The New & Emerging MPI Standard

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presented by

Richard L. Graham- Chairman

Oak Ridge National Laboratory
U.S. Department of Energy

Outline

- Goal
- Current standard
- MPI-3 directions
- Future work

Goal

To produce new versions of the MPI standard that better serves the needs of the parallel computing user community

Structure

- Chairman and Convener: Rich Graham
- Secretary: Jeff Squyres
- Steering committee:
  Jack Dongarra
  Al Geist
  Rich Graham
  Bill Gropp
  Andrew Lumsdaine
  Rusty Lusk
  Rolf Rabenseifner

Current Standard: MPI 2.2

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Supported Functionality

- Point-to-Point Communication
  - Blocking/Nonblocking communications
  - Persistence
- Datatypes
  - Predefined datatypes
  - Derived Datatypes (user defined)

Supported Functionality – cont'd

- Collective Communication - blocking
  - 15 collective functions (barrier, broadcast, reduction, …)
- Groups, Contexts, Communicators
- Process Topologies
  - Perhaps the best kept secret
- Environment Management
- The Info Object

Supported Functionality – cont'd

- Process Creation and Management
  - Does not require interaction with a resource manager
- One-Sided Communication
- External Interfaces – such as thread support
- File I/O
- Profiling Interface
- Deprecated Functions
  - C++ bindings

MPI-3 Status

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MPI 3.0 - Scope

Additions to the standard that are needed for better platform and application support. These are to be consistent with MPI being a library providing of parallel process management and data exchange. This includes, but is not limited to, issues associated with scalability (performance and robustness), multi-core support, cluster support, and application support.

Backwards compatibility maybe maintained - Routines may be deprecated

- Target release date:
  - Considering end of 2011, with incremental draft standard releases (starting Nov, 2010)

First MPI 3.0 draft standard posted at:

http://lists.mpi-forum.org/

Support for nonblocking collectives is added

Final version of the standard may be different

Tracking Forum Activities and Commenting on them

`Mailing list: mpi-comments@mpi-forum.org`

Subscribe at: http://lists.mpi-forum.org/

One MUST subscribe to the list to post messages to it

Current Active Working Groups

- Collective Operations and Topologies : Torsten Hoefler – University of Illinois at Urbana-Champaign, Andrew Lumsdaine - Indiana University
- Backwards Compatibility – David Solt, HP
- Fault Tolerance : Richard Graham - Oak Ridge National Laboratory
- Fortran Bindings : Craig Rasmussen - Los Alamos National Laboratory
- Remote Memory Access : Bill Gropp, University of Ilinois Champaign/Urbana - Rajeev Thakur, Argonne National Laboratory

Current Active Working Groups

- Tools support: Martin Schulz and Bronis de Supinski, Lawrence Livermore National Laboratory
- Hybrid Programming: Pavan Balaji, Argonne National Laboratory
- Persistence: Anthony Skjellum, University of Alabama at Birmingham

Backward Compatibility Working Group

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Backward Compatibility - Charter

- Address backward compatibility issues
- The goal is to provide recommendations to MPI 3.0 proposals and introduce new proposals when appropriate to provide a reasonable transition of MPI 2.x users and the implementations that support those users to MPI 3.0 without hindering the general goals of MPI 3.0.

The Big Issue: Counts Larger Than 2^{31}

- Counts are expressed as “int” / “INTEGER”
  - Usually limited to 2^{31}
- Propose a new type: MPI_Count
  - Can be larger than an int / INTEGER
- “Mixed sentiments” within the Forum
  - Is it useful? Do we need it? …oy!

MPI_SEND(void *buf, **int** count, …)

MPI_SEND(void *buf, **MPI_Count** count, …)

Do we need MPI_Count?

YES

✓

- Some users have asked for it
- Trivially send large [illegible]gs.
  - No need to make [illegible]atype
- PO[illegible] went t[illegible]e_t
  - [illegible]ot M[illegible]
- Th[illegible] the future:
  - B[illegible]AM makes 2^{31} relevant
  - Datasets getting larger
  - Disk IO getting larger
  - Coalescing off-node msgs.

NO

- Very few users
- Affects many, many MPI API functions
- Potential incompatibilities
  - E.g., mixing int and MPI_Count in the same application

Ok, so how to do it? (1 of 2)

1. Use MPI_Count only for new MPI-3 routines	✖	Inconsistent, confusing to users
2. Change C bindings – Rely on C auto-promotion	✖	Bad for Fortran, bad for C OUT params
3. Only fix MPI IO functions – Where MPI_BYTE is used	✖	Inconsistent, confusing to users
4. New, duplicate functions – E.g., MPI_SEND_LARGE	✖	What about sizes, tags, ranks, …oy!

Ok, so how to do it? (2 of 2)

5. Fully support large datatypes
   - E.g., MPI_GET_COUNT_LONG
6. Create a system for API versioning
7. Update all functions to use MPI_Count
8. Make new duplicate functions with MPI_Count, MPI_Tag, MPI_Size, …
   - E.g., MPI_SEND_EX

✓ Might be ok…?

✖ Forum has hated every proposal

✖ Technically makes current codes invalid

✓ Rip the band-aid off! Preserves backward Compatibility ☺

Collective Communications and Topology Working Group

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Nonblocking Collective Operations

- Moving forward in standardization process
  - No substantial changes since Jan. 2010
  - Reference Implementation (LibNBC) stable
- Final vote on 10/11
  - Unanimously accepted
- Has been released as Draft Standard on [put date here]
  - Ready to be implemented in MPI libraries

Sparse Collective Operations on Process Topologies

- New feature to enhance scalability and performance of MPI-3
- MPI process topologies (Cartesian and (distributed) graph) usable for communication
  - MPI_Sparse_gather(v)
  - MPI_Sparse_alltoall(v,w)
  - Also nonblocking variants
- Allow for optimized communication scheduling and scalable resource binding

Scalable Irregular Collectives

- Distribute argument lists of vector collectives
  - Simple interface extension
  - Low overhead
  - Reduce memory overhead from O(P) to O(1)

- Proposal under discussion
  - Reference implementation on the way
  - Use-cases under investigation

Fault Tolerance Working Group

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Fault Tolerance

- Goal: To define any additional support needed in the MPI standard to enable implementation of portable Fault Tolerant solutions for MPI based applications.
- Assumptions:
  - Backward compatibility is required.
  - Errors are associated with specific call sites.
  - An application may choose to be notified when an error occurs anywhere in the system.
  - An application may ignore failures that do not impact its MPI requests.
  - An MPI process may ignore failures that do not impact its MPI requests
  - An application that does not use collective operations will not require collective recovery
  - Byzantine failures are not dealt with

Fault Tolerance

- Goal: To define any additional support needed in the MPI standard to enable implementation of portable Fault Tolerant solutions for MPI based applications.
  - Support restoration of consistent internal state
  - Add support to for building fault-tolerant “applications” on top of MPI (piggybacking)

Fault Tolerance

Items being discussed

- Define consistent error response and reporting across the standard
- Clearly define the failure response for current MPI dynamics - master/slave fault tolerance
- Recovery of
  - Communicators
  - File handles
  - RMA windows
- Data piggybacking
- Dynamic communicators
- Asynchronous dynamic process control
- Current activity: run-through process failure prototyping – AKA run through stabilization proposal

Updates to the MPI One-Sided Interface

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MPI RMA Working Group

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Background of MPI-2 One Sided

- MPI-2's One-Sided provides a programming model for put/get/update programming that can be implemented on a wide variety of systems
- The "public/private" memory model is suitable for systems without local memory coherence (e.g., special memory in the network; separate, non-coherent caches between actors working together to implement MPI One-Sided)
- However, the MPI One-Sided interface does not support other common one-sided programming models well. Good features of the MPI-2 One-sided, including the following, must be preserved
  - To allow for overlap of communication with other operations, nonblocking RMA operations are required
  - The RMA model must support non-cache-coherent and heterogeneous environments
  - Transfers of noncontiguous data, including strided (vector) and scatter/gather must be supported
  - Scalable completion (a single call for a group of processes) is required

Goals for MPI-3 One Sided

- The goal of the MPI-3 RMA Working Group is to address many of these limitations, including
  - In order to support RMA to arbitrary locations, no constraints on memory, such as symmetric allocation or collective window creation, can be required
  - RMA operations that are imprecise (such as access to overlapping storage) must be permitted, even if the behavior is undefined
  - The required level of consistency, atomicity, and completeness should be flexible
  - Read-modify-write operations and compare and swap are needed for efficient algorithms

Major New Features

- New Window Types
  - MPI_Win_allocate – memory allocated by routine, permits symmetric allocation
  - MPI_Win_create_dynamic – memory attached to window as needed by a local operation
- New Read-Modify-Write operations
  - MPI_Get_accumulate, MPI_Compare_and_swap
- New synchronization and completion calls
- Query for new mode (MPI_RMA_UNIFIED) to allow applications to tune for cache-coherent architectures
- Relaxed rules for certain access patterns
  - Results undefined rather than erroneous; matches other share-memory and RDMA approaches

Tool Interfaces for MPI-3

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Status Report: November 2010

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MPI-3 Tools Working Group

- Goals of the tools working group
  - Extend tool support in MPI-3 beyond the PMPI interface
  - Document state of the art for de-facto standard APIs

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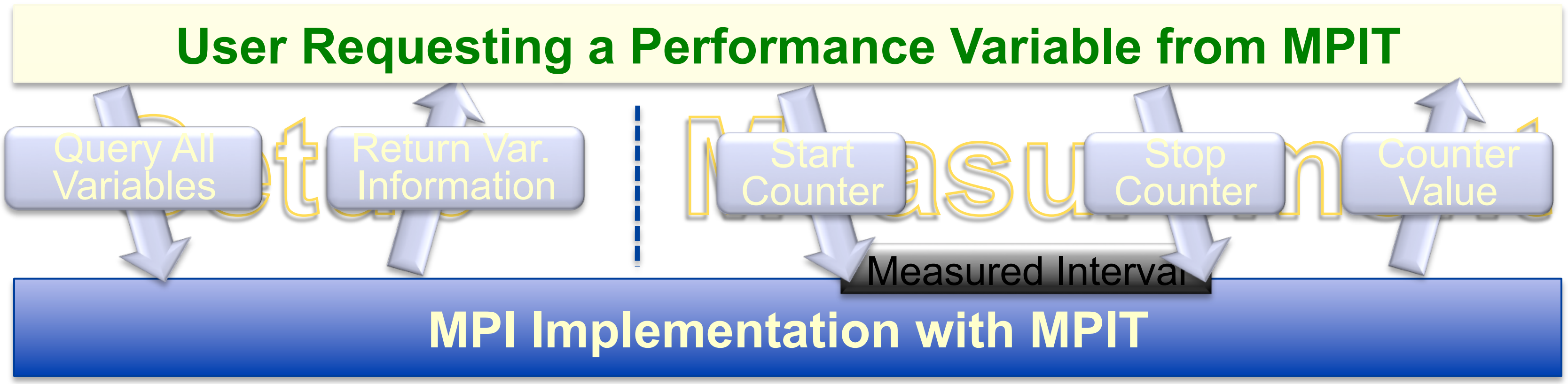
The MPIT Performance Interface

- Goal: provide tools with access to MPI internal information
  - Access to configuration/control and performance variables
  - MPI implementation agnostic: tools query available information



Examples of Performance Vars

- Number of packets sent
- Time spent blocking
- Memory allocated

Similar process for Control Vars.

- Parameters like Eager Limit
- Startup control
- Buffer sizes and management

The MPIT Performance Interface (cont.)

- Main philosophy
  - MPI specifies what information is available
  - Tools can query this information (similar concept as PAPI)
  - Complementary to/will NOT replace the MPI profiling interface PMPI
- Information provided as a set of variables
  - **Performance variables**
    Provided functionality: Query internal state of the MPI library at runtime
  - **Configuration/control variables**
    Provided functionality: List, query, and (if the MPI implementation supports this) set configuration settings
- Status of MPIT
  - Current draft available on MPI-3 tools WG WiKi
  - (Hopefully) final discussions in tools WG
  - Feedback wanted!

Draft Available on the Tools Wiki, Comments Welcome!

The MPIR Companion Document

- MPIR = established process acquisition interface for MPI
  - Enables tools to query all processes involved in an MPI job
  - Implemented by most MPIs
  - Used by many tools, (Totalview, DDT, O|SS)
  - MPIR not standardized / Exists in several variants
- Goal of MPIR activity in tools WG
  - Document the current state of the art as a guide for users
  - No extensions or changes (for now)
  - Published as a companion document to MPI
- Status
  - Final draft available on MPI-3 tools WG WiKi
  - Passed first vote, Second vote scheduled for December

Next Steps for the Tools WG

- Additional areas under discussion or possible directions
  - Companion document to describe the message queue interface
  - Extensions for further third party debug interfaces
  - Standardization of a more scalable process acquisition API
  - Extended version of MPI_Pcontrol
  - Low-level tracing options in MPIT

- **Other suggestions/contributions welcome!**
  - MPI-3 tools working open to everyone
  - Bi-weekly phone calls: Monday 8am PT
  - Documents, Minutes, Discussion on WG Wiki: ***http://svn.mpi-forum.org/*** ➔ ***MPI 3.0, Tools Workgroup***

MPI-3 Fortran

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Finally, quality MPI interfaces for Fortran

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Severe Problems with the Existing MPI Fortran Interfaces

- Use of “`mpif.h`” provides no type checking
- The “`use mpi`” module is impossible to fully implement in a standards-compliant way
- Very scary issues with compiler optimizations:
  - Compiler may copy buffers used with non-blocking communication
  - Compiler can move code statements surrounding MPI_WAIT calls

Some of the Proposed Changes

- Existing “`use mpi`” module with full compile time argument checking
- New “`use mpi_f08`” module with typed MPI handles
  - `MPI_Comm, MPI_Datatype, MPI_Errhandler, MPI_Info, MPI_Request,` …etc.
- Array subsections supported
- The IERROR argument in Fortran calls is optional
- Formal guidence provided to users how to use non-blocking MPI functionality

✓ Strong type checking

✓ Enhanced type checking

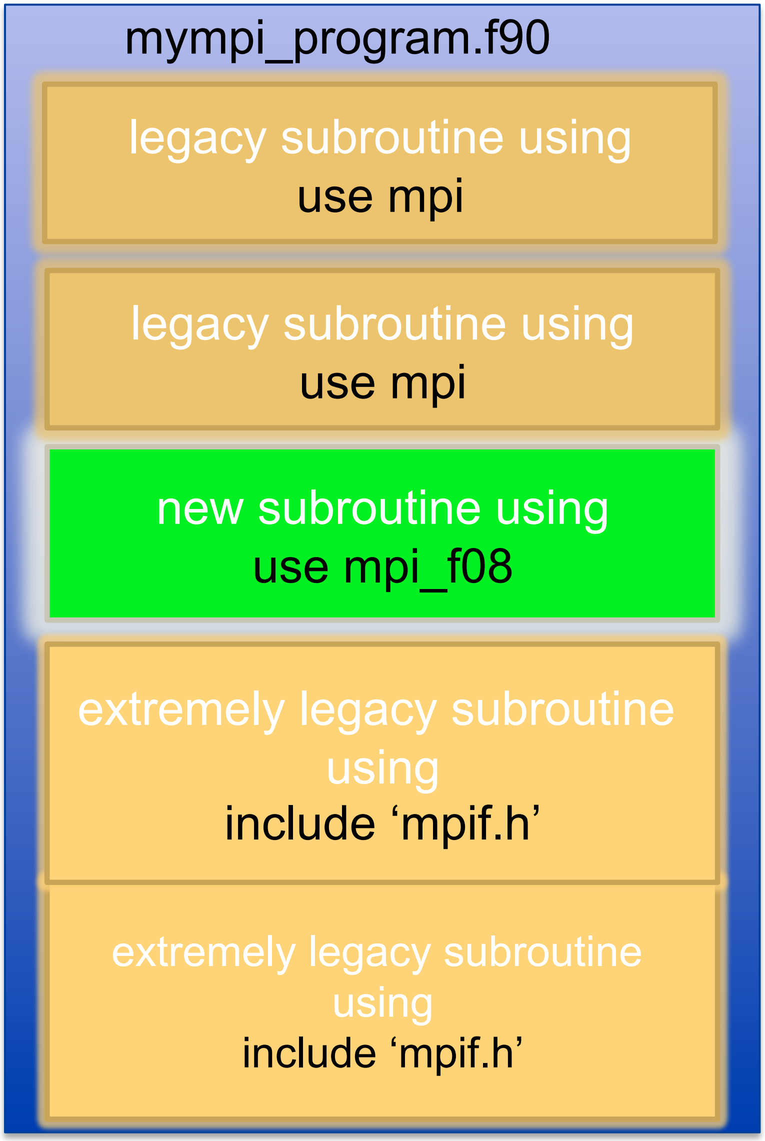
✓ Yay!

✓ No one uses it anyway

✓ Safety in asynchronicity

Implications

- Backwards compatibility is preserved
  - New features are available in a new module
  - You must modify your code to get the new features
- Old and new Fortran MPI features can be combined in a single MPI application
- Implementation being protyped in Open MPI


mympi_program.f90
legacy subroutine using use mpi
legacy subroutine using use mpi
new subroutine using use mpi_f08
extremely legacy subroutine using include 'mpif.h'
extremely legacy subroutine using include 'mpif.h'

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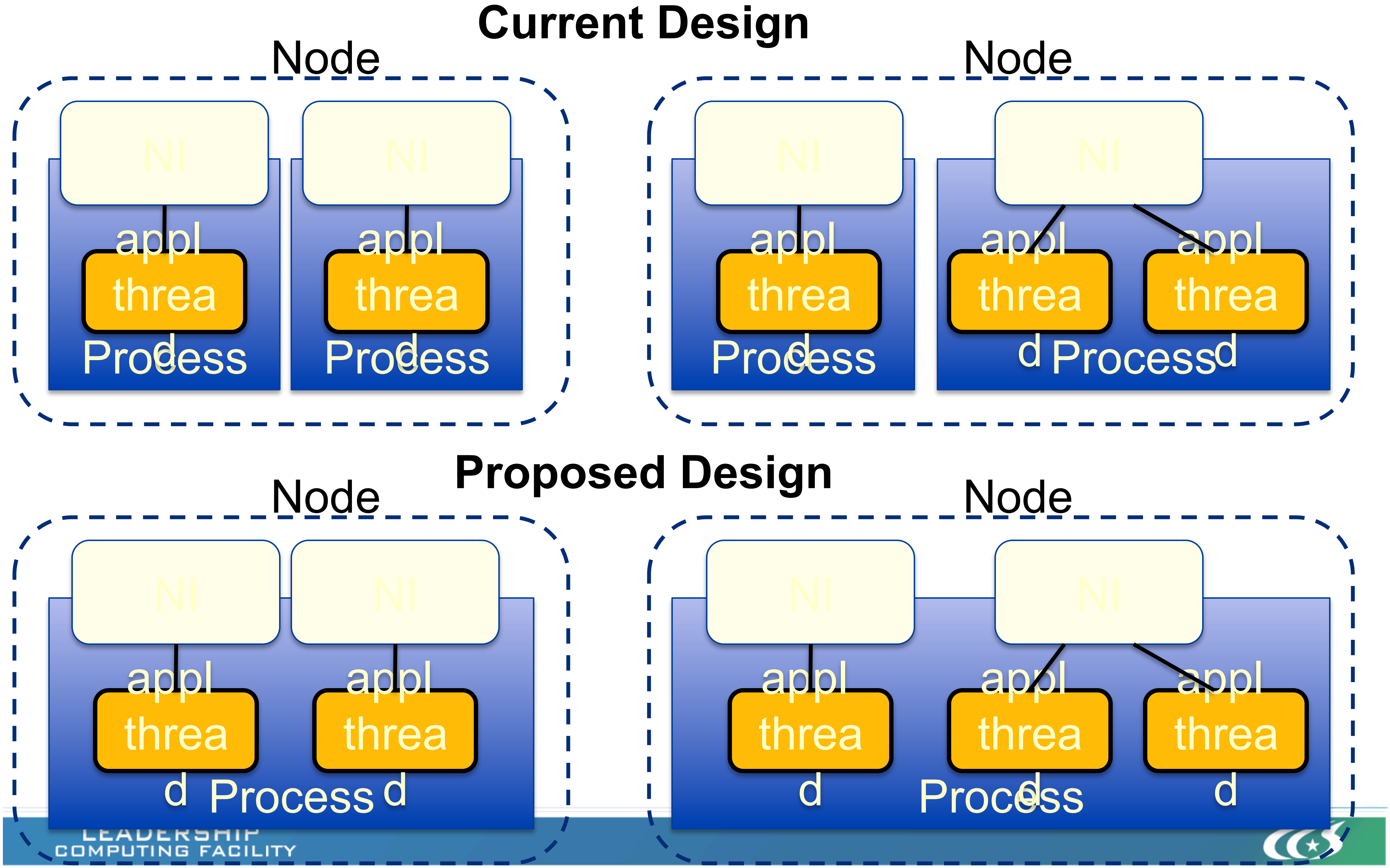
Hybrid Programming WG Goals

- Ensure that MPI has the features necessary to facilitate efficient hybrid programming
- Investigate what changes are needed in MPI to better support:
  - Traditional thread interfaces (e.g., Pthreads, OpenMP)
  - Emerging interfaces (like TBB, OpenCL, CUDA, and Ct)
  - PGAS (UPC, CAF, etc.)
  - Shared Memory
- Mailing list: mpi3-hybridpm@lists.mpi-forum.org
- Wiki: https://svn.mpi-forum.org/trac/mpi-forum-web/wiki/MPI3Hybrid
- Biweekly telecons every Tuesday at 11am Central time

Threads with Endpoints



Current Design

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Proposed Design

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MPI Helper Thread Teams

- Thread teams are allowed to share MPI work
  - Group of threads join the team, and make MPI calls – MPI will share resources provided by all threads for all the MPI calls together (compute resources, end points)
- Useful for OpenMP applications where threads are forked for computational parallelism, but the MPI part is serialized

Shared Memory Extensions to MPI

- Allowing MPI to create and destroy SystemV style shared memory regions
  - MPI_COMM_ALLOC_SHM and MPI_COMM_FREE_SHM
- User's responsibility to figure out what processes can create shared memory regions and what processes cannot

On Line Information

meetings.mpi-forum.org

- Meeting Schedule
- Meeting logistics
- Mailing list signup
- Mail archives
- Wiki pages for each working group