Performance Analysis for Target Devices with the OpenMP Tools Interface

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Motivation

- **Requirement for large compute capabilities**
  - → Wide use and acceptance of new architectures
  - → New user friendly programming paradigms (e.g., OpenMP 4.0, OpenACC)
  - → But: adequate tools support is important as well

- **Tools support for OpenMP**
  - → OpenMP Architecture Review Board (ARB) published a technical report describing the OpenMP Tools (OMPT) interface to extend the standard
  - → Support only for OpenMP 3.1

Agenda

- **Introduction**
  - → The OpenMP Tools Interface (OMPT)
  - → The OpenMP 4.0 Target Constructs
- **Contributions**
  - → Extension of OMPT for Target Constructs
  - → Runtime Implementation (LLVM/Intel OpenMP)
  - → Tool Integration (Measurements with Score-P, Visualization with Vampir)
  - → Performance Evaluation
- **Conclusion**

OpenMP Tools Interface (OMPT)

- **OMPT Features**
  - → Support for asynchronous sampling
  - → Blame shifting techniques
  - → Callbacks definitions for instrumentation-based monitoring of runtime events
  - → Standardized interface

- **OMPT Design Objectives**
  - → Should provide sufficient information about the program and the OpenMP runtime system
  - → Low overhead API
  - → Low development burden for the runtime and tool developer
  - → OpenMP runtime
    - → maintains information about the state of each thread
    - → provides API calls to interrogate the runtime

OMPT: Benefits

- **Benefits**
  - → Event-based performance analysis with low overhead
  - → Standardized interface (OMPT only for 3.1 at the moment)
  - → Runtime information (OMPT) vs. source-to-source instrumentation (OPARI2)
    - → OPARI2
      - can deliver exact user code mapping
      - independent of OpenMP implementation
      - recompiling necessary
      - Low detail level of information, e.g.
        - → data transfer size
        - → mapping of variable or array
      - no chance for standardization
    - → OMPT is vice versa
    - → Overhead of both is similar [1]

Reference

[1] Daniel Lorenz, Robert Dietrich, Ronny Tschüter, and Felix Wolf. A comparison between OPARI2 and the OpenMP tools interface in the context of Score-P. In *Proc. of the 10th International Workshop on OpenMP (IWOMP), Salvador, Brazil, September 2014*, volume 8766 of *LNCS*, pages 161– 172. Springer International Publishing, September 2014.

OpenMP 4.0: Target Constructs (SAXPY Example)

```
int n = 10240; float a = 42.0f; float b = 23.0f;
float *x, *y;
// Allocate and initialize x, y
// Run SAXPY TWICE and process data on host

{

  #pragma omp parallel for
  for (int i = 0; i < n; ++i){
    y[i] = a*x[i] + y[i];
  }

  processDataOnHost(y);


  #pragma omp parallel for
  for (int i = 0; i < n; ++i){
    y[i] = b*x[i] + y[i];
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```

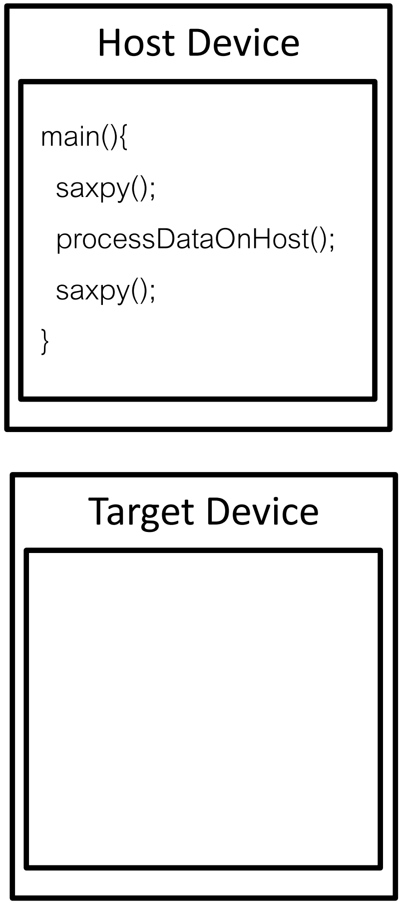

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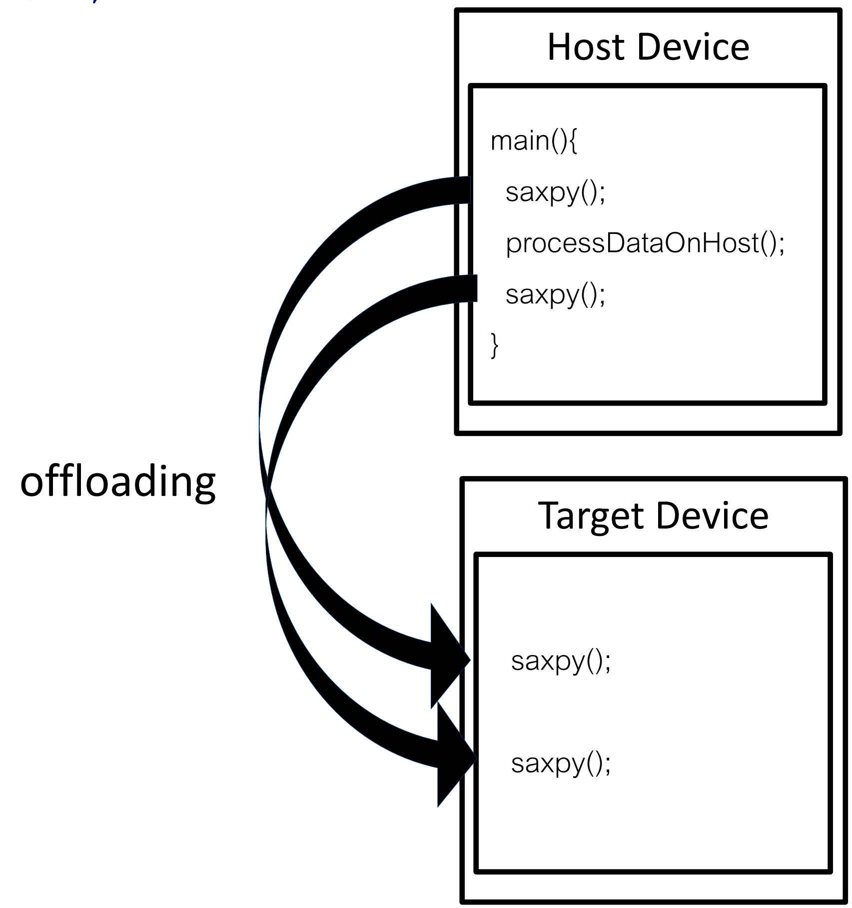

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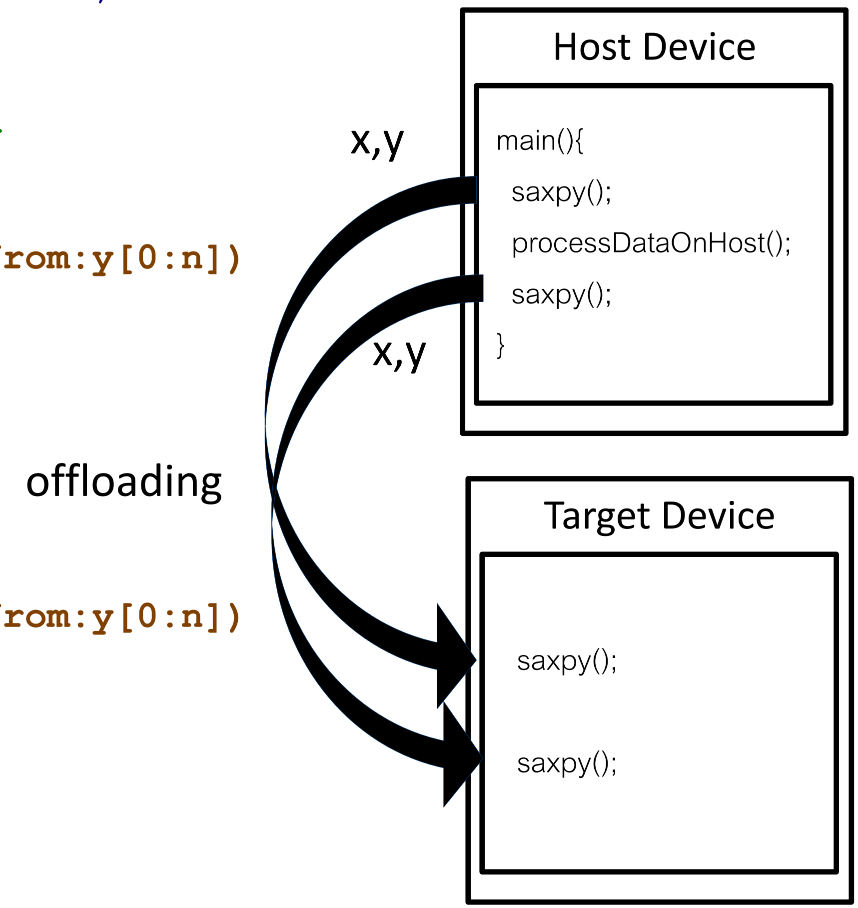

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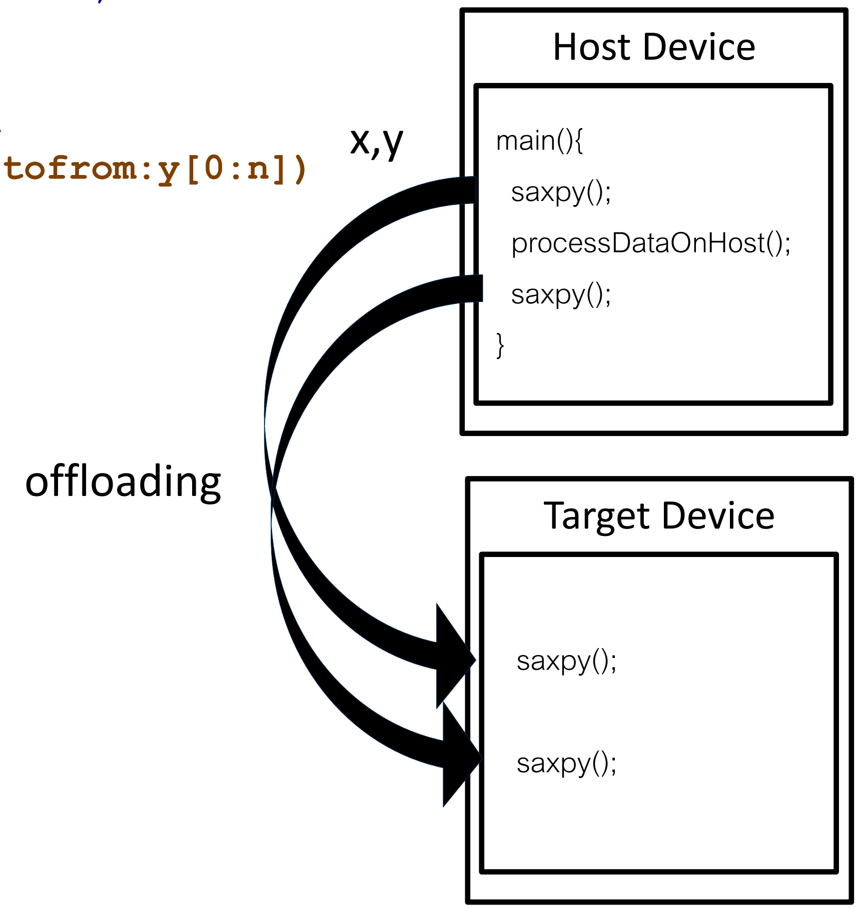

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  for (int i = 0; i < n; ++i){
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  }
  #pragma omp target update from(y[0:n])
  processDataOnHost(y);
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  #pragma omp target
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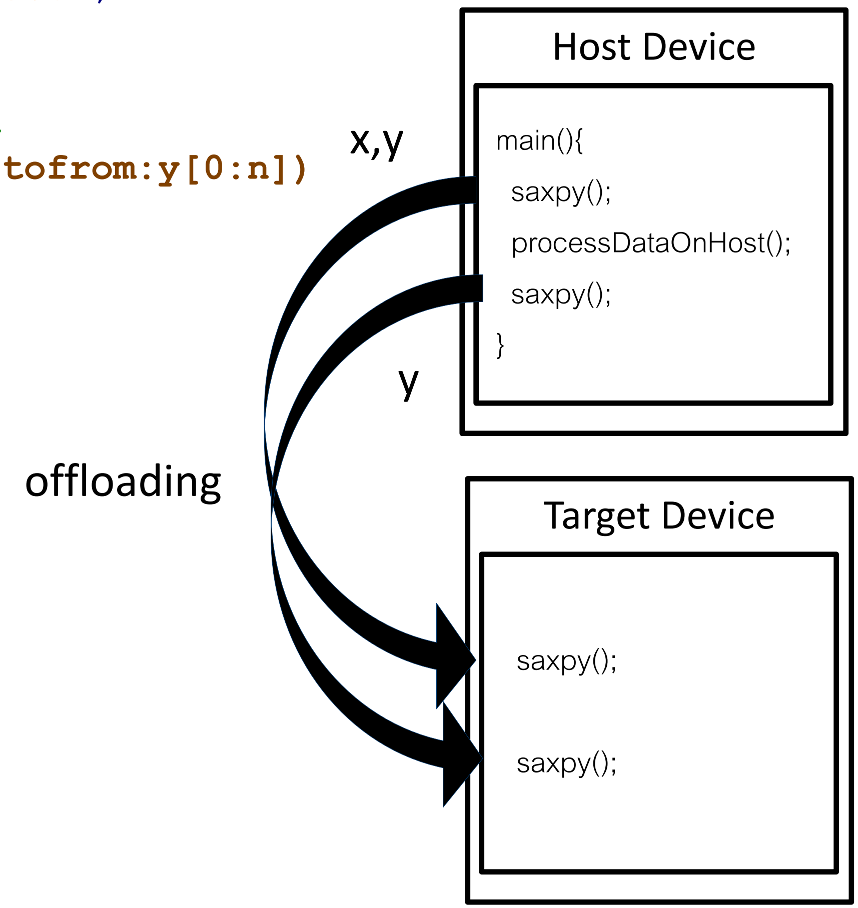

OMPT: Begin Events for Target Directives

- **Relevant information for performance analysis**

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		after	*before*

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Data transfer host <-> device	data map	-	a variable is mapped (event for each variable)
Kernel invocation	target invoke (in relation to an enclosing target region)	the target* begin event and after all variables are mapped	target function is invoked on a device

OMPT: Signatures for Target Events

- **Signatures**
  - → Only two different signature types needed for begin events

Signature	Events	Parameter
new target callback	target, target data, target update, target invoke	task id, target id, device id, target function
new data map	data map	task id, target id, map id, device id, sync type, map type, data size

  - → Possible additional information for
    - → target* events: source code line (In general: Missing source code information is a big disadvantage of OMPT compared to source-to-source instrumentation)
    - → data map: variable name
  - → OpenMP 4.1: Each target* region will be an implicit task
    - ➔ target id will be obsolete

OMPT Inquiry Functions (1/2)

- **Prerequisite**
  - → calling of OpenMP runtime library routine is unsafe (e.g., `omp_get_theread_num()`) → OMPT inquiry functions
  - → all device inquiry functions are only allowed to be called in the extend of a
    - → `target data` region
    - → `target update` region
    - → in the specified target event callbacks
  - → undefined behavior otherwise

OMPT Inquiry Functions (2/2)

Function	Description
`OMPT_API ompt_target_device_id_t` **`ompt_get_target_device_id`**`();`	Returns the ID of the active target device.
`OMPT_API ompt_target_id_t` **`ompt_get_target_id`**`();`	Returns the ID of the current target region.
`OMPT_API ompt_target_device_time_t` **`ompt_get_target_device_time`**` ( omp_target_device_id_t id );`	Returns the current time stamp on the target device with ID `id`. (Can be used to synchronize time stamps on the target device with time stamps on the host.)
`OMPT_API void` **`ompt_target_map`**` ( void* dst, void* src, ompt_target_device_id_t id, ompt_data_map_t map_type, ompt_target_sync_t sync_type, ompt_data_size_t bytes );`	Maps the specified number of bytes between host and target device according to the map type. (Can be used to map collected performance data / OMPT events from the device to the host.)

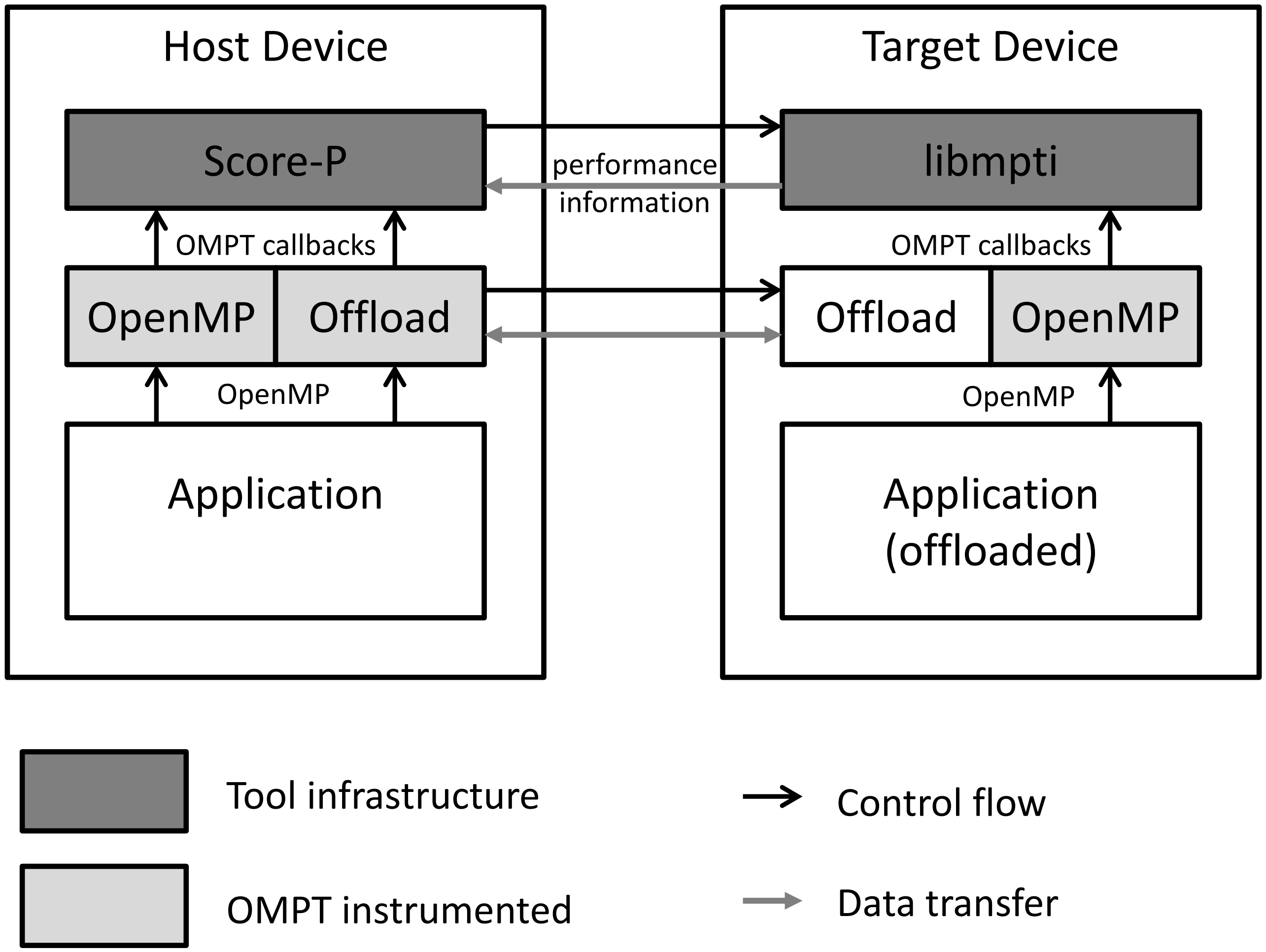
OMPT: Prototype Implementation

- **Extension of the Intel-/LLVM-based OpenMP implementation**
  - → OMPT 3.1 is part of the LLVM OpenMP runtime already [1]
  - → OMPT 4.0 target support available as separated branch / fork [2]
  - → Intel uses additional offload library (OpenMP library is not called for target* directives)
  - → All target device events / signatures are implemented
  - → Only the inquiry functions `ompt_get_device_time()` and `ompt_target_data_map()` are missing (work in progress)
- **Event Handling**
  - → All target events: host-side only invocation
  - → Analysis of "normal" OMPT events on a device
    - → Callback registration on device possible (e.g., with preloading)
    - → Tools developer are responsible for event handling (device and/or host)

[1] http://openmp.llvm.org
[2] https://github.com/OpenMPToolsInterface

OMPT: Tool Integration (1/3)

- **Using the OMPT extension in Score-P**

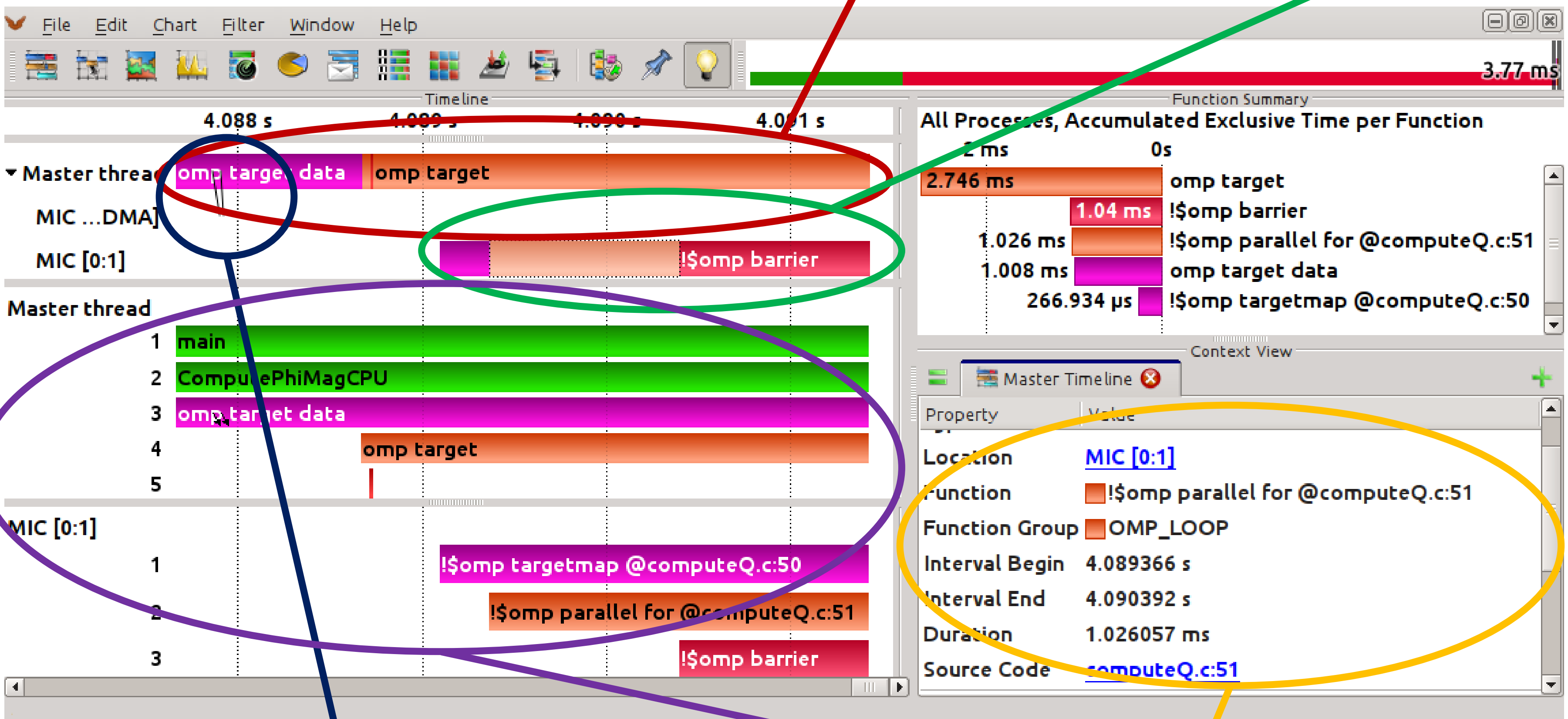


OMPT: Tool Integration (2/3)

- **Visualization in Vampir**
  - → SPEC ACCEL Benchmark 314.omrig (ported to OpenMP 4.0)

OpenMP target* regions on host

OpenMP regions on the MIC



Data mapping operations

Region stack

Context view

OMPT: Tool Integration (3/3)

- **OMPT + Score-P Overhead**
  - → Synthetic double buffering benchmark (maps 4 GB in 200 MB chunks)

	Runtime [s]	Overhead
Uninstrumented	28.08	-
Score-P (host-sided events only)	28.50	1.5 %
Score-P (host-sided and devices sided events)	32.23	12.9 %

  - → Overhead for host- and device-sided events is basically the data transfer
    - → Only little influence on the application runtime itself
  - → Used test system
    - → Host: 2-socket Intel Sandybridge (Xeon E5-2650) CPUs
    - → Target device: Intel Xeon Phi 5110P coprocessors

Summary & Conclusion

- **Extension of OMPT**
  - → All OpenMP 4.x features should be covered in OMPT
  - → Proposal for target directives includes 10 new events, 4 signatures and 4 inquiry functions
  - → Prototype reference implementation in LLVM-based OpenMP runtime available
  - → Prototype support in Score-P measurement infrastructure available
  - → Source code information is missing in OMPT
  - → High detail level of information (size of mapped variables)
  - → Low overhead for proposed new events

- **Outlook**
  - → Extend the OpenMP technical report to get proposed extension into the standard

Thank you for your attention.

Questions?