Lessons learned from Implementing OMPD

A Debugging Interface for OpenMP

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Debugging OpenMP: gdb backtrace

```
(gdb) thread 3
[Switching to thread 3 (Thread 0x7ffff74ee780 (LWP 18484))]#0
tdm::L__ZN3tdm8residuumERPd_67__par_loop0_2_10 () at tdm.C:70
70                      sum=fabs(x[i-1]*e[i]+x[i]*d[i]+x[i+1]*f[i]-b[i]);
(gdb) bt
#0  tdm::L__ZN3tdm8residuumERPd_67__par_loop0_2_10 () at tdm.C:70
#1  0x00007ffff7d2abc3 in __kmp_invoke_microtask () from
/opt/intel/Compiler/16.0/0.109/rwthlnk/compiler/lib/intel64_lin/libiomp5.so
#2  0x00007ffff7cfc8c7 in __kmp_invoke_task_func (gtid=5) at
../../src/kmp_runtime.c:7585
#3  0x00007ffff7cfbfd5 in __kmp_launch_thread (this_thr=0x5) at
../../src/kmp_runtime.c:6037
#4  0x00007ffff7d2aee3 in __kmp_launch_worker (thr=0x5) at ../../src/z_Linux_util.c:786
#5  0x0000003f890079d1 in start_thread (arg=0x7ffff74ee780) at pthread_create.c:301
#6  0x0000003f888e88fd in clone () at ../sysdeps/unix/sysv/linux/x86_64/clone.S:115
(gdb)
```

Debugging OpenMP: gdb backtrace (master)

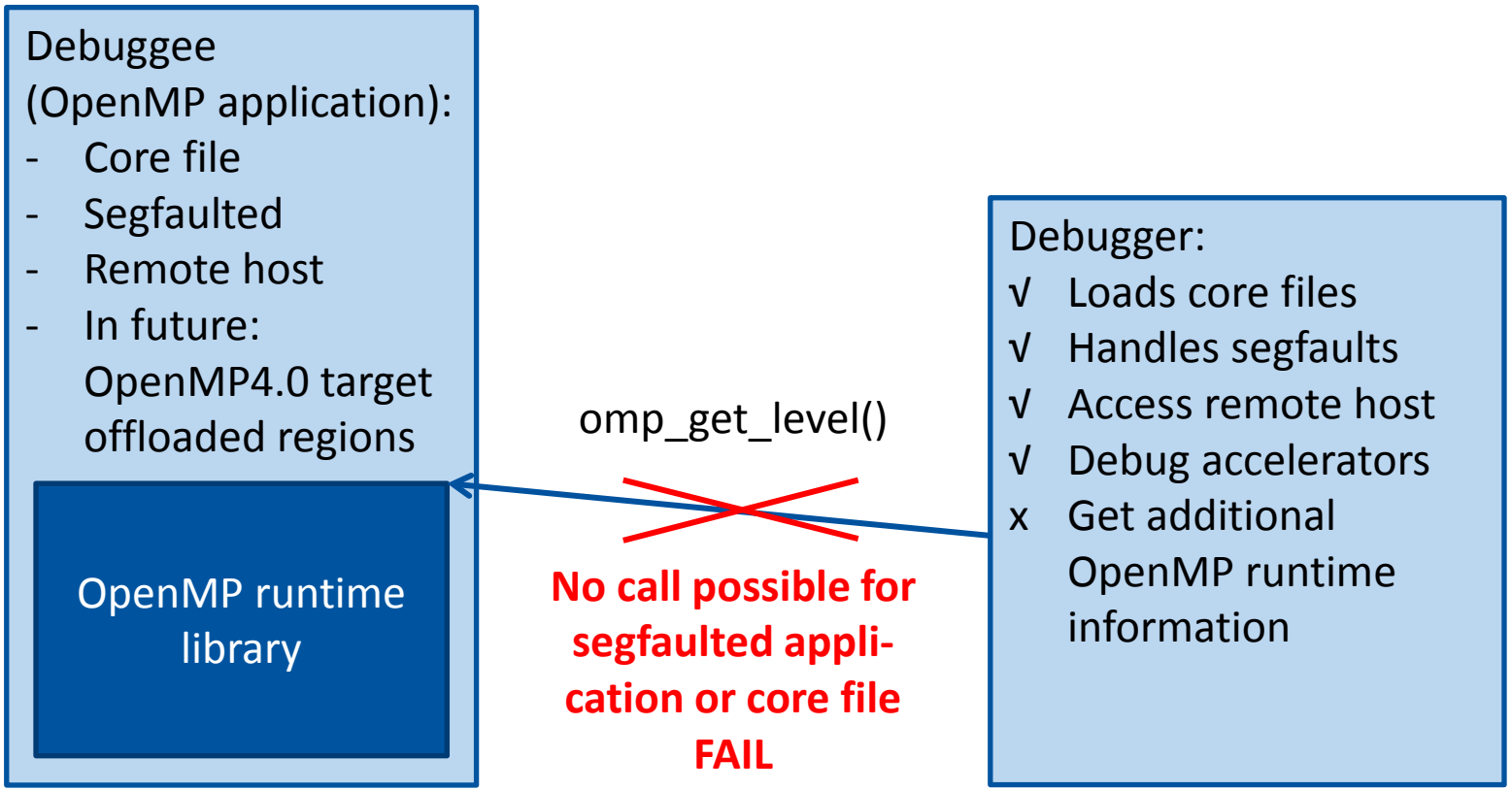
```
(gdb) thread 1
[Switching to thread 1 (Thread 0x7ffff76f1720 (LWP 18478))]#0
tdm::L__ZN3tdm8residuumERPd_67__par_loop0_2_10 () at tdm.C:70
70                      sum=fabs(x[i-1]*e[i]+x[i]*d[i]+x[i+1]*f[i]-b[i]);
(gdb) bt
#0  tdm::L__ZN3tdm8residuumERPd_67__par_loop0_2_10 () at tdm.C:70
#1  0x00007ffff7d2abc3 in __kmp_invoke_microtask () from
/opt/intel/Compiler/16.0/0.109/rwthlnk/compiler/lib/intel64_lin/libiomp5.so
#2  0x00007ffff7cfc8c7 in __kmp_invoke_task_func (gtid=1) at
../../src/kmp_runtime.c:7585
#3  0x00007ffff7cfdd0c in __kmp_fork_call(ident_t *, int, enum fork_context_e,
kmp_int32, microtask_t, launch_t, va_list *) (loc=0x1, gtid=0, call_context=4, argc=0,
    microtask=0x7ffff7618200, invoker=0x7fffffff7adc, ap=0x7fffffff7f80) at
../../src/kmp_runtime.c:2559
#4  0x00007ffff7cd26c8 in __kmpc_fork_call (loc=0x1, argc=0, microtask=0x4) at
../../src/kmp_csupport.c:325
#5  0x0000000000404094 in tdm::residuum (this=0x7fffffff8140, x=@0x7fffffff81a0) at
tdm.C:67
#6  0x0000000000402c48 in main (argc=1, argv=0x7fffffff8368) at solve.C:33
(gdb)
```

Overview

- **OMPD Interface**
- **Use cases:**
  - → OpenMP aware backtrace
  - → Stepping OpenMP application
- **Resolve target values**

What is OMPD? Why do we need OMPD?

- **OMPD: OpenMP Debugging Interface**



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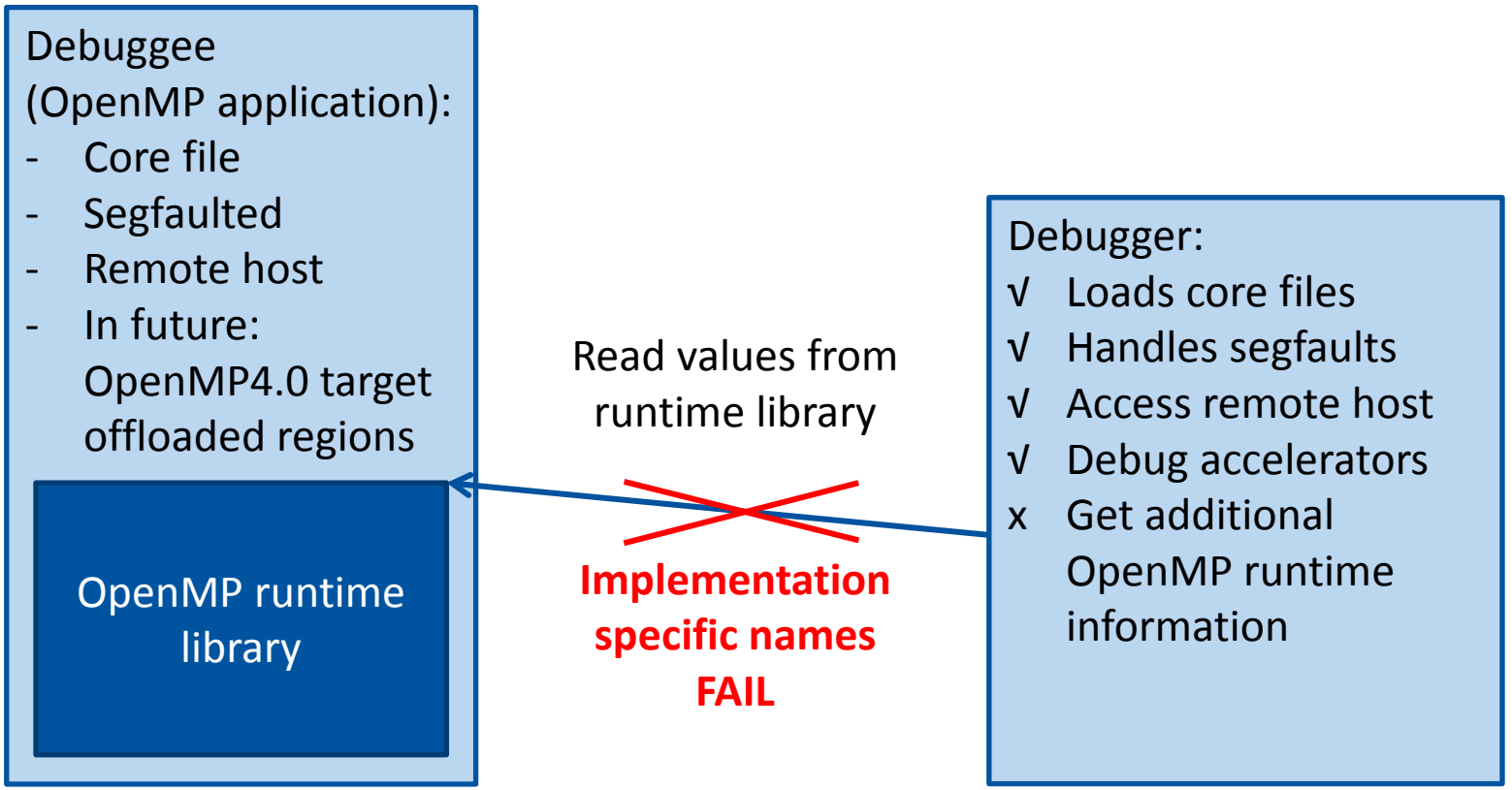

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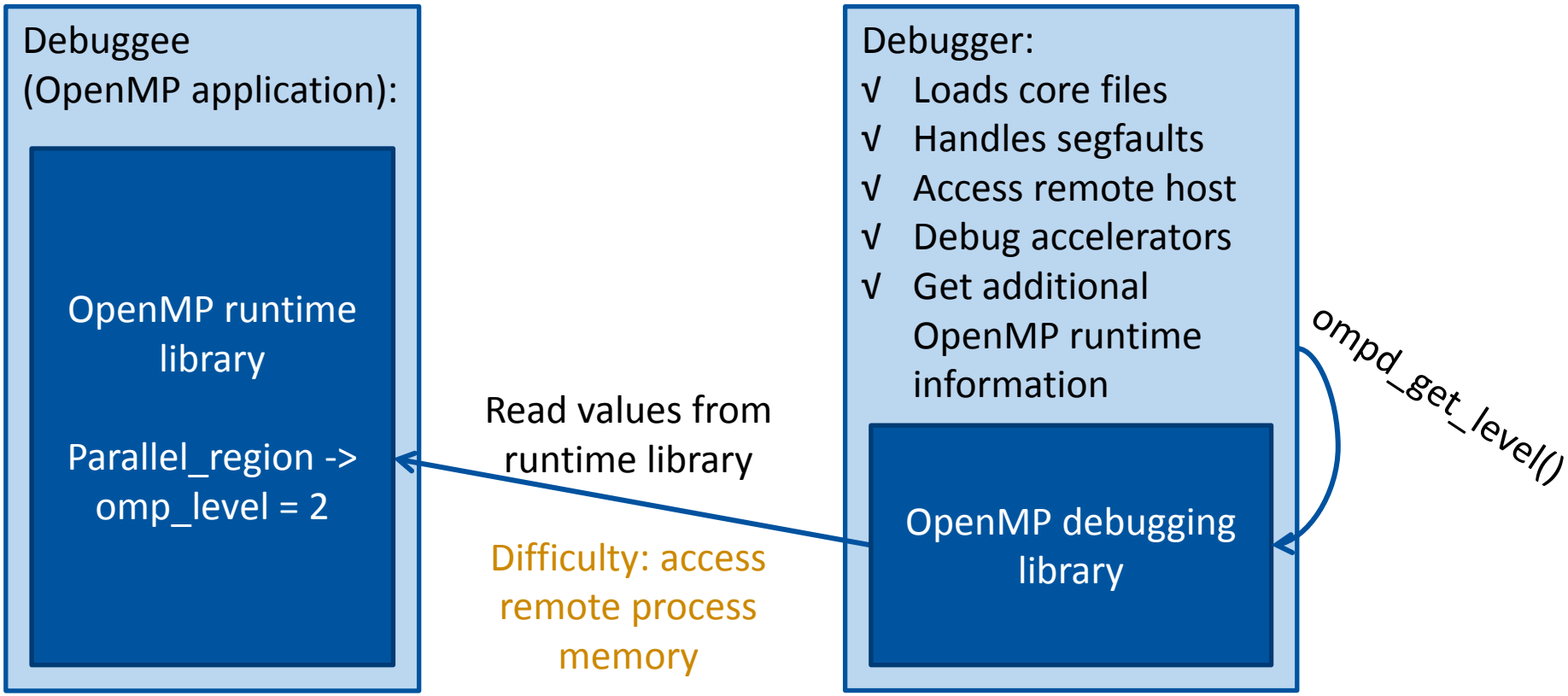

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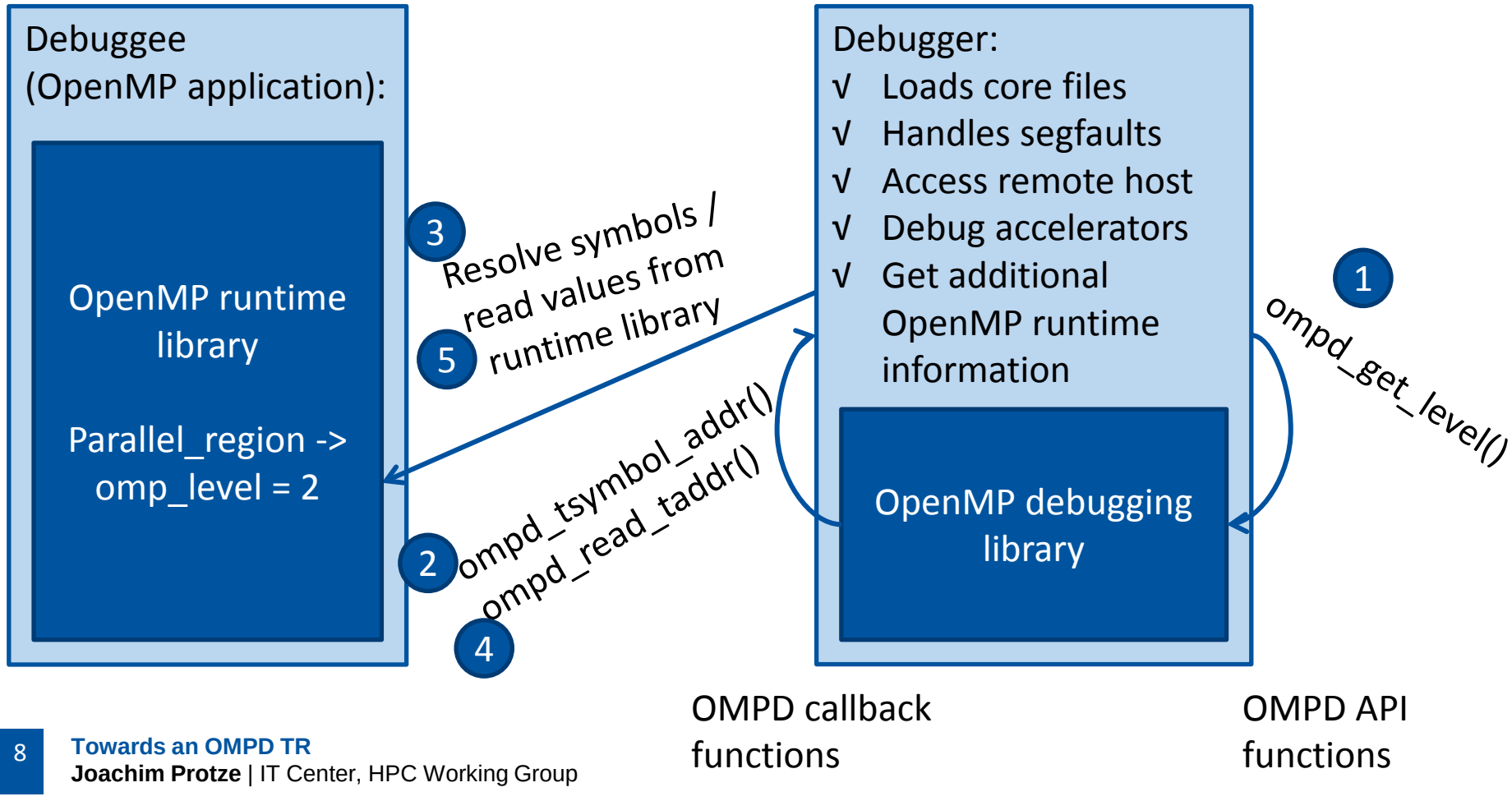
- **OMPD: OpenMP Debugging interface**



The two interfaces of OMPD

- **OMPD callback interface**

  Functions implemented by the debugger / debugging tool:

  → Resolve target symbols

  → Read/ write target memory

  → Alloc/free local memory

  → Output

  → Endianess conversion

  → ~~*Type size/offset lookup*~~

- **OMPD API**

  Functions called by the debugger / debugging tool

  → Function analogues for OpenMP / OMPT API functions.

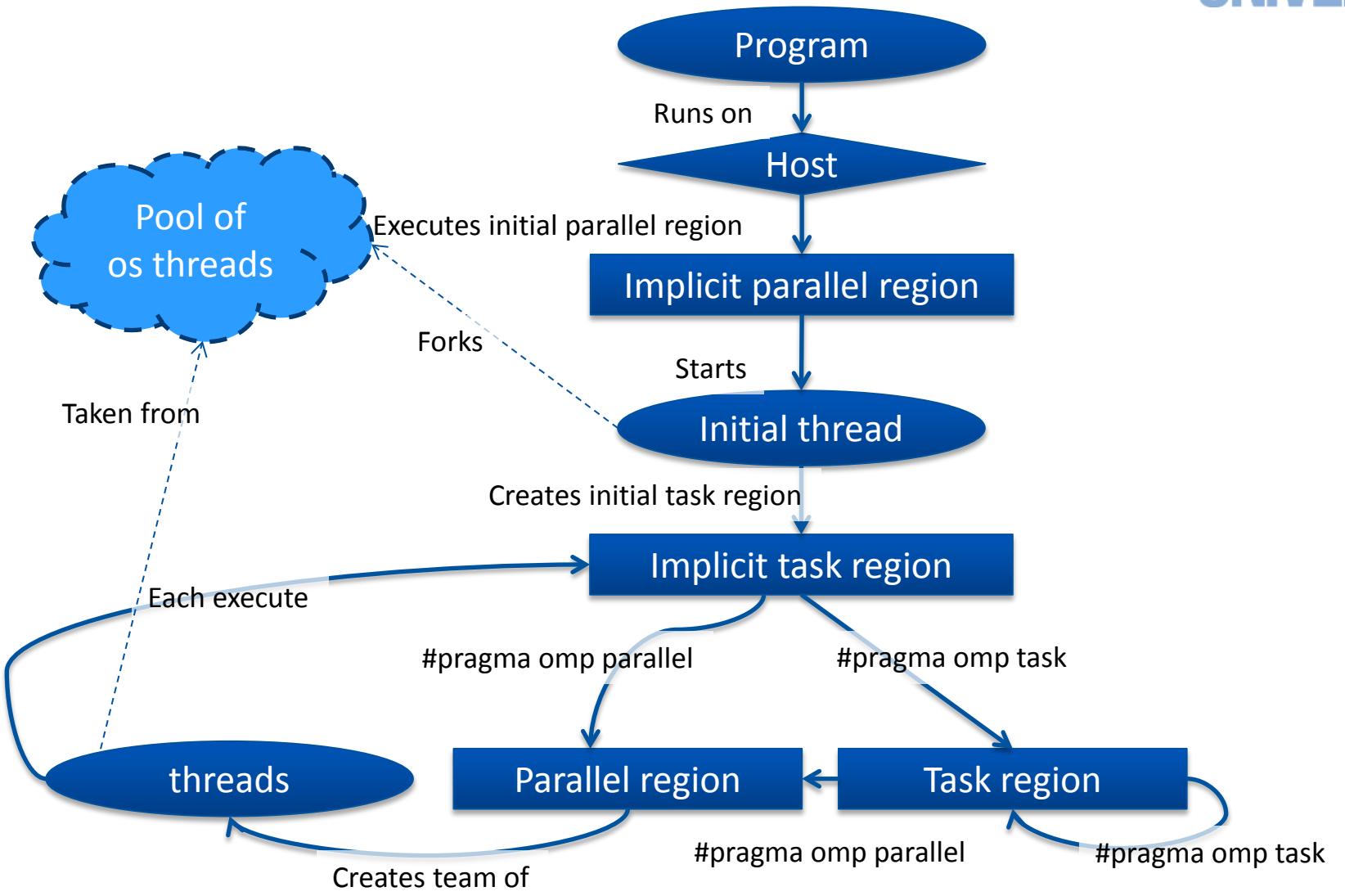
  → Functions to navigate to the scope of interest (unwinding the stack of scopes)

Scoping of API functions

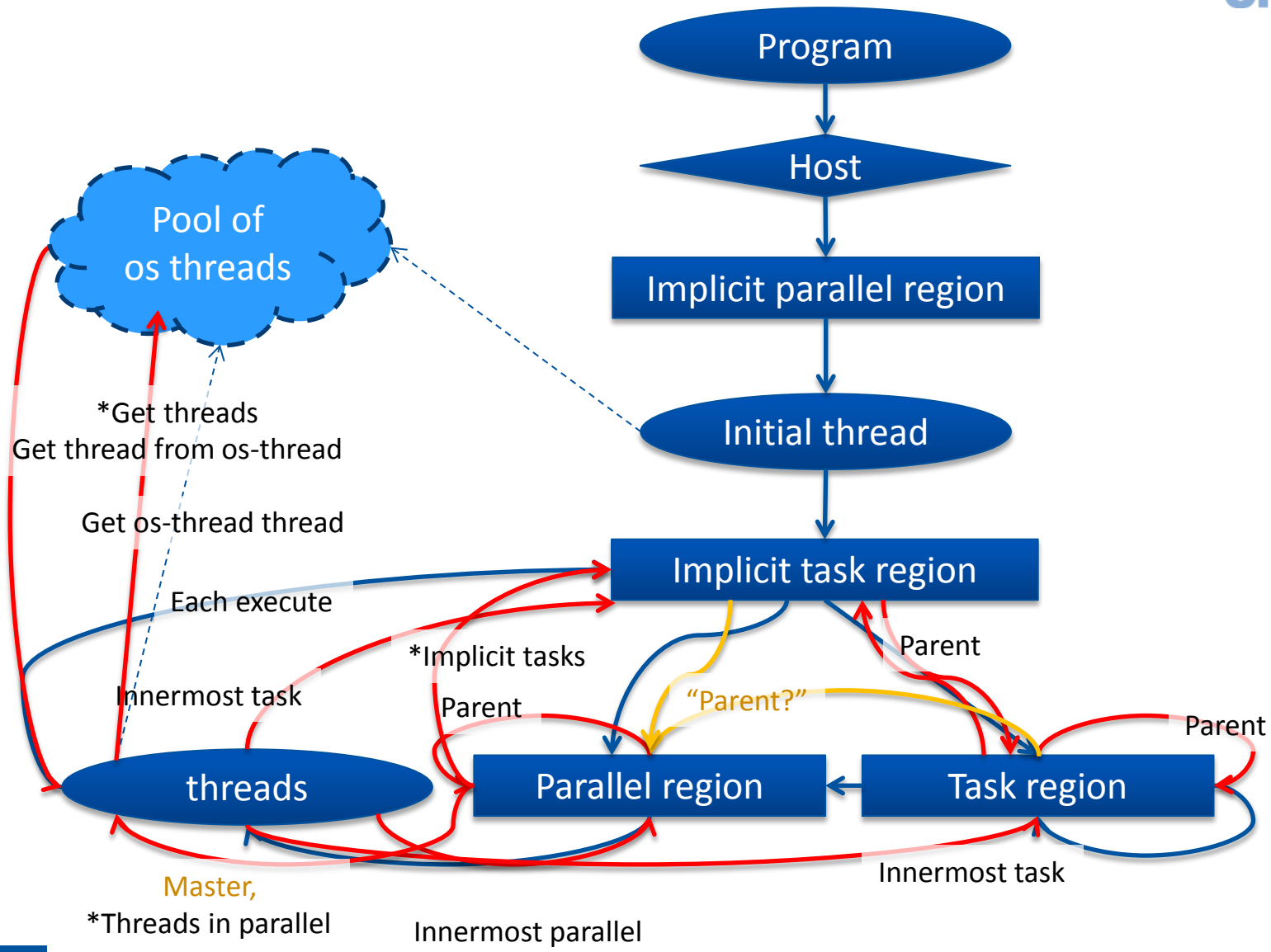
- **For OpenMP API calls and OMPT functions, the scope of interest is given by the scope of execution.**
  - → Current device, thread, parallel region, task region
  - → *`level`* argument to address ancestor scopes.

- **For OMPD there is no natural scope**
  - → We use scope handles to address a specific scope.
  - → Need for functions to navigate to the scope of interest
  - → Reduce overhead for successive queries on a single scope

Execution model of OpenMP (3.1)



Navigating between scopes in OMPD



Labels represent API function calls to navigate to scopes, labels with * return a list

Use Cases

OpenMP aware Backtrace

Stepping OpenMP Application

Use case: OpenMP Backtrace

```
1   {
2     // code before parallel region
3     #pragma omp parallel
4     {
5       // parallel region code
6     }
7     // code after parallel region
8   }
```

Backtrace I want to get:

```
in #omp parallel from file:5 @ T3
in block () from file:3 @ T1
```

```
1   void parallel_region_block()
2   {
3     // parallel region code
4   }
5   [...]
6   {
7     // code before parallel region
8     omprt_run_parallel(parallel_region_block);
9     // code after parallel region
10  }
```

Backtrace you get:

```
in parallel_region_block () from file:5
in omprt_internal () from libopenmp
in omprt_run_parallel () from libopenmp
in block () from file:8
```

Use case: OpenMP Backtrace

```
1   {
2     // code before parallel region
3     #pragma omp parallel
4     {
5       // parallel region code
6     }
7     // code after parallel region
8   }
```

Backtrace I want to get:

```
in #omp parallel from file:5 @ T3
in block () from file:3 @ T1
```

Get information on the parallel region from the handle returned by get_top_parallel_region

Get information about the calling thread with get_master_thread

Parallel region handle provides:
- Frame information
- Other threads in this region

Possibility to continue backtrace on this thread with provided frame information

Use case: OpenMP Single-Stepping

- **Use case: single stepping into a parallel region**
- **Single step should go from line 2 to line 5**
- **Debugger might single step though OpenMP runtime**

```
1   {
2     // code before parallel region
3     #pragma omp parallel
4     {
5       // parallel region code
6     }
7     // code after parallel region
8   }
```

- **Better: Debugger gets information about line 5 from OMPD**
  - → Breakpoint at ompd_break_pre_parallel()
  - → Query parallel_function from OMPD
  - → Set breakpoint at parallel_function

Specification of Breakpoints

- **Provide an address to break at:**
  - → Address differs from process to process: not scalable for hybrid MPI+OpenMP
- **Provide a function name to break at:**
  - → Need to query for the function name
- **Our proposal:**
  - → OMPD requires to call an empty dummy function with specified name:
    - →void ompd_break_pre_parallel() {}
    - →void ompd_break_post_parallel() {}
    - →void ompd_break_pre_task() {}
    - →void ompd_break_post_task() {}

Resolve target symbols

Resolve Structures for Target Architecture

- **Example: omp_get_num_threads():**
  - → `return __kmp_entry_thread() -> th.th_team -> t.t_nproc;`
  - → Equivalent to `__kmp_threads[__kmp_gtid] -> th.th_team -> t.t_nproc;`

Value in thread local storage (TLS) of the local thread.

- **Read `__kmp_gtid` from TLS**
  - → get_thread_context_for_osthread(tcontext, …)
  - → tsymbol_addr(tcontext, “__kmp_gtid”, address …)
  - → read_tmemory(tcontext, address, …)

Resolve Structures for Target Architecture

- **Example: omp_get_num_threads():**
  - → `return __kmp_entry_thread() -> th.th_team -> t.t_nproc;`
  - → Equivalent to `__kmp_threads[__kmp_gtid] -> th.th_team -> t.t_nproc;`

Access array element

- **Access array element in `__kmp_threads`**
  - → Size of `__kmp_threads` needed
  - → Runtime provides size information:

    const uint64_t ompd_sizeof__##t = sizeof(t);

Resolve Structures for Target Architecture

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- **Example: omp_get_num_threads():**
  - → `return __kmp_entry_thread() -> th.th_team -> t.t_nproc;`
  - → Equivalent to `__kmp_threads[__kmp_gtid] -> th.th_team -> t.t_nproc;`

- **Access structure element `th_team` in `th`**
  - → Need offset of `th_team` in `th`
  - → Runtime provides offset information:

```
const uint64_t ompd_access__##t##__##m = (uint64_t)&(((t*)0)->m);
```

Status of the work

- **OMPD prototype (for OpenMP 3.1) almost finished**
- **Based on and written for Intel OpenMP runtime**
  - → Runtime code: 5 files changed, 65 insertions(+), 7 deletions(-)
  - → Total: 12 files changed, 308 insertions(+), 9 deletions(-)
- **Currently in process of releasing it from LLNL internal**

Next steps

- **OpenMP for accelerators**
- **The current model of OMPD does not care for devices or target construct**

- **We already changed the semantics of context to be prepared for devices**

Thanks for your attention!