FlexSC

Flexible System Call Scheduling with Exception-Less System Calls

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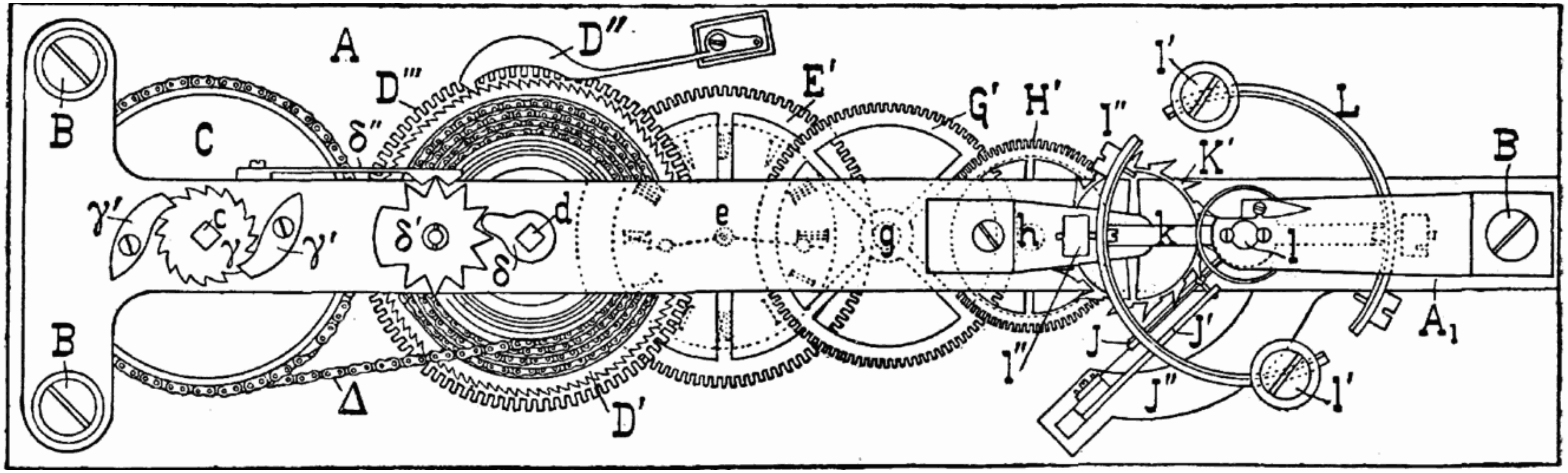
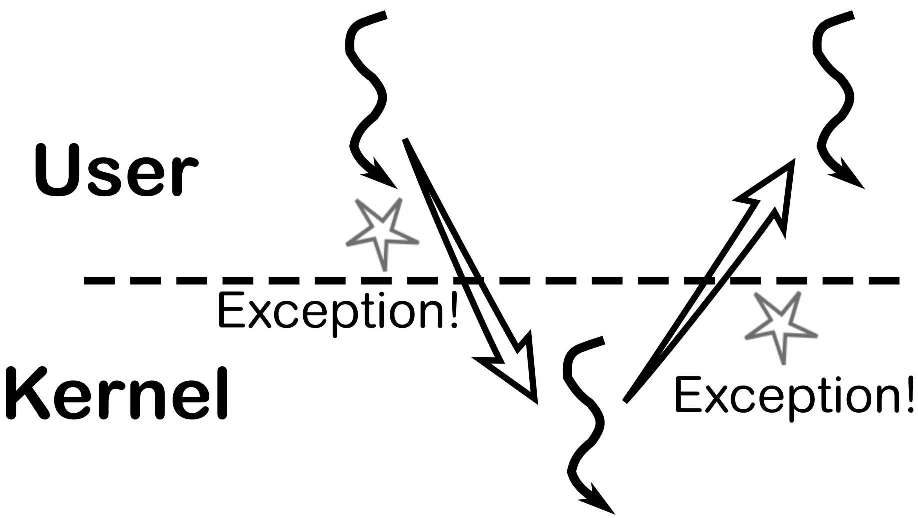


Motivation

The **synchronous** system call interface is a legacy from the single core era



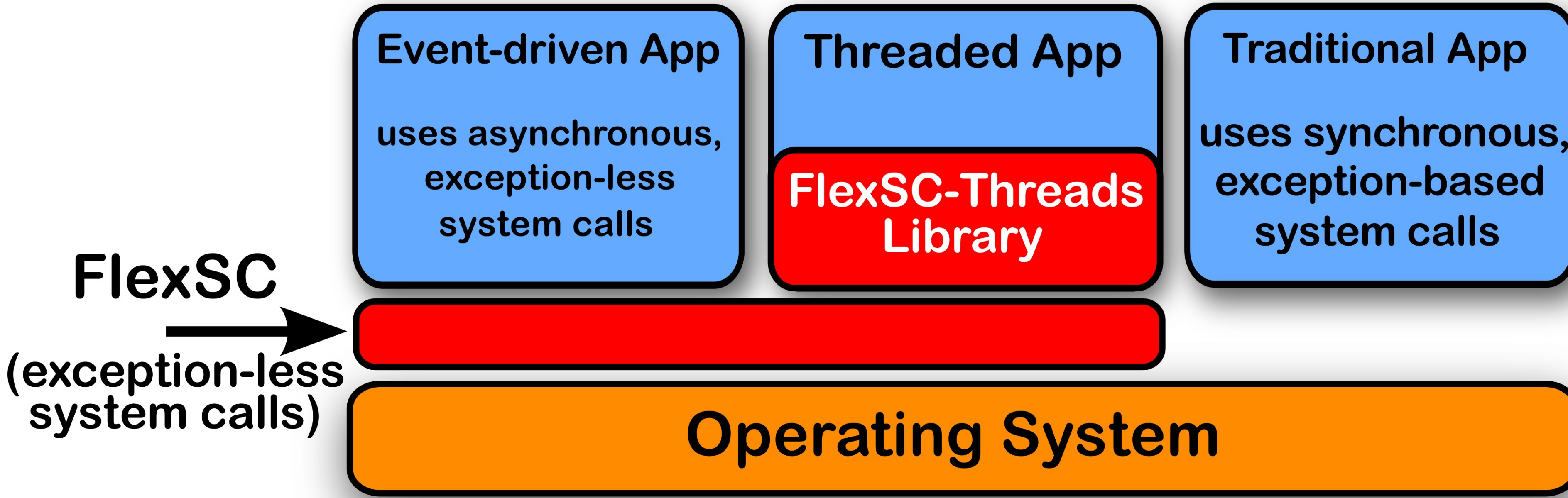
Expensive! Costs are:

- ➔ **direct**: mode-switch
- ➔ **indirect**: processor structure pollution

FlexSC implements **efficient and flexible** system calls for the multicore era

FlexSC overview

Two contributions: FlexSC and FlexSC-Threads



Results in:

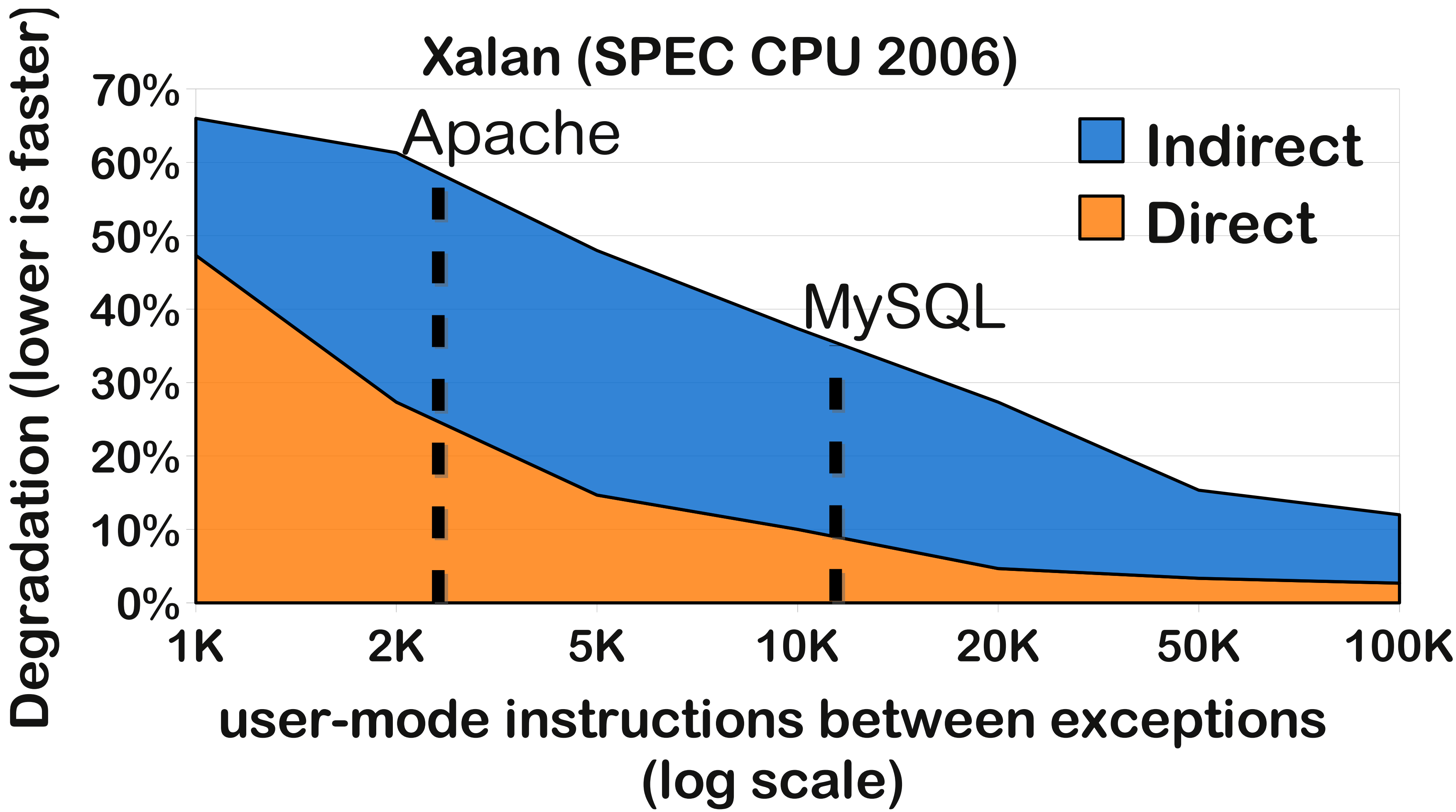
1) MySQL throughput increase of up to 40% and latency reduction of 30%
2) Apache throughput increase of up to 115% and latency reduction of 50%

Performance impact of synchronous syscalls

- Xalan from SPEC CPU 2006
  - Virtually no time in the OS
- Linux on Intel Core i7 (Nehalem)
- Injected exceptions with varying frequencies
  - **Direct**: emulate null system call
  - **Indirect**: emulate “write()” system call
- Measured only user-mode time
  - Kernel time ignored

Ideally, user-mode performance is unaltered

Degradation due to sync. syscalls



System calls can **half** processor efficiency;
indirect cause is major contributor

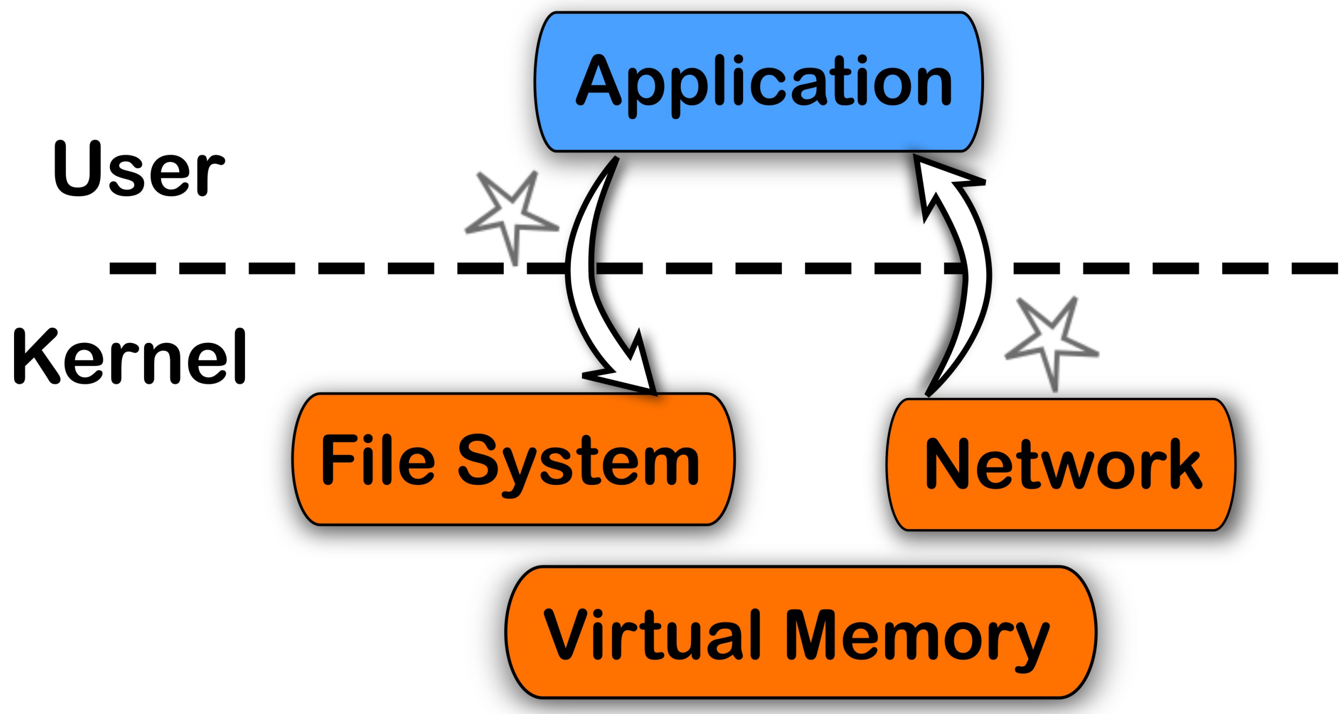
Processor state pollution

- ➔ Key source of performance impact

- ➔ On a Linux write() call:
  - ➔ up to 2/3rd of the L1 data cache and data TLB are **evicted**

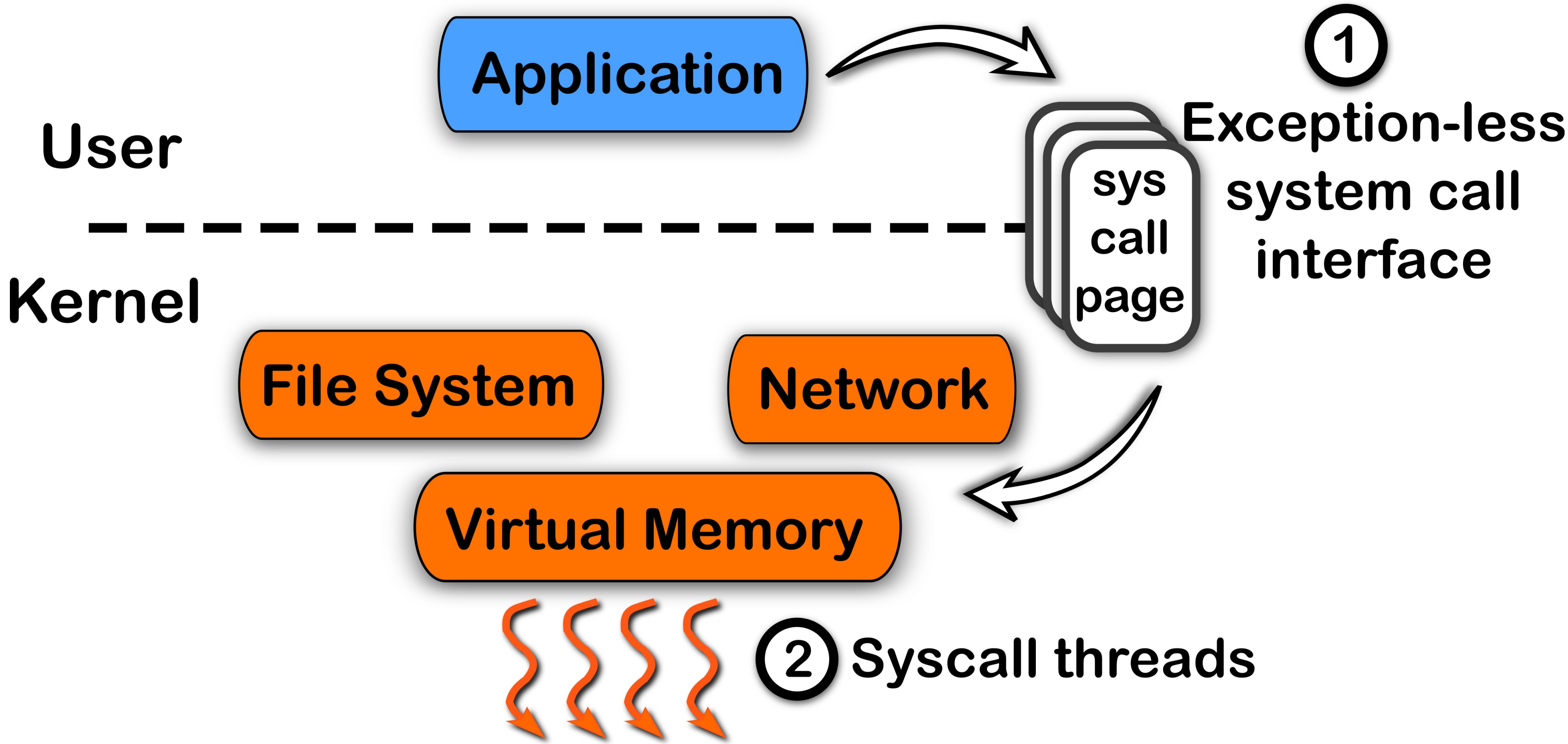
- ➔ Kernel performance equally affected
  - ➔ Processor efficiency for OS code is also cut in **half**

Synchronous system calls are expensive



Traditional system calls are synchronous and use exceptions to cross domains

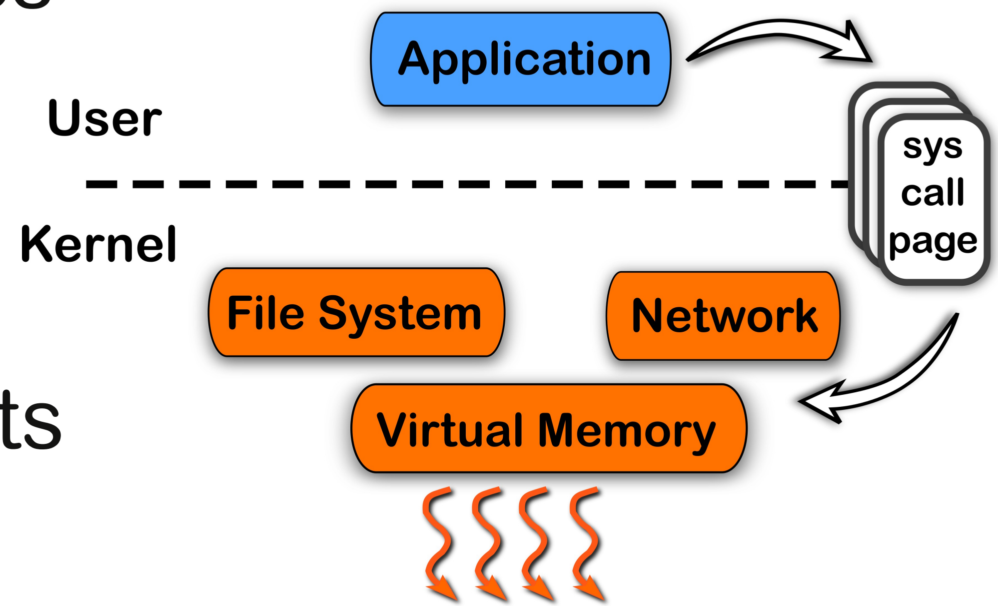
Alternative: side-step the boundary



Exception-less syscalls remove synchronicity by decoupling invocation from execution

Benefits of exception-less system calls

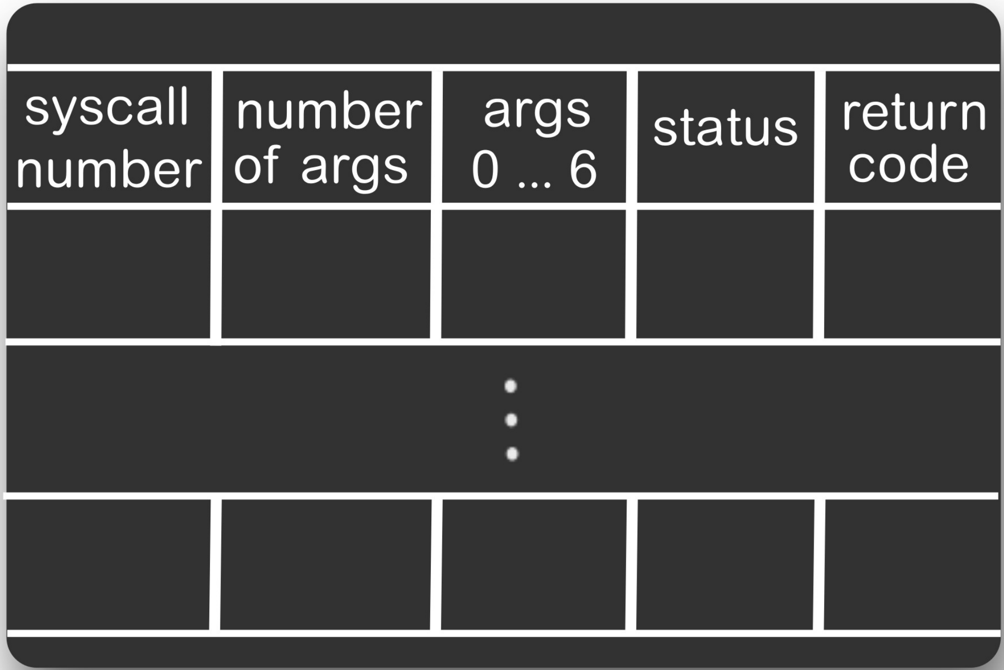
- Significantly reduce direct costs
  - Fewer mode switches
- Allow for batching
  - Reduce indirect costs



- Allow for dynamic multicore specialization
  - Further reduce direct and indirect costs

Exception-less interface: syscall page

```
write(fd, buf, 4096);



entry = free_syscall_entry();

/* write syscall */
entry->syscall = 1;
entry->num_args = 3;
entry->args[0] = fd;
entry->args[1] = buf;
entry->args[2] = 4096;
entry->status = SUBMIT;

while (entry->status != DONE)
   do_something_else();

return entry->return_code;
```



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syscall number	number of args	args 0 ... 6	status	return code
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1	3	fd, buf, 4096	SUBMIT	

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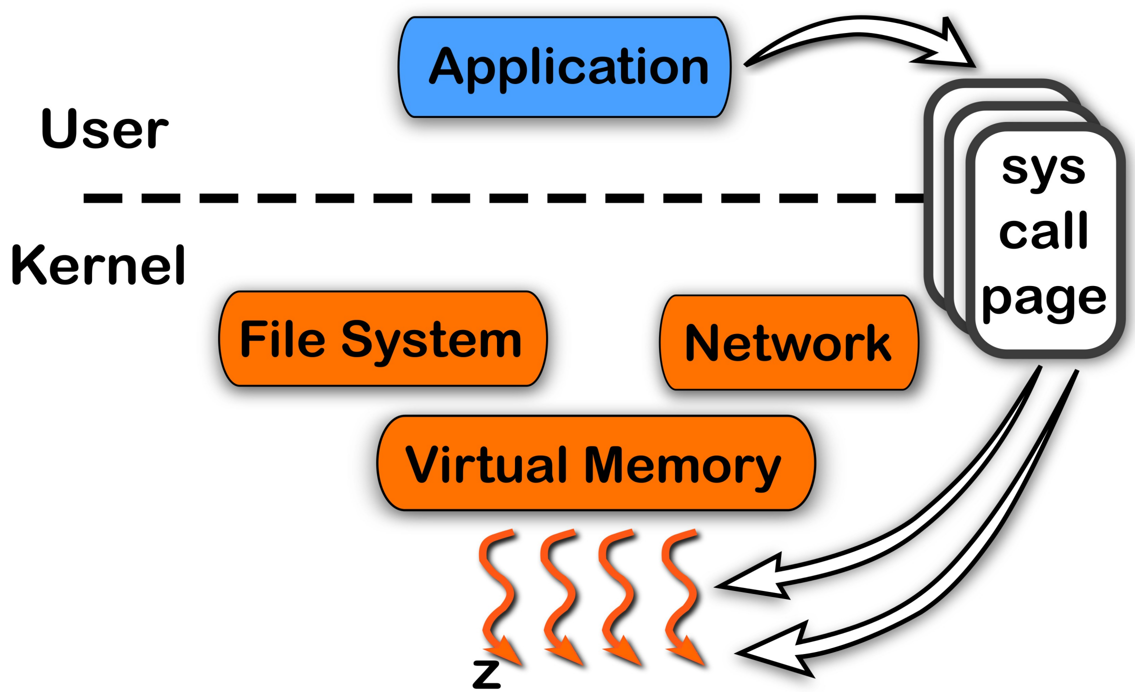
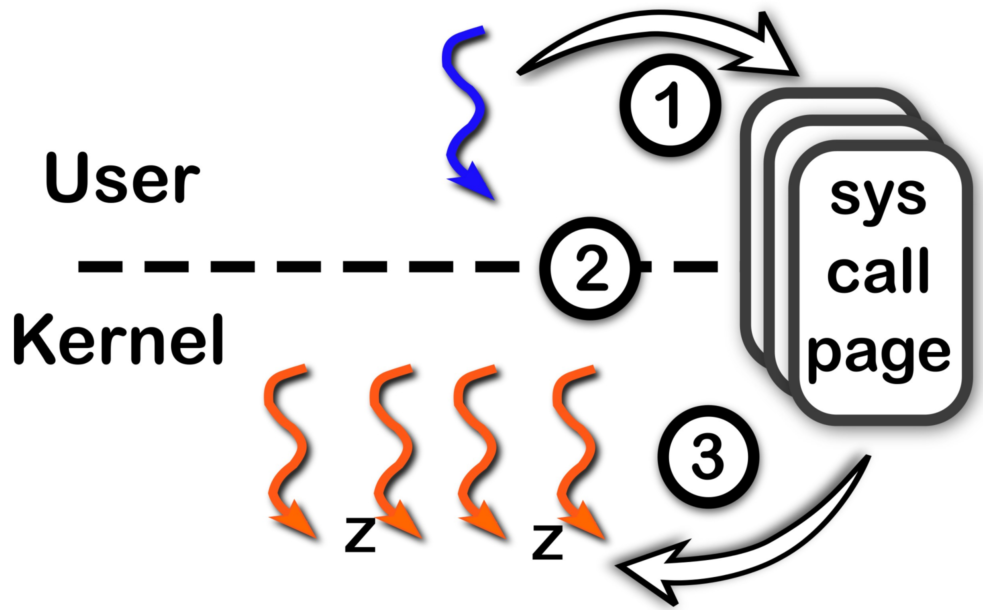
syscall number	number of args	args 0 ... 6	status	return code
		⋮		
1	3	fd, buf, 4096	DONE	4096

Syscall threads

- Kernel-only threads
  - Part of application process
- Execute requests from syscall page
- Schedulable on a per-core basis



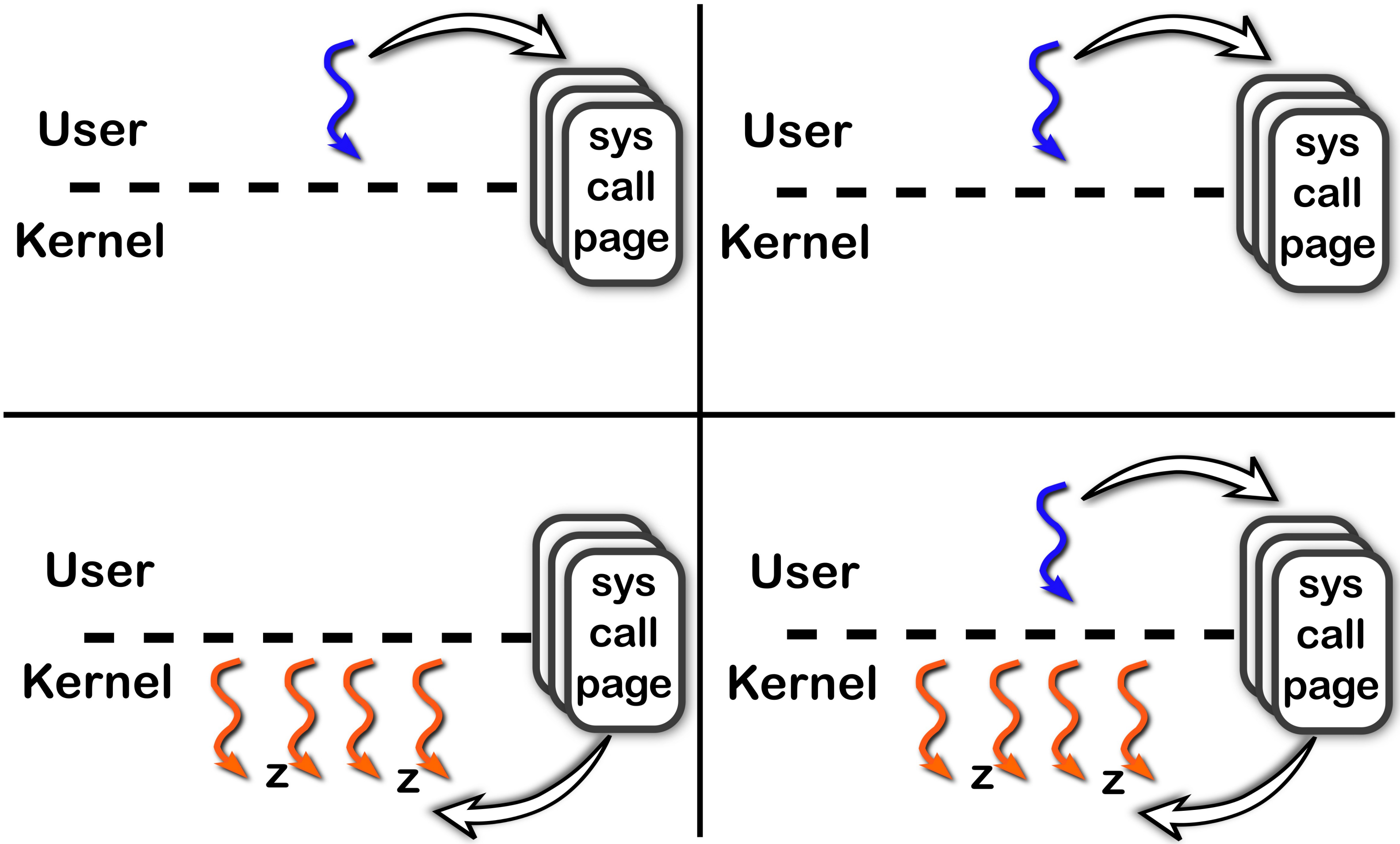
System call batching



① Request as many system calls as possible
② Switch to kernel-mode
③ Start executing all posted system calls

Avoids direct and indirect costs,
even on a single core

Dynamic multicore specialization



FlexSC makes specializing cores simple
Dynamically adapts to workload needs

What programs can benefit from FlexSC?

Event-driven servers

(e.g., memcached, nginx webserver)

- ➔ Use asynchoronous calls, similar to FlexSC
- ➔ Can use FlexSC *directly*
- ➔ Mix sync and exception-less system calls

Multi-threaded servers: **FlexSC-Threads**

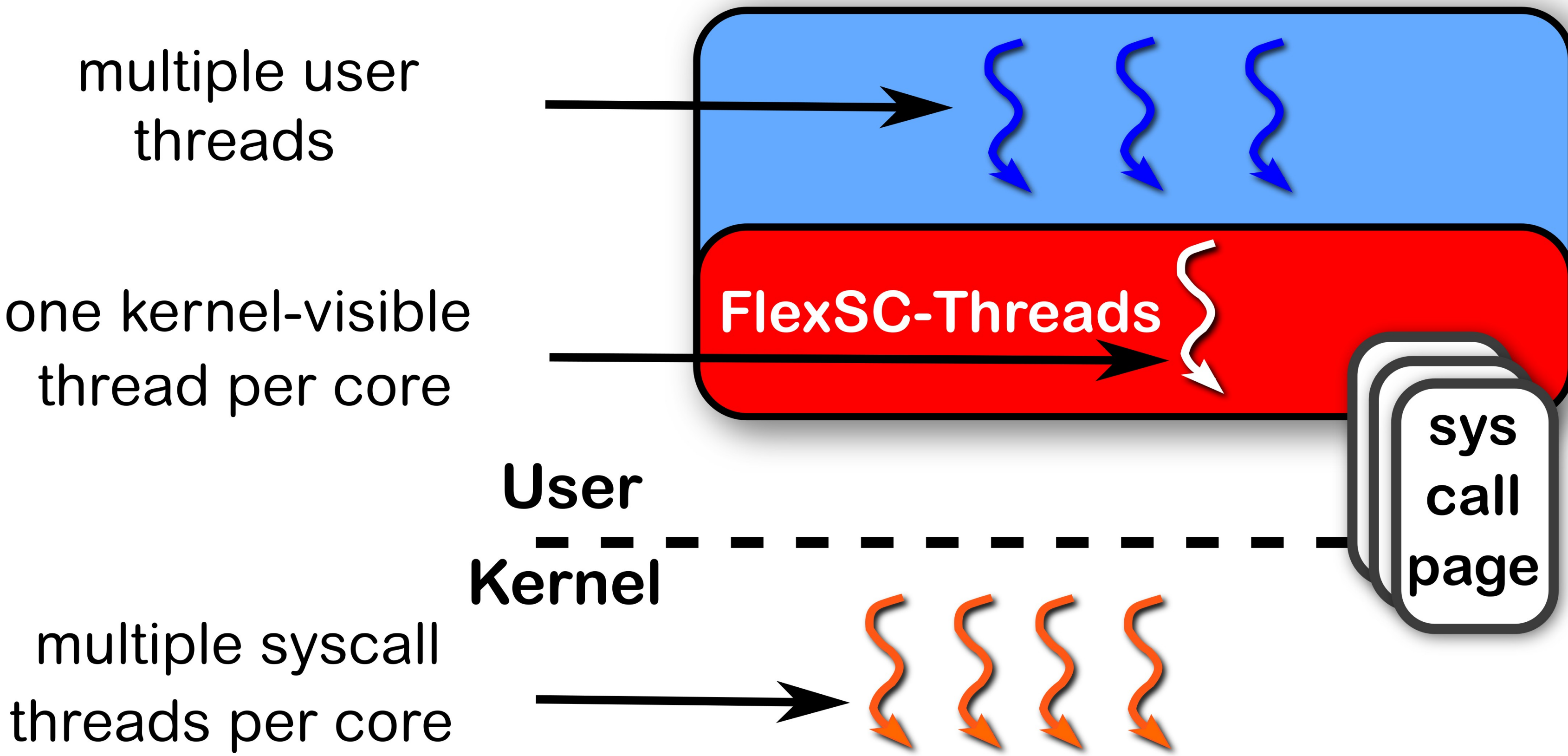
- ➔ Thread library, compatible with Pthreads
- ➔ No changes to app. code or recompilation required
- ➔ Transparently converts legacy syscalls into exception-less ones

FlexSC-Threads library

- Hybrid (M-on-N) threading model
  - One kernel visible thread per core
  - Many user threads per kernel-visible thread
- Redirects system calls (*libc* wrappers)
  - Posts exception-less syscall to syscall page
  - Switches to other user-level thread
  - Resumes thread upon syscall completion

Benefits of exception-less syscalls while maintaining sequential syscall interface

FlexSC-Threads in action



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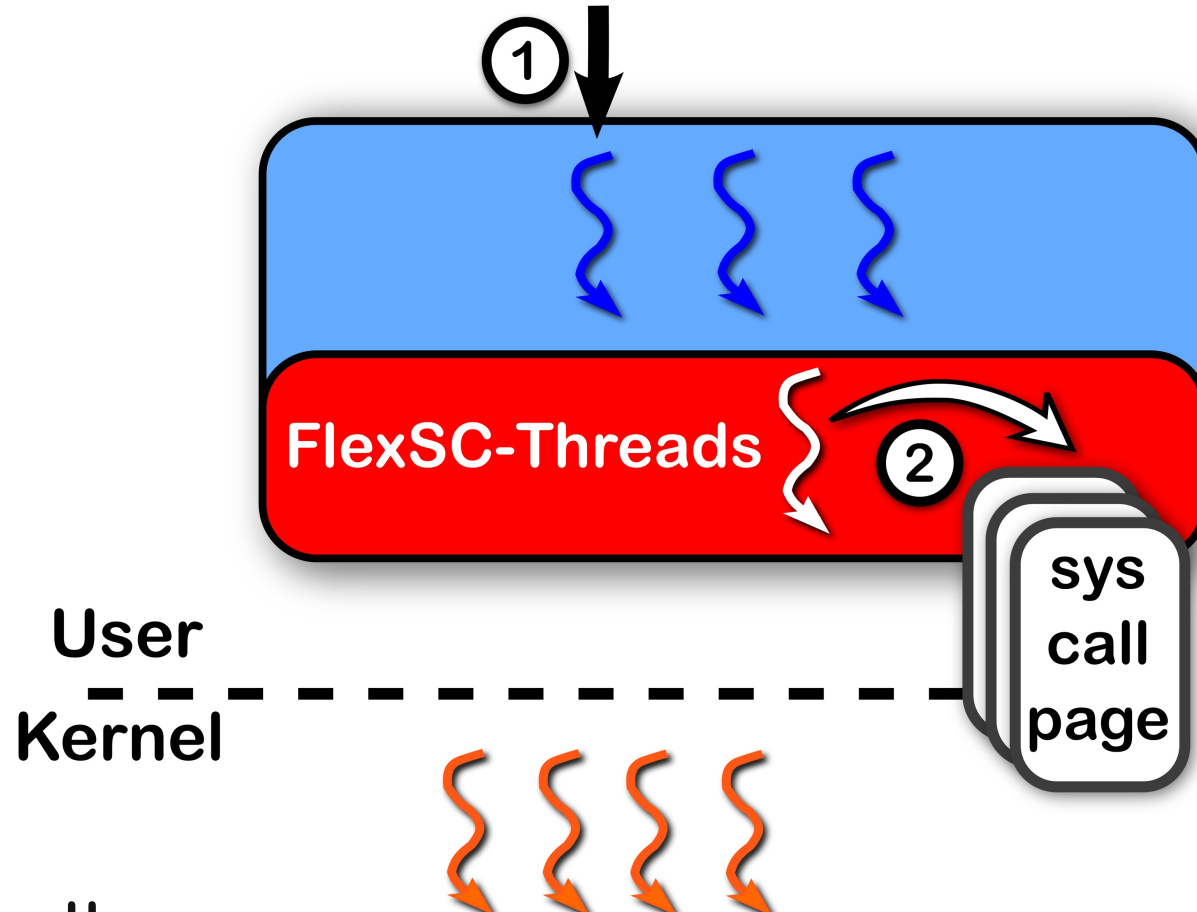
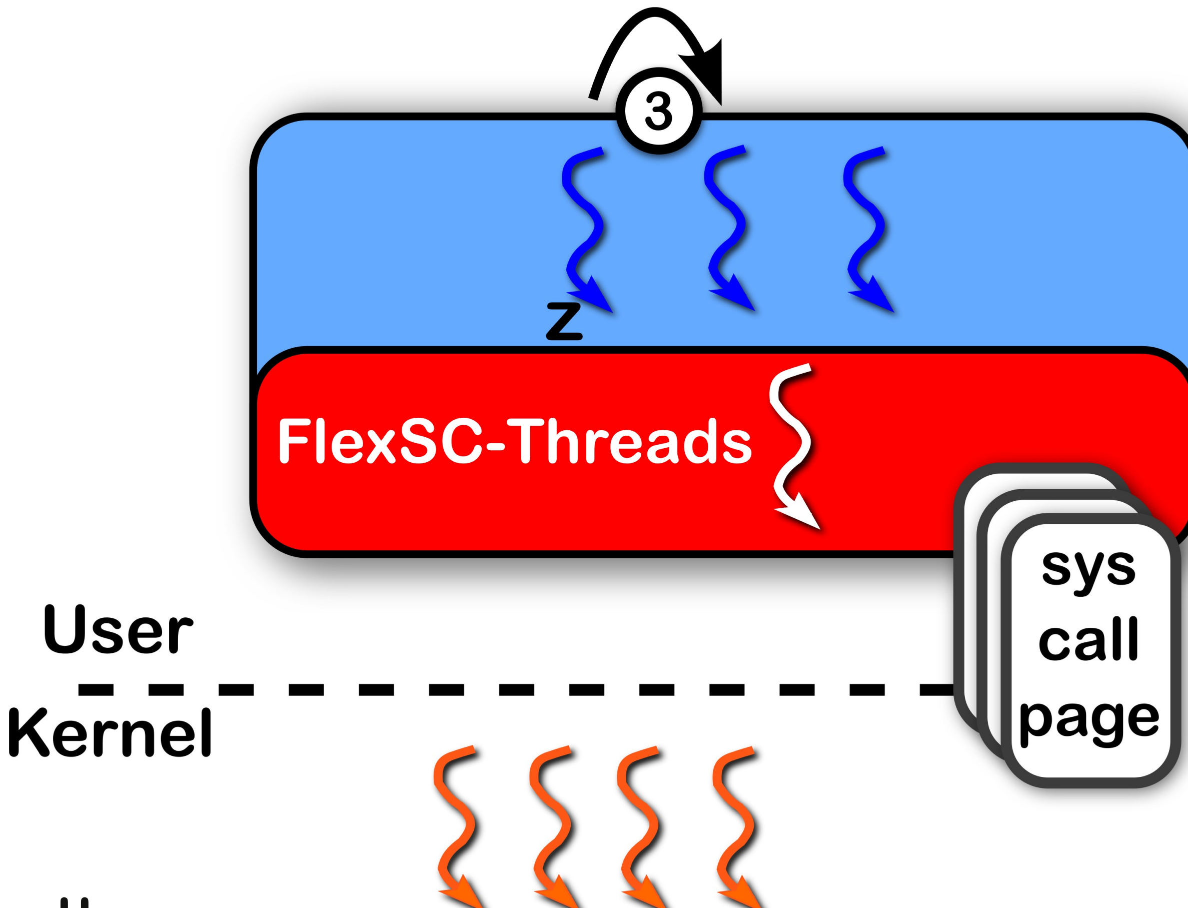


On a syscall:

1. Post request to system call page
2. Block user-level thread

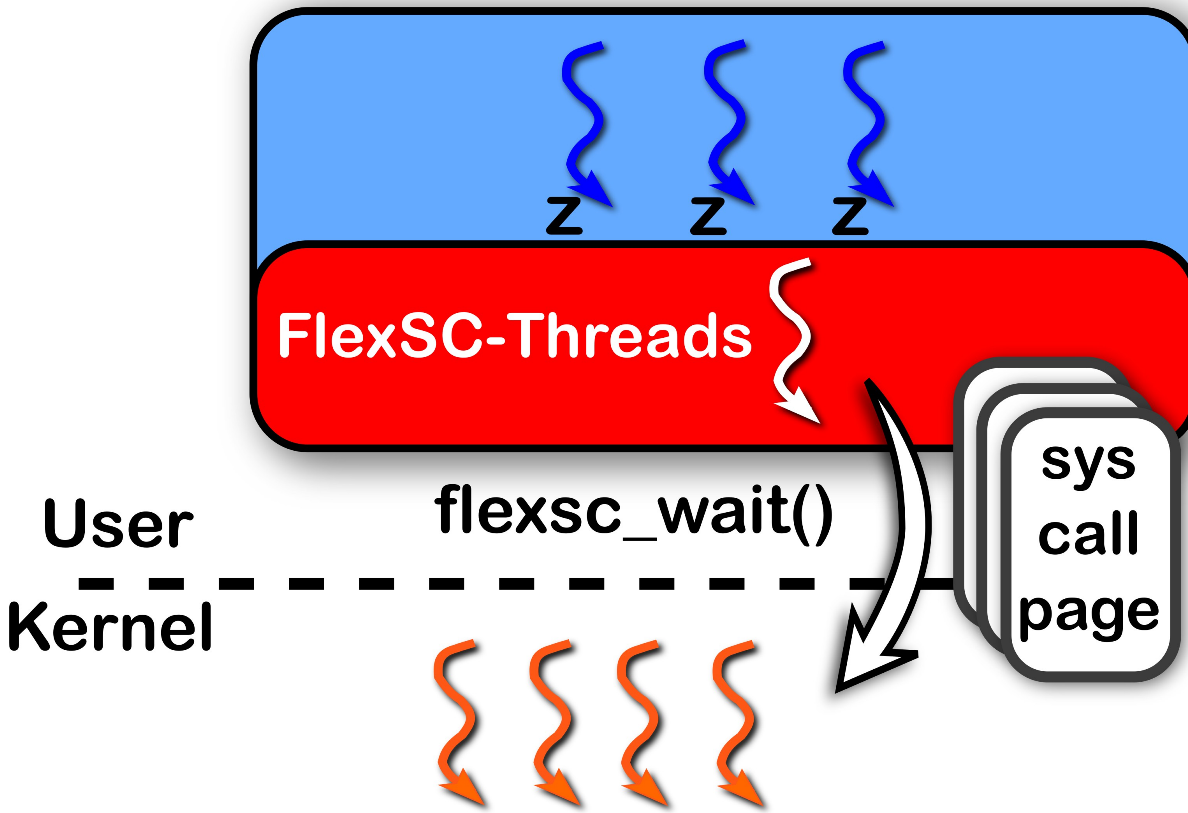
FlexSC-Threads in action



On a syscall:

① Post request to system call page
② Block user-level thread
③ Switch to next ready thread

FlexSC-Threads in action



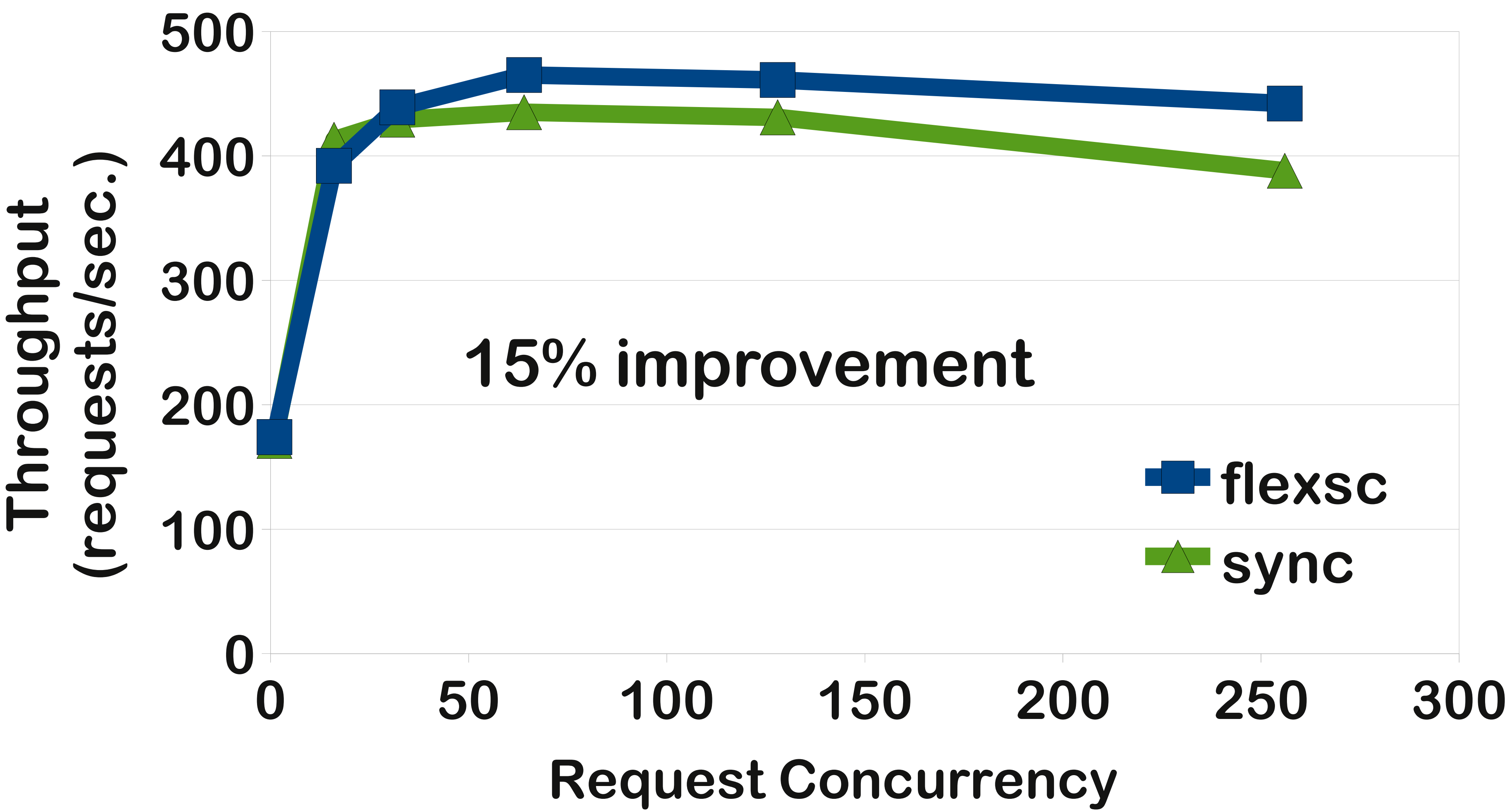
If all user-level threads become blocked:

1) enter kernel
2) wait for completion of at least 1 syscall

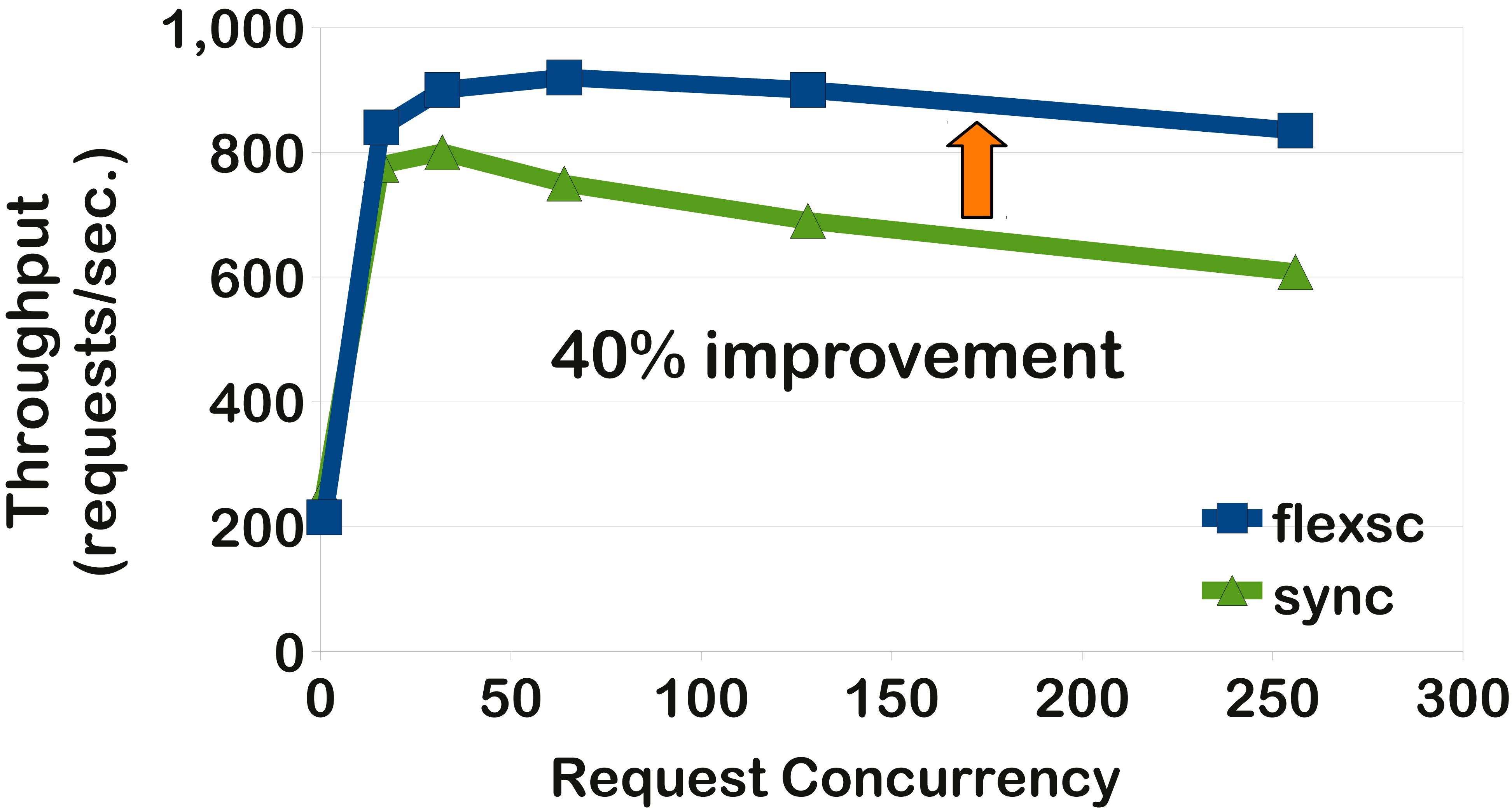
Evaluation

- Linux 2.6.33
- Nehalem (Core i7) server, 2.3GHz
  - 4 cores on a chip
- Clients connected on 1 Gbps network
- Workloads
  - Sysbench on MySQL (80% user, 20% kernel)
  - ApacheBench on Apache (50% user, 50% kernel)
- Default Linux NTPL ("**sync**") vs.
  FlexSC-Threads ("**flexsc**")

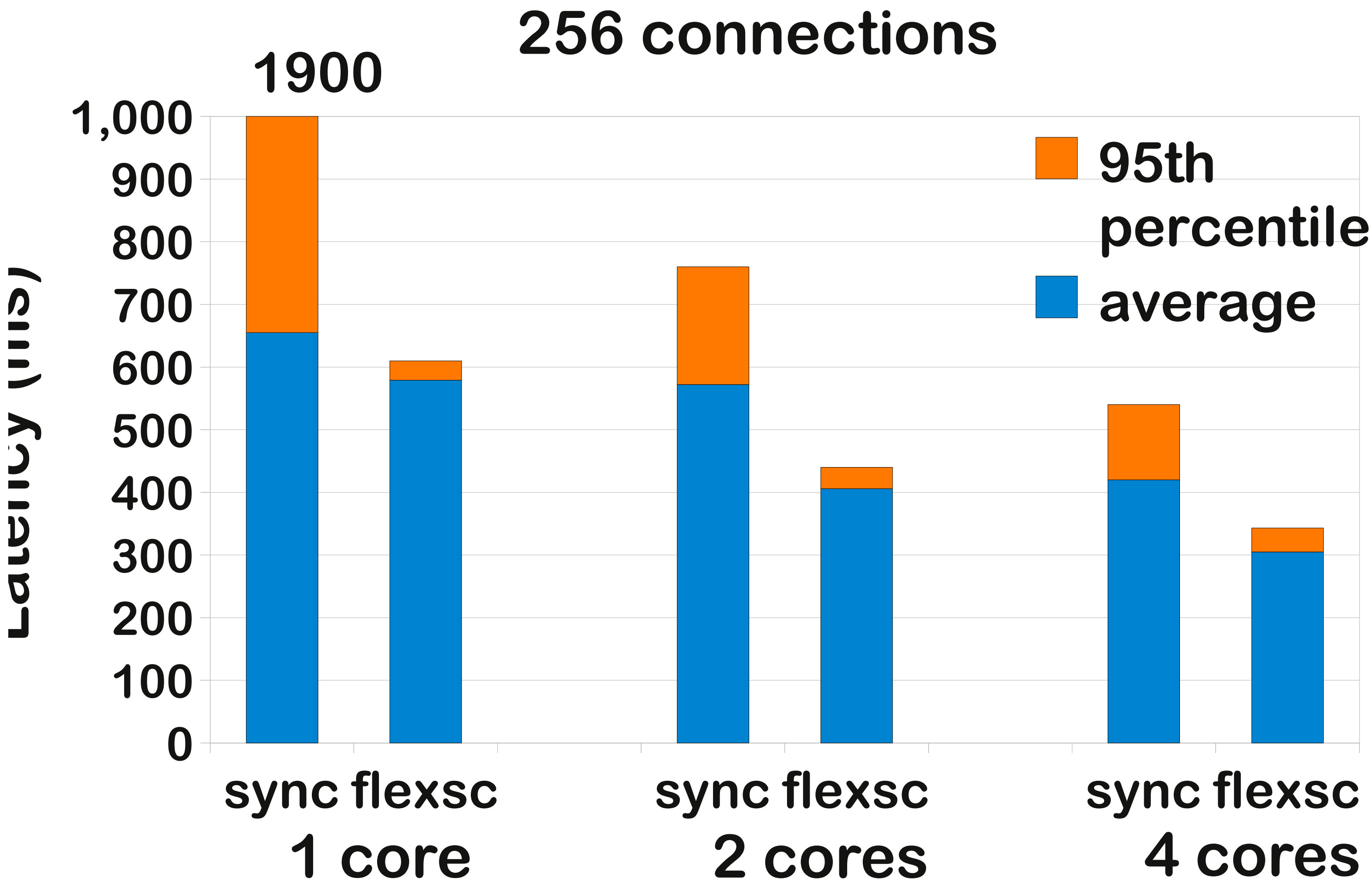
Sysbench: "OLTP" on MySQL (1 core)



Sysbench: “OLTP” on MySQL (4 cores)

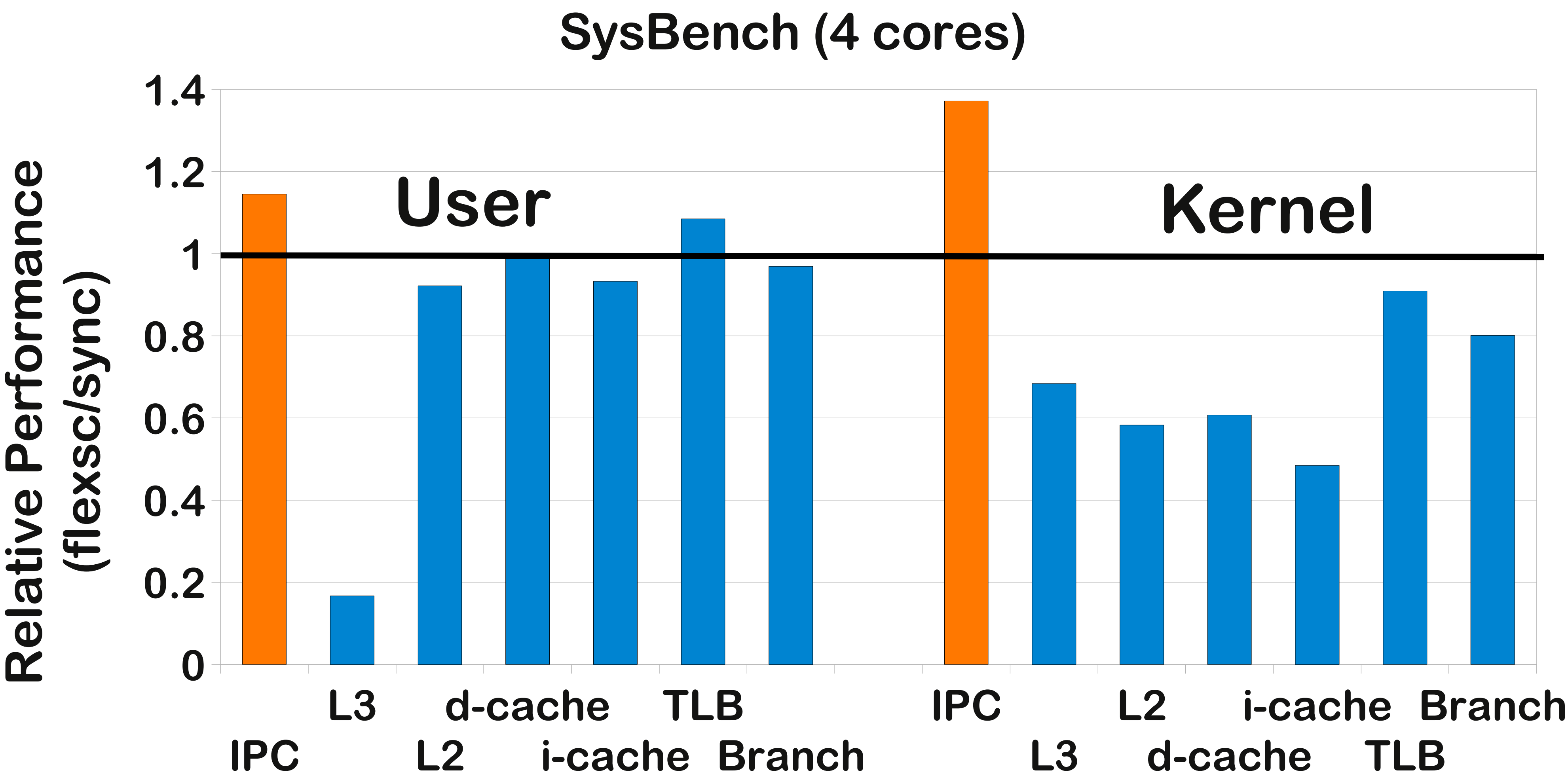


MySQL latency per client request



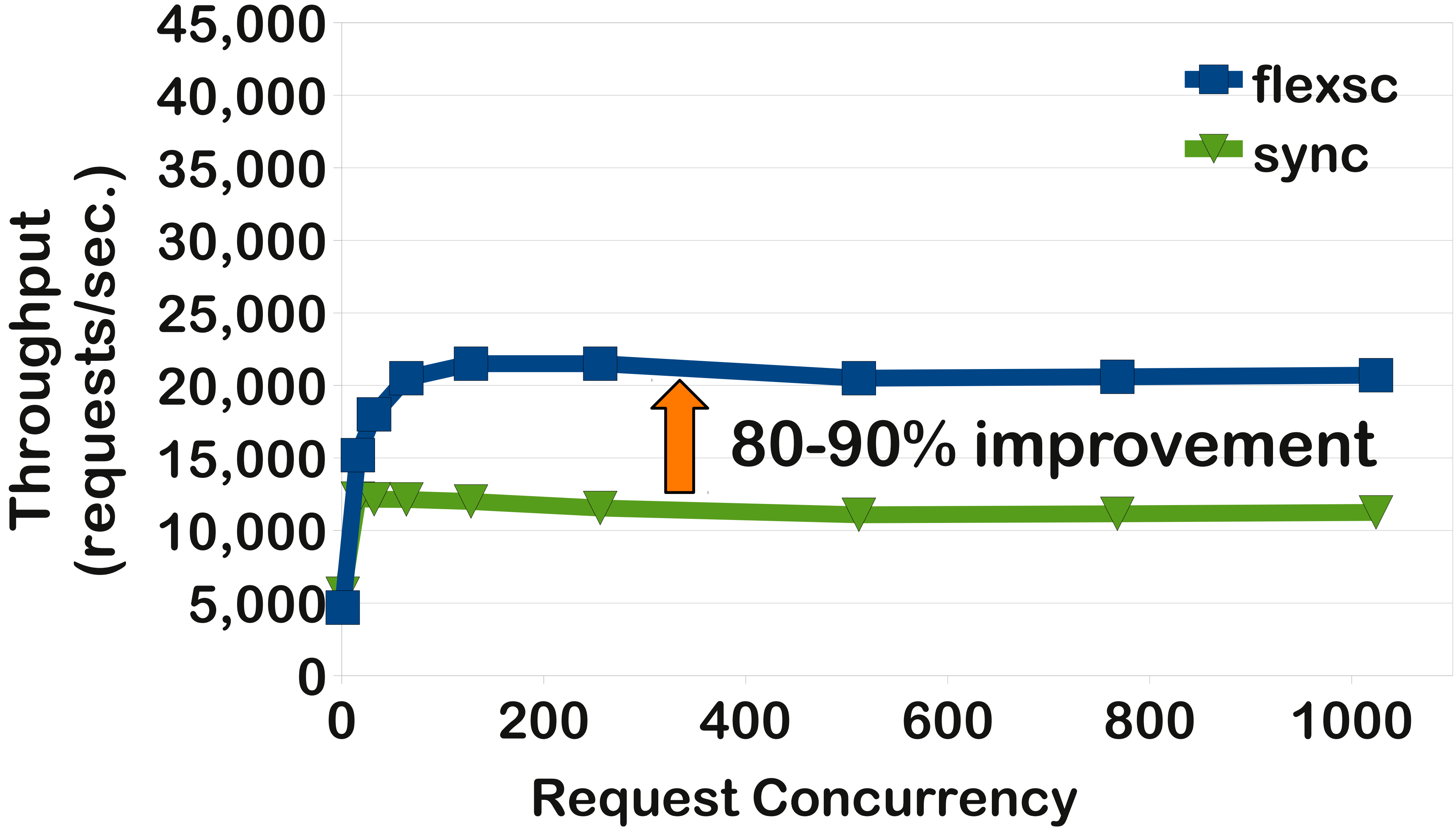
Up to 30% reduction of average request latencies

MySQL processor metrics

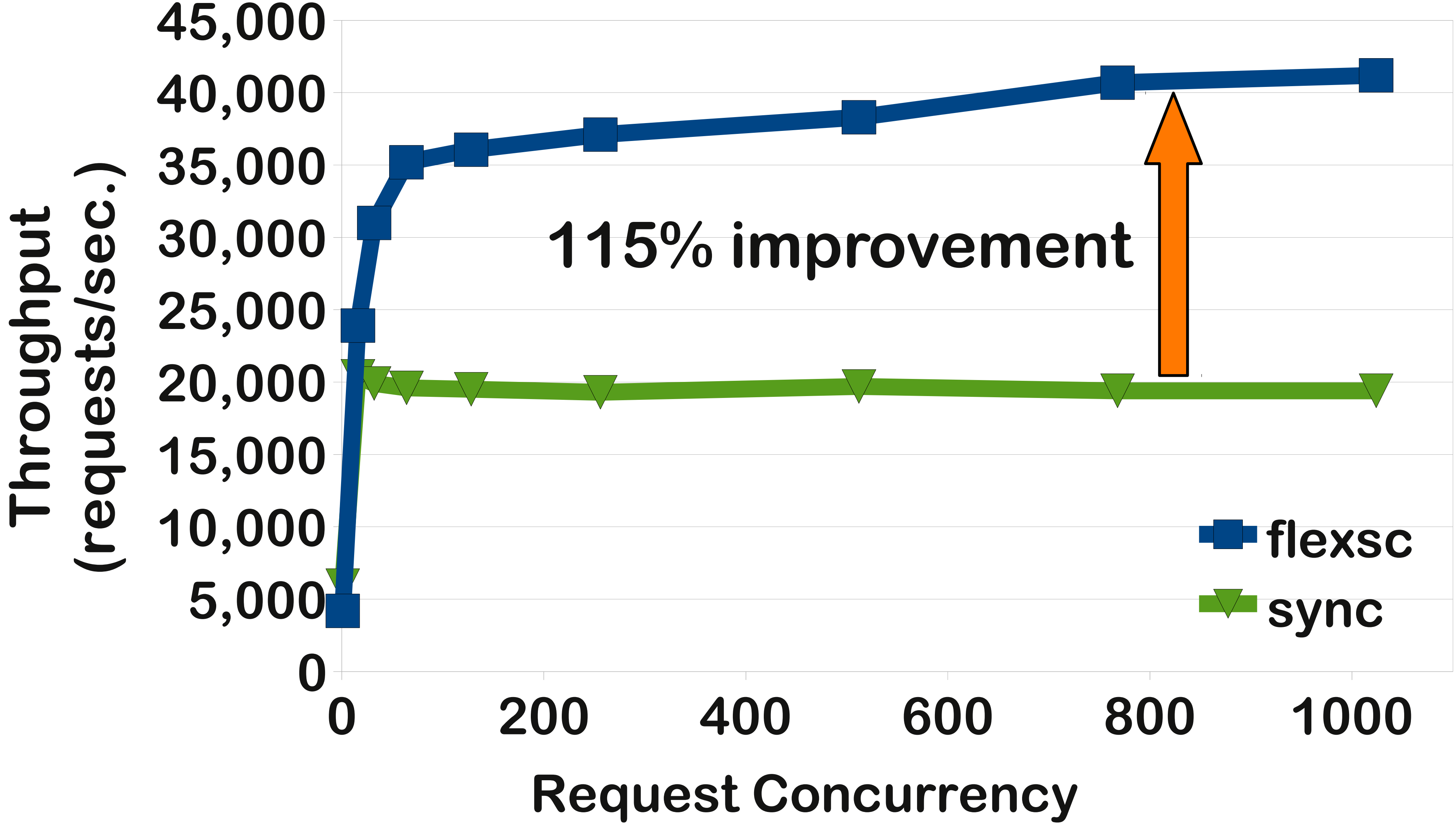


Performance improvements consequence of more efficient processor execution

ApacheBench throughput (1 core)



ApacheBench throughput (4 cores)



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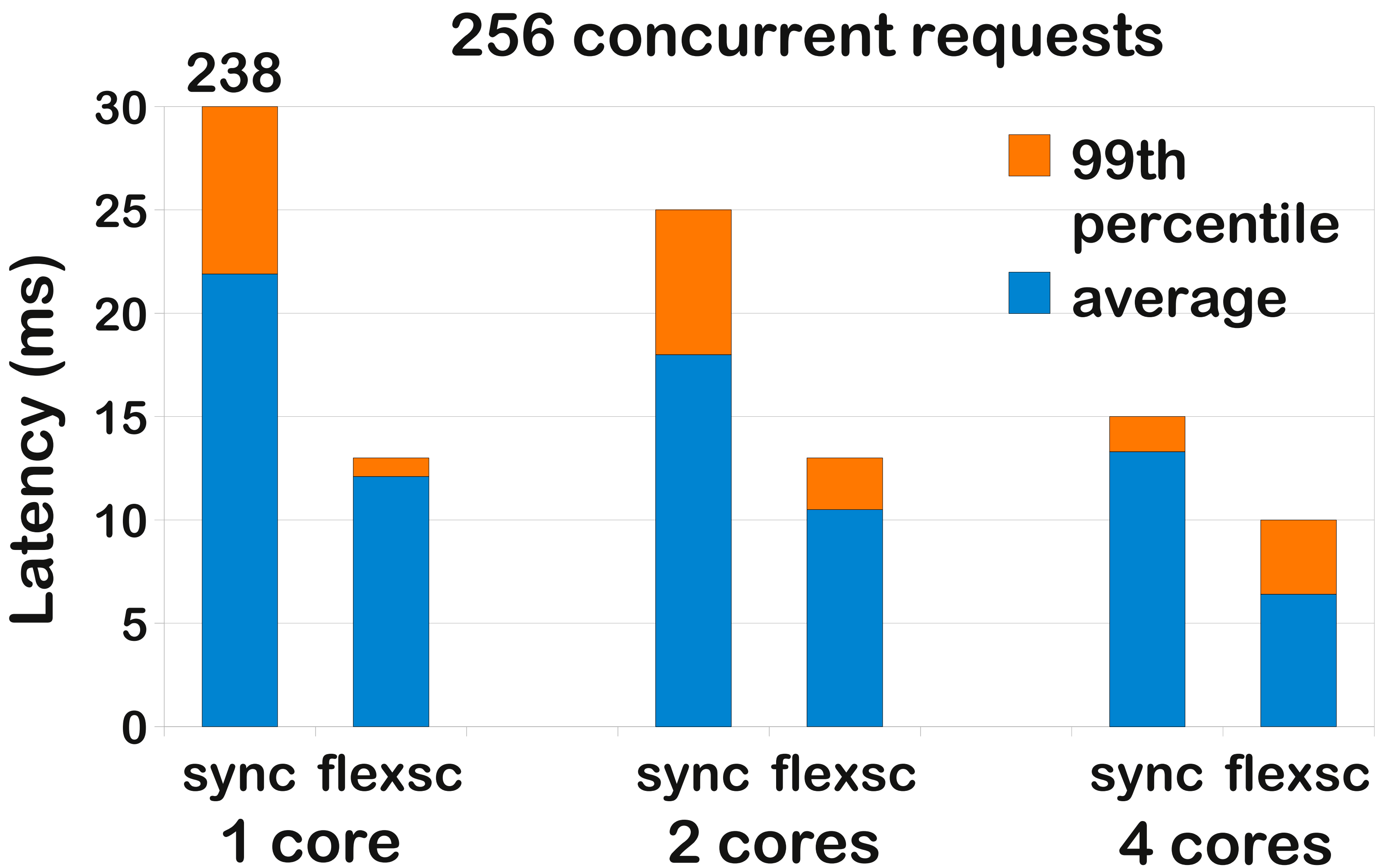
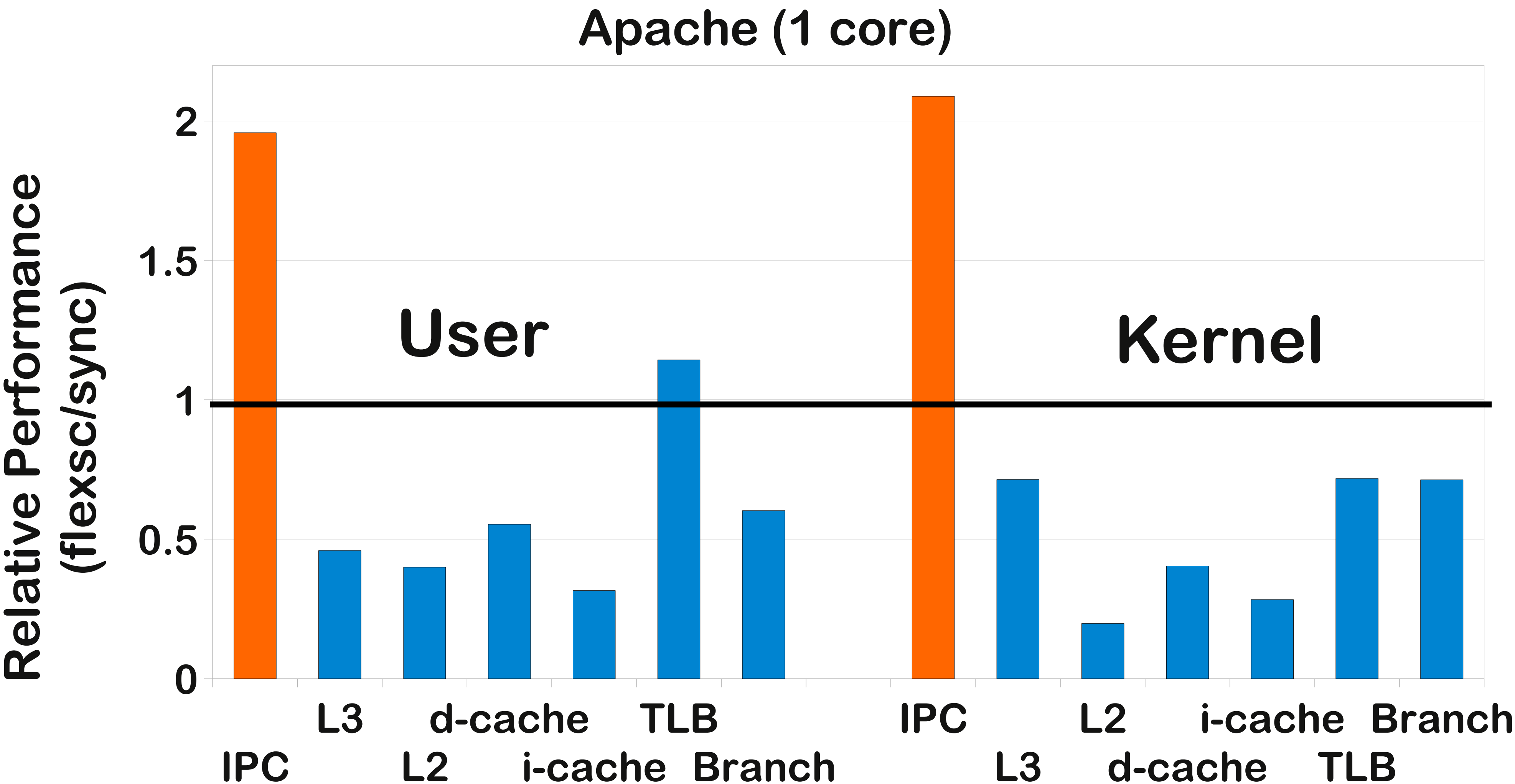


Up to 50% reduction of average request latencies

Apache processor metrics



Processor efficiency doubles for kernel and user-mode execution

Discussion

- New OS architecture not necessary
  - Exception-less syscalls can coexist with legacy ones
- Foundation for non-blocking system calls
  - select() / poll() in user-space
  - Interesting case of non-blocking free()
- Multicore ***ultra***-specialization
  - TCP Servers (Rutgers; Iftode et.al), FS Servers
- Single-ISA asymmetric cores
  - OS-friendly cores (HP Labs; Mogul et. al)

Concluding Remarks

- System calls degrade server performance
  - Processor pollution is inherent to synchronous system calls
- **Exception-less syscalls**
  - Flexible and efficient system call execution
- **FlexSC-Threads**
  - Leverages exception-less syscalls
  - No modifications to multi-threaded applications
- Throughput & latency gains
  - 2x throughput improvement for Apache and BIND
  - 1.4x throughput improvement for MySQL

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