Memory debugging for MPI-applications in Open MPI

Rainer Keller – HLRS
Shiqing Fan – HLRS
Michael Resch – HLRS

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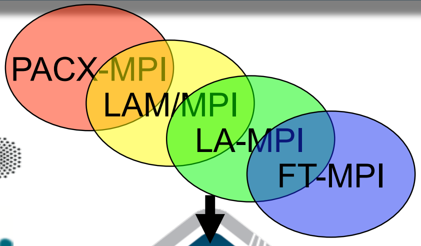
Overview

- Introduction to Open MPI
- Introduction into Valgrind
- Memchecker Component for Memory checking in Open MPI
- Conclusion

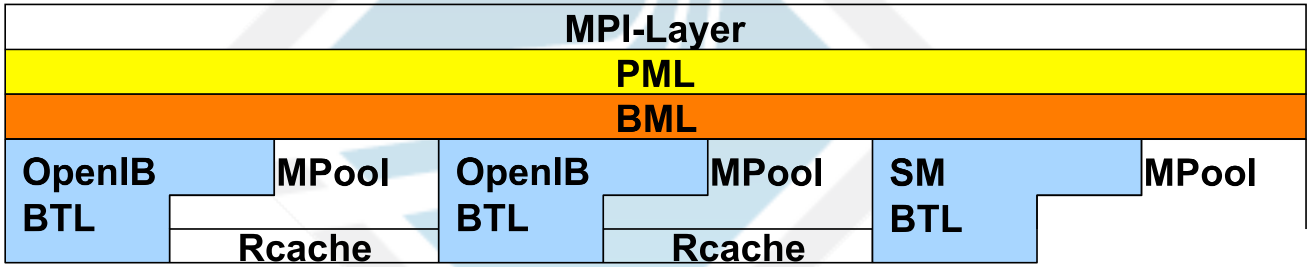
About Open MPI

- Features of Open MPI:
  - Full MPI-2 implementation,
  - Fast, reliable and extensible,
  - Production-grade code quality as a base for research.
- Current status:
  - Stable: v1.2.8 (as of October)
  - Release v1.3 for SC08



Open MPI Architecture

- Very modular architecture allows (holds for OMPI / ORTE / OPAL):
  - Dynamically load available modules and check for hardware
  - Select best modules and unload others (e.g. if hw not available)
  - Fast indirect calls into each component.



MPI-Layer

PML

BML

OpenIB BTL | MPool | Rcache

OpenIB BTL | MPool | Rcache

SM BTL | MPool

- Very versatile setup for varying installations (ship one RPM)
- Allows easy integration of new functionality

Introduction into Valgrind

- An Open-Source Debugging & Profiling tool
- Works with dynamically & statically linked applications
- Emulates CPU:
  i.e. executes instructions on a synthetic x86/Opteron/Power
- It‘s easily configurable to ease debugging & profiling through *tools*:
  - Cachegrind: A memory & cache profiler
  - Helgrind: Find Races in multithreaded programs
  - Callgrind: A Cache & Call-tree profiler
  - **Memcheck**: Every memory access is being checked…

Introduction into Valgrind

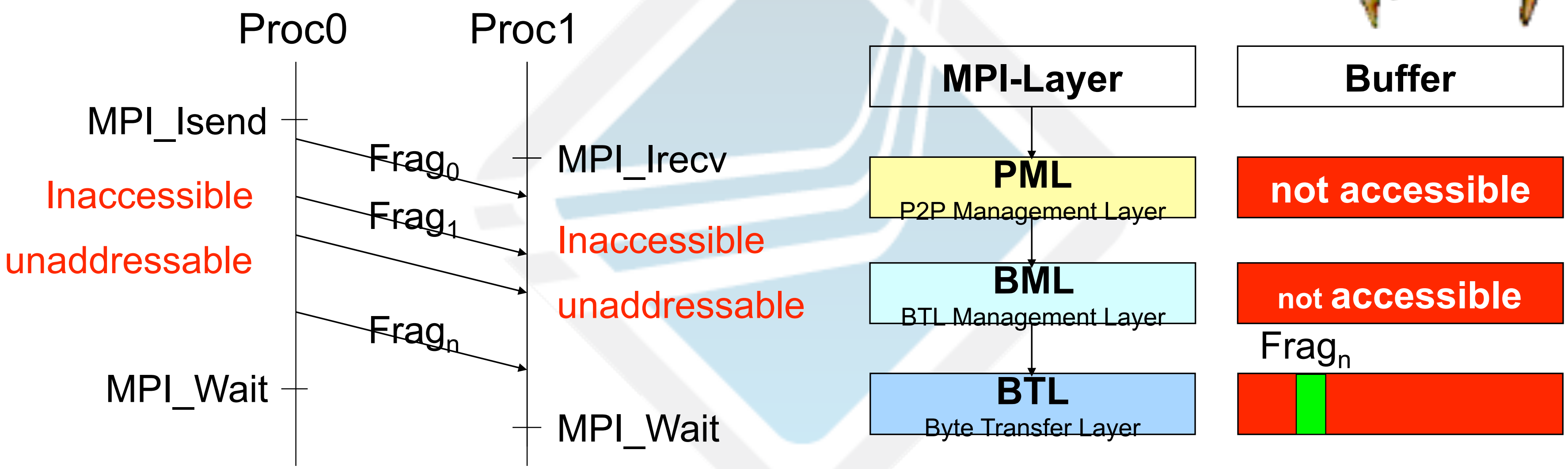
- Memcheck tool scans for:
  - Use of uninitialized memory
  - Malloc Errors:
    - Usage of free‘d memory
    - Double free
    - Reading/writing past malloc’d memory
    - Lost memory pointers
    - Mismatched malloc/new & free/delete
  - Stack write errors
  - Overlapping arguments to system functions like `memcpy`.
- Why not use this functionality for MPI checking purposes?

Open MPI valgrind extension

- Detect application’s memory violation of MPI-standard:
  - Application’s usage of undefined data
  - Application’s memory access due to MPI-semantics
- Detect Non-blocking/One-sided communication errors:
  - Functions in BTL layer for both communications
  - Set memory accessibility independent of MPI operations
  - i.e. only set accessibility for the fragment to be sent/received
- MPI object checking:
  - Check definedness of MPI objects that passing to MPI API
  - `MPI_Status`, `MPI_Comm`, `MPI_Request` and `MPI_Datatype`
  - Could be disabled for better performance

Open MPI valgrind extension

- Non-blocking send/receive buffer error checking



Proc0

Proc1

MPI_Isend

$Frag_0$

MPI_Irecv

Inaccessible

$Frag_1$

unaddressable

Inaccessible

unaddressable

$Frag_n$

MPI_Wait

MPI_Wait

MPI-Layer

Buffer

PML
P2P Management Layer

not accessible

BML
BTL Management Layer

not accessible

$Frag_n$

BTL
Byte Transfer Layer

Open MPI valgrind extension

- Non-blocking buffer accessed/modified before finished

```
MPI_Isend (buffer, SIZE, MPI_INT, …, &request);
buffer[1] = 4711;
MPI_Wait (&req, &status);
```

- The standard does not (*yet*) allow **read** access:

```
MPI_Isend (buffer, SIZE, MPI_INT, …, &request);
result[1] = buffer[1];
MPI_Wait (&request, &status);
```

- Side note:
  - MPI-1, p30, Rationale for restrictive access rules; “allows better performance on some systems”.

Open MPI valgrind extension

- Access to buffer under control of MPI:

```
MPI_Irecv (buffer, SIZE, MPI_CHAR, …, &request);
buffer[1] = 4711;
MPI_Wait (&request, &status);
```

- Side note: CRC-based methods do not reliably catch these cases.

- Memory that is outside receive buffer is overwritten :

```
buffer = malloc( SIZE * sizeof(MPI_CHAR) );
memset (buffer, SIZE * sizeof(MPI_CHAR), 0);
MPI_Recv(buffer, SIZE+1, MPI_CHAR, …, &status);
```

- Side note: MPI-1, p21, rationale of overflow situations: “no memory that outside the receive buffer will ever be overwritten.”

Open MPI valgrind extension

- Usage of the Undefined Memory passed from Open MPI

```
MPI_Wait(&request, &status);
if (status.MPI_ERROR != MPI_SUCCESS)
```

- Side note: This field should remain undefined.
  - MPI-1, p22 (not needed for calls that return only one status)
  - MPI-2, p24 (Clarification of status in single-completion calls).
- Write to buffer before accumulate is finished :

```
MPI_Accumulate(A, NROWS*NCOLS, MPI_INT, 1, 0, 1, \
               xpose, MPI_SUM, win);
A[0][1] = 4711;
MPI_Win_fence(0, win);
```

Thank You

- Thank You very much!