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MPI Correctness Checking and Debugging

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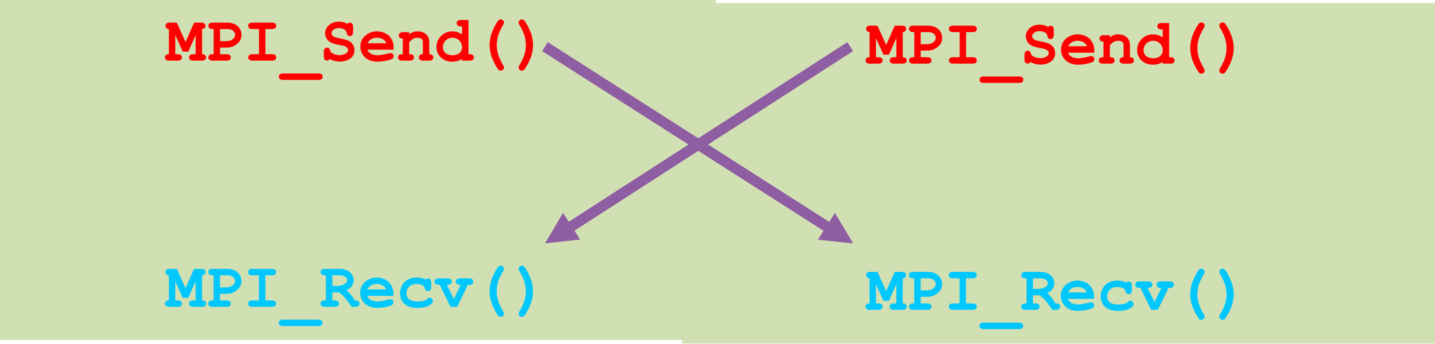
Common MPI Problems

Common MPI Problems

Deadlocks because communication relies on buffering in MPI:



```
MPI_Send()        MPI_Send()

MPI_Recv()        MPI_Recv()
```

May or may not work, depending on the message size and MPI implementation!

- Characterized as “unsafe” in the MPI Specification!
- In a “safe” code all MPI_Send calls can be replaced by synchronous MPI_Ssend calls

Common MPI Problems (cont.)

Memory reused in concurrent MPI operations

```
message =...
MPI_Isend(message)
message = ...
MPI_Isend(message)
...
MPI_Wait()
MPI_Wait()
```

Violates the MPI specification!

Can lead to message corruption due to unfinished buffering!

MPI Correctness Checking

MPI Correctness Checking

A technology which validates MPI correctness

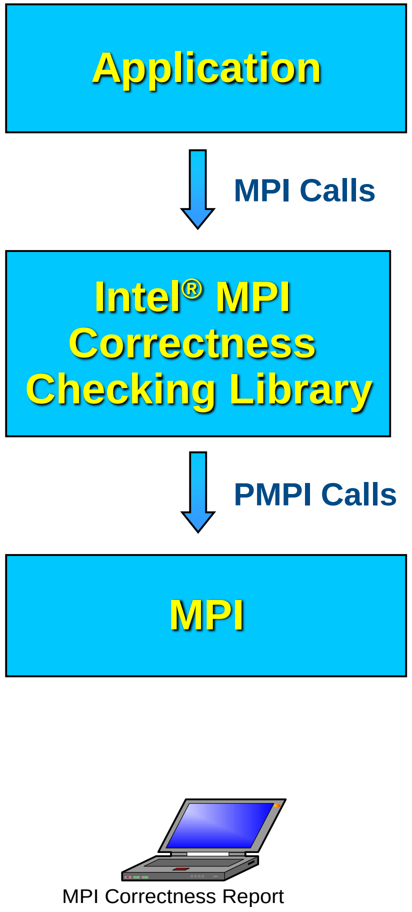
- Detects over 50 distinct MPI programming and run-time errors:
  - ○ Issues with data types, buffers, communicators,
  - ○ point-to-point messages and collective operations,
  - ○ deadlocks, and data corruption.

In-place analysis

- Collects and analyzes MPI event data as the application runs
- Reports errors to console as they are detected
- Shows error location in GUI
- Can trigger debugger breakpoints for in-place analysis

Availability

- Packaged with Intel® Trace Analyzer and Collector (ITAC), for usage with Intel® MPI



MPI Correctness Checking - Goal

Solves two problems:

- Finding programming mistakes in MPI application which need to be fixed by the application developer (e.g. illegal buffer re-usage)
- Detecting errors in the execution environment
  (e.g. by checksum comparison of sent/received message)

Two aspects:

- *Error detection* – done ***automatically*** by the tool
- *Error analysis* – manually by the user based on
  - information provided about an error
  - GUI and knowledge of source code, system, ...

MPI Correctness Checking - Usage

The application runs in the MPI correctness checking mode by running:

```
mpirun -check_mpi ...
```

Or by library pre-loading (mc for "message checking"):

```
mpirun -genv LD_PRELOAD libVTmc.so ...
```

alternative:

```
export LD_PRELOAD=libVTmc.so[:libmpi.so]
mpirun ...
```

or `srun ...` for SLURM

Or by static linkage with **`libVTmc.a`**

Prerequisite: Setup the Intel® Trace Analyzer and Collector environment

At best, the application is compiled with **`-g`** so that errors get a source code reference.

MPI Correctness Checking - Output

Usage with temporary LD_PRELOAD:

```
$ env LD_PRELOAD=libVTmc.so:libmpi.so srun -n 2 overlap
[...]
[0] WARNING: LOCAL:MEMORY:OVERLAP: warning
[0] WARNING:    New send buffer overlaps with currently active send
buffer at address 0x7fbfffec10.
[0] WARNING:    Control over active buffer was transferred to MPI at:
[0] WARNING:       MPI_Isend(*buf=0x7fbfffec10, count=4,
datatype=MPI_INT, dest=0, tag=103, comm=COMM_SELF [0],
*request=0x508980)
[0] WARNING:       overlap.c:104
[0] WARNING:    Control over new buffer is about to be transferred to
MPI at:
[0] WARNING:       MPI_Isend(*buf=0x7fbfffec10, count=4,
datatype=MPI_INT, dest=0, tag=104, comm=COMM_SELF [0],
*request=0x508984)
[0] WARNING:       overlap.c:105
```

MPI Correctness Checking - Output

Recommended usage is via `–check_mpi`:

```
$ mpirun –check_mpi –n 2 overlap
[...]
[0] WARNING: LOCAL:MEMORY:OVERLAP: warning
[0] WARNING:    New send buffer overlaps with currently active send
buffer at address 0x7fbfffec10.
[0] WARNING:    Control over active buffer was transferred to MPI at:
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*request=0x508984)
[0] WARNING:       overlap.c:105
```
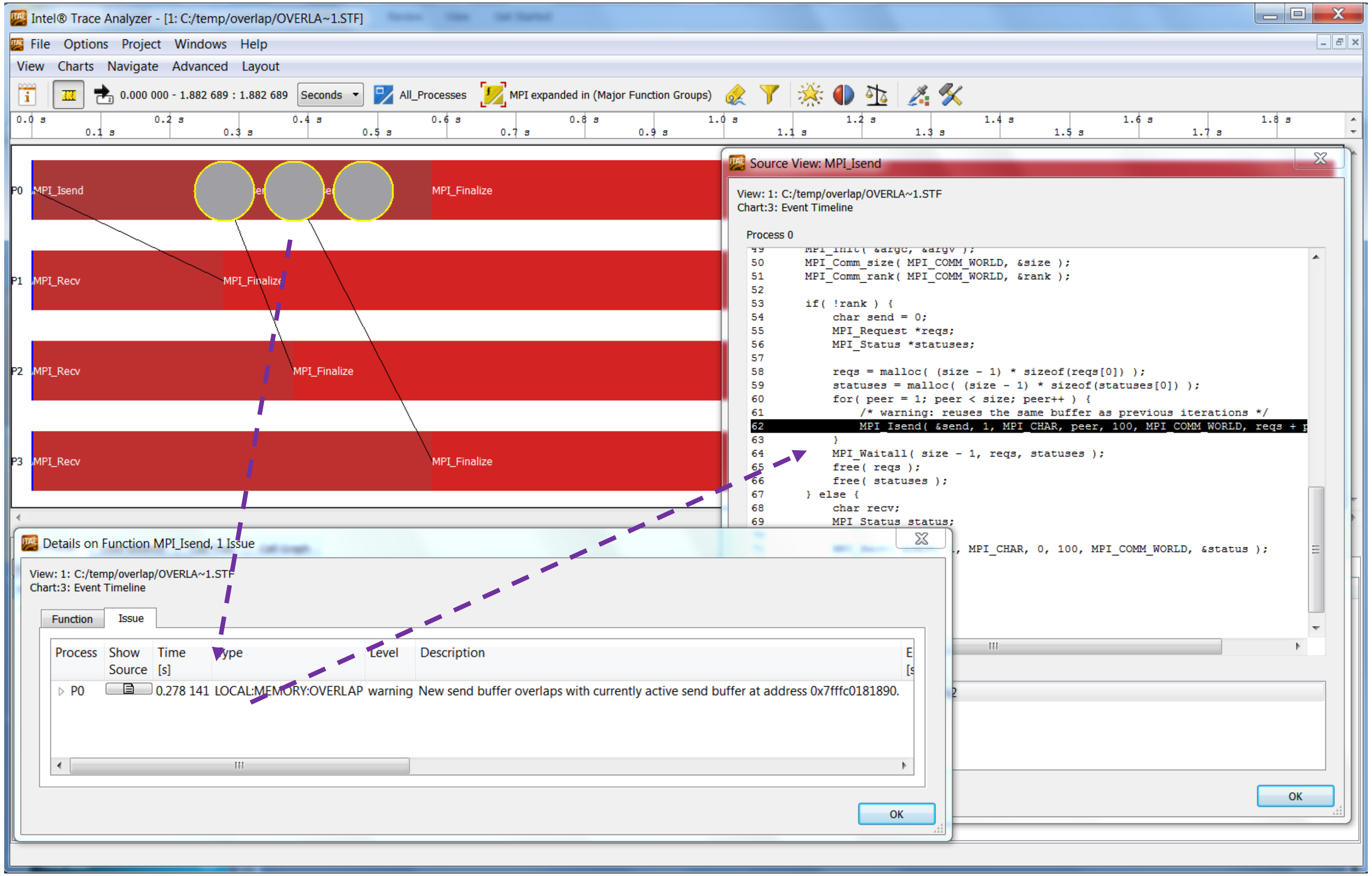

MPI Correctness Checking in the GUI


Intel® Trace Analyzer - [1: C:/temp/overlap/OVERLA~1.STF]
File Options Project Windows Help
View Charts Navigate Advanced Layout
0.000 000 - 1.882 689 : 1.882 689
Seconds
All_Processes
MPI expanded in (Major Function Groups)
0.0 s 0.1 s 0.2 s 0.3 s 0.4 s 0.5 s 0.6 s 0.7 s 0.8 s 0.9 s 1.0 s 1.1 s 1.2 s 1.3 s 1.4 s 1.5 s 1.6 s 1.7 s 1.8 s
P0
MPI_Isend
MPI_Finalize
P1
MPI_Recv
MPI_Finalize
P2
MPI_Recv
MPI_Finalize
P3
MPI_Recv
MPI_Finalize
Source View: MPI_Isend
Details on Function MPI_Isend, 1 Issue
Function
Issue
OK
OK

Source View: MPI_Isend

View: 1: C:/temp/overlap/OVERLA~1.STF
Chart:3: Event Timeline

Process 0

```
    MPI_Init( &argc, &argv );
    MPI_Comm_size( MPI_COMM_WORLD, &size );
    MPI_Comm_rank( MPI_COMM_WORLD, &rank );

    if( !rank ) {
        char send = 0;
        MPI_Request *reqs;
        MPI_Status *statuses;

        reqs = malloc( (size - 1) * sizeof(reqs[0]) );
        statuses = malloc( (size - 1) * sizeof(statuses[0]) );
        for( peer = 1; peer < size; peer++ ) {
            /* warning: reuses the same buffer as previous iterations */
            MPI_Isend( &send, 1, MPI_CHAR, peer, 100, MPI_COMM_WORLD, reqs + p
        }
        MPI_Waitall( size - 1, reqs, statuses );
        free( reqs );
        free( statuses );
    } else {
        char recv;
        MPI_Status status;

                        , MPI_CHAR, 0, 100, MPI_COMM_WORLD, &status );
```

Details on Function MPI_Isend, 1 Issue

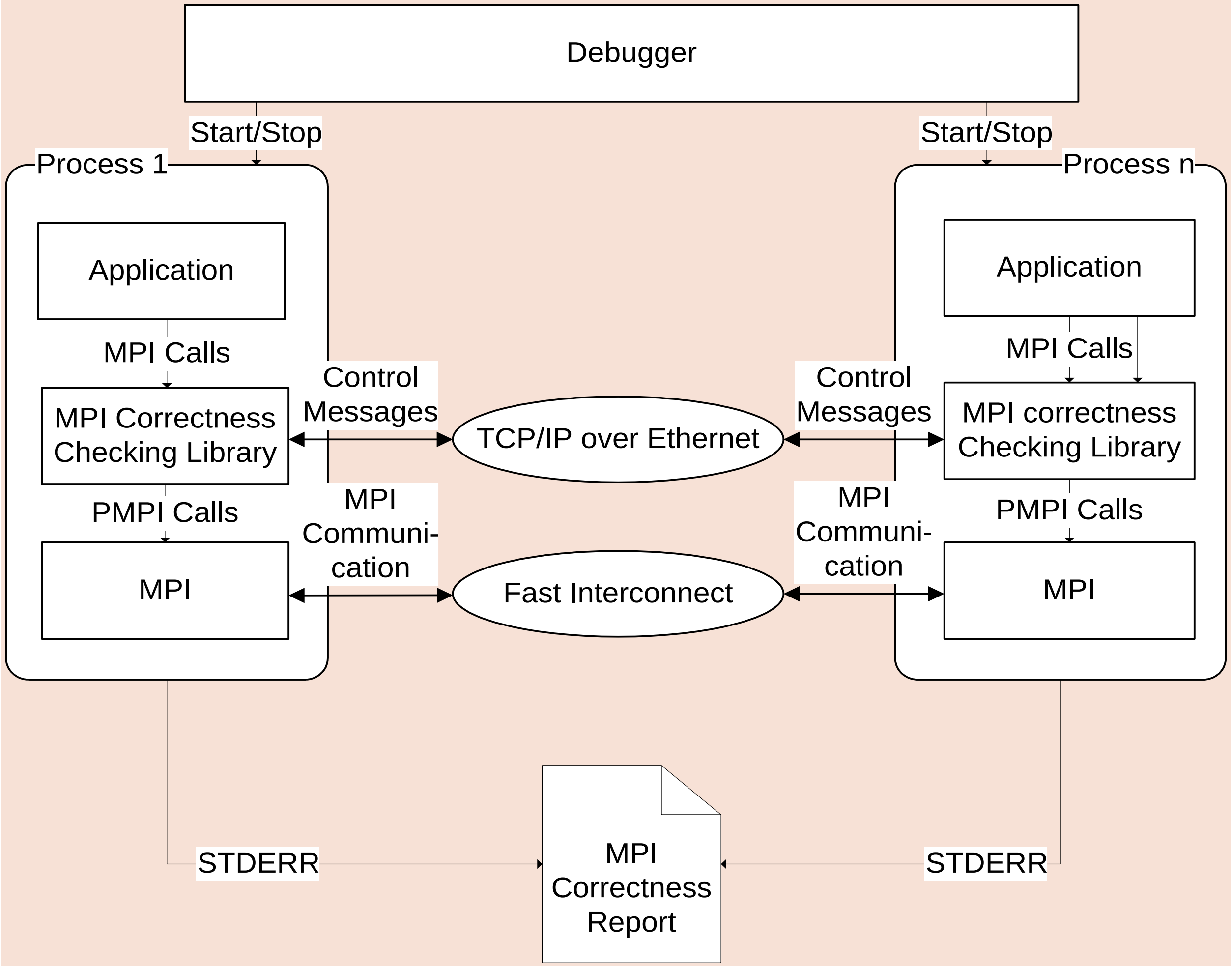
View: 1: C:/temp/overlap/OVERLA~1.STF
Chart:3: Event Timeline

Process	Show Source	Time [s]	Type	Level	Description	E [s
▷ P0	🗎	0.278 141	LOCAL:MEMORY:OVERLAP	warning	New send buffer overlaps with currently active send buffer at address 0x7fffc0181890.	

Set **CHECK-TRACING on** to enable writing of trace file.

MPI Correctness Checking: How it works

- All checks are done at runtime in MPI wrappers.
- Detected problems are reported on stderr immediately in textual format.
- A debugger can be used to investigate the problem at the moment when it is found.



Supported Checks

Two different categories:

- ***Local checks:*** only need information available in the process itself and thus do not require additional communication between processes
- ***Global checks:*** information from other processes is required

Different levels:

- ***Warning:*** application can continue
- ***Error:*** application can continue, but almost certainly not as intended
- ***Fatal error:*** application must be aborted

Some checks may find both warnings and errors, for example:

- Invalid parameter in MPI_Send() => message cannot be sent => **Error**
- Invalid parameter in MPI_Request_free() => resource leak => **Warning**

Local Checks

Unexpected process termination, e.g.

- **EXIT:BEFORE_MPI_FINALIZE**

Buffer handling, e.g.

- **MEMORY:ILLEGAL_MODIFICATION**

Request and data type management, e.g.

- **REQUEST:ILLEGAL_CALL**

Parameter errors found by MPI, e.g. wrong types

NB: Full name qualified with leading ”**LOCAL:**”

Global checks for point-to-point and collective operations

Pending messages

- **MSG:PENDING**

Data type issues

- **MSG/COLLECTIVE:DATATYPE:MISMATCH**

Corrupted data transmission (can detect HW issues)

- **MSG/COLLECTIVE:DATA_TRANSMISSION_CORRUPTED**

For collective operations only

- **COLLECTIVE:ROOT_MISMATCH**

NB: Full name qualified with leading ”**GLOBAL:**”

Deadlock Detection

Very useful is the global check for detection of deadlocks:

- **DEADLOCK:HARD**
- **DEADLOCK:POTENTIAL**
- **DEADLOCK:NO_PROGRESS**

The default time (60s) for deadlock detection can be adjusted:

DEADLOCK-TIMEOUT 10s

Meaning: After 10s with

no progress in the MPI communication

on all processes the application will be interrupted and debug diagnostics shown.

Configuration

Each MPI correctness checking run writes a protocol file <executable>.prot which lists all default or explicit settings

Specify configuration file “-genv VT_CONFIG <configfile>”

- Easily derived from the protocol file <executable>.prot of a previous run

Each check can be turned on and off individually (`CHECK ** ON`), e.g.:

```
CHECK GLOBAL:DEADLOCK:POTENTIAL ON/OFF
```

Number of warnings and errors that are printed are configurable, defaults are:

- Abort immediately at first real error

  ```
  CHECK-MAX-ERRORS 1
  ```

- Keep running regardless how many warnings are issued

  ```
  CHECK-MAX-REPORTS 0
  ```

- Print at most 20 warnings/errors of each type

  ```
  CHECK-SUPPRESSION-LIMIT 20
  ```

Static Linkage

A code linked statically against the ITAC library libVT (by flags –trace or –tcollect for the linking) cannot immediately be run with MPI correctness checking

Reason: Calls to the MPI library are already intercepted by the static library.

Solution: Re-link without ITAC tracing or,
when API functions (like VT_traceon/off) have to be resolved, by:

```
-L${VT_SLIB_DIR} -lVTnull
```

Intel® MPI Debug Output

Intel® MPI Debug Output

Use environment variable I_MPI_DEBUG to print out debugging information

I_MPI_DEBUG	Debug information provided
1	Verbose error diagnostics
2	Confirm which I_MPI_FABRICS was used
3	Effective MPI rank, `pid` and node mapping table
4	Process pinning information
5	Intel® MPI-specific environment variables
6	Show defaults of MPI collectives
>6	Add extra levels of debug information

Intel® MPI Debug Output (contd.)

Add comma separated list of flags to fine tune debug output:

```
I_MPI_DEBUG=<level>,<flags>
```

<flags>	Debug information provided
pid	Process id for each debug message
tid	Thread id for each debug message for the multi-threaded library
host	Host name for each debug message
flock	Synchronize output from different processes or threads
nobuf	Do not use buffered I/O for debug output
…	…

Intel® MPI Debug Output (contd.)

Use environment variable I_MPI_DEBUG_OUTPUT to re-direct the output to a file (or stderr instead of stdout).

- Annotation of the file name with “%r” will produce one output file per rank!
- Use format strings “%p” or “%h” to add pid or host name to the file name

Compiling with „-g“ will print out additional debug information

Hydra process manager and Libfabric

Enable debug output from the Hydra process manager:

- mpirun --verbose
- I_MPI_HYDRA_DEBUG=1|on|enable|yes

For Intel MPI 2019+ use debug functionality of libfabric:

- FI_LOG_LEVEL=Warn, =Trace, =Info, =Debug
- See https://ofiwg.github.io/libfabric/master/man/fabric.7.html
- Simple tool to query for fabric interfaces:
  fi_info [-l]

Summary

The MPI correctness checking from the Intel® Trace Analyzer and Collector (ITAC) detects MPI programming and run time errors

Intel® MPI provides built-in debug output for the MPI communication

Use Libfabric commands and flags for debug output from the provider level intel®