COLO: COarse-grain LOck-stepping Virtual Machine for Non-stop Service

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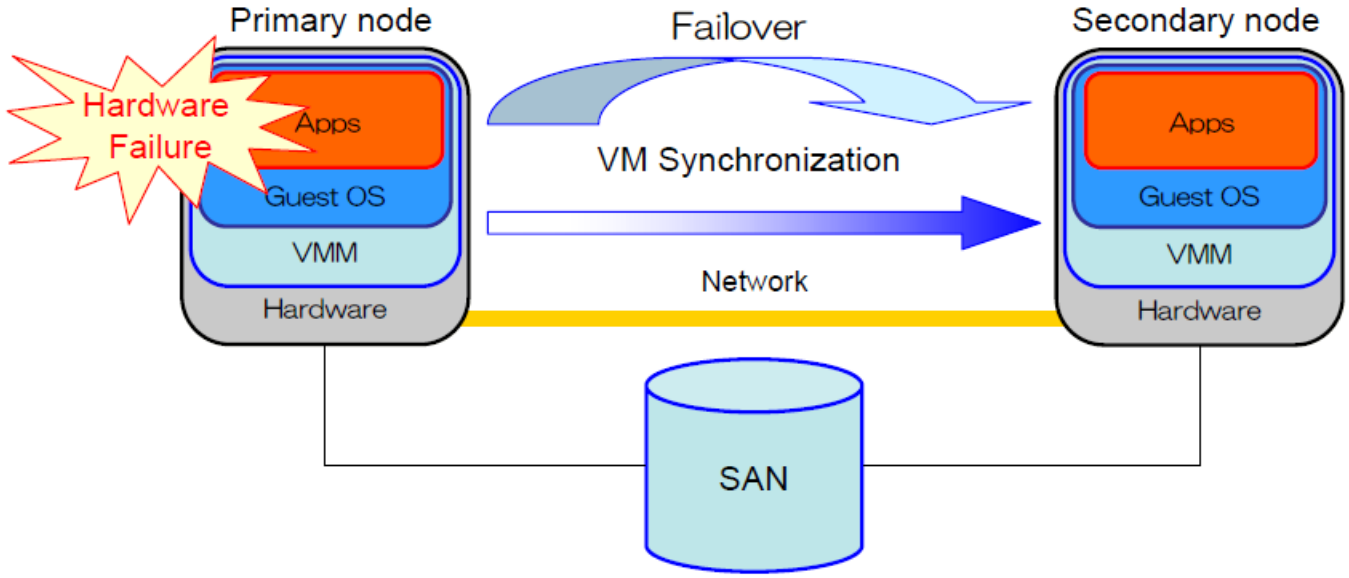
Legal Disclaimer

Agenda

- Background
- COarse-grain LOck-stepping
- Performance Optimization
- Evaluation
- Summary

Non-Stop Service with VM Replication

- Typical Non-stop Service Requires
  - Expensive hardware for redundancy
  - Extensive software customization
- VM Replication: Cheap Application-agnostic Solution



Existing VM Replication Approaches

- Replication Per Instruction: Lock-stepping
  - Execute in parallel for deterministic instructions
  - Lock and step for un-deterministic instructions
- Replication Per Epoch: Continuous Checkpoint
  - Secondary VM is synchronized with Primary VM per epoch
  - Output is buffered within an epoch

Problems

- Lock-stepping
  - Excessive replication overhead
    - memory access in an MP-guest is un-deterministic
- Continuous Checkpoint
  - Extra network latency
  - Excessive VM checkpoint overhead

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Why COarse-grain LOck-stepping (COLO)

- VM Replication is an overly strong condition
  - Why we care about the VM state ?
    - The client care about response only
  - Can the control failover *without* "precise VM state replication"?
- Coarse-grain lock-stepping VMs
  - Secondary VM is a replica, as if it can generate same response with primary so far
    - Be able to failover without service stop

Non-stop service focus on server response, not internal machine state!

How COLO Works

- Response Model for C/S System

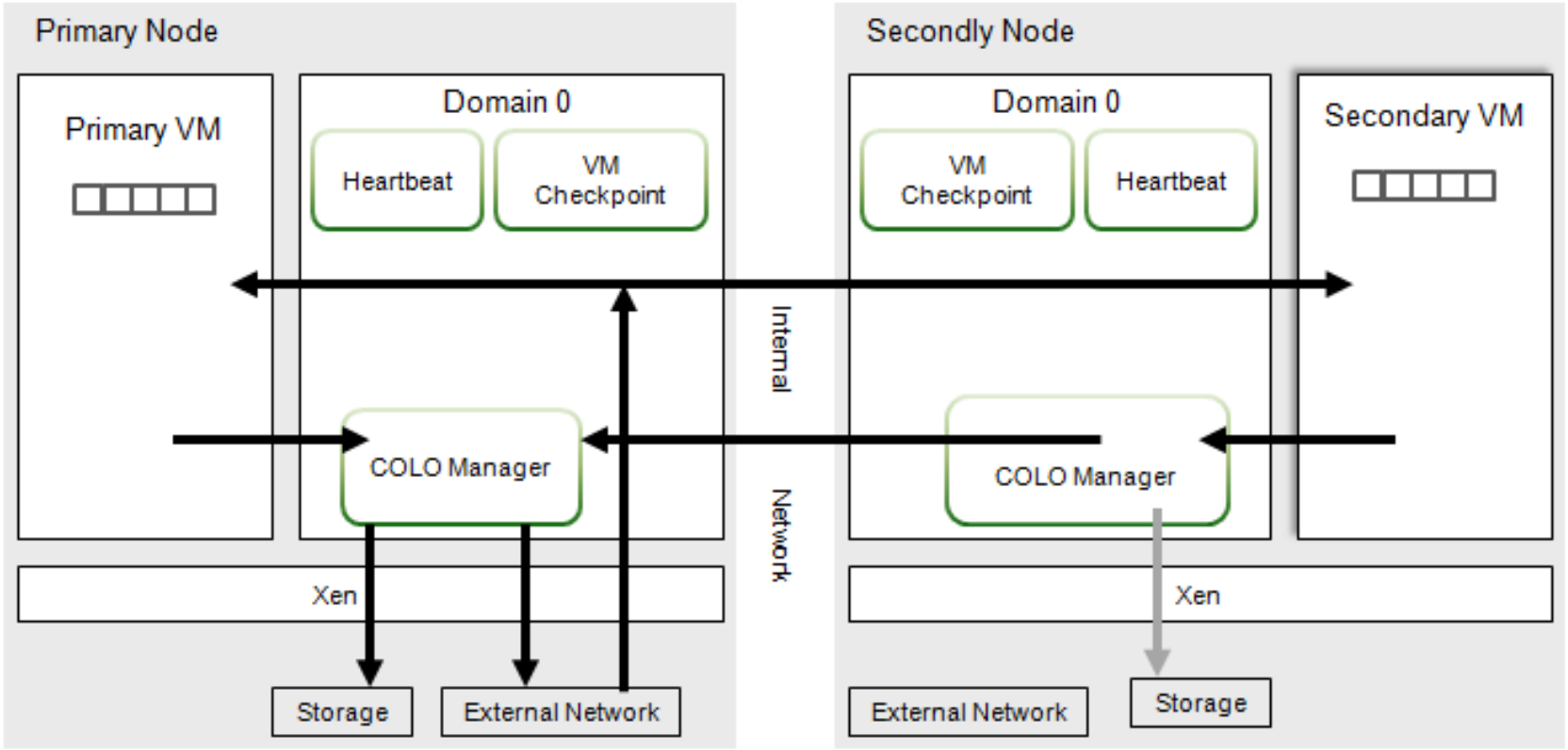
$$R_n = g_n(r_0, r_1, r_2, \dots, r_n, u_0, \dots, u_m)$$

  - r_i & u_i are the request and the execution result of an un-deterministic instruction
  - Each response packet from the equation is a semantics response
- Successfully failover at k^{th} packet if

$$C = \{R_1^P, \dots, R_k^P, R_{k+1}^S, \dots\} \qquad \forall i \leq k, R_i^S = R_i^P$$

  (C is the packet series the client received)

Architecture of COLO



COarse-grain LOck-stepping Virtual Machine for Non-stop Service

Why Better

- Comparing with Continuous VM checkpoint
  - No buffering-introduced latency
  - Less checkpoint frequency
    - On demand vs. periodic
- Comparing with lock-stepping
  - Eliminate excessive overhead of un-deterministic instruction execution due to MP-guest memory access

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Performance Challenges

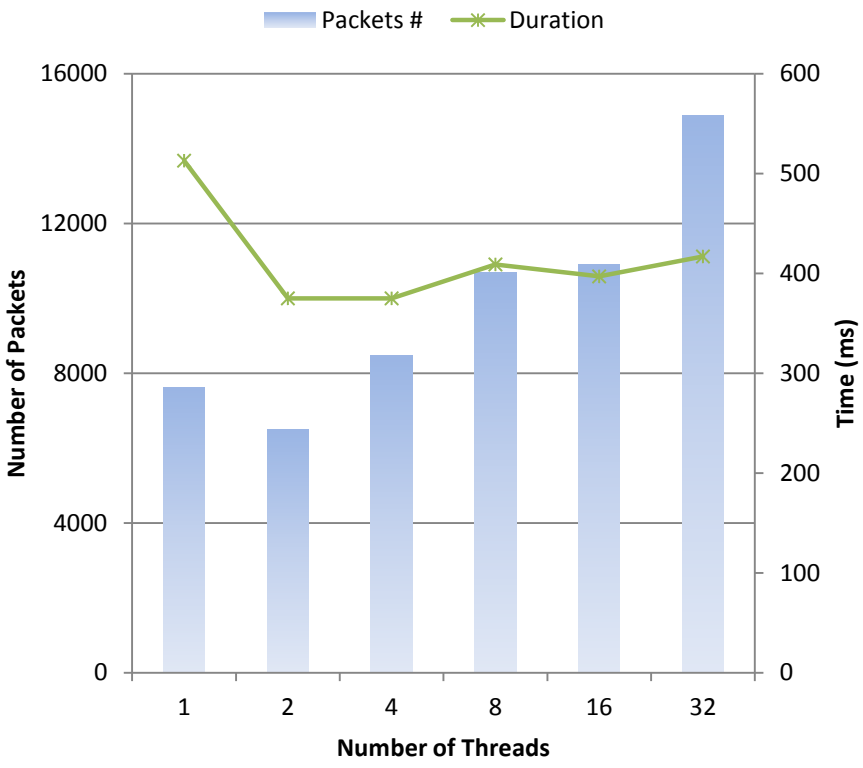
- Frequency of Checkpoint
  - Highly dependent on the *Output Similarity*, or *Response Similarity*
    - Key Focus is TCP packet!
- Cost of Checkpoint
  - Xen/Remus uses passive-checkpoint
    - Secondary VM is not resumed until failover → Slow path
  - COLO implements active-checkpoint
    - Secondary VM resumes frequently

Improving Response Similarity

- Minor Modification to Guest TCP/IP Stack
  - Coarse Grain Time Stamp
  - Highly-deterministic ACK mechanism
  - Coarse Grain Notification Window Size
  - Per-Connection Comparison

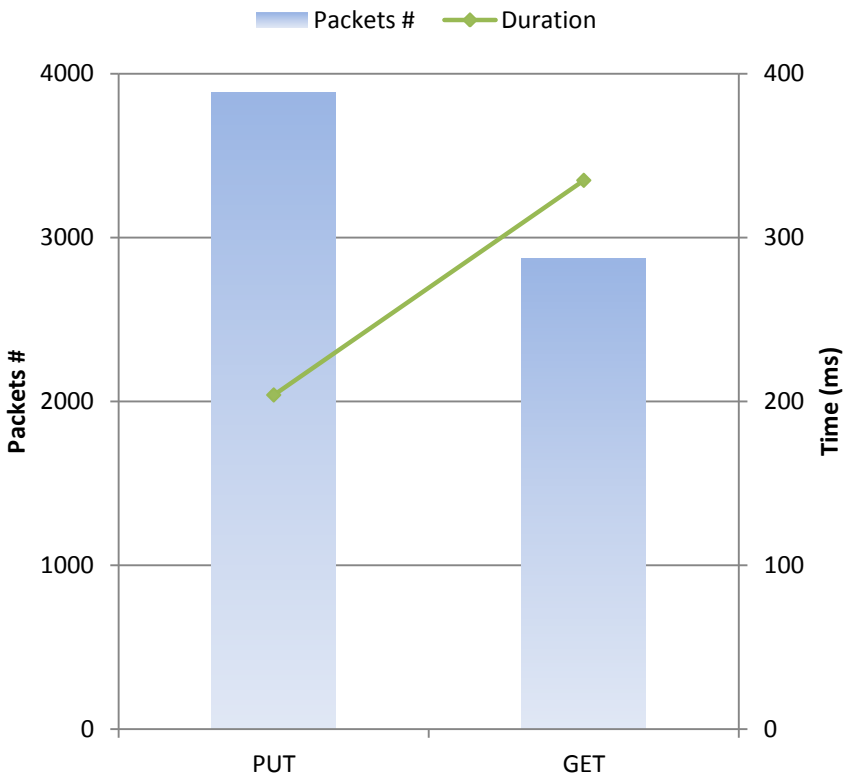
Similarities after Optimization

- Web Server



*Run Web Bench in Client

- FTP Server

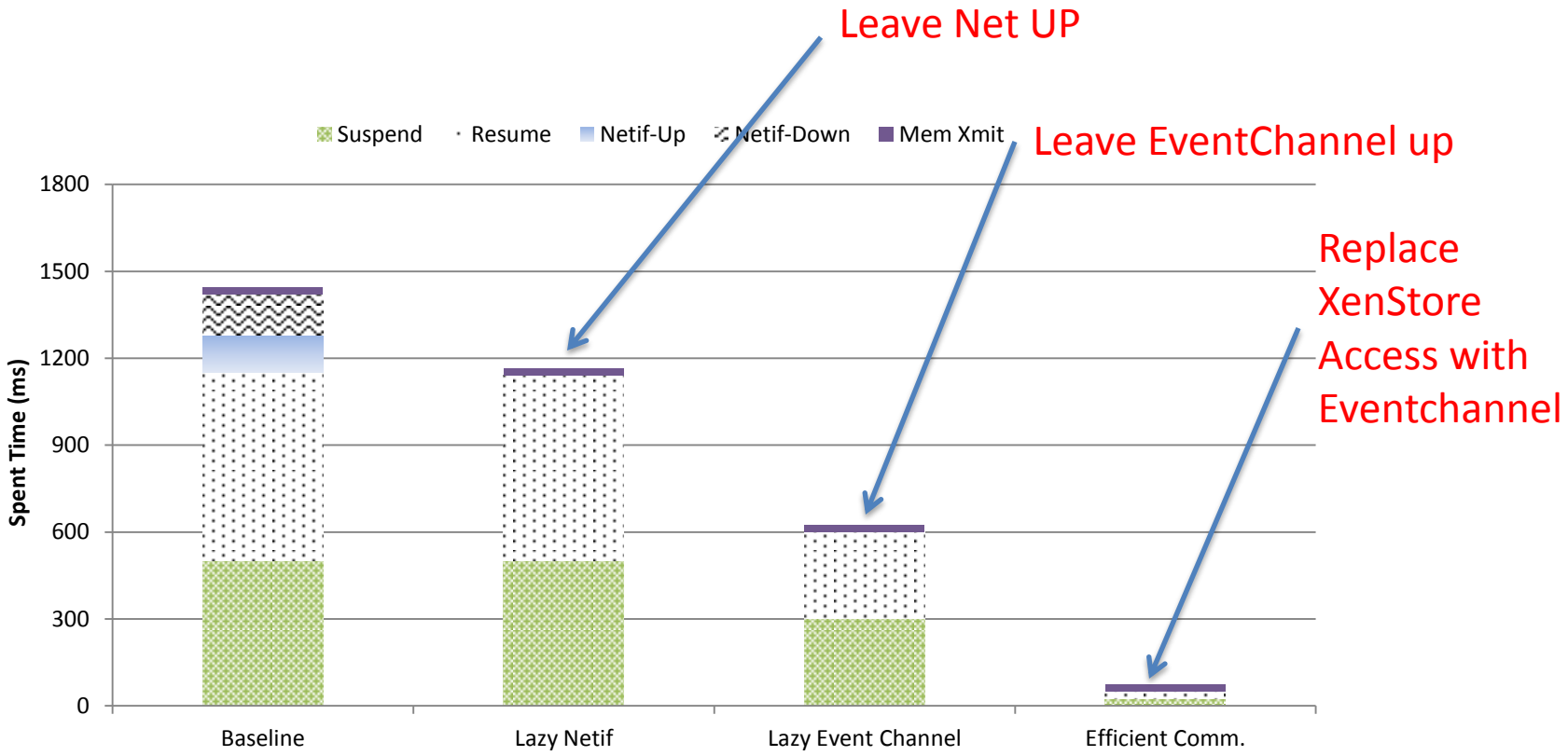


For more complete information about performance and benchmark results, visit Performance Test Disclosure

Reducing the Cost of Active-checkpoint

- Lazy Device State Update
  - Lazy network interface up/down
  - Lazy event channel up/down
- Fast Path Communication

Checkpoint Cost with Optimizations



Final cost: 74ms/checkpoint: (1/3 on page transmission, 2/3 on suspend/resume)

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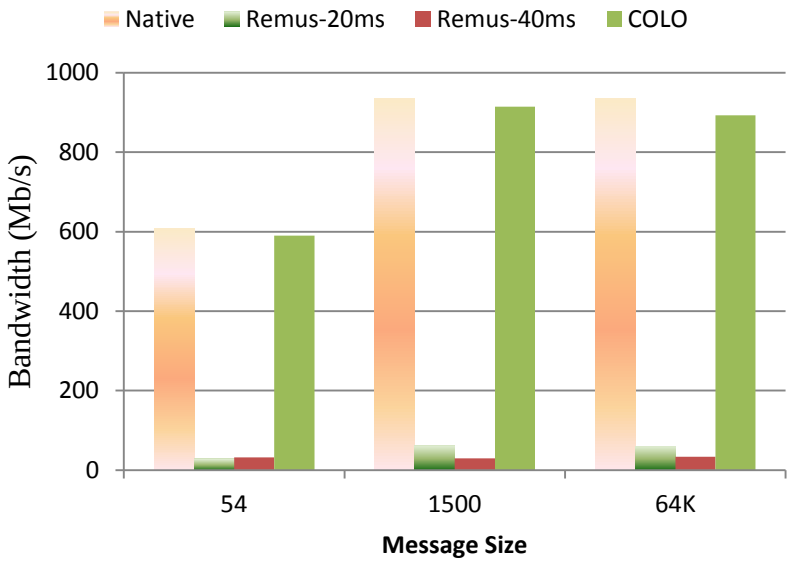
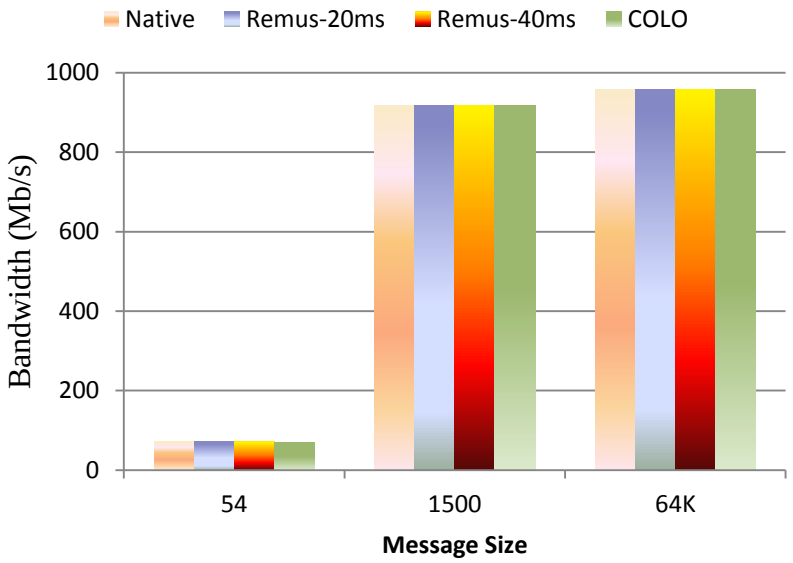
Configurations

- Hardware
  - Intel® Core™ i7 platform, a 2.8 GHz quad-core processor
  - 2GB RAM
  - Intel® 82576 1Gbps NIC * 2 (internal & external)
- Software
  - Xen 4.1
  - Domain 0: RHEL5U5
  - Guest: 32-bit BusyBox 1.20.0, Linux kernel 2.6.32
    - 256MB RAM and uses a ramdisk for storage

Bandwidth of NetPerf



TCP



UDP

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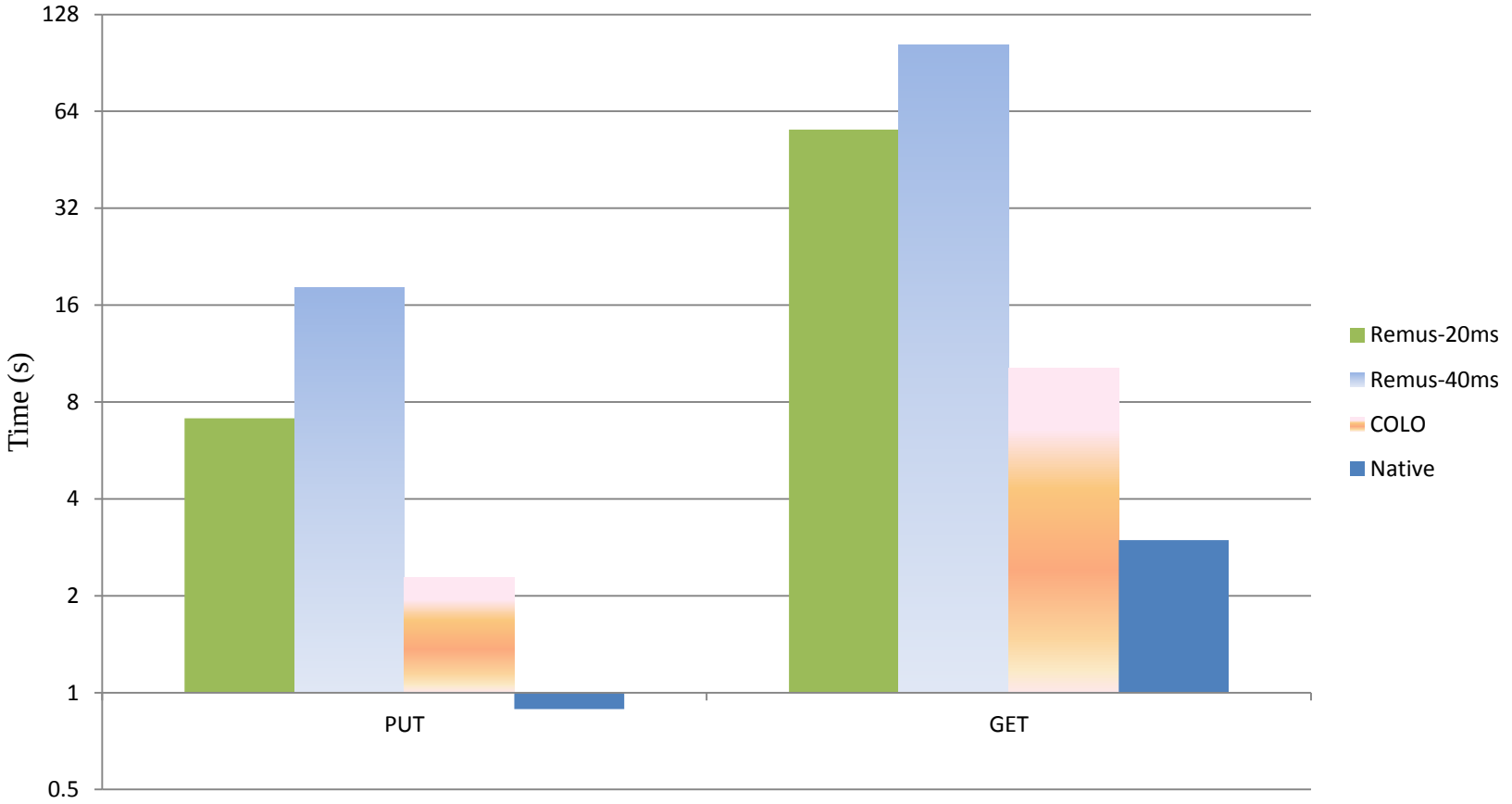
FTP Server



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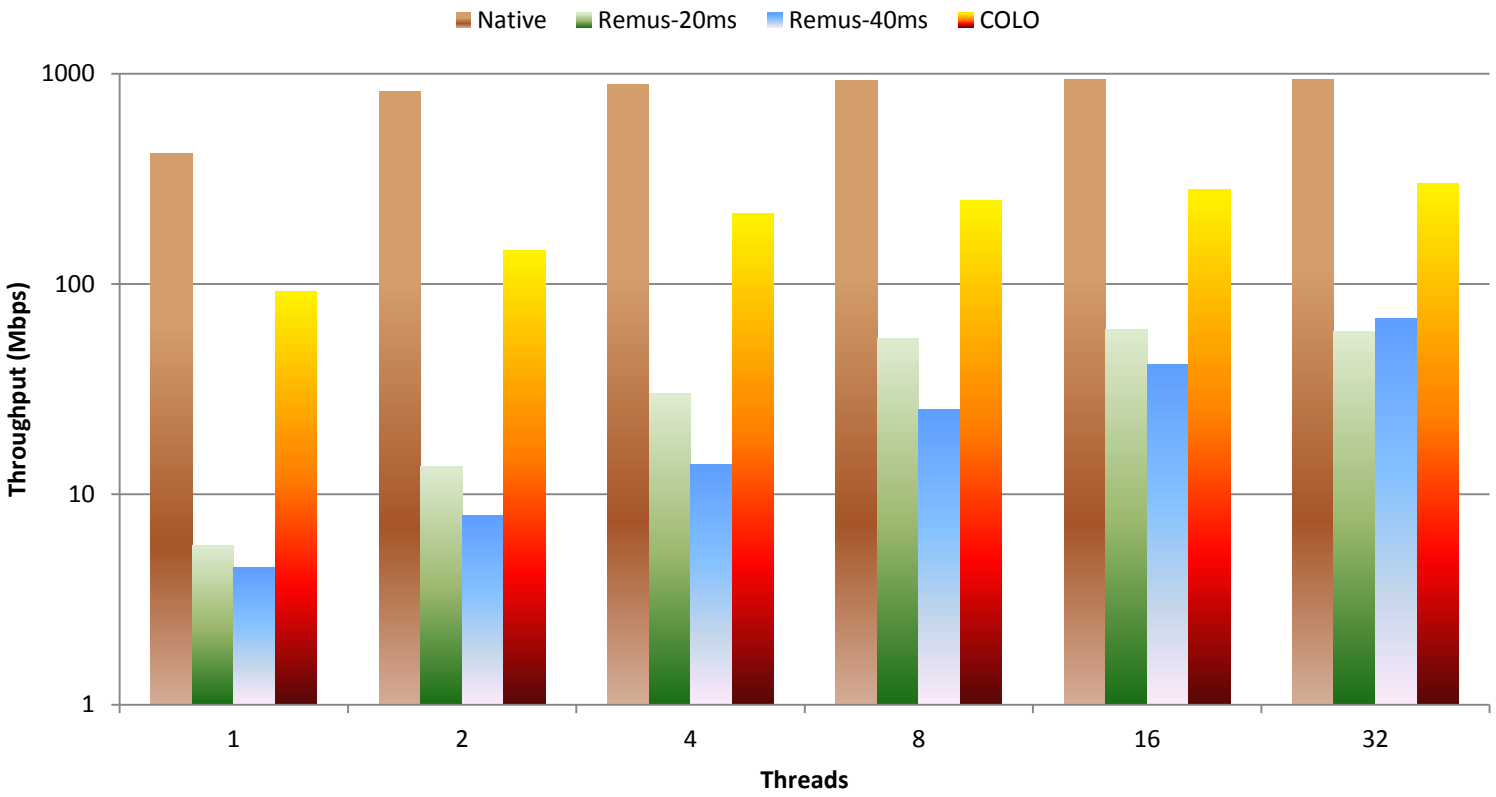
Web Server - Concurrency



Run Web Bench in Client

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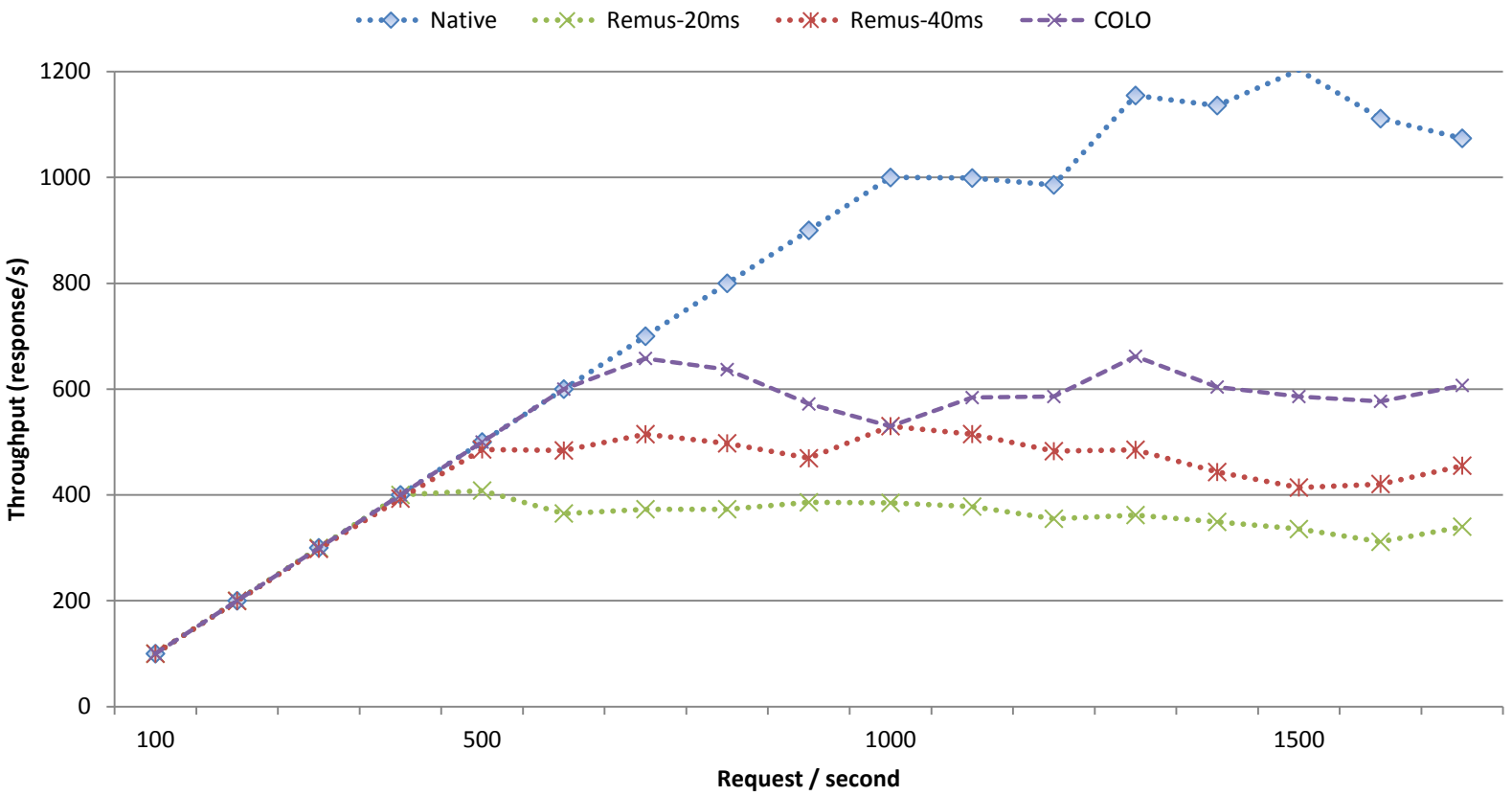
Web Server - Throughput



Run httperf in Client

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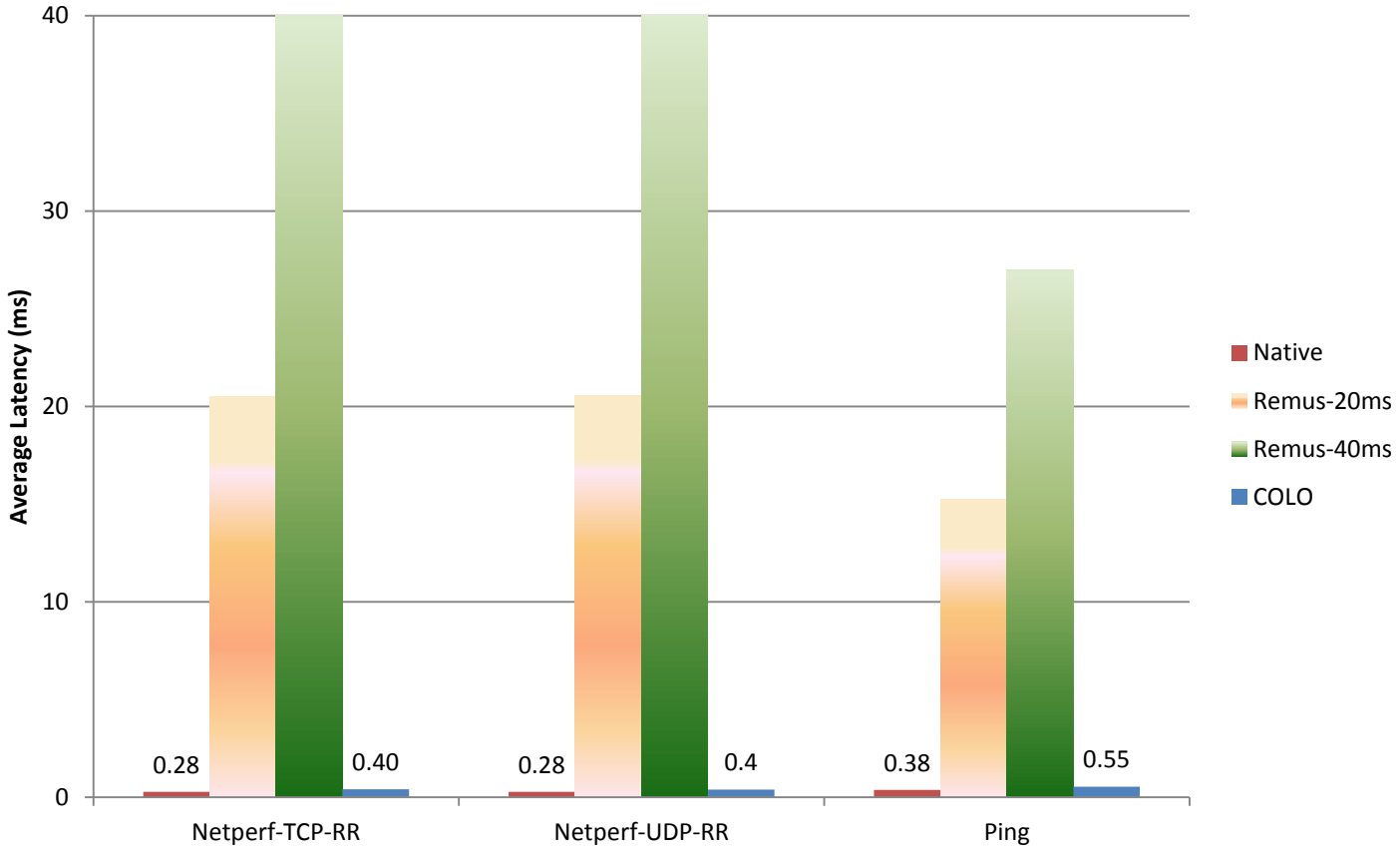
Latency in Netperf/Ping



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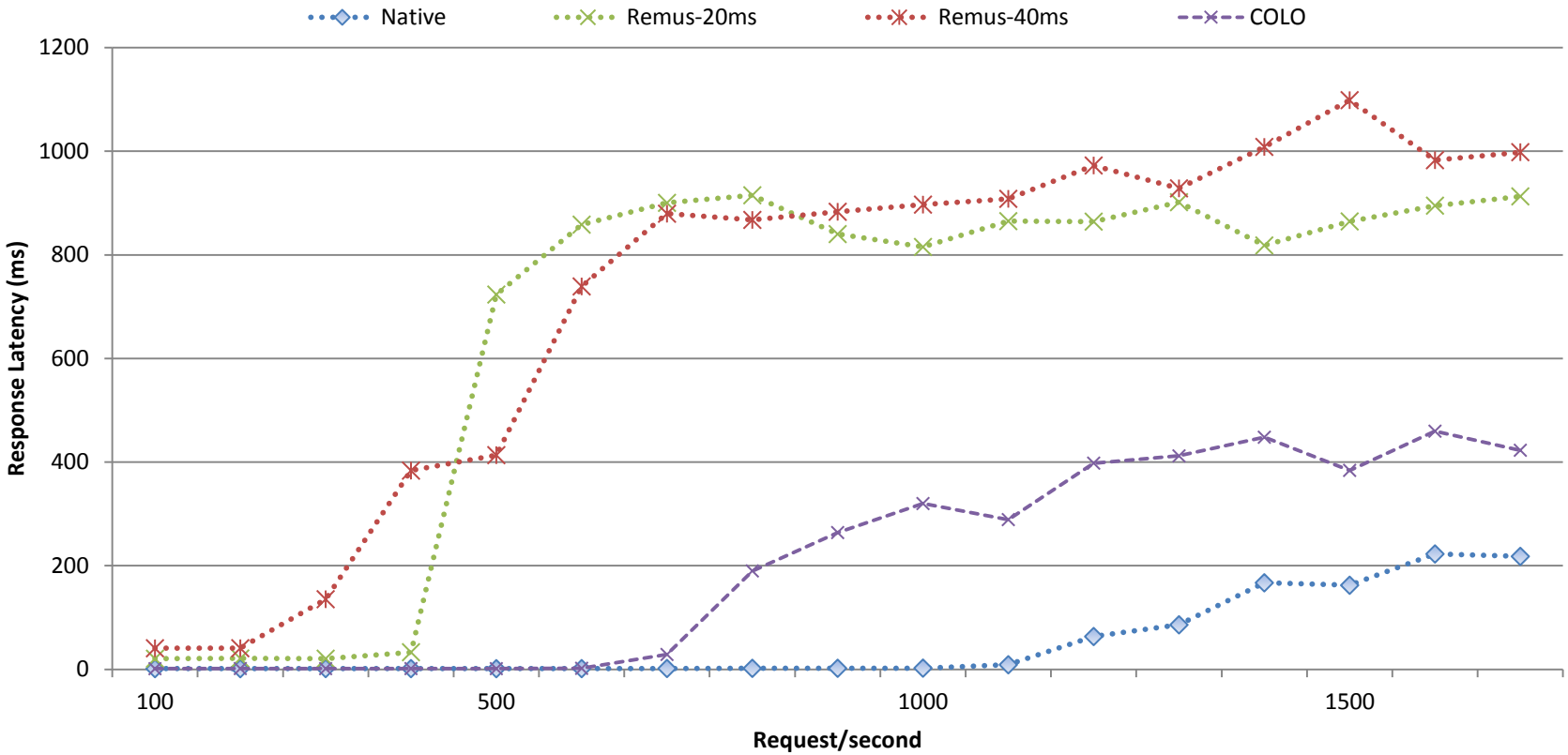
Web Server - Latency



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Summary

- COLO is an ideal Application-agnostic Solution for Non-stop service
  - Web server: 67% of native performance
  - CPU, memory and netperf: near-native performance
- Next steps:
  - Merge into Xen
  - More optimizations


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