Tempesta FW
Linux Application Delivery Controller

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Who am I?

- CEO & CTO at **Tempesta Technologies** *(Seattle, WA)*
- Developing **Tempesta FW** – open source Linux *Application Delivery Controller (ADC)*
- **Custom software development** in:
  - *high performance network traffic processing* e.g. **WAF** mentioned in **Gartner magic quadrant**
  - *Databases* e.g. **MariaDB SQL System Versioning** is coming soon (*https://github.com/tempesta-tech/mariadb_10.2*)

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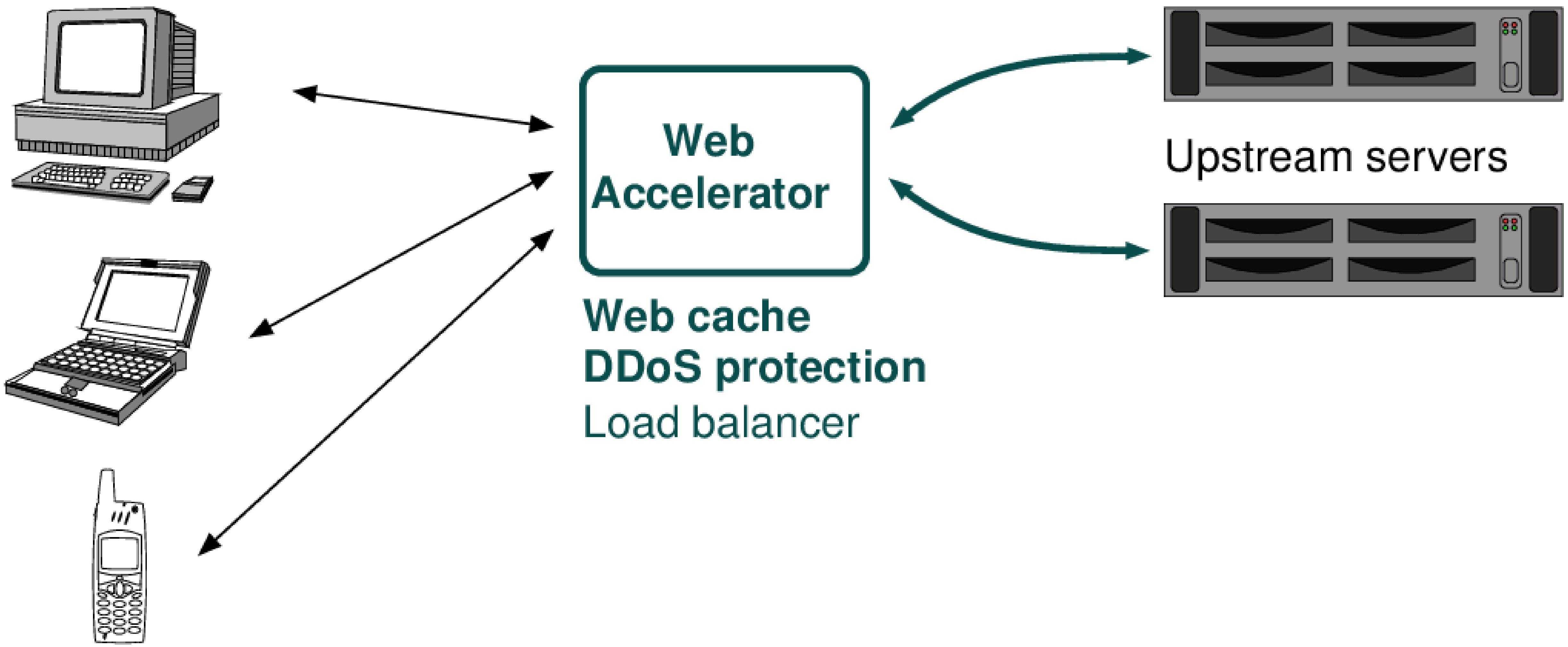
Challenges

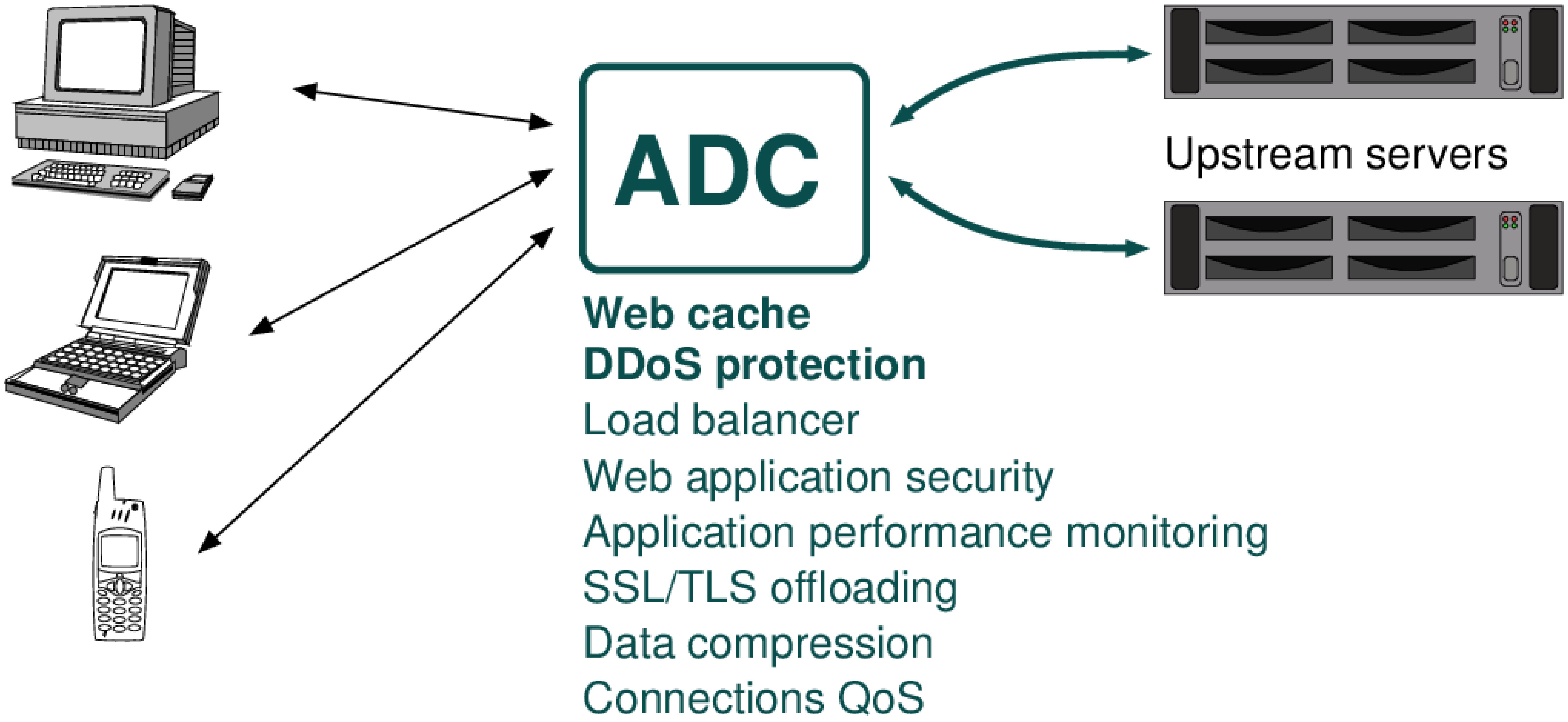
- Usual Web accelerators aren’t suitable for HTTP filtering
- Kernel HTTP accelerators are better, but they’re dead
- => need a **hybrid of HTTP accelerator and a firewall**
  - Very **fast HTTP parser** to process HTTP floods
  - Very fast Web cache to mitigate DDoS which we can’t filter out
  - Network I/O optimized for **massive ingress traffic**
  - **Advanced filtering** abilities at all network layers

L7 DDoS mitigation Web accelerator?



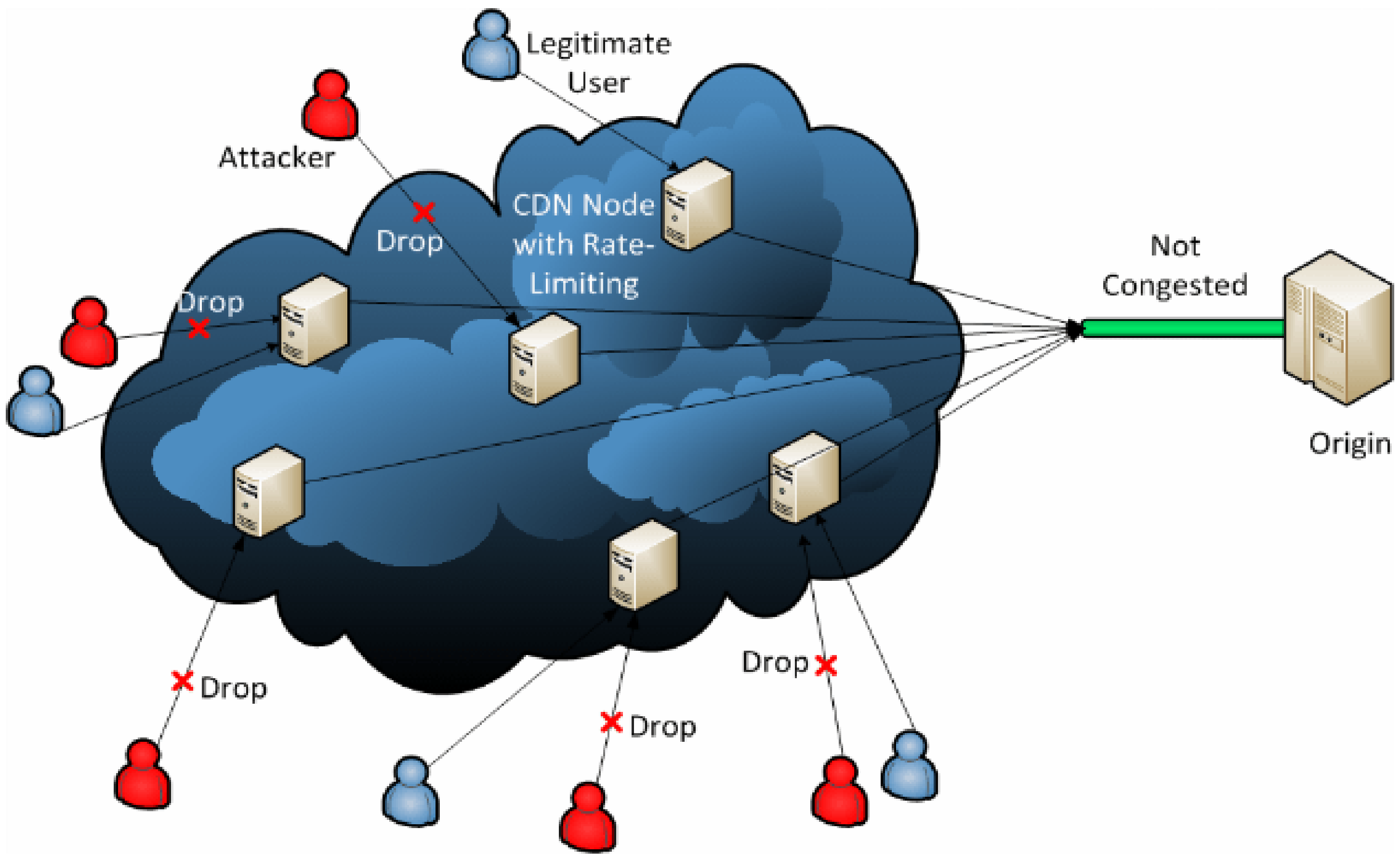
Web cache
DDoS protection
Load balancer

Application Delivery Controller (ADC)



Use cases

- CMSes, CDNs, virtual hostings, heavy loaded Web sites, OEMs in Web security etc.
- Usual ADC cases:
  - **When you need performance**
  - Web content acceleration
  - Web application **protection**
  - HTTP load balancing



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Application layer DDoS

	Service from Cache	Rate limit
Nginx	22us	23us

- *(Additional logic in limiting module)*
- **Fail2Ban**: write to the log, parse the log, write to the log, parse the log…

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Application layer DDoS

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Nginx	22us	23us

- *(Additional logic in limiting module)*
- **Fail2Ban**: write to the *log*, parse the *log*, write to the *log*, parse the *log*… **- really in 21th century?!**
- **tight integration** of Web accelerator and a firewall is needed

Web-accelerator capabilities

- Nginx, Varnish, Apache Traffic Server, Squid, Apache HTTPD etc.
  - cache static Web-content
  - load balancing
  - rewrite URLs, ACL, Geo, filtering etc.

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  - **C10K**

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  - what about tons of `'GET / HTTP/1.0\n\n'`?

CORNER CASES!

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CORNER CASES!

- **Kernel-mode Web-accelerators**: TUX, kHTTPd
  - basically the same sockets and threads
  - zero-copy → *sendfile(), lazy TLB*

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CORNER CASES! NEED AGAIN TO MITIGATE DDOS

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Web-accelerators are slow: SSL/TLS copying

- User-kernel space copying
  - Copy network data to user space
  - Encrypt/decrypt it
  - Copy the date to kernel for transmission
- **Kernel-mode TLS**
  - Facebook,RedHat: *https://lwn.net/Articles/666509/*
  - Netflix: *https://people.freebsd.org/~rrs/asiabsd_2015_tls.pdf*
  - **TLS handshake is still an issue**

Web-accelerators are slow: profile

%	symbol name
1.5719	ngx_http_parse_header_line
1.0303	ngx_vslprintf
0.6401	memcpy
0.5807	recv
0.5156	ngx_linux_sendfile_chain
0.4990	ngx_http_limit_req_handler

=> flat profile

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Web-accelerators are slow: syscalls

```
epoll_wait(.., {{EPOLLIN, ....}},...)
recvfrom(3, "GET / HTTP/1.1\r\nHost:...", ...)
write(1, “...limiting requests, excess...", ...)
writev(3, "HTTP/1.1 503 Service...", ...)
sendfile(3,..., 383)
recvfrom(3, ...) = -1 EAGAIN
epoll_wait(.., {{EPOLLIN, ....}}, ...)
recvfrom(3, "", 1024, 0, NULL, NULL) = 0
close(3)
```

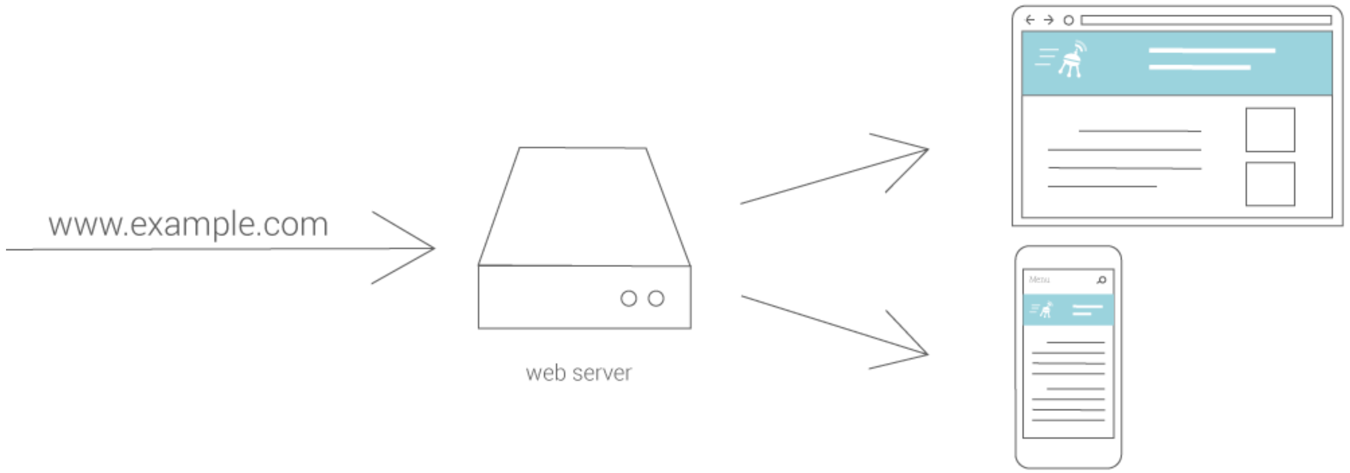
Web-accelerators are slow: filesystem database

- **Plain files database**
  - Nginx, Squid, Apache HTTPD

DDOS VULNERABLE!

```
/cache/0/1d/4af4c50ff6457b8cabfdcd32d0b2f1d0
/cache/5/2e/9f351cdfc8027852656aac5d3f9372e5
/cache/f/22/554a5c654f189c1630e49834c25ae229
```

  - Apache Traffic Server (ATS) uses database like Web-cache
- **Vary** header requires **secondary key** (say “hello” to databases)



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Web-accelerators are slow: HTTP parser

Start: *state = 1, *str_ptr = 'b'*

```
while (++str_ptr) {
    switch (state) { <= check state
    case 1:
        switch (*str_ptr) {
        case 'a':
            ...
            state = 1
        case 'b':
            ...
            state = 2
        }
    case 2:
        ...
    }
    ...
}
```

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Start: *state = 1, *str_ptr = 'b'*

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    switch (state) {
    case 1:
        switch (*str_ptr) {
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            ...
            state = 1
        case 'b':
            ...
            state = 2 <= set state
        }
    case 2:
        ...
    }
    ...
}
```

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Web-accelerators are slow: HTTP parser

Start: *state = 1, *str_ptr = 'b'*

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        switch (*str_ptr) {
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            ...
            state = 1
        case 'b':
            ...
            state = 2
        }
    case 2:
        ...
    }
    ... <= jump to while
}
```

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    }
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```

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        case 'a':
            ...
            state = 1
        case 'b':
            ...
            state = 2
        }
    case 2:
        ...   <= do something
    }
    ...
}
```

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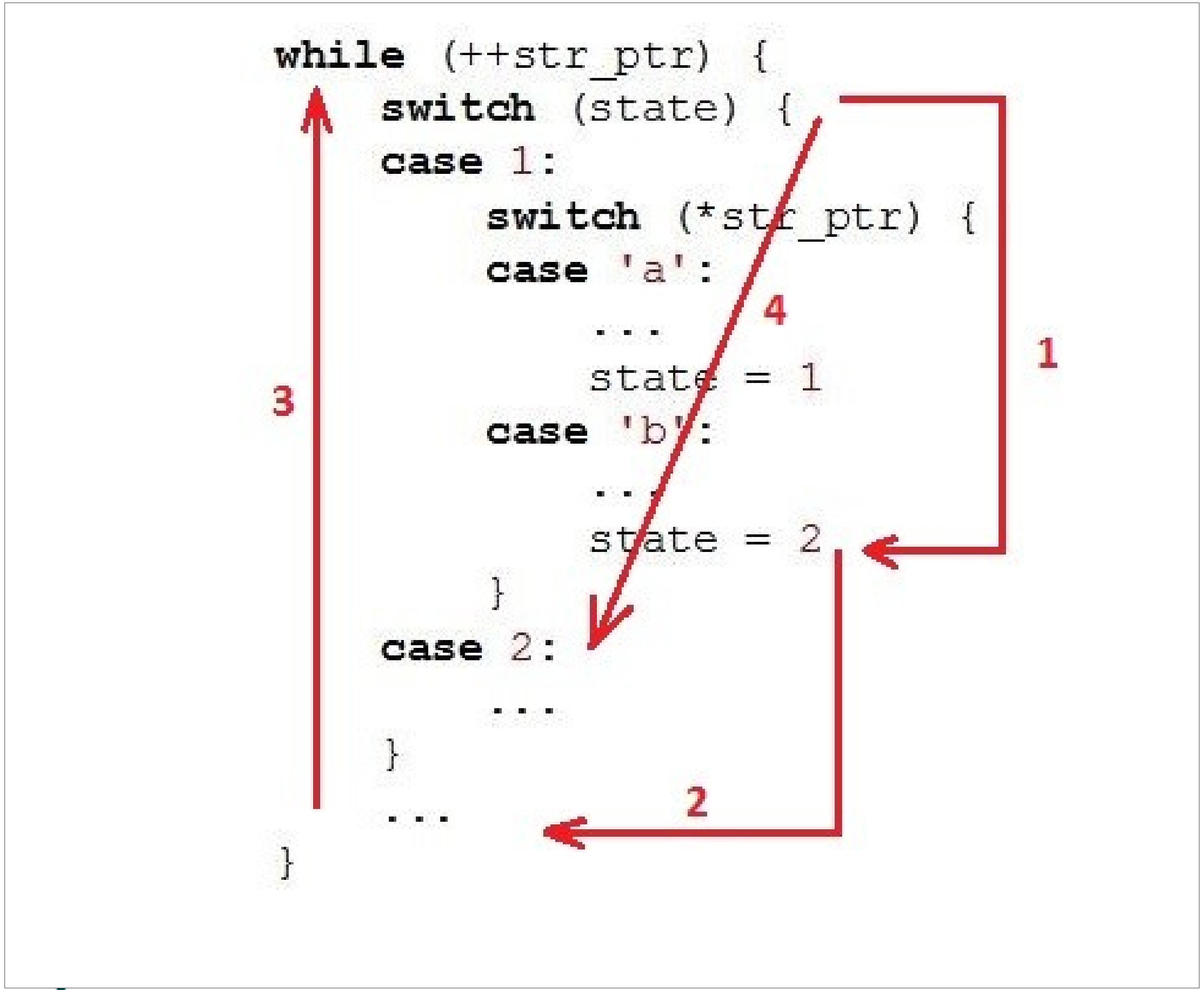
Web-accelerators are slow: HTTP parser

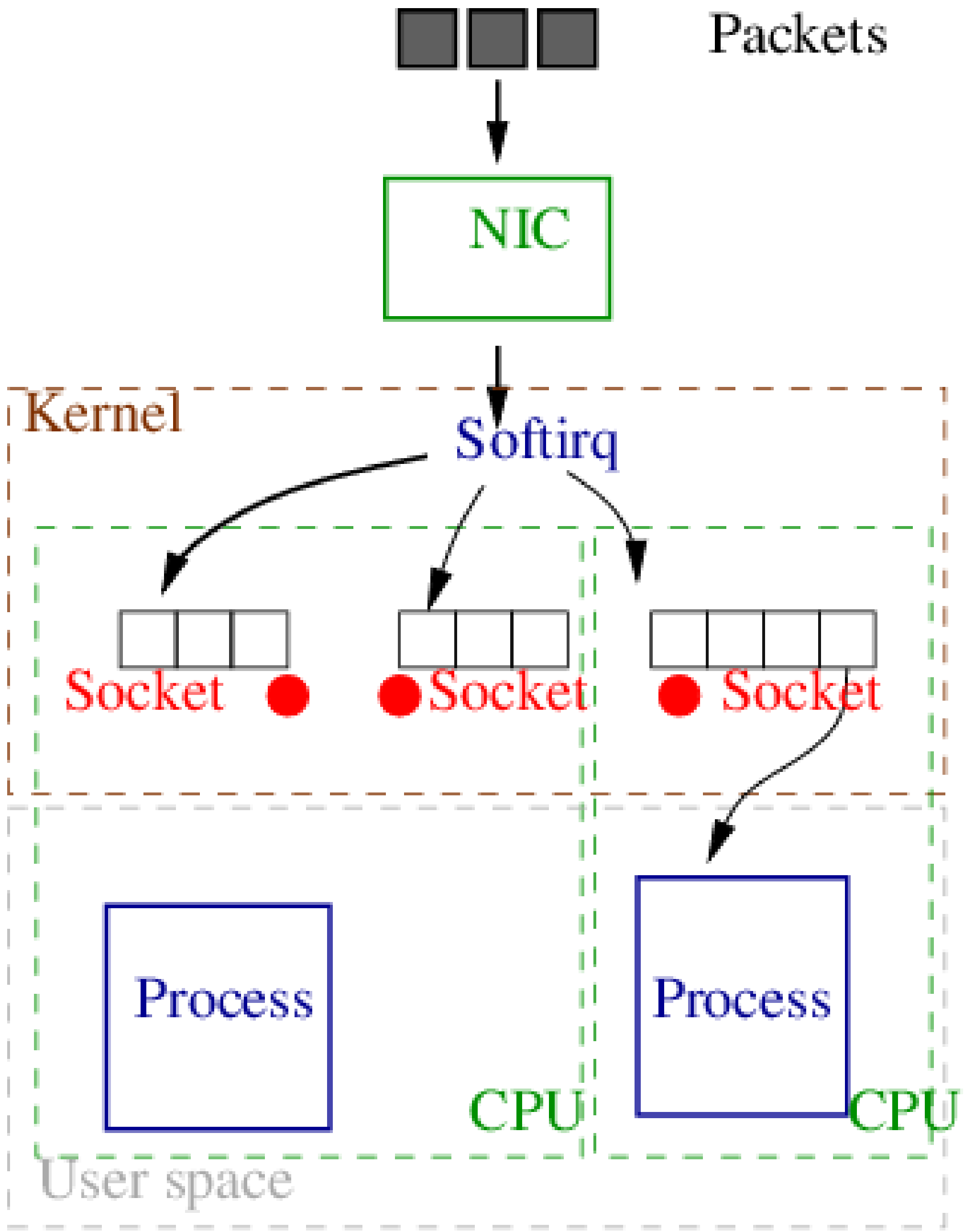



```
while (1):
STATE_1:
    switch (*str_ptr) {
    case 'a':
        ...
        ++str_ptr
        goto STATE_1
    case 'b':
        ...
        ++str_ptr
STATE_2:
    ...
```

Web-accelerators are slow: strings

- We have AVX2, but GLIBC doesn’t still use it
- HTTP strings are special:
  - No `‘\0’`-terminatin (if you’re zero-copy)
  - Special delimiters (`‘:’` or `CRLF`)
  - `strcasecmp()`: no need case conversion for one string
  - `strspn()`: limited number of accepted alphabets
- `switch()`-driven FSM is even worse

Web-accelerators are slow: async I/O



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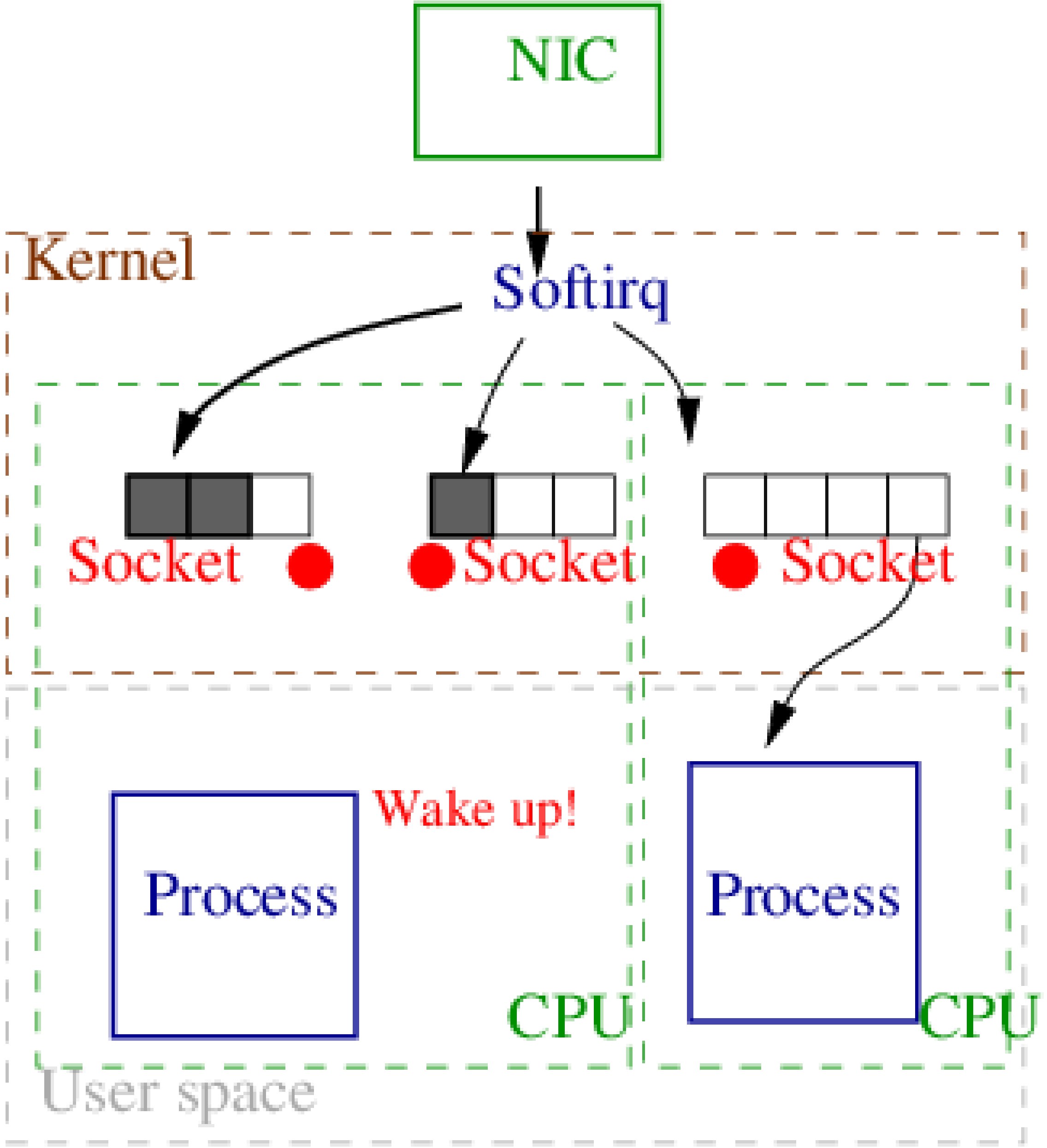
Web-accelerators are slow: async I/O



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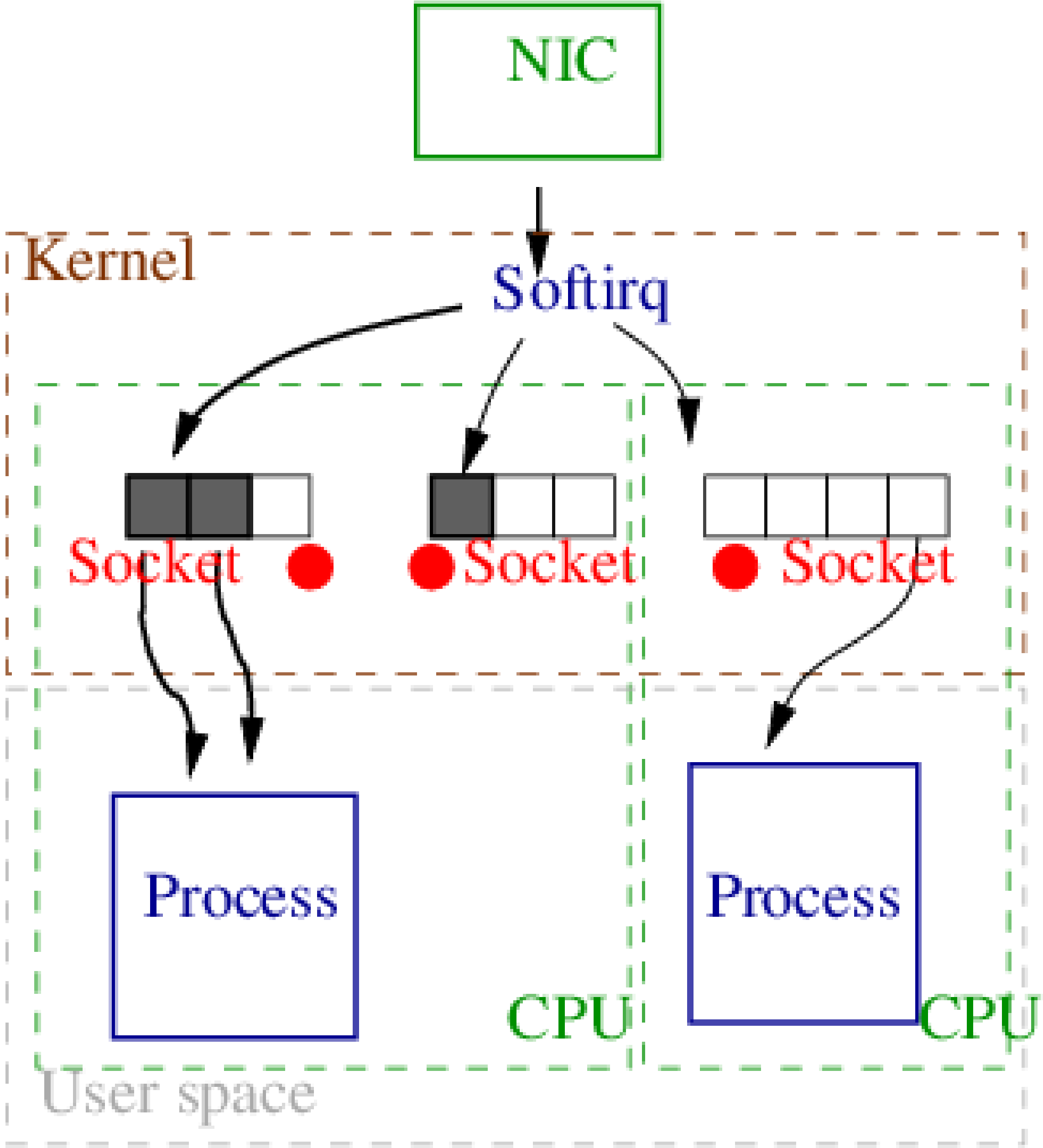
Web-accelerators are slow: async I/O



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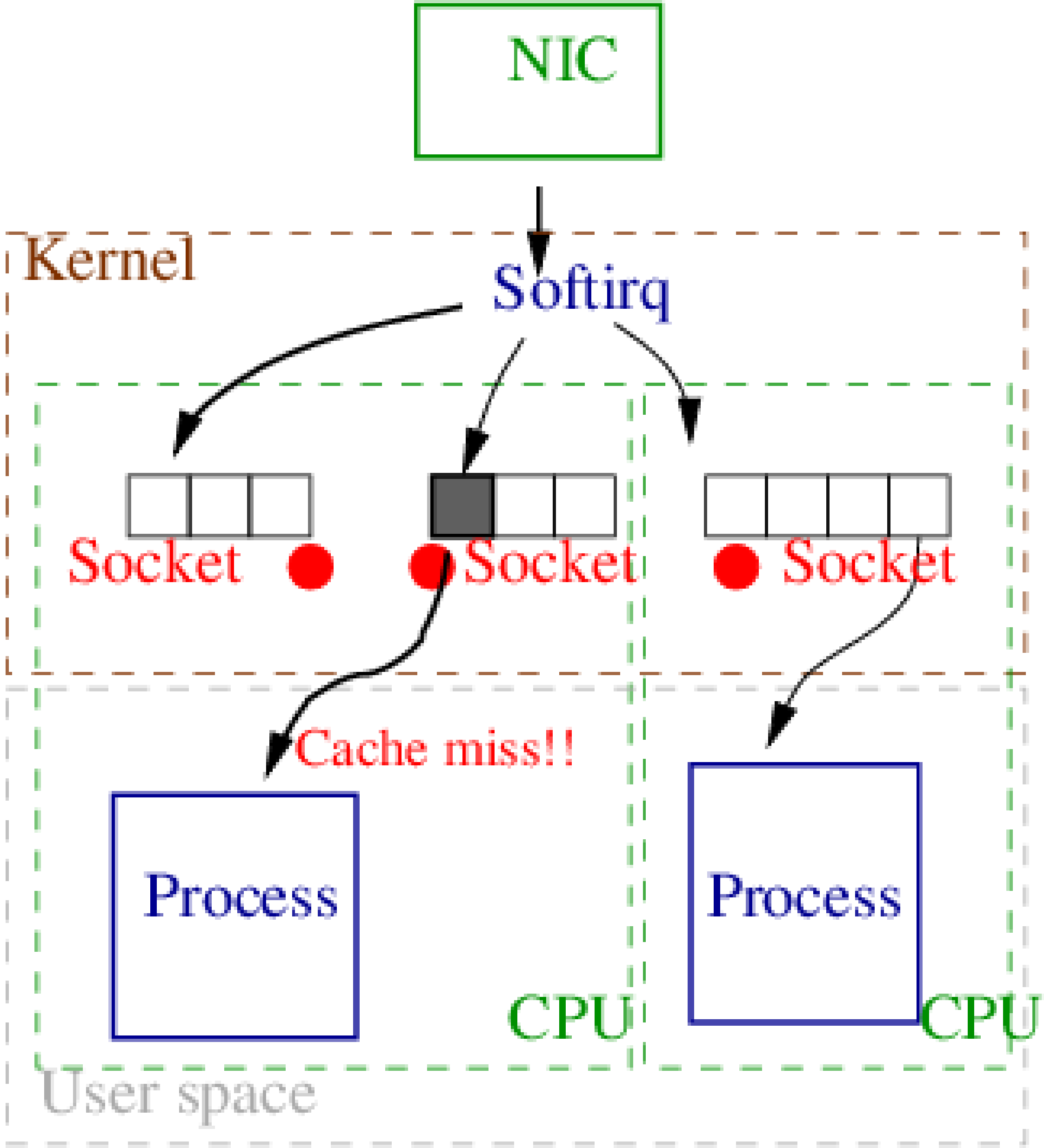
Web-accelerators are slow: async I/O

DCA

(Intel's CPUs

with Intel's NICs)



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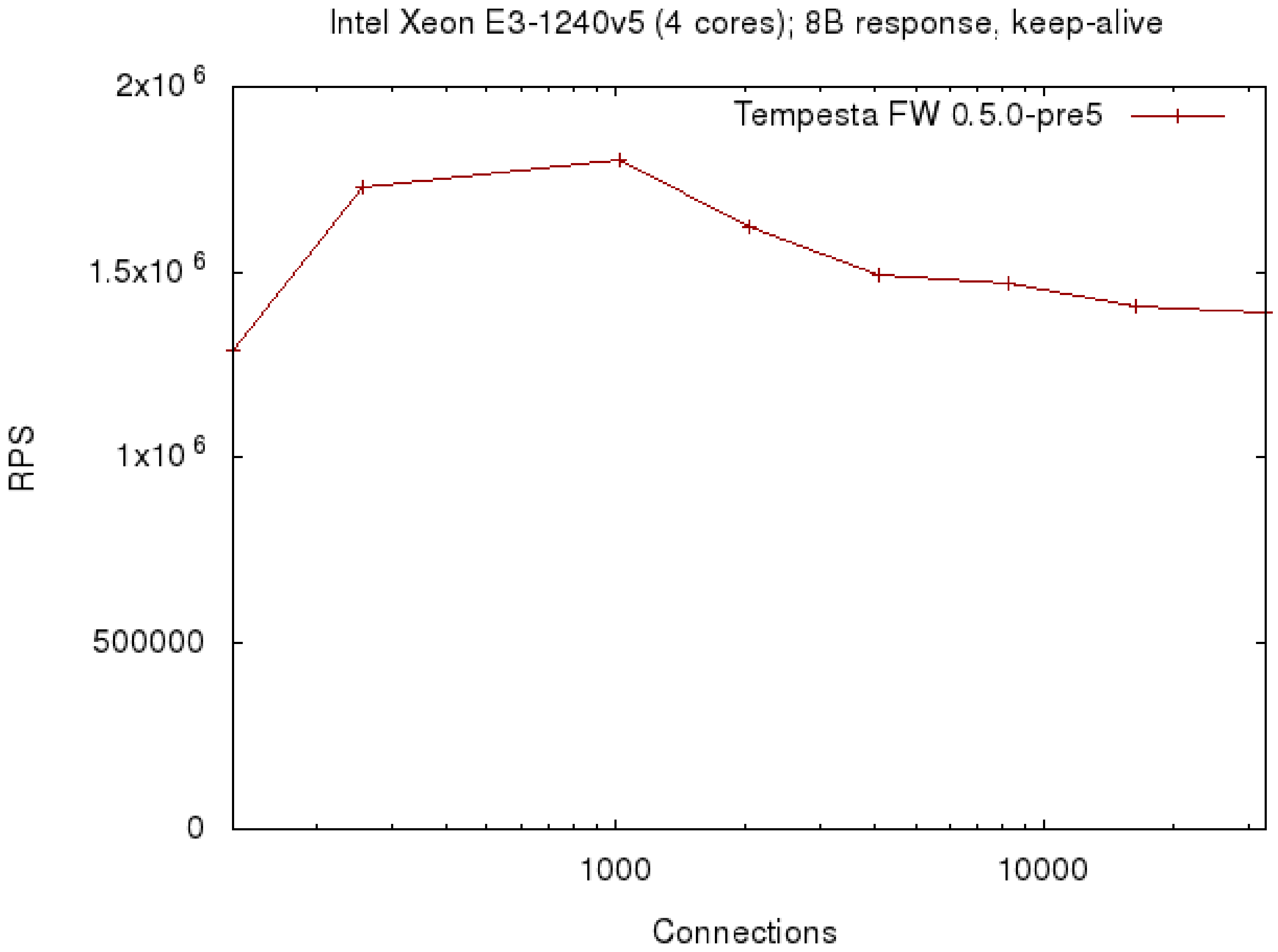
- ADC architecture: a **hybrid of HTTP accelerator and FireWall**
- **Multi-layer FireWall**: layer 3 (IP) – layer 7 (HTTP) filter
- **Directly embedded** into Linux TCP/IP stack *(as traditional firewalls)*
- Built-in filters for **L7 DDoS** and **Web application attacks**
- Very f**ast HTTP parser** and strings processing using AVX2
- **Kernel TLS** (fork from mbedTLS) – no copying!
- **NUMA-aware** x86-64 **cache conscious** Web-cache on **huge pages**
- **Advanced load balancing**
- This is **Open Source** (GPLv2)

Performance



https://github.com/tempesta-tech/tempesta/wiki/Tempesta-FW-benchmark

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Performance analysis

- **~x3 faster than Nginx** for normal Web cache operations
- Must be **much faster to block HTTP DDoS**
(*DDoS emulation is an issue)*
- Similar to DPDK/user-space TCP/IP stacks
  - e.g. Seastar seems shows just 1.3MRPS on 4 cores
    http://www.seastar-project.org/http-performance/
- ...bypassing Linux TCP/IP **isn't the only way** to get a fast Web server
- ...**can be integrated** with LVS, tc, IPtables, tcpdump etc.

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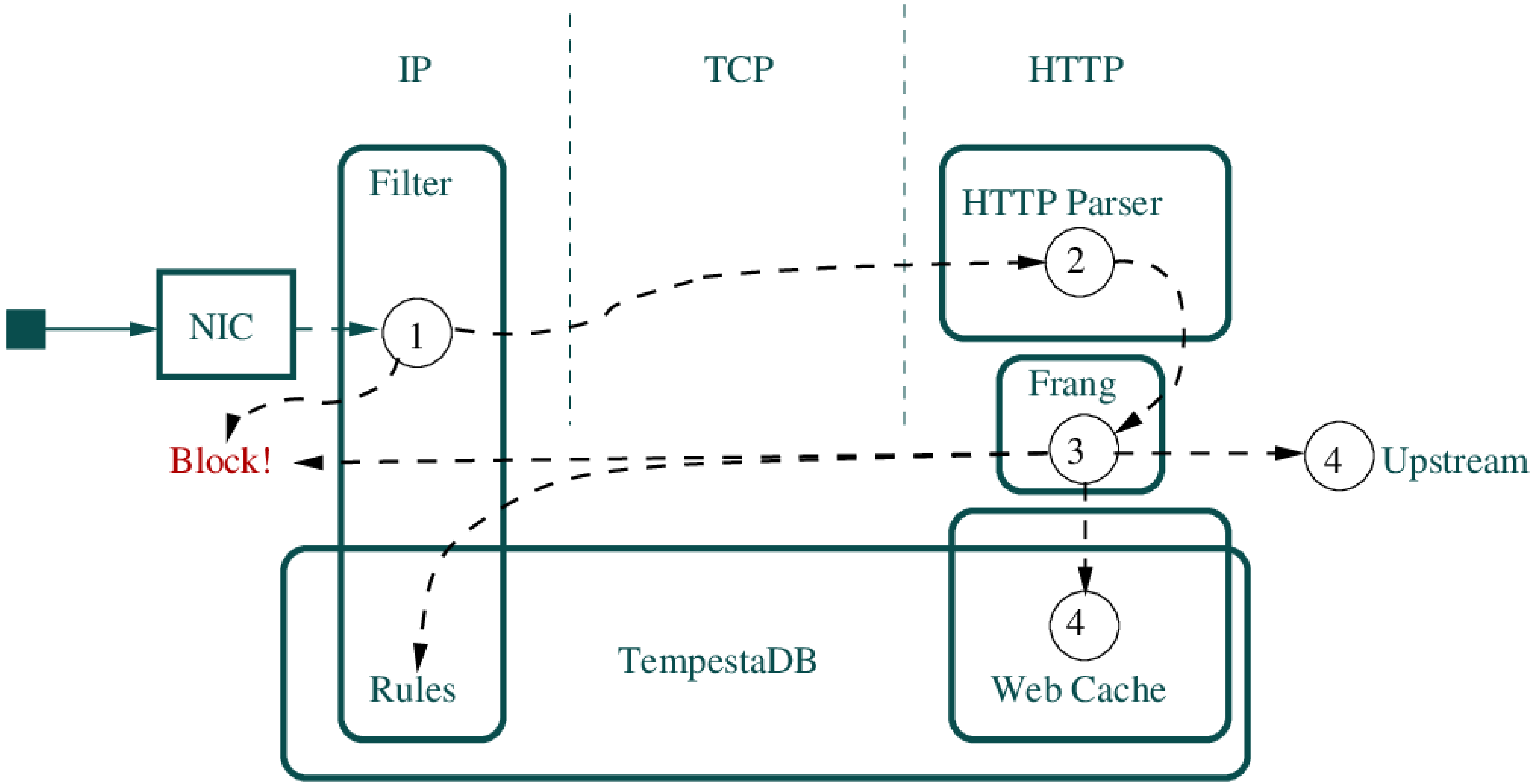

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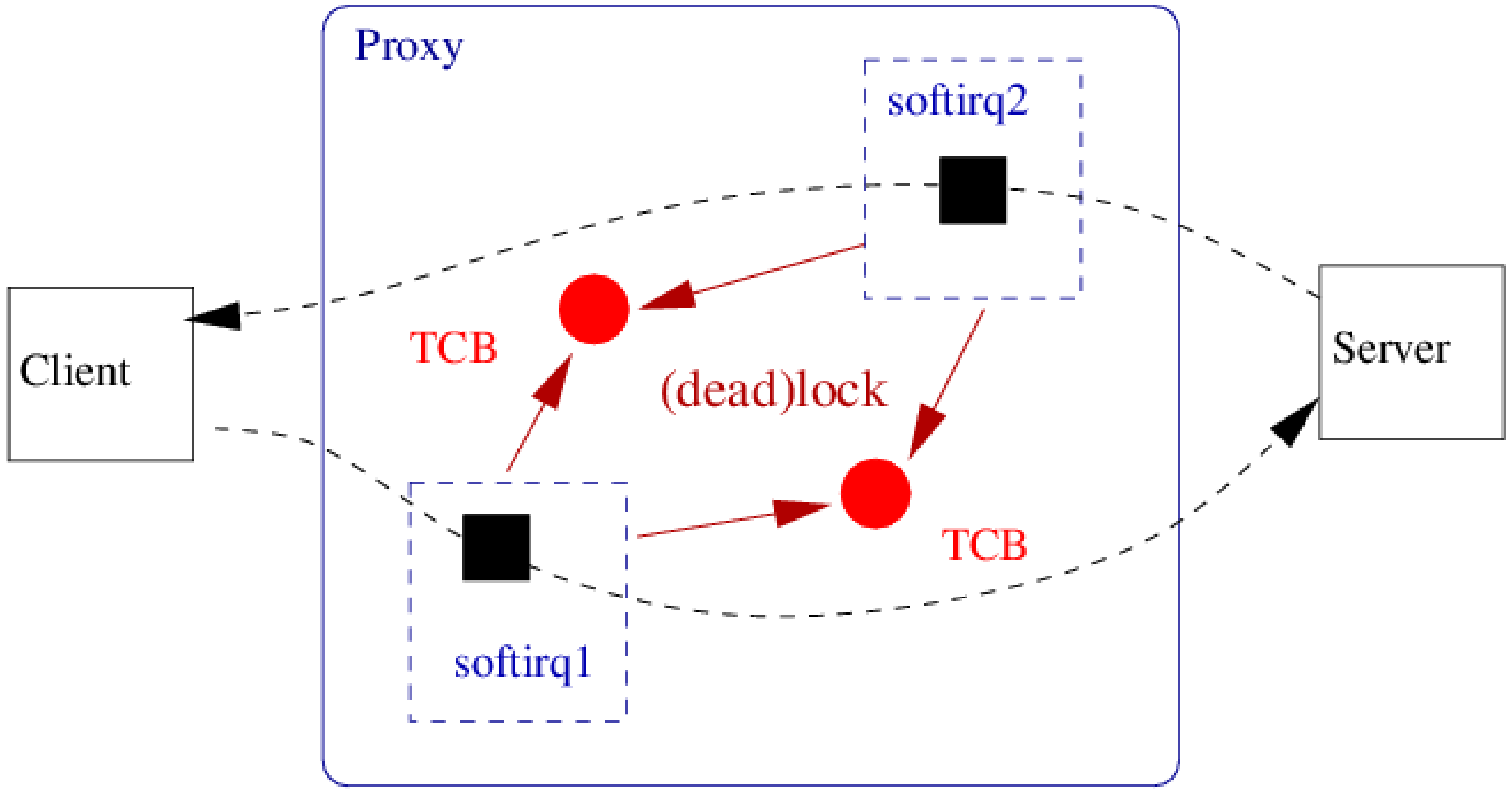
Synchronous sockets: HTTP/TCP/IP stack

- HTTP is built into TCP/IP stack
- Everything is processing in softirq (while the data is hot)
- No input queue
- No file descriptors
- Less locking



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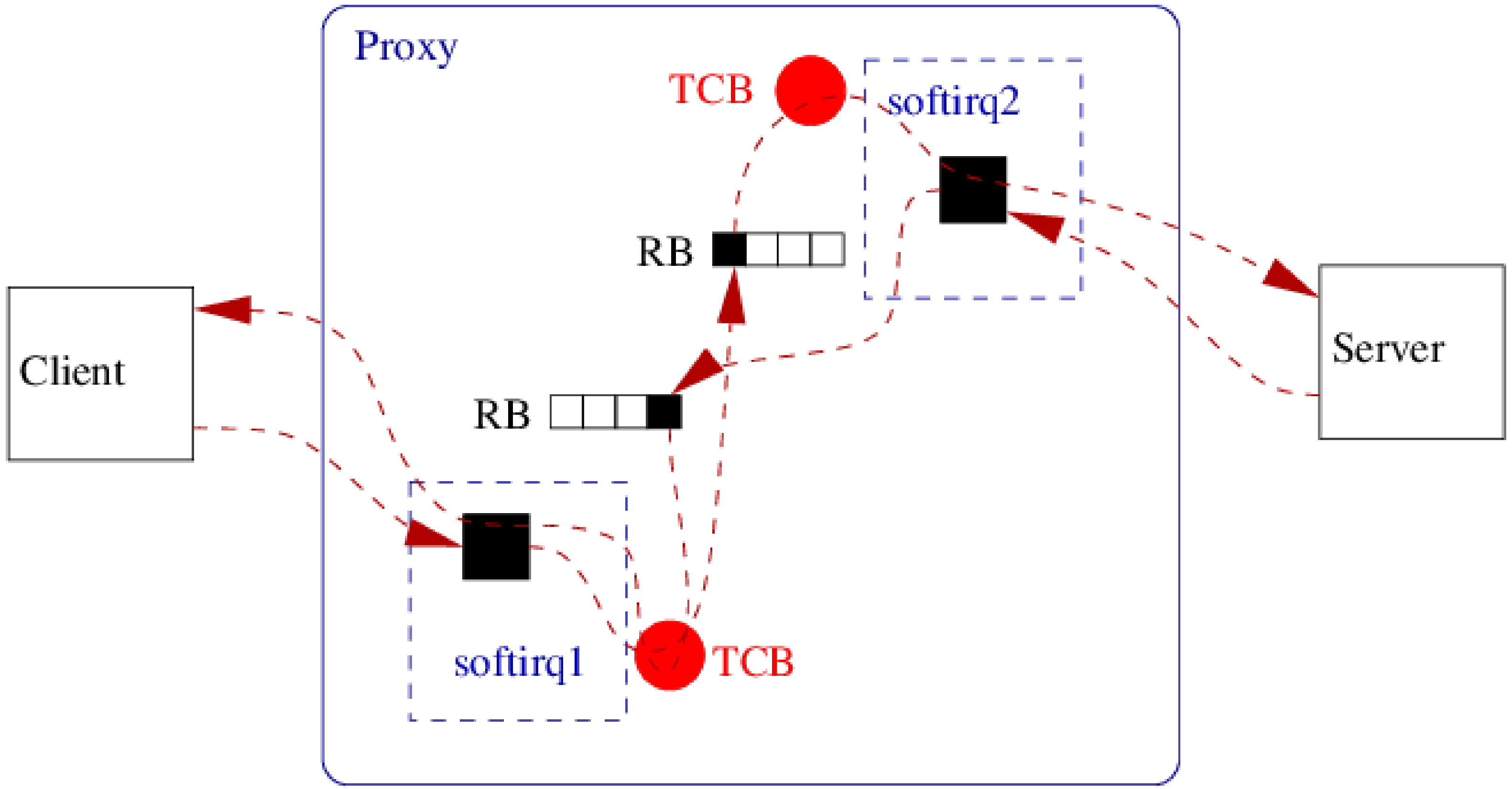
Synchronous sockets: HTTP/TCP/IP stack

- HTTP is built into TCP/IP stack
- Everything is processing in softirq (while the data is hot)
- No input queue
- No file descriptors
- Less locking
- Lock-free inter-CPU transport
- **=> faster socket reading**
- **=> lower latency**



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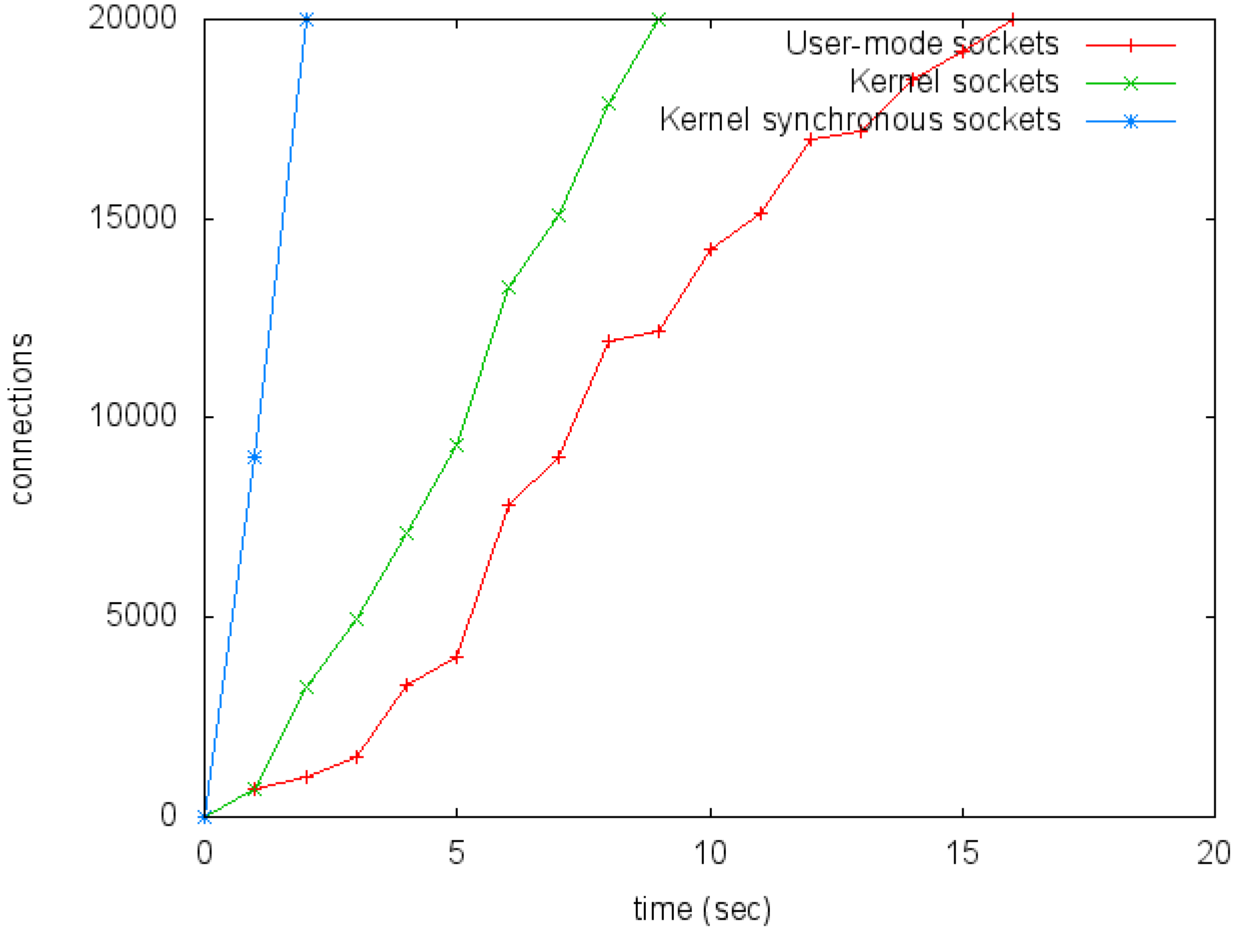
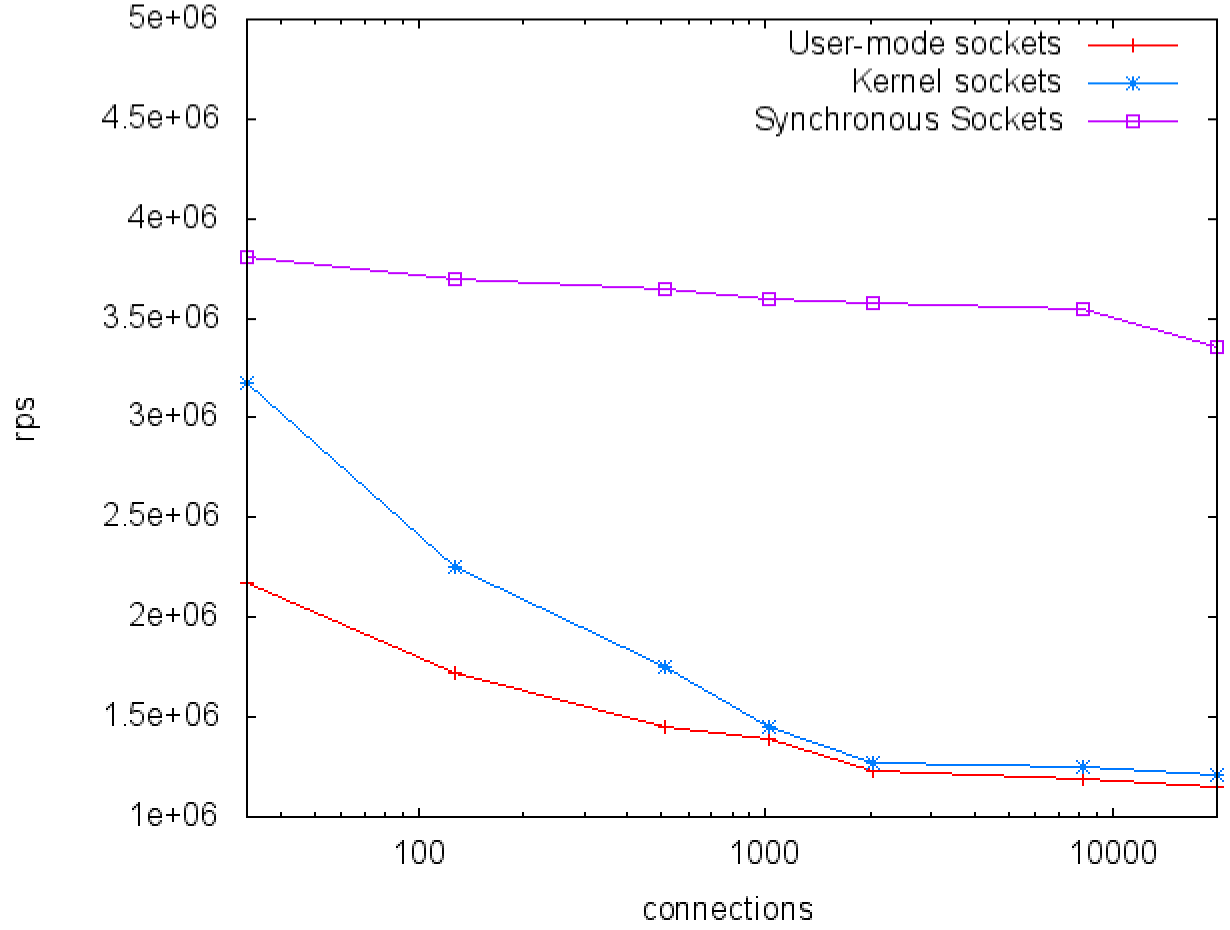
Synchronous sockets: performance





http://natsys-lab.blogspot.ru/2013/03/whats-wrong-with-sockets-performance.html

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Fast HTTP parser

- *http://natsys-lab.blogspot.ru/2014/11/the-fast-finite-state-machine-for-http.html*
  - **1.6-1.8 times faster than Nginx's**
- HTTP optimized AVX2 strings processing: *http://natsys-lab.blogspot.ru/2016/10/http-strings-processing-using-c-sse42.html*
  - *~1KB strings:*
  - *Strncasecmp()* **~x3 faster** than GLIBC's
  - URI matching **~x6 faster** than GLIBC's strspn()

```
while (1):
STATE_1:
    switch (*str_ptr) {
    case 'a':
        ...
        ++str_ptr
        goto STATE_1
    case 'b':
        ...
        ++str_ptr
STATE_2:
    ...
```

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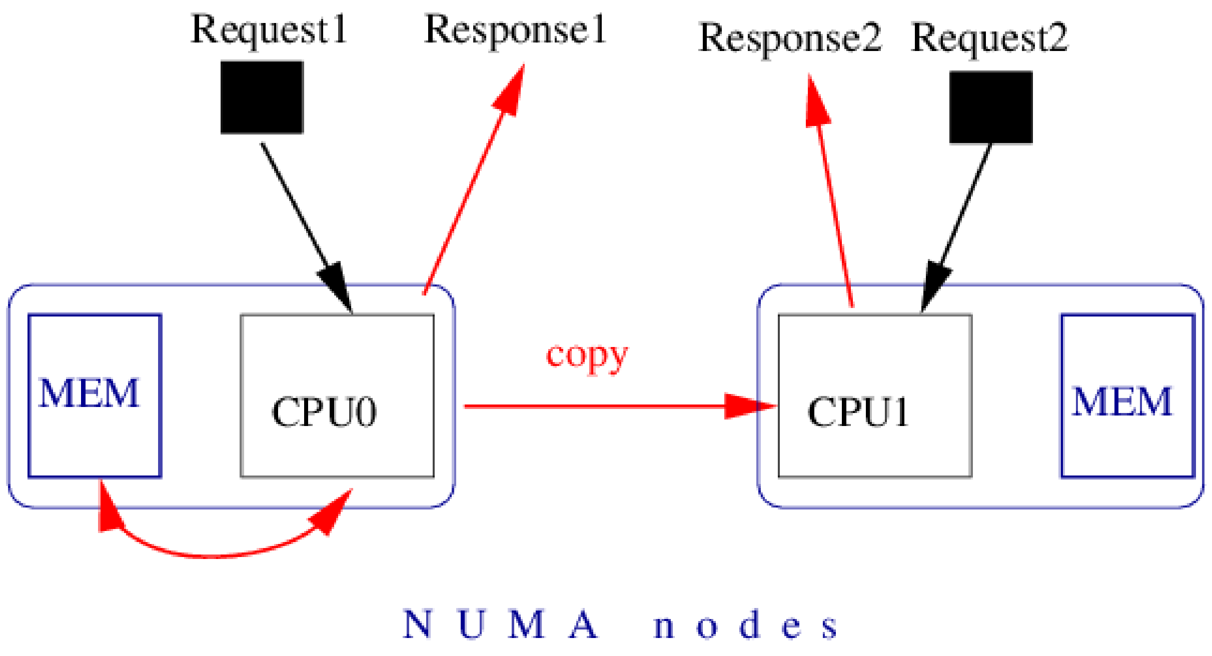
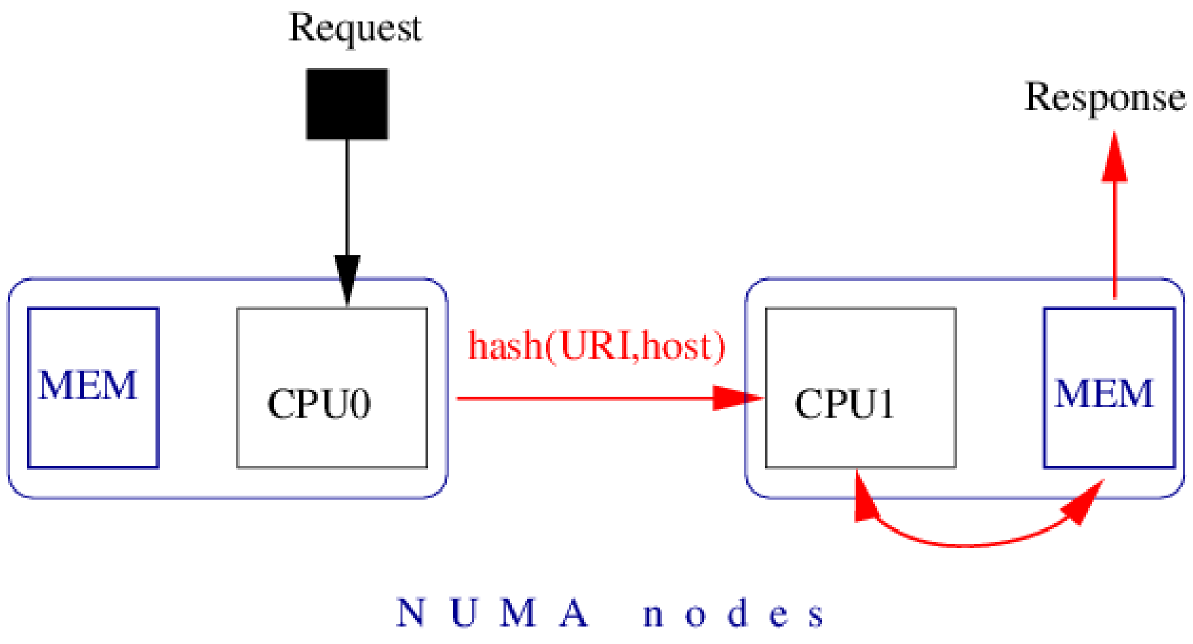
TempestaDB

- Web cache
- Firewall rules
  - Cache conscious Burst Hash Trie
  - Lock-free index
    (data blocks still have locks)
  - Huge pages
  - NUMA aware (replication or shardning)





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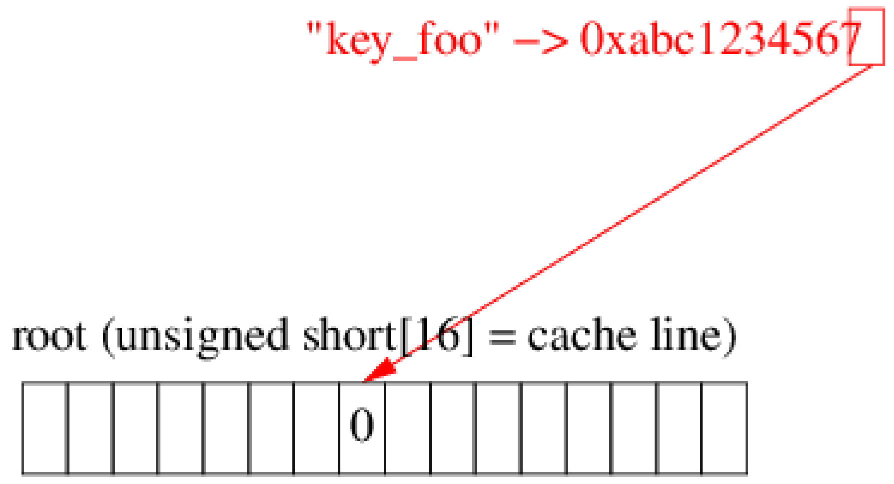
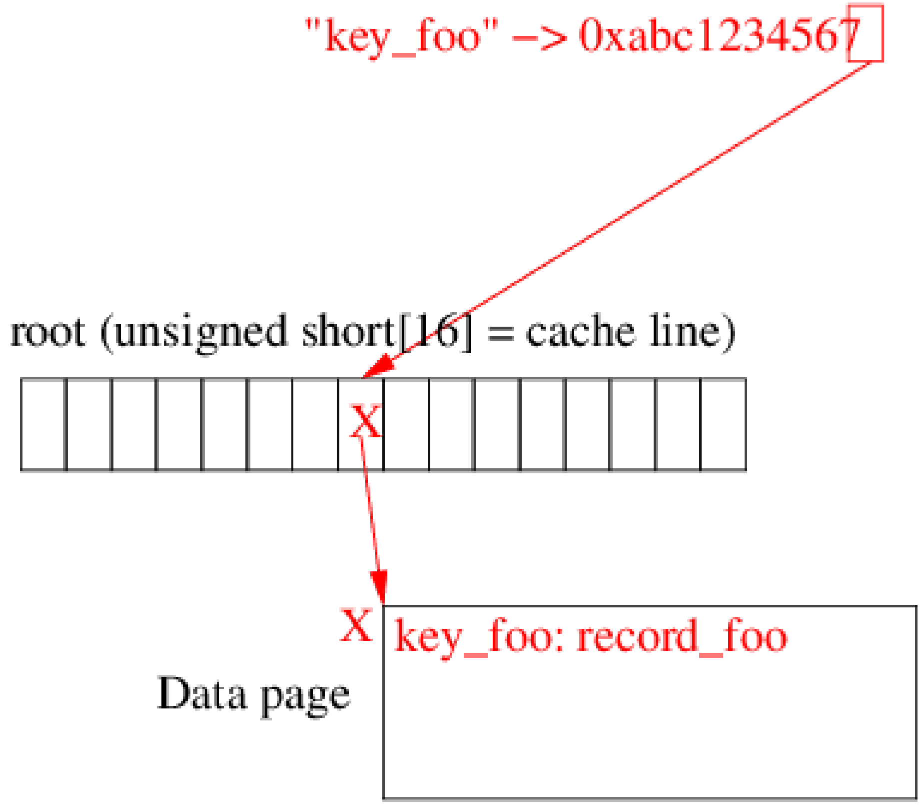
TempestaDB: memory optimizations

- **Cache conscious Burst Hash Trie**
  - **short offsets** instead of pointers
  - (almost) **lock-free**
- **lock-free block allocator** for virtually contiguous memory

Burst Hash Trie



Burst Hash Trie



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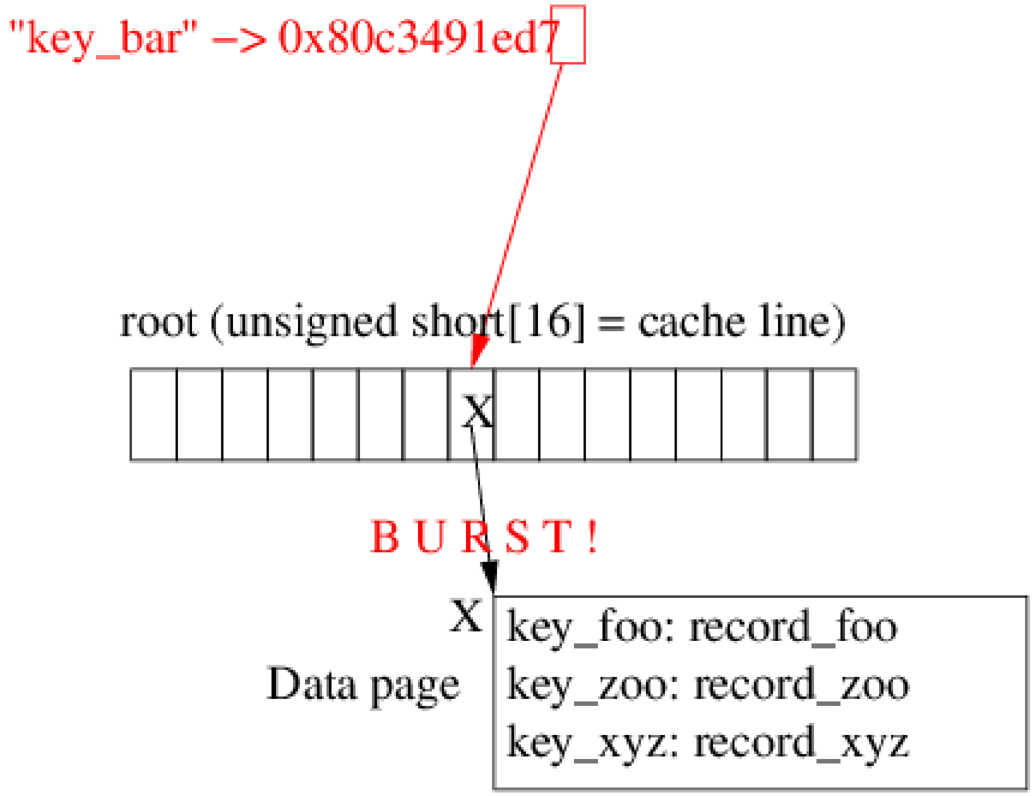

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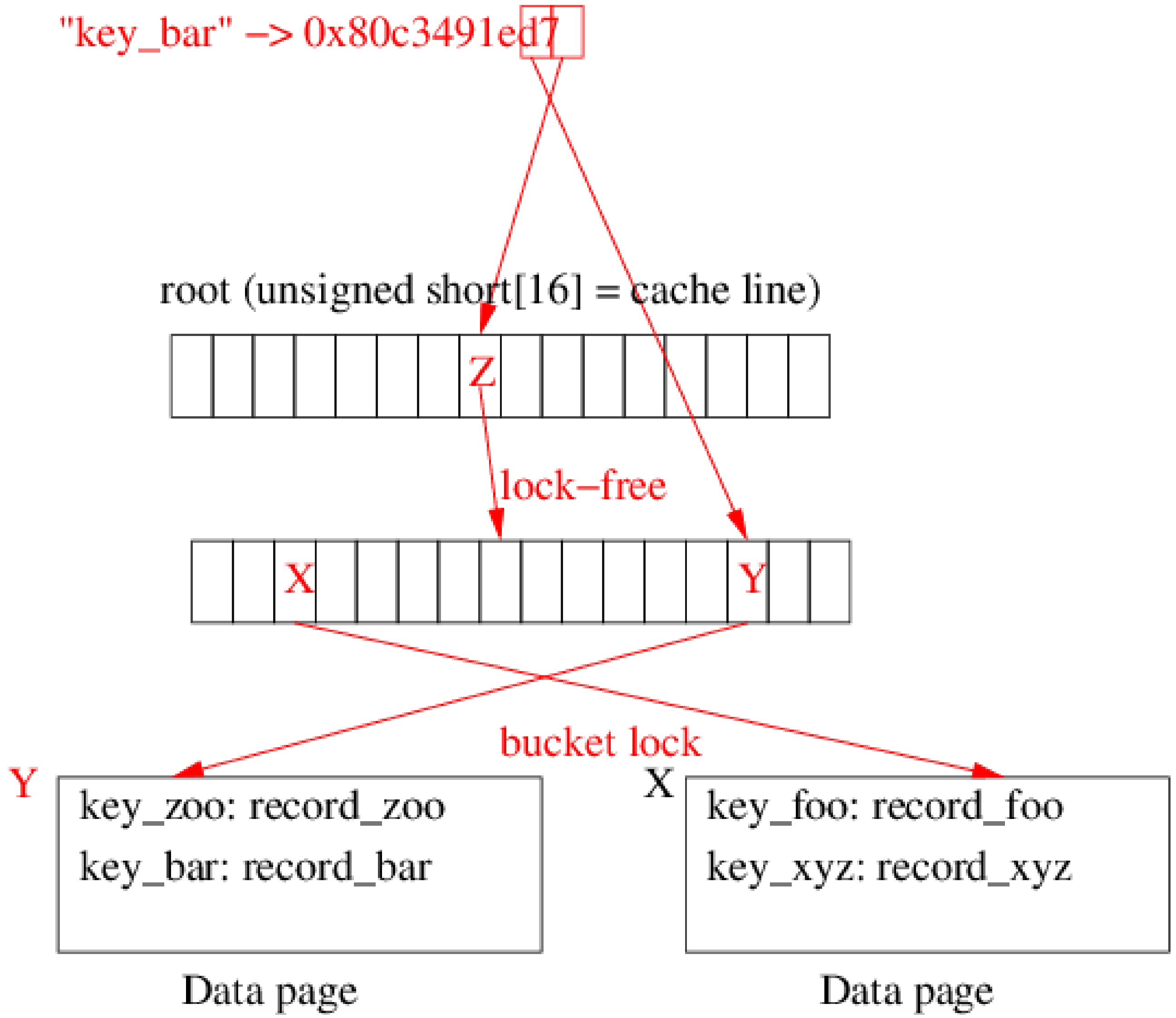

Frang: HTTP DoS

- **Rate limits**
  - request_rate, request_burst
  - connection_rate, connection_burst
  - concurrent_connections
- **Slow HTTP**
  - client_header_timeout, client_body_timeout
  - http_header_cnt
  - http_header_chunk_cnt, http_body_chunk_cnt

Frang: WAF

- **Length limits:** http_uri_len, http_field_len, http_body_len
- **Content validation:** http_host_required, http_ct_required, http_ct_vals, http_methods
- **HTTP Response Splitting:** count and match requests and responses
- **Injections:** carefully verify allowed character sets
- ...and many upcoming filters: *https://github.com/tempesta-tech/tempesta/labels/security*
- **Not a featureful WAF**

Load balancing

- Dynamic **reconnections**
- Configurable number of upstream **keep-alive** connections
- Configurable **non-idempotent** requests handling
- Schedulers
  - **HTTP** (server groups):
    - Method, URI, Host & other headers, wildcards, full match, prefix
  - **Rendezvous hashing** (<Method, URI,Host>, inside server group)
  - **Ratio** (weighted round-robin, inside server group)
  - **Adaptive & predictive** load balancing

Load balancing: configuration example

```
srv_group static { # sched=round-robin
    server 10.10.0.1:8080;
    server [fc00::2]:8081;
}

srv_group dynamic sched=hash {
    server 10.10.0.3:8080; # conns_n = 4
    server [fc00::4]:8081 conns_n=32;
}

srv_group black_hole { }

sched_http_rules {
    match black_hole  hdr_raw   prefix  "X-Bad:";
    match static      uri       prefix  "/static/";
    match dynamic     *         *       *;
}
```

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Sticky cookie

- User/session identification
  - Cookie challenge for dummy DDoS bots
  - Persistent/sessions scheduling (no rescheduling on a server failure)
- **Enforce:** HTTP 302 redirect

```
sticky name=__tfw_user_id__ enforce;
```

Prerequisites

- Haswell: AVX2, SSE 4.2 (“`avx2`”, “`sse4_2`” in `/proc/cpuinfo`)
- Huge pages (“`pse`” in `/proc/cpuinfo`)
- Custom Linux kernel (KVM or dedicated server)

Build the kernel

```
$ git clone https://github.com/tempesta-tech/linux-4.8.15-tfw.git
$ cd linux-4.8.15-tfw
$ make && make modules && make modules_install && make install
$ reboot
```

Build & run

```
$ git clone https://github.com/tempesta-tech/tempesta.git
$ cd tempesta && make
$ cat > etc/tempesta_fw.conf
  server 127.0.0.1:8080;  # upstream
  cache 1;                # cache sharding
  ^D
$ ./scripts/tempesta.sh --start
```

Is it safe to live in kernel?

- Just **30K LoC** (compare w/ 120K LoC of BtrFS)
- Tests, tests, tests, tests, tests, tests…
- Mandatory code reviews
- Upcoming zero-copy **kernel-user space transport** for minimizing kernel code
- **Usability:**
  - Debian and CentOS packages in 0.5 (current)
  - Full Linux distribution in 0.6

Why Tempesta FW?

- Faster than user space Web-accelerators
- Built-in filtering to block L7 DDoS and Web application attacks
- Many HTTP schedulers

Thanks!

- Web-site: *http://tempesta-tech.com* ***(Powered by Tempesta FW)***
- Availability: *https://github.com/tempesta-tech/tempesta*
- Blog: *http://natsys-lab.blogspot.com*
- E-mail: *ak@tempesta-tech.com*

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