# Benchmarking Clusters with High Core-Count Nodes

9th LCI International Conference on High-Performance Clustered Computing
29 April, 2008

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# Motivation

- **The most common interconnnect benchmarks exercise one core on each of two nodes**
- **Nodes are becoming larger in terms of core-count.**
  - The interconnect needs to keep pace
  - What benchmarks are appropriate in this environment?

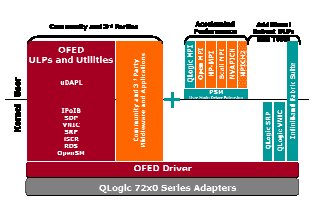
# Overview

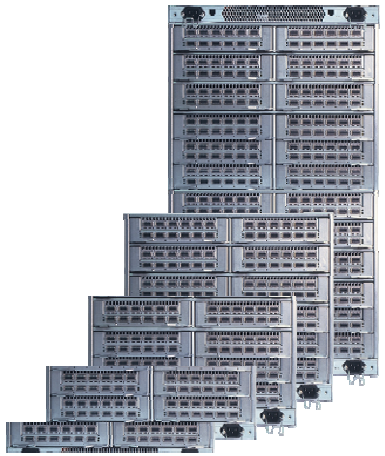
- QLogic Background
- InfiniBand Host Channel Adapters
- MPI Benchmarks for
  High core-count nodes & clusters

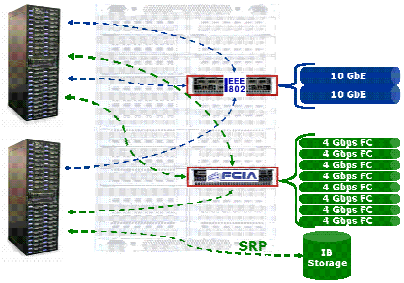
# QLogic Acquired Two Leading InfiniBand Companies in 2006

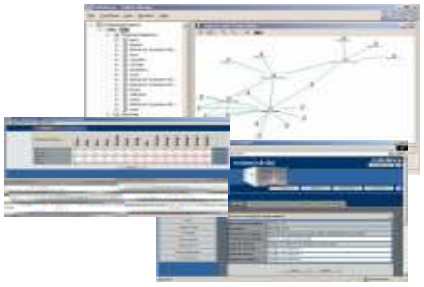
# Complete InfiniBand Solution

- HPC oriented Host Channel Adaptors
- OFED Plus software stacks
- High Port-count Director Switches
- Edge Switches
- Multi-protocol gateways
- Cables
- InfiniBand Fabric Management
- InfiniBand Silicon
- Worldwide Support





# QLogic commitment to HPC

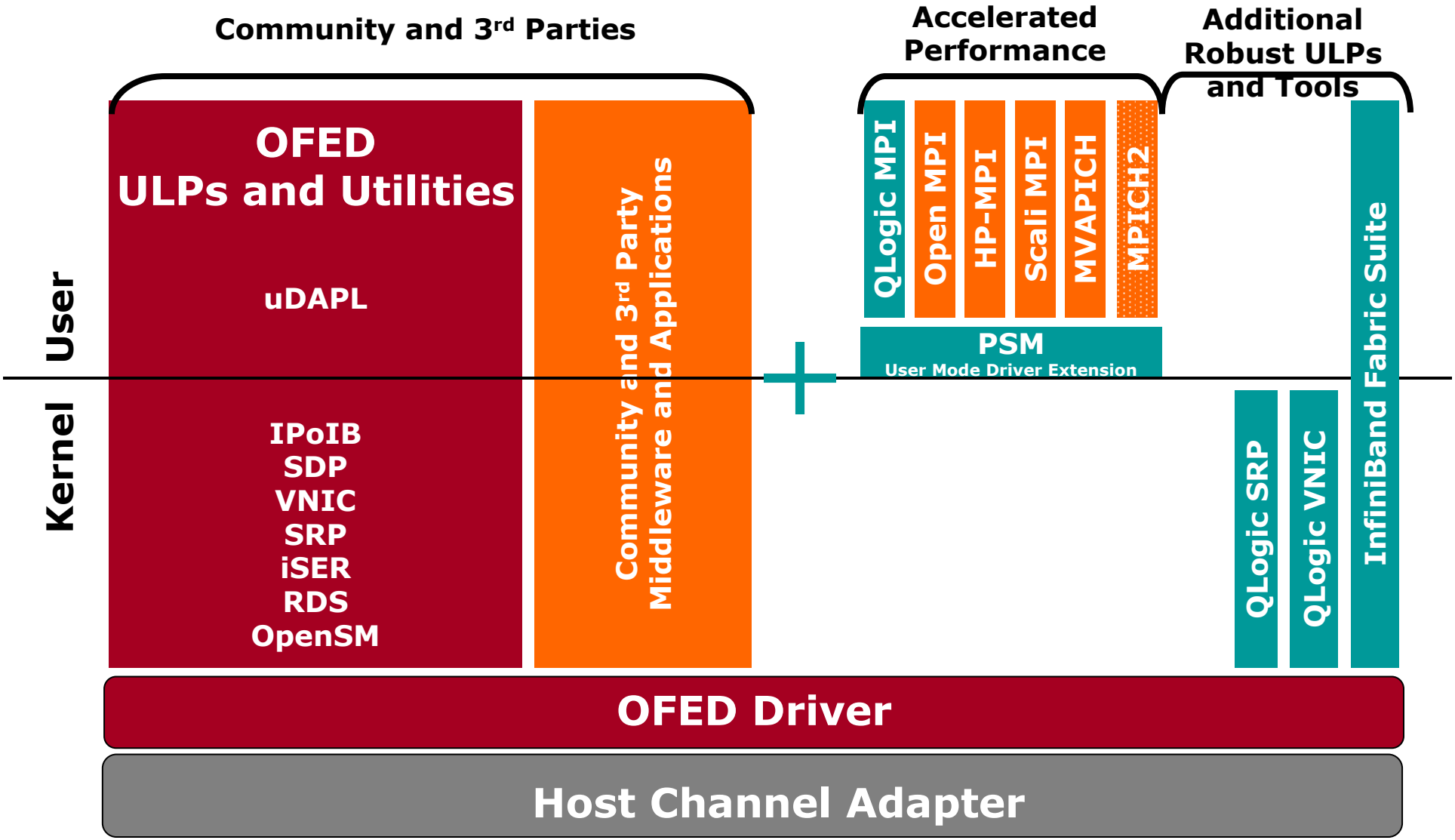
- **Application performance steered development**
  - SPEC HPG member and contributor to MPI2007
  - InfiniBand DDR fabric for bandwidth-intensive apps
  - QLogic InfiniPath HCAs for latency and message-rate sensitive apps

- **Two paths to the interconnect**
  1. OpenFabrics driver and libraries interoperate with the InfiniBand ecosystem and high-performance storage
  2. QLogic-specific libraries evolve as a top-down software stack; leverages ASIC capabilities specifically for HPC Apps and parallel programming models.

# QLogic InfiniBand HCAs

- **In this presentation**
  - QLogic DDR (20 Gbit/s) HCAs
    - QLE7240, PCIe x8
    - QLE7280, PCIe x16
  - QLogic SDR (10 Gbit/s) HCA
    - QLE7140, PCIe x8

# OFED+ Provides OpenFabrics Benefits Plus Optional Value Added Capabilities



# What is the spectrum of MPI benchmarks?

- **Microbenchmarks include (there are more):**
  - OSU MPI Benchmarks (OMB)
  - Intel MPI Benchmarks (IMB) formerly Pallas
- **Mid-level Benchmarks**
  - HPC Challenge
  - Linpack, e.g. HPL
  - NAS Parallel Benchmarks (NPB)
- **Application Benchmark Suites**
  - SPEC MPI2007
  - TI-0n (TI-06, TI-07, TI-08) DOD benchmarks
- **Your MPI application**

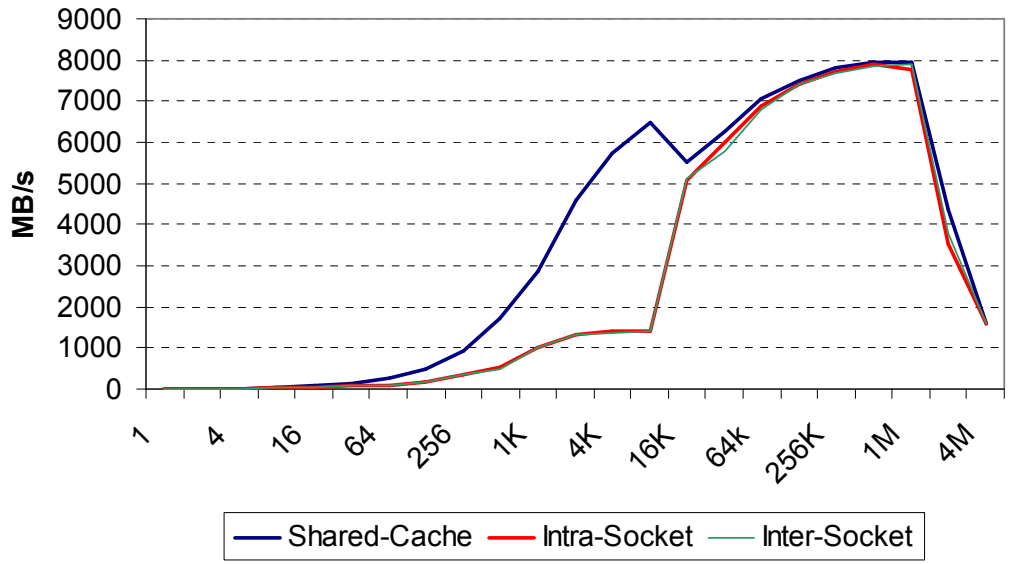
# OSU MPI Benchmarks applicable to high-core-count nodes


- **The MVAPICH group publishes results on one node**
  - Intra-node MPI performance importance growing as nodes grow their core-counts
  - Pure MPI applications under some competition from more complex hybrid OpenMP – MPI styles of development
- **OMB includes the Multiple Bandwidth, Message Rate test**
- **OMB v3.1 has added a benchmark: Multiple Latency test (osu_multi_lat.c)**

# Intra-node MPI Bandwidth measurement

- **Most current MPIs use shared-memory copies for intra-node communications – might expect that they all do equally well**
- **QLogic PSM 2.2 provides a large improvement in intra-node bandwidth; All MPIs it supports (MVAPICH, Open MPI, HP-MPI, Scali, QLogic) get the benefit.**
  - Results in a 2% improvement in average applications performance (SPEC MPI2007 on 8x 4-core nodes)

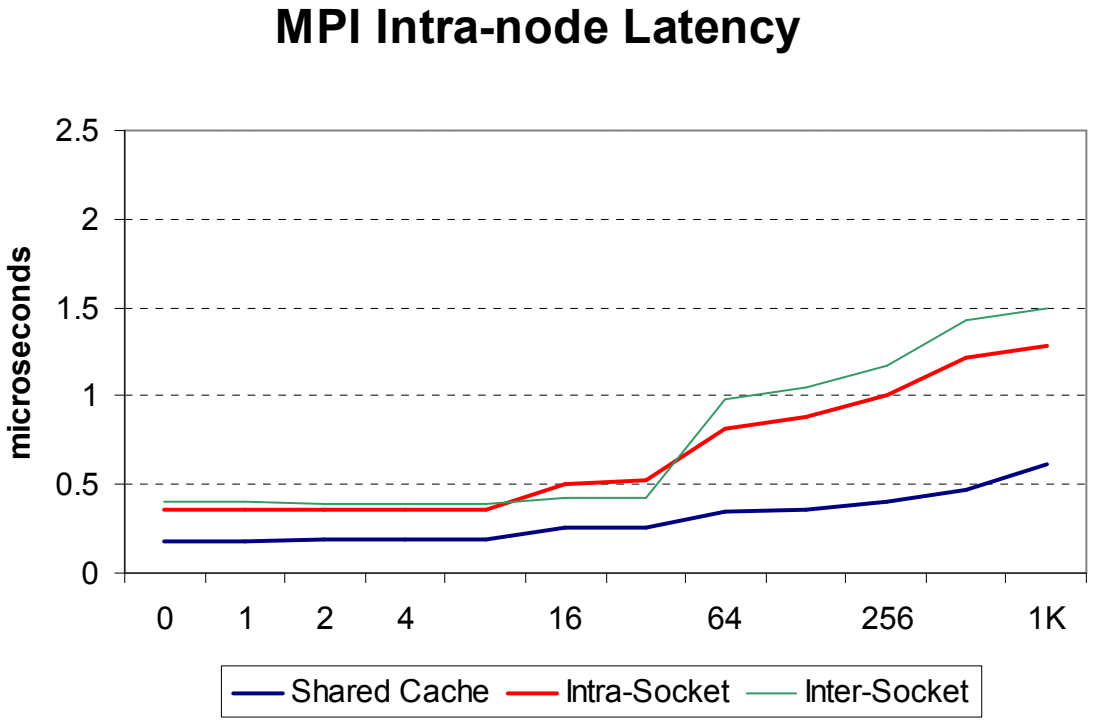
**MPI Intra-node Bandwidth (osu_bw)**




Measured on one node w/ Xeon E5410 2.33 GHz quad-core CPUs, 8-cores; QLogic InfiniPath 2.2 software

# Intra-node MPI Latency measurement

- Most current MPIs use shared-memory copies for intra-node communications – might expect that they all do equally well
- QLogic PSM 2.2 provides a nice improvement in intra-node latency; All MPIs it supports (MVAPICH, Open MPI, HP-MPI, Scali, QLogic) get the benefit.

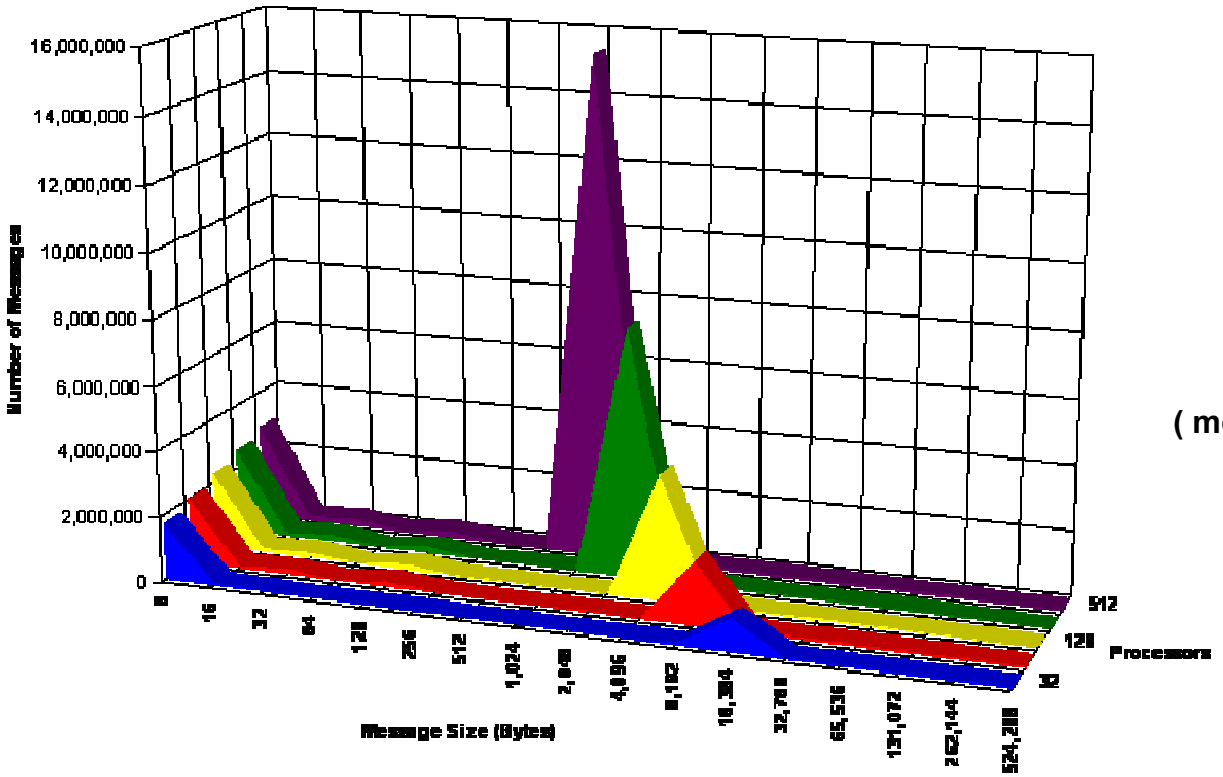



Lower is better

Measured on one node w/ Xeon E5472 3.0 GHz quad-core CPUs, 8-cores; QLogic InfiniPath 2.2 software

# Relationship of applications to micro-benchmarks

- **As the number of processors is increased:**
  - Message size goes down (→ small-message latency)
  - Number of messages goes up (→ message rate)

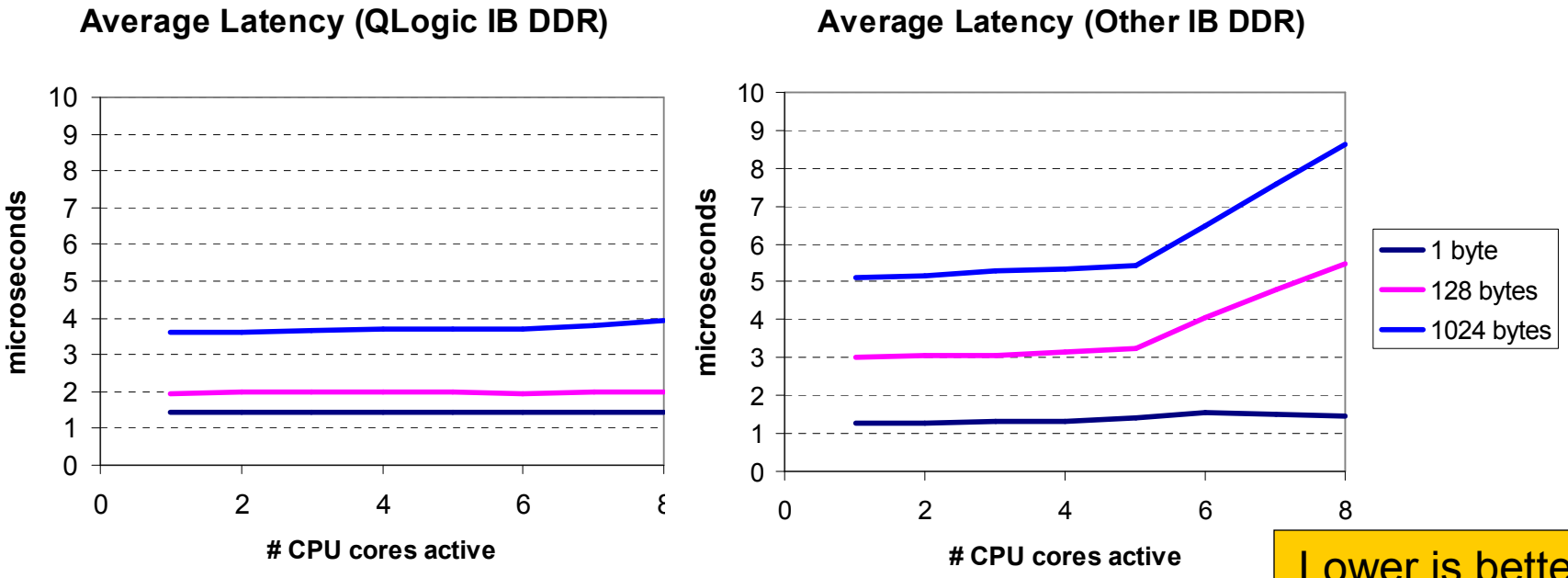



**DL Poly**

**( molecular dynamics)**

# New OSU Multiple Latency Test

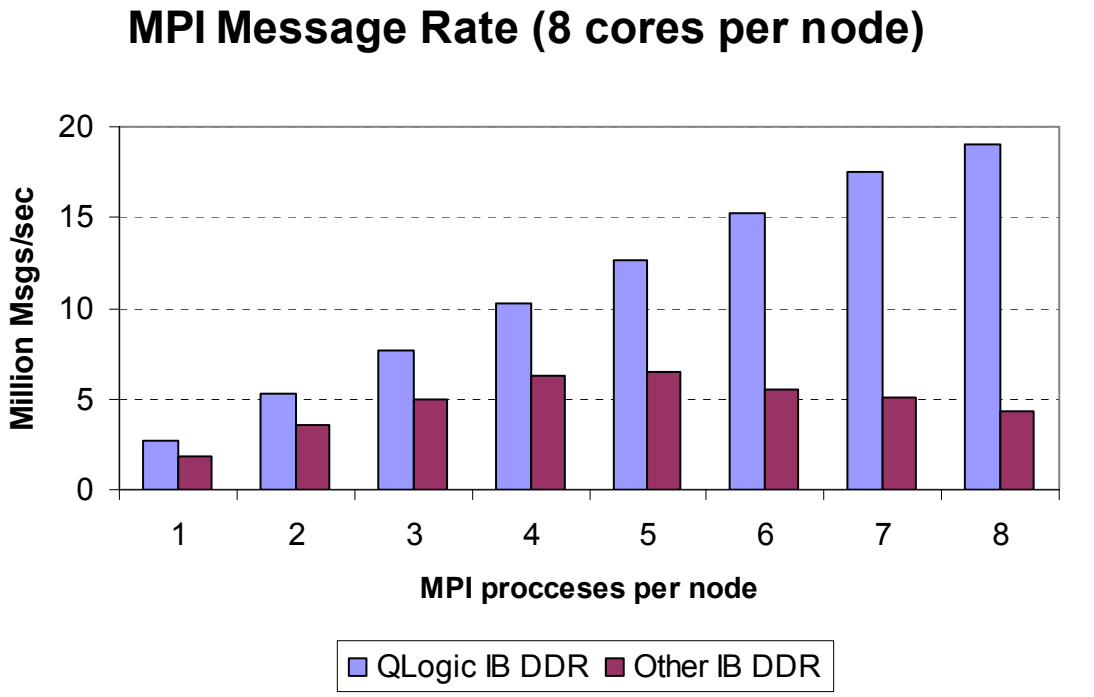
- Measure avg. latency as you add active cores running the latency benchmark in parallel
- Interesting to measure on large core-count nodes, and at multiple small message sizes …




Measured on 2x Xeon E5410 2.33 GHz quad-core CPUs, 8-cores per node; both PCIe x8, DDR InfiniBand Adapters; benchmark is osu_multilat.c

# MPI Message Rate

- **Using osu_mbw_mr to measure Message Rate:**
  - Measure at several processes per node counts
  - See if results scale with additional processes per node

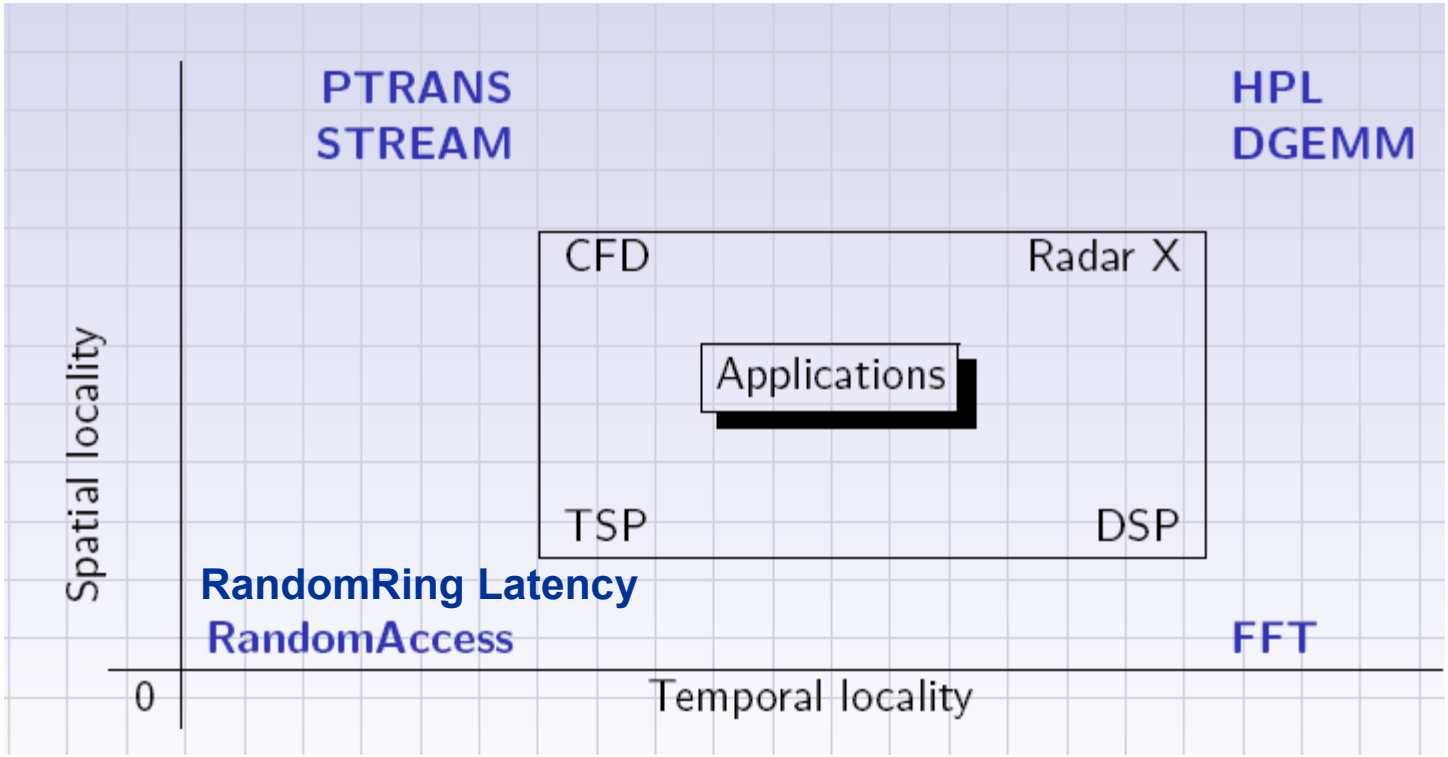



Higher is better

Measured on 2x Xeon E5410 2.33 GHz quad-core CPUs, 8-cores per node; both PCIe x8, DDR InfiniBand Adapters

# HPC Challenge Overview

- **HPC Challenge component benchmarks are intended to test very different memory access patterns**



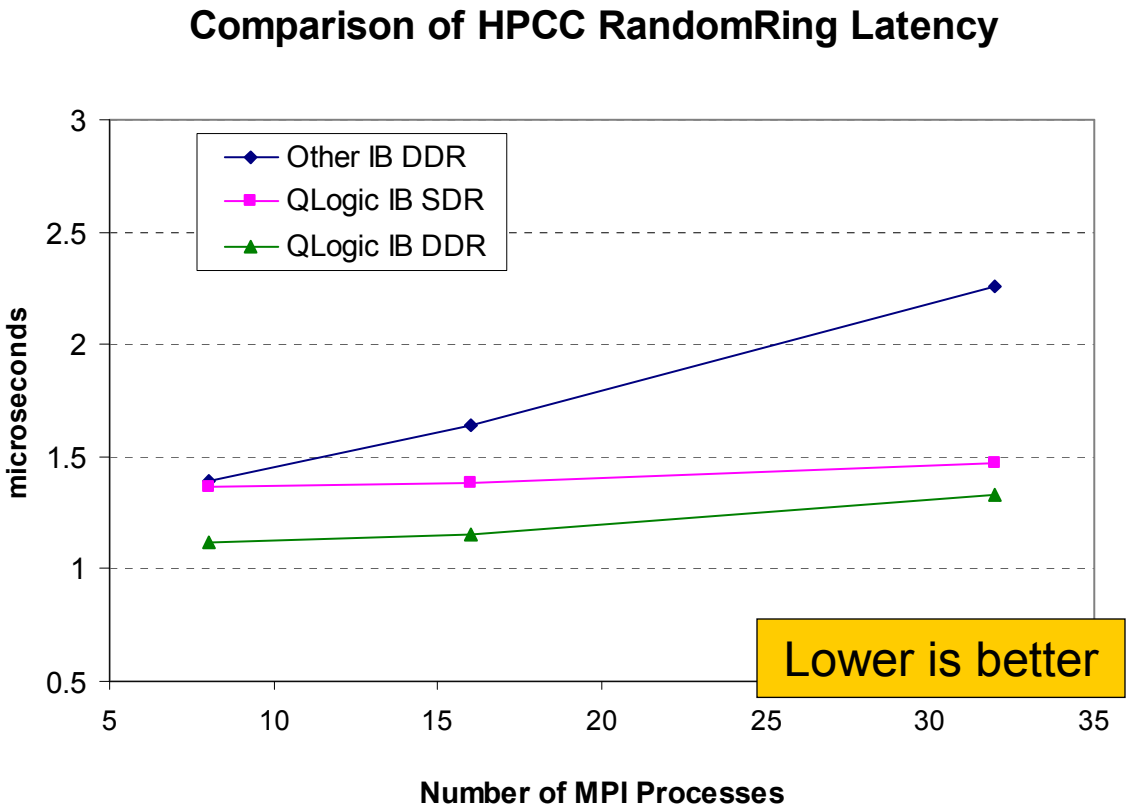

Source: "HPC Challenge Benchmark," Piotr Luszczek, University of Tennessee Knoxville, SC2004, November 6-12, 2004, Pittsburgh, PA

# Relationship of HPC Challenge to Point-to-Point benchmarks

- **Are there benchmarks in HPCC that focus on latency, bandwidth & message rate but involve more of the cluster than 2 cores on 2 nodes, or 16 cores on 2 nodes?**
  - Latency: Random Ring Latency
  - Bandwidth: PTRANS and Random Ring Bandwidth
  - Message Rate: MPI Random Access

# Scalable Latency: Number of cores

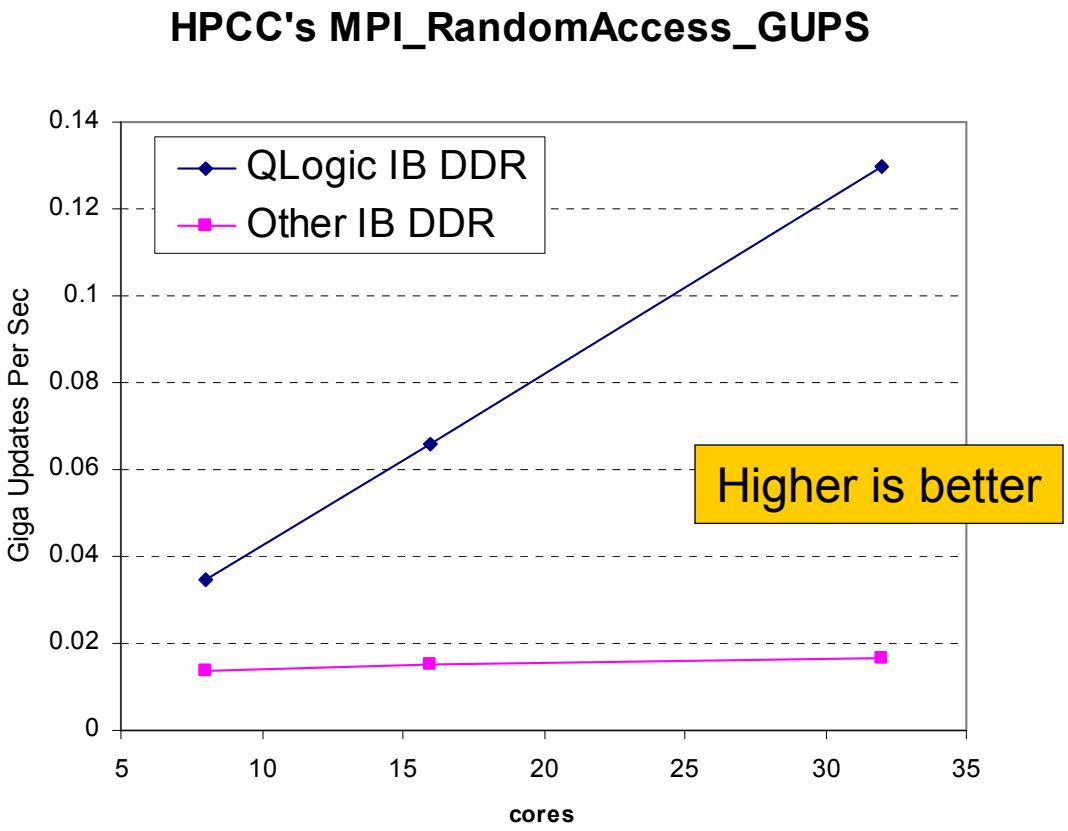
- **QLogic HCAs' MPI latency scales better with larger clusters**
- **QLogic InfiniBand DDR advantage over Other InfiniBand DDR is**
  - **70%** at 8 nodes, 32 cores




From a **QLogic white paper**: "Understanding Low and Scalable Message Passing Interface Latency" available at http://www.qlogic.com/EducationAndResources/WhitePapersResourcelibraryHpc.aspx

# Scalable Message Rate: GUPS

- QLogic QLE7200 series HCAs Message Rates scales better
- 8x faster than Other InfiniBand DDR HCA at 32 cores (and advantage climbing)
- GUPS = Giga (Billion) Updates Per Second are a measure of the rate at which messages can be sent to/from random cluster nodes/cores.




* QLogic measurements, one QLogic SilverStorm 9024 DDR switch, 8 Systems: 2 x 2.6 GHz Opteron 2218 CPUs, 8 GB DDR2-667 memory; NVIDIA MCP55 PCIe chipset. Base MPI RandomAccess source code used – no source tweaks to reduce # of messages sent.

# Application Benchmarks

# Application Benchmarks: SPEC MPI2007

- **Suite that measures: CPU, memory, interconnect, MPI, compiler, and file system performance.**
- **SPEC institutes discipline and fairness in benchmarking:**
  - Rigorous run rules
  - All use same source code, or performance-neutral alternate sources
  - Disclosure rules: system, adapter, switch, firmware, driver, compiler optimizations, etc.
  - Peer review of submissions
  - Therefore, more difficult to game

# SPEC MPI2007 Benchmarks 1- 6

QLOGIC

| Benchmark | Language | Application Area | Brief Description |
|---|---|---|---|
| 104.milc | C | Quantum Chromodynamics | A gauge field generating program for lattice gauge theory programs with dynamical quarks |
| 107.leslie3d | Fortran | Computational Fluid Dynamics | CFD using Large-Eddy Simulations with linear-eddy mixing model in 3D. |
| 113.GemsFDTD | Fortran | Computational Electromagnetics | Solves the Maxwell equations in 3D using the finite-difference time-domain (FDTD) method |
| 115.fds4 | Fortran | CFD: Fire dynamics simulator | A CFD model of fire-driven fluid flow, with an emphasis on smoke and heat transport from fires |
| 121.pop2 | Fortran/C | Climate Modeling | The Parallel Ocean Program (POP) developed at LANL |
| 122.tachyon | C | Graphics: Ray Tracing | A nearly E.P. parallel ray tracing program with low MPI usage |

# SPEC MPI2007 Benchmarks 7- 13

| Benchmark | Language | Application Area | Brief Description |
|---|---|---|---|
| 126.lammps | C++ | Molecular Dynamics | a classical molecular dynamics simulation code designed for parallel computers |
| 127.wrf2 | C/Fortran | Weather Forecasting | Code is based on the Weather Research and Forecasting (WRF) Model |
| 128.GAPgeofem | C/Fortran | Heat Transfer using FEM | A parallel finite element method (FEM) code for transient thermal conduction with gap radiation |
| 129.tera_tf | Fortran | 3D Eulerian Hydrodynamics | Code uses a 2nd order Gudenov scheme and a 3rd order remapping |
| 130.socorro | C/Fortran | Molecular Dynamics | Molecular Dynamics using density-functional theory (DFT) |
| 132.zeusmp2 | Fortran | Computational Astrophysics | Performs various hydrodynamic simulations on 1, 2, and 3D grids |
| 137.lu | Fortran | Implicit CFD | Solves a regular sparse block Lower- and Upper-triangular system using SSOR |

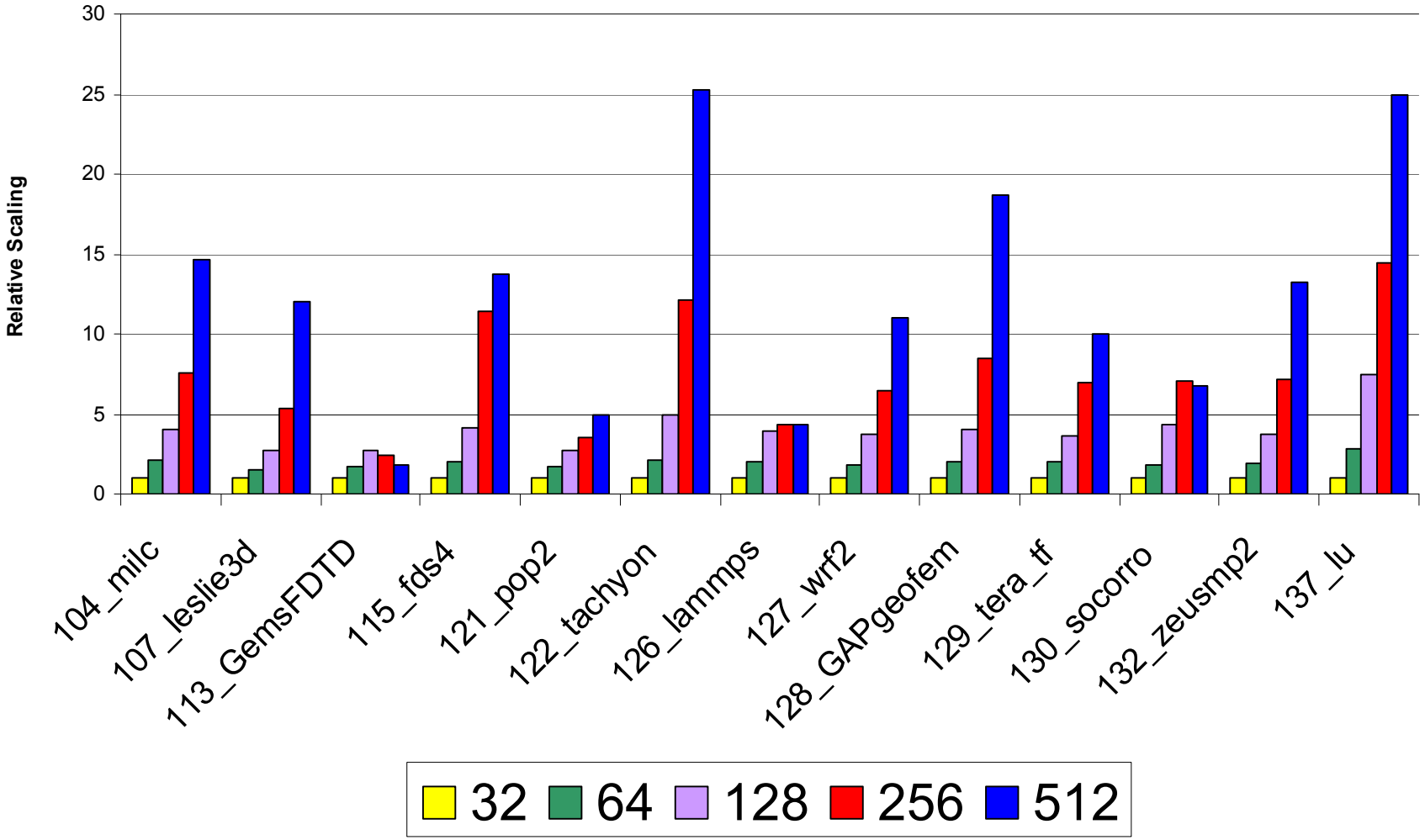
# SPEC MPI2007 on the web

- Result score is an average of ratios for each of 13 codes: the ratio of the run time of a code on your system to the runtime on the reference platform (1st listed).

| Test Sponsor | System Name | System Configuration | | | | Results | |
|---|---|---|---|---|---|---|---|
| | | MPI Ranks | Compute Threads Used | Compute Nodes Used | Compute Cores Enabled | Base | Peak |
| Advanced Micro Devices | A2210 ("Serenade") -- Reference Platform HTML \| CSV \| Text \| PDF \| PS \| Config | 16 | 16 | 8 | 16 | 0.999 | 0.999 |
| Hewlett-Packard Company | HP Proliant BL460c blade Cluster Platform 3000BL HTML \| CSV \| Text \| PDF \| PS \| Config | 128 | 128 | 32 | 128 | 11.9 | Not Run |
| Hewlett-Packard Company | HP Proliant BL460c blade Cluster Platform 3000BL HTML \| CSV \| Text \| PDF \| PS \| Config | 256 | 256 | 64 | 256 | 19.8 | Not Run |
| Hewlett-Packard Company | HP Proliant BL460c blade Cluster Platform 3000BL HTML \| CSV \| Text \| PDF \| PS \| Config | 64 | 64 | 16 | 64 | 6.39 | Not Run |
| Hewlett-Packard Company | HP Proliant BL460c blade Cluster Platform 3000BL HTML \| CSV \| Text \| PDF \| PS \| Config | 32 | 32 | 8 | 32 | 3.40 | Not Run |
| Hewlett-Packard Company | HP Proliant BL460c blade Cluster Platform 3000BL HTML \| CSV \| Text \| PDF \| PS \| Config | 16 | 16 | 4 | 16 | 1.75 | Not Run |
| Intel Corporation | Endeavor HTML \| CSV \| Text \| PDF \| PS \| Config | 256 | 256 | 32 | 256 | 18.5 | Not Run |
| Intel Corporation | Endeavor HTML \| CSV \| Text \| PDF \| PS \| Config | 32 | 32 | 4 | 32 | 3.05 | Not Run |
| Intel Corporation | Endeavor HTML \| CSV \| Text \| PDF \| PS \| Config | 64 | 64 | 8 | 64 | 6.21 | Not Run |
| Intel Corporation | Endeavor HTML \| CSV \| Text \| PDF \| PS \| Config | 128 | 128 | 16 | 128 | 11.6 | Not Run |

# Scaling with SPEC MPI2007

## Scaling by application to 512 Cores



# In Summary

- **The best benchmark is "your application,"** particularly since they are usually run on all cores of the nodes used on the job.
- **There is a range of MPI benchmarks because they all have their place:**
  - microbenchmarks are easier, quicker to run and are evolving to test multi-core nodes
  - application benchmarks are a bit more difficult to run, but are a better predictor of performance across a range of applications
- **Benchmarks are evolving to serve the needs of ever-expanding multi-core systems**