PARTEC CLUSTER COMPETENCE CENTER

MANAGED HPC

Introduction to JuRoPA:

ParaStation Cluster Suite

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Ralph Krotz

krotz@par-tec.com

History

Components

- Communication Library
- Process Management
- MPI

ParaStation @ JSC

Infiniband

- Hardware Components
- Topology

MPI scaling

Running your program

History

ParaStation1 (1995)
- Univ. of Karlsruhe

ParaStation2 (1998)
- ParTec was founded

ParaStation3 (2001)
- Support for new interconnects – GigE

ParaStation4 (2003)
- More interconnects, new features provide a comprehensive cluster suite

ParaStation goes open source (2004)
- support contract is mandatory for enterprise customers

ParaStation V5 (2007)
- MPI2 support

ParaStation Consortium

ParaStation is open source

- Still owned by ParTec
- Co-Development by the Consortium partners
- Guarantee for other partners, if ParTec disappears
- Free for educational customers – without support
- ParTec has the exclusive right commercial utilization
- Support contract mandatory for enterprise customers
- Closed source add-ons

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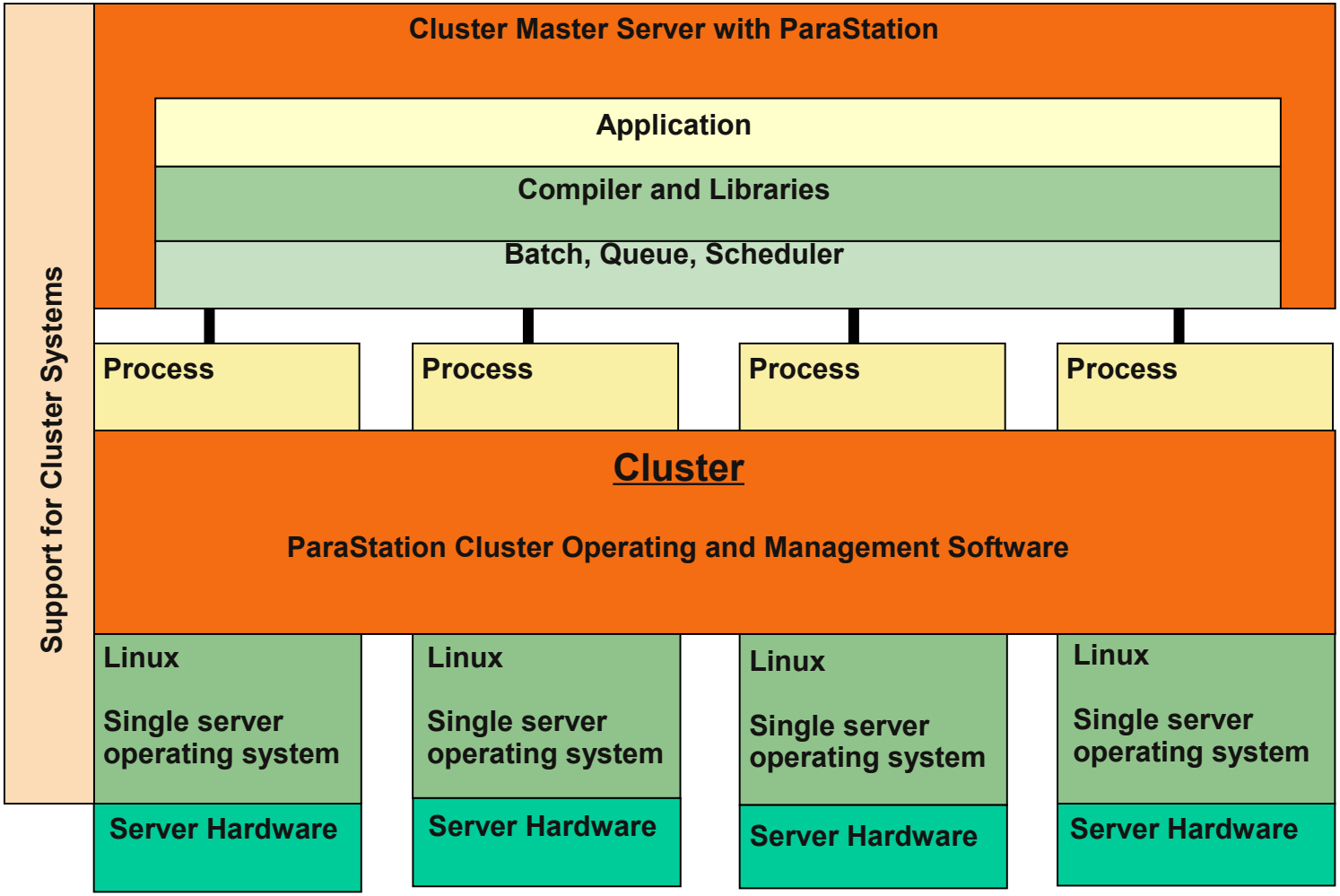
ParaStation Components

ParaStation MPI	(psmpi)
ParaStation Process Management	(psmgmt)
ParaStation Communication Library	(pscom)
GridMonitor	(psgridmon)
ParaStation System Provisioning	(pscluster)
Toolbox	
(Batch Queuing System)	
(Standard Distribution)	

Σ ParaStation Cluster Suite

Cluster Operating and Management



ParaStation Communication Library

Supports multiple interconnects & protocols in parallel

Interconnects

- Infiniband
- Shared memory
- Ethernet (GbE, 10GbE)

Protocols

- VAPI (IB)
- DAPL (10GbE, IB)
- TCP/IP
- p4sock (GbE, 10GbE)

Used by MPI

- Uses „best“ interconnect found at startup
- Efficient usage of resources (buffers)

ParaStation MPI

ParaStation MPI library:

- Implements MPI2 (MPIch2 (version 1.2.1p1, 1.4.1p1))
- Uses *pscom* library
- all interconnects from *pscom*
- Supports all MPIch-tools (Tracing, Debugging, ...)
- “One” executable for all interconnects:
  - *Communication path automatically selected at run-time*
  - *Optionally configurable by the user*
  - *Takes care of network problems/bad host adapters*
- Interactive usage incl. resource management
  - *Multi-user environment*
  - *No overbooking of nodes*

Supports various compilers:

- GCC, Intel
- PGI, Pathscale

ParaStation MPI

MPI Features required by Juropa

MPI must scale to more than 25000 processes .

MPI should be optimized for the environment – low memory consumption
(< 0.5MB/connection)

MPI with less memory consumption / connection = More memory for the linpack = better performance & higher efficiency

Only establish "used" connections. (establish the IB connection with the first byte send – **on demand**)

ParaStation MPI:

-More memory for your application
-Better use of your IB fabric

ParaStation Process Management

Daemon concept

- ParaStation **psid** on each cluster node
- Resource monitoring (node, processes, load, …)
- Process startup
- Process monitoring/termination
- Setting up user environment
- Efficient and scalable communication subsystem for inter-daemon messages (RDP, only one socket per daemon)
- No dedicated master daemon - fault tolerance

ParaStation Process Management

Job monitoring (psid)

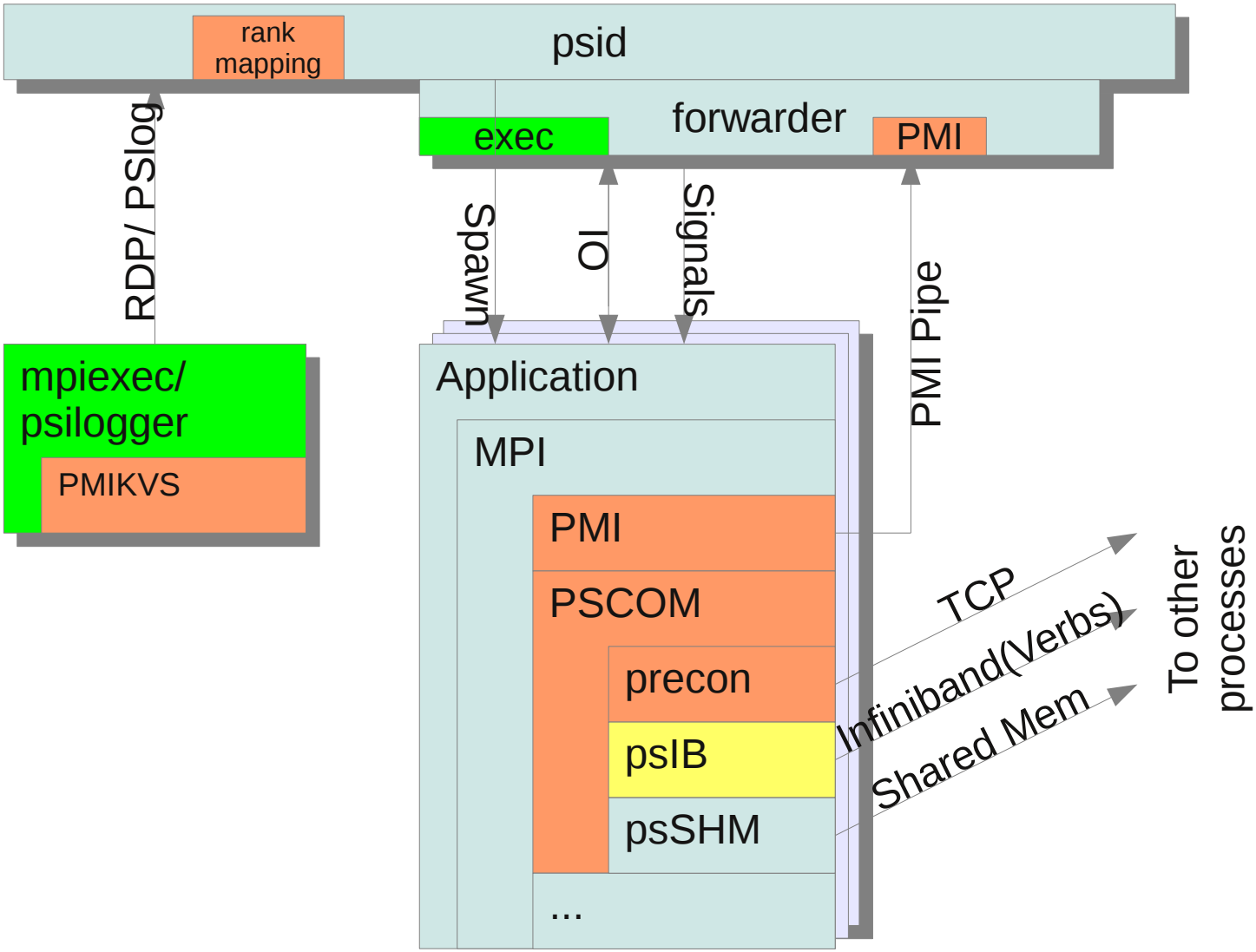
- All processes within all jobs are continuously monitored
- Jobs are cleaned up, if
  - *node dies*
  - *process dies*
  - *job terminates*
- All processes belonging to a particular job are terminated!
- All resources are available for next job
- Job accounting

ParaStation Process Management

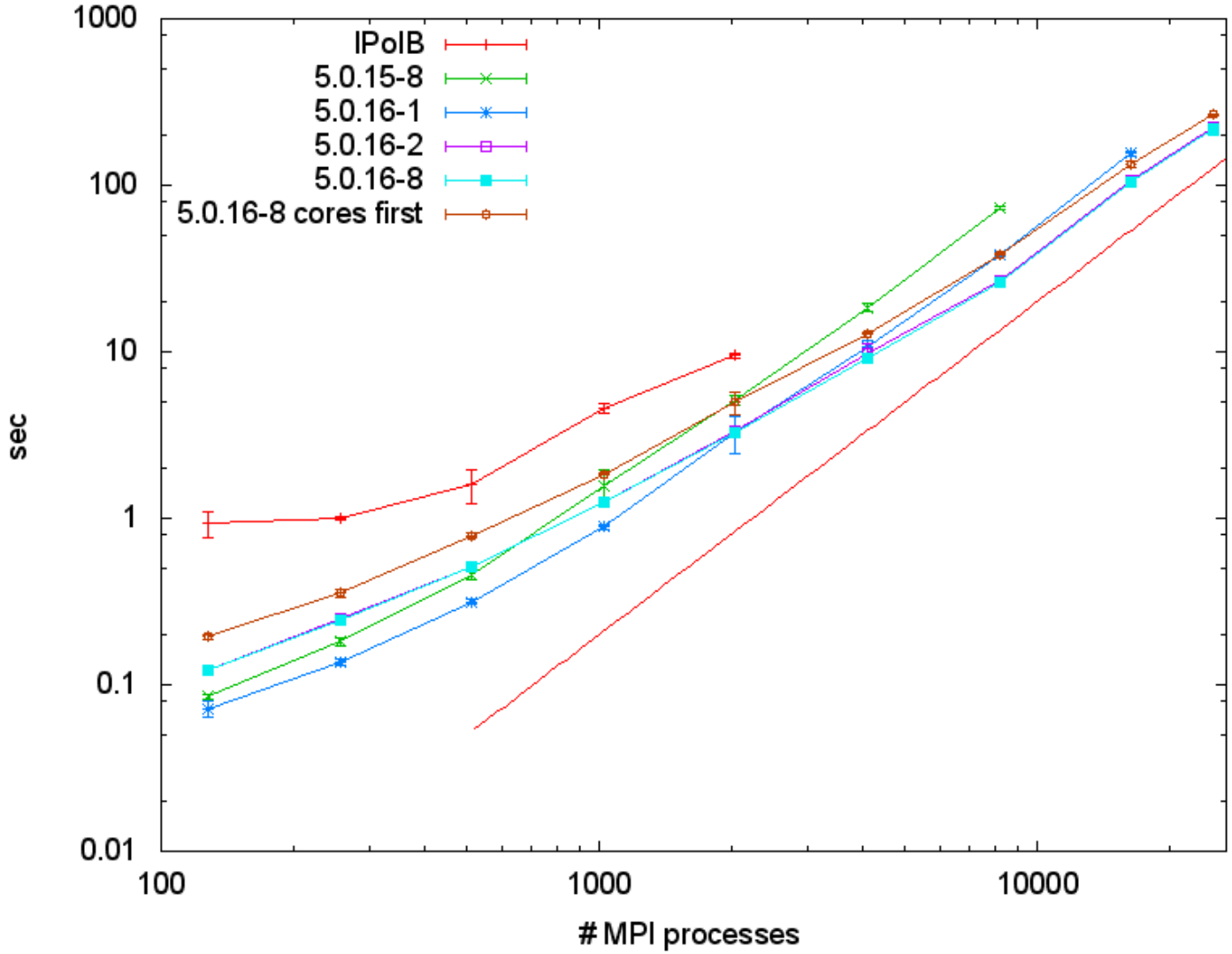
Process placement / load balancing

- Only available nodes are used, dead nodes are ignored!
- Only one process per CPU (default)
- Current load is observed
- Exclusive use of nodes possible
- Explicit node list generated by batch subsystem
- Integrated with TORQUE & Moab
  - *psmom plug-in to psid*
  - *psmom provides communication between psid and batch system*

MPI: Application startup



MPI: Application startup times



- History
- Components
  - Communication Library
  - Process Management
  - MPI
- ParaStation @ JSC
- Infiniband
  - Hardware Components
  - Topology
- MPI scaling
- Running your program

ParaStation @ JSC

ParaStation in Production since 2004

Various Clusters use ParaStation today

JUDGE	2472 cores Intel X5650 412 GPUs Nvidia M2050	IB QDR
Softcomp	500 cores AMD64	GigE / InfiniPath
JUGGLE	176 cores AMD64	InfiniPath

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Why QDR Infiniband ?

Naive answer:

- Higher bandwidth (now at 32 Gbit/s)
- Lower latency (Mellanox claims less than 1.0 µsec)

Actual reasons:

- Huge fabrics build out of small building-blocks
- “Small” crossbar-switches (few dozen ports)
- Specific topology: Clos, fat-tree, Ω-network,....
- QDR has 36-port building blocks (24-ports in earlier versions)
- Reduced complexity
- QDR supports adaptive routing
- IB's static routing might lead to congestion

Infiniband debugging

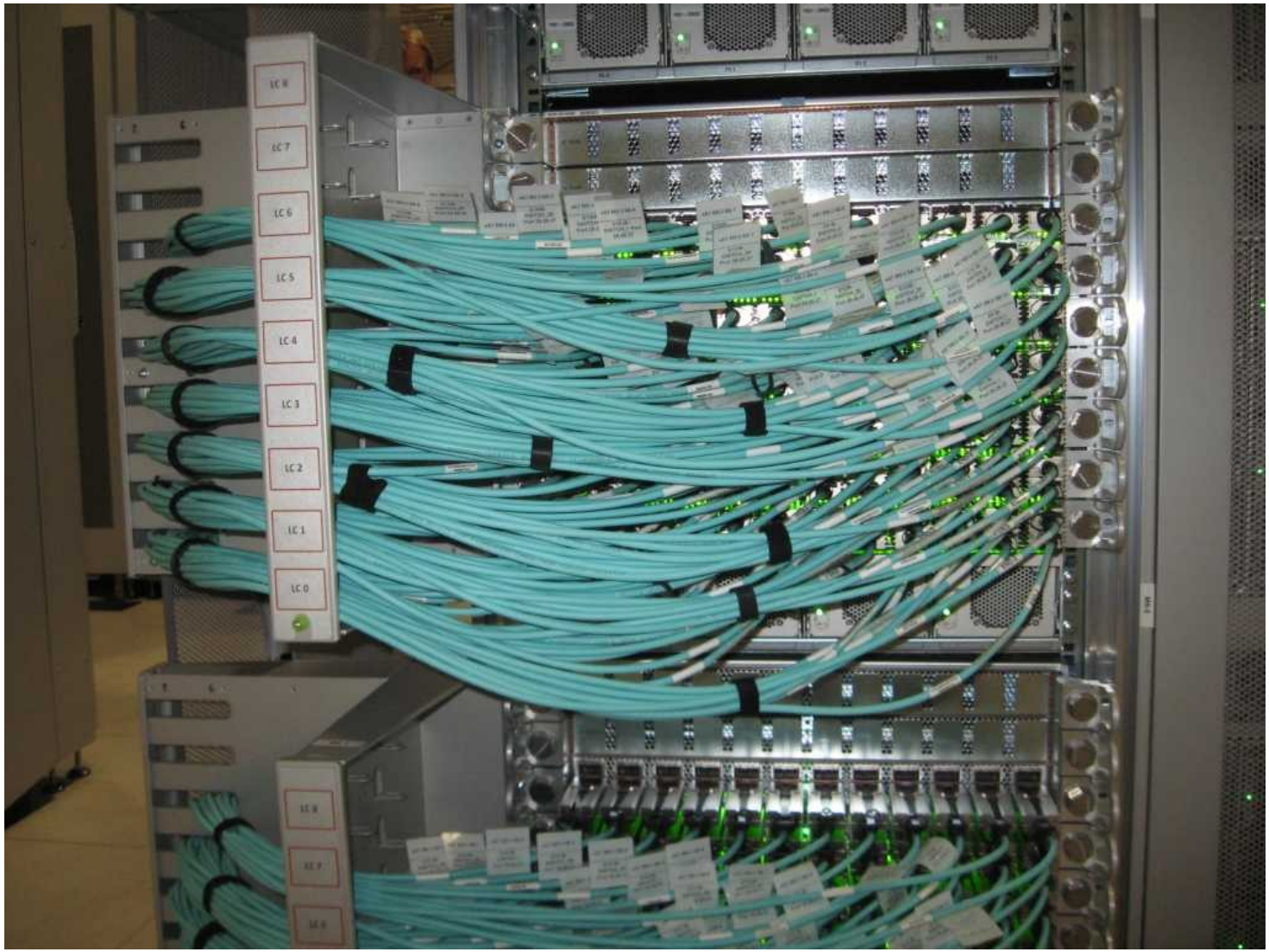
Deal with this:

Extract of output of ibdiagnet:

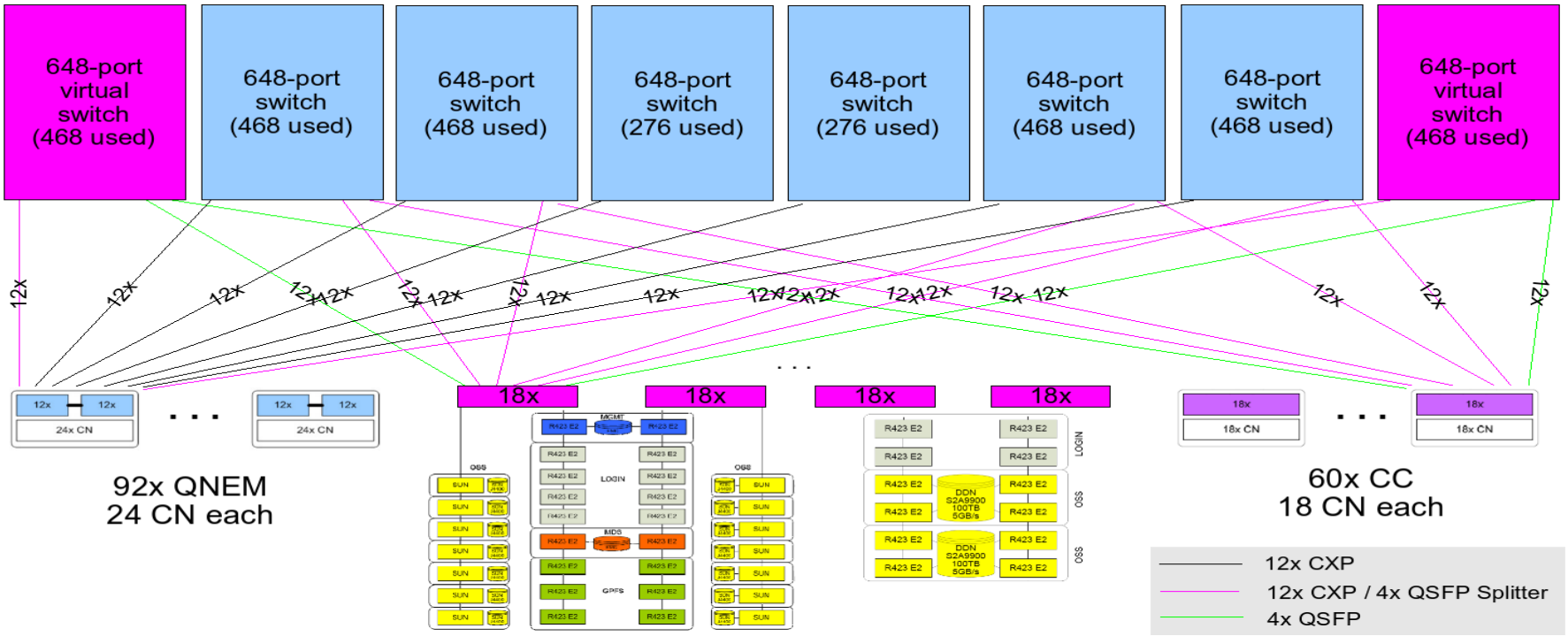
```
-I- Using port 1 as the local port
-W- Local system name was not specified (-s option).
    "jj27y01/U1" will be used as the local system name.
-I- Discovering ... 3881 nodes (588 Switches & 3293 CA-s) discovered.
```

Very large # of IB components – need a Plan to manage this complexity and quickly identify & locate faulty components.

M9 switch



IB Topology - Heterogeneous



23 x 4 QNEM modules, 24 ports each

6 x M9 switches, 648 ports max. each, 468/276 links used

Mellanox MTS3600 switches (Shark), 36 ports, for service nodes

4 Compute Sets (CS) with 15 Compute Cells (CC) each

CC with 18 Compute Nodes (CN) and 1 Mellanox MTS3600 (Shark) switch each

Virtual 648-port switches constructed from 54x/44x Mellanox MTS3600

Results

Single HPL benchmark run – across entire Heterogeneous Cluster

274.8 TFlops with 3200 nodes -> ~91.6% of peak

Nodes used: 2157 Sun nodes and 1043 Bull nodes.

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MPI Scaling

IB design based on reliable connections (rc mode)

- Needs private memory for each connection
- Might have significant impact for huge jobs

ParaStation MPI is not special in this respect

- Each IB connection requires 0.55 MB of memory (with default settings)
- No real problem for small jobs

Largest jobs currently on JuRoPA have 8192 processes

- Thus, 8192 connections for each process
- ~ 4 GB of memory occupied just by MPI
- Each core has just 3 GB of memory (24 GB/node)

MPI Scaling – solution I

Most MPI programs do not need every connection

- Nearest neighbor communication
- Scatter/Gather and Allreduce based on binary trees
- Typically just a few dozen connections when having hundreds of processes

ParaStation MPI supports this with “on demand connections”

- `export PSP_ONDEMAND=1`
- was used for the Linpack runs (np > 24000)
- `mpiexec –ondemand`

Backdraw

- Late all-to-all communication might fail due to short memory

Default on JuRoPA is not to use “on demand connections”

MPI Scaling – solution II

Sometimes all-to-all communication is required

Try to reduce memory-usage by reducing number of buffers

- ParaStation MPI uses pre-allocated buffers
  - *Copy data into local send-buffers*
  - *RDMA into remote receive buffers*
  - *Copy into final destination*
- Default is to pre-allocate 16 send and receive buffers
- Each buffer has 16 kB

Steering via environment variables

- PSP_OPENIB_SENDQ_SIZE
- PSP_OPENIB_RECVQ_SIZE

MPI Scaling – solution II

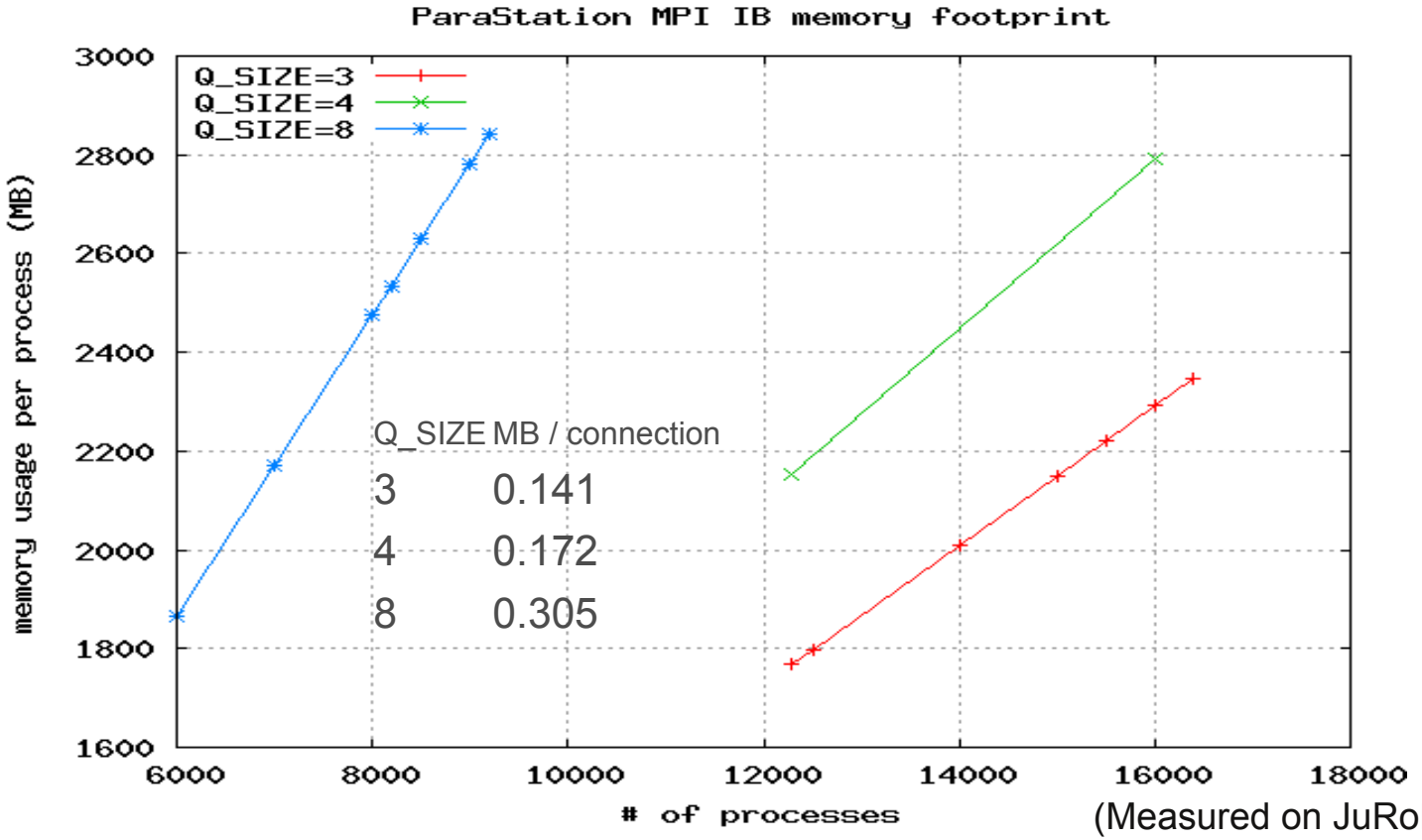
Example:

```
export PSP_OPENIB_SENDQ_SIZE=4
export PSP_OPENIB_RECVQ_SIZE=4
export PSP_ONDEMAND=0
```

allocates 4 * 2 fixed size (16 kB) buffers, resulting in ~170 kB per connection
For np=10000 memory consumption was measured:
~1800 MB/process = ~14 GB/node

Memory footprint (all 2 all)

With 16k processes you loose more than 75% of your memory for communication buffers and connection handling!
(JuRoPA 24GB/node ~ 3GB/process)



(Measured on JuRoPA by N.Eicker)

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Running your program

compilation

- Using the wrapper mpicc, mpicxx, mpif90, ...
- Compiler selection:
  - *Module avail*
  - *Module list*
  - *See overview by JSC*

Running your program

mpiexec

- which options for mpiexec?
- which environmental variables?

Running your program

Options:

- mpiexec -np <N> # procs to start
- Normally, no other options necessary

Running your program

Checking Startup

```
machine:/some/dir>export PSP_DEBUG=3
machine:/some/dir>mpiexec -np 2 ./hello
<PSP 8536:set PSP_DEBUG = 3>
<PSP 8536:# Version(PSCOM): Mar 26 2009>
<PSP 8536:default PSP_SO_SNDBUF = 32768>
<PSP 8536:default PSP_SO_RCVBUF = 32768>
… (some more environment variables)
<PSP 8536:default PSP_TCP = 1>
<PSP 8536:Register arch tcp with priority 01.02>
<PSP 8536:default PSP_SHM = 1>
<PSP 8536:Register arch shm with priority 01.90>
<PSP 8536:default PSP_P4S = 1>
<PSP 8536:Register arch p4s with priority 01.10>
<PSP 8536:default PSP_OPENIB = 1>
<PSP 8536:Using   /opt/parastation/lib64/libpscom4openib.so>
<PSP 8536:Register arch openib with priority 01.20>
<PSP 8536:default PSP_MVAPI = 1>
…
<PSP 8536:ACCEPT  (134.94.172.25,8538,0x605398,r0000001)
to (134.94.172.25,8536,0x605398,r0000000) via shm>
```

Running your program

Stopping your job

```
kill <one pid of your MPI job>
PSIlogger: Child with rank 1 exited on signal 15: Terminated
PSIlogger: Child with rank 0 exited on signal 15: Terminated
```

If the job aborted:

Check the first lines of your output

Available memory exceeded ?

Running your program

My program does not start ...

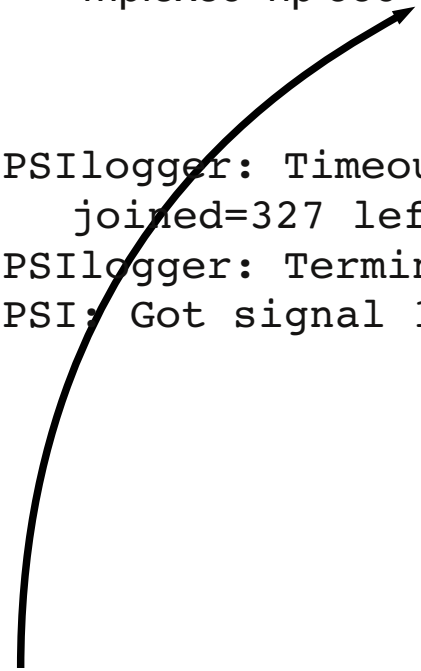
- PMI Barrier problems...
- MPI/ParaStation problems...
- IB problems...
- Use PSP_DEBUG=3 to see what's going on.

Running your program

PMI Barrier problem:

Symptom:

mpiexec -np 336 -x ./binary -options...



```
PSIlogger: Timeout: Not all clients joined the first pmi barrier:
   joined=327 left=9 round=1
PSIlogger: Terminating the job.
PSI: Got signal 15 from 0x0bb8235f[3000:9055]
```

-x exports the whole environment, too much stress

Running your program

PMI Barrier problem: how to avoid it

- Don't use -x, use --export and a , separated list
  --export=MYVAR,YOURVAR
- Try increase the PMI barrier timeout:
  export PMI_BARRIER_TMOUT=<secs>, -1 for infinite wait, default is 60 seconds
- Try increase the rounds of PMI barriers
  export PMI_BARRIER_ROUND=<#>, default is 1 round

Running your program

Other tuning parameters:

- Check out *man ps_environment*
- Beware: some for debugging, testing …
- Example:
  PSP_ OPENIB_PATH_MTU: Controls IB MTU: 1 = 256 Bytes, 2 = 512 Bytes, 3 = 1024 Bytes (default)
- See above:
  - PSP_ONDEMAND

    Works best with nearest neighbor communications, scatter/gather, allreduce
  - PSP_OPENIB_SENDQ_SIZE
    PSP_OPENIB_RECVQ_SIZE

    Queue size modification is only viable option for all-to-all communication

Thank you!