Beyond MPI-1.X

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CS-594
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What we are here for

- All the stuff extra stuff in the MPI-2 Spec and a few things in the MPI-1 Spec you have not thought about yet
  - MPI 2 is it really out there ?
  - Do you trust your implementation ?
- Some of this is a warm up for the MetaComputing- GRID classes coming up later..

Overview

- MPI-1 what it missed out
  - And why…
- MPI-2 what it included
  - Language issues
  - Process Management
  - Establishing Communication

Overview

- MPI-2 what it included
  - Single sided Communication
  - Intercommunicator Collective Operations
  - I/O including Parallel IO (PIO)

Overview

- MPI-1 the other things
  - How profiling works
    - Using profiling libraries such as JUMPSHOT
    - Building a library yourself
  - How do collectives work
  - Using communicators for distributed computing

What MPI-1 Missed out

- A lot of things that were hard to agree on for a standard
- Anything that might not run well on a early 90s late 80s MPP
  - Remember who made the standard
    - NEC, IBM, SGI, Intel, HP…..

Basics of MPI-1

- **All** characteristics of message passing are contained within ***communicators***
- Communicators contain:
  - Process lists or groups
  - Connection/communication structures ***topologies***
  - System derived message tags/envelopes to separate messages from each other

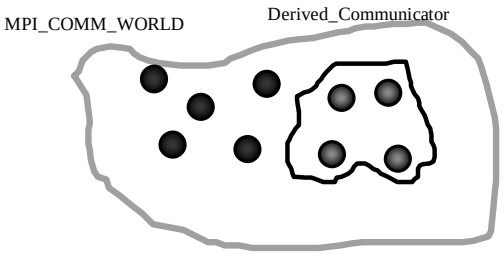
MPI-1 internals Communicators

- All processes in an MPI-1 application belong to a global communicator called MPI_COMM_WORLD
- All other communicators are derived from this global communicator.
- Communication can only occur within a communicator.
  - Safe communication

MPI-1 Internals Processes

- All process groups are derived from the membership of the MPI_COMM_WORLD communicator.
  - i.e.. no external processes.
- MPI-1 process membership is **static** not *dynamic* like PVM or LAM 6.X
  - simplified consistency reasoning
  - fast communication (fixed addressing) even across complex topologies.
  - interfaces well to simple run-time systems as found on many MPPs.

MPI-1 Application



Disadvantages of MPI-1

- Static process model
  - If a process fails, all communicators it belongs to become invalid. I.e. No fault tolerance.
  - Dynamic resources either cause applications to fail due to loss of nodes or make applications inefficient as they cannot take advantage of new nodes by starting/spawning additional processes.
  - When using a dedicated MPP MPI implementation you cannot usually use off-machine or even off-partion nodes.

Disadvantages of MPI-1

- Multi-language operation is not supported
  - MPI specifies both ANSI C and F77 binding
  - No agreed standard for data type conversions between languages even upon the same architecture
  - Communicators cannot be passed between different language modules due to their representation
    - In F77 a communicator is an INTEGER
    - In C it is usually a pointer to a structure
    - non standard methods exist in different implementations

MPI-2

- Problem areas and needed additional features identified in MPI-1 are being addressed by the MPI-2 forum.
- These include:
  - inter-language operation
  - dynamic process control / management
  - parallel IO
  - extended collective operations
- Support for inter-implementation communication/control is **not** being considered.
  - See the MetaComputing lectures for more…

MPI-2: Language Issues

- Think back to MPI-1
  - What is a communicator in 'C'
  - What is a communicator in 'Fortran'
  - Does it depend on the implementation ?
  - How could I write a program in both 'C' and 'Fortran' and have them pass communicators?

MPI-2: Language Issues

- MPI-2 Handle conversion
  - Fortran to C/C++
    - C 'Wrappers convert Fortran handles
  - C/C++ to Fortran
    - Not supported
      - Why do you think not ??
  - C to C++
    - Overloading C++ operators called on the C++ side
  - C++ to C
    - Not supported
      - Want to write a new C++ compiler ??

MPI-2: Language Issues

- All wrappers of the form:
  - MPI_<C_CLASS> MPI_<CLASS>_f2c (MPI_Fint handle)
    - All handles in fortran are integers (INT*4)

MPI-2: Language Issues

```
!     FORTRAN PROCEDURE
SUBROUTINE MPI_SEND_ONEINT (COMM, I, IERR)
INTEGER COMM, I, IERR
CALL C_ROUTINE (COMM, I, IERR)
RETURN
END
```


MPI-2: Language Issues

```
void c_routine (MPI_Fint *fh, MPI_Fint *i, MPI_Fint *ierr)
{
MPI_Comm fcom;

mycom = MPI_Comm_f2c (fh);
MPI_Send (i, 1, MPI_INT, 1, 1, mycom);
}
```

MPI-2: Language Issues

- Added a C++ binding
  - Constants and names the same as C except when they have been made into an object or special class

MPI-2: Language Issues

- C++ binding
  - C++ has types C does not such as
    - MPI::COMPLEX, MPI::BOOL etc
  - Uses a namespace called MPI that contains all object types such as:
    - Class comm; class Cartcomm, class Datatype..

MPI-2: Process Management

- In MPI-1
  - You get a set of process after you call MPI_Init ()
  - You keep them until you call MPI_Finalize
  - Or you halt…

MPI-2: Process Management

- How do you add more nodes to an already running MPI-1 application ??

MPI-2: Process Management

- How would we handle a node failure ??

MPI-2: Process Management

- How could we couple two or more applications ??

MPI-2: Process Management

- How could we couple two or more applications ??
  - Running using two or more different MPI implementations, such as one on an IBM SP and the other on a SGI/Cray ??

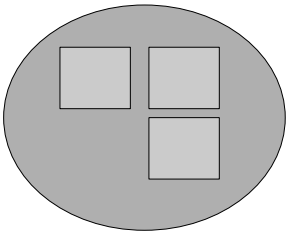
MPI-2: Process Management

- MPI-2 provides both a Spawn (or remote start) call
  - Depending on the implementation you have LAM 6.X+ does MPICH 1.3.1 does not
  - Different vendor versions do
    - Such as NEC/SUN

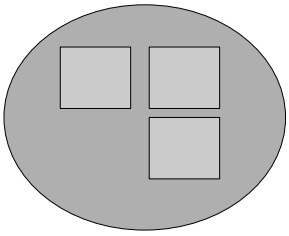
MPI-2: Process Management

- Two flavors
  - MPI_Comm _spawn ( )
    - Starts new processes from a single binary and returns an intercommunicator to them
  - MPI_Comm_spawn_multiple ( )
    - Starts new processes from more than one binary

MPI-2: Process Management

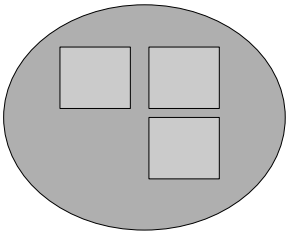


MPI-2: Process Management



MPI_Comm_spawn (other..)

MPI-2: Process Management



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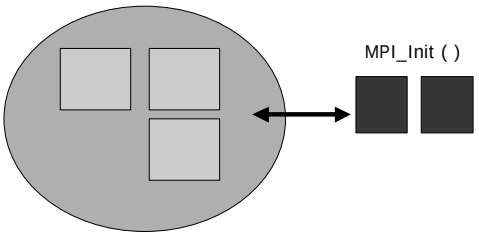

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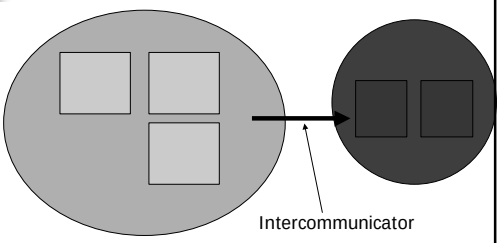
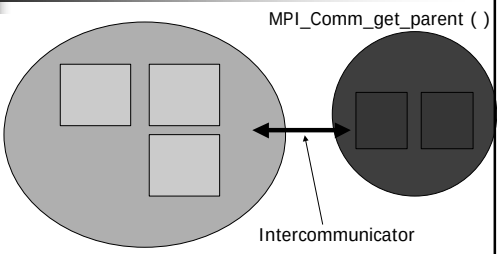


MPI-2: Process Management



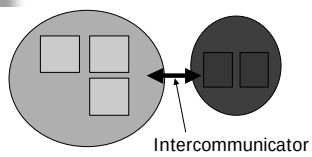
MPI-2: Process Management

- The creating processes get an intercommunicator to the child group as soon as the spawn call returns..
  - They can send to it before the children have called MPI_Init ()

MPI-2: Process Management

- Is the Intercommunicator functionality enough to allow for a full dynamic process model with efficient communications ?
  - Hints
    - What are the limits of an intercommunicator
    - How are multiple child groups

MPI-2: Process Management



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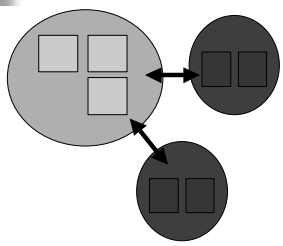
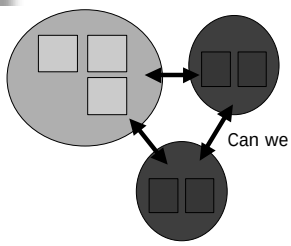


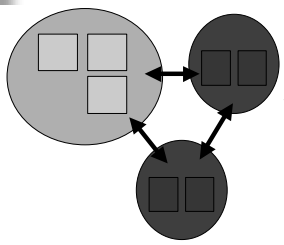
MPI-2: Process Management



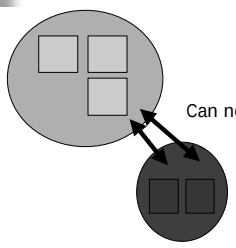
MPI-2: Process Management

- Can the two children groups create a direct connection?
  - using an MPI communicator create / merge call of some kind?

MPI-2: Process Management



MPI-2: Process Management



MPI-2: Establishing communications

- How do we do communications between MPI applications that have not been started by each other?

MPI-2: Establishing communications

- MPI-2 has a TCP socket style abstraction
- Process can wait and accept connections from other processes
- Server – Client interface

MPI-2: Establishing communications

- How does the client find the server ?
- MPI does not mandate a nameservice but they did make an interface for one.

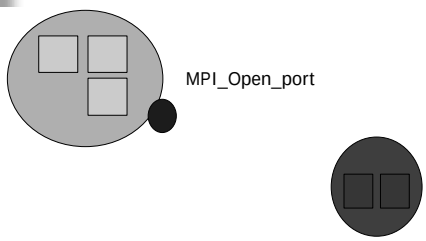
MPI-2: Establishing communications

- Server Side
  - Three routines
    - MPI_Open_port (info, port_name)
      - Creates a port that other can connect to
    - MPI_Close_port (port_name)
    - MPI_Comm_accept (port_name, info, root, comm, newcomm)
      - comm is a intracommunicator
      - newcomm is an intercommunicator

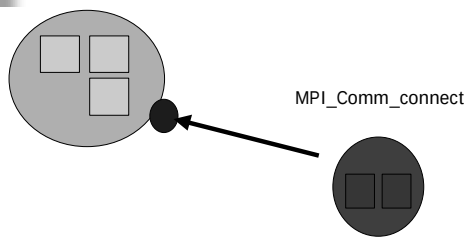
MPI-2: Establishing communications

- Client side
  - MPI_Comm_connect (port_name, info, root, comm, newcomm)
    - comm is a intracommunicator
    - newcomm is an intercommunicator
  - This call does have a timeout dependant on the implementation

MPI-2: Establishing communications



MPI-2: Establishing communications



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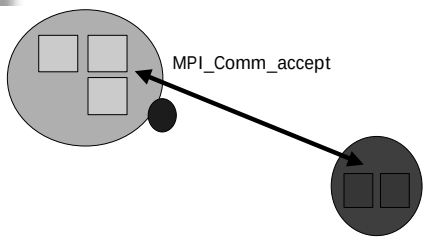
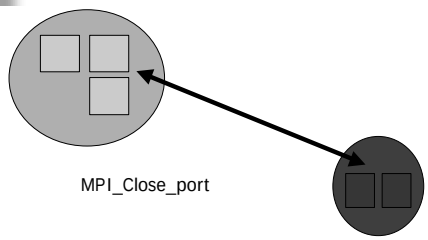


MPI-2: Establishing communications



MPI-2: Establishing communications

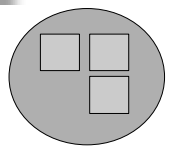
Naming service is build on a simple third party publish and lookup nameservice

3 calls exist

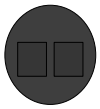
MPI_Publish_name (servicename, info, port_name)
MPI_Unpublish_name (servicename, info, port_name)

MPI_Lookup_name (servicename, info, port_name)

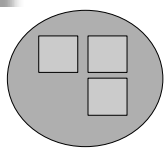
MPI-2: Establishing communications

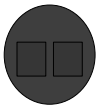


MPI_Open_port (..)
MPI_Publish_name (service..)
...
MPI_Comm_accept



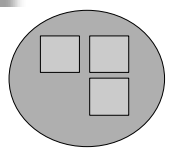
MPI-2: Establishing communications

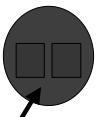




MPI_Lookup_name (service.. port_name)
MPI_Comm_connect (… port_name)

MPI-2: Establishing communications

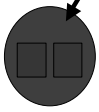




Child 1

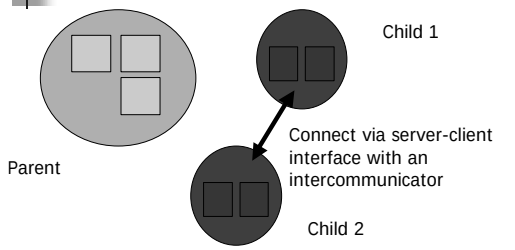
How do they communicate?

Parent



Child 2

MPI-2: Establishing communications



MPI-2: Establishing communications

- Does this interface solve all of our problems?
  - Can we create an intracommunicator between the two child groups?
  - Can we now do collectives between children?
- What kind of operations/types of computing is it good for?

MPI-2: Establishing communications

- Once the communication is finished
  - MPI_Comm_disconnect ()
- And lastly
  - MPI_Comm_join (fd, intercomm)

    Yes fd is a TCP socket descriptor

    used in cases when your applications can join via other means outside the MPI library

MPI-2: Single sided communications

- Normal message passing operation needs at least two parties
  - A sender who performs a send call
  - A receiver who performs a receive call

Why is this? And what does it have to do with… memory management / protection?

MPI-2: Single sided communications

- Earlier Cray MPP systems allowed processes to remotely access other processes memory via shmget and shmput system function calls.
  - This is known as Remote Memory Access (RMA)

MPI-2: Single sided communications

- Remote Memory Access (RMA)
  - Is fast
  - Can allow for simple program design
  - An operation specifies all the send and receive arguments together

MPI-2: Single sided communications

- Data (memory) in a fixed range (a window) is made available with a MPI_Win_create ( ) call.
  - Freed with MPI_Win_free ( )
- Data can then be accessed via
  - MPI_Put ( )
  - MPI_Get ( )
  - MPI_Accumulate ( )

MPI-2: Single sided communications

- The communication calls (put/get/accumulate) are non-blocking
- The operation occurs sometime after the call BUT before a synchronization point

MPI-2: Single sided communications

- RMA communication is in two classes
  - Active
    - Memory is moved from one process to another
    - One process calls the move
    - Both must call the synchronization (including the owner of the target memory)
  - Like message passing

MPI-2: Single sided communications

- RMA communication is in two classes
  - Passive
    - Memory is copied from a target to two other processes
    - Both processes call the copy
    - Both must synchronize (complete) their move, expect the target does not need to synchronize
  - Like shared memory

MPI-2: Single sided communications

- Semantics of an active target operation cycle are:
  - Sync on a win (RMA target window)

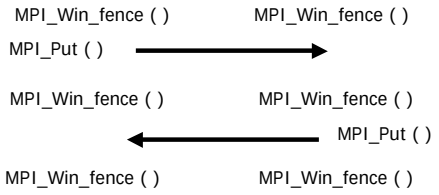
  Start of an epoch
  - Perform zero or more transfer operations
    - Such as put/get/accumulate

  End of an epoch
  - Sync on a win
- Passive target operations require no sync operations

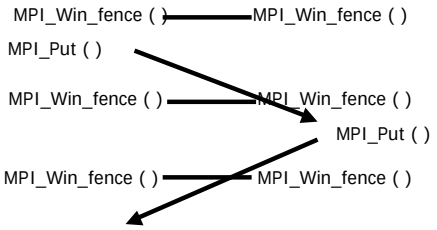
MPI-2: Single sided communications

- MPI_Win_fence ( )
  - A collective that can be used across the whole application to control operations so that they occur at the correct time such as exchanging data at the end of a time step

MPI-2: Single sided communications



MPI-2: Single sided communications



MPI-2: Single sided communications

- MPI_Win_fence ( ) is a collective that allows groups to sync their memory operations.
- Think of a set of MPI_Isends/MPI_Irecvs followed by a MPI_Waitall and a MPI_Barrier

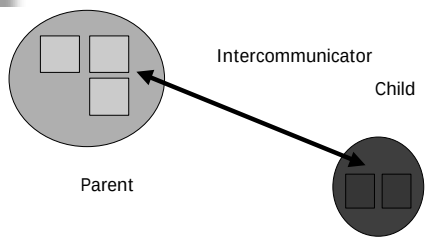
MPI-2: Single sided communications

- For fine grain control between pairs of processes only there is a more complex interface
  - MPI_Win_start, MPI_Win_complete, MPI_Win_post, MPI_Win_wait, MPI_Win_lock, MPI_Win_unlock
- Close to some of the Posix threads interface

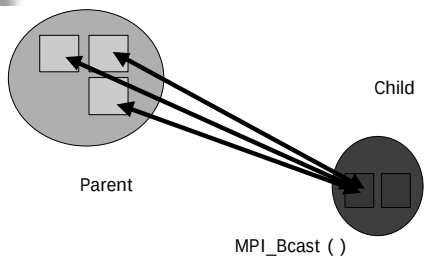
MPI-2: Intercommunicator collectives

- Collective operations require an intracommunicator
  - Sometimes it would be useful to perform a collective (such as a broadcast) across an intracommunicator
  - As in the case of when we cannot create an intracommunicator

MPI-2: Intercommunicator collectives



MPI-2: Intercommunicator collectives



MPI-2: Intercommunicator collectives

- Semantics of these (MPIX*) calls
  - We need to know which is the root group and which is the leaf (target) group
  - How do we know the root group?
    - All processes in that group other that the real root call the operation with MPI_PROC_NULL as their root
    - The root calls the operation with the root set to a special constant MPI_ROOT
  - MPIX was a project at MSU that first proposed these extensions to MPI (hence MPIX)

MPI-2: MPI I/O

- Will be covered in the next lecture
  - When you get to compare it against distributed file systems

MPI-1

- Back to MPI-1 stuff
  - Some things you may have missed before
  - Many of them to do with using MPI under the covers
    - (like reading a book under the covers with the lights turned off)

MPI-1: Profiling

- Tool writers like to tell you what is happening when running an MPI application so you can improve things
  - Three ways of doing this
    - Instrument the MPI library
      - Common way of doing it
    - Instrument your application before it links to the MPI library
      - Useful for very complex debuggers
    - Catch the runtime calls
      - Pardym (do it without the source available)

MPI-1: Profiling

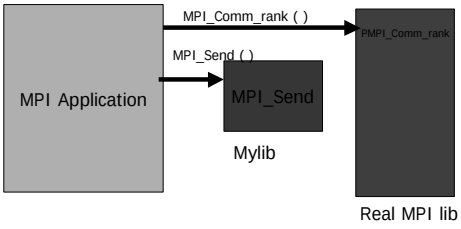
- MPI-1 provides a built in method of doing this
  - Known as the profiling interface
  - Allows instrumentation or replacing of only the required calls at run time
  - Relies on weak linking in most implementations

MPI-1: Profiling

- How it works
  - All MPI calls have a non-profiled version called:
    - PMPI_<CALL>
  - The standard MPI_<CALL> links to this PMPI_<CALL> unless a replacement MPI_<CALL> is provided.

MPI-1: Profiling

- Mylib has MPI_Send ( ) implemented



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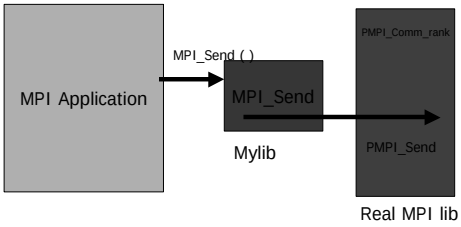


MPI-1: Profiling

- The profile library does have full access to the real MPI library, by calling the PMPI_<CALL> calls.
- The tool writer only needs to implement the calls they require
  - Rather than 248+

MPI-1: Profiling

- An application can pass information to the profile library
  - MPI_Pcontrol (level)
    - Indicated to the profile library what level of debugging you might want
    - Can also use the MPI key attributes as well.

MPI-1: Profiling

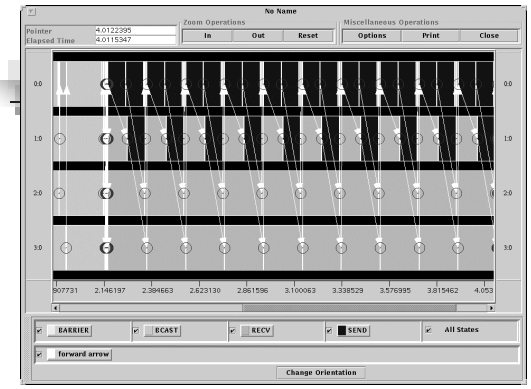
- MPICH comes with multiple profile libraries
  - We are interested in the mpilog library
  - Mpicc myfile.c –o myfile –mpilog –lmpe …

MPI-1: Profiling

- When executed will produce a
  - <exename>.clog file
- This needs to be converted to an slog (scalable log file) before viewing etc
- /usr/local/mpich-1.2.1/clog2slog myfile.clog

MPI-1: Profiling

- Then run the logview on it
  - /usr/local/mpich-1.2.1/bin/logviewer myfile.slog
  - Choose the <MPI Process> button and hit <display>



MPI-1: Profiling

- That was a barrier followed by a set of broadcasts so that they could be benchmarked.
- You will need to show that you can use the logfile viewer for your homework exercises

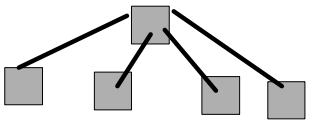
MPI-1: How do collectives work

- If we look back at the logfile there is no bcast marker
  - Or reduce, scatter, etc
  - It shows collectives as being built on point to point operations
- When is this less efficient ?

MPI-1: How do collectives work

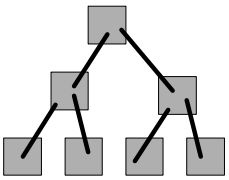
- Collectives can be built using a number of different topologies, such as rings, trees, meshes etc
- Some of these topologies are better than others in terms of latency or obtaining peak bi-sectional bandwidth

MPI-1: How do collectives work



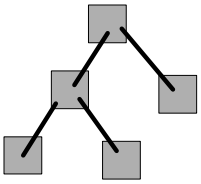
Flat tree (or sequential broadcast)

MPI-1: How do collectives work



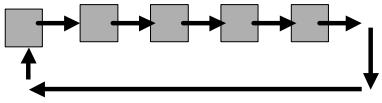
Binary tree (fan out of 2)

MPI-1: How do collectives work



Binomial tree

MPI-1: How do collectives work



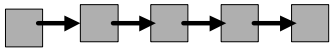
Pipeline / ring

MPI-1: How do collectives work

- What are the properties of these topologies?
  - Number of steps required to complete an operations (maximum latency)
  - How many concurrent operations?

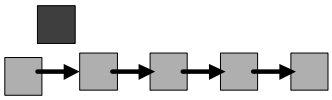
MPI-1: How do collectives work

- Say we send a message of length X in one step down a pipeline…



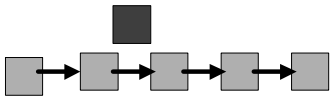
MPI-1: How do collectives work

- Step 1



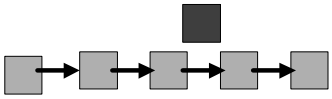
MPI-1: How do collectives work

- Step 2



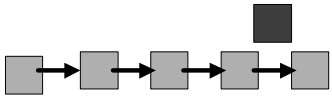
MPI-1: How do collectives work

- Step 3



MPI-1: How do collectives work

- Step 4

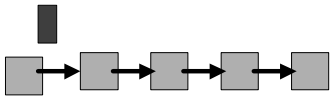


MPI-1: How do collectives work

- Can we do better ?
- Well we could segment the message into smaller parts….
  - End to end latency (to get the first part), would it be different?
  - Overall end to end bandwidth would it change?

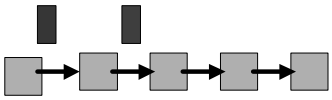
MPI-1: How do collectives work

- Step 1



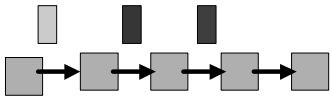
MPI-1: How do collectives work

- Step 2



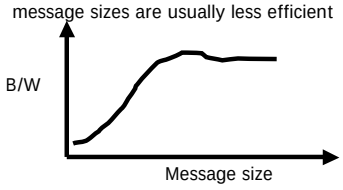
MPI-1: How do collectives work

- Step 3



MPI-1: How do collectives work

- What happens with a tree ? Is it even better.
- Comm systems have peak performances and small message sizes are usually less efficient

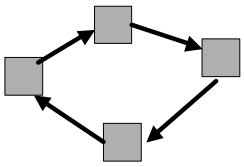


MPI-1: Communicators for distributed computing

- If an application is spread across multiple systems but acts as a single MPI application, performance problems can occur.

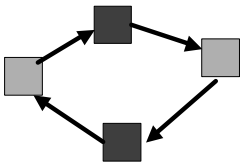
MPI-1: Communicators for distributed computing

- Say the collective is a ring



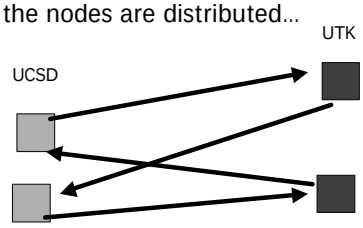
MPI-1: Communicators for distributed computing

- But the nodes are distributed…



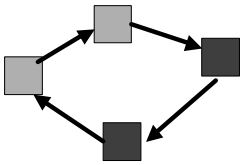
MPI-1: Communicators for distributed computing

- But the nodes are distributed…



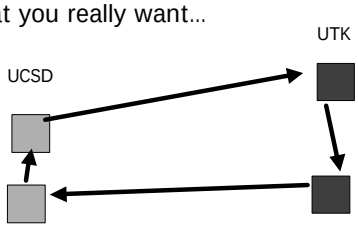
MPI-1: Communicators for distributed computing

- What you really want…



MPI-1: Communicators for distributed computing

- What you really want…



MPI-1: Communicators for distributed computing

- You can create multiple new communicators
  - One for each of sites
  - A new one that is made by merging the new communicators in the right order
    - Works well if you know how your MPI implementation works
    - Or you have to build your own collectives