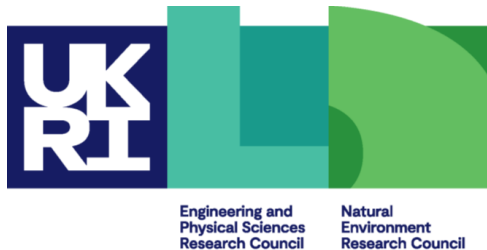


MPI Evolution

Advanced Message-Passing Programming



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Overview

- History of the MPI Standard
 - Before MPI
 - MPI 1
 - MPI 2
- Present of the MPI Standard
 - MPI 3.1
 - MPI 4.0
- Future of the MPI Standard
- MPI Implementations

Before MPI

- Before MPI, many competing message passing libraries.
 - Most computer vendors developed their own proprietary libraries.
 - There were also various portable libraries:
 - These targeted a variety of systems/interconnects.
 - Mostly developed by academic groups.
 - Usually only optimised for a small subset of the supported platforms.
- Different libraries used different models of communication
- This made application development very hard
 - Applications often needed their own communication module to encapsulate the different message passing systems.
- MPI was an attempt to define a standard set of communication calls.

MPI Forum

- Main web site at <http://mpi-forum.org/meetings/>
- The MPI Forum contains representatives from many of the vendors and academic library developers.
- This is one reason the specification is so large:
 - MPI supports many different models of communication, corresponding to various communication models supported by its predecessors.
- Much of the specification driven by the library developers.
 - leaves a lot of scope for optimised versions on different hardware.
 - many aspects of the MPI specification deliberately allow different implementations the freedom to work in different ways.
 - this makes it easy to port/optimize MPI for new hardware.
 - application developers need to be aware of this when writing code.
 - erroneous applications may work fine on one MPI implementation but fail using a different one.

Early History of MPI

- MPI is an “Application Programming Interface” (API) specification.
 - it is a specification not a piece of code.
 - there are many different implementations of the MPI specification.
- The MPI Standard is defined by the MPI Forum
 - Work started 1992
 - V 1.0 in 1994 – basic point-to-point, collectives, data-types, etc
 - V 1.1 in 1995 – fixes and clarifications to MPI 1.0
 - V 1.2 in 1996 – fixes and clarifications to MPI 1.1
 - V 1.3 in 1997 – refers to MPI 1.2 after combination with MPI-2.0
 - V 2.0 in 1997 – parallel I/O, RMA, dynamic processes, C++, etc

More recent History of MPI

- ... V 2.0 in 1997 – parallel I/O, RMA, dynamic processes, C++, etc
- Stable for 10 years
 - Version 2.1 in 2008 – fixes and clarifications to MPI 2.0
 - Version 2.2 in 2009 – small updates and additions to MPI 2.1
 - Version 3.0 in 2012 – neighbour collectives, unified RMA model, etc
 - Version 3.1 in 2015 – fixes, clarifications and additions to MPI 3.0
 - Version 4.0 in 2021 – persistent collectives, partitioned point-to-point

MPI-2 One-sided communication

- Separates data transmission from process synchronisation
- All comms parameters specified by a single process
- Definitions: “origin” calls MPI, memory accessed at “target”
- Initialise by creating a “window”
 - A chunk of local memory that will be accessed by remote processes
- Open origin “access epoch” (and target “exposure epoch”)
 - Communicate: MPI_Put, MPI_Get, MPI_Accumulate
 - Synchronise: passive target (or active target)
 - Use data that has been communicated
- Tidy up by destroying the window – MPI_Win_free

MPI 3.0

- Major new features
 - Non-blocking collectives, neighbourhood collectives
 - Improvements to one-sided communication
 - Added a new tools interface and new bindings for Fortran 2008
- Other new features
 - Matching Probe and Recv for thread-safe probe and receive
 - Non-collective communicator creation function
 - Non-blocking communication duplication function
 - “const” correct C language bindings
 - New MPI_Comm_split_type function
 - New MPI_Type_create_hindexed_block function
- C++ language bindings removed
 - previously deprecated functions removed

MPI 3.0 – Changes to collectives

- Non-blocking versions of all collective communication functions added
 - MPI_Ibcast, MPI_Ireduce, MPI_Iallreduce, etc
 - There is even a non-blocking barrier, MPI_Ibarrier
 - They return MPI_Request like other non-blocking functions
 - The user code must complete the operation with (one of the variants of) MPI_Test or MPI_Wait
 - Multiple non-blocking collectives can be outstanding but they must be called in the same order by all MPI processes
- New neighbourhood collective functions added
 - MPI_Neighbor_allgather and MPI_Neighbor_alltoall (plus variants)
 - Neighbours defined using a virtual topology, i.e. cartesian or graph
 - Extremely useful for nearest-neighbour stencil-based computations
 - Allow a scalable representation for common usage of MPI_Alltoally

MPI 3.0 – Changes to One-sided

- New window creation functions
 - New options for where, when and how window memory is allocated
- New atomic read-modify-write operations
 - MPI_Fetch_and_op and MPI_Compare_and_swap
- New “unified” memory model
 - Old one still supported, now called “separate” memory model
 - Simplifies memory consistency rules on cache-coherent machines
- New local completion semantics for one-sided operations
 - MPI_Rput, MPI_Rget and MPI_Raccumulate return MPI_Request
 - User can use MPI_Test or MPI_Wait to check for local completion

MPI 4.0: selected features

- Persistent collectives
 - Extends existing persistent point-to-point functions
 - Many more runtime optimisations are possible for collectives
- Partitioned communications
 - Also extends existing persistent point-to-point functions
 - Multiple contributions to a message before being sent
 - e.g. from many OpenMP threads

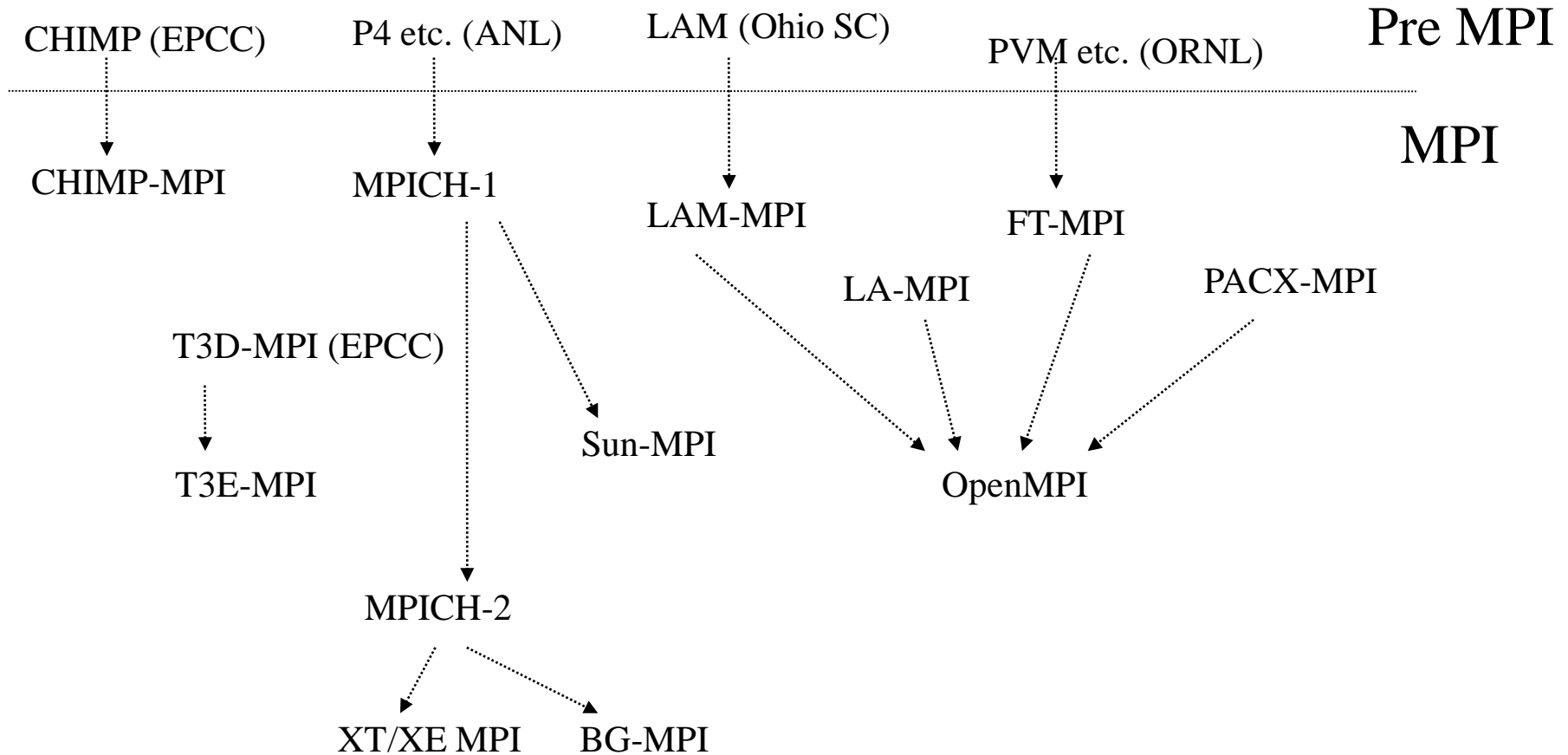
MPI 5.0 working groups (selected)

- Application Binary Interface (ABI)
 - Fault Tolerance
 - Hardware & Virtual Topologies
 - Hybrid & Accelerator
 - Languages
 - Remote Memory Access
 - Sessions
- See <https://www.mpi-forum.org/mpi-41/> for complete list

MPI implementations

- There are many different implementations of the MPI specification.
- Many of the early ones were based on pre-existing portable libraries.
- Currently there are 2 main open source MPI implementations
 - MPICH
 - OpenMPI
- Many vendor MPI implementations are now based on these open source versions.

MPI family tree (partial)



MPICH

- Virtually the default MPI implementation
 - Mature implementation, now supports MPI-4
 - Good support for generic clusters (TCP/IP & shared memory).
 - Many vendor MPIs now based on MPICH.
- Original called MPICH (MPI-1 functionality only)
- Re-written from scratch to produce MPICH-2 (MPI-2)
- Incorporated MPI-3 and renamed back to MPICH again
- Ported to new hardware by implementing a small core ADI
 - ADI = Abstract Device Interface.
 - Full API has default implementation using the core ADI functions.
 - Any part can be overridden to allow for optimisation.

OpenMPI

- Newer MPI implementation
 - Joint project between developers of
 - FT-MPI
 - LA-MPI
 - LAM/MPI
 - PACX/MPI
- Very active project
 - Special emphasis on support for infiniband hardware
 - Initially had an emphasis on Grid MPI
 - Fault tolerant communication
 - Heterogeneous communication
 - Current version supports MPI-4
 - Open Source project with large and varied community effort

Summary

- Most MPI implementations use a common “superstructure”
 - lots of lines of code dealing with a whole range of MPI issues: datatypes, communicators, argument checking, ...
 - will implement a number of different ways (protocols) of sending data
 - all hardware-specific code kept separate from the rest of the code, e.g. hidden behind an Abstract Device Interface
- To optimise for a particular architecture
 - rewrite low-level communication functions in the ADI
 - optimise the collectives especially for offload hardware
 - use machine-specific capabilities when advantageous
- Multi-core nodes
 - modern MPI libraries are aware of shared-memory nodes
 - already include optimisations to speed up node-local operations
 - uses multiple implementations of the same ADI in a single library