USENIX ATC 2010

IsoStack – Highly Efficient Network Processing on Dedicated Cores

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Outline

- Motivation
- IsoStack architecture
- Prototype – TCP/IP over 10GE on a single core
- Performance results
- Summary

TCP/IP End System Performance Challenge

- TCP/IP stack is a major “consumer” of CPU cycles
  - “easy” benchmark workloads can consume 80% CPU
  - “difficult” workloads cause throughput degradation at 100% CPU
- TCP/IP stack wastes CPU cycles:
  - 100s of "useful" instructions per packet
  - 10,000s of CPU cycles

Long History of TCP/IP Optimizations

- Decrease per-byte overhead
  - Checksum calculation offload
- Decrease the number of interrupts
  - interrupt mitigation (coalescing)
- Decrease the number of packets (for bulk transfers)
  - Jumbo frames
  - Large Send Offload (TCP Segmentation Offload)
  - Large Receive Offload

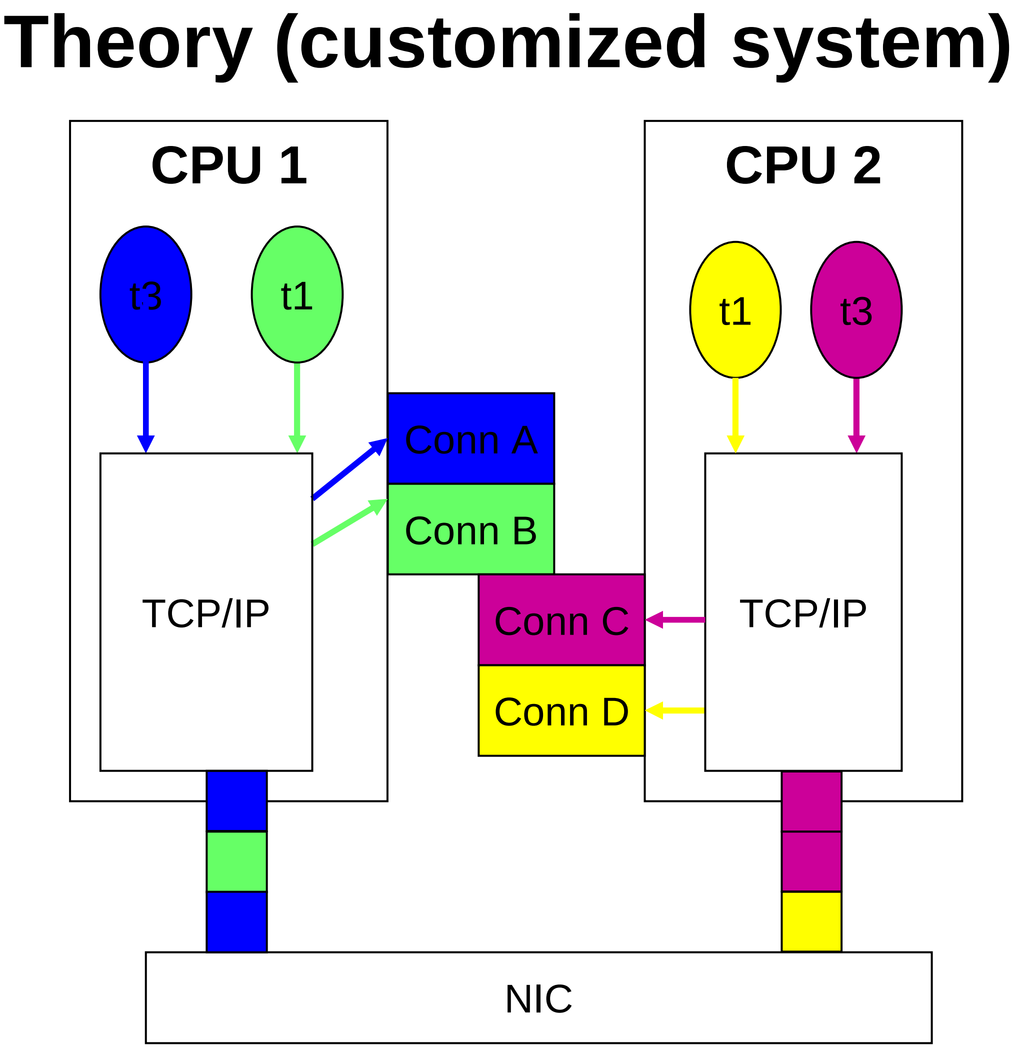
History of TCP Optimizations cont` – Full Offload

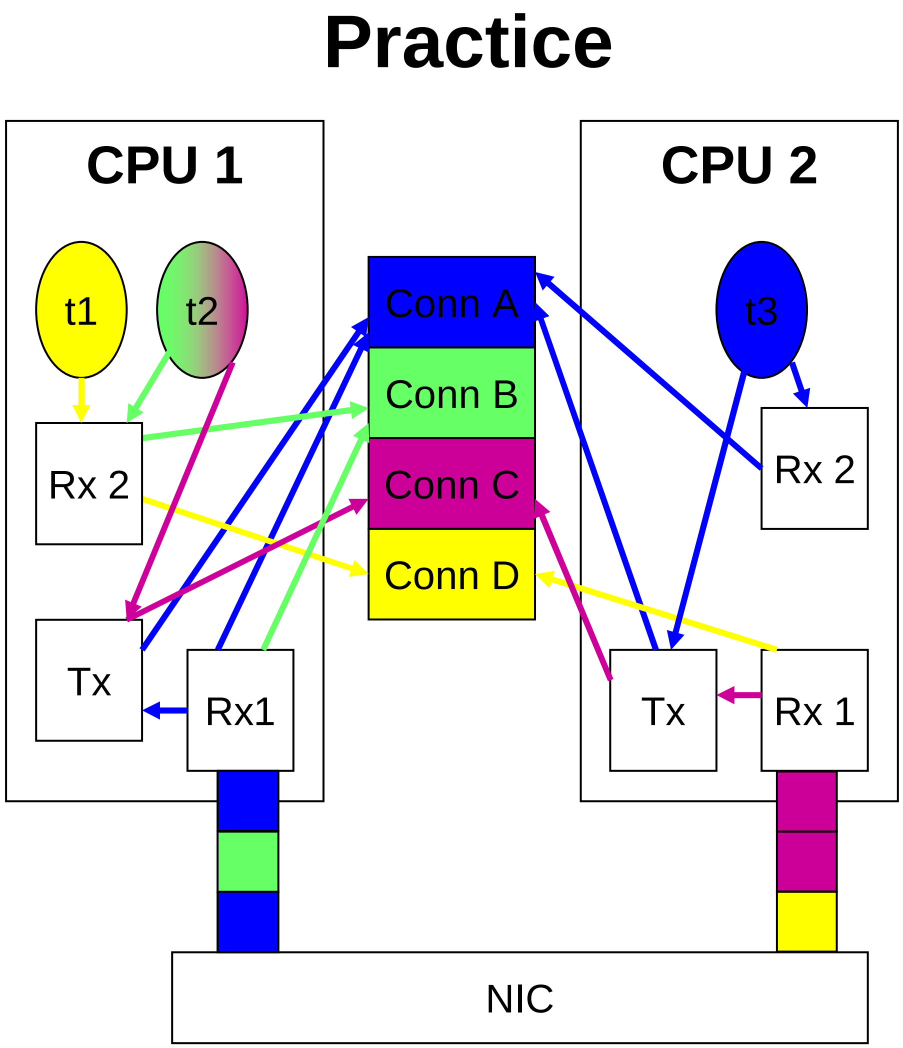
- Instead of optimizations - offload to hardware
  - TOE (TCP Offload Engine)
    - Expensive
    - Not flexible
    - Not robust - dependency on device vendor
    - Not supported by some operating systems on principle
  - RDMA
    - Requires support on the remote side
    - not applicable to legacy upper layer protocols
- TCP onload – offload to a dedicated main processor
  - Using a multiprocessor system asymmetrically

TCP/IP Parallelization

- Naïve initial transition to multiprocessor systems
  - Using one lock to protect it all
- Incremental attempts to improve parallelism
  - Use more locks to decrease contention
  - Use kernel threads to perform processing in parallel
  - Hardware support to parallelize incoming packet processing – Receive-Side Scaling (RSS)

Parallelizing TCP/IP Stack Using RSS



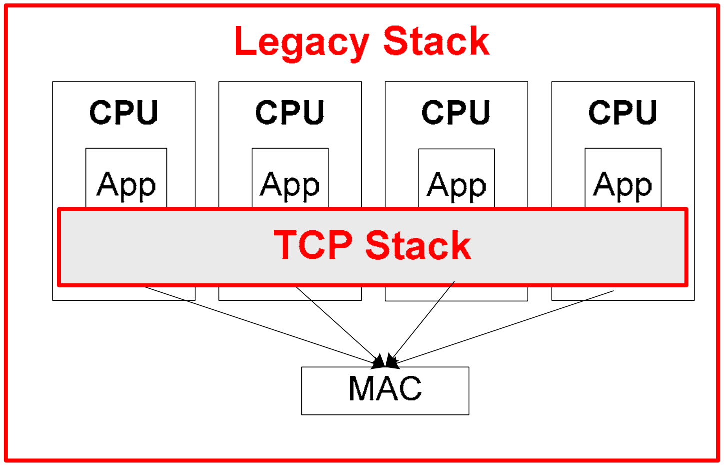


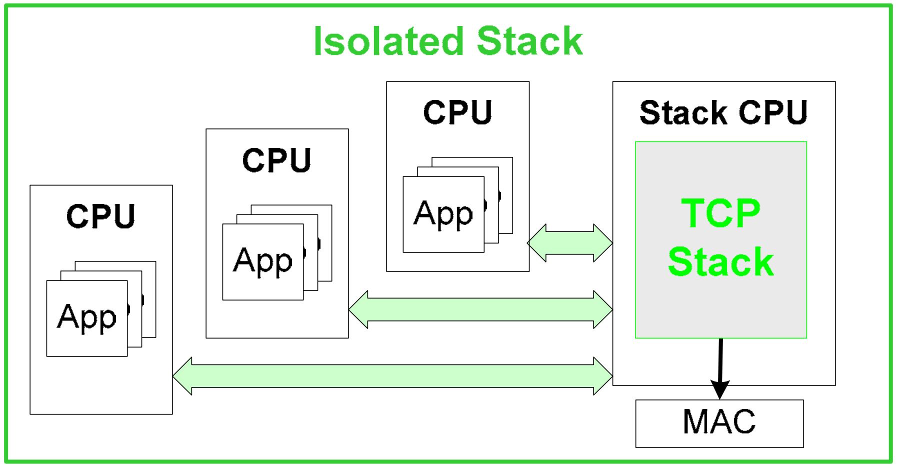
So, Where Do the Cycles Go?

- No clear hot-spots
  - Except lock/unlock functions
- CPU is “misused” by the network stack:
  - Interrupts, context switches, cache pollution
    - due to CPU sharing between applications and stack
  - IPIs, locking and cache line bouncing
    - due to stack control state shared by different CPUs

Our Approach – Isolate the Stack

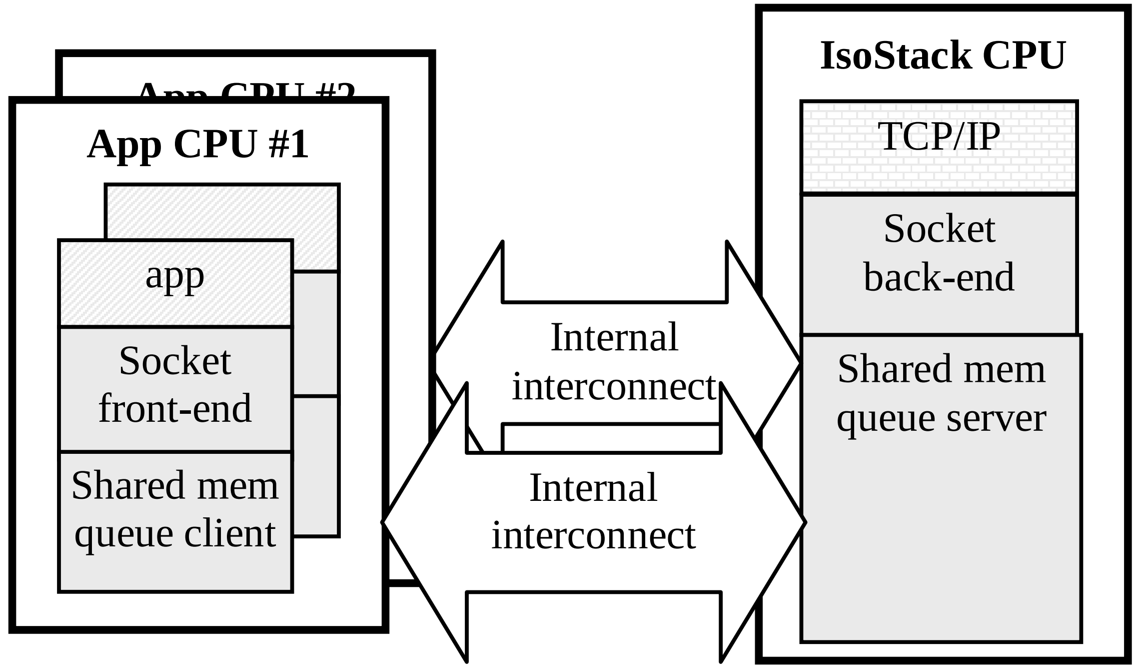
- Dedicate CPUs for network stack
- Use light-weight internal interconnect
  - Scaling for many applications and high request rates
- Make it transparent to applications
  - Not just API-compatible – hide the latency of interaction





IsoStack Architecture

- Split socket layer:
  - front-end in application
    - Maintains socket buffers
    - posts socket commands onto command queue
  - back-end in IsoStack
    - On dedicated core[s]
      - With connection affinity
    - Polls for commands
    - Executes the socket operations asynchronously
    - “Zero-copy”



- Shared-memory queues for socket delegation
  - Asynchronous messaging
  - Flow control and aggregation
  - Data copy by socket front-end

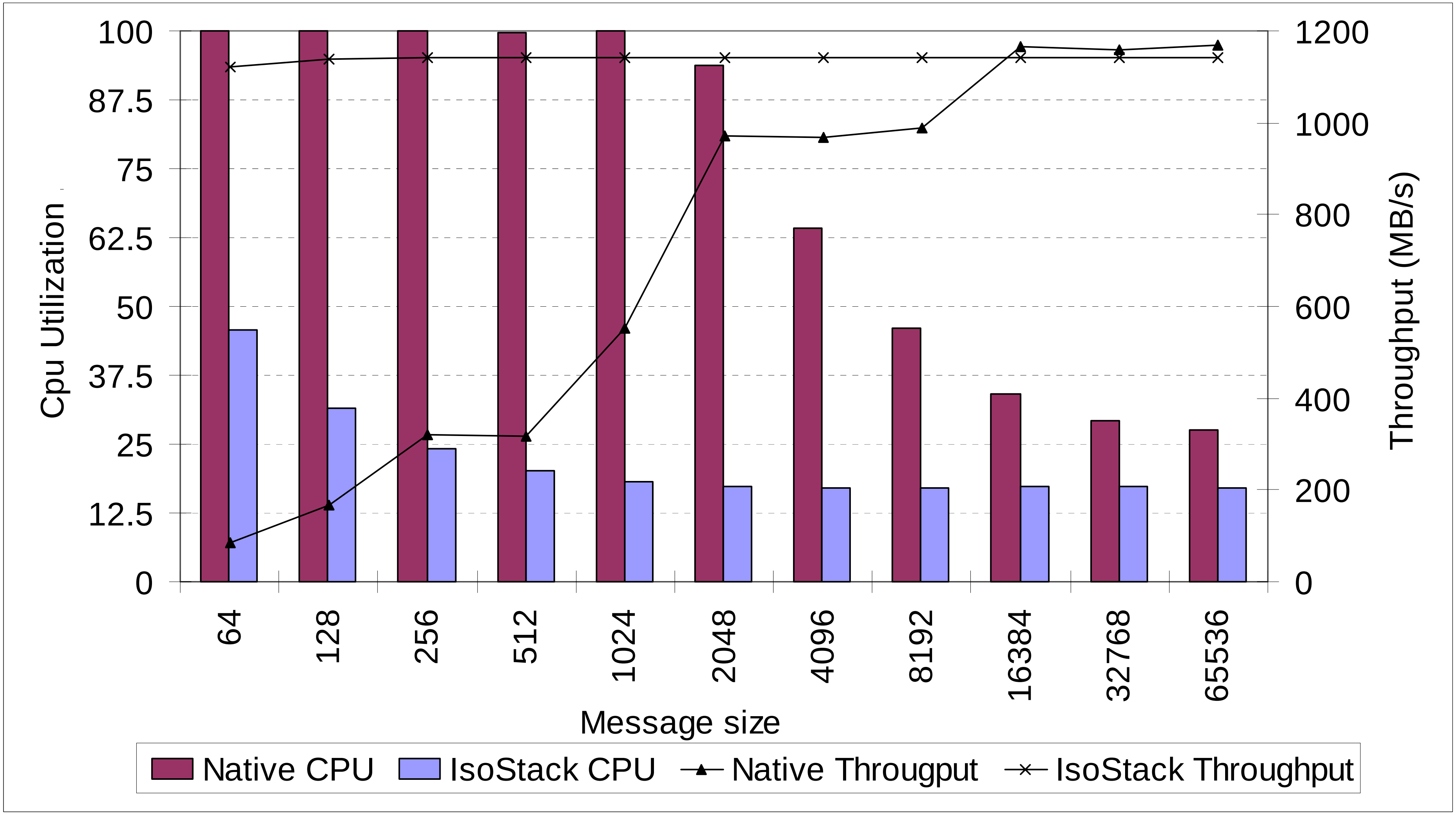
IsoStack Shared Memory Command Queues

- Low overhead multiple-producers-single-consumer mechanism
  - Non-trusted producers
- Design Principles:
  - Lock-free, cache-aware
  - Bypass kernel whenever possible
    - problematic with the existing hardware support
  - Interrupt mitigation
- Design Choices Extremes:
  - A single command queue
    - Con - high contention on access
  - Per-thread command queue
    - Con - high number of queues to be polled by the server
- Our choice:
  - Per-socket command queues
    - Aggregation of tx and rx data
  - Per-CPU notification queues
    - Requires kernel involvement to protect access to these queues

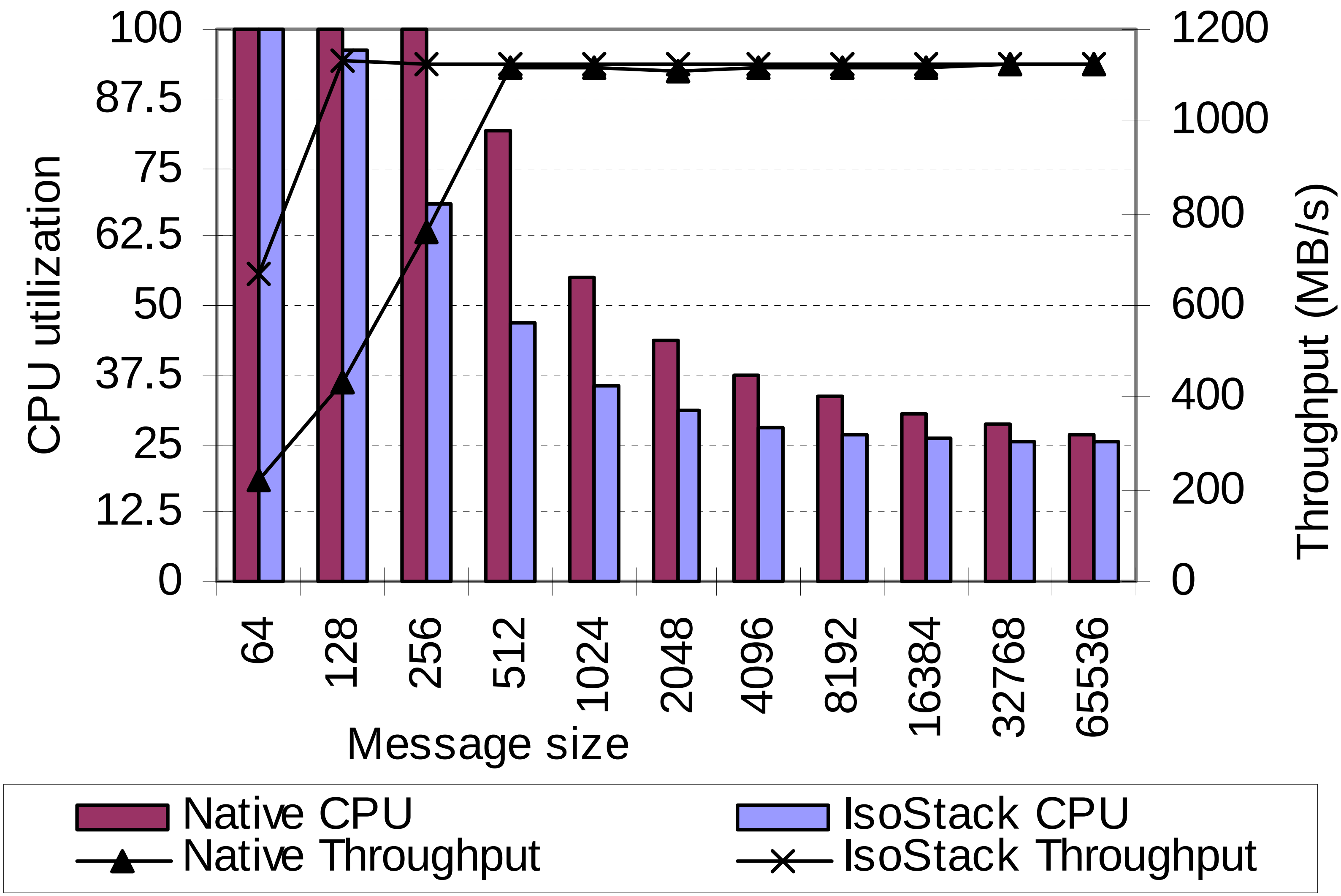
IsoStack Prototype Implementation

- Power6 (4x2 cores), AIX 6.1
- 10Gb/s HEA
- Same codebase for IsoStack and legacy stack
- IsoStack runs as single kernel thread “dispatcher”
  - Polls adapter rx queue
  - Polls socket back-end queues
  - Invokes regular TCP/IP processing
- Network stack is [partially] optimized for serialized execution
  - Some locks eliminated
  - Some control data structures replicated to avoid sharing
- Other OS services are avoided when possible
  - E.g., avoid wakeup calls
  - Just to workaround HW and OS support limitations

TX Performance

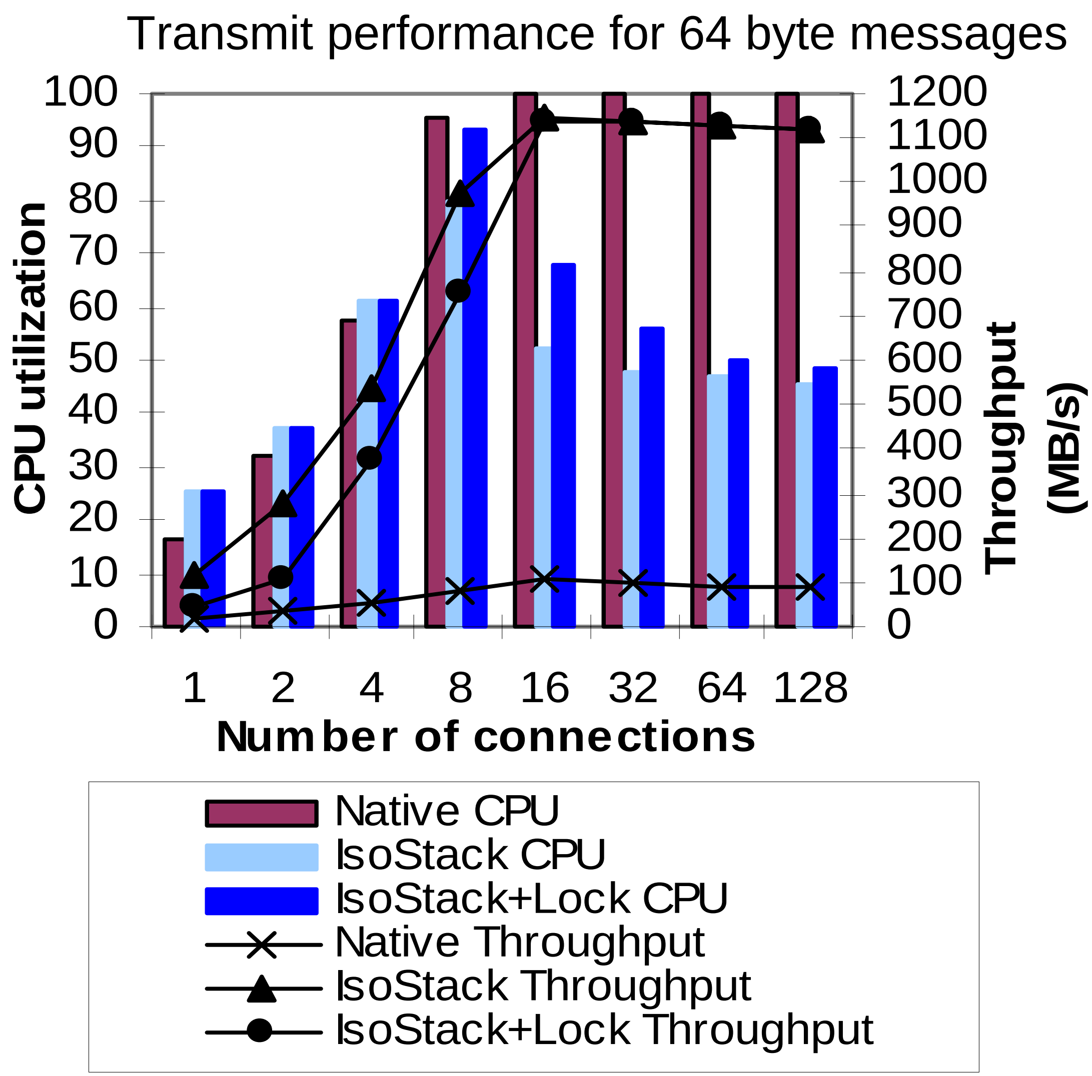


Rx Performance



Impact of Un-contended Locks

- Impact of unnecessary lock re-enabled in IsoStack:
  - For low number of connections:
    - Throughput decreased
    - Same or higher CPU utilization
  - For higher number of connections:
    - Same throughput
    - Higher CPU utilization
- Even when un-contended, locks have tangible cost!



IsoStack – Summary

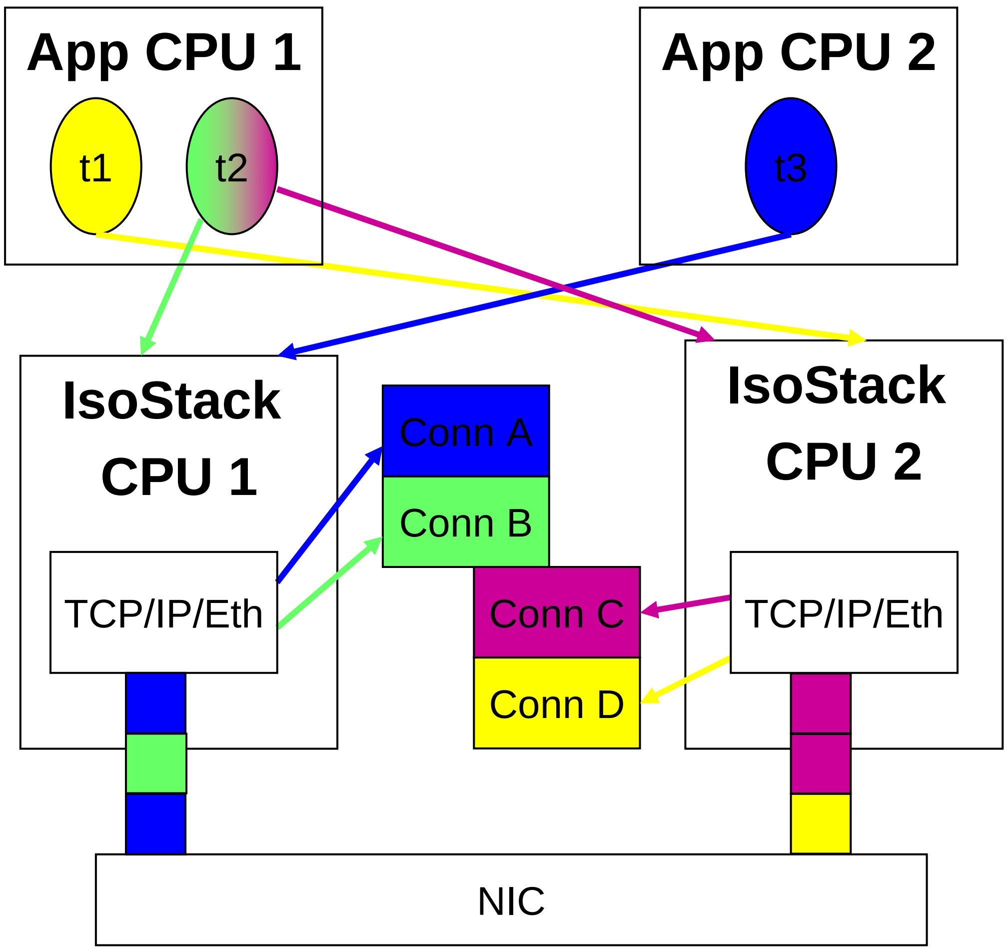
- Isolation of network stack dramatically reduces overhead
  - No CPU sharing costs
  - Decreased memory sharing costs
- Explicit asynchronous messaging instead of blind sharing
  - Optimized for large number of applications
  - Optimized for high request rate (short messages)
- Opportunity for further improvement with hardware and OS extensions
  - Generic support for subsystem isolation

Questions?

Backup

Using Multiple IsoStack Instances

- Utilize adapter packet classification capabilities
- Connections are “assigned” to IsoStack instances according to the adapter classification function
- Applications can request connection establishment from any stack instance, but once the connection is established, socket back-end notifies socket front-end which instance will handle this connection.



Potential for Platform Improvements

- The hardware and the operating systems should provide a better infrastructure for subsystem isolation:
  - efficient interaction between large number of applications and an isolated subsystem
    - in particular, better notification mechanisms, both to and from the isolated subsystem
  - Non-shared memory pools
  - Energy-efficient wait on multiple memory locations