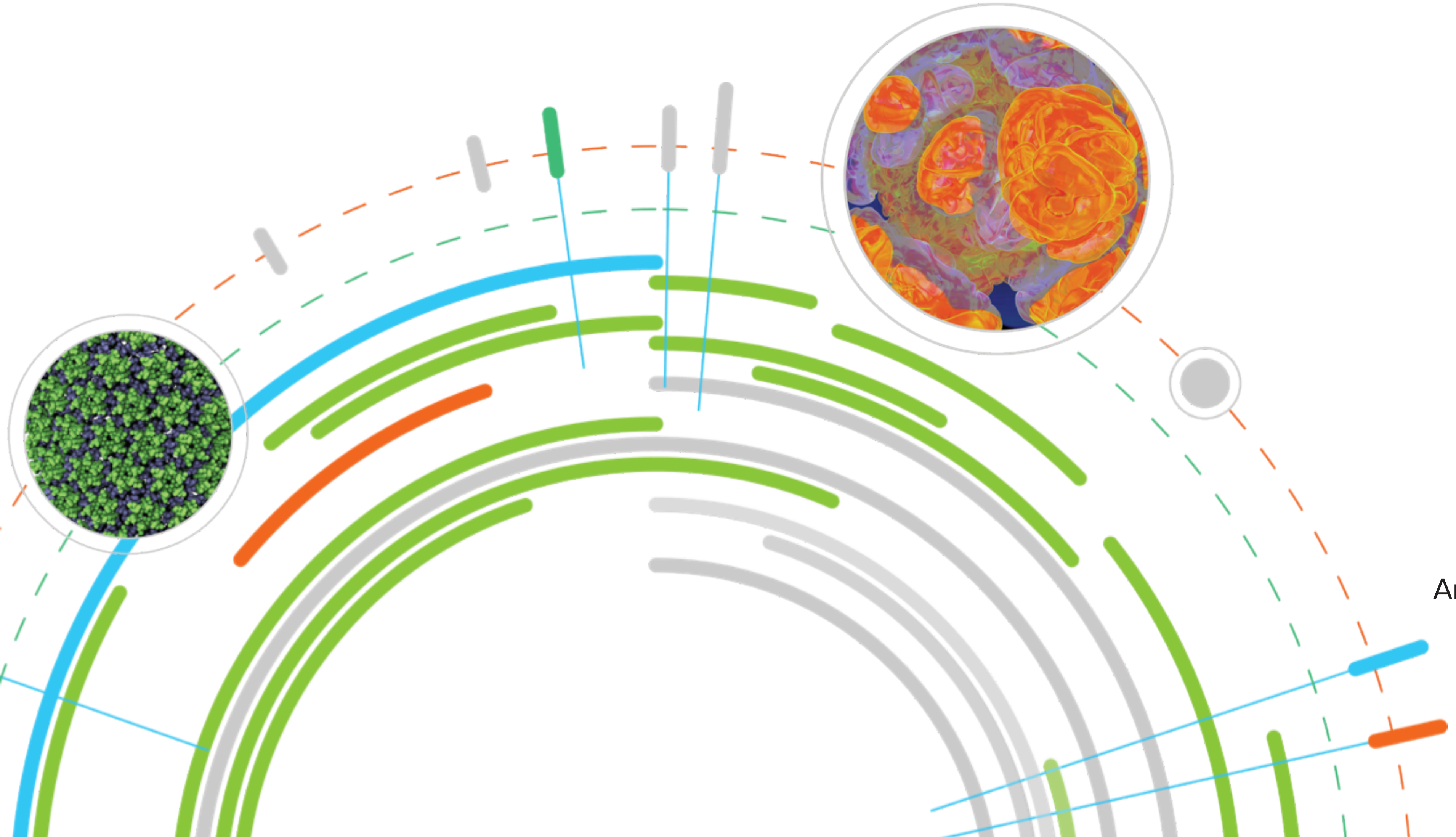
ALCF BLUE GENE /Q SYSTEMS
PART 2: INTER-NODE COMMUNICATION



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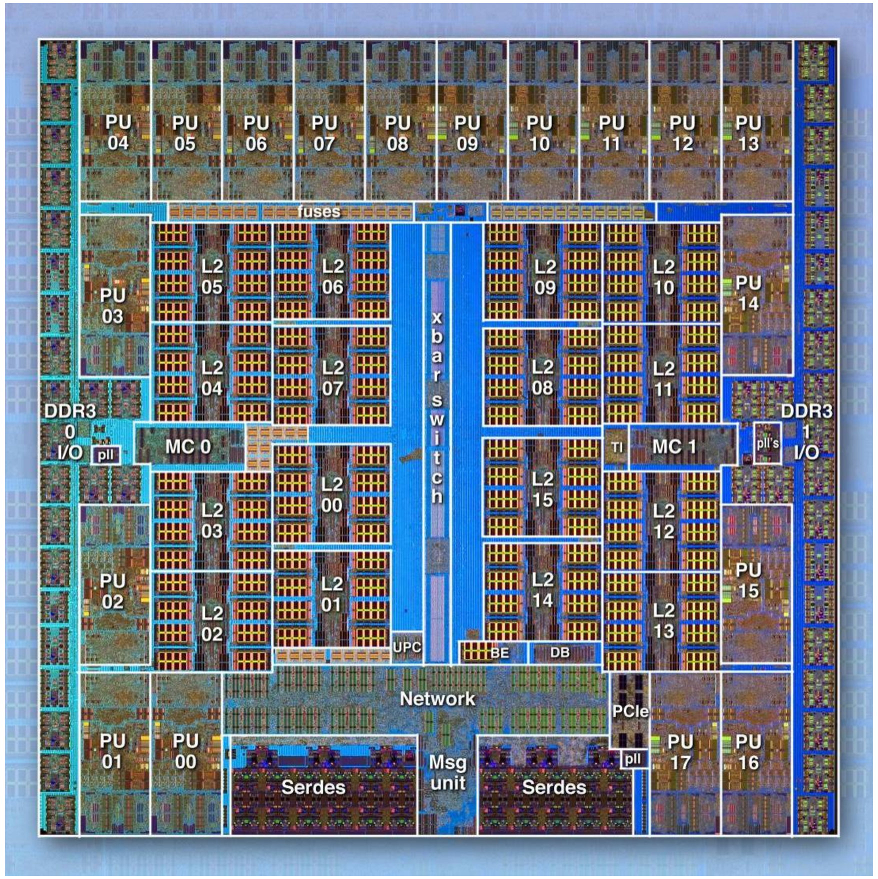
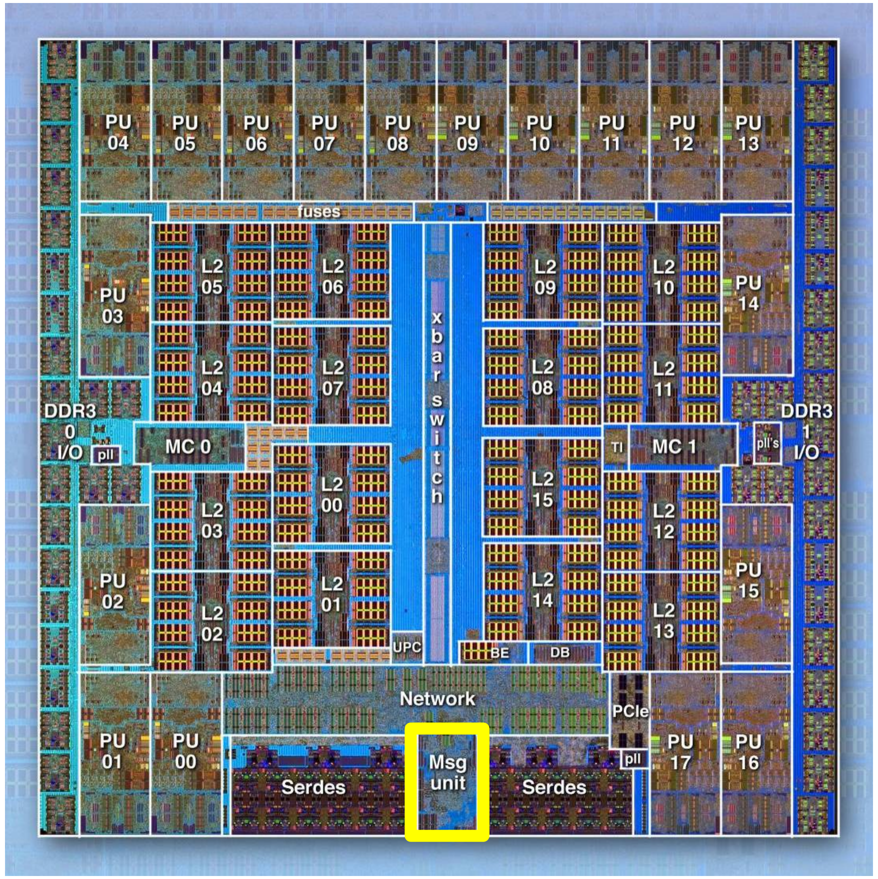
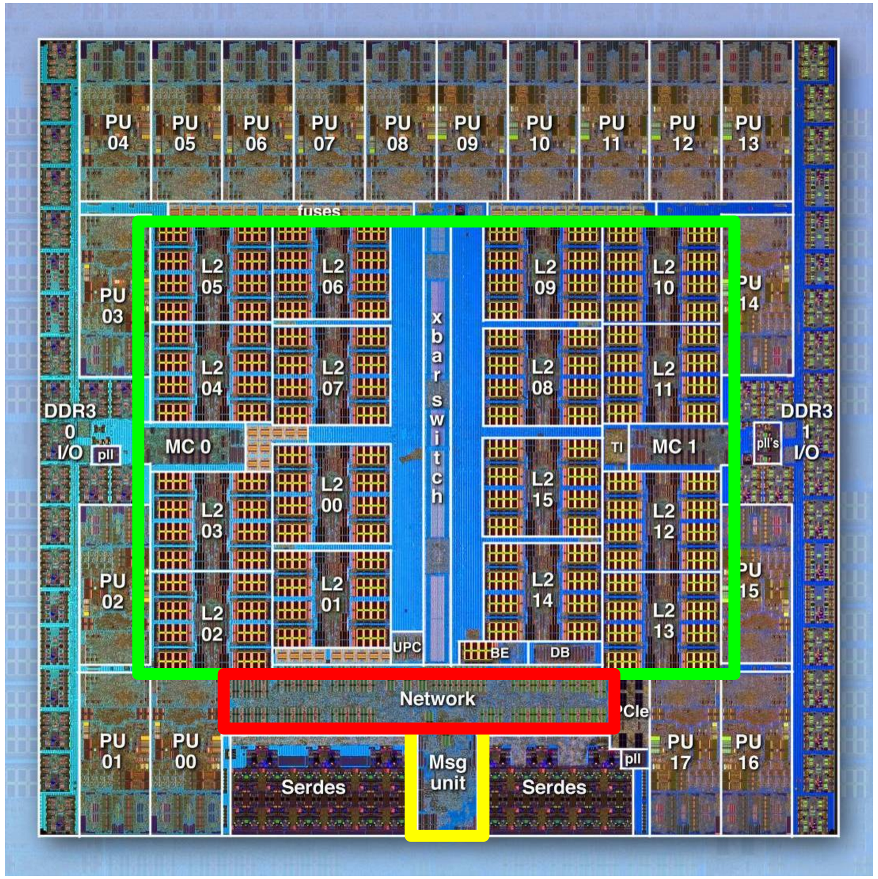
BG/Q COMPUTE CHIP



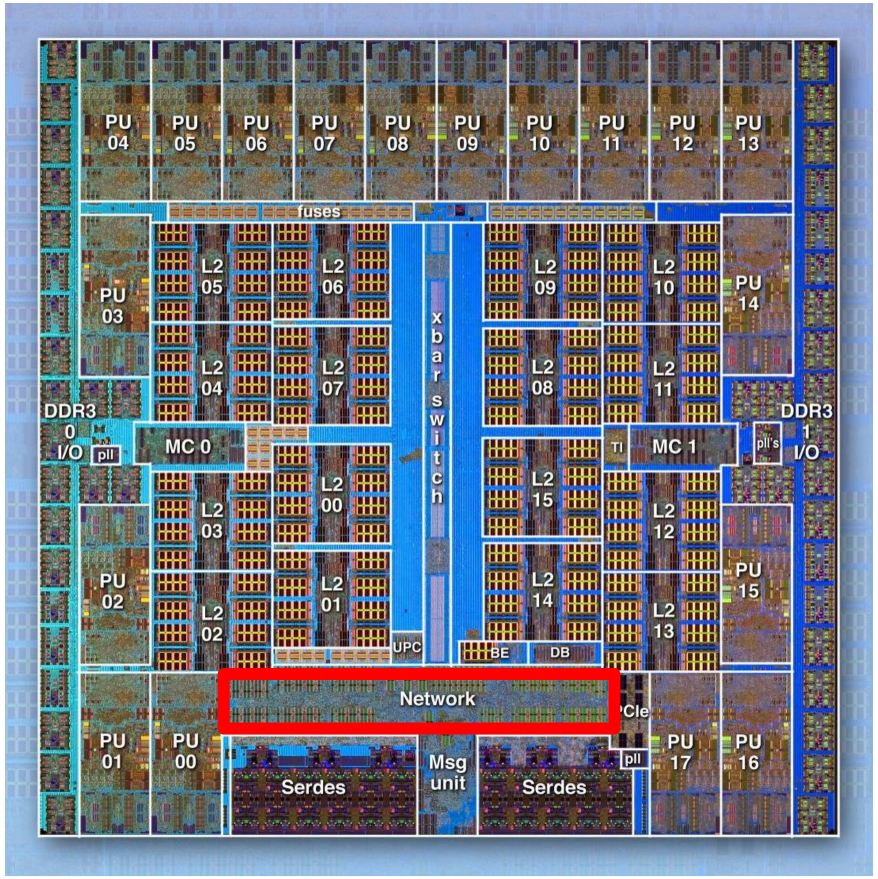
BG/Q COMPUTE CHIP



BG/Q COMPUTE CHIP

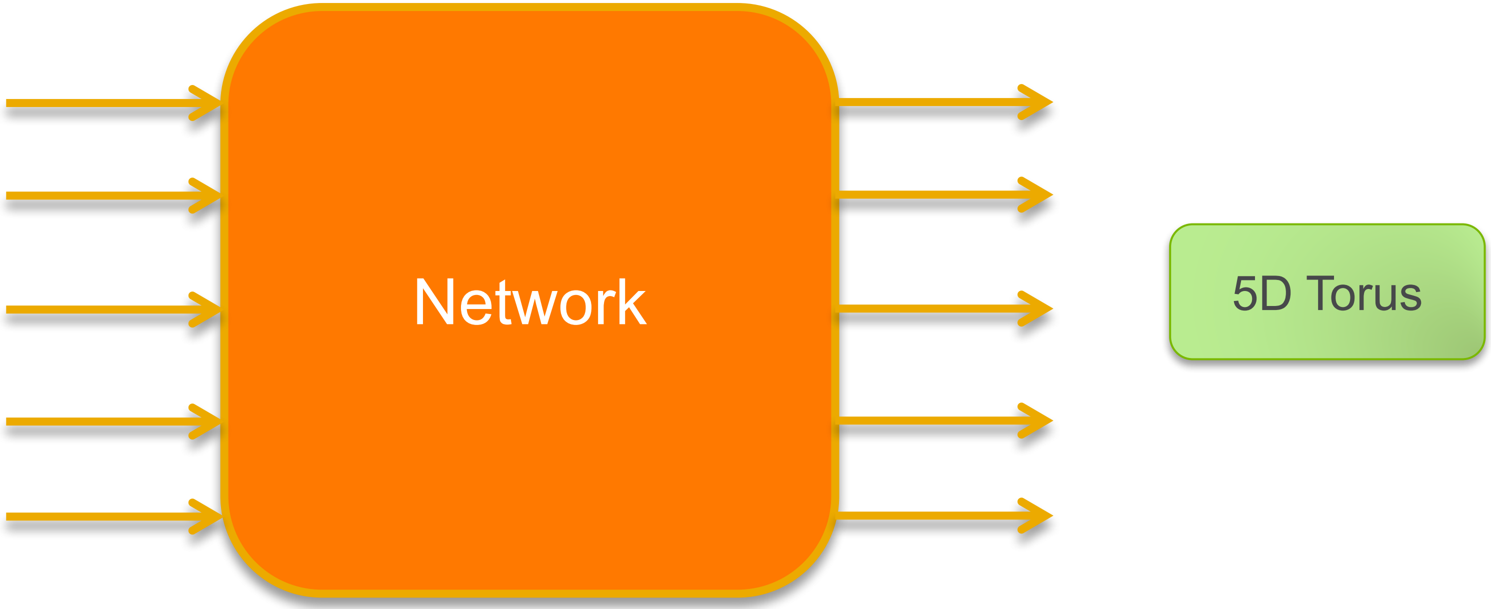


BG/Q COMPUTE CHIP

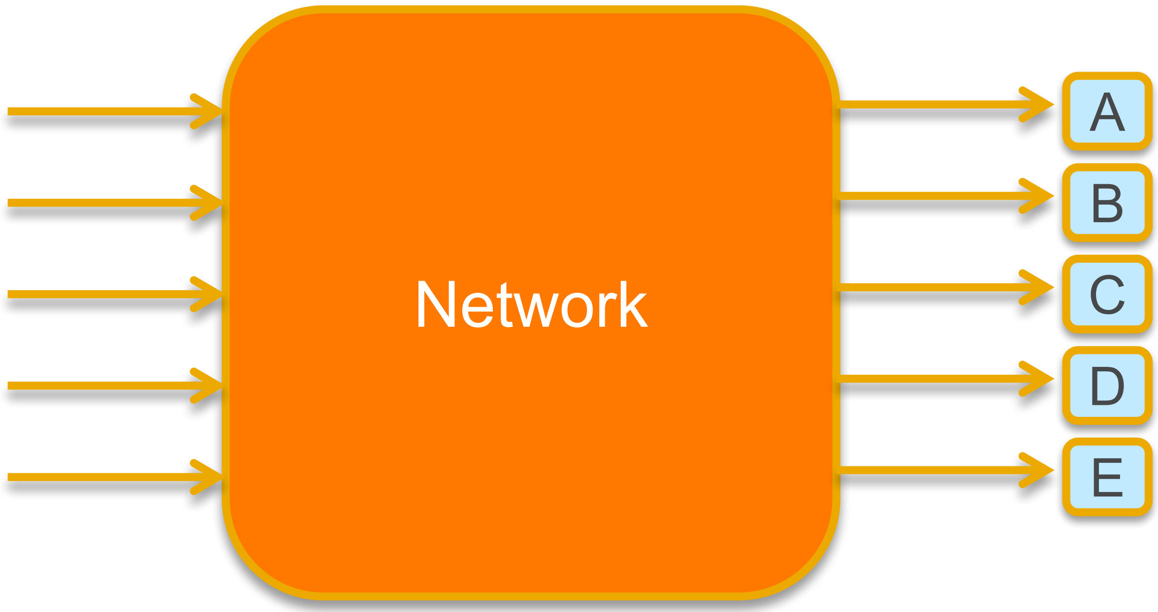


BG/Q NETWORK

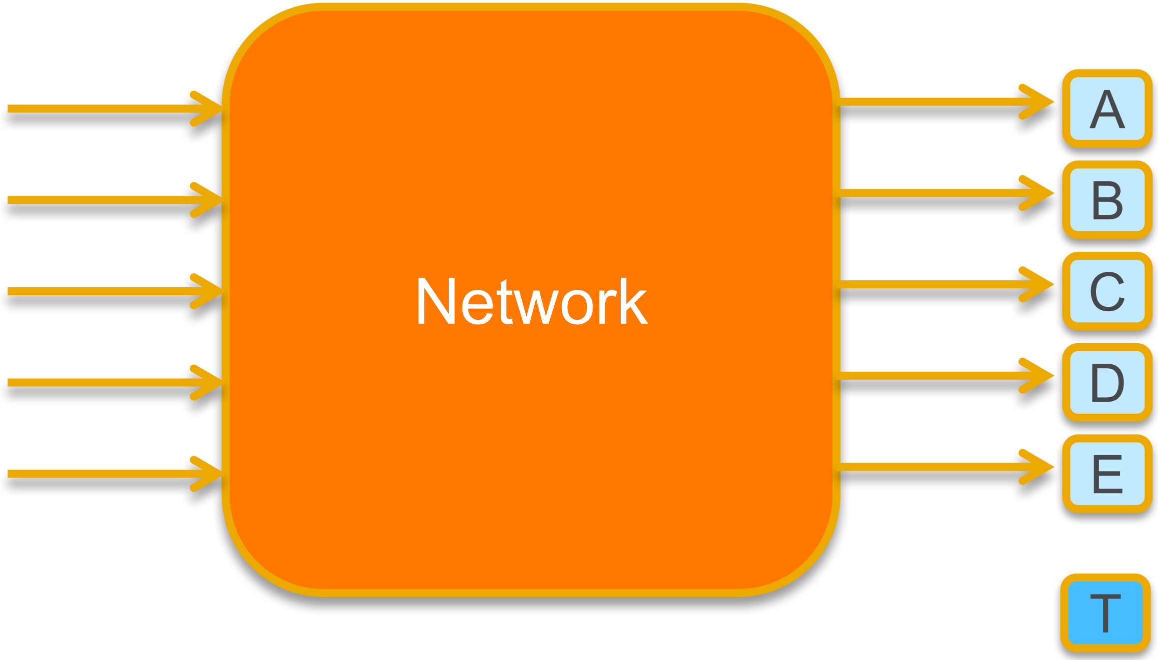
BG/Q NETWORK



BG/Q NETWORK



BG/Q NETWORK



Process number within node

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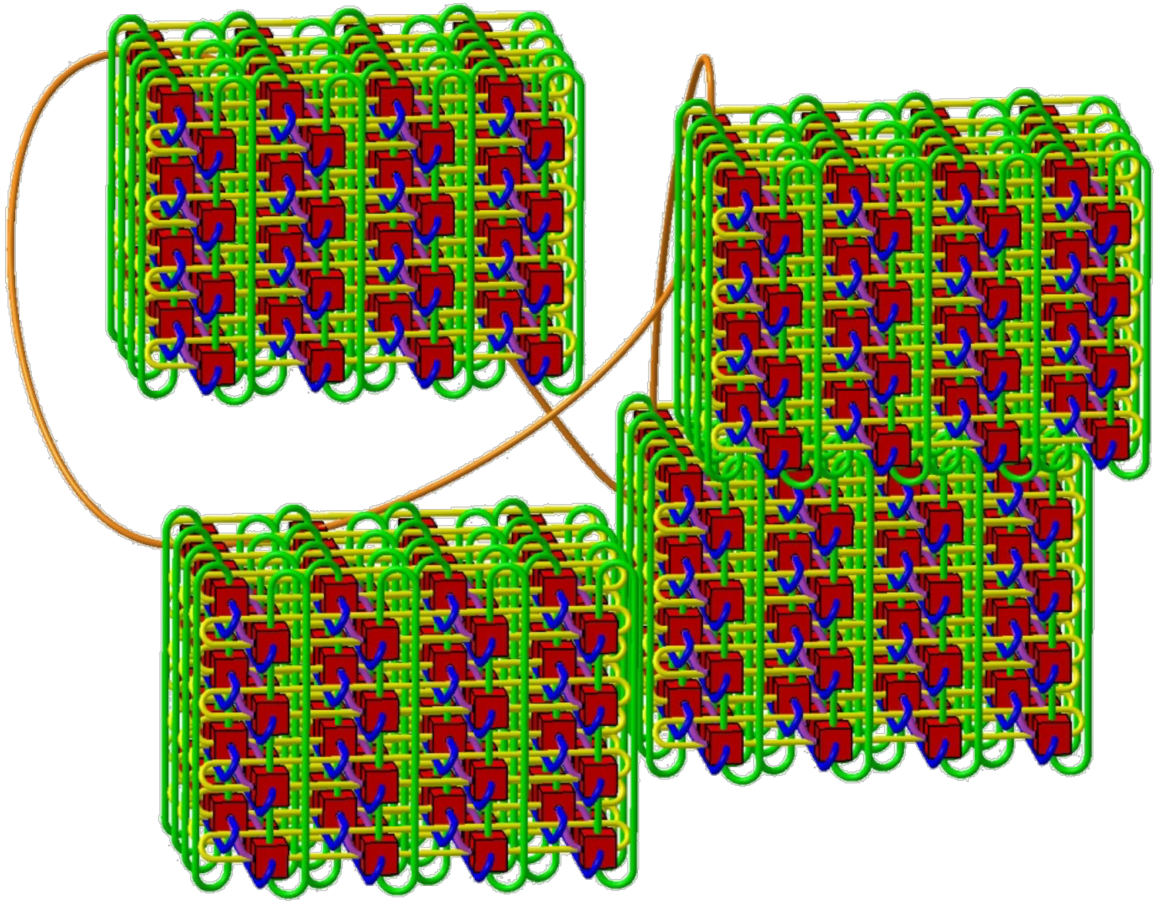
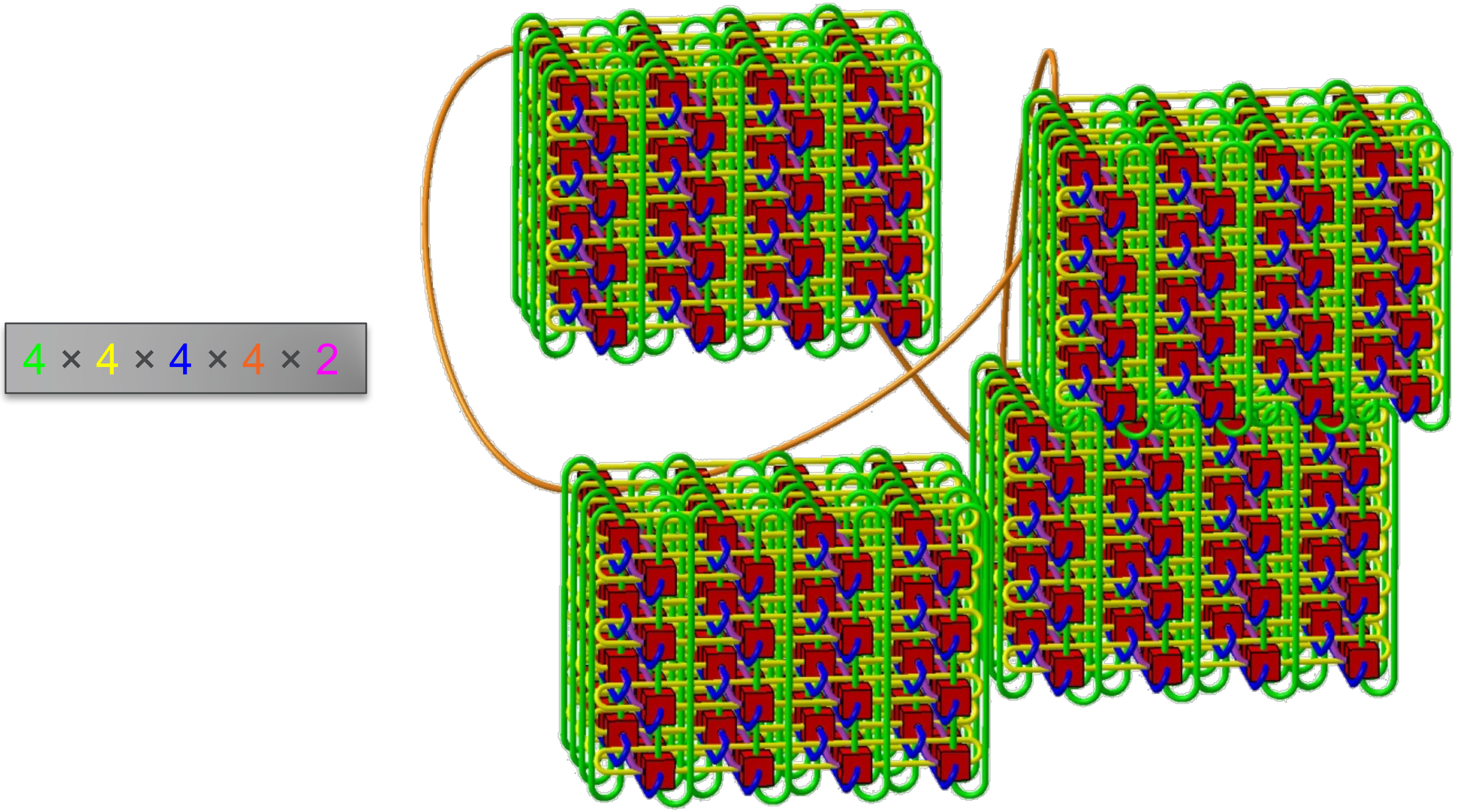
BG/Q 512 NODE TORUS PARTITION



BG/Q 512 NODE TORUS PARTITION



MAPPING RANKS/PROCESSES TO NODES

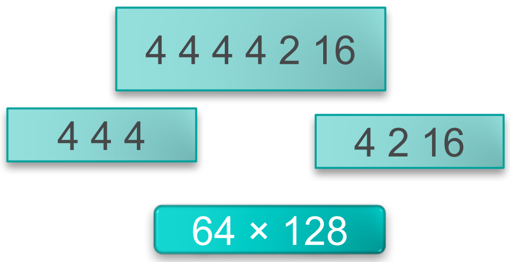
- Permutation of ABCDET
  - ABCDET on midplane --mode c1 <4,4,4,4,2,1>

    Rank 0 coordinates <0,0,0,0,0,0>
    Rank 1 coordinates <0,0,0,0,1,0>
    Rank 2 coordinates <0,0,0,1,0,0>
    Rank 3 coordinates <0,0,0,1,1,0>
    Rank 4 coordinates <0,0,0,2,0,0>
    Rank 5 coordinates <0,0,0,2,1,0>
    Rank 6 coordinates <0,0,0,3,0,0>
    Rank 7 coordinates <0,0,0,3,1,0>
    Rank 8 coordinates <0,0,1,0,0,0>
    …
    Rank 511 coordinates <3,3,3,3,1,0>
  - runjob --mapping TEDCBA

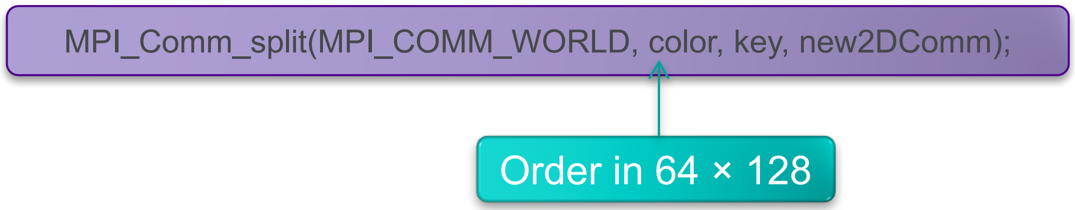
- Mapping file
  - 0 0 0 0 0 0 # rank 0
    0 0 0 0 1 0 # rank 1
    0 0 0 1 0 0 # rank 2
    …
  - runjob --mapping *mapfilename*

MAPPING RANKS/PROCESSES TO NODES (CONT'D)

- **Goal:** in cartesian topology
  - Preserve locality for nearest-neighbor
  - Minimize extra hops in partition
- Example: 2D logical topology
  - Midplane c16 <4,4,4,4,2,16>



- Two ways to implement
  1. Generate map file
  2. Order the ranks in a new MPI communicator



TOPOLOGY ACCESS: MPIX

#include <mpix.h>

MPIX_Init_hw(MPIX_Hardware_t *hw)

int MPIX_Torus_ndims(int *numdimensions)

int MPIX_Rank2torus(int rank, int *coords)

int MPIX_Torus2rank(int *coords, int *rank)

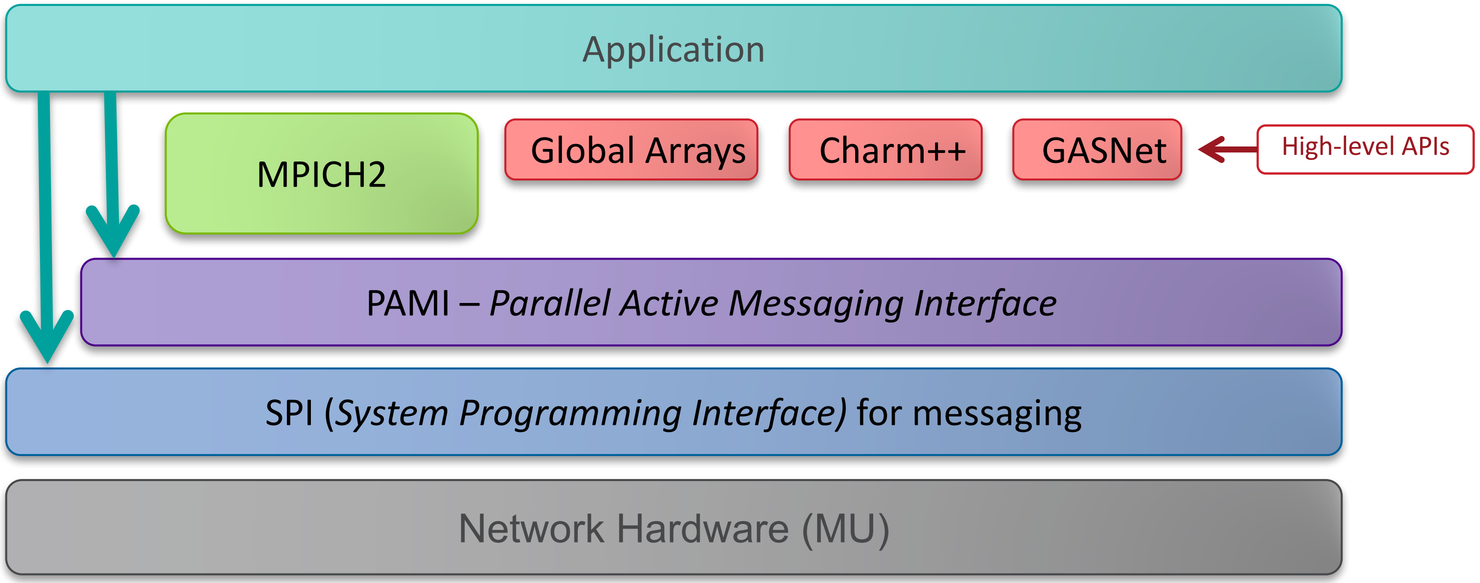
MPIX_Hardware_t

- Physical rank irrespective of mapping
- Size of block irrespective of mapping
- Number of processes per node
- Core-thread ID of this process
- Frequency of the processor clock
- Size of the memory on the compute node
- Number of torus dimensions
- Size of each torus dimension
- Torus coordinates of this process
- Wrap-around link attribute for each torus dimension

NETWORK SPEED IS A MAJOR STRENGTH OF BG/Q

- Each A/B/C/D/E link bandwidth: 4 GB/s
- Bisection bandwidth (32 racks): 13.1 TB/s
- HW latency
  - Best: 80 ns (nearest neighbor)
  - Worst: 3 μs (96-rack 20 PF system, 31 hops)
- MPI latency (zero-length, nearest-neighbor): 2.2 μs

BLUE GENE/Q COMMUNICATION PROGRAMMING



MPI ON BG/Q

- Based on MPICH
- Fully open source
- MPI-2.2
  - *Except* incompatible features (needing fork, e.g. MPI_Comm_spawn)

MPI ON BG/Q

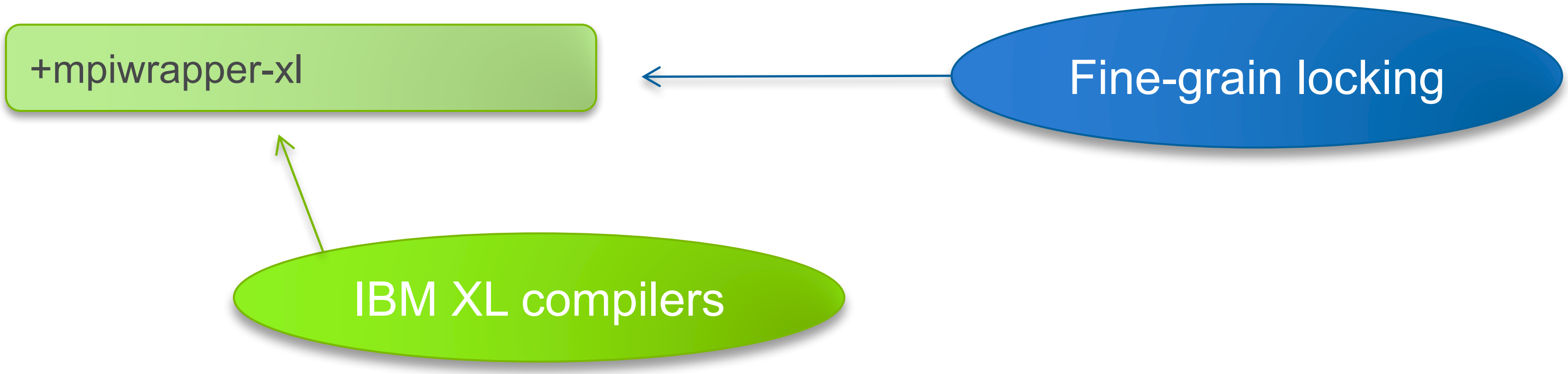
+mpiwrapper-xl

MPI ON BG/Q

+mpiwrapper-xl

IBM XL compilers

MPI ON BG/Q



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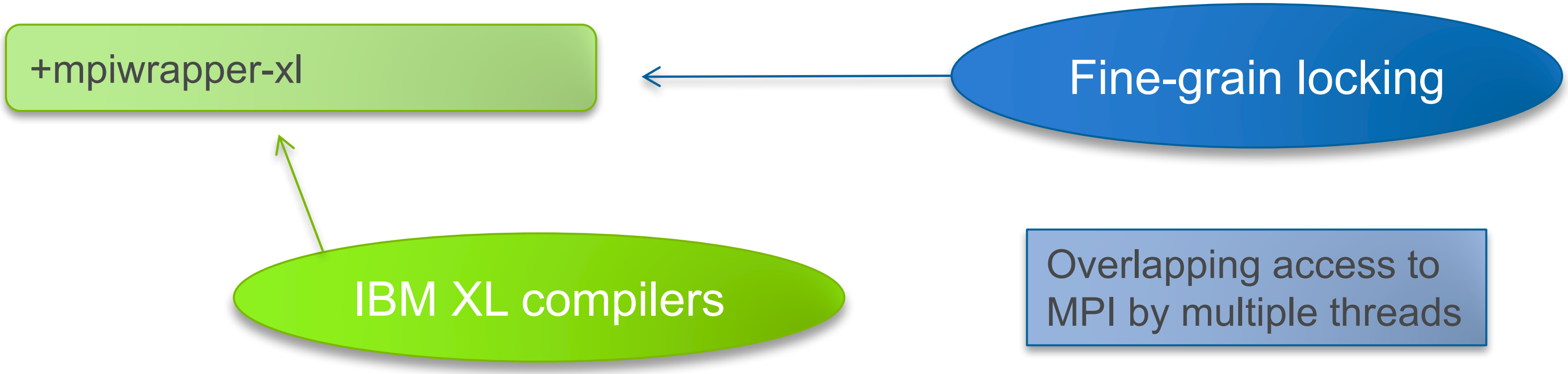
MPI ON BG/Q



+mpiwrapper-xl
Fine-grain locking
IBM XL compilers
Overlapping access to MPI by multiple threads

MPI ON BG/Q

+mpiwrapper-xl.legacy

MPI ON BG/Q

+mpiwrapper-xl.legacy

Coarse-grain locking

MPI ON BG/Q

+mpiwrapper-xl.legacy

Coarse-grain locking

Mutual exclusion between threads at MPI function level

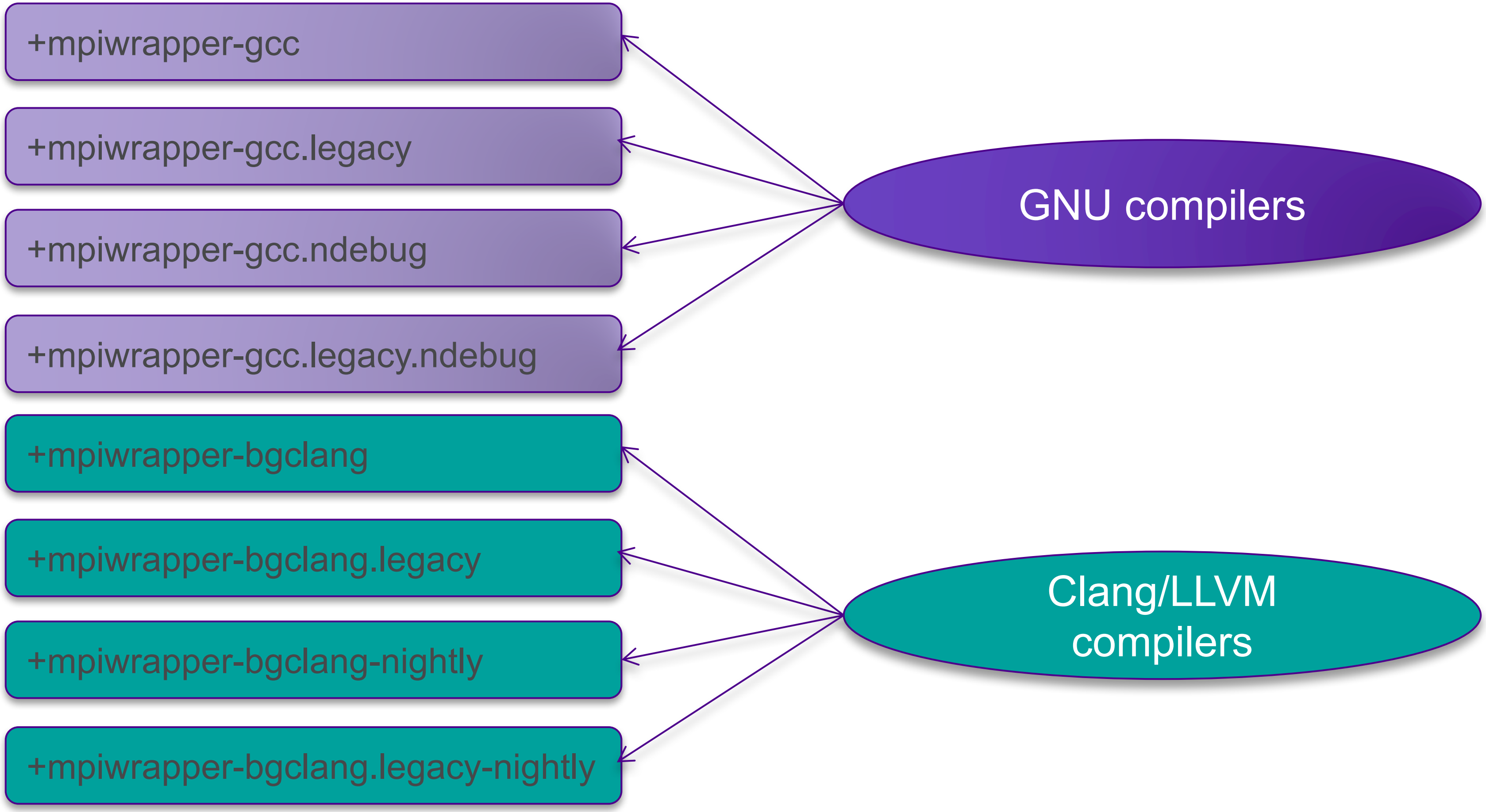
MPI ON BG/Q

+mpiwrapper-xl.ndebug

+mpiwrapper-xl.legacy.ndebug

No error checking
or asserts

MPI ON BG/Q



+mpiwrapper-gcc
+mpiwrapper-gcc.legacy
+mpiwrapper-gcc.ndebug
+mpiwrapper-gcc.legacy.ndebug
+mpiwrapper-bgclang
+mpiwrapper-bgclang.legacy
+mpiwrapper-bgclang-nightly
+mpiwrapper-bgclang.legacy-nightly
GNU compilers
Clang/LLVM compilers

MPI-3

- No official support on BG/Q – consider it a supported beta
- Nonblocking collectives: *use PAMI*
- Remote Memory Access (RMA): *use PAMI*
- Other MPI-3 features:
  - MPI + MPIX + PAMI + SPI
- There's also a OFI-based version under development

SIMPLE TUNING WITH PAMI

- PAMI is to BG/Q as IBVERBs is to a Beowulf or uGNI is to a Cray
- point-to-point communication routing can either be:
  - Deterministic:
    - packets always take the same route
    - lower latency
    - hotspots are possible
  - Adaptive:
    - packets can take several different routes determined at runtime based on load
    - keeps things balanced
    - adds latency

SIMPLE TUNING WITH PAMI

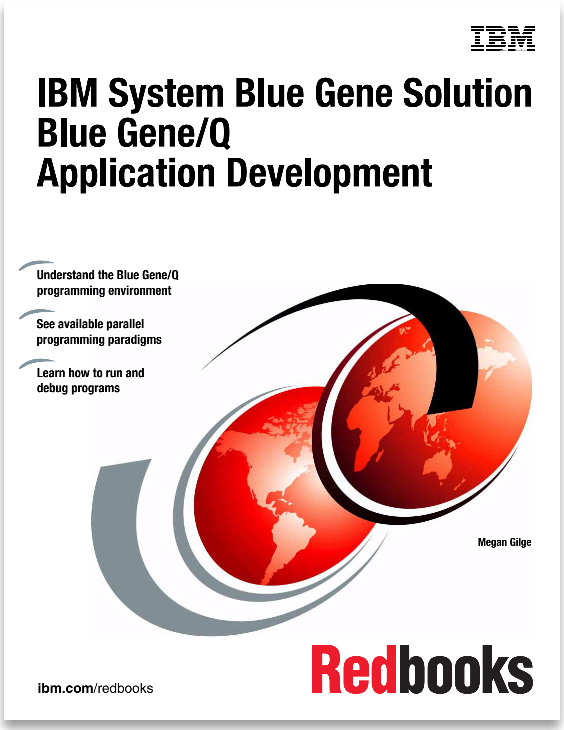
- Routing depends on protocol – defaults:

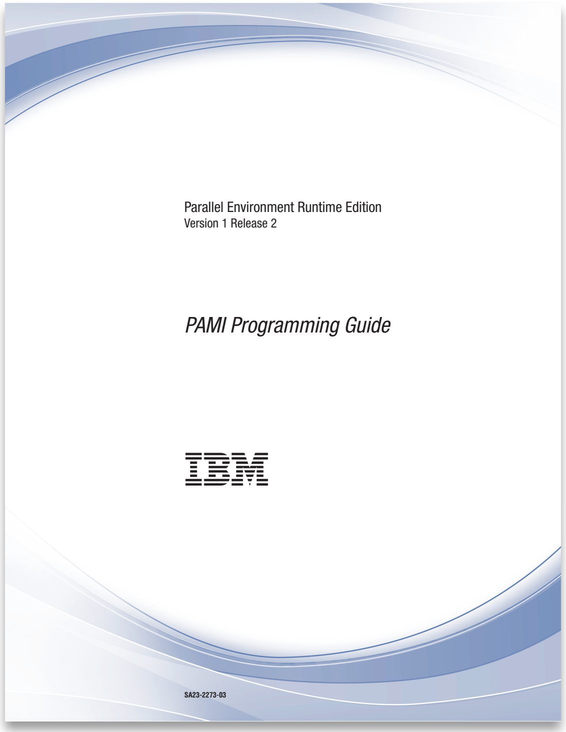
Protocol	Packet Size	Routing	Notes
Immediate	<= 112 bytes	Deterministic	Cut off set by PAMID_SHORT variable
Short	512 bytes (496 usable)	Deterministic	Single packet messages only
Eager	Medium sized < 2048 bytes	Deterministic	Sends without negotiating that the receiver is ready which can eat memory.
Rendezvous	Large messages >= 2048 bytes. Provides highest bandwidth.	Adaptive	Handshaking required. Receiver negotiates a DMA transfer from the sender.

SIMPLE TUNING WITH PAMI

- One can choose to use rendezvous protocol with the PAMID_RZV variable
- Profile for your communication patterns, then:
  - Lower if:
    - There's high overlap of communication and computation
    - Eager is creating congestion
    - Latency isn't a huge factor for medium size messages
    - You run out of memory due to MPI_*Sends
  - Raise if:
    - Most communication is nearest-neighbor
    - Latency is important for medium-sized messages
  - Drop to 0 if:
    - Eager messages are causing full-system jobs to run out of memory

REFERENCES





- PAMI Doxygen documentation
- /bgsys/drivers/ppcfloor/comm/sys/include/pami.h
- IPDS 2012 Talk (Sameer Kumar)
- OpenSHMEM 2013 talk (Alan Benner)
- Mysteries of the Deep (J. Hammond)
- pami-examples on Google Code

END