Flash: an efficient and portable web server

Context

- Around 2000, a single application — the web server — became a critical piece of the computing infrastructure
- Lessons from building a fast web server carry over to other server applications as well
- Goal of the paper: build the fastest possible web server running on a single node (with potentially many cores)

- Discuss:
  - what you liked about the paper?
  - what you disliked?
  - what did not make sense or what was not clear?

High Level Ideas

- Server performance has several dimensions
  - What are those?
- Lots of different choices on how to express and effect concurrency in a program
- Paper argues that event-driven asynchronous I/O has least overhead and greatest scalability but Unix has poor support

Performance Model

- Need to understand all aspects of delivering a webpage
  - How do TCP/HTTP connections work?
  - What is a web page access look like?
  - What does a disk access mean?
  - How is processor sharing performed using kernel/user-level threads?
  - What is the typical load on the system?

Model of a TCP Connection

- TCP flows provide reliable in-order delivery
- Flow control ensures that there is enough buffer space at the destination
- Congestion control reacts to packet loss
- Slow start allows TCP to probe for available bandwidth starting with a conservative estimate of 1 packet per RTT

- What implications does this have for the design of a web server?

Model of a Web page

- Body of the page is HTML content
- Includes links to embedded images and CSS
- Also includes Javascipt that can execute at the client and trigger loads of other types of content
- Embedded HTML in the form of iFrames
- Server side computation in the form of CGI, PHP, etc.
    - potentially a multi-tier architecture

Model of an HTTP Fetch

- Establish TCP connection
- Send HTTP get request
- Server reads requested content from the file system
- Server performs server-side computation
- Server sends data to the client

- What implications does this have for performance? for re-designing HTTP? for the web-server?

HTTP Improvements

- Multiple concurrent connections per client
    - Early browsers: 4 concurrent connections
    - HTTP/1.1 spec: no more than two per hostname
        - browsers ignore this guideline; tend to do ~6 per hostname and subdomains are separate
        - What implications does this have for TCP?
- Persistent HTTP connections
    - Single congestion window is learned for the session; avoid slow start for each
    - Fewer packets, less memory on server side, lower overheads

HTTP Improvements

- Pipelining
  - Send multiple back to back requests on a single persistent connection without waiting for replies
  - Server sends replies in same order as requests
  - Ability to mask the latency of HTTP request/response delay
- SPDY
  - Experimental session protocol
  - Multiplexes many HTTP sessions on a single TCP connection; virtualizes many TCPs on a single TCP
  - Eliminates the “in the same order” limitation of pipelining

Model of a Processor

- Processes incur context switching costs, occupy memory (for stack frames)
- User-level threads implemented within a single process; OS knows only about the process and not the threads inside of it
- Kernel threads implemented as OS visible entities; context switching handled by the kernel
- What are the trade-offs between user-level threads and kernel threads? What about processes and kernel threads?

Model of a Disk

- Disks contain tracks (concentric circles) across multiple surfaces (same track on multiple surfaces form a cylinder)
- Access costs:
  - Seek to the appropriate cylinder
  - Wait for the appropriate segment to rotate underneath the disk head
- Performance governed by mechanics ==> improvements are modest over time
  - single disk read is about a few milliseconds
  - throughput is many tens of mb/s
- What implications does this have for the design of a web server?

Back of the Envelope Calculations

- What would you guess is a typical web page load in terms of latency?
- How would you determine the number of "active" web requests on a server?

- Key distinction: "open loop" vs. "closed loop" systems

Flash Paper

- Four alternatives
  - Multiple process (MP): pool of idle processes
  - Multiple threads (MT): similar, but pool of idle threads
  - Single process Event Driven (ET)
  - This paper: a hybrid
- Discuss:
  - what are the different dimensions by which we should compare them?

Concurrency in a web server

- Why do we want to exploit it?
  - Multi-core: want to be able to exploit multiple CPUs concurrently
  - Multiple disks: want to be able to exploit multiple disk arms concurrently
  - Overcoming latency of networks, flow/congestion control
    - Want to be working on a different request while propagation delay of other requests in flight (or if buffers/windows are full)

OS Issues

- Potentially blocking system calls
  - Some system calls may, in practice, block the calling execution context (kernel thread/process)
  - network receive: caller blocks until data is available
  - network send: caller block until send buffer has space available
  - network accept: caller blocks until new connection arrives
- Potentially high latency system calls: file I/O
- Core issue: some way to either
  - have multiple contexts so that it's OK if they are blocked
  - prevent blocking (i.e., use non-blocking calls)

AMPED

- Approach:
  - Use event driven to process network
  - Use MT or MP to process disk, helper processes, etc.
  - Connect using pipes
- Benefits:
  - the thing that is likely to capture the most blocking (networking I/O) is the thing that is lightest-weight
  - have shared-memory, and single thread tweaking it, so avoid synchronization issues
- Disadvantages?

Comparison Metrics

- Concurrency/utilization:
  - Not be blocked and utilize all resources efficiently
  - SPED blocks on disk I/O leading to low concurrency (also bad on multi-cores)
- Overhead
  - Memory overheads, context switching costs, inter-process communication, etc. SPED is least overhead
- Coordination
  - MT/MP models require more effort for application-wide information gathering
  - Application-wide data structures are difficult in MP

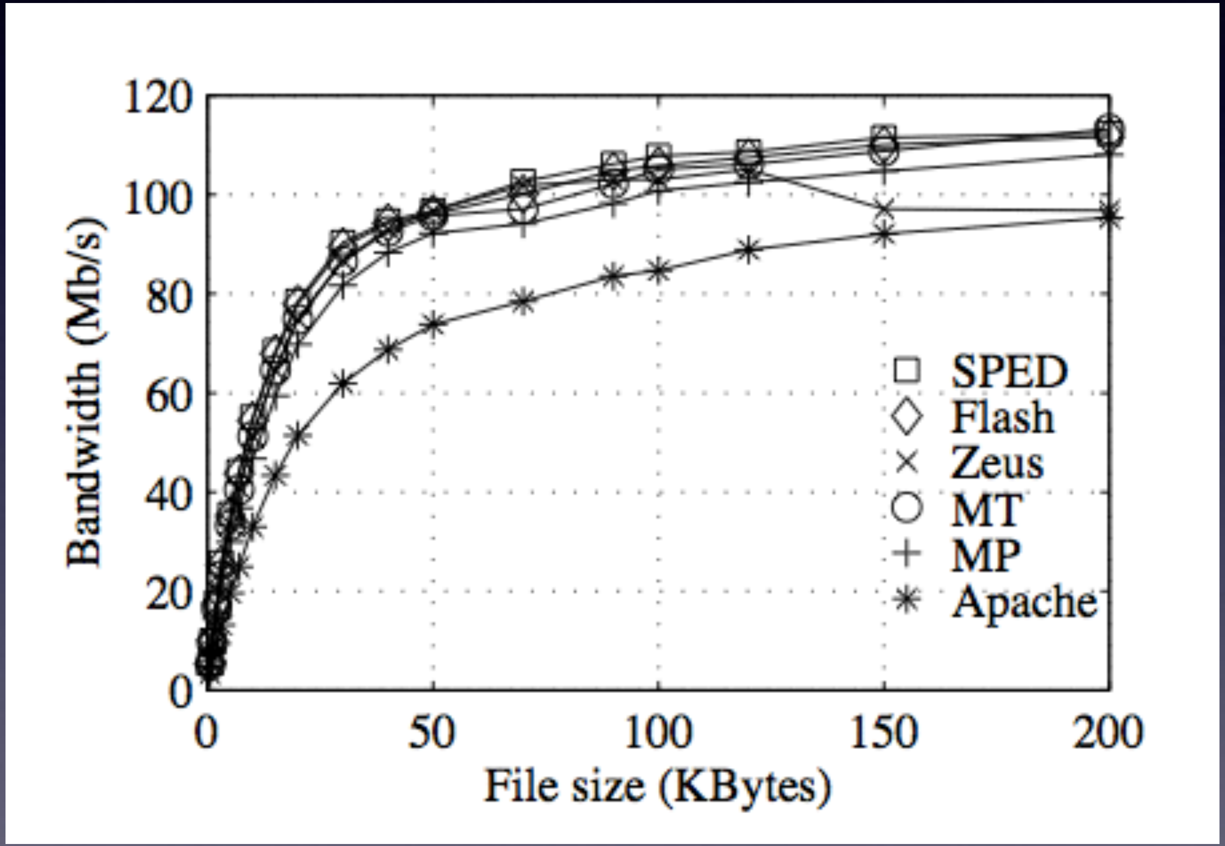
Performance Tricks

- Use caches for as many things as possible:
  - name translation caches
  - response header caches
- Maintain memory mapped files and send data directly without requiring copies
- Use writev() and padding to minimize overheads
- Test for memory residency before passing task to helper
- Pre-created CGI helper applications

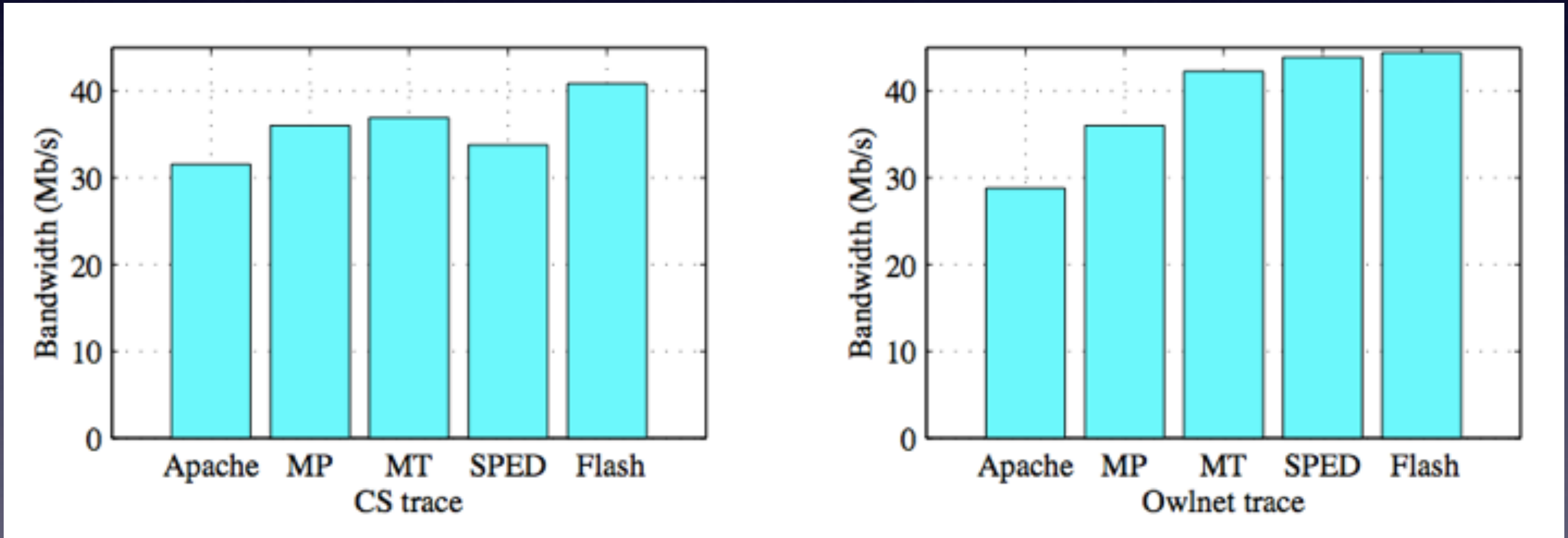
Evaluations

- What does the paper do well and what does the paper not accomplish in the evaluations?

Cachable Experiments

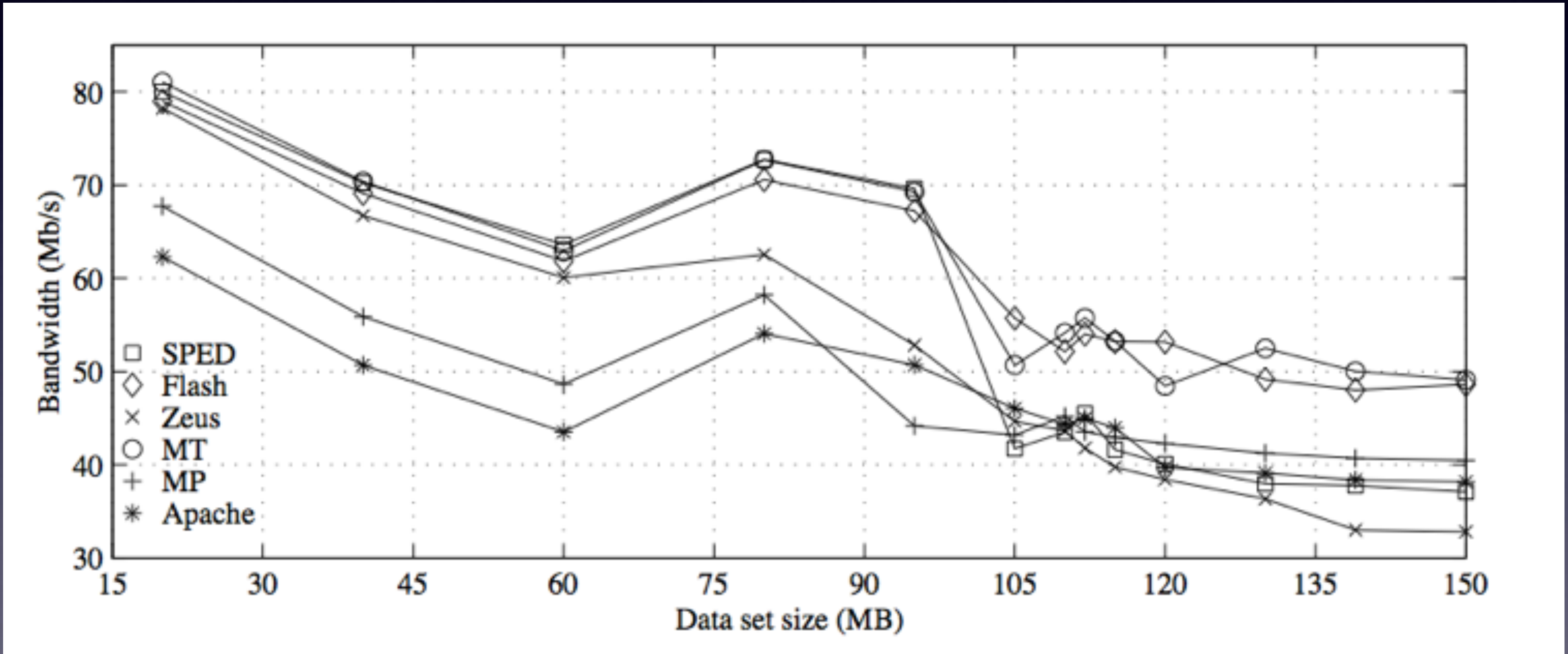


Real Traces



Bandwidth (Mb/s)
0
10
20
30
40
Apache
MP
MT
SPED
Flash
CS trace
Bandwidth (Mb/s)
0
10
20
30
40
Apache
MP
MT
SPED
Flash
Owlnet trace

Control Working Set Size



WAN Performance