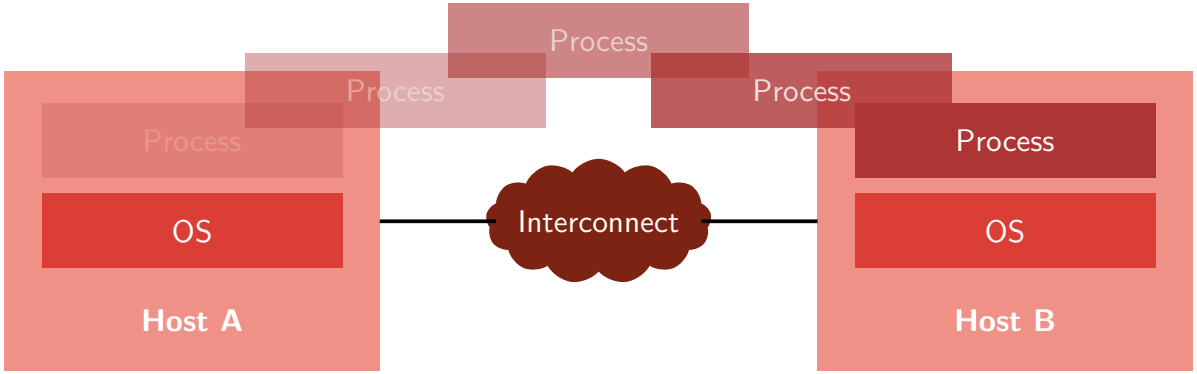

Non-Intrusive Migration of MPI Processes in OS-bypass Networks

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Why do we need Migration?

Resiliency

- Increasing hard- and software failures with growing cluster sizes
- Evacuation of faulty nodes instead of whole job aborts

Load balancing

- Applications' scalability is usually limited by a single resource
- Co-scheduling can help to improve the overall cluster utilization
  - Revocation of an exclusive node assignment
  - Necessity for dynamic schedules

What about Checkpoint / Restart?

- Can be regarded as heavyweight counterpart of migration
- All processes of a job are affected
- Unnecessary synchronization overhead
- *local* vs. *global* consistency
  - Node evacuation only affects processes running on the particular node
  - Load balancing by moving only a subset of processes

Agenda

- Goals
- Background
  - The pscom Library
  - OS-bypass Networks
- Migration of MPI Processes
- Evaluation
  - Overhead
  - Migration Time
- Conclusion

Goals

1. Avoidance of any runtime overhead
2. Minimization of the additional migration costs
3. Application transparency
4. Platform / hardware independence

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   → No influence on the application's performance without migrations
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   → Minimal influence on the migration performance itself
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   → Migrations without adaption to the application's code
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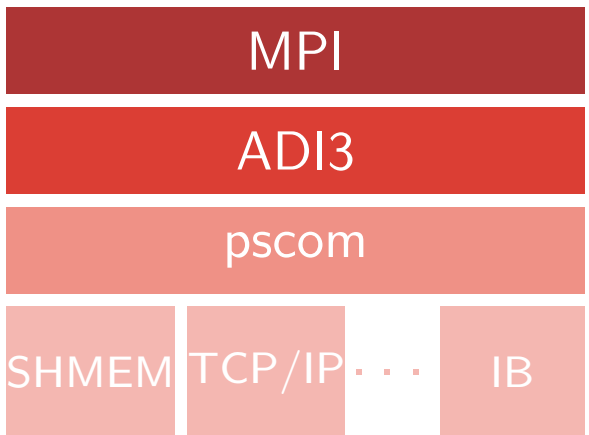
3. Application transparency
   → Migrations without adaption to the application's code
4. Platform / hardware independence
   → No tailored solution to one interconnect

The pscom Library

- Communication layer of ParaStation MPI
- MPICH derivate with full MPI-3 support
- Plugins for different interconnects
  - Chosen based on a priority / fall-back scheme
  - Point-to-point channels
- Internal message queueing facility
- On-demand connection establishment



OS-bypass Networks

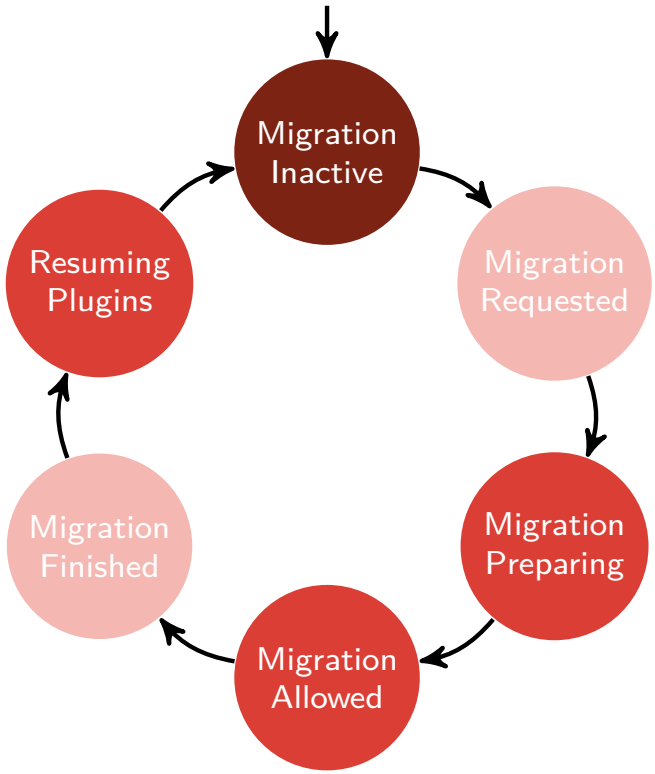
- Direct access to the hardware from the user application
- Connection state information managed within the hardware
- Employment in virtualized environments via
  - PCIe pass-through
  - Single-root I / O virtualization
- *Location-dependent* resources exacerbate migrations

Application Transparent Migration

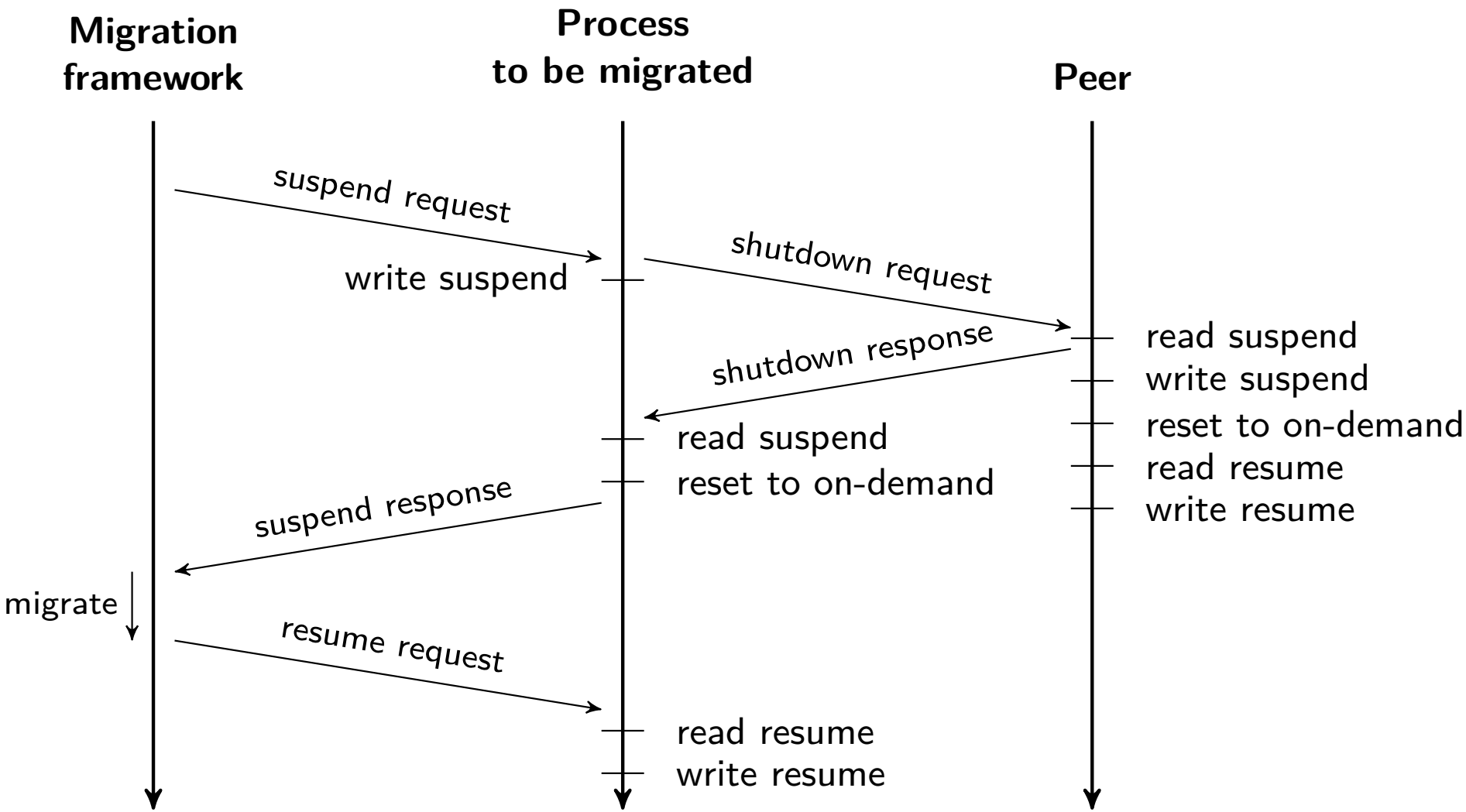
- Shutdown / Reconnect instead of Checkpoint/Restart
  - Local consistency is sufficient
  - Distinguish between migratable and non-migratable connections
- Requirements for the protocol
  - Point-to-point communication Channels
  - Reliable channels
- Employed in virtualization context
  1. *Tear-down of all non-migratable connections*
  2. Detach the HCA via ACPI hot-plug
  3. Migrate the VM to the target host
  4. Attach the new HCA on the target host to the VM
  5. *Re-establish the connection on-demand*

Application Transparent Migration (contd.)

- Add migration states to pscom
- Trigger cycle by external request
- Only affects non-migratable connections



Application Transparent Migration (contd.)



What about “Ungracious” Applications?

Lazy / Cooperative

- Set flag in callback function
- Delay Shutdown / Reconnect until process enters pscom
  - → Asynchronous Shutdown / Reconnect
- Pro
  - No further communication channel
  - Minimal overhead during migration
- Contra
  - Migrated process has to enter pscom
  - Peer processes have to enter pscom
  - → Delays in long computation phases

What about “Ungracious” Applications? (contd.)

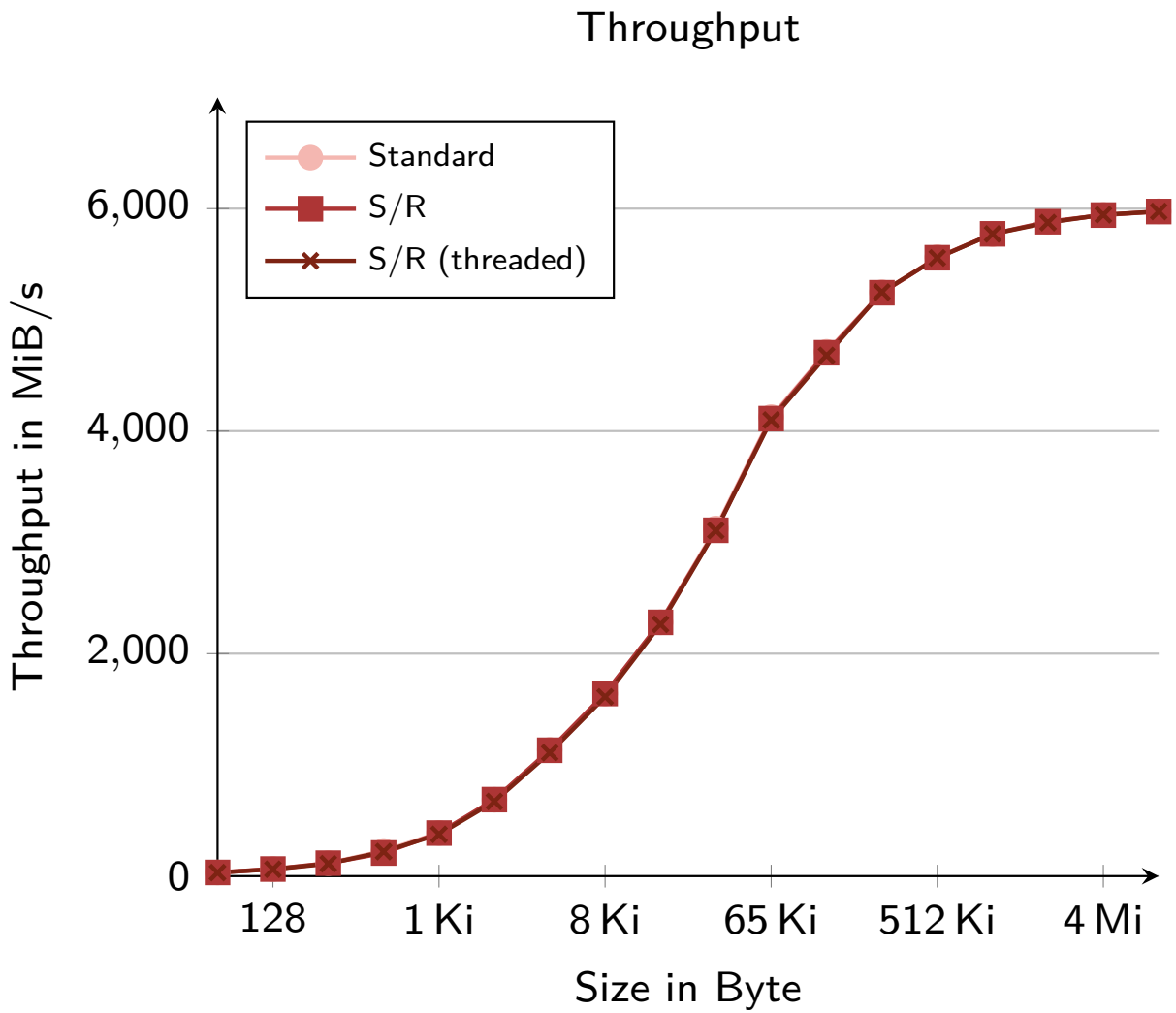
Instantaneous / Threaded

- Trigger Shutdown / Reconnect protocol within callback
- Start progress thread on receipt of *remote* migration request
- Pro
  - Instantaneous migration
  - No dependencies to the application’s communication behavior
- Contra
  - Little overhead during migration (i. e., caused by progress thread)
  - Out-of-band channel with multi-cast required

Test Environment

- 4-node Cluster
  - 2 Sandy-bridge Systems
  - 2 Ivy-bridge Systems
- InfiniBand FDR Mellanox Fabric
  - Up to 56 GiB/s
  - Support for SR-IOV
- Software stack
  - CentOS 7.1
  - Mellanox OFED stack (v 3.0-1.0.1)
  - QEMU / KVM 2.3.0

Runtime Overhead

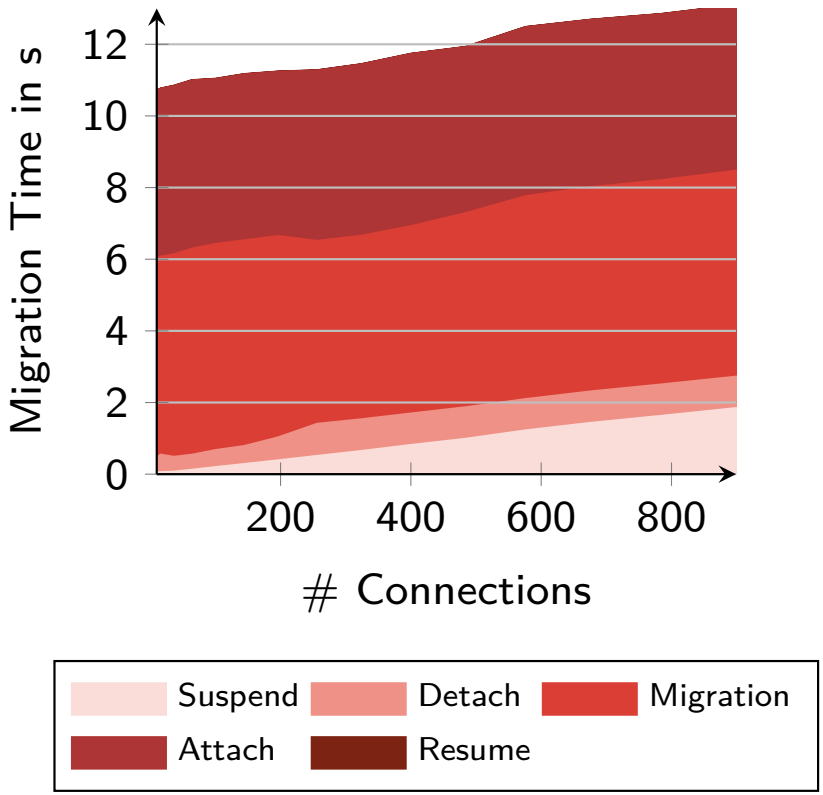


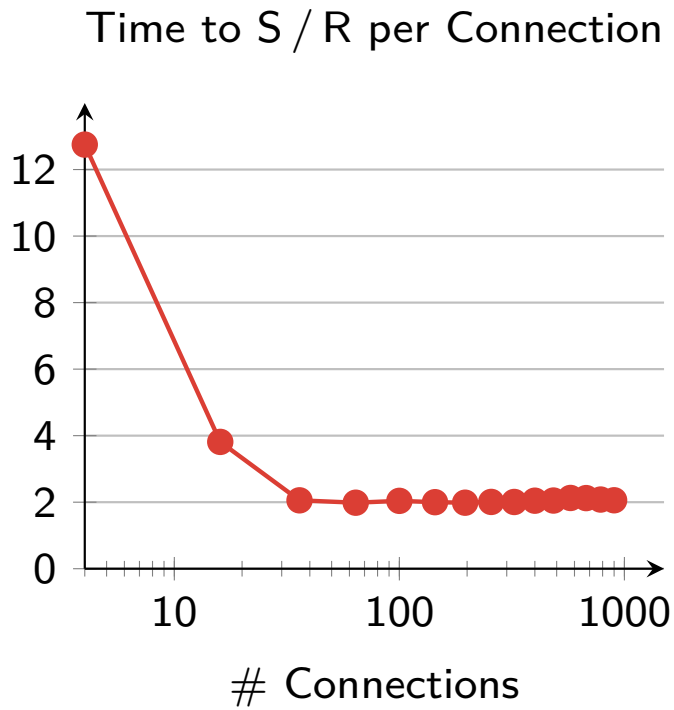
Latency

- No influence on the critical path
- In case of permanently enabled thread function
  - Period 1 ms
  - More contention on internal locks

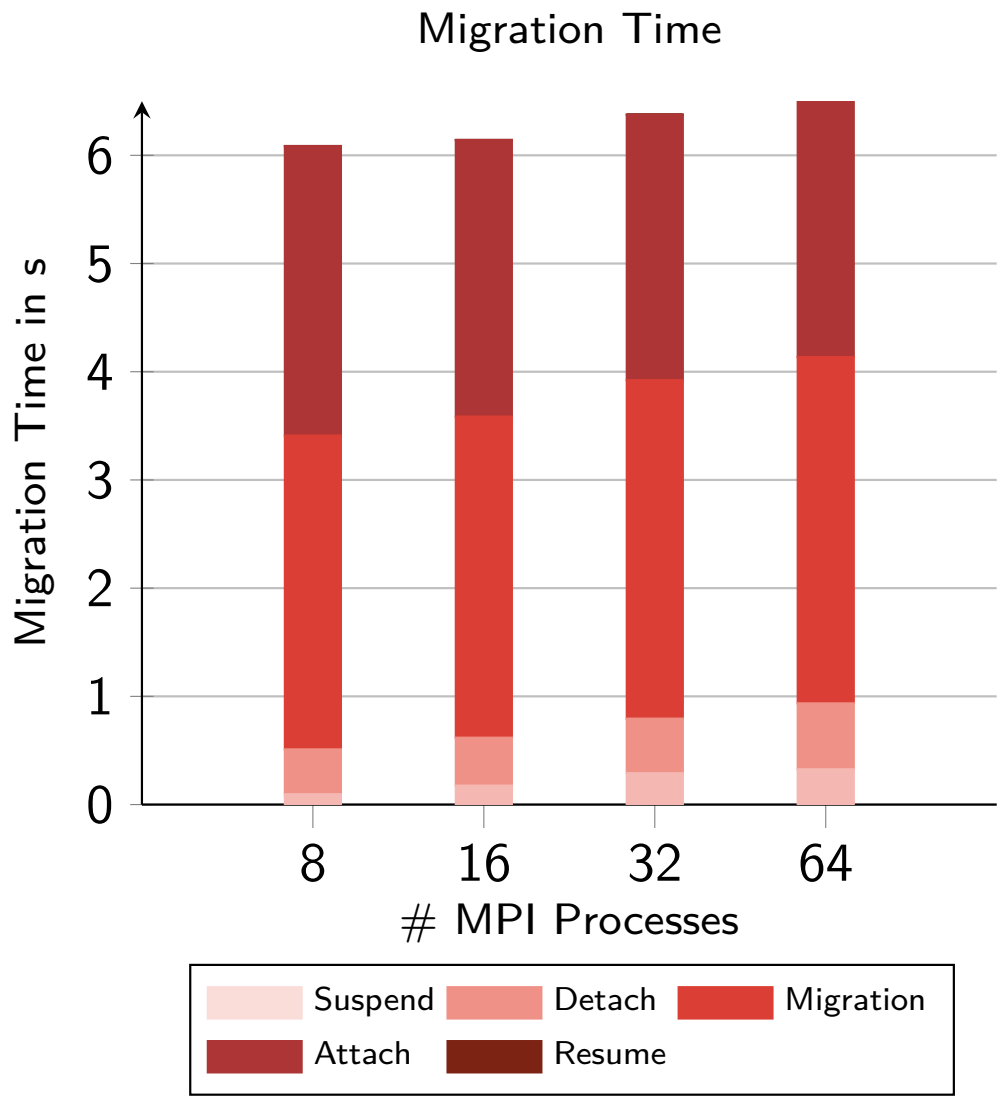
	Disabled	**S/R**	**S/R (threaded)**	
			Norm	Perm
Ø	1.10	1.10	1.10	1.17
σ	0.11	0.11	0.11	0.83

Scalability





Migrating mpiBLAST



Conclusion

- Protocol for application transparent migration
  - Establishes local consistency
  - Executed on a per-connection basis
- Working prototype
  - No runtime overhead
  - Minimal migration cost
  - Successfully evaluated for InfiniBand
- Future work
  - User container-based migration
  - Try mechanism with load balancer to proove benefits at a larger scale
  - Comparison to Checkpoint / Restart mechanisms
- Open source: `https://github.com/fast-project/pscom`

Thank you for your kind attention!

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Migrating mpiBLAST