Intel® MPI Benchmarks

User Guide and Methodology Description

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Revision 3.2.4

Contents

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The Intel(R) MPI Benchmarks home page can be found at:

http://www.intel.com/go/imb

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- The Intel(R) MPI Benchmarks package name and version information
- Host architecture (for example, IA-32 or Intel(R) 64 architecture)
- Compiler(s) and versions
- Operating system(s) and versions
- Specifics on how to reproduce the problem. Include makefiles, command lines, small test cases, and build instructions.

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1. Go to https://premier.intel.com
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3. Click on the **Submit Issue** link in the left navigation bar.
4. Choose **Development Environment (tools, SDV, EAP)** from the **Product Type** drop-down list. If this is a software or license-related issue, choose the **Intel(R) Cluster Studio [XE], Linux*** or the **Intel(R) Cluster Studio [XE], Windows*** from the **Product Name** drop-down list.
5. Enter your question and complete the required fields to successfully submit the issue.

NOTE:

Notify your support representative prior to submitting source code where access needs to be restricted to certain countries to determine if this request can be accommodated.

Introduction

This Guide presents the Intel® MPI Benchmarks 3.2.4. The objectives of the Intel® MPI Benchmarks are:

- Provide a concise set of benchmarks targeted at measuring the most important MPI functions.
- Set forth a precise benchmark methodology.
- Report bare timings rather than provide interpretation of the measured results. Show throughput values if and only if these values are well defined.

Intel® MPI Benchmarks is developed using ANSI C plus standard MPI.

Intel® MPI Benchmarks is distributed as an open source project to enable use of benchmarks across various cluster architectures and MPI implementations.

Introducing Intel(R) MPI Benchmarks

Intel® MPI Benchmarks performs a set of MPI performance measurements for point-to-point and global communication operations for a range of message sizes. The generated benchmark data fully characterizes:

- performance of a cluster system, including node performance, network latency, and throughput
- efficiency of the MPI implementation used

The Intel® MPI Benchmarks package consists of the following components:

- *IMB-MPI1* - benchmarks for MPI-1 functions
- Two components for MPI-2 functionality:
  - *IMB-EXT* - one-sided communications benchmarks
  - *IMB-IO* - input/output (I/O) benchmarks

Each component corresponds to a separate executable file. You can run all of the supported benchmarks, or specify a single executable file in the command line to get results for a specific subset of benchmarks.

If you do not have the MPI-2 extensions available, you can install and use IMB-MPI1 that uses only standard MPI-1 functions.

Intended Audience

This guide is intended for users who want to measure performance of MPI implementations.

What's New

This section provides changes for the Intel® MPI Benchmarks as compared to the previous versions of this product.

Changes in Intel® MPI Benchmarks 3.2.4

This release includes the following updates as compared to the Intel® MPI Benchmarks 3.2.3:

- Changes of document layout.

Changes in Intel® MPI Benchmarks 3.2.3

This release includes the following updates as compared to the Intel® MPI Benchmarks 3.2.2:

- Option `-msglog` to control the message length. Use this option to control the maximum and the second largest minimum of the message transfer sizes. The minimum message transfer size is always 0.
- Thread safety support in the MPI initialization phase. Use `MPI_Init()`by default because it is supported for all MPI implementations. You can choose `MPI_Init_thread()`by defining the appropriate macro.
- Option `–thread_level` to specify the desired thread level support for `MPI_Init_thread.`
- Support for the Microsoft* Visual Studio* 2010 project folder.

Changes in Intel® MPI Benchmarks 3.2.2

This release includes the following updates as compared to the Intel® MPI Benchmarks 3.2.1:

- Support for large buffers greater than 2 GB for some MPI collective benchmarks (`Allgather`, `Alltoall`, `Scatter`, `Gather`) to support large core counts.
- New benchmarks: `PingPongSpecificSource` and `PingPingSpecificSource`. The exact destination rank is used for these tests instead of `MPI_ANY_SOURCE` as in the `PingPong` and `PingPing` benchmarks. These are not executed by default. Use the `-include` option to enable the new benchmarks. For example,

```
$ mpirun  n 2 IMB_MPI -include PingPongSpecificSource \
PingPingSpecificSource
```

- New options `-include/-exclude` for better control over the benchmarks list. Use these options to include or exclude benchmarks from the default execution list.

Changes in Intel® MPI Benchmarks 3.2.1

This release includes the following updates as compared to the Intel® MPI Benchmarks 3.2:

- Fix of the memory corruption issue when the command-line option `-msglen` is used with the Intel® MPI Benchmarks executable files.

- Fix in the accumulated benchmark related to using the CHECK conditional compilation macro.
- Fix for the integer overflow in dynamic calculations on the number of iterations.
- Recipes for building IA-32 executable files within Microsoft* Visual Studio* 2005 and Microsoft* Visual Studio* 2008 project folders associated with the Intel® MPI Benchmarks.

Changes in Intel(R) MPI Benchmarks 3.2

Intel® MPI Benchmarks 3.2 has the following changes as compared to the previous version:

- The default settings are different.
- Microsoft* Visual Studio* project folders are added and can be used on the Microsoft* Windows* platforms.
- Makefiles for the Microsoft* Windows* nmake utility provided with the Intel® MPI Benchmarks 3.1 are removed.

Run Time Control by Default

The impoved run time control that is associated with the –time flag. This is the default value for the Intel® MPI Benchmarks executable files (with a maximum run time per sample set to 10 seconds by the SECS_PER_SAMPLE parameter in the include file IMB_settings.h).

Makefiles

The nmake files for Windows* OS were removed and replaced by Microsoft* Visual Studio* solutions.

The Linux* OS Makefiles received new targets:

- Target MPI1 (default) for building IMB-MPI1
- Target EXT for building IMB-EXT
- Target IO for building IMB-IO
- Target all for building all three of the above

Microsoft* Visual Studio* Project Folders

Intel® MPI Benchmarks 3.2 contains Microsoft* Visual Studio* solutions based on an installation of the Intel® MPI Library. A dedicated folder is created for the Microsoft* Windows* OS without duplicating source files. The solutions refer to the source files that are located at their standard location within the Intel® MPI Benchmarks directory structure.

As such solutions are highly version-dependent, see the information in the corresponding ReadMe.txt files that unpack with the folder. You are recommended to learn about the Microsoft* Visual Studio* philosophy and the run time environment of your Windows cluster.

Changes in Intel(R) MPI Benchmarks 3.1

This release includes the following updates as compared to the Intel® MPI Benchmarks 3.0:

- New control flags

- Better control of the overall repetition counts, run time, and memory exploitation
- A facility to avoid cache re-usage of message buffers as far as possible
- A fix of IMB-IO semantics
- New benchmarks
    - `Gather`
    - `Gatherv`
    - `Scatter`
    - `Scatterv`
- New command-line flags for better control
    - `-off_cache`

      Use this flag when measuring performance on high speed interconnects or, in particular, across the shared memory within a node. Traditional Intel® MPI Benchmarks results included a very beneficial cache re-usage of message buffers which led to idealistic results. The flag -off_cache allows avoiding cache effects and lets the Intel® MPI Benchmarks use message buffers which are very likely not resident in cache.
    - `-iter, -time`

      Use these flags for enhanced control of the overall run time, which is crucial for large clusters, where collectives tend to run extremely long in the traditional Intel® MPI Benchmarks settings.

      CAUTION

      In the Intel® MPI Benchmarks, the -time flag has been implemented as default.
    - `-mem`

Use this flag to determine an a priori maximum (per process) memory usage of the Intel® MPI Benchmarks for the overall message buffers.

Miscellaneous Changes

In the Exchange benchmark, the two buffers sent by `MPI_Isend` are separate. The command line is repeated in the output. Memory management is completely encapsulated in the functions `IMB_v_alloc/IMB_v_free.`

Changes in Intel® MPI Benchmarks 3.0

This release includes the following updates as compared to the Intel® MPI Benchmarks 2.3:

- A call to the `MPI_Init_thread` function to determine the MPI threading environment. The MPI threading environment is reported each time an Intel® MPI Benchmark application is executed.
- A call to the function `MPI_Get_version` to report the version of the Intel MPI library implementation that the three benchmark applications are linking to.

- New Alltoallv benchmark.
- New command-line flag -h[elp] to display the calling sequence for each benchmark application.
- Removal of the outdated Makefile templates. There are three complete makefiles called Makefile, make_ict, and make_mpich. The make_ict option uses the Intel® Composer XE compilers. This option is available for both Intel and non-Intel microprocessors but it may result in additional optimizations for Intel microprocessors.
- Better command-line argument checking, clean message and break on most invalid arguments.

Notational Conventions

The following conventions are used in this document.

Conventions and Symbols Used in This Document

This type style	**Document or product names**
This type style	Hyperlinks
`This type style`	Commands, arguments, options, file names
THIS_TYPE_STYLE	Environment variables
<*this type style*>	Placeholders for actual values
[items]	Optional items
{ item | item }	Selectable items separated by vertical bar(s)

Document Version Information

Document Number	Revision Number	Description	Revision Date
320714-001	2.3	Initial version	/10/2004
320714-002	3.0	The following topics were added:	/06/2006

		• Descriptions of environment amendments • The Alltoallv	
320714-003	3.1	The following updates were added: • Description of Windows version • Four new benchmarks (Scatter(v), Gather(v)) • IMB-IO functional fix	/07/2007
320714-004	3.2	The following topics were added: • Run time control as default • Microsoft* Visual Studio* solution templates	/08/2008
320714-005	3.2.1	The following updates were added: • Fix of the memory corruption • Fix in accumulate benchmark related to using the CHECK conditional compilation macro • Fix for integer overflow in dynamic calculations on the number of iterations • Recipes for building IA-32 executable files within Microsoft* Visual Studio* 2005 and Microsoft* Visual Studio* 2008 project folders associated with the Intel® MPI Benchmarks	/04/2010
320714-006	3.2.2	The following updates were added: • Support for large buffers greater than 2 GB for some MPI benchmark • New benchmarks PingPongSpecificSource and PingPingSpecificSource • New options -include/-exclude	/09/2010
320714-007	3.2.3	The following topics were updated and	/08/2011

		added: • Changes in the Intel® MPI Benchmarks 3.2.3 • Command-line Control • Parameters Controlling IMB • Microsoft* Visual Studio* 2010 project folder support	
320714-008	3.2.4	The following updates were added: • Changes of document layout	/06/2012

Related Information

For more information, you can see the following related resources:

Intel® MPI Benchmarks Download

Intel® MPI Library Product

Installation and Quick Start

This section explains how to install and start using the Intel® MPI Benchmarks.

Requirements

Software Requirements

To run the Intel® MPI Benchmarks, you need:

- cpp, ANSI C compiler, gmake on Linux* OS or Unix* OS.
- Enclosed Microsoft Visual* C++ solutions as the basis for Microsoft Windows* OS.
- MPI installation, including a startup mechanism for parallel MPI programs.

Memory and Disk Space Requirements

The table below lists memory requirements for benchmarks run with the default settings (standard mode) and with the user-defined settings (optional mode). In this table:

- Q is the number of active processes.
- X is the maximal size of the passing message.

Benchmarks	**Standard Mode**	**Optional Mode**
Alltoall	Qx8 MB	Qx2X bytes
Allgather, Allgatherv	(Q+1)x4 MB	(Q+1)xX bytes
Exchange	12 MB	3X bytes
All other MPI-1 benchmarks	8 MB	2X bytes
IMB-EXT	80 Mbytes	2 max(X,OVERALL_VOL) bytes
IMB-IO	32 Mbytes	3X bytes

NOTE:

If you do not select the -cache flag, add 2X cache size to all of the above.

For IMB-IO benchmarks, make sure you have enough disk space available:

- 16MB in the standard mode

- max(X,OVERALL_VOL) bytes in the optional mode

For instructions on enabling the optional mode, see Parameters Controlling Intel® MPI Benchmarks.

Installing Intel® MPI Benchmarks

To install the Intel® MPI Benchmarks, unpack the installation file. The installation directory structure is as follows:

- ReadMe_first.txt
- ./doc - documentation directory that contains the following documents:
  - ReadMe_IMB.txt
  - User's guide, in PDF and HTML Uncompressed Help formats: Users_Guide.pdf and imb_userguide/index.htm.
- ./src - program source- and Make-files.
- ./WINDOWS - Microsoft* Visual Studio* solution files.
- ./license - license agreement directory that contains the following files:
  - license.txt - specifies the source code license granted to you.
  - use-of-trademark-license.txt - specifies the license for using the name and/or trademark of the Intel® MPI Benchmarks.
- ./versions_news - version history and update information.

For basic instructions on how to use the Intel® MPI Benchmarks, see ./doc/ReadMe_IMB.txt.

See Also

Buliding Intel® MPI Benchmarks

Building Intel® MPI Benchmarks

After you successfully install the Intel® MPI Benchmarks, do the following:

On Linux* OS:

1. Set the CC environment variable to point to the compiler you are using.
2. Run one or more makefile commands listed below.

Command	**Description**
make clean	Remove legacy binary object files and executable files

`make MPI1`	Build the executable file for the IMB-MPI1 component.
`make EXT`	Build the executable file for one-sided communications benchmarks.
`make IO`	Build the executable file for I/O benchmarks.
`make all`	Build all executable files available.

On Microsoft* Windows* OS:

On Windows* OS, you can use the enclosed solution files as a starting point and revise these files according to your needs.

See Also

Running Intel® MPI Benchmarks

Running Intel® MPI Benchmarks

To run the Intel® MPI Benchmarks, use the following command-line syntax:

```
mpirun -np <P> IMB-<component> [arguments]
```

where

- `<P>` is the number of processes. `P=1` is recommended for all I/O and message passing benchmarks except the single transfer ones.
- `<component>` is the component-specific suffix that can take `MPI1`, `EXT`, or `IO` values.

By default, all benchmarks run on `Q` *active processes* defined as follows:

`Q=[1,] 2, 4, 8, ...,` largest 2^x

For example, if `P=11`, the benchmarks run on `Q=[1,]2,4,8,11` active processes. Single transfer `IMB-IO` benchmarks run with `Q=1`. Single transfer `IMB-EXT` benchmarks run with `Q=2`.

To pass control arguments other than `P`, you can use `(argc,argv)`. Process 0 in `MPI_COMM_WORLD` reads all command-line arguments and broadcasts them to all other processes. Control arguments can define various features, such as time measurement, message length, and selection of communicators. For details, see Command-Line Control.

See Also

Command-Line Control
Parameters Controlling Intel® MPI Benchmarks

Benchmarks

Intel® MPI Benchmarks provides a set of elementary MPI benchmarks.

You can run all benchmarks in the following modes:

- standard (default) - the benchmarks run in a single process group.
- multiple - the benchmarks run in several process groups.

To run the benchmarks in the multiple mode, add the multi- prefix to the benchmark name.

In the multiple mode, the number of groups may differ depending on the benchmark. For example, if PingPong is running on N≥4 processes, N/2 separate groups of two processes are formed. These process groups are running PingPong simultaneously. Thus, the benchmarks of the single transfer class behave as parallel transfer benchmarks when run in the multiple mode.

See Also

Classification of MPI-1 Benchmarks
Classification of MPI-2 Benchmarks

MPI-1 Benchmarks

IMB-MPI1 component of the Intel® MPI Benchmarks provides benchmarks for MPI-1 functions. IMB-MPI1 contains the following benchmarks:

Standard Mode	**Multiple Mode**
PingPong	Multi-PingPong
PingPongSpecificSource,	Multi-PingPongSpecificSource (excluded by default)
PingPing	Multi-PingPing
PingPingSpecificSource	Multi-PingPingSpecificSource (excluded by default)
Sendrecv	Multi-Sendrecv
Exchange	Multi-Exchange
Bcast	Multi-Bcast
Allgather	Multi-Allgather
Allgatherv	Multi-Allgatherv

Scatter	Multi-Scatter
Scatterv	Multi-Scatterv
Gather	Multi-Gather
Gatherv	Multi-Gatherv
Alltoall	Multi-Alltoall
Alltoallv	Multi-Alltoallv
Reduce	Multi-Reduce
Reduce_scatter	Multi-Reduce_scatter
Allreduce	Multi-Allreduce
Barrier	Multi-Barrier

Classification of MPI-1 Benchmarks

Intel® MPI Benchmarks introduces the following classes of benchmarks:

- Single Transfer
- Parallel Transfer
- Collective benchmarks

Each class interprets results in a different way.

Single Transfer Benchmarks

Single transfer benchmarks involve two active processes into communication. Other processes wait for the communication completion. Each benchmark is run with varying message lengths. The timing is averaged between two processes. The basic MPI data type for all messages is MPI_BYTE.

Throughput values are measured in MBps and can be calculated as follows:

$throughput = X/2^{20} * 10^{6}/time = X/1.048576/time$,

where

- time is measured in μ sec.
- X is the length of a message, in bytes.

Parallel Transfer Benchmarks

Parallel transfer benchmarks involve more than two active processes into communication. Each benchmark runs with varying message lengths. The timing is averaged over multiple samples. The basic MPI data type for all messages is MPI_BYTE.The throughput calculations of the benchmarks take into account the multiplicity nmsg of messages outgoing from or incoming to a particular process. For the Sendrecv benchmark, a particular process sends and receives X bytes, the turnover is 2X bytes, nmsg=2. For the Exchange benchmark, the turnover is 4X bytes, nmsg=4.

Throughput values are measured in MBps and can be calculated as follows:

$\texttt{throughput} = \texttt{nmsg*X/2}^{20} * \texttt{10}^{6}\texttt{/time} = \texttt{nmsg*X/1.048576/time}$,

where

- time is measured in μ sec.
- X is the length of a message, in bytes.

Collective Benchmarks

Collective benchmarks measure MPI collective operations. Each benchmark is run with varying message lengths. The timing is averaged over multiple samples. The basic MPI data type for all messages is MPI_BYTE for pure data movement functions and MPI_FLOAT for reductions.

Collective benchmarks show bare timings.

The following table lists the MPI-1 benchmarks in each class:

Single Transfer	**Parallel Transfer**	**Collective**
PingPong	Sendrecv	Bcast Multi-Bcast
PingPongSpecificSource	Exchange	Allgather Multi-Allgather
PingPing	Multi-PingPong	Allgatherv Multi-Allgatherv
PingPingSpecificSource	Multi-PingPing	Alltoall Multi-Alltoall
	Multi-Sendrecv	Alltoallv Multi-Alltoallv
	Multi-Exchange	Scatter Multi-Scatter
		Scatterv

		Multi-Scatterv
		Gather Multi-Gather
		Gatherv Multi-Gatherv
		Reduce Multi-Reduce
		Reduce_scatter Multi-Reduce_scatter
		Allreduce Multi-Allreduce
		Barrier Multi-Barrier

Single Transfer

The following benchmarks belong to the single transfer class:

- PingPong
- PingPongSpecificSource
- PingPing
- PingPingSpecificSources

See sections below for definitions of these benchmarks.

PingPong, PingPongSpecificSource

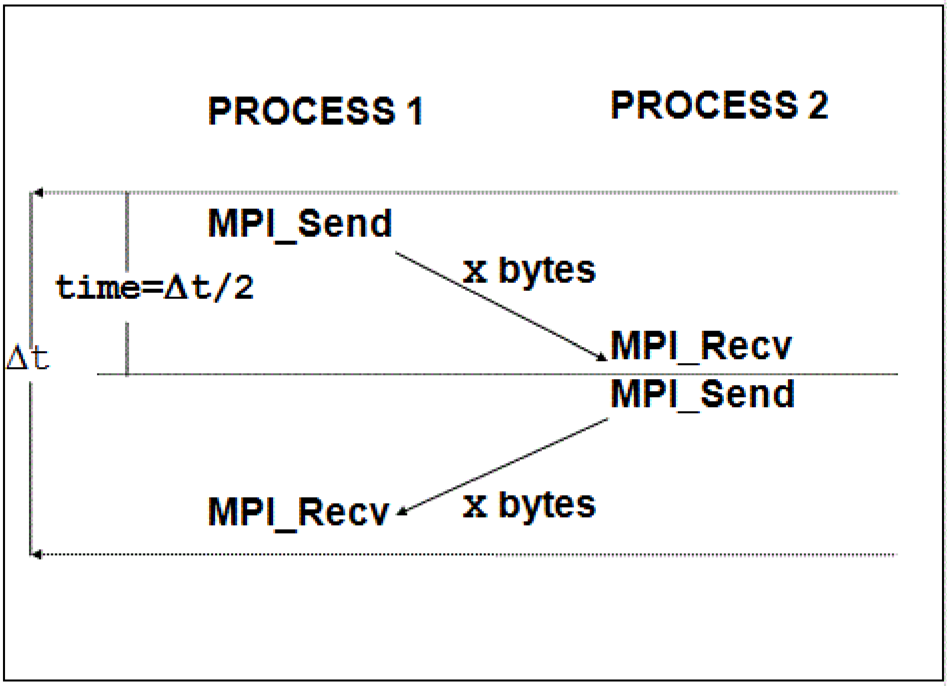
Use PingPong and PingPongSpecificSource for measuring startup and throughput of a single message sent between two processes. PingPong uses the MPI_ANY_SOURCE value for destination rank, while PingPongSpecificSource uses an explicit value.

PingPong Definition

Property	**Description**

Measured pattern	As symbolized between ⇠ ⇠ in the figure below. This benchmark runs on two active processes (Q=2).
MPI routines	MPI_Send, MPI_Recv
MPI data type	MPI_BYTE
Reported timings	time=Δt/2 (in μsec) as indicated in the figure below.
Reported throughput	X/(1.048576*time)

PingPong Pattern



PingPing, PingPingSpecificSource

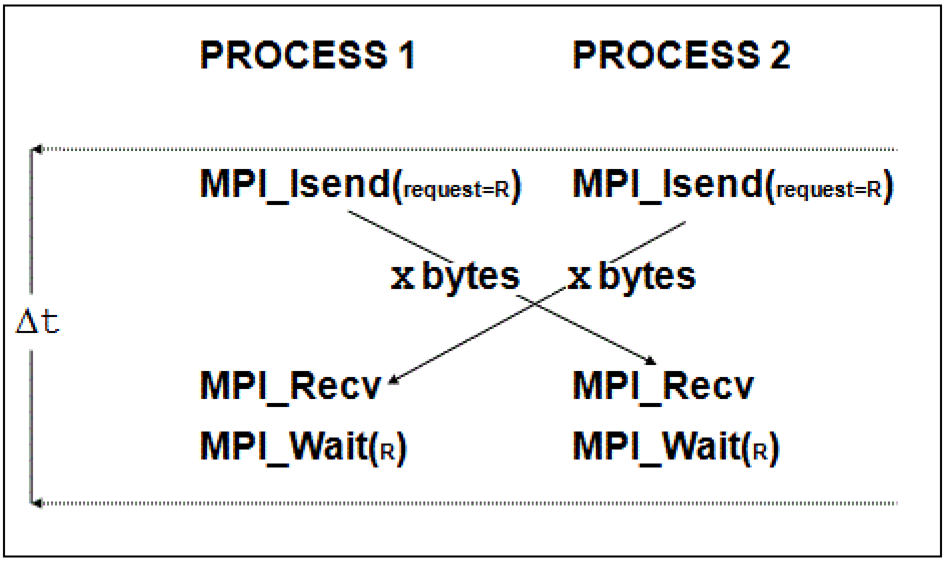
PingPing and PingPingSpecificSource measure startup and throughput of single messages that are obstructed by oncoming messages. To achieve this, two processes communicate with each other using MPI_Isend/MPI_Recv/MPI_Wait calls. The MPI_Isend calls are issued simultaneously by both processes. For destination rank, PingPing uses the MPI_ANY_SOURCE value, while PingPingSpecificSource uses an explicit value.

PingPing Definition

Property	**Description**

Measured pattern	As symbolized between ← ← in the figure below. This benchmark runs on two active processes (Q=2).
MPI routines	MPI_Isend/MPI_Wait, MPI_Recv
MPI data type	MPI_BYTE
Reported timings	time=Δt (in μsec)
Reported throughput	X/(1.048576*time)

PingPing Pattern



Parallel Transfer Benchmarks

The following benchmarks belong to the parallel transfer class:

- Sendrecv
- Exchange
- Multi-PingPong
- Multi-PingPing
- Multi-Sendrecv
- Multi-Exchange

See sections below for definitions of these benchmarks.

NOTE:

The definitions of the multiple mode benchmarks are analogous to their standard mode counterparts in the single transfer class.

Sendrecv

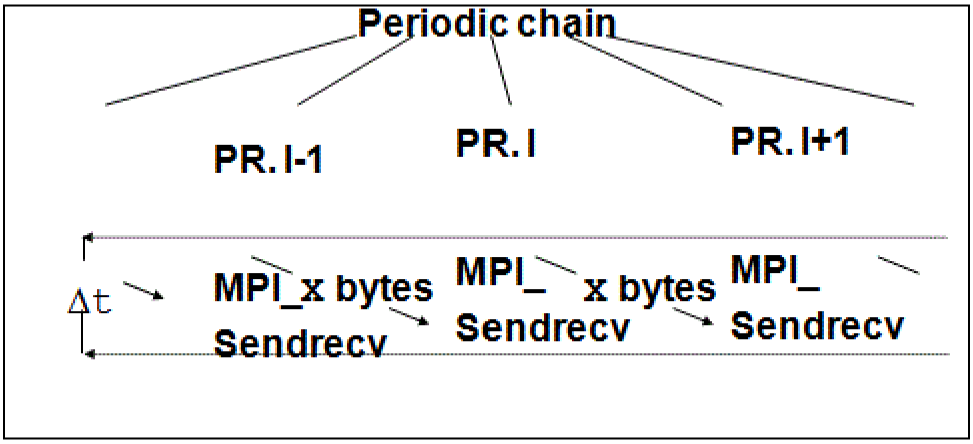
The `Sendrecv` benchmark is based on `MPI_Sendrecv`. In this benchmark, the processes form a periodic communication chain. Each process sends a message to the right neighbor and receives a message from the left neighbor in the chain. The turnover count is two messages per sample (one in, one out) for each process.

In the case of two processes, `Sendrecv` is equivalent to the `PingPing` benchmark of `IMB1.x`. For two processes, it reports the bidirectional bandwidth of the system, as obtained by the optimized `MPI_Sendrecv` function.

Sendrecv Definition

Property	**Description**
Measured pattern	As symbolized between ⇇ in the figure below.
MPI routines	`MPI_Sendrecv`
MPI data type	`MPI_BYTE`
Reported timings	`time=Δt` (in `μsec`) as indicated in the figure below.
Reported throughput	`2X/(1.048576*time)`

Sendrecv Pattern



Exchange

Exchange is a communication pattern that often occurs in grid splitting algorithms (boundary exchanges). The group of processes is similar to a periodic chain, and each process exchanges data with both left and right neighbor in the chain.

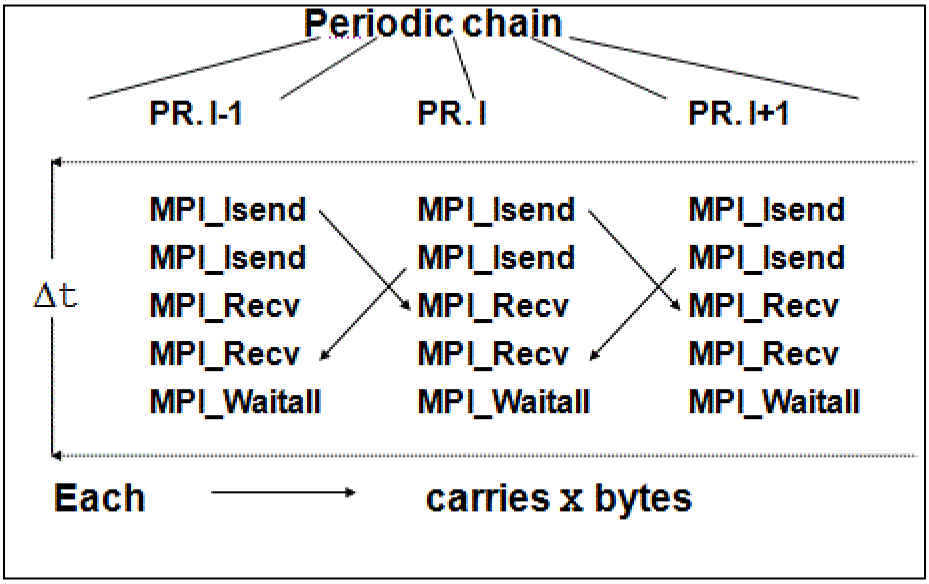
The turnover count is four messages per sample (two in, two out) for each process.

For two Isend messages, separate buffers are used.

Exchange Definition

Property	**Description**
Measured pattern	As symbolized between ⇠ in the figure below.
MPI routines	MPI_Isend/MPI_Waitall, MPI_Recv
MPI data type	MPI_BYTE
Reported timings	time=Δt (in μsec)
Reported throughput	4X/(1.048576*time)

Exchange Pattern



Collective Benchmarks

The following benchmarks belong to the collective class:

- Bcast/multi-Bcast

- Allgather/multi-Allgather
- Allgatherv/multi-Allgatherv
- Alltoall/multi-Alltoall
- Alltoallv/multi-Alltoallv
- Scatter/multi-Scatter
- Scatterv/multi-Scatterv
- Gather/multi-Gather
- Gatherv/multi-Gatherv
- Reduce/multi-Reduce
- Reduce_scatter/multi-Reduce_scatter
- Allreduce/multi-Allreduce
- Barrier/multi-Barrier

See sections below for definitions of these benchmarks.

Reduce

The benchmark for the MPI_Reduce function. It reduces a vector of length L = X/sizeof(float) float items. The MPI data type is MPI_FLOAT. The MPI operation is MPI_SUM. The root of the operation is changed round-robin.

Reduce Definition

Property	**Description**
Measured pattern	MPI_Reduce
MPI data type	MPI_FLOAT
MPI operation	MPI_SUM
Root	i%num_procs in iteration i
Reported timings	Bare time
Reported throughput	None

Reduce_scatter

The benchmark for the MPI_Reduce_scatter function. It reduces a vector of length L = X/sizeof(float) float items. The MPI data type is MPI_FLOAT. The MPI operation is MPI_SUM. In the scatter phase, the L items are split as evenly as possible. To be exact, for np number of processes:

L = r*np+s

where

- r = ⌊L/np⌋
- s = L mod np

In this case, the process with rank i gets:

- r+1 items when i<s
- r items when i≥s

Property	Description
Measured pattern	MPI_Reduce_scatter
MPI data type	MPI_FLOAT
MPI operation	MPI_SUM
Reported timings	Bare time
Reported throughput	None

Allreduce

The benchmark for the MPI_Allreduce function. It reduces a vector of length L = X/sizeof(float) float items. The MPI data type is MPI_FLOAT. The MPI operation is MPI_SUM.

Property	Description
Measured pattern	MPI_Allreduce
MPI data type	MPI_FLOAT
MPI operation	MPI_SUM
Reported timings	Bare time
Reported throughput	None

Allgather

The benchmark for the MPI_Allgather function. Every process inputs X bytes and receives the gathered X*np bytes, where np is the number of processes.

Property	Description
Measured pattern	MPI_Allgather
MPI data type	MPI_BYTE
Reported timings	Bare time
Reported throughput	None

Allgatherv

The benchmark for the MPI_Allgatherv function. Every process inputs X bytes and receives the gathered X*np bytes, where np is the number of processes. Unlike Allgather, this benchmark shows whether MPI produces overhead.

Property	Description
Measured pattern	MPI_Allgatherv
MPI data type	MPI_BYTE
Reported timings	Bare time
Reported throughput	None

Scatter

The benchmark for the MPI_Scatter function. The root process inputs X*np bytes (X for each process). All processes receive X bytes. The root of the operation is changed round-robin.

Property	Description
Measured pattern	MPI_Scatter
MPI data type	MPI_BYTE
Root	i%num_procs in iteration i
Reported timings	Bare time

Reported throughput	None

Scatterv

The benchmark for the MPI_Scatterv function. The root process inputs X*np bytes (X for each process). All processes receive X bytes. The root of the operation is changed round-robin.

Property	Description
Measured pattern	MPI_Scatterv
MPI data type	MPI_BYTE
Root	i%num_procs in iteration i
Reported timings	Bare time
Reported throughput	None

Gather

The benchmark for the MPI_Gather function. The root process inputs X*np bytes (X from each process). All processes receive X bytes. The root of the operation is changed round-robin.

Property	Description
Measured pattern	MPI_Gather
MPI data type	MPI_BYTE
Root	i%num_procs in iteration i
Reported timings	Bare time
Reported throughput	None

Gatherv

The benchmark for the MPI_Gatherv function. All processes input X bytes. The root process receives X*np bytes, where np is the number of processes. The root of the operation is changed round-robin.

Property	Description
Measured pattern	MPI_Gatherv

MPI data type	MPI_BYTE
Root	i%num_procs in iteration i
Reported timings	Bare time
Reported throughput	None

Alltoall

The benchmark for the MPI_Alltoall function. In the case of np number of processes, every process inputs X*np bytes (X for each process) and receives X*np bytes (X from each process).

Property	Description
Measured pattern	MPI_Alltoall
MPI data type	MPI_BYTE
Reported timings	Bare time
Reported throughput	None

Bcast

The benchmark for MPI_Bcast. The root process broadcasts X bytes to all other processes. The root of the operation is changed round-robin.

Property	Description
Measured pattern	MPI_Alltoall
MPI data type	MPI_BYTE
Reported timings	Bare time
Reported throughput	None

Barrier

The benchmark for the MPI_Barrier function.

Property	Description
Measured pattern	MPI_Barrier

Reported timings	Bare time
Reported throughput	None

MPI-2 Benchmarks

Intel® MPI Benchmarks provides benchmarks for MPI-2 functions in two components: IMB-EXT and IMB-IO. The table below lists all MPI-2 benchmarks available and specifies whether they support the aggregate mode. For I/O benchmarks, the table also lists non-blocking flavors.

Benchmark	**Aggregate Mode**	**Non-blocking Mode**
	IMB-EXT	
Window Multi-Window		
Unidir_Put Multi-Unidir_Put	Supported	
Unidir_Get Multi-Unidir_Get	Supported	
Bidir_Get Multi-Bidir_Get	Supported	
Bidir_Put Multi-Bidir_Put	Supported	
Accumulate Multi-Accumulate	Supported	
Benchmark	**Aggregate Mode**	**Non-blocking Mode**
	IMB-IO	
Open_Close Multi-Open_Close		

S_Write_indv Multi-S_Write_indv	Supported	S_IWrite_indv Multi-S_IWrite_indv
S_Read_indv Multi-S_Read_indv		S_IRead_indv Multi-S_IRead_indv
S_Write_expl Multi-S_Write_expl	Supported	S_IWrite_expl Multi-IS_Write_expl
S_Read_expl Multi-S_Read_expl		S_IRead_expl Multi-IS_Read_expl
P_Write_indv Multi-P_Write_indv	Supported	P_IWrite_indv Multi-P_IWrite_indv
P_Read_indv Multi-P_Read_indv		P_IRead_indv Multi-P_IRead_indv
P_Write_expl Multi-P_Write_expl	Supported	P_IWrite_expl Multi-P_IWrite_expl
P_Read_expl Multi-P_Read_expl		P_IRead_expl Multi-P_IRead_expl
P_Write_shared Multi-P_Write_shared	Supported	P_IWrite_shared Multi-P_IWrite_shared
P_Read_shared Multi-P_Read_shared		P_IRead_shared Multi-P_IRead_shared
P_Write_priv Multi-P_Write_priv	Supported	P_IWrite_priv Multi-P_IWrite_priv
P_Read_priv Multi-P_Read_priv		P_IRead_priv Multi-P_IRead_priv
C_Write_indv Multi-C_Write_indv	Supported	C_IWrite_indv Multi-C_IWrite_indv

C_Read_indv Multi-C_Read_indv		C_IRead_indv Multi-C_IRead_indv
C_Write_expl Multi-C_Write_expl	Supported	C_IWrite_expl Multi-C_IWrite_expl
C_Read_expl Multi-C_Read_expl		C_IRead_expl Multi-C_IRead_expl
C_Write_shared Multi-C_Write_shared	Supported	C_IWrite_shared Multi-C_IWrite_shared
C_Read_shared Multi-C_Read_shared		C_IRead_shared Multi-C_IRead_shared

See Also

Benchmark Modes
IMB-IO Non-Blocking Benchmarks

Naming Conventions

MPI-2 benchmarks have the following naming conventions:

Convention	Description
Unidir/Bidir	Unidirectional/bidirectional one-sided communications. These are the one-sided equivalents of PingPong and PingPing.
S_	Single transfer benchmark.
C_	Collective benchmark.
P_	Parallel transfer benchmark.
expl	I/O with explicit offset.
indv	I/O with an individual file pointer.

shared	I/O with a shared file pointer.
priv	I/O with an individual file pointer to one private file for each process opened for MPI_COMM_SELF.
[ACTION]	A placeholder for Read or Write component of the benchmark name.
I	Non-blocking flavor. For example, S_IWrite_indv is the non-blocking flavor of the S_IWrite_indv benchmark.
Multi-	The benchmark runs in the multiple mode.

IMB-MPI-2 Benchmark Classification

Intel® MPI Benchmarks introduces three classes of benchmarks:

- Single Transfer
- Parallel Transfer
- Collective

Each class interprets results in a different way.

NOTE:

The following benchmarks do not belong to any class:

- Window - measures overhead of one-sided communications for the MPI_Win_create / MPI_Win_free functions
- Open_close - measures overhead of input/output operations for the MPI_File_open / MPI_File_close functions

Single Transfer Benchmarks

This class contains benchmarks of functions that operate on a single data element transferred between one source and one target. For MPI-2 benchmarks, the source of the data transfer can be an MPI process or, in the case of Read benchmarks, an MPI file. The target can be an MPI process or an MPI file.

For I/O benchmarks, the single transfer is defined as an operation between an MPI process and an individual window or a file.

- Single transfer IMB-EXT benchmarks only run with two active processes.

- Single transfer IMB-IO benchmarks only run with one active process.

Parallel Transfer Benchmarks

This class contains benchmarks of functions that operate on several processes in parallel. The benchmark timings are produced under a global load. The number of participating processes is arbitrary.

In the Parallel Transfer, more than one process participates in the overall pattern.

The final time is measured as the maximum of timings for all single processes. The throughput is related to that time and the overall amount of transferred data (sum over all processes).

Collective Benchmarks

This class contains benchmarks of functions that are collective as provided by the MPI standard. The final time is measured as the maximum of timings for all single processes. The throughput is not calculated.

MPI-2 Benchmarks Classification

Single Transfer	Parallel Transfer	Collective	Other
Unidir_Get	Multi_Unidir_Get	Accumulate	Window
Unidir_Put	Multi_Unidir_Put	Multi_Accumulate	Multi_Window
Bidir_Get	Multi_Bidir_Get		
Bidir_Put	Multi_Bidir_Put		
S_[I]Write_indv	P_[I]Write_indv	C_[I]Write_indv	Multi-C_[I]Write_indv
S_[I]Write_indv	P_[I]Write_indv	C_[I]Write_indv Multi-C_[I]Write_indv	Open_close Multi-Open_close
S_[I]Read_indv	P_[I]Read_indv	C_[I]Read_indv Multi-C_[I]Read_indv	
S_[I]Write_expl	P_[I]Write_expl	C_[I]Write_expl Multi-C_[I]Write_expl	
S_[I]Read_expl	P_[I]Read_expl	C_[I]Read_expl Multi-C_[I]Read_expl	
	P_[I]Write_shared	C_[I]Write_shared	

		Multi-C_[I]Write_shared	
	P_[I]Read_shared	C_[I]Read_shared Multi-C_[I]Write_shared	
	P_[I]Write_priv		
	P_[I]Read_priv		

Benchmark Modes

MPI-2 benchmarks can run in the following modes:

- Blocking/non-blocking mode. These modes apply to the IMB-IO benchmarks only. For details, see sections IMB-IO Blocking Benchmarks and IMB-IO Non-Blocking Benchmarks.

- Aggregate/non-aggregate mode. Non-aggregate mode is not available for non-blocking flavors of IMB-IO benchmarks.

The following example illustrates aggregation of M transfers for IMB-EXT and blocking Write benchmarks:

```
Select a repetition count M
time = MPI Wtime();
issue M disjoint transfers
assure completion of all transfers
time = (MPI_Wtime() - time) / M
```

In this example:

- M is a repetition count:
  - M = 1 in the non-aggregate mode
  - M = n_sample in the aggregate mode. For the exact definition of n_sample see the Actual Benchmarking section.

- A transfer is issued by the corresponding one-sided communication call (for IMB-EXT) and by an MPI-IO write call (for IMB-IO).

- *Disjoint* means that multiple transfers (if M>1) are to/from disjoint sections of the window or file. This permits to avoid misleading optimizations when using the same locations for multiple transfers.

The variation of M provides important information about the system and the MPI implementation, crucial for application code optimizations. For example, the following possible internal strategies of an implementation could influence the timing outcome of the above pattern.

- Accumulative strategy. Several successive transfers (up to M in the example above) are accumulated without an immediate completion. At certain stages, the accumulated transfers are completed as a whole. This approach may save time of expensive synchronizations. This strategy is expected to produce better results in the aggregate case as compared to the non-aggregate one.

- Non-accumulative strategy. Every Transfer is completed before the return from the corresponding function. The time of expensive synchronizations is taken into account. This strategy is expected to produce equal results for aggregate and non-aggregate cases.

Assured Completion of Transfers

Following the MPI standard, *assured completion of transfers* is the minimum sequence of operations after which all processes of the file communicator have a consistent view after a write.

The aggregate and non-aggregate modes differ in when the assured completion of data transfers takes place:

- after each transfer (non-aggregate mode)

- after a bunch of multiple transfers (aggregate mode)

For Intel® MPI Benchmarks, assured completion means the following:

- For IMB-EXT benchmarks, `MPI_Win_fence`

- For IMB-IO Write benchmarks, a triplet `MPI_File_sync/MPI_Barrier(file_communicator)/MPI_File_sync`. This fixes the non-sufficient definition in the Intel® MPI Benchmarks 3.0.

IMB-EXT Benchmarks

This section provides definitions of IMB-EXT benchmarks. The benchmarks can run with varying transfer sizes `X`, in bytes. The timings are averaged over multiple samples. See the Benchmark Methodology section for details. In the definitions below, a single sample with a fixed transfer size `X` is used.

The `Unidir` and `Bidir` benchmarks are exact equivalents of the message passing `PingPong` and `PingPing`, respectively. Their interpretation and output are analogous to their message passing equivalents.

Unidir_Put

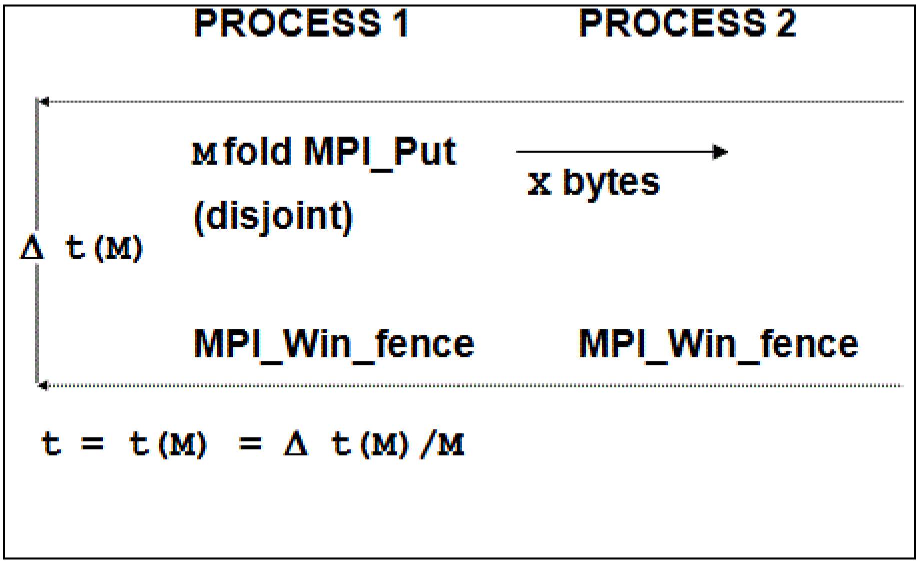
This is the benchmark for the `MPI_Put` function. The following table and figure provide the basic definitions and a schematic view of the pattern.

Unidir_Put Definition

Property	**Description**
Measured pattern	As symbolized between ⇇ in the figure below. This benchmark runs on two active processes (`Q=2`).

MPI routine	MPI_Put
MPI data type	MPI_BYTE (origin and target)
Reported timings	t=t(M) (in μsec) as indicated in the figure below, non-aggregate (M=1)and aggregate (M=n_sample). For details, see Actual Benchmarking.
Reported throughput	X/t, aggregate and non-aggregate

Unidir_Put Pattern



Unidir_Get

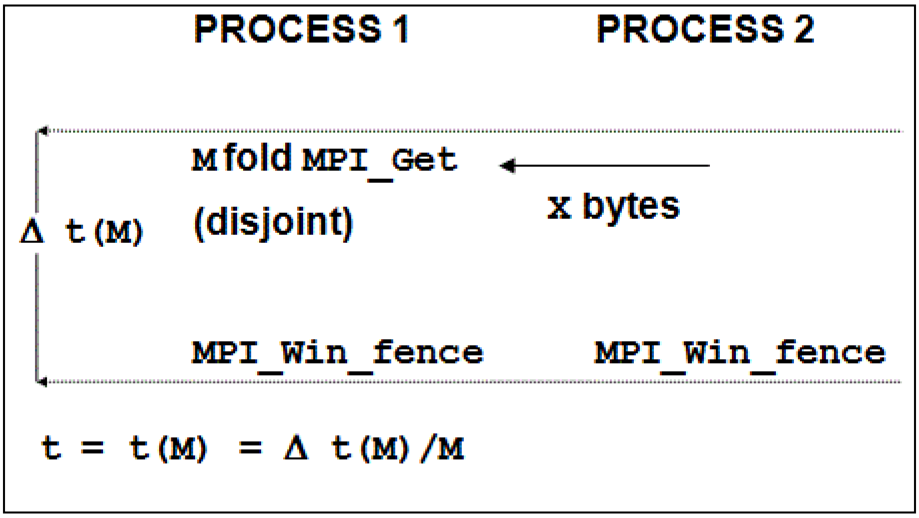
This is the benchmark for the MPI_Get

Unidir_Get Definition

Property	Description
Measured pattern	As symbolized between ⇇ in the figure below. This benchmark runs on two active processes (Q=2).
MPI routine	MPI_Get
MPI data type	MPI_BYTE, for both origin and target

Reported timings	t=t(M) (in μsec) as indicated in the figure below, non-aggregate (M=1)and aggregate (M=n_sample). For details, see Actual Benchmarking.
Reported throughput	X/t, aggregate and non-aggregate

Unidir_Get Pattern



Bidir_Put

This is the benchmark for the MPI_Put function with bidirectional transfers. See the basic definitions below.

Bidir_Put Definition

Property	Description
Measured pattern	As symbolized between in the figure below. This benchmark runs on two active processes (Q=2).
MPI routine	MPI_Put
MPI data type	MPI_BYTE, for both origin and target
Reported timings	t=t(M) (in μsec)as indicated in the figure below, non-aggregate (M=1)and aggregate (M=n_sample). For details, see Actual Benchmarking.

Reported throughput	X/t, aggregate and non-aggregate

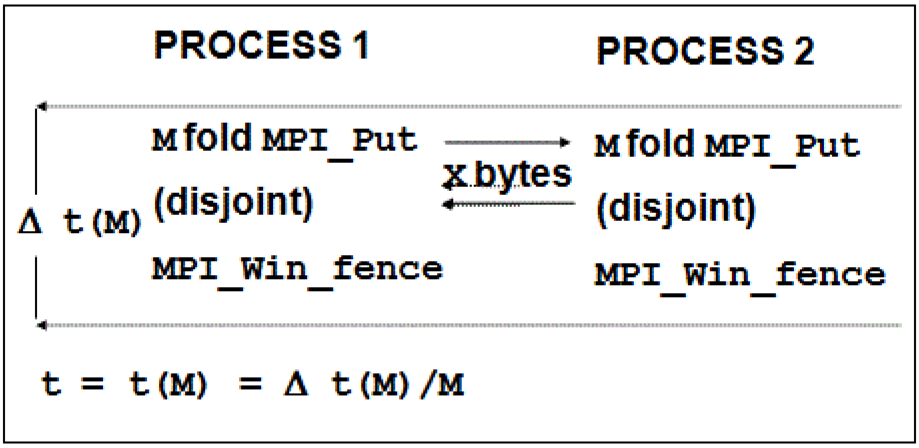
Bidir_Get

This is the benchmark for the MPI_Get function, with bidirectional transfers. Below see the basic definitions and a schematic view of the pattern.

Bidir_Get Definition

Property	**Description**
Measured pattern	As symbolized between ⇇ in the figure below. This benchmark runs on two active processes (Q=2).
MPI routine	MPI_Get
MPI data type	MPI_BYTE, for both origin and target
Reported timings	t=t(M) (in µsec) as indicated in the figure below, non-aggregate (M=1)and aggregate (M=n_sample). For details, see Actual Benchmarking.
Reported throughput	X/t, aggregate and non-aggregate

Bidir_Get Pattern



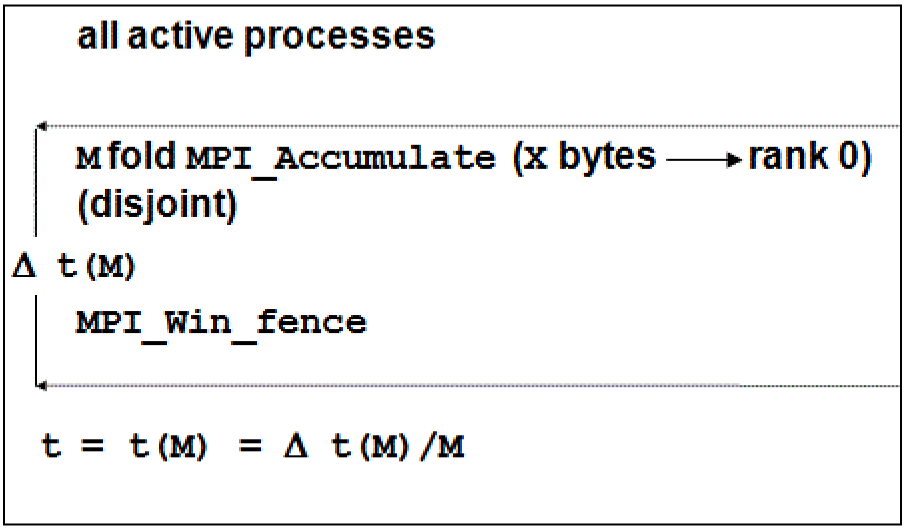
Accumulate

This is the benchmark for the MPI_Accumulate function. It reduces a vector of length L = x/sizeof(float) of float items. The MPI data type is MPI_FLOAT. The MPI operation is MPI_SUM. See the basic definitions and a schematic view of the pattern below.

Accumulate Definition

Property	Description
Measured pattern	As symbolized between ← ← in the figure below. This benchmark runs on two active processes (Q=2).
MPI data type	MPI_FLOAT
MPI operation	MPI_SUM
Root	0
Reported timings	t=t(M) (in µsec) as indicated in the figure below, non-aggregate (M=1)and aggregate (M=n_sample). For details, see Actual Benchmarking.
Reported throughput	None

Accumulate Pattern



Window

This is the benchmark for measuring the overhead of an MPI_Win_create/MPI_Win_fence/MPI_Win_free combination. In the case of an unused window, a negligible non-trivial action is performed inside the window. It minimizes optimization effects of the MPI implementation.

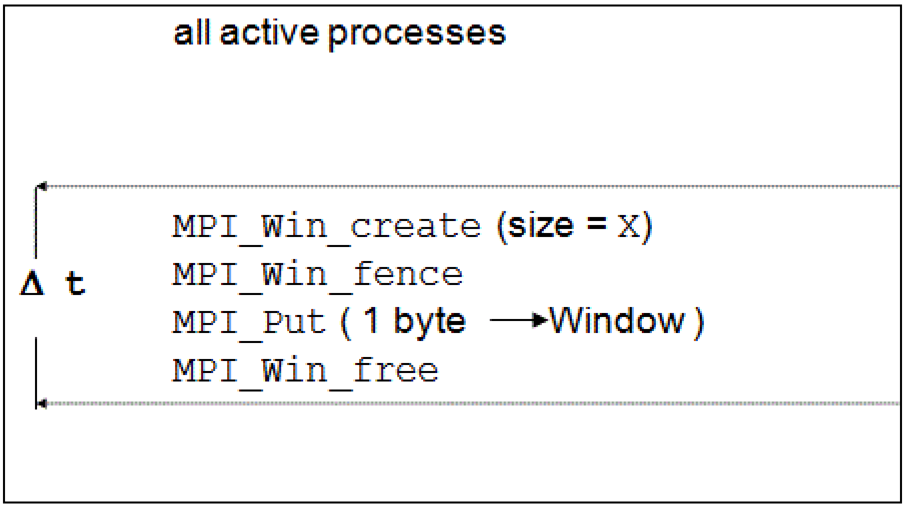
The MPI_Win_fence function is called to properly initialize an access epoch. This is a correction as compared to earlier releases of the Intel® MPI Benchmarks.

See the basic definitions and a schematic view of the pattern below.

Window Definition

Property	Description
Measured pattern	MPI_Win_create/MPI_Win_fence/MPI_Win_free
Reported timings	t=Δt(M) (in μsec) as indicated in the figure below.
Reported throughput	None

Window Pattern



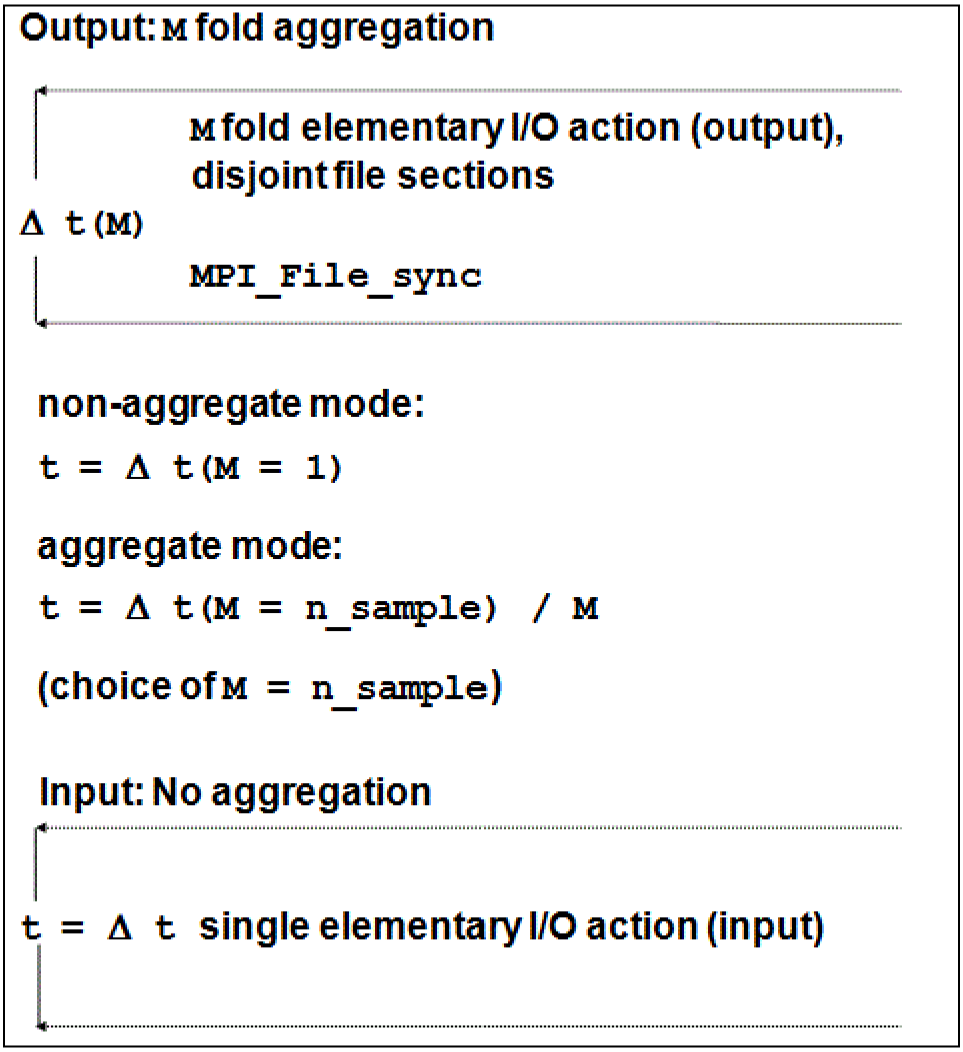
IMB-IO Blocking Benchmarks

This section describes blocking I/O benchmarks. The benchmarks can run with varying transfer sizes X, in bytes. The timings are averaged over multiple samples. The basic MPI data type for all data buffers is MPI_BYTE. In the definitions below, a single sample with a fixed I/O size X is used.

Every benchmark contains an elementary I/O action, denoting a pure read or write. Thus, all benchmark flavors have a Write and a Read component. The [ACTION] placeholder denotes a Read or a Write alternatively.

The Write flavors of benchmarks include a file synchronization with different placements for aggregate and non-aggregate modes.

Figure: I/O Benchmarks, Aggregation for Output


Output: M fold aggregation
M fold elementary I/O action (output), disjoint file sections
Δ t(M)
MPI_File_sync
non-aggregate mode:
t = Δ t(M = 1)
aggregate mode:
t = Δ t(M = n_sample) / M
(choice of M = n_sample)
Input: No aggregation
t = Δ t single elementary I/O action (input)

S_[ACTION]_indv

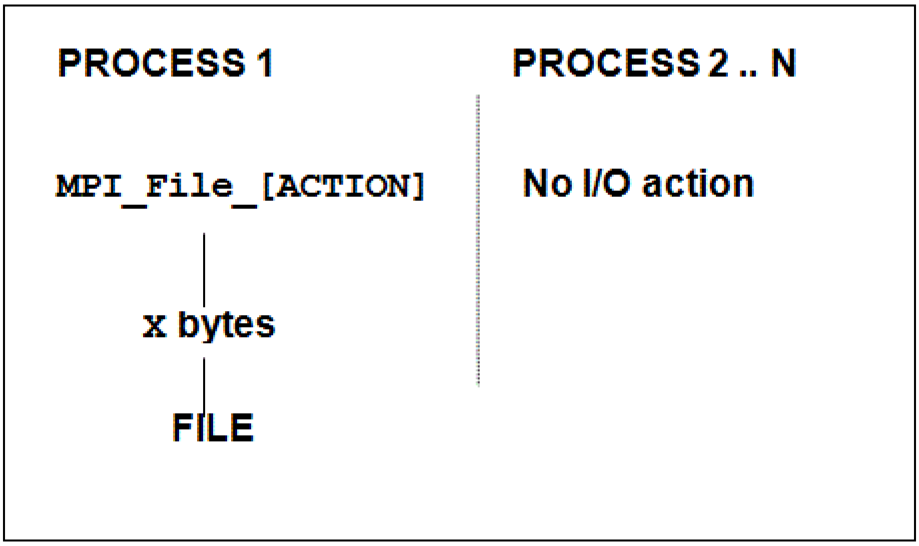
File I/O performed by a single process. This pattern mimics the typical case when a particular master process performs all of the I/O. See the basic definitions and a schematic view of the pattern below.

S_[ACTION]_indv Definition

Property	Description
Measured pattern	As symbolized in figure I/O benchmarks, aggregation for output
Elementary I/O action	As symbolized in the figure below.
MPI routines for the blocking mode	MPI_File_write/MPI_File_read
MPI routines for the non-blocking mode	MPI_File_iwrite/MPI_File_iread

etype	MPI_BYTE
File type	MPI_BYTE
MPI data type	MPI_BYTE
Reported timings	t (in μsec) as indicated in the figure I/O benchmarks, aggregation for output, aggregate and non-aggregate for the Write flavor.
Reported throughput	x/t, aggregate and non-aggregate for the Write flavor

S_[ACTION]_indv Pattern



S_[ACTION]_expl

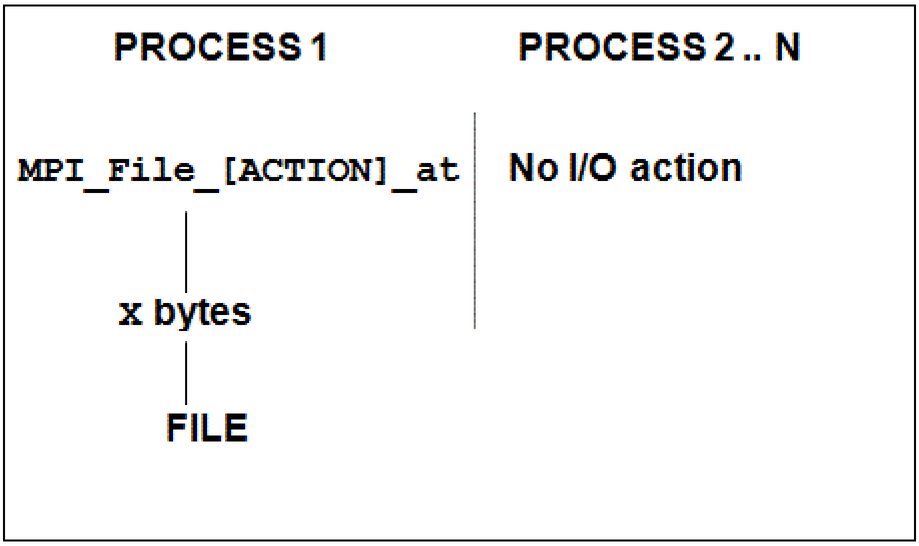
This benchmark mimics the same situation as S_[ACTION]_indv, with a different strategy to access files. See the basic definitions and a schematic view of the pattern below.

S_[ACTION]_expl Definition

Property	**Description**
Measured pattern	As symbolized in figure I/O benchmarks, aggregation for output
Elementary I/O action	As symbolized in the figure below.

MPI routines for the blocking mode	MPI_File_write_at/MPI_File_read_at
MPI routines for the non-blocking mode	MPI_File_iwrite_at/MPI_File_iread_at
etype	MPI_BYTE
File type	MPI_BYTE
MPI data type	MPI_BYTE
Reported timings	t (in μsec) as indicated in the figure I/O benchmarks, aggregation for output, aggregate and non-aggregate for the Write flavor.
Reported throughput	x/t, aggregate and non-aggregate for the Write flavor

S_[ACTION]_expl pattern



P_[ACTION]_indv

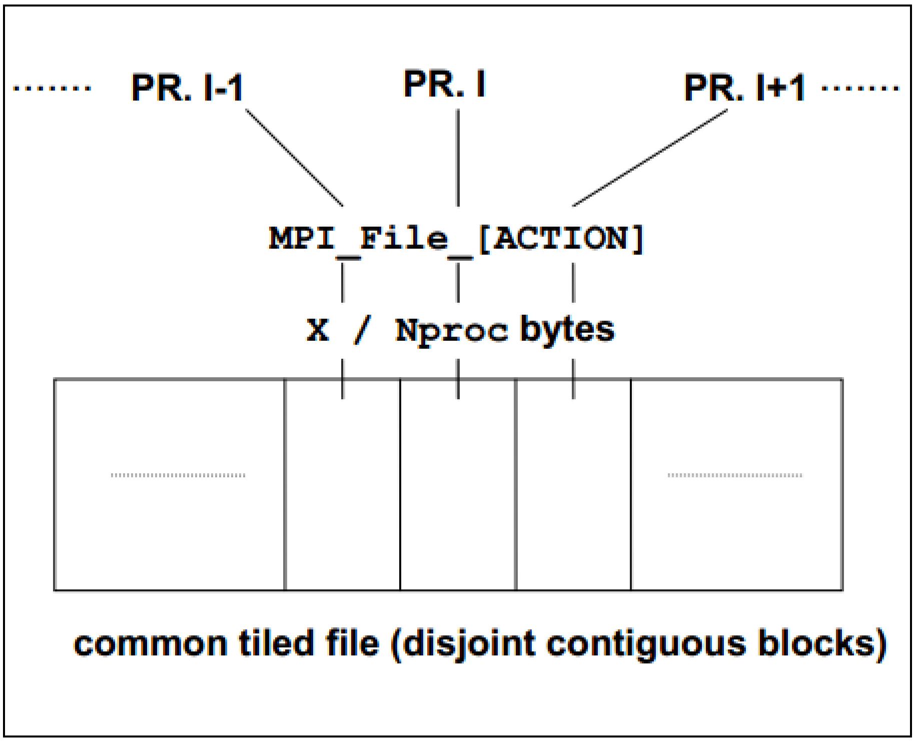
This pattern accesses the file in a concurrent manner. All participating processes access a common file. See the basic definitions and a schematic view of the pattern below.

P_[ACTION]_indv Definition

Property	**Description**
Measured pattern	As symbolized in figure I/O benchmarks,

	aggregation for output
Elementary I/O action	As symbolized in the figure below. In this figure, Nproc is the number of processes.
MPI routines for the blocking mode	MPI_File_write/MPI_File_read
MPI routines for the non-blocking mode	MPI_File_iwrite/MPI_File_iread
etype	MPI_BYTE
File type	Tiled view, disjoint contiguous blocks
MPI data type	MPI_BYTE
Reported timings	t (in μsec) as indicated in the figure I/O benchmarks, aggregation for output, aggregate and non-aggregate for the Write flavor.
Reported throughput	x/t, aggregate and non-aggregate for the Write flavor

P_[ACTION]_indv Pattern



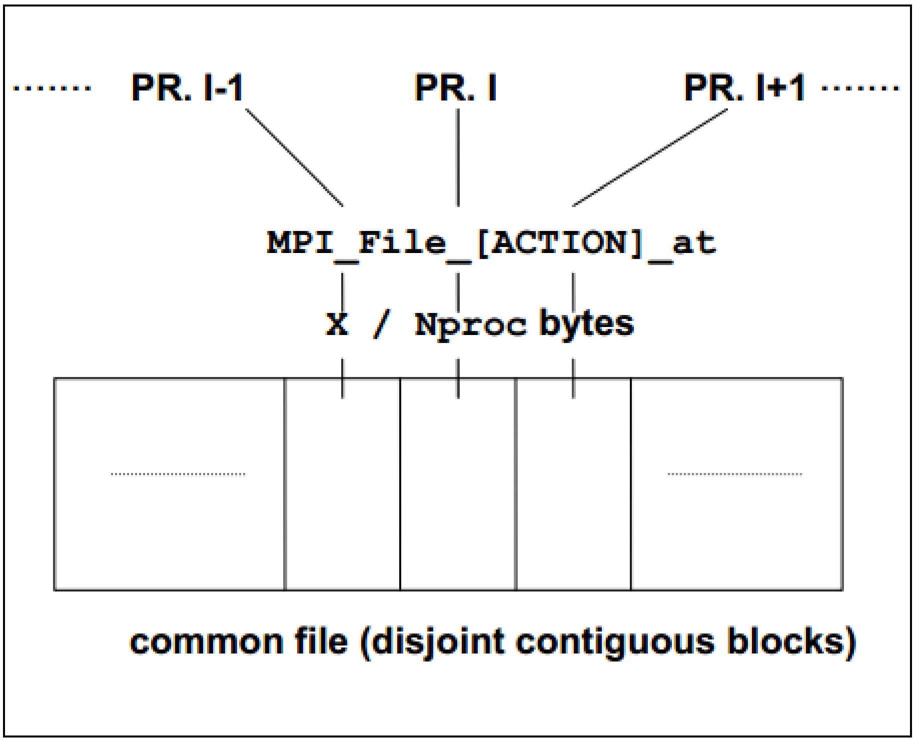
P_ACTION_expl

P_[ACTION]_expl follows the same access pattern as P_[ACTION]_indv with an explicit file pointer type. See the basic definitions and a schematic view of the pattern below.

P_[ACTION]_expl Definition

Property	**Description**
Measured pattern	As symbolized in figure I/O benchmarks, aggregation for output
Elementary I/O action	As symbolized in the figure below. In this figure, Nproc is the number of processes.
MPI routines for the blocking mode	MPI_File_write_at/MPI_File_read_at
MPI routines for the non-blocking mode	MPI_File_iwrite_at/MPI_File_iread_at
etype	MPI_BYTE
File type	MPI_BYTE
MPI data type	MPI_BYTE
Reported timings	t (in μsec) as indicated in the figure I/O benchmarks, aggregation for output, aggregate and non-aggregate for the Write flavor.
Reported throughput	x/t, aggregate and non-aggregate for the Write flavor

P_[ACTION]_expl Pattern



P_[ACTION]_shared

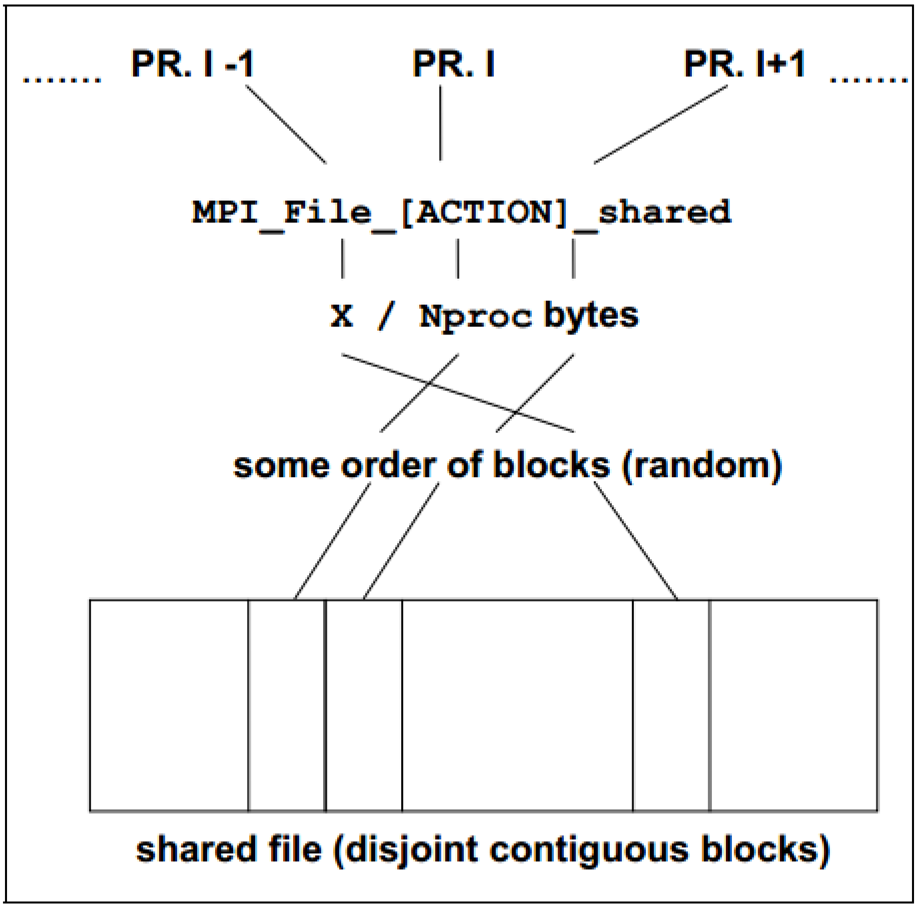
Concurrent access to a common file by all participating processes, with a shared file pointer. See the basic definitions and a schematic view of the pattern below.

P_[ACTION]_shared Definition

Property	**Description**
Measured pattern	As symbolized in figure I/O benchmarks, aggregation for output
Elementary I/O action	As symbolized in the figure below. In this figure, Nproc is the number of processes.
MPI routines for the blocking mode	MPI_File_write_at/MPI_File_read_at
MPI routines for the non-blocking mode	MPI_File_iwrite_at/MPI_File_iread_at
etype	MPI_BYTE
File type	MPI_BYTE
MPI data type	MPI_BYTE

Reported timings	t (in µsec) as indicated in the figure I/O benchmarks, aggregation for output, aggregate and non-aggregate for the Write flavor.
Reported throughput	x/t, aggregate and non-aggregate for the Write flavor

P_[ACTION]_shared Pattern



P_[ACTION]_priv

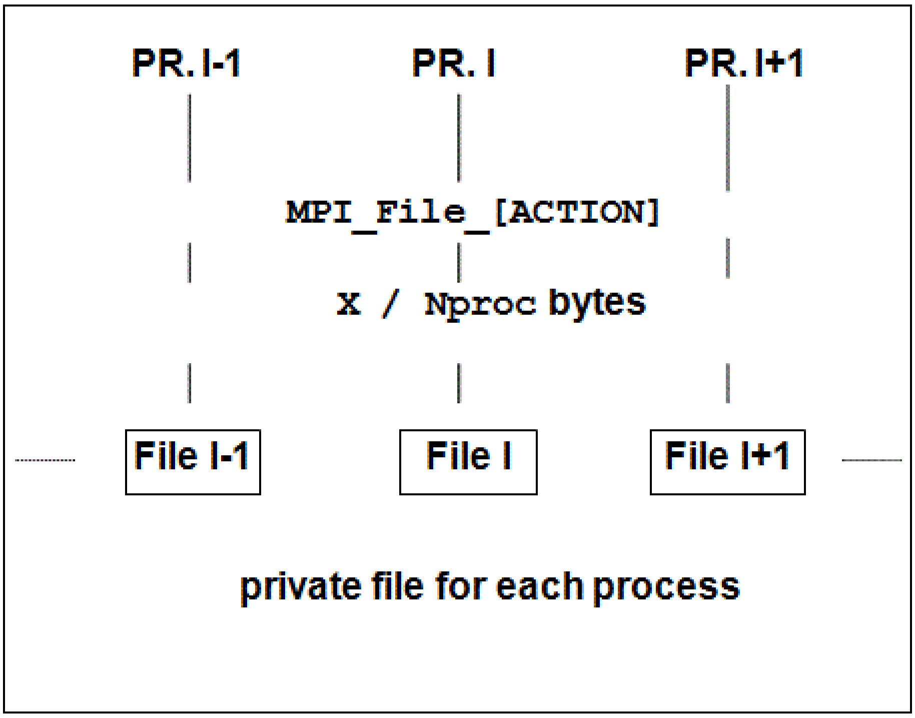
This pattern tests the case when all participating processes perform concurrent I/O to different private files. This benchmark is particularly useful for the systems that allow completely independent I/O operations from different processes. The benchmark pattern is expected to show parallel scaling and obtain optimum results. See the basic definitions and a schematic view of the pattern below.

P_[ACTION]_priv Definition

Property	**Description**

Measured pattern	As symbolized in figure I/O benchmarks, aggregation for output
Elementary I/O action	As symbolized in the figure below. In this figure, Nproc is the number of processes.
MPI routines for the blocking mode	MPI_File_write/MPI_File_read
MPI routines for the non-blocking mode	MPI_File_iwrite/MPI_File_iread
etype	MPI_BYTE
File type	MPI_BYTE
MPI data type	MPI_BYTE
Reported timings	Δt (in μsec), aggregate and non-aggregate for the Write flavor.
Reported throughput	x/Δt, aggregate and non-aggregate for the Write flavor

P_[ACTION]_priv Pattern



C_[ACTION]_indv

C_[ACTION]_indv tests collective access from all processes to a common file, with an individual file pointer. Below see the basic definitions and a schematic view of the pattern.

This benchmark is based on the following MPI routines:

- MPI_File_read_all/MPI_File_write_all for the blocking mode
- MPI_File_..._all_begin/MPI_File_..._all_end for the non-blocking mode

All other parameters and the measuring method are the same as for the P_[ACTION]_indv benchmark.

See Also

P_[ACTION]_indv

C_[ACTION]_expl

This pattern performs collective access from all processes to a common file, with an explicit file pointer.

This benchmark is based on the following MPI routines:

- MPI_File_read_at_all/MPI_File_write_at_all for the blocking mode
- MPI_File_..._at_all_begin/MPI_File_..._at_all_end for the non-blocking mode

All other parameters and the measuring method are the same as for the P_[ACTION]_expl benchmark.

See Also

P_[ACTION]_expl

C_[ACTION]_shared

The benchmark of a collective access from all processes to a common file, with a shared file pointer.

This benchmark is based on the following MPI routines:

- MPI_File_read_ordered/MPI_File_write_ordered for the blocking mode
- MPI_File_..._ordered_begin/MPI_File_..._ordered_end for the non-blocking mode

All other parameters and the measuring method are the same as for the P_[ACTION]_shared benchmark.

See Also

P_[ACTION]_shared

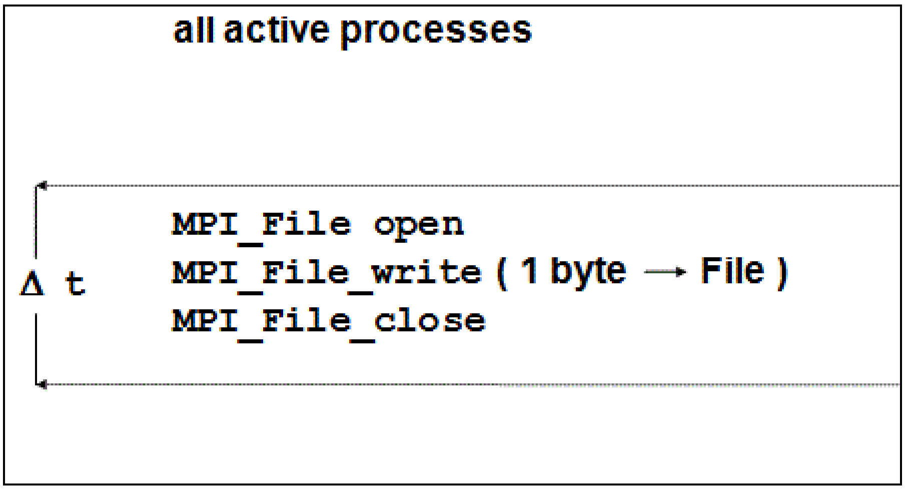
Open_Close

The benchmark for the MPI_File_open/MPI_File_close functions. All processes open the same file. To avoid MPI implementation optimizations for an unused file, a negligible non-trivial action is performed with the file. See the basic definitions of the benchmark below.

Open_Close Definition

Property	Description
Measured pattern	MPI_File_open/MPI_File_close
etype	MPI_BYTE
File type	MPI_BYTE
Reported timings	t=Δt (in μsec), as indicated in the figure below.
Reported throughput	None

Open_Close Pattern



IMB-IO Non-blocking Benchmarks

Intel® MPI Benchmarks implements blocking and non-blocking modes of the IMB-IO benchmarks as different benchmark flavors. The Read and Write components of the blocking benchmark name are replaced for non-blocking flavors by IRead and IWrite, respectively.

The definitions of blocking and non-blocking flavors are identical, except for their behavior in regard to:

- Aggregation. The non-blocking versions only run in the non-aggregate mode.
- Synchronism. Only the meaning of an elementary transfer differs from the equivalent blocking benchmark.

Basically, an elementary transfer looks as follows:

```
time = MPI_Wtime()
```

```
for ( i=0; i<n_sample; i++ )
{
Initiate transfer
Exploit CPU
Wait for the end of transfer
}
time = (MPI_Wtime()-time)/n_sample
```

The `Exploit CPU` section in the above example is arbitrary. Intel® MPI Benchmarks exploits CPU as described below.

Exploiting CPU

Intel® MPI Benchmarks uses the following method to exploit the CPU. A kernel loop is executed repeatedly. The kernel is a fully vectorizable multiplication of a 100x100 matrix with a vector. The function is scalable in the following way:

```
CPU_Exploit(float desired_time, int initialize);
```

The input value of `desired_time` determines the time for the function to execute the kernel loop, with a slight variance. At the very beginning, the function is called with `initialize=1` and an input value for `desired_time`. This determines an Mflop/s rate and a timing `t_CPU`, as close as possible to `desired_time`, obtained by running without any obstruction. During the actual benchmarking, `CPU_Exploit` is called with `initialize=0`, concurrently with the particular I/O action, and always performs the same type and number of operations as in the initialization step.

Displaying Results

Three timings are crucial to interpret the behavior of non-blocking I/O , overlapped with CPU exploitation:

- `t_pure` is the time for the corresponding pure blocking I/O action, non-overlapping with CPU activity
- `t_CPU` is the time the `CPU_Exploit` periods (running concurrently with non-blocking I/O) would use when running dedicated
- `t_ovrl` is the time for the analogous non-blocking I/O action, concurrent with CPU activity (exploiting `t_CPU` when running dedicated)

A perfect overlap means: `t_ovrl = max(t_pure,t_CPU)`

No overlap means: `t_ovrl = t_pure+t_CPU`.

The actual amount of overlap is:

`overlap=(t_pure+t_CPU-t_ovrl)/min(t_pure,t_CPU)`(*)

The Intel® MPI Benchmarks result tables report the timings `t_ovrl, t_pure, t_CPU` and the estimated overlap obtained by the (*) formula above. At the beginning of a run, the Mflop/s rate is corresponding to the `t_CPU` displayed.

Benchmark Methodology

This section describes:

- Different ways to manage Intel® MPI Benchmarks control flow
- Command-line syntax for running the benchmarks
- Sample output data you can receive

Command-line Control

The command line is repeated in the output. The general command-line syntax is the following:

```
IMB-MPI1    [-h{elp}]
            [-npmin     <NPmin>]
            [-multi     <MultiMode>]
            [-off_cache <cache_size[,cache_line_size]>
[-iter
<msgspersample[,overall_vol[,msgs_nonaggr]]>]
            [-time     <max_runtime per sample>]
            [-mem       <max. mem usage per process>]
            [-msglen    <Lengths_file>]
            [-map       <PxQ>]
            [-input     <filename>]
            [-include]  [benchmark1 [,benchmark2 [,...]]]
            [-exclude]  [benchmark1 [,benchmark2 [,...]]]
            [-msglog [<minlog>:]<maxlog>]
            [benchmark1 [,benchmark2 [,...]]]
```

The options may appear in any order.

Examples:

```
Get out-of-cache data for PingPong:
mpirun -np 2  IMB-MPI1 pingpong -off_cache -1
```

Run a very large configuration: restrict iterations to 20, max. 1.5 seconds run time per message size, max. 2 GBytes for message buffers:

```
mpirun -np 512 IMB-MPI1 -npmin 512
       alltoallv -iter 20 -time 1.5 -mem 2
```

Other examples:

```
mpirun -np 8  IMB-IO
mpirun -np 10 IMB-MPI1 PingPing Reduce
mpirun -np 11 IMB-EXT  -npmin 5
mpirun -np 14 IMB-IO P_Read_shared -npmin 7
mpirun -np 3  IMB-EXT  -input IMB_SELECT_EXT
mpirun -np 14 IMB-MPI1 -multi 0 PingPong Barrier
                       -map 2x7
mpirun -np 16 IMB-MPI1 -msglog 2:7 -include PingPongSpecificsource
PingPingSpecificsource -exclude Alltoall Alltoallv
mpirun -np 4 IMB-MPI1 -msglog 16 PingPong PingPing
PingPongSpecificsource PingPingSpecificsource
```

Benchmark Selection Arguments

Benchmark selection arguments are a sequence of blank-separated strings. Each argument is the name of a benchmark in exact spelling, case insensitive.

For example, the string `IMB-MPI1 PingPong Allreduce` specifies that you want to run `PingPong` and `Allreduce` benchmarks only.

Default: no benchmark selection. All benchmarks of the selected component are run.

-npmin Option

Specifies the minimum number of processes `P_min` to run all selected benchmarks on. The `P_min` value after `-npmin` must be an integer.

Given `P_min`, the benchmarks run on the processes with the numbers selected as follows:

`P_min, 2P_min, 4P_min, ...,` largest 2^x`P_min <P, P`

NOTE:

You may set `P_min` to 1. If you set `P_min > P`, Intel MPI Benchmarks interprets this value as `P_min = P.`

Default: no `-npmin` selection. Active processes are selected as described in the Running Intel® MPI Benchmarks section.

-multi outflag Option

Defines whether the benchmark runs in the multiple mode. The argument after `-multi` is a meta-symbol `<outflag>` that can take an integer value of 0 or 1. This flag controls the way of displaying results:

- `Outflag = 0` only display maximum timings (minimum throughputs) over all active groups

- `Outflag = 1` report on all groups separately. The report may be long in this case.

When the number of processes running the benchmark is more than half of the overall number `MPI_COMM_WORLD`, the multiple benchmark coincides with the non-multiple one, as not more than one process group can be created.

Default: no -multi selection. Intel® MPI Benchmarks run non-multiple benchmark flavors.

-off_cache cache_size[,cache_line_size] Option

Use the -off_cache flag to avoid cache re-usage. If you do not use this flag (default), the communications buffer is the same within all repetitions of one message size sample. In this case, Intel® MPI Benchmarks reuses the cache, so throughput results might be non-realistic.

The argument after off_cache can be a single number (cache_size), two comma-separated numbers (cache_size,cache_line_size), or -1:

- cache_size is a float for an upper bound of the size of the last level cache, in MB.
- cache_line_size is assumed to be the size of a last level cache line (can be an upper estimate).
- -1 indicates that the default values from IMB_mem_info.h should be used. The cache_size and cache_line_size values are assumed to be statically defined in IMB_mem_info.h.

The sent/received data is stored in buffers of size ~2x MAX(cache_size, message_size). When repetitively using messages of a particular size, their addresses are advanced within those buffers so that a single message is at least 2 cache lines after the end of the previous message. When these buffers are filled up, they are reused from the beginning.

-off_cache is effective for IMB-MPI1 and IMB-EXT. You are not recommended to use this option for IMB-IO.

Examples

Use the default values defined in IMB_mem_info.h:

```
-off_cache -1
```

2.5 MB last level cache, default line size:

```
-off_cache 2.5
```

16 MB last level cache, line size 128:

```
-off_cache 16,128
```

The off_cache mode might also be influenced by eventual internal caching with the Intel® MPI Library. This could make results interpretation complicated.

Default: no cache control. Data may come out of cache.

-iter Option

Use this option to control iterations. The argument after -iter can be a single, two comma-separated, or three comma-separated integer numbers that override the default values of MSGSPERSAMPLE, OVERALL_VOL, and MSGS_NONAGGR defined in IMB_settings.h

Examples

```
-iter 2000        (override MSGSPERSAMPLE by value 2000)
```

```
-iter 1000,100    (override OVERALL_VOL by 100)
-iter 1000,40,150 (override MSGS_NONAGGR by 150)
```

The -iter option is overridden by a dynamic selection that is a new default in the Intel® MPI Benchmarks 3.2: when a maximum run time (per sample) is expected to be exceeded, the iteration number is cut down. See -time

Default: iteration control through parameters MSGSPERSAMPLE, OVERALL_VOL, and MSGS_NONAGGR defined in IMB_settings.h.

-time Option

Specifies the number of seconds for the benchmark to run per message size. The argument after -time is a floating-point number.

The combination of this flag with the -iter flag or its default alternative ensures that the Intel MPI Benchmarks always chooses the maximum number of repetitions that conform to all restrictions.

A rough number of repetitions per sample to fulfill the -time request is estimated in preparatory runs that use ~1 second overhead.

Default: -time is activated. The floating-point value specifying the run-time seconds per sample is set in the SECS_PER_SAMPLE variable defined in IMB_settings.h/IMB_settings_io.h. The current value is 10.

-mem Option

Specifies the number of GB to be allocated per process for the message buffers benchmarks/message. If the size is exceeded, a warning is returned, stating how much memory is required for the overall run not to be interrupted.

The argument after -mem is a floating-point number.

Default: the memory is restricted by MAX_MEM_USAGE defined in IMB_mem_info.h.

-input <File> Option

Use the ASCII input file to select the benchmarks. For example, the IMB_SELECT_EXT file looks as following:

```
#
# IMB benchmark selection file
#
# Every line must be a comment (beginning with #), or it
# must contain exactly one IMB benchmark name
#
#Window
Unidir_Get
#Unidir_Put
#Bidir_Get
#Bidir_Put
```

```
Accumulate
```

With the help of this file, the following command runs only Unidir_Get and Accumulate benchmarks of the IMB-EXT component:

```
mpirun .... IMB-EXT -input IMB_SELECT_EXT
```

-msglen <File> Option

Enter any set of non-negative message lengths to an ASCII file, line by line, and call the Intel® MPI Benchmarks with arguments:

```
-msglen Lengths
```

The Lengths value overrides the default message lengths. For IMB-IO, the file defines the I/O portion lengths.

-map PxQ Option

Numbers processes along rows of the matrix:

0	P	…	(Q-2)P	(Q-1)P
1				
…				
P-1	2P-1		(Q-1)P-1	QP-1

For example, to run Multi-PingPongbetween two nodes of size P, with each process on one node communicating with its counterpart on the other, call:

```
mpirun -np <2P> IMB-MPI1 -map <P>x2 PingPong
```

-include [[benchmark1] benchmark2 …]

Specifies the list of additional benchmarks to run. For example, to add PingPongSpecificSource and PingPingSpecificSource benchmarks, call:

```
mpirun -np 2 IMB-MPI1 -
include PingPongSpecificSource PingPingSpecificSource
```

-exclude [[benchmark1] benchmark2 …]

Specifies the list of benchmarks to be exclude from the run. For example, to exclude Alltoall and Allgather, call:

```
mpirun -np 2 IMB-MPI1 -exclude Alltoall Allgather
```

-msglog [<minlog>:]<maxlog>

This option allows you to control the lengths of the transfer messages. This setting overrides the MINMSGLOG and MAXMSGLOG values. The new message sizes are 0, 2^minlog, ..., 2^maxlog.

For example, try running the following command line:

```
mpirun -np 2 IMB-MPI1 -msglog 3:7 PingPong
```

Intel® MPI Benchmarks selects the lengths 0,8,16,32,64,128, as shown below:

```
#---------------------------------------------------
# Benchmarking PingPong
# #processes = 2
#---------------------------------------------------
       #bytes #repetitions      t[μsec]   Mbytes/sec
            0         1000         0.70         0.00
            8         1000         0.73        10.46
           16         1000         0.74        20.65
           32         1000         0.94        32.61
           64         1000         0.94        65.14
          128         1000         1.06       115.16
```

Alternatively, you can specify only the maxlog value:

```
#---------------------------------------------------
# Benchmarking PingPong
# #processes = 2
#---------------------------------------------------
       #bytes #repetitions      t[μsec]   Mbytes/sec
            0         1000         0.69         0.00
            1         1000         0.72         1.33
            2         1000         0.71         2.69
            4         1000         0.72         5.28
            8         1000         0.73        10.47
```

-thread_level Option

This option specifies the desired thread level for MPI_Init_thread(). See description of MPI_Init_thread() for details. The option is available only if the Intel® MPI Benchmarks is built with the USE_MPI_INIT_THREAD macro defined. Possible values for <level> are single, funneled, serialized, and multiple.

Parameters Controlling Intel® MPI Benchmarks

Parameters controlling the default settings of the Intel® MPI Benchmarks are set by preprocessor definition in files IMB_settings.h (for IMB-MPI1 and IMB-EXT benchmarks) and IMB_settings_io.h (for IMB-IO benchmarks). Both include files have identical structure, but differ in the predefined parameter values.

To enable the optional mode, define the IMB_OPTIONAL parameter in the IMB_settings.h/IMB_settings_io.h. After you change the settings in the optional section, you need to recompile the Intel® MPI Benchmarks.

The following table describes the Intel MPI Benchmarks parameters and lists their values for the standard mode.

Parameter	**Values in IMB_settings.h**	**Values in IMB_settings_io.h**	**Description**
USE_MPI_INIT_THREAD	Not set	Not set	Set to initialize Intel® MPI Benchmarks by MPI_Init_thread() instead of MPI_Init()
IMB_OPTIONAL	Not set	Not set	Set to activate optional settings
MINMSGLOG	0	0	The second smallest data transfer size is max(unit,$2^{MINMSGLOG}$ (the smallest size is always 0), where unit=sizeof(float) for reductions, unit=1 for all other cases. You can override this parameter value using the -msglog flag.
MAXMSGLOG	22	24	The largest message size used is $2^{MAXMSGLOG}$ You can override this parameter value using the -msglog flag.

MSGSPERSAMPLE	1000	50	The maximum repetition count for all IMB-MPI1 benchmarks. You can override this parameter value using the -iter flag.
MSGS_NONAGGR	100	10	The maximum repetition count for non-aggregate benchmarks (relevant only for IMB-EXT). You can override this parameter value using the -time flag.
OVERALL_VOL	40 Mbytes	16*1048576	For all sizes smaller than OVERALL_VOL, the repetition count is reduced so that not more than OVERALL_VOL bytes are processed all in all. This permits you to avoid unnecessary repetitions for large message sizes. Finally, the real repetition count for message size X is MSGSPERSAMPLE (X=0), min(MSGSPERSAMPLE, max(1,OVERALL_VOL/X)) (X>0) Note that OVERALL_VOL does *not* restrict the size of the maximum data transfer. $2^{MAXMSGLOG}$ OVERALL_VOL. You can override this parameter value using the -mem flag.
SECS_PER_SAMPLE	10		Number of iterations is dynamically set so that this number of run time seconds is not exceeded per message length.
N_BARR	2	2	Number of MPI_Barrier for synchronization.
TARGET_CPU_SECS	0.01 seconds	0.1 seconds	CPU seconds (as float) to run concurrently with

			non-blocking benchmarks (currently irrelevant for IMB-MPI1)

In the example below, the IMB_settings_io.h. file has the IMB_OPTIONAL parameter enabled, so that user-defined parameters are used. I/O sizes of 32 and 64 MB, and a smaller repetition count are selected, extending the standard mode tables. You can modify the optional values as required.

```
#define FILENAME IMB_out
#define IMB_OPTIONAL
#ifdef IMB_OPTIONAL
#define MINMSGLOG  25
#define MAXMSGLOG  26
#define MSGSPERSAMPLE  10
#define MSGS_NONAGGR  10
#define OVERALL_VOL  16*1048576
#define SECS_PER_SAMPLE  10
#define TARGET_CPU_SECS 0.1 /* unit seconds */
#define N_BARR   2
#else
/*Do not change anything below this line*/
#define MINMSGLOG  0
#define MAXMSGLOG  24
#define MSGSPERSAMPLE  50
#define MSGS_NONAGGR  10
#define OVERALL_VOL 16*1048576
#define TARGET_CPU_SECS  0.1 /* unit seconds */
#define N_BARR   2
#endif
```

If IMB_OPTIONAL is deactivated, Intel MPI Benchmarks uses the default standard mode values.

Hard-Coded Settings

The sections below describe Intel® MPI Benchmarks hard-coded settings.

Communicators, Active Processes

Communicator management is repeated in every "select MY_COMM" step. If it exists, the previous communicator is freed. When running Q<=P processes, the first Q ranks of MPI_COMM_WORLD are put into one group, and the remaining P-Q get MPI_COMM_NULL.

The group of MY_COMM calls the active processes group.

Other Preparations for Benchmarking

Window (IMB_EXT)

An Info is set and MPI_Win_create is called, creating a window of size X for MY_COMM. Then, MPI_Win_fence is called to start an access epoch.

File (IMB-IO)

To initialize the IMB-IO file, follow these steps:

1. Select a file name. This parameter is located in the IMB_settings_io.h include file. In the case of a multi-<MPI command>, a suffix _g<groupid> is appended to the name. If the file name is per process, a second event suffix _<rank> is appended.
2. Delete the file if it exists: open the file with MPI_MODE_DELETE_ON_CLOSE and close it.
3. Select a communicator to open the file: MPI_COMM_SELF for S_benchmarks and P_[ACTION]_priv.
4. Select a mode: MPI_MODE_CREATE | MPI_MODE_RDWR
5. Select an info routine as explained below.

Info

Intel® MPI Benchmarks uses an external function User_Set_Info which you implement for the current system. The default version is:

```
#include mpi.h
void User_Set_Info ( MPI_Info* opt_info)
#ifdef MPIIO
{/*  Set info for all MPI_File_open calls  */
*opt_info = MPI_INFO_NULL;
}
#endif
#ifdef EXT
{/*  Set info for all MPI_Win_create calls  */
*opt_info = MPI_INFO_NULL;
}
#endif
```

The Intel® MPI Benchmarks use no assumptions and imposes no restrictions on how this routine is implemented.

View (IMB-IO)

The file view is determined by the following settings:

- disp = 0,
- datarep = native

- etype, filetypeas defined in the benchmark definitions above
- info as defined in the "Info" section above.

Message/I-O Buffer Lengths

IMB-MPI1, IMB-EXT

Set in IMB_settings.h and used unless the –msglen flag is selected.

IMB-IO

Set in IMB_settings_io.h and used unless the –msglen flag is selected.

Buffer Initialization

Communication and I/O buffers are dynamically allocated as void* and used as MPI_BYTE buffers for all benchmarks except Accumulate, see Memory Requirements. To assign the buffer contents, a cast to an assignment type is performed. This facilitates result checking which may become necessary. Besides, a sensible data type is mandatory for Accumulate.

Intel® MPI Benchmarks sets the buffer assignment type assign_type in IMB_settings.h/IMB_settings_io.h. Currently, int is used for IMB-IO, float for IMB-EXT. The values are set by a CPP macro as follows.

For IMB-EXT benchmarks:

```
#define BUF_VALUE(rank,i) (0.1*((rank)+1)+(float)( i)
```

For IMB-IO benchmarks:

```
#define BUF_VALUE(rank,i) 10000000*(1+rank)+i%10000000
```

In every initialization, communication buffers are seen as typed arrays and initialized as follows:

```
((assign_type*)buffer)[i] = BUF_VALUE(rank,i;
```

where rank is the MPI rank of the calling process.

Warm-up Phase (IMB-MPI1, IMB-EXT)

Before starting the actual benchmark measurement for IMB-MPI1 and IMB-EXT, the selected benchmark is executed N_WARMUP times with a sizeof(assign_type) message length. The N_WARMUP value is defined in IMB_settings.h, see Parameters Controlling Intel® MPI Benchmarks for details. The warm-up phase eliminates the initialization overheads from the benchmark measurement.

Synchronization

Before the actual benchmark measurement is performed, the constant N_BARR is used to regulate calls to:

MPI_Barrier(MPI_COMM_WORLD)

The N_BARR constant is defined in IMB_settings.h and IMB_settings_io.h, with the current value of 2.

See figure Control flow of IMB to ensure that all processes are synchronized.

Actual Benchmarking

To reduce measurement errors caused by insufficient clock resolution, every benchmark is run repeatedly. The repetition count is as follows:

For MPI-1 and aggregate IMB-EXT/IO benchmarks, the repetition count is MSGSPERSAMPLE. This constant is defined in IMB_settings.h/IMB_settings_io.h, with 1000 and 50 values, respectively.

To avoid excessive run times for large transfer sizes X, an upper bound is set to OVERALL_VOL/X. The OVERALL_VOL value is defined in IMB_settings.h/IMB_settings_io.h, with 4MB and 16MB values, respectively.

Given transfer size X, the repetition count for all aggregate benchmarks is defined as follows:

```
n_sample = MSGSPERSAMPLE (X=0)

n_sample = max(1,min(MSGSPERSAMPLE,OVERALL_VOL/X)) (X>0)
```

The repetition count for non-aggregate benchmarks is defined completely analogously, with MSGSPERSAMPLE replaced by MSGS_NONAGGR. A reduced count is recommended as non-aggregate run times are usually much longer.

In the following examples, *elementary transfer* means a pure function (MPI_[Send, ...], MPI_Put, MPI_Get, MPI_Accumulate, MPI_File_write_XX, MPI_File_read_XX), without any further function call. Assured completion transfer completion is:

- MPI_Win_fence for IMB-EXT benchmarks
- a triplet MPI_File_sync/MPI_Barrier(file_communicator)/MPI_File_sync for IMB-IO Write benchmarks
- empty for all other benchmarks

MPI-1 Benchmarks

```
for ( i=0; i<N_BARR; i++ ) MPI_Barrier(MY_COMM)
time = MPI_Wtime()
for ( i=0; i<n_sample; i++ )
   execute MPI pattern
time = (MPI_Wtime()-time)/n_sample
```

IMB-EXT and Blocking I/O Benchmarks

For aggregate benchmarks, the kernel loop looks as follows:

```
for ( i=0; i<N_BARR; i++ )MPI_Barrier(MY_COMM)
/* Negligible integer (offset) calculations ... */
```

```
time = MPI_Wtime()
for ( i=0; i<n_sample; i++ )
   execute elementary transfer
   assure completion of all transfers
time = (MPI_Wtime()-time)/n_sample
```

For non-aggregate benchmarks, every single transfer is safely completed:

```
for ( i=0; i<N_BARR; i++ )MPI_Barrier(MY_COMM)
/* Negligible integer (offset) calculations ... */
time = MPI_Wtime()
for ( i=0; i<n_sample; i++ )
   {
   execute elementary transfer
   assure completion of transfer
   }
time = (MPI_Wtime()-time)/n_sample
```

Non-blocking I/O Benchmarks

A non-blocking benchmark has to provide three timings:

- t_pure - blocking pure I/O time
- t_ovrl- non-blocking I/O time concurrent with CPU activity
- t_CPU - pure CPU activity time

The actual benchmark consists of the following stages:

- Calling the equivalent blocking benchmark as defined in Actual Benchmarking and taking benchmark time as t_pure.
- Closing and re-opening the particular file(s).
- Re-synchronizing the processes.
- Running the non-blocking case, concurrent with CPU activity (exploiting t_CPU when running undisturbed), taking the effective time as t_ovrl.

The desired CPU time to be matched approximately by t_CPU is set in IMB_settings_io.h:

```
#define TARGET_CPU_SECS 0.1 /* unit seconds */
```

Checking Results

To check whether your MPI implementation is working correctly, you can use the CPP flag -DCHECK.

Activate the CPP flag -DCHECK through the CPPFLAGS variable and recompile the Intel® MPI Benchmarks executable files. Every message passing result from the Intel® MPI Benchmarks are checked against the expected outcome. Output tables contain an additional column called Defects that displays the difference as floating-point numbers.

NOTE:

The `-DCHECK` results are not valid as real benchmark data. Deactivate `-DCHECK` and recompile to get the proper results.

Output

The benchmark output includes the following information:

- General information:

  machine, system, release, and version are obtained by `IMB_g_info.c`.
- The calling sequence (command-line flags) are repeated in the output chart
- Results for the non-multiple mode

After a benchmark completes, three time values are available, extended over the group of active processes:

- `Tmax` - the maximum time
- `Tmin` - the minimum time
- `Tavg` - the average time

The time unit is µ.

Single Transfer Benchmarks:

```
Display X = message size [bytes], T=Tmax[µsec], bandwidth = X / 1.048576 / T
```

Parallel Transfer Benchmarks:

```
Display X = message; size, Tmax, Tmin and Tavg, bandwidth based on time = Tmax
```

Collective Benchmarks:

```
Display X = message size;(except for Barrier), Tmax, Tmin; and Tavg
```

Results for the multiple mode

- -multi 0: the same as above, with min, avg over all groups.
- -multi 1: the same for all groups, max, min, avg over single groups.

Sample 1 - IMB-MPI1 PingPong Allreduce

The following example shows the results of the `PingPong` and `Allreduce` benchmark:

```
<..>  np 2 IMB-MPI1 PingPong Allreduce
#---------------------------------------------------
# Intel (R) MPI Benchmark Suite V3.2, MPI1 part
```

```
#---------------------------------------------------
# Date                  : Thu Sep  4 13:20:07 2008
#  Machine               : x86_64
#  System                : Linux
#  Release               : 2.6.9-42.ELsmp
#  Version               : #1 SMP Wed Jul 12 23:32:02 EDT 2006
#  MPI Version           : 2.0
#  MPI Thread Environment: MPI_THREAD_SINGLE


#  New default behavior from Version 3.2 on:
#  the number of iterations per message size is cut down
# dynamically when a certain run time (per message size sample)
# is expected to be exceeded. Time limit is defined by variable
#  SECS_PER_SAMPLE (=> IMB_settings.h)
#  or through the flag => -time

#  Calling sequence was:

#  ./IMB-MPI1 PingPong Allreduce

#  Minimum message length in bytes:   0
#  Maximum message length in bytes:   4194304
#
#  MPI_Datatype                   :   MPI_BYTE
#  MPI_Datatype for reductions    :   MPI_FLOAT
#  MPI_Op                         :   MPI_SUM
#
#

#  List of Benchmarks to run:

#  PingPong
#  Allreduce

#---------------------------------------------------
#  Benchmarking PingPong
#  #processes = 2
#---------------------------------------------------
 #bytes  #repetitions      t[µsec]   Mbytes/sec
      0          1000         ..        ..
      1          1000
      2          1000
      4          1000
      8          1000
     16          1000
     32          1000
     64          1000
```

```
    128         1000
    256         1000
    512         1000
   1024         1000
   2048         1000
   4096         1000
   8192         1000
  16384         1000
  32768         1000
  65536          640
 131072          320
 262144          160
 524288           80
1048576           40
2097152           20
4194304           10
#-------------------------------------------------------
#  Benchmarking Allreduce
#  ( #processes = 2 )
#-------------------------------------------------------
 #bytes  #repetitions  t_min[µsec]  t_max[µsec]   t_avg[µsec]
      0         1000         ..          ..          ..
      4         1000
      8         1000
     16         1000
     32         1000
     64         1000
    128         1000
    256         1000
    512         1000
   1024         1000
   2048         1000
   4096         1000
   8192         1000
  16384         1000
  32768         1000
  65536          640
 131072          320
 262144          160
 524288           80
1048576           40
2097152           20
4194304           10

# All processes entering MPI_Finalize
```

Sample 2 - IMB-MPI1 PingPing Allreduce

The following example shows the results of the PingPing

```
<..>
 -np 6 IMB-MPI1
  pingping allreduce -map 2x3 -msglen Lengths -multi 0
Lengths
 file:
0
100
1000
10000
100000
1000000
#---------------------------------------------------
# Intel (R) MPI Benchmark Suite V3.2.2, MPI1 part
#---------------------------------------------------
# Date                   : Thu Sep 4 13:26:03 2008
# Machine                : x86_64
# System                 : Linux
# Release                : 2.6.9-42.ELsmp
# Version                : #1 SMP Wed Jul 12 23:32:02 EDT 2006
# MPI Version            : 2.0
# MPI Thread Environment: MPI_THREAD_SINGLE

# New default behavior from Version 3.2 on:
# the number of iterations per message size is cut down
# dynamically when a certain run time (per message size sample)
# is expected to be exceeded. Time limit is defined by variable
# SECS_PER_SAMPLE (=> IMB_settings.h)
# or through the flag => -time

# Calling sequence was:
# IMB-MPI1 pingping allreduce -map 3x2 -msglen Lengths
#          -multi 0

# Message lengths were user-defined
#
# MPI_Datatype                          :   MPI_BYTE
# MPI_Datatype for reductions    :   MPI_FLOAT
# MPI_Op                                  :   MPI_SUM
#
#
# List of Benchmarks to run:
# (Multi-)PingPing
# (Multi-)Allreduce
#--------------------------------------------------------------
```

```
# Benchmarking Multi-PingPing
# ( 3 groups of 2 processes each running simultaneously )
# Group  0:      0    3
#
# Group  1:      1    4
#
# Group  2:      2    5
#
#---------------------------------------------------------------
# bytes #rep.s t_min[µsec] t_max[µsec] t_avg[µsec] Mbytes/sec
      0   1000       ..          ..          ..          ..
    100   1000
   1000   1000
  10000   1000
 100000    419
1000000     41
#---------------------------------------------------------------
# Benchmarking Multi-Allreduce
# ( 3 groups of 2 processes each running simultaneously )
# Group  0:      0    3
#
# Group  1:      1    4
#
# Group  2:      2    5
#
#---------------------------------------------------------------
#bytes #repetitions  t_min[µsec]  t_max[µsec]  t_avg[µsec]
      0         1000         ..          ..           ..
    100         1000
   1000         1000
  10000         1000
 100000          419
1000000           41

#---------------------------------------------------------------
# Benchmarking Allreduce
#
#processes = 4; rank order (rowwise):
#     0    3
#
#     1    4
#
# ( 2 additional processes waiting in MPI_Barrier)
#---------------------------------------------------------------
# bytes #repetitions  t_min[µsec]  t_max[µsec]  t_avg[µsec]
      0         1000         ..          ..           ..
    100         1000
   1000         1000
  10000         1000
 100000          419
1000000           41
#---------------------------------------------------------------
# Benchmarking Allreduce
#
# processes = 6; rank order (rowwise):
#     0    3
#
#     1    4
#
#     2    5
#
#---------------------------------------------------------------
# bytes #repetitions  t_min[µsec]  t_max[µsec]  t_avg[µsec]
      0         1000         ..          ..           ..
    100         1000
   1000         1000
  10000         1000
 100000          419
1000000           41

# All processes entering MPI_Finalize
```

Sample 3 - IMB-IO p_write_indv

The following example shows the results of the p_write_indv benchmark:

```
<..> IMB-IO -np 2 p_write_indv -npmin 2
#---------------------------------------------------
# Date                  : Thu Sep  4 13:43:34 2008
# Machine               : x86_64
# System                : Linux
# Release               : 2.6.9-42.ELsmp
# Version               : #1 SMP Wed Jul 12 23:32:02 EDT 2006
# MPI Version           : 2.0
# MPI Thread Environment: MPI_THREAD_SINGLE

# New default behavior from Version 3.2 on:
# the number of iterations per message size is cut down
# dynamically when a certain run time (per message size sample)
# is expected to be exceeded. Time limit is defined by variable
# SECS_PER_SAMPLE (=> IMB_settings.h)
# or through the flag => -time

# Calling sequence was:
# ./IMB-IO p_write_indv -npmin 2
# Minimum io portion in bytes:   0
# Maximum io portion in bytes:   16777216
#
#
#
# List of Benchmarks to run:
# P_Write_Indv
#--------------------------------------------------------------
# Benchmarking P_Write_Indv
# #processes = 2
#--------------------------------------------------------------
#
#    MODE: AGGREGATE
#
  #bytes #rep.s t_min[µsec]     t_max     t_avg Mb/sec
       0     50       ..         ..        ..      ..
       1     50
       2     50
       4     50
       8     50
      16     50
      32     50
      64     50
     128     50
     256     50
     512     50
    1024     50
    2048     50
    4096     50
    8192     50
   16384     50
   32768     50
   65536     50
  131072     50
  262144     50
  524288     32
 1048576     16
 2097152      8
 4194304      4
 8388608      2
16777216      1

#--------------------------------------------------------------
# Benchmarking P_Write_Indv
# #processes = 2
#--------------------------------------------------------------
#
#    MODE: NON-AGGREGATE
```

```
#
  #bytes #rep.s t_min[μsec]     t_max     t_avg Mb/sec
       0     10     ..           ..         ..    ..
       1     10
       2     10
       4     10
       8     10
      16     10
      32     10
      64     10
     128     10
     256     10
     512     10
    1024     10
    2048     10
    4096     10
    8192     10
   16384     10
   32768     10
   65536     10
  131072     10
  262144     10
  524288     10
 1048576     10
 2097152      8
 4194304      4
 8388608      2
16777216      1

# All processes entering MPI_Finalize
```

Sample 4 - IMB-EXT.exe

The example below shows the results for the `Window` benchmark received after running `IMB-EXT.exe` on a Microsoft Windows* cluster using two processes. The performance diagnostics for `Unidir_Get`, `Unidir_Put`, `Bidir_Get, Bidir_Put`, and `Accumulate` are omitted.

```
<..> -n 2 IMB-EXT.exe

#---------------------------------------------------
#    Intel (R) MPI Benchmark Suite V3.2.2, MPI-2 part
#---------------------------------------------------
# Date                  : Fri Sep 05 12:26:52 2008
# Machine               : Intel64 Family 6 Model 15 Stepping 6, GenuineIntel
# System                : Windows Server 2008
# Release               : .0.6001
# Version               : Service Pack 1
# MPI Version           : 2.0
# MPI Thread Environment: MPI_THREAD_SINGLE

# New default behavior from Version 3.2 on:
# the number of iterations per message size is cut down
# dynamically when a certain run time (per message size sample)
# is expected to be exceeded. Time limit is defined by variable
# SECS_PER_SAMPLE (=> IMB_settings.h)
# or through the flag => -time

# Calling sequence was:
# \\master-node\MPI_Share_Area\IMB_3.1\src\IMB-EXT.exe
# Minimum message length in bytes:   0
# Maximum message length in bytes:   4194304
#
# MPI_Datatype                   :   MPI_BYTE
# MPI_Datatype for reductions    :   MPI_FLOAT
# MPI_Op                         :   MPI_SUM
#
#

# List of Benchmarks to run:
# Window
# Unidir_Get
# Unidir_Put
# Bidir_Get
# Bidir_Put
# Accumulate

#----------------------------------------------------------------
# Benchmarking Window
# #processes = 2
#---------------------------------------------------------------
       #bytes #repetitions  t_min[μsec]  t_max[μsec] t_avg[μsec]
            0          100       ..           ..           ..
            4          100
            8          100
           16          100
           32          100
           64          100
          128          100
          256          100
          512          100
         1024          100
         2048          100
         4096          100
         8192          100
        16384          100
```

```
         32768          100
         65536          100
        131072          100
        262144          100
        524288           80
       1048576           40
       2097152           20
       4194304           10
...
# All processes entering MPI_Finalize
```

The above example listing shows the results of running IMB-EXT.exe on a Microsoft Windows* cluster using two processes.

The listing only shows the result for the Window benchmark. The performance diagnostics for Unidir_Get, Unidir_Put, Bidir_Get, Bidir_Put, and Accumulate are omitted.