TCPivo
A High-Performance Packet Replay Engine

Wu-chang Feng Ashvin Goel Abdelmajid Bezzaz
Wu-chi Feng Jonathan Walpole

OGI SCHOOL OF SCIENCE & ENGINEERING
OREGON HEALTH & SCIENCE UNIVERSITY

Motivation

- Many methods for evaluating network devices
  - Simulation
    - Device simulated, traffic simulated
    - `ns-2`, IXP network processor simulator
  - Model-based emulation
    - Actual device, traffic synthetically generated from models
    - IXIA traffic generator
  - Trace-driven emulation
    - Actual device, actual traffic trace
    - Particularly good for evaluating functions that rely on actual address mixes and packet interarrival/size distributions

Goal of work

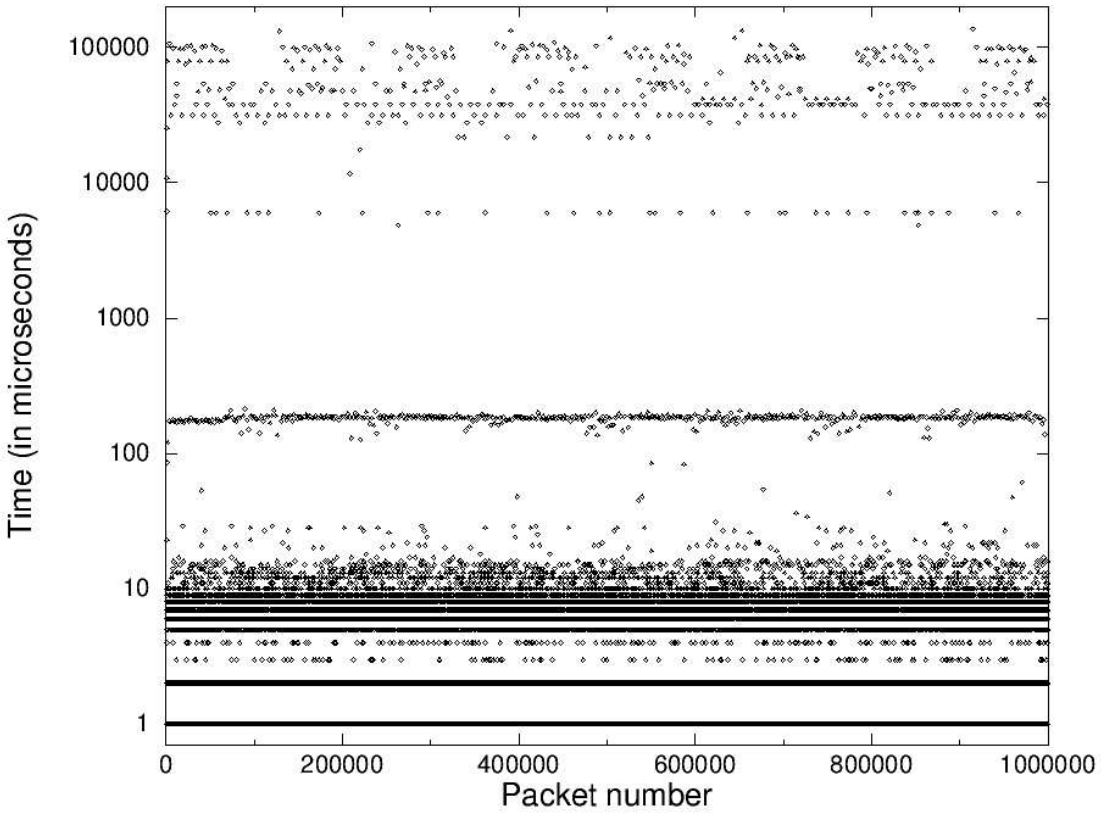
- Packet replay tool for trace-driven evaluation
  - Accurate
  - High-performance
  - Low-cost
    - Commodity hardware
    - Open-source software
- Solution: `TCPivo`
  - Accurate replay above OC-3 rates
    - Pentium 4 Xeon 1.8GHz
    - Custom Linux 2.4.20 kernel with ext3
    - Intel 82544 1000Mbs
    - ~$2,000

Challenges

- Trace management
  - Getting packets from disk
- Timer mangement
  - Time-triggering packet transmission
- Scheduling and pre-emption
  - Getting control of the OS
- Efficient sending loop
  - Sending the packet

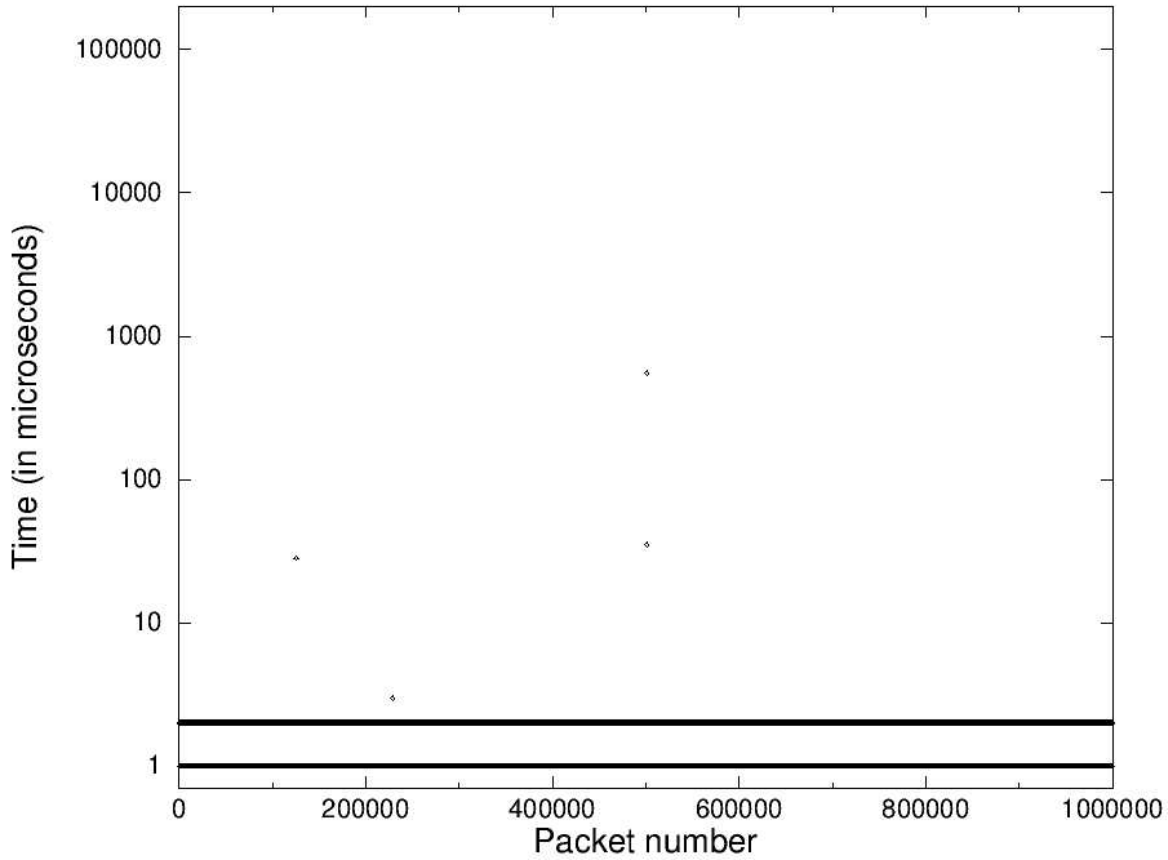
Trace management problem

- Getting packets from disk
  - Requires intelligent pre-fetching
  - Most OSes support transparent pre-fetch via `fread()`
- Default Linux `fread()` latency reading trace



Trace management in TCPivo

- Double-buffered pre-fetching
- `mmap()/madvise()` with sequential access hint

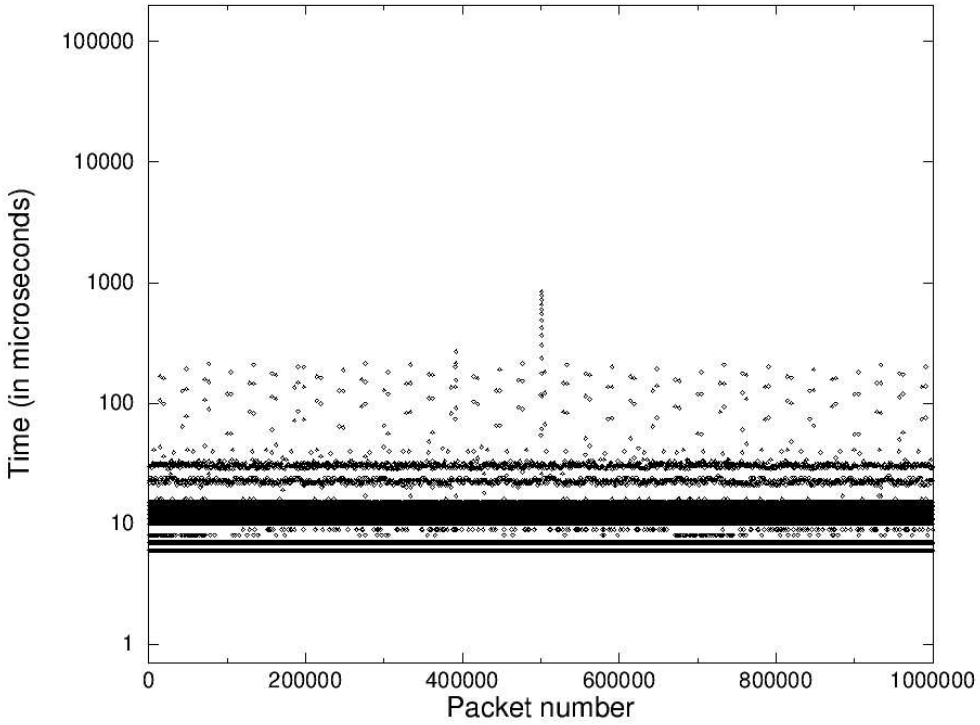


Timer management problem

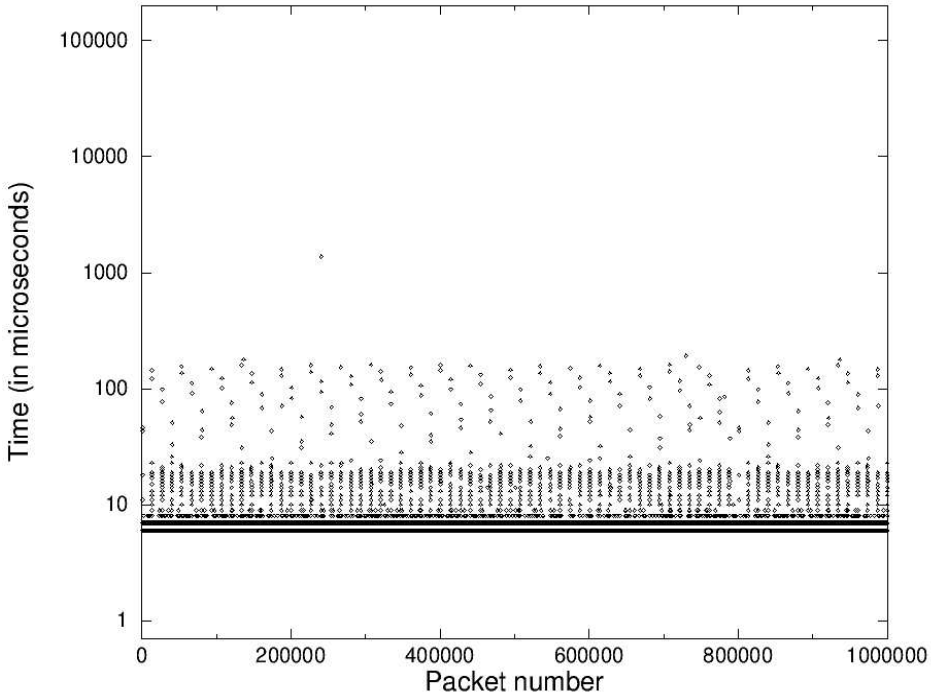
- Must accurately interrupt OS to send packets
- Approaches
  - Polling loop
    - Spin calling `gettimeofday()` until time to send
    - High overhead, accurate
  - `usleep()`
    - Register timer interrupt
    - Low overhead, potentially inaccurate
- Examine each approach using fixed workloads
  - 1 million packet trace
  - Constant-interarrival times δ=70 µsec, δ=2500 µsec

Timer management problem

- Polling loop



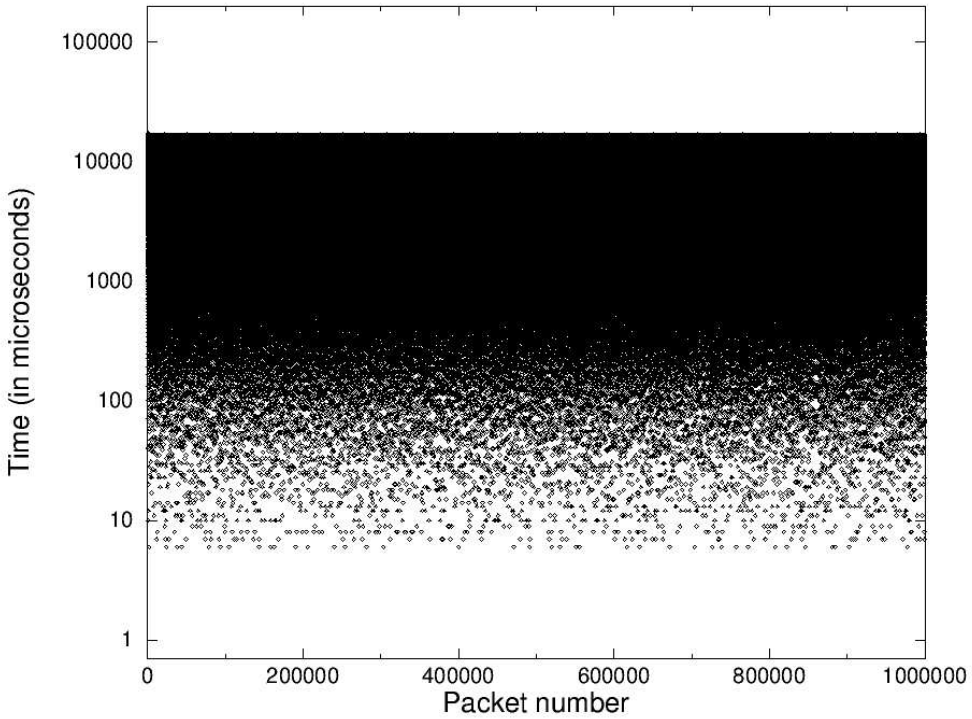
δ=70 µsec
78% User-space CPU utilization



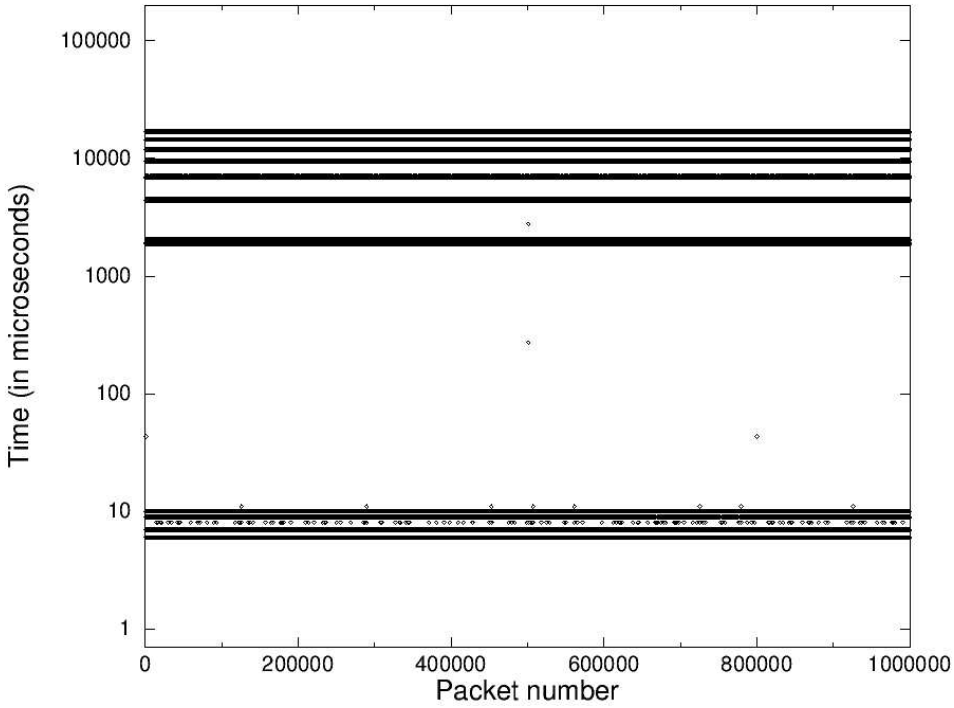
δ=2500 µsec
99% User-space CPU utilization

Timer management problem

- `usleep()`



δ=70 µsec
40% User-space CPU utilization



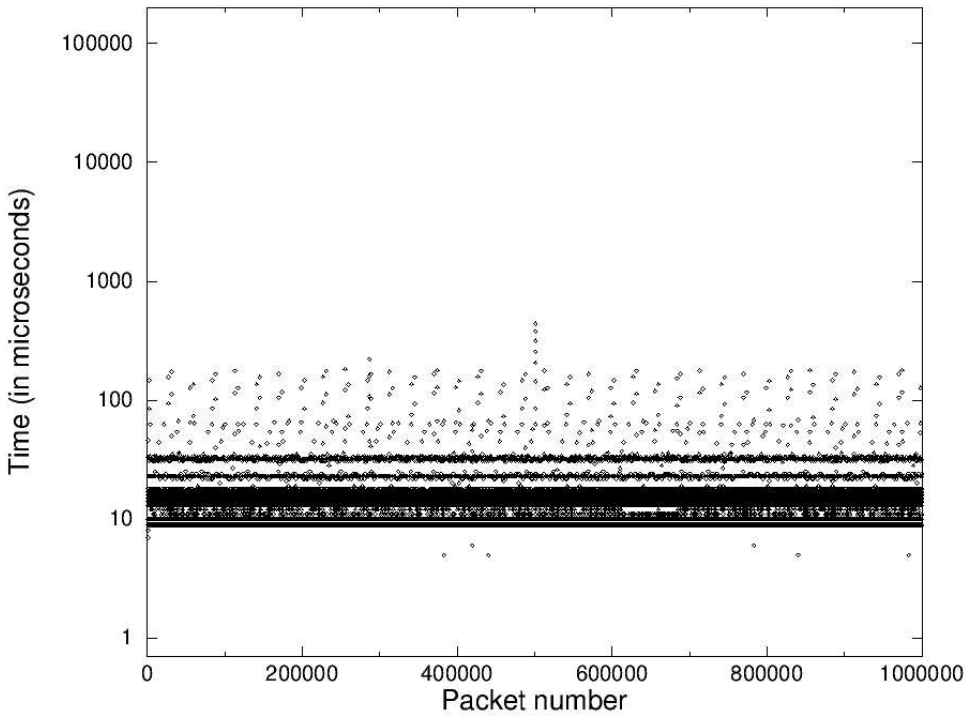
δ=2500 µsec
4% User-space CPU utilization

Timer management in TCPivo

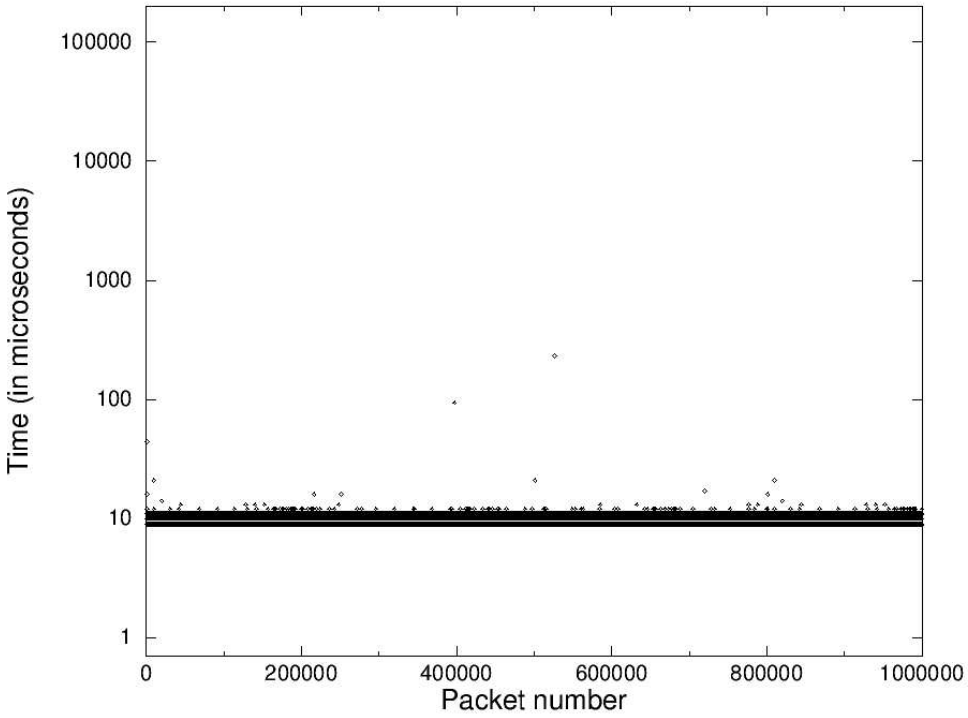
- "Firm timers"
  - Combination of periodic and one-shot timers in x86
    - PIT (programmable interval timer)
    - APIC (advanced programmable interrupt controller)
    - Use PIT to get close, use APIC to get the rest of the way
  - Timer reprogramming and interrupt overhead reduced via soft timers approach
  - Transparently used via changes to `usleep()`

Timer management in TCPivo

- Firm timers



δ=70 µsec
19% User-space CPU utilization



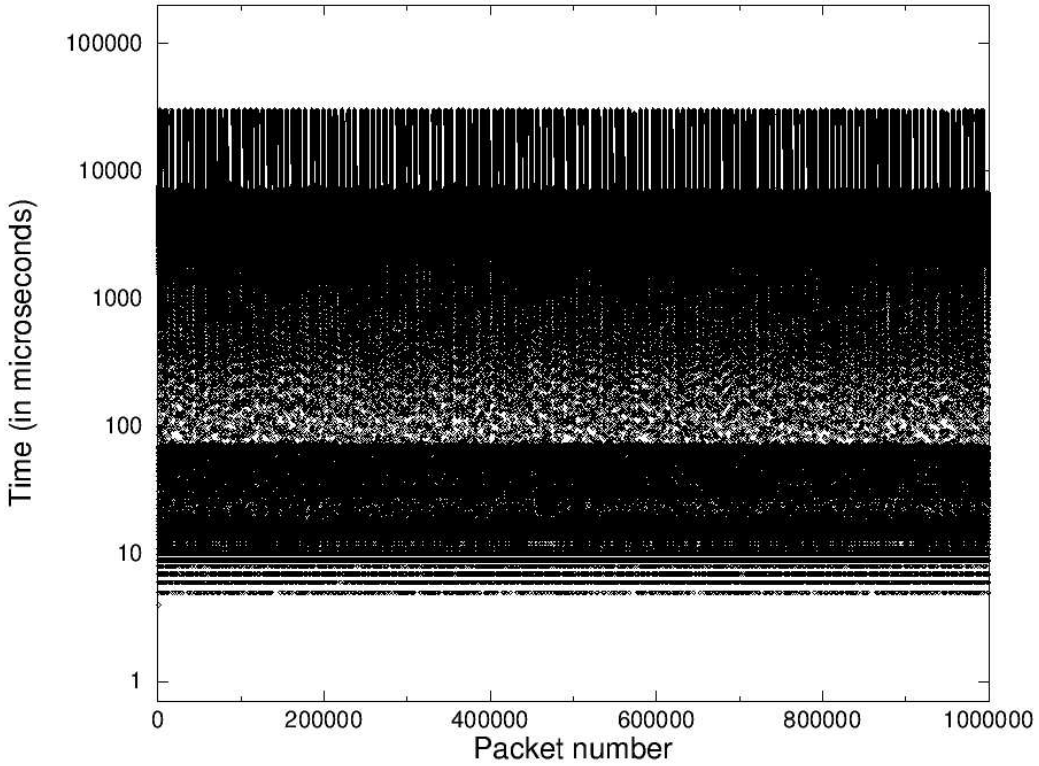
δ=2500 µsec
1% User-space CPU utilization

Scheduling and pre-emption problem

- Getting control of the OS when necessary
- Low-latency, pre-emptive kernel patches
  - Reduce length of critical sections
- Examine performance under stress
  - I/O workload
    - File system stress test
    - Continuously open/read/write/close an 8MB file
  - Memory workload (see paper)

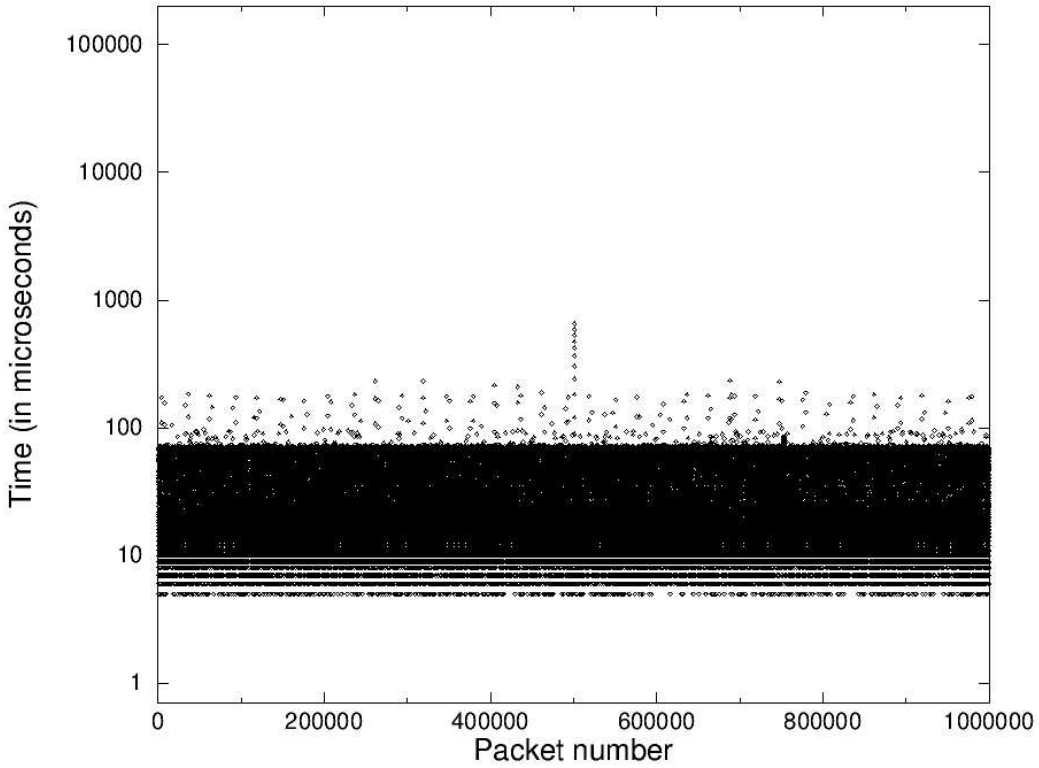
Scheduling and pre-emption problem

- Firm timer kernel without low-latency and pre-emptive patches
- I/O Workload, δ=70µsec



Scheduling and pre-emption in TCPivo

- Firm timer kernel with low-latency and pre-emptive patches
- I/O Workload, δ=70µsec



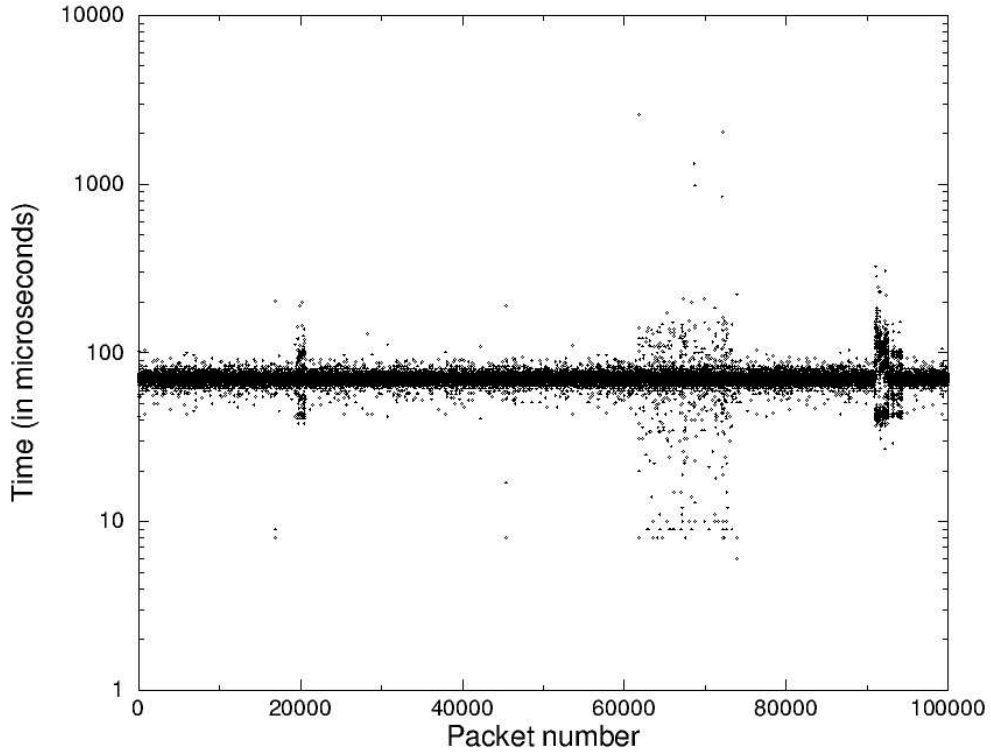
Efficient sending loop in TCPivo

- Zeroed payload
- Optional pre-calculation of packet checksums

Task	Average time spent
Trace read	1.30 µsec
Data padding	1.45 µsec
Checksum calculation	1.27 µsec
sendto()	5.16 µsec
Main loop	**9.38 µsec**

Putting it all together

- On the wire accuracy
  - δ=70μsec workload at the sender
  - Point-to-point Gigabit Ethernet link
  - Measured inter-arrival times of packets at receiver



Software availability

- TCPivo
  - http://www.cse.ogi.edu/sysl/projects/tcpivo
  - Formerly known as NetVCR before an existing product of the same name forced a change to a less catchier name.
- Linux 2.4
  - Firm timers
    - http://www.cse.ogi.edu/sysl/projects/TSL
  - Andrew Morton's low-latency patch
    - http://www.zip.com.au/~akpm/linux/schedlat.html
  - Robert Love's pre-emptive patch
    - http://kpreempt.sourceforge.net
- Linux 2.5
  - Low-latency, pre-emptive patches included
  - High-resolution timers via 1ms PIT (No firm timer support)

Open issues

- Multi-gigabit replay
  - Zero-copy
  - TOE
  - SMP
- Accurate, but not realistic for evaluating everything
  - Open-loop (not good for AQM)
  - Netbed/PlanetLab?
    - Requires on-the-fly address rewriting

Questions?