EXS – EXtended Sockets

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Extended Sockets API (ES-API)

- Published by The Open Group in 2005
  - **opengroup.org/bookstore/catalog/c050.htm**

- Defines 2 major new extensions to “normal” sockets
  - **memory registration** for zero-copy I/O
  - **event queues** for asynchronous I/O

- Designed to give programmer access to RDMA

EXS Goals

- Expose RDMA features to programmer
  - do **not** totally hide RDMA from programmer
  - provide a more convenient interface than verbs
- Extend well-known sockets API
  - “normal” sockets are inadequate for direct RDMA use
  - add a few new functions and data types
  - repurpose many existing functions and data types
- Target audience
  - new applications intended for RDMA
  - porting existing applications requires source code changes

UNH-EXS

- Based on Open Group's ES-API
  - with additional extensions in order to run entirely in user space (because ES-API is expected to be integrated into existing kernel sockets)
- Runs on InfiniBand, iWARP, and RoCE
- Provides both SOCK_SEQPACKET and SOCK_STREAM connections using RC only
- Library designed for use by user threads in Linux
- Implemented entirely with user-space OFS verbs
- Requires no change to OFS or Linux

UNH-EXS stack

user space	Application Program **UNH-EXS Library** OFS Verbs Library		
kernel space	OFS Kernel Modules		
	InfiniBand Driver	RoCE Driver	iWARP Driver
CA	InfiniBand HCA	RoCE NIC	iWARP RNIC
wire	InfiniBand Fabric	10Gig Ethernet	

EXS event queues

- Extensions to deal with asynchronous events
- New “event queue” and “event” data structures
  - **exs_qhandle_t**
  - **exs_event_t**
- New queue manipulation functions
  - **exs_qcreate()** - creates new event queue
  - **exs_qdelete()** - deletes existing event queue
  - **exs_qdequeue()** - removes events from existing event queue
  - **exs_qmodify()** - modifies existing event queue
  - **exs_qstatus()** - returns event queue attributes

EXS event queue usage

- send(), recv(), accept(), connect(), close() have extended versions: exs_send(), exs_recv(), etc.
  - all these extended operations just start an action
  - control returns immediately to user
  - operation proceeds in parallel to user code
- Extended operations have extra parameters, 1st is
  - **exs_qhandle_t** parameter required to designate event queue
- When I/O operation completes, EXS library adds
  - **exs_event_t** containing status to designated event queue

EXS memory registration

- Extensions to deal with registered memory

- New “memory region” data structure
  - **exs_mhandle_t**

- Two new registration functions
  - **exs_mregister()** - creates new **exs_mhandle_t** by registering user-defined virtual memory
  - **exs_mderegister()** - destroys existing **exs_mhandle_t** by unregistering its memory region

EXS memory region usage

- New exs_send() and exs_recv() functions designate “memory region” with additional parameter
  - **exs_mhandle_t** result of previous registration

- Normal address and length parameters must refer to memory entirely within designated “memory region”

Parameters to exs_send()

- Four “normal socket” parameters
  - fd – socket descriptor
  - address – of data to be sent
  - length – number of data bytes to send
  - flags

- Three new “extension” parameters
  - event_queue – for posting completion event
  - request_id – user-defined transaction id
  - memory_region – must cover all data bytes

Parameters to exs_recv()

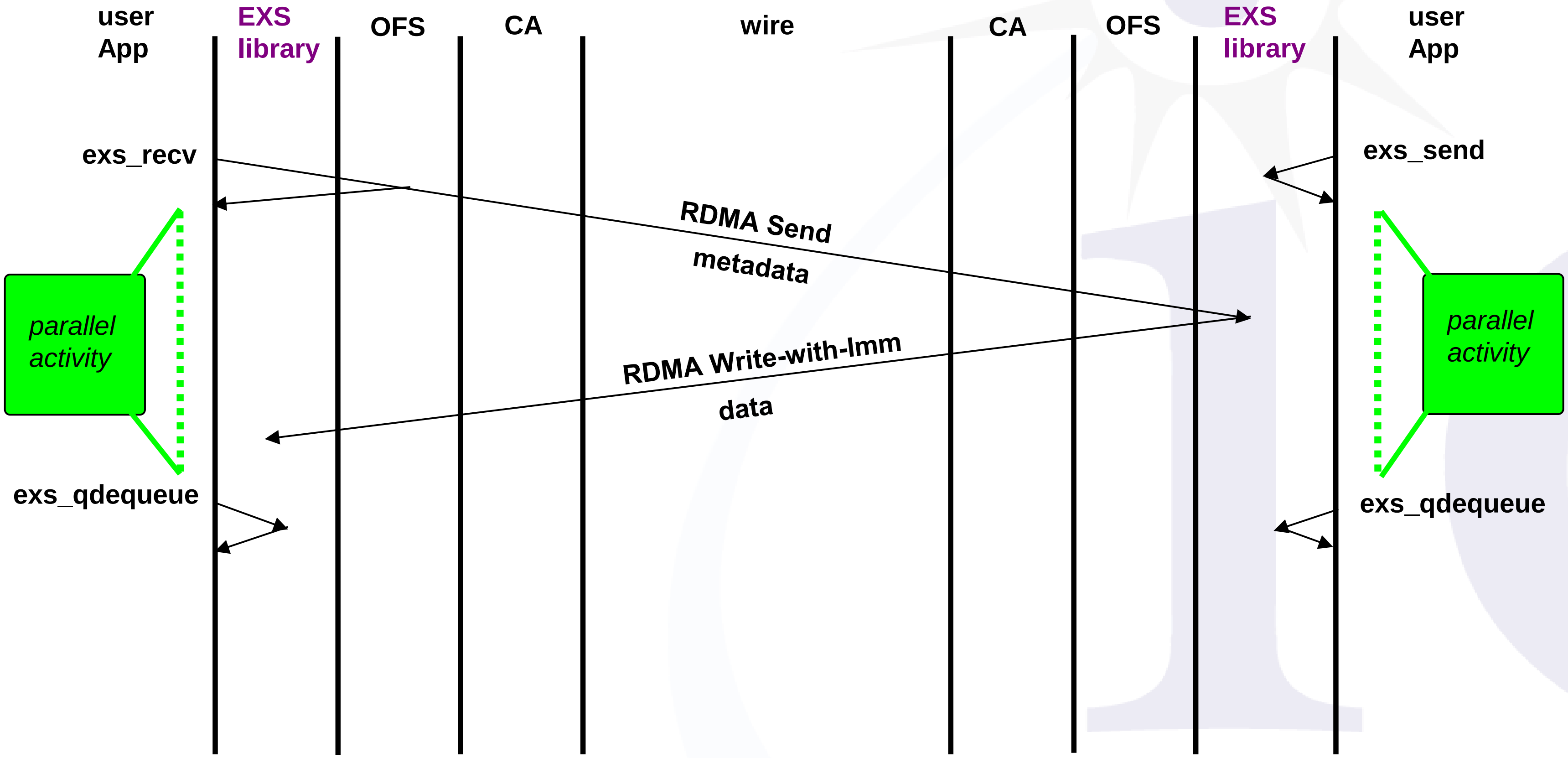
- Four “normal socket” parameters
  - fd – socket descriptor
  - address – of where to put received data
  - length – maximum number of data bytes to receive
  - flags

- Three new “extension” parameters
  - event_queue – for posting completion event
  - request_id – user-defined transaction id
  - memory_region – must cover all data bytes

How EXS maps transfers onto verbs

- exs_recv() issues RDMA SEND to “advertise” its “metadata” to other side
  - **address** – where to put data
  - **length** – maximum number of bytes of data to receive
  - remote “key” from the **memory_region**
- exs_send() matches its “metadata” with advertised “metadata” and issues RDMA WRITE_WITH_IMM to transfer data
- on both sides, EXS library gets completion status and enqueues it in **event_queue** along with user-defined **request_id**

Typical EXS Data Transfer



Other UNH-EXS functions

- exs_accept() – ES-API standard
- exs_bind() – UNH extension
- exs_close() – UNH extension
- exs_connect() – ES-API standard
- exs_fcntl() – UNH extension
- exs_init() – ES-API standard
- exs_listen() – UNH extension
- exs_socket() – UNH extension

Tuning UNH-EXS with exs_fcntl()

- Modeled on “normal UNIX” **fcntl()**
- Allows user to:
  - set maximum “small packet” size
  - set maximum “inline data” size
  - set completion thread’s CPU affinity
  - turn on “busy-polling” for completions
  - set receive buffer size (for SOCK_STREAMs only)
  - turn off use of receive buffer (for SOCK_STREAMs only)
  - set maximum “advertisement” credits

Obtaining UNH-EXS

- Complete source code tar file
  - www.iol.unh.edu/services/research/unh-exs
  - includes README giving installation instructions
  - includes overview document for programmers

- User overview documentation (how to use it)
  - www.iol.unh.edu/services/reseach/unh-exs/exs-overview.pdf
  - describes each EXS function in detail
  - has examples of converting existing sockets code to EXS

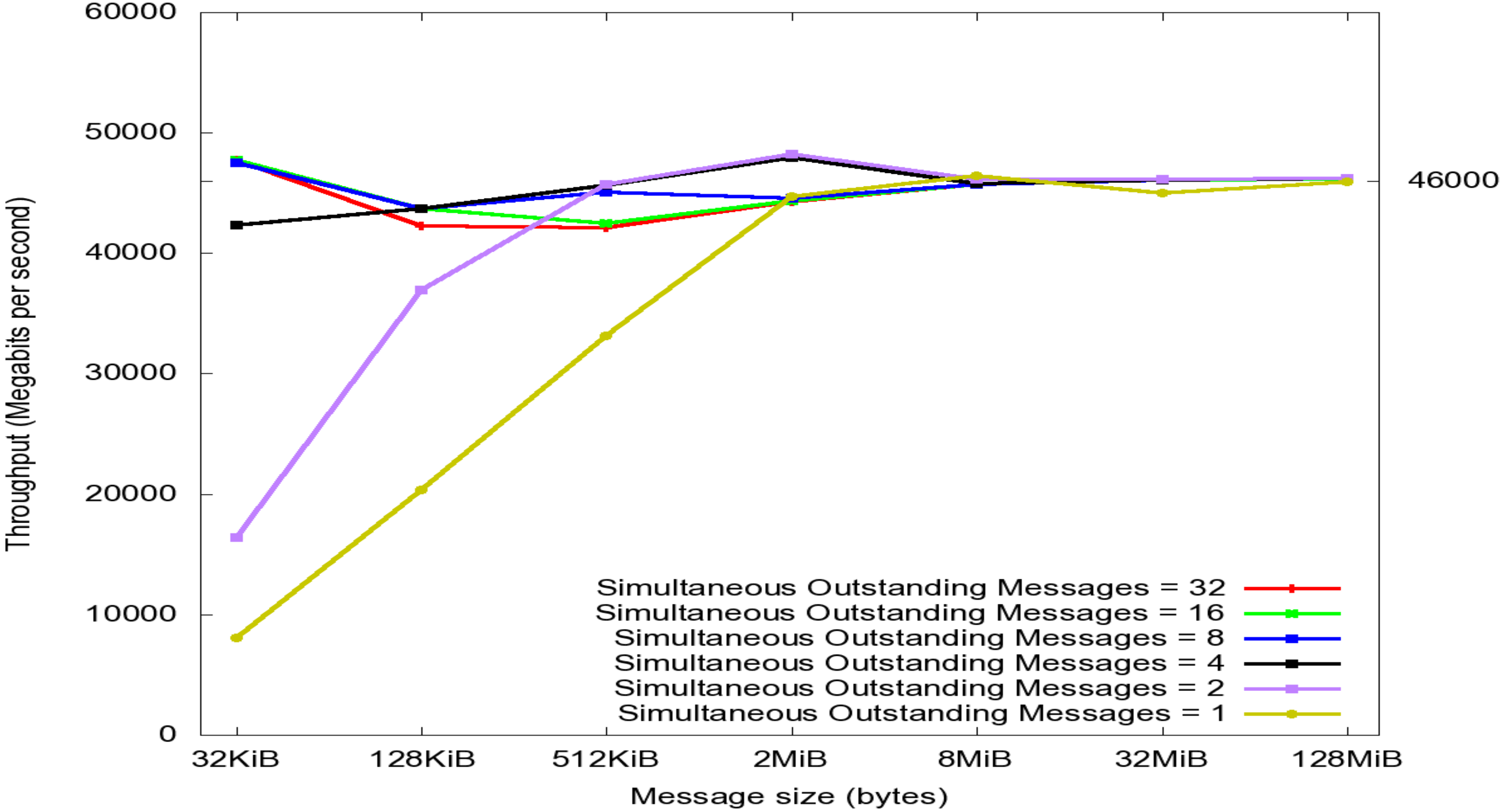
Relationships between EXS and “normal” socket and UNIX functions

- ❖ EXS memory regions, event queues, and fds can NOT be inherited by a child process

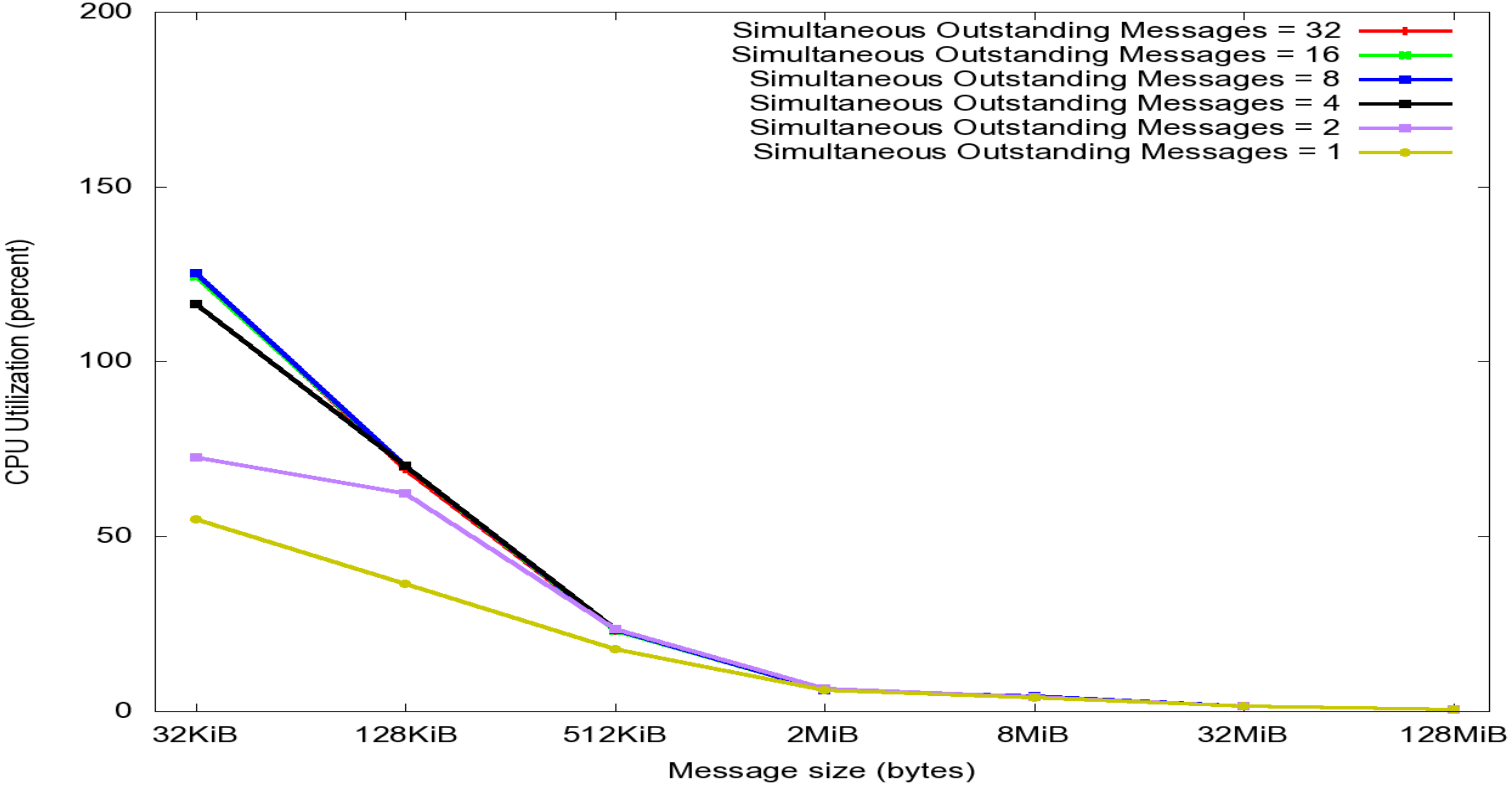
- ❖ UNH-EXS fds cannot be used with “normal” socket or UNIX I/O functions, such as:
  - – read(), write(), poll(), select(), fcntl(), fstat(), etc.

- – UNH-EXS is thread safe, but not thread cancellation safe

EXS blast throughput over FDR



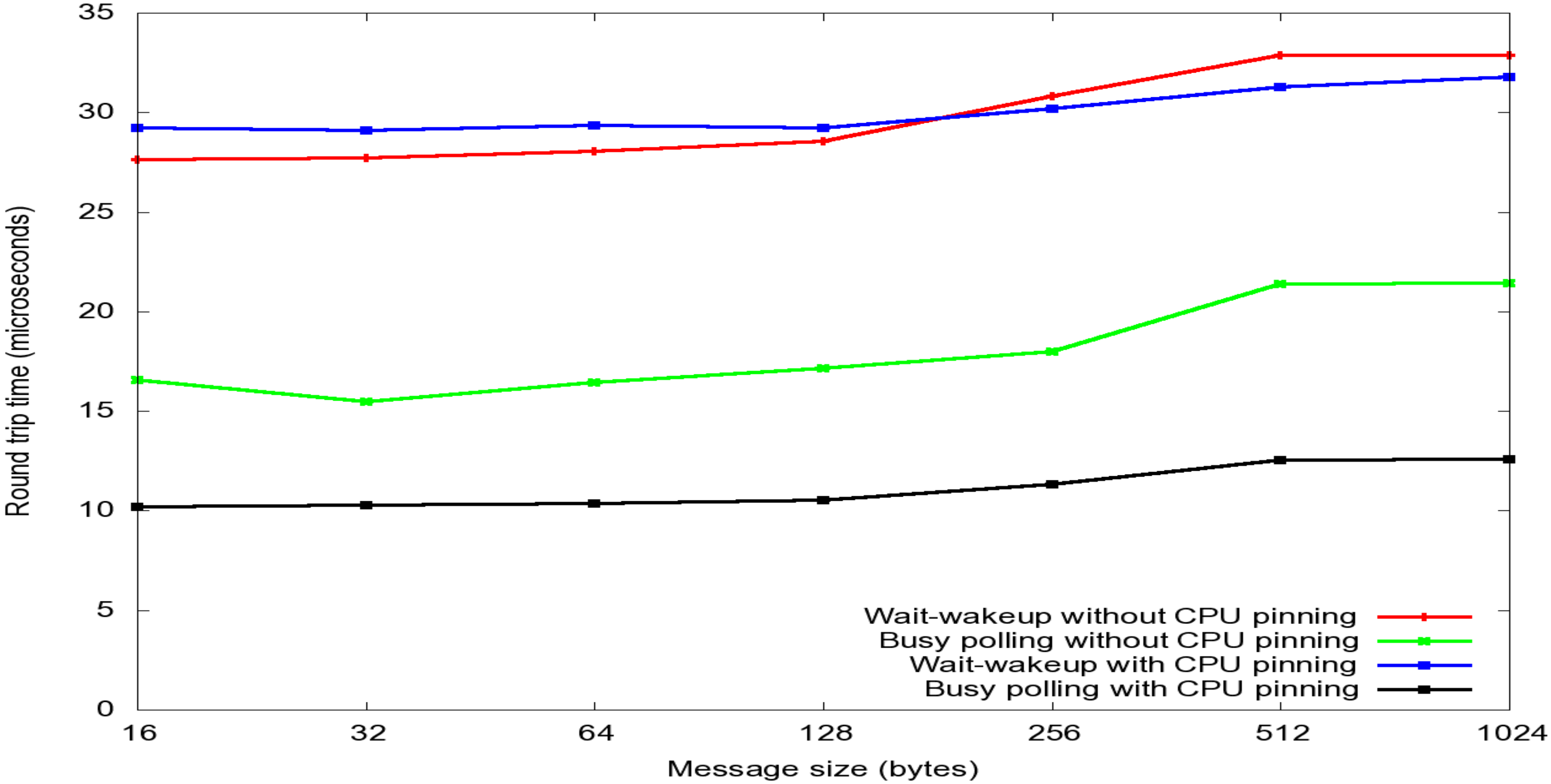
EXS blast CPU usage over FDR



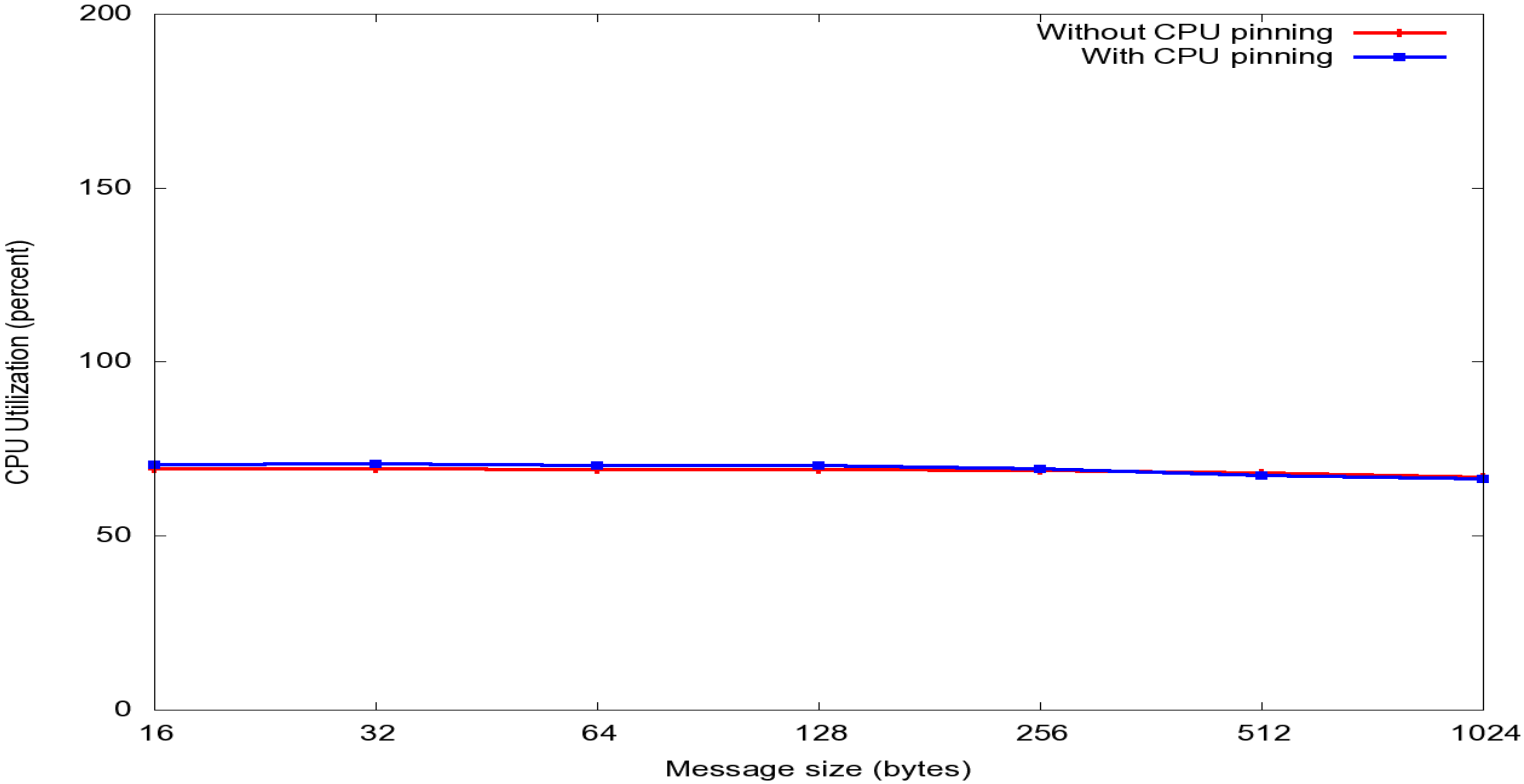
EXS throughput performance

- The bigger the message, the smaller the CPU usage (for fixed number of outstanding messages)
- The more simultaneously outstanding messages, the higher the throughput (for fixed message size)
- Reasonable “sweet spot”: 512 Kibibytes, 4 messages
  - throughput: 45.6 Gigabytes/second
  - CPU usage: 14.0% user, 9.4% kernel, 23.4% total
- Ideal “sweet spot”: 2 Mibibytes, 4 messages
  - throughput: 47.9 Gigabytes/second
  - CPU usage: 4.2% user, 2.3% kernel, 6.5% total

EXS ping-pong round-trip time over FDR



EXS ping-pong CPU usage over FDR



EXS ping-pong performance

- ❖Small messages very sensitive to 2 factors:
  - – “busy-polling” vs “wait-for-notify” for completions
  - – “pinning” threads to CPUs or not
    - two threads to pin: completion thread, mainline thread
  - – together, “busy-polling” and “pinning” reduce RTT by 1/3, from 30 microseconds to 10 microseconds
    - one-way time reduced from 15 to 5 microseconds
- ❖“busy-polling” is expensive in CPU usage
  - – total for 2 threads increases from about 60% to 200%
- ❖“wait-for-notify” not cheap due to kernel involvement

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QUESTIONS?

THANK YOU!