotetu/
http://infonet.naist.jp/products/kotetu/
```

Please contact me

k-chinen @ is . aist-nara . ac . jp

History of Our Team

1992:

NAIST was funded

1993:

Our laboratory was born

We meet WWW (Mosaic)

1994:

Proxy Server (CERN httpd) was born

I made a prototype of prefetching proxy

network is slow, and narrow bandwidth

1995-1998:

History of Our Team (*cont*.)

We developed the proxy (Wcol)

support ICP

1999:

I start developing of brand new proxy

code-name is FALCON

2000:

FALCON was released as 'KOTETU'

and here.

Object Packing - Example

Cache capacity = 30GB

Average object size = 10KB

1) Store to single file

```
30GB/10KB = 3M files
```

2) Store to packed file

Block size = 8K
The number of blocks in file = 1500

```
1500 / ceil[10KB/8KB] = 750 objects/file
750 * 8KB = 6MB/file
30GB / 6MB = 500 files
```

Necessary or not

- Date attributes (create, modify, access)
  - WWW cache have to record dates
  - But It needs many types
    - ⋆ (HTTP) Last-Modified, Expire, Date, If-Modified-Since
    - ⋆ (internal) create, requested, delete
  - Generic date attributes is not useful
- Directory

Rigstered System for 4th Cache-Off

Current plan

- Dual 1GMHz Pentium 3
- Four 256MB Registered ECC memory
- Five 10Krpm 9G SCSI disks for caching
- Single channel SCSI RAID card
- Single 10Krpm 18G SCSI disk for boot and logs
  - 5600 US$
  - Reach 300rps under polymix-4