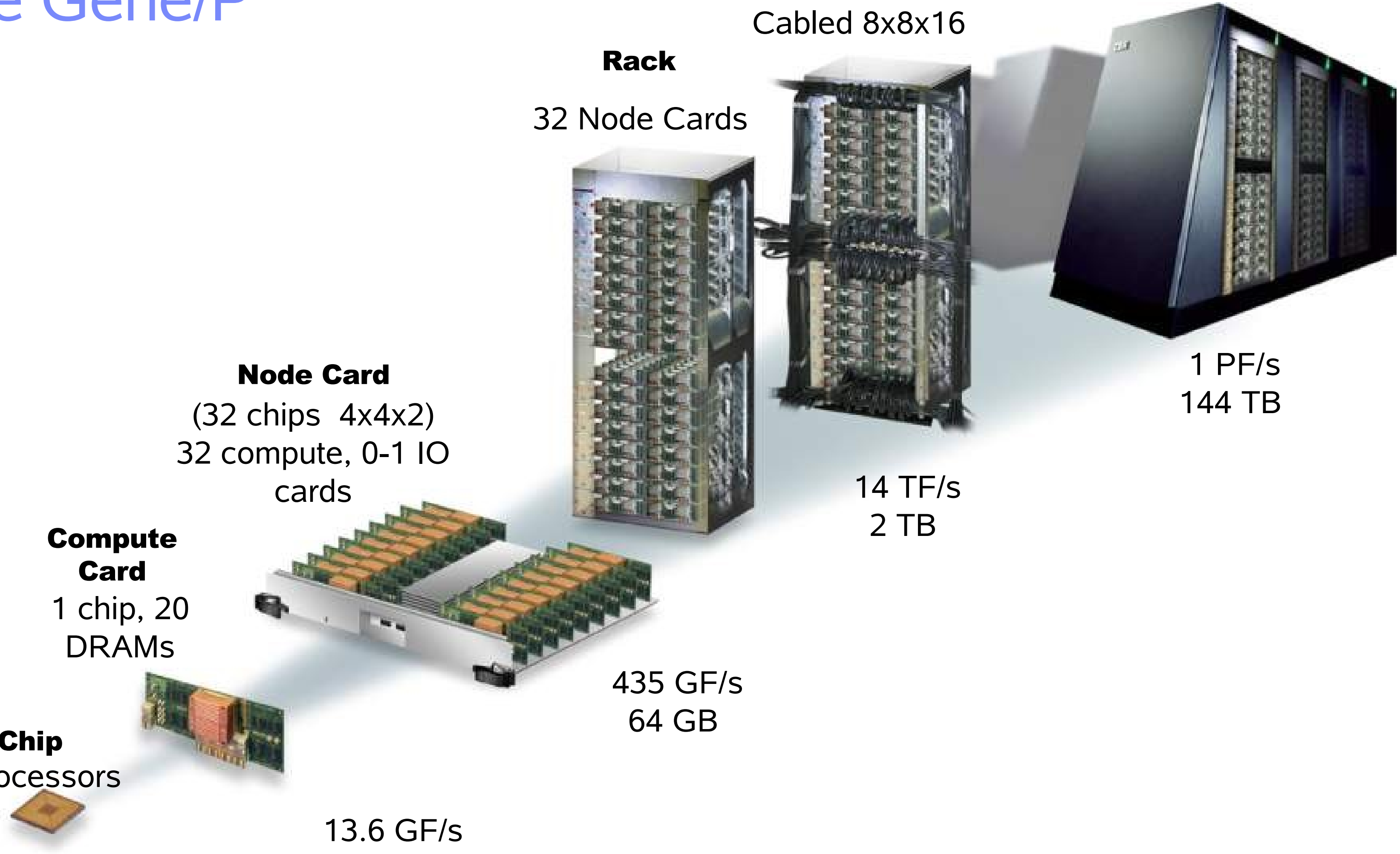
Porting Applications to Blue Gene/P

Dr. Christoph Pospiech pospiech@de.ibm.com

Agenda

- **What beast is this ?**
- Compile - link – go !
- MPI subtleties
- Help ! It doesn't work (the way I want) !

Blue Gene/P



Chip
4 processors

13.6 GF/s
8 MB
EDRAM

Compute Card
1 chip, 20 DRAMs

13.6 GF/s
2.0 (or 4.0) GB
DDR

Node Card
(32 chips 4x4x2)
32 compute, 0-1 IO cards

435 GF/s
64 GB

Rack

32 Node Cards

14 TF/s
2 TB

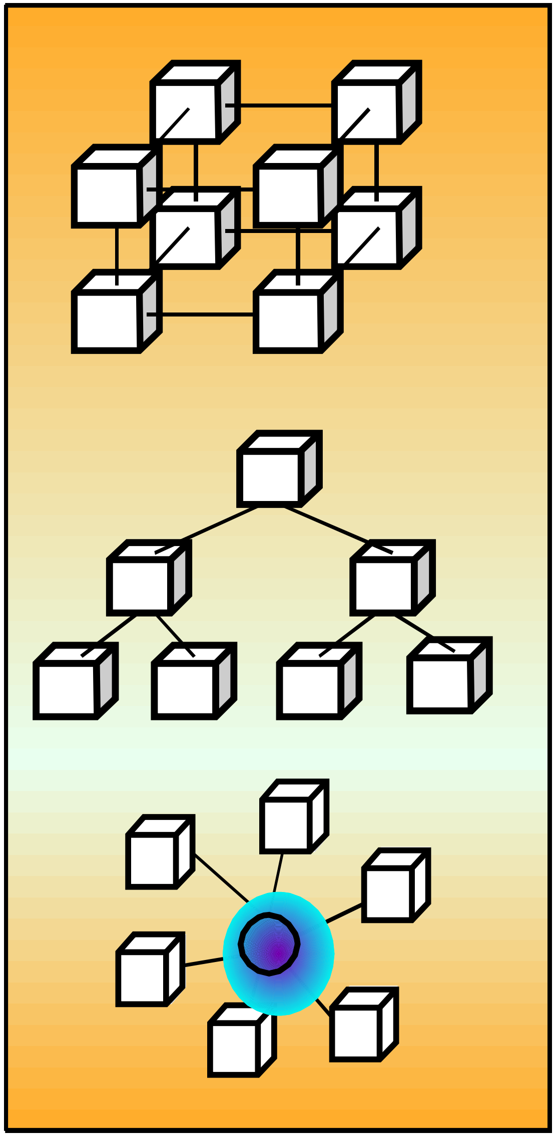
Cabled 8x8x16

System

72 Racks

1 PF/s
144 TB

Blue Gene/P Spider Webs



3 Dimensional Torus

- Interconnects all compute nodes (73,728)
- Virtual cut-through hardware routing
- 3.4 Gb/s on all 12 node links (5.1 GB/s per node)
- 0.5 µs latency between nearest neighbors, 5 µs to the farthest
- MPI: 3 µs latency for one hop, 10 µs to the farthest
- Communications backbone for computations
- 1.7/3.9 TB/s bisection bandwidth, 188TB/s total bandwidth

Collective Network

- One-to-all broadcast functionality
- Reduction operations functionality
- 6.8 Gb/s of bandwidth per link
- Latency of one way tree traversal 1.3 µs, MPI 5 µs
- ~62TB/s total binary tree bandwidth (72k machine)
- Interconnects all compute and I/O nodes (1152)

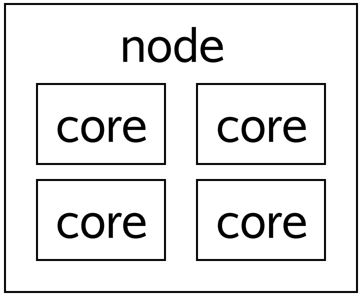
Low Latency Global Barrier and Interrupt

- Latency of one way to reach all 72K nodes 0.65 µs, MPI 1.6 µs

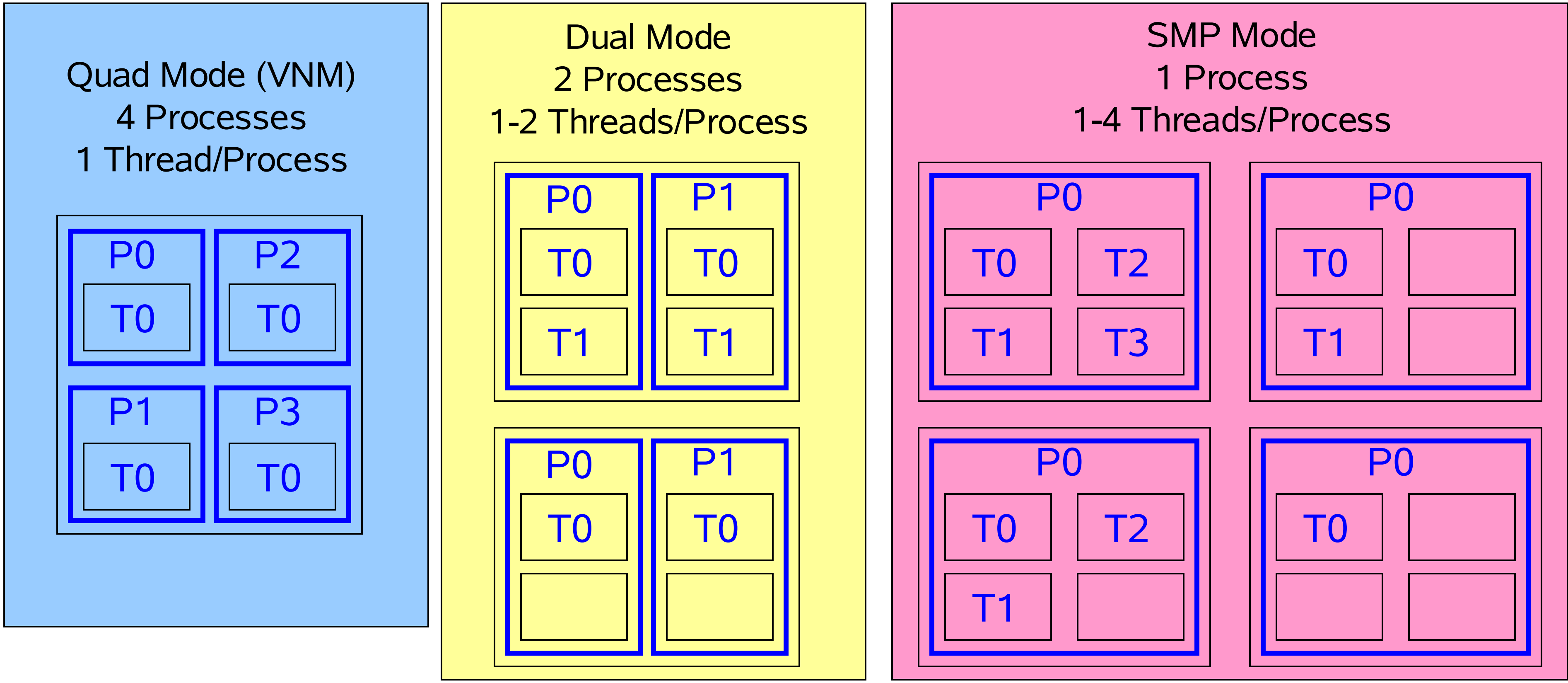
Other networks

- 10Gb Functional Ethernet
- I/O nodes only
- 1Gb Private Control Ethernet
- Provides JTAG access to hardware. Accessible only from Service Node system

You have the choice !



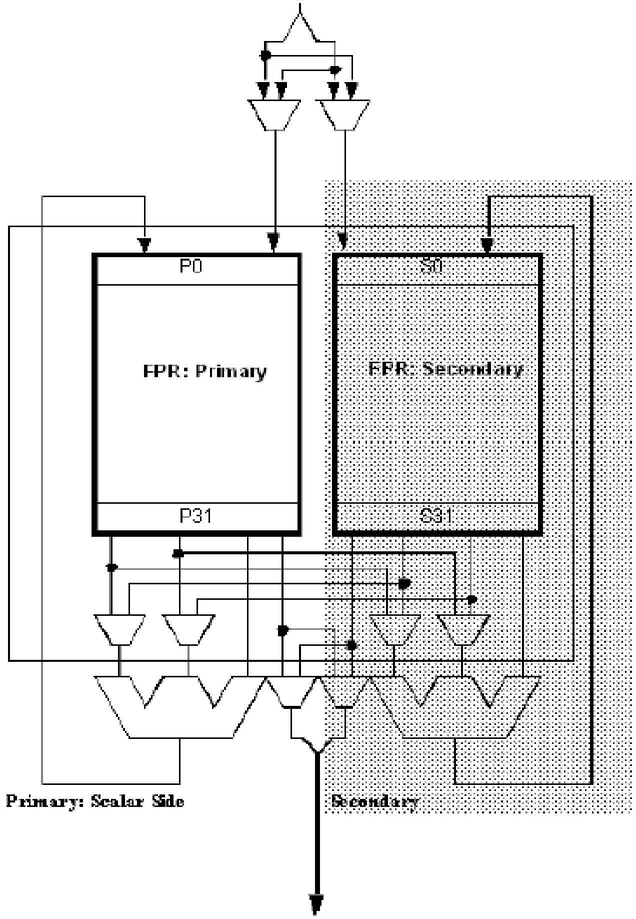
Software Abstractions Blue


Quad Mode (VNM)
4 Processes
1 Thread/Process

Dual Mode
2 Processes
1-2 Threads/Process

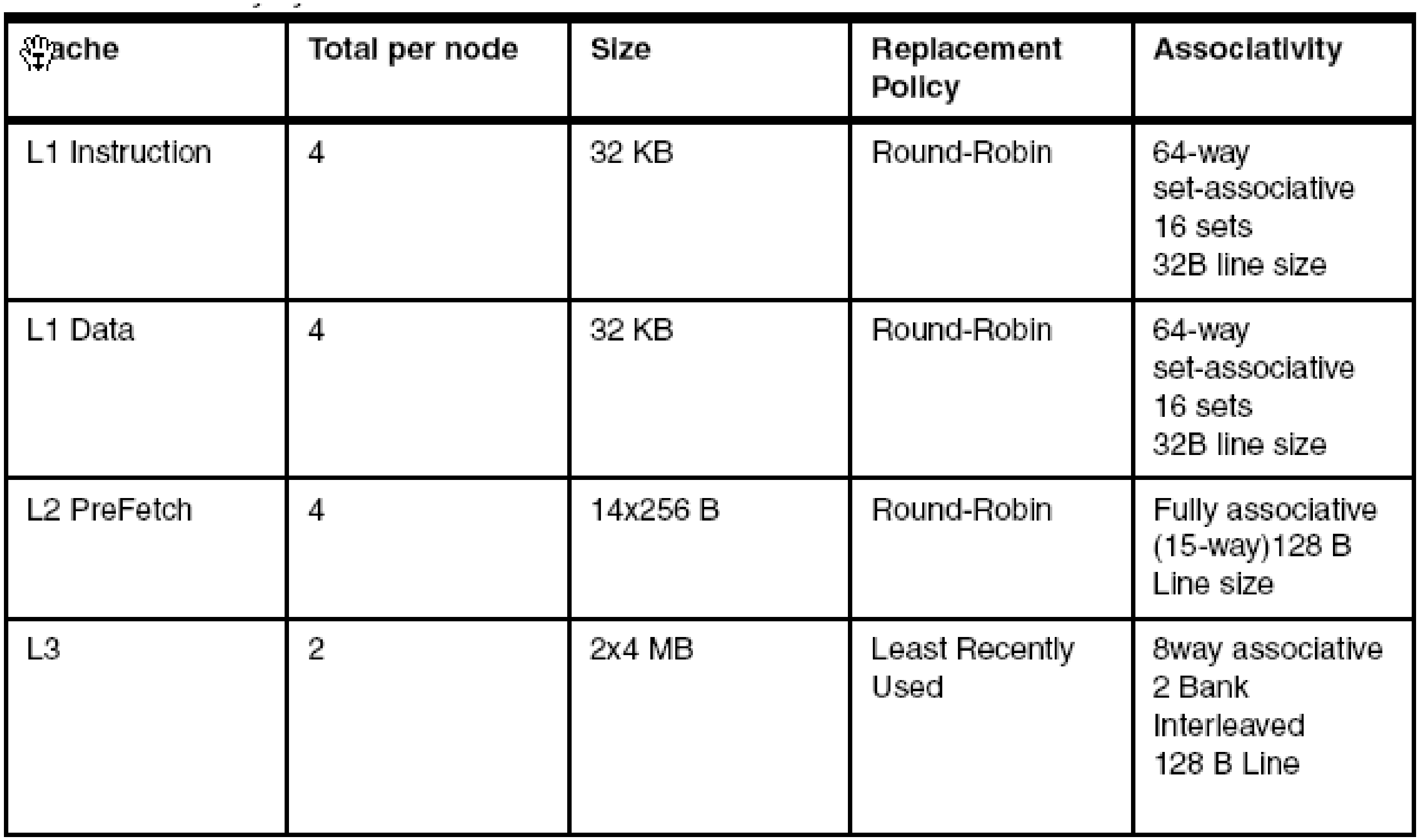
SMP Mode
1 Process
1-4 Threads/Process

Dual FPU Architecture



- SIMD instructions over both register files
- FMA operations over double precision data
- Parallel (quadword) loads/stores
- Data needs to be 16-byte aligned

Caches



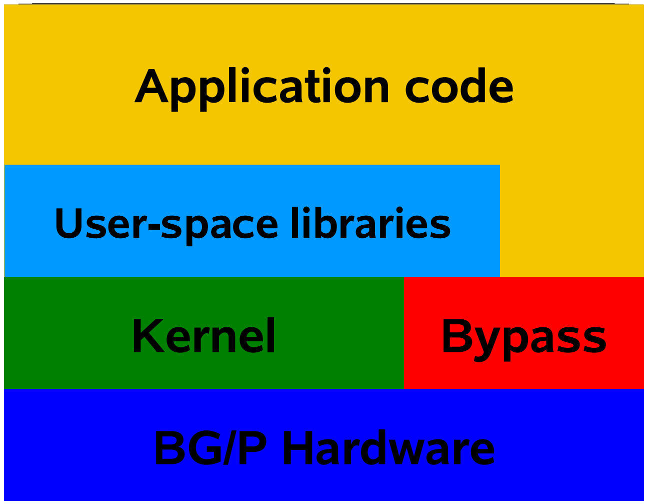
Cache	Total per node	Size	Replacement Policy	Associativity
L1 Instruction	4	32 KB	Round-Robin	64-way set-associative 16 sets 32B line size
L1 Data	4	32 KB	Round-Robin	64-way set-associative 16 sets 32B line size
L2 PreFetch	4	14x256 B	Round-Robin	Fully associative (15-way)128 B Line size
L3	2	2x4 MB	Least Recently Used	8way associative 2 Bank Interleaved 128 B Line

Jitter-free Execution

- **Compute node runs nothing but application**
- **I/O delegated to I/O nodes**
- **Cross-Compiling on the front end node**

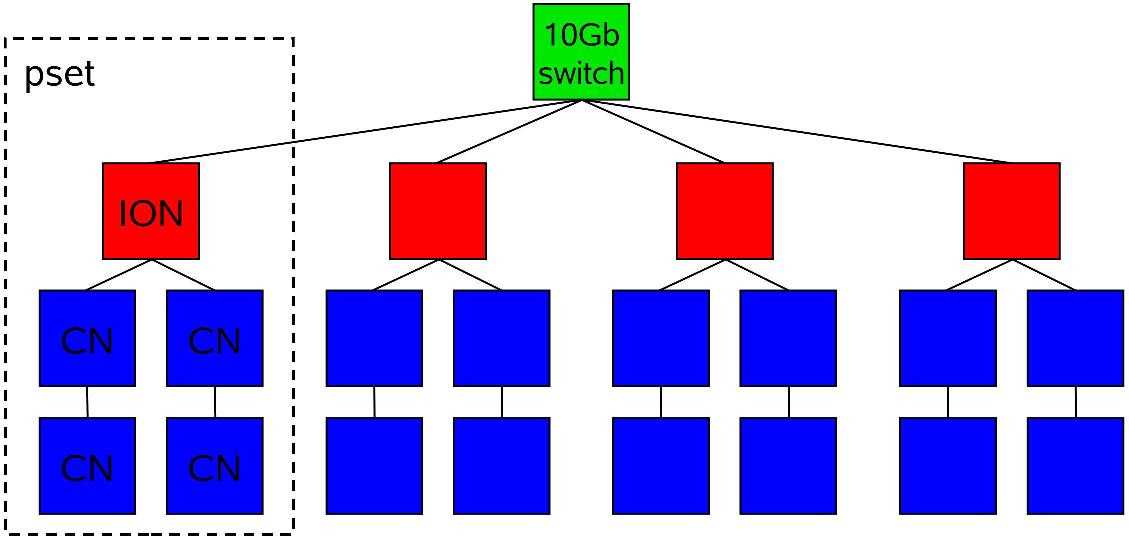
Software Stack in Blue Gene Compute Node

- Compute Node Kernel (CNK) controls access to hardware, and enables bypass for application use
- User-space libraries and applications can directly access torus and collective network through bypass
- Application code can use all processors in a compute node



Processing Sets (Psets)

- **I/O node dedicated to a fixed group of compute nodes**
- **Compute to I/O ratio is fixed within a partition**
  - 128:1, 64:1, 32:1, 16:1



I/O Node Kernel

- **SMP Linux**
- **No persistent store (network filesystems only; no swap)**
- **10Gb Ethernet interface**
- **Several CNK System calls are function shipped to here**
  - Linux compatibility by executing these syscalls on Linux
  - Function ship occurs over Collective network
  - The ciod daemon manages a fixed set of compute nodes in a processing set (pset)
  - Linux provides the portable filesystem and network layer interfaces

Agenda

- What beast is this ?
- **Compile - link – go !**
- MPI subtleties
- Help ! It doesn't work (the way I want) !

Getting started is simple

- …for simple cases
- BGP_SYS=/bgsys/drivers/ppcfloor
- make CC=$BGP_SYS/comm/bin/mpixlc_r
- llrun -mode VN -np 512 ./hello_par

IBM XL Compilers for Blue Gene

- **XLF 11.1/VACPP 9.0 will be the compiler releases**
  - /opt/ibmcmp/xlf/bg/11.1/bin
  - /opt/ibmcmp/vacpp/bg/9.0/bin
- **Differences in this release:**
  - xlf2003 (the 2003 Fortran standard) is available
  - BGP wrapper names are different
    - blrts_ is replaced by bg
    - bgxlf, bgxlc, bgcc, etc.
    - On BG/L for xlf 11.1/vacpp 9.0 both blrts_ and bg will be supported.
  - -qarch=450d/450 are accepted in addition to 440d/440

Some key options for IBM compilers

- -qarch=440, 450 generates only instructions for one floating point (option minimal option with blrts_)
- -qarch=440d, 450d generates only instructions for 2 floating point pipes
- -qtune=440
- -O3 (-qstrict) minimal level for SIMDization
- -O3 –qhot (=simd)
- -O4 (-qnoipa)
- -O5
- -qdebug=diagnostic provide details about SIMDization, only with –qhot
- -qreport –qlist –qsource provide pseudo-assembler code .lst

What's new from BG/L …

- pthreads and OpenMP support
- Dynamic linking
- Use of mmap for shared memory
- Protected readonly data and application code
- Protection for stack overflow
- Full socket support (client and server)

ESSL for Blue Gene

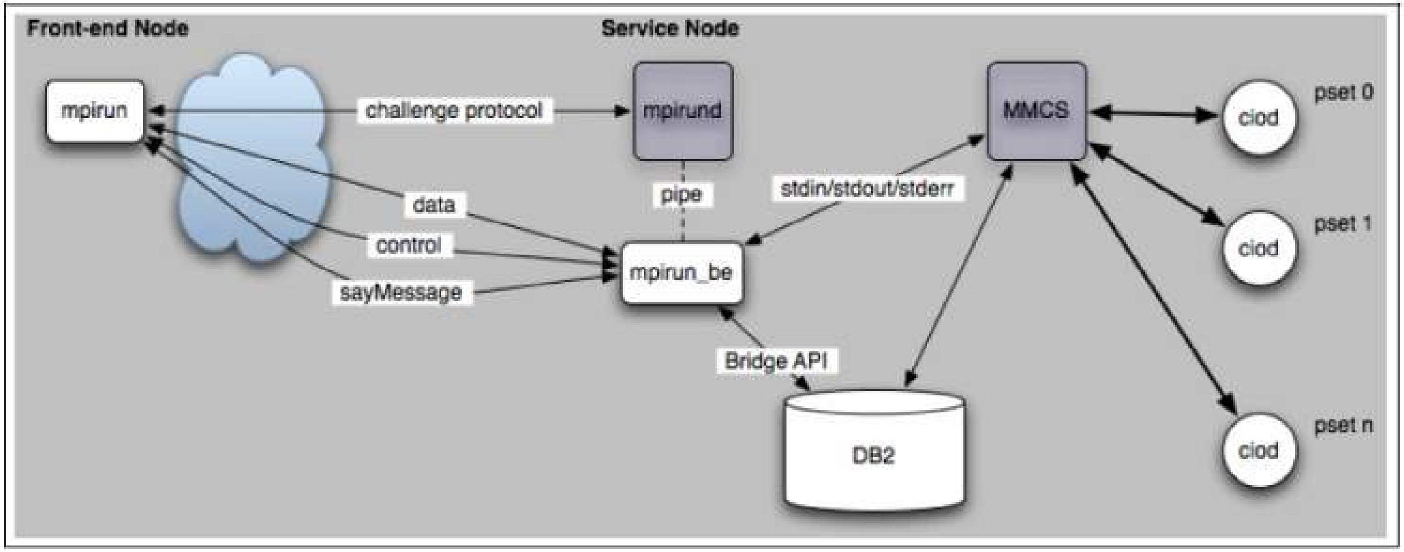
- **Engineering and Scientific Subroutine Library**
- **Optimization library and intrinsics for better application performance**
- **Serial Static Library supporting 32-bit applications**
- **Callable from FORTRAN, C, and C++**
- **SMP support and ppc450 tuning done for BG/P**
- **libesslbg.a (.so) and libesslsmpbg.a (.so)**

Lib Mass for Blue Gene

- **Mathematical Acceleration Subsystem (MASS) libraries) consists of libraries of tuned mathematical intrinsic functions**
- **Location:**
  - /opt/ibmcmp/xlmass/bg/4.4/bglib
    - libmass.a libmassv.a
  - /opt/ibmcmp/xlmass/bg/4.4/include

MPIRUN implementation on BGP

- no rsh/ssh mechanism
- Option -free
- STDIN handling



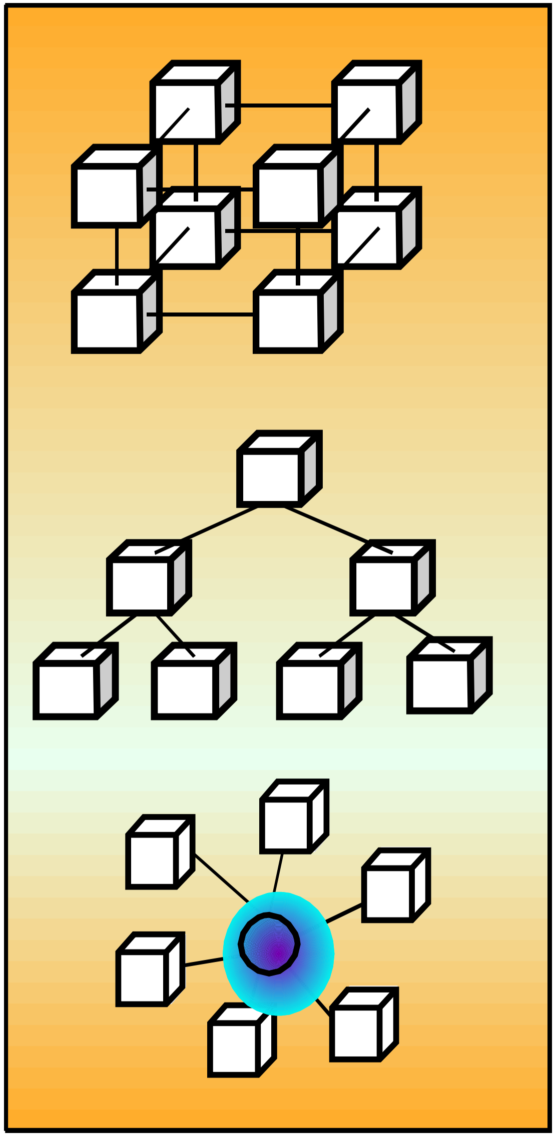
Partitioning

- **Subdivision of a single Blue Gene system**
- **Partitions are software defined**
- **Torus, Collective and Barrier networks are completely isolated from traffic from other partitions**
- **A single job runs on a partition**
  - i.e. jobs never share resources or interfere with each other
- **Custom kernels may be booted in a partition**

Agenda

- What beast is this ?
- Compile - link – go !
- **MPI subtleties**
- Help ! It doesn't work (the way I want) !

Blue Gene/P Spider Webs



3 Dimensional Torus

- Interconnects all compute nodes (73,728)
- Virtual cut-through hardware routing
- 3.4 Gb/s on all 12 node links (5.1 GB/s per node)
- 0.5 µs latency between nearest neighbors, 5 µs to the farthest
- MPI: 3 µs latency for one hop, 10 µs to the farthest
- Communications backbone for computations
- 1.7/3.9 TB/s bisection bandwidth, 188TB/s total bandwidth

Collective Network

- One-to-all broadcast functionality
- Reduction operations functionality
- 6.8 Gb/s of bandwidth per link
- Latency of one way tree traversal 1.3 µs, MPI 5 µs
- ~62TB/s total binary tree bandwidth (72k machine)
- Interconnects all compute and I/O nodes (1152)

Low Latency Global Barrier and Interrupt

- Latency of one way to reach all 72K nodes 0.65 µs, MPI 1.6 µs

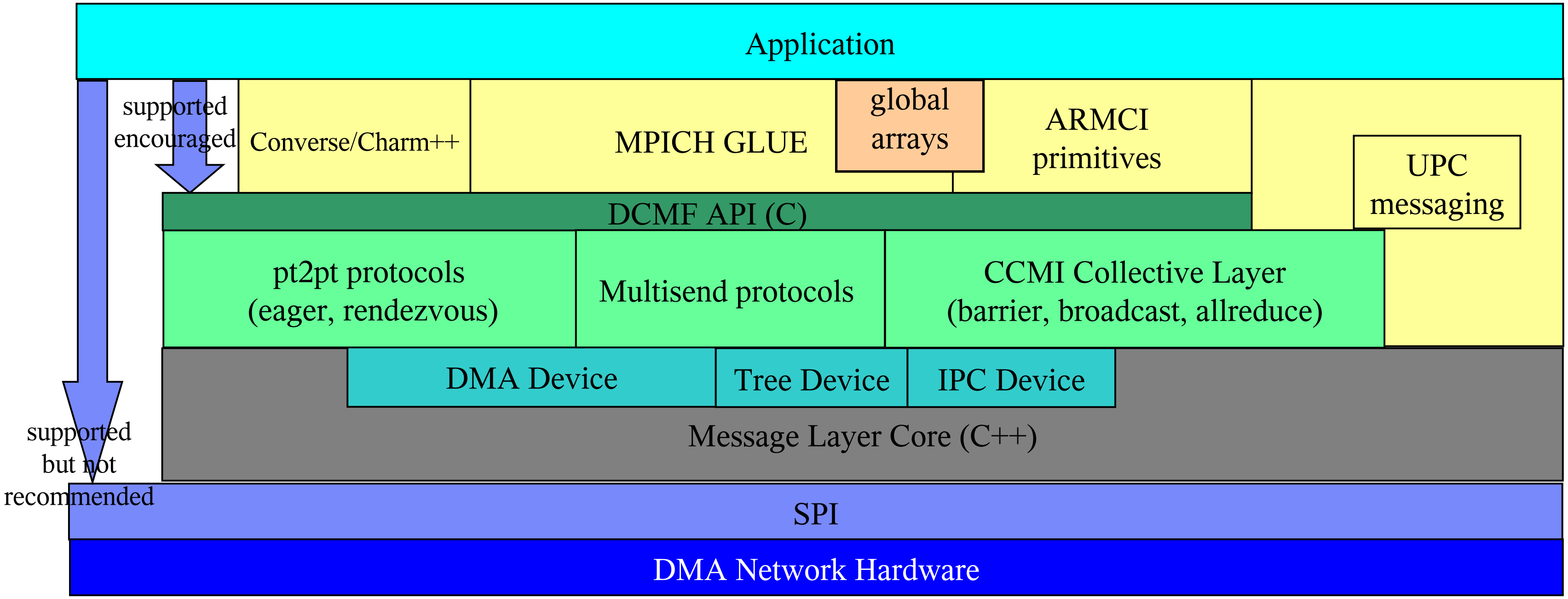
Other networks

- 10Gb Functional Ethernet
- I/O nodes only
- 1Gb Private Control Ethernet
- Provides JTAG access to hardware. Accessible only from Service Node system

Collectives

- **Use the hardware support in the collective network and global interrupt networks**
- **Supported operations**
  - Barrier
  - Broadcast
  - Allreduce
  - Alltoall
  - Allgather

Messaging Framework



Multiple programming paradigms supported

MPI, Charm++, ARMCI, GA, UPC (as a research initiative)

SPI : Low level systems programming interface

DCMF : Portable active-message API

Agenda

- What beast is this ?
- Compile - link – go !
- MPI subtleties
- **Help ! It doesn't work (the way I want) !**

Debugger Interfaces

- **ptrace-like interfaces available via ciod**
  - non-parallel: gdbserver for direct use with gdb
  - parallel: Totalview, or other tools
- **lightweight core files**
  - each node writes a small file with regs, traceback, etc
  - superset of parallel tools consortium format
  - Use addr2line for translating HEX into source lines
- **Coreprocessor**

GNU Debugger

- Simple debug server call «gdbserver »
- Only one gdb instance for one compute node (to debug multiple CNs at the same time you need to launch multipleGDB clients)
- Limited subset of primitives (however enough to be useful)
- Standard Linux gdb client, not aware about Double FPU.
- Gdserver must start before the application; mpirun has a special option «-start_gdbserver »
- Compile and link with –g (-O2)
- Location: /bgsys/drivers/ppcfloor/gnu-linux/bin

Performance Tools

- **Low level SPI provided to configure, reset and read hardware perf counters**
- **PAPI interface to the perf counters**
- **HPC Toolkit**
- **Considering addition of per-job performance metrics recorded via job history**
- **Unix gprof command (compiler with –g –pg)**

IBM High Performance Computing (HPC) Toolkit

- Message-passing performance
  - MP_Profiler (MPI and SHMEM)
  - MP_Trace (MPI and SHMEM)
  - SHMEM Library (Cray API) – AIX only
- CPU performance
  - Xprofiler
  - HPM (Hardware counters)
- Thread performance
  - Pomp Profiler (OpenMP)
- Memory performance
  - SiGMA memory profiler
  - Prediction Assistant
- Visualization and analysis
  - PeekPerf

More Information

- **IBM Redbooks for Blue Gene**
  - Application Development Guide
  - System Administration Guide
  - Performance Tools
- **Open Source Communities (Argonne website, …)**
- **BlueGene Rochester website**
  - http://bgweb.rchland.ibm.com/~jratt/
- ***Doxygen* documentations (DCMF, SPI, …)**