GNU Offloading and Multi Processing Runtime Library

The GNU OpenMP and OpenACC Implementation

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Short Contents

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1 Enabling OpenMP

To activate the OpenMP extensions for C/C++ and Fortran, the compile-time flag `-fopenmp` must be specified. For C and C++, this enables the handling of the OpenMP directives using `#pragma omp` and the `[[omp::directive(...)]]`, `[[omp::sequence(...)]]` and `[[omp::decl(...)]]` attributes. For Fortran, it enables for free source form the `!$omp` sentinel for directives and the `!$` conditional compilation sentinel and for fixed source form the `c$omp`, `*$omp` and `!$omp` sentinels for directives and the `c$`, `*$` and `!$` conditional compilation sentinels. The flag also arranges for automatic linking of the OpenMP runtime library (Chapter 3 [Runtime Library Routines], page 15).

The `-fopenmp-simd` flag can be used to enable a subset of OpenMP directives that do not require the linking of either the OpenMP runtime library or the POSIX threads library.

A complete description of all OpenMP directives may be found in the OpenMP Application Program Interface (`https://www.openmp.org`) manuals. See also Chapter 2 [OpenMP Implementation Status], page 3.

2 OpenMP Implementation Status

The _OPENMP preprocessor macro and Fortran's openmp_version parameter, provided by omp_lib.h and the omp_lib module, have the value 202111 (i.e. OpenMP 5.2).

2.1 OpenMP 4.5

The OpenMP 4.5 specification is fully supported.

2.2 OpenMP 5.0

New features listed in Appendix B of the OpenMP specification

Description	Status	Comments
Array shaping	N	
Array sections with non-unit strides in C and C++	N	
Iterators	Y	
metadirective directive	Y	
declare variant directive	Y	
target-offload-var ICV and OMP_TARGET_OFFLOAD env variable	Y	
Nested-parallel changes to *max-active-levels-var* ICV	Y	
requires directive	Y	See also Chapter 12 [Offload-Target Specifics], page 113,
teams construct outside an enclosing target region	Y	
Non-rectangular loop nests	P	Full support for C/C++, partial for Fortran (PR110735 (https://gcc.gnu.org/PR110735))
!= as relational-op in canonical loop form for C/C++	Y	
nonmonotonic as default loop schedule modifier for worksharing-loop constructs	Y	
Collapse of associated loops that are imperfectly nested loops	Y	
Clauses if, nontemporal and order(concurrent) in simd construct	Y	
atomic constructs in simd	Y	
loop construct	Y	
order(concurrent) clause	Y	
scan directive and in_scan modifier for the reduction clause	Y	
in_reduction clause on task constructs	Y	
in_reduction clause on target constructs	P	nowait only stub
task_reduction clause with taskgroup	Y	
task modifier to reduction clause	Y	

`affinity` clause to `task` construct	Y	Stub only
`detach` clause to `task` construct	Y	
`omp_fulfill_event` runtime routine	Y	
`reduction` and `in_reduction` clauses on `taskloop` and `taskloop simd` constructs	Y	
`taskloop` construct cancelable by `cancel` construct	Y	
`mutexinoutset` *dependence-type* for `depend` clause	Y	
Predefined memory spaces, memory allocators, allocator traits	Y	See also Section 11.3 [Memory allocation], page 107,
Memory management routines	Y	
`allocate` directive	P	C++ unsupported; see also Section 11.3 [Memory allocation], page 107,
`allocate` clause	P	Clause has no effect on `target` (PR113436 (`https://gcc.gnu.org/PR113436`))
`use_device_addr` clause on `target data`	Y	
`ancestor` modifier on `device` clause	Y	
Implicit declare target directive	Y	
Discontiguous array section with `target update` construct	N	
C/C++'s lvalue expressions in `to`, `from` and `map` clauses	Y	
C/C++'s lvalue expressions in `depend` clauses	Y	
Nested `declare target` directive	Y	
Combined `master` constructs	Y	
`depend` clause on `taskwait`	Y	
Weak memory ordering clauses on `atomic` and `flush` construct	Y	
`hint` clause on the `atomic` construct	Y	Stub only
`depobj` construct and depend objects	Y	
Lock hints were renamed to synchronization hints	Y	
`conditional` modifier to `lastprivate` clause	Y	
Map-order clarifications	P	
`close` *map-type-modifier*	Y	
Mapping C/C++ pointer variables and to assign the address of device memory mapped by an array section	P	
Mapping of Fortran pointer and allocatable variables, including pointer and allocatable components of variables	Y	
`defaultmap` extensions	Y	

`declare mapper` directive	P	Initial support and for C/C++, only
`omp_get_supported_active_levels` routine	Y	
Runtime routines and environment variables to display runtime thread affinity information	Y	
`omp_pause_resource` and `omp_pause_resource_all` runtime routines	Y	
`omp_get_device_num` runtime routine	Y	
OMPT interface	N	
OMPD interface	N	

Other new OpenMP 5.0 features

Description	Status	Comments
Supporting C++'s range-based for loop	Y	

2.3 OpenMP 5.1

New features listed in Appendix B of the OpenMP specification

Description	Status	Comments
OpenMP directive as C++ attribute specifiers	Y	
`omp_all_memory` reserved locator	Y	
target_device trait in OpenMP Context	Y	
`target_device` selector set in context selectors	Y	
C/C++'s delimited `declare variant` directive: support elision of preprocessed code and interpret enclosed function definitions as variant functions	Y	
`declare variant`: new clauses `adjust_args` and `append_args`	Y	
`dispatch` construct	Y	
device-specific ICV settings with environment variables	Y	
`assume` and `assumes` directives	Y	
`nothing` directive	Y	
`error` directive	Y	
`masked` construct	Y	
`scope` directive	Y	
Loop transformation constructs	Y	
`strict` modifier in the `grainsize` and `num_tasks` clauses of the `taskloop` construct	Y	
`align` clause in `allocate` directive	P	Only C and Fortran
`align` modifier in `allocate` clause	Y	
`thread_limit` clause to `target` construct	Y	
`has_device_addr` clause to `target` construct	Y	
Iterators in `target update` motion clauses and `map` clauses	P	Limited support for C/C++
Indirect calls to the device version of a procedure or function in `target` regions	Y	

`interop` directive	Y	Cf. Chapter 12 [Offload-Target Specifics], page 113,
`omp_interop_t` object support in runtime routines	Y	
`nowait` clause in `taskwait` directive	Y	
Extensions to the `atomic` directive	Y	
`seq_cst` clause on a `flush` construct	Y	
`inoutset` argument to the `depend` clause	Y	
`private` and `firstprivate` argument to `default` clause in C and C++	Y	
`present` argument to `defaultmap` clause	Y	
`omp_set_num_teams`, `omp_set_teams_thread_limit`, `omp_get_max_teams`, `omp_get_teams_thread_limit` runtime routines	Y	
`omp_target_is_accessible` runtime routine	Y	
`omp_target_memcpy_async` and `omp_target_memcpy_rect_async` runtime routines	Y	
`omp_get_mapped_ptr` runtime routine	Y	
`omp_calloc`, `omp_realloc`, `omp_aligned_alloc` and `omp_aligned_calloc` runtime routines	Y	
`omp_alloctrait_key_t` enum: `omp_atv_serialized` added, `omp_atv_default` changed	Y	
`omp_display_env` runtime routine	Y	
`ompt_scope_endpoint_t` enum: `ompt_scope_beginend`	N	
`ompt_sync_region_t` enum additions	N	
`ompt_state_t` enum: `ompt_state_wait_barrier_implementation` and `ompt_state_wait_barrier_teams`	N	
`ompt_callback_target_data_op_emi_t`, `ompt_callback_target_emi_t`, `ompt_callback_target_map_emi_t` and `ompt_callback_target_submit_emi_t`	N	
`ompt_callback_error_t` type	N	
`OMP_PLACES` syntax extensions	Y	
`OMP_NUM_TEAMS` and `OMP_TEAMS_THREAD_LIMIT` environment variables	Y	

Other new OpenMP 5.1 features

Description	Status	Comments
Support of strictly structured blocks in Fortran	Y	
Support of structured block sequences in C/C++	Y	
`unconstrained` and `reproducible` modifiers on `order` clause	Y	
Support `begin/end declare target` syntax in C/C++	Y	

Pointer predetermined firstprivate getting initialized to address of matching mapped list item per 5.1, Sect. 2.21.7.2	N	
For Fortran, diagnose placing declarative before/between `USE`, `IMPORT`, and `IMPLICIT` as invalid	N	
Optional comma between directive and clause in the `#pragma` form	Y	
`indirect` clause in `declare target`	Y	
`device_type(nohost)`/`device_type(host)` for variables	N	
`present` modifier to the `map`, `to` and `from` clauses	Y	
Changed interaction between `declare target` and OpenMP context	Y	
Dynamic selector support in `metadirective`	Y	
Dynamic selector support in `declare variant`	P	Fortran rejects non-constant expressions in dynamic selectors; C/C++ reject expressions using argument variables. (PR113904 (`https://gcc.gnu.org/PR113904`))

2.4 OpenMP 5.2

New features listed in Appendix B of the OpenMP specification

Description	Status	Comments
`omp_in_explicit_task` routine and *explicit-task-var* ICV	Y	
`omp`/`ompx`/`omx` sentinels and `omp_`/`ompx_` namespaces	N/A	warning for `ompx/omx` sentinels[1]
Clauses on `end` directive can be on directive	Y	
`destroy` clause with destroy-var argument on `depobj`	Y	
Deprecation of no-argument `destroy` clause on `depobj`	N/A	undeprecated in OpenMP 6
`linear` clause syntax changes and `step` modifier	Y	
Deprecation of minus operator for reductions	Y	
Deprecation of separating `map` modifiers without comma	Y	

[1] The `ompx` sentinel as C/C++ pragma and C++ attributes are warned for with `-Wunknown-pragmas` (implied by `-Wall`) and `-Wattributes` (enabled by default), respectively; for Fortran free-source code, there is a warning enabled by default and, for fixed-source code, the `omx` sentinel is warned for with `-Wsurprising` (enabled by `-Wall`). Unknown clauses are always rejected with an error.

`declare mapper` with iterator and `present` modifiers	N	
If a matching mapped list item is not found in the data environment, the pointer retains its original value	Y	
New `enter` clause as alias for `to` on declare target directive	Y	
Deprecation of `to` clause on declare target directive	Y	
Extended list of directives permitted in Fortran pure procedures	Y	
New `allocators` directive for Fortran	Y	
Deprecation of `allocate` directive for Fortran allocatables/pointers	Y	
Optional paired `end` directive with `dispatch`	Y	
New `memspace` and `traits` modifiers for `uses_allocators`	P	Only predefined allocators
Deprecation of traits array following the allocator_handle expression in `uses_allocators`	Y	
New `otherwise` clause as alias for `default` on metadirectives	Y	
Deprecation of `default` clause on metadirectives	Y	Both `otherwise` and `default` are accepted without diagnostics.
Deprecation of delimited form of `declare target`	Y	
Reproducible semantics changed for `order(concurrent)`	N	
`allocate` and `firstprivate` clauses on `scope`	Y	
`ompt_callback_work`	N	
Default map-type for the `map` clause in `target enter/exit data`	Y	
New `doacross` clause as alias for `depend` with `source`/`sink` modifier	Y	
Deprecation of `depend` with `source`/`sink` modifier	Y	
`omp_cur_iteration` keyword	Y	

Other new OpenMP 5.2 features

Description	**Status**	**Comments**
For Fortran, optional comma between directive and clause	N	
Conforming device numbers and `omp_initial_device` and `omp_invalid_device` enum/PARAMETER	Y	
Initial value of *default-device-var* ICV with `OMP_TARGET_OFFLOAD=mandatory`	Y	
`all` as *implicit-behavior* for `defaultmap`	Y	
interop_types in any position of the modifier list for the `init` clause of the `interop` construct	Y	

Invoke virtual member functions of C++ objects created on the host device on other devices	N	
`mapper` as map-type modifier in `declare mapper`	N	

2.5 OpenMP 6.0

New features listed in Appendix B of the OpenMP specification

Features deprecated in versions 5.0, 5.1 and 5.2 were removed	N/A	Backward compatibility
Full support for C23 was added	P	
Full support for C++23 was added	P	
Full support for Fortran 2023 was added	P	
`_ALL` suffix to the device-scope environment variables	P	Host device number wrongly accepted
`num_threads` clause now accepts a list	N	
Abstract names added for `OMP_NUM_THREADS`, `OMP_THREAD_LIMIT` and `OMP_TEAMS_THREAD_LIMIT`	N	
Supporting increments with abstract names in `OMP_PLACES`	N	
Extension of `OMP_DEFAULT_DEVICE` and new `OMP_AVAILABLE_DEVICES` environment vars	N	
New `uid` trait for target devices and for `OMP_AVAILABLE_DEVICES` and `OMP_DEFAULT_DEVICE`	N	
New `OMP_THREADS_RESERVE` environment variable	N	
The `decl` attribute was added to the C++ attribute syntax	Y	
The OpenMP directive syntax was extended to include C23 attribute specifiers	Y	
Support for pure directives in Fortran's `do concurrent`	N	
All inarguable clauses take now an optional Boolean argument	N	
The `adjust_args` clause was extended to specify the argument by position and supports variadic arguments	N	
For Fortran, *locator list* can be also function reference with data pointer result	N	
Concept of *assumed-size arrays* in C and C++	N	
directive-name-modifier accepted in all clauses	N	
Extension of `interop` operation of `append_args`, allowing all modifiers of the `init` clause	Y	
New argument-free version of `depobj` with repeatable clauses and the `init` clause	N	
Undeprecate omitting the argument to the `depend` clause of the argument version of the `depend` construct	Y	
For Fortran, atomic with BLOCK construct and, for C/C++, with unlimited curly braces supported	N	

For Fortran, atomic with pointer comparison	N	
For Fortran, atomic with enum and enumeration types	N	
For Fortran, atomic compare with storing the comparison result	N	
Canonical loop sequences and new `looprange` clause	N	
For Fortran, handling polymorphic types in data-sharing-attribute clauses	P	`private` not supported
For Fortran, rejecting polymorphic types in data-mapping clauses	N	not diagnosed (and mostly unsupported)
New `taskgraph` construct including `saved` modifier and `replayable` clause	N	
`default` clause on the `target` directive and accepting variable categories	N	
Semantic change regarding the reference count update with `use_device_ptr` and `use_device_addr`	N	
Support for inductions	N	
Reduction over private variables with `reduction` clause	N	
Implicit reduction identifiers of C++ classes	N	
New `init_complete` clause to the `scan` directive	N	
`ref` modifier to the `map` clause	N	
New `storage` map-type modifier; context-dependent `alloc` and `release` are aliases	N	
Change of the *map-type* property from *ultimate* to *default*	N	
`self` modifier to `map` and `self` as `defaultmap` argument	N	
Mapping of *assumed-size arrays* in C, C++ and Fortran	N	
`delete` as delete-modifier not as map type	N	
For Fortran, the `automap` modifier to the `enter` clause of `declare_target`	N	
`groupprivate` directive	N	
`local` clause to `declare_target` directive	N	
`part_size` allocator trait for `interleaved` allocator partitions	N	
`pin_device`, `preferred_device` and `target_access` allocator traits	N	
`access` allocator trait changes	N	
New `partitioner` value to `partition` allocator trait	N	
Semicolon-separated list to `uses_allocators`	N	
New `need_device_addr` modifier to `adjust_args` clause	N	
`interop` clause to `dispatch`	Y	
Scope requirement changes for `declare_target`	N	
`message` and `severity` clauses to `parallel` directive	N	

`self_maps` clause to `requires` directive	Y
`no_openmp_constructs` assumptions clause	N
Restriction for `ordered` regarding loop-transforming directives	N
`apply` clause to loop-transforming constructs	N
Non-constant values in the `sizes` clause	N
`fuse` loop-transformation construct	N
`interchange` loop-transformation construct	N
`reverse` loop-transformation construct	N
`split` loop-transformation construct	N
`stripe` loop-transformation construct	N
`tile` permitting association of grid and inter-tile loops	N
`strict` modifier keyword to `num_threads`	N
`safesync` clause to the `parallel` construct	N
`omp_curr_progress_width` identifier	N
`omp_get_max_progress_width` runtime routine	N
Lifted restrictions on `order(concurrent)` and, hence, the `loop` construct	N
`atomic` permitted in a construct with `order(concurrent)`	N
Lifted restrictions on not-strictly-nested regions with `order(concurrent)`	N
`workdistribute` directive for Fortran	N
Fortran `DO CONCURRENT` as associated loop in a `loop` construct	N
New `task_iteration` directive inside `taskloop`	N
`threadset` clause in task-generating constructs	N
New `priority` clause to `target`, `target_enter_data`, `target_data`, `target_exit_data` and `target_update`	N
New `device_type` clause to the `target` directive	N
`target_data` as composite construct	N
`nowait` clause with reverse-offload `target` directives	N
Extended *prefer-type* modifier to `init` clause	Y
Boolean argument to `nowait` and `nogroup` may be non constant	N
`memscope` clause to `atomic` and `flush`	N
New `transparent` clause for multi-generational task-dependence graphs	N
The `cancel` construct now completes tasks with unfulfilled events	N
`omp_fulfill_event` routine was restricted regarding fulfillment of event variables	N
Added rule for compound-directive names, permitting many more combinations	N
`omp_is_free_agent` and `omp_ancestor_is_free_agent` routines	N

omp_get_device_from_uid and omp_get_uid_from_device routines	Y
omp_get_device_num_teams, omp_set_device_num_teams, omp_get_device_teams_thread_limit, and omp_set_device_teams_thread_limit routines	N
omp_target_memset and omp_target_memset_async routines	Y
Fortran version of the interop runtime routines	Y
Routines for obtaining memory spaces/allocators for shared/device memory	N
omp_get_memspace_num_resources routine	N
omp_get_memspace_pagesize routine	N
omp_get_submemspace routine	N
omp_init_mempartitioner, omp_destroy_mempartitioner, omp_init_mempartition, omp_destroy_mempartition, omp_mempartition_set_part, omp_mempartition_get_user_data routines	N
Deprecation of the target_data_op, target, target_map and target_submit callbacks and as values that set_callback must return	N
ompt_target_data_transfer and ompt_target_data_transfer_async values in ompt_target_data_op_t enum	N
The values ompt_target_data_transfer_to_device, ompt_target_data_transfer_from_device, ompt_target_data_transfer_to_device_async and ompt_target_data_transfer_from_device_async of the target_data_op OMPT type were deprecated	N
ompt_get_buffer_limits OMPT routine	N

Deprecated features, unless listed above

Deprecation of omitting the optional white space to separate adjacent keywords in the directive-name in Fortran (fixed and free source form)	N
Deprecation of the combiner expression in the declare_reduction argument	N
Deprecation of the Fortran include file omp_lib.h	N

Other new OpenMP 6.0 features

Multi-word directives now use underscore by default	N
Relaxed Fortran restrictions to the aligned clause	N
Mapping lambda captures	N
New omp_pause_stop_tool constant for omp_pause_resource	N

In Fortran (fixed and free source form), spaces between directive names are mandatory	N
Update of the map-type decay for mapping and `declare_mapper`	N

2.6 OpenMP Technical Report 14

Technical Report (TR) 14 is the first preview for OpenMP 6.1.

New features listed in Appendix B of the OpenMP specification

The `depth` clause to `fuse` directive	N
The `attach` modifier to the `map` clause	N
The `dyn_groupprivate` clause and the `omp_get_dyn_groupprivate_ptr`, `omp_get_dyn_groupprivate_size`, and `omp_get_dyn_groupprivate_size` routines	N
`begin declare_variant` directive in Fortran	N
`grid` and `tile` modifier to the `size` clause	N
New `flatten` loop-transforming directive	N
`scaled` modifier to `simdlen` clause	N
New `omp_default_device` identifier as conforming device number	Y
Clarify when `omp_target_is_accessible` routine returns zero	N

Deprecated features, unless listed above

Deprecation of conditional-update-capture structured block without a capture statement	N

3 OpenMP Runtime Library Routines

The runtime routines described here are defined by Section 18 of the OpenMP specification in version 5.2.

3.1 Thread Team Routines

Routines controlling threads in the current contention group. They have C linkage and do not throw exceptions.

3.1.1 `omp_set_num_threads` – Set upper team size limit

Description:
Specifies the number of threads used by default in subsequent parallel sections, if those do not specify a `num_threads` clause. The argument of `omp_set_num_threads` shall be a positive integer.

C/C++:
Prototype: `void omp_set_num_threads(int num_threads);`

Fortran:
Interface:
```
subroutine omp_set_num_threads(num_threads)
integer, intent(in) :: num_threads
```

See also: Section 4.12 [OMP_NUM_THREADS], page 63, Section 3.1.2 [omp_get_num_threads], page 15, Section 3.1.3 [omp_get_max_threads], page 16,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.1.

3.1.2 `omp_get_num_threads` – Size of the active team

Description:
Returns the number of threads in the current team. In a sequential section of the program `omp_get_num_threads` returns 1.

The default team size may be initialized at startup by the `OMP_NUM_THREADS` environment variable. At runtime, the size of the current team may be set either by the `NUM_THREADS` clause or by `omp_set_num_threads`. If none of the above were used to define a specific value and `OMP_DYNAMIC` is disabled, one thread per CPU online is used.

C/C++:
Prototype: `int omp_get_num_threads(void);`

Fortran:
Interface: `integer function omp_get_num_threads()`

See also: Section 3.1.3 [omp_get_max_threads], page 16, Section 3.1.1 [omp_set_num_threads], page 15, Section 4.12 [OMP_NUM_THREADS], page 63,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.2.

3.1.3 `omp_get_max_threads` – Maximum number of threads of parallel region

Description:
Return the maximum number of threads used for the current parallel region that does not use the clause `num_threads`.

C/C++:

Prototype: `int omp_get_max_threads(void);`

Fortran:

Interface: `integer function omp_get_max_threads()`

See also: Section 3.1.1 [omp_set_num_threads], page 15, Section 3.1.6 [omp_set_dynamic], page 17, Section 3.3.6 [omp_get_thread_limit], page 24,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.3.

3.1.4 `omp_get_thread_num` – Current thread ID

Description:
Returns a unique thread identification number within the current team. In a sequential parts of the program, `omp_get_thread_num` always returns 0. In parallel regions the return value varies from 0 to `omp_get_num_threads`-1 inclusive. The return value of the primary thread of a team is always 0.

C/C++:

Prototype: `int omp_get_thread_num(void);`

Fortran:

Interface: `integer function omp_get_thread_num()`

See also: Section 3.1.2 [omp_get_num_threads], page 15, Section 3.1.18 [omp_get_ancestor_thread_num], page 21,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.4.

3.1.5 `omp_in_parallel` – Whether a parallel region is active

Description:
This function returns `true` if currently running in parallel, `false` otherwise. Here, `true` and `false` represent their language-specific counterparts.

C/C++:

Prototype: `int omp_in_parallel(void);`

Fortran:

Interface: `logical function omp_in_parallel()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.6.

3.1.6 `omp_set_dynamic` – Enable/disable dynamic teams

Description:

Enable or disable the dynamic adjustment of the number of threads within a team. The function takes the language-specific equivalent of `true` and `false`, where `true` enables dynamic adjustment of team sizes and `false` disables it.

C/C++:

Prototype: `void omp_set_dynamic(int dynamic_threads);`

Fortran:

Interface:
```
subroutine omp_set_dynamic(dynamic_threads)
logical, intent(in) :: dynamic_threads
```

See also: Section 4.7 [OMP_DYNAMIC], page 62, Section 3.1.7 [omp_get_dynamic], page 17,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.7.

3.1.7 `omp_get_dynamic` – Dynamic teams setting

Description:

This function returns `true` if enabled, `false` otherwise. Here, `true` and `false` represent their language-specific counterparts.

The dynamic team setting may be initialized at startup by the `OMP_DYNAMIC` environment variable or at runtime using `omp_set_dynamic`. If undefined, dynamic adjustment is disabled by default.

C/C++:

Prototype: `int omp_get_dynamic(void);`

Fortran:

Interface: `logical function omp_get_dynamic()`

See also: Section 3.1.6 [omp_set_dynamic], page 17, Section 4.7 [OMP_DYNAMIC], page 62,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.8.

3.1.8 `omp_get_cancellation` – Whether cancellation support is enabled

Description:

This function returns `true` if cancellation is activated, `false` otherwise. Here, `true` and `false` represent their language-specific counterparts. Unless `OMP_CANCELLATION` is set true, cancellations are deactivated.

C/C++:

Prototype: `int omp_get_cancellation(void);`

Fortran:

Interface: `logical function omp_get_cancellation()`

See also: Section 4.3 [OMP_CANCELLATION], page 61,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.9.

3.1.9 `omp_set_nested` – Enable/disable nested parallel regions

Description:

Enable or disable nested parallel regions, i.e., whether team members are allowed to create new teams. The function takes the language-specific equivalent of `true` and `false`, where `true` enables dynamic adjustment of team sizes and `false` disables it.

Enabling nested parallel regions also sets the maximum number of active nested regions to the maximum supported. Disabling nested parallel regions sets the maximum number of active nested regions to one.

Note that the `omp_set_nested` API routine was deprecated in the OpenMP specification 5.0 in favor of `omp_set_max_active_levels`.

C/C++:

Prototype: `void omp_set_nested(int nested);`

Fortran:

Interface: `subroutine omp_set_nested(nested)`
`logical, intent(in) :: nested`

See also: Section 3.1.10 [omp_get_nested], page 18, Section 3.1.15 [omp_set_max_active_levels], page 20, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62, Section 4.10 [OMP_NESTED], page 63,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.10.

3.1.10 `omp_get_nested` – Nested parallel regions

Description:

This function returns `true` if nested parallel regions are enabled, `false` otherwise. Here, `true` and `false` represent their language-specific counterparts.

The state of nested parallel regions at startup depends on several environment variables. If `OMP_MAX_ACTIVE_LEVELS` is defined and is set to greater than one, then nested parallel regions will be enabled. If not defined, then the value of the `OMP_NESTED` environment variable will be followed if defined. If neither are defined, then if either `OMP_NUM_THREADS` or `OMP_PROC_BIND` are defined with a list of more than one value, then nested parallel regions are enabled. If none of these are defined, then nested parallel regions are disabled by default.

Nested parallel regions can be enabled or disabled at runtime using `omp_set_nested`, or by setting the maximum number of nested regions with `omp_set_max_active_levels` to one to disable, or above one to enable.

Note that the `omp_get_nested` API routine was deprecated in the OpenMP specification 5.0 in favor of `omp_get_max_active_levels`.

C/C++:

Prototype: `int omp_get_nested(void);`

Fortran:

Interface: `logical function omp_get_nested()`

See also: Section 3.1.16 [omp_get_max_active_levels], page 21, Section 3.1.9 [omp_set_nested], page 18, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62, Section 4.10 [OMP_NESTED], page 63,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.11.

3.1.11 `omp_set_schedule` – Set the runtime scheduling method

Description:

Sets the runtime scheduling method. The *kind* argument can have the value `omp_sched_static`, `omp_sched_dynamic`, `omp_sched_guided` or `omp_sched_auto`. Except for `omp_sched_auto`, the chunk size is set to the value of *chunk_size* if positive, or to the default value if zero or negative. For `omp_sched_auto` the *chunk_size* argument is ignored.

C/C++

Prototype:
```
void omp_set_schedule(omp_sched_t kind, int
chunk_size);
```

Fortran:

Interface:
```
subroutine omp_set_schedule(kind, chunk_size)
integer(kind=omp_sched_kind) kind
integer chunk_size
```

See also: Section 3.1.12 [omp_get_schedule], page 19, Section 4.16 [OMP_SCHEDULE], page 66,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.12.

3.1.12 `omp_get_schedule` – Obtain the runtime scheduling method

Description:

Obtain the runtime scheduling method. The *kind* argument is set to `omp_sched_static`, `omp_sched_dynamic`, `omp_sched_guided` or `omp_sched_auto`. The second argument, *chunk_size*, is set to the chunk size.

C/C++

Prototype:
```
void omp_get_schedule(omp_sched_t *kind, int
*chunk_size);
```

Fortran:

Interface:
```
subroutine omp_get_schedule(kind, chunk_size)
integer(kind=omp_sched_kind) kind
integer chunk_size
```

See also: Section 3.1.11 [omp_set_schedule], page 19, Section 4.16 [OMP_SCHEDULE], page 66,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.13.

3.1.13 `omp_get_teams_thread_limit` – Maximum number of threads imposed by teams

Description:

Return the maximum number of threads that are able to participate in each team created by a teams construct.

C/C++:

Prototype: `int omp_get_teams_thread_limit(void);`

Fortran:

Interface: `integer function omp_get_teams_thread_limit()`

See also: Section 3.3.5 [omp_set_teams_thread_limit], page 24, Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 66,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.4.6.

3.1.14 `omp_get_supported_active_levels` – Maximum number of active regions supported

Description:

This function returns the maximum number of nested, active parallel regions supported by this implementation.

C/C++

Prototype: `int omp_get_supported_active_levels(void);`

Fortran:

Interface: `integer function omp_get_supported_active_levels()`

See also: Section 3.1.16 [omp_get_max_active_levels], page 21, Section 3.1.15 [omp_set_max_active_levels], page 20,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.2.15.

3.1.15 `omp_set_max_active_levels` – Limits the number of active parallel regions

Description:

This function limits the maximum allowed number of nested, active parallel regions. *max_levels* must be less or equal to the value returned by `omp_get_supported_active_levels`.

C/C++

Prototype: `void omp_set_max_active_levels(int max_levels);`

Fortran:

Interface:
```
subroutine omp_set_max_active_levels(max_levels)
integer max_levels
```

See also: Section 3.1.16 [omp_get_max_active_levels], page 21, Section 3.1.20 [omp_get_active_level], page 22, Section 3.1.14 [omp_get_supported_active_levels], page 20,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.15.

3.1.16 `omp_get_max_active_levels` – Current maximum number of active regions

Description:
This function obtains the maximum allowed number of nested, active parallel regions.

C/C++
Prototype: `int omp_get_max_active_levels(void);`

Fortran:
Interface: `integer function omp_get_max_active_levels()`

See also: Section 3.1.15 [omp_set_max_active_levels], page 20, Section 3.1.20 [omp_get_active_level], page 22,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.16.

3.1.17 `omp_get_level` – Obtain the current nesting level

Description:
This function returns the nesting level for the parallel blocks, which enclose the calling call.

C/C++
Prototype: `int omp_get_level(void);`

Fortran:
Interface: `integer function omp_level()`

See also: Section 3.1.20 [omp_get_active_level], page 22,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.17.

3.1.18 `omp_get_ancestor_thread_num` – Ancestor thread ID

Description:
This function returns the thread identification number for the given nesting level of the current thread. For values of *level* outside zero to `omp_get_level` -1 is returned; if *level* is `omp_get_level` the result is identical to `omp_get_thread_num`.

C/C++
Prototype: `int omp_get_ancestor_thread_num(int level);`

Fortran:
Interface: `integer function omp_get_ancestor_thread_num(level)`
`integer level`

See also: Section 3.1.17 [omp_get_level], page 21, Section 3.1.4 [omp_get_thread_num], page 16, Section 3.1.19 [omp_get_team_size], page 22,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.18.

3.1.19 omp_get_team_size – Number of threads in a team

Description:

This function returns the number of threads in a thread team to which either the current thread or its ancestor belongs. For values of *level* outside zero to omp_get_level, -1 is returned; if *level* is zero, 1 is returned, and for omp_get_level, the result is identical to omp_get_num_threads.

C/C++:

Prototype: `int omp_get_team_size(int level);`

Fortran:

Interface:
```
integer function omp_get_team_size(level)
integer level
```

See also: Section 3.1.2 [omp_get_num_threads], page 15, Section 3.1.17 [omp_get_level], page 21, Section 3.1.18 [omp_get_ancestor_thread_num], page 21,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.19.

3.1.20 omp_get_active_level – Number of parallel regions

Description:

This function returns the nesting level for the active parallel blocks, which enclose the calling call.

C/C++

Prototype: `int omp_get_active_level(void);`

Fortran:

Interface: `integer function omp_get_active_level()`

See also: Section 3.1.17 [omp_get_level], page 21, Section 3.1.16 [omp_get_max_active_levels], page 21, Section 3.1.15 [omp_set_max_active_levels], page 20,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.20.

3.2 Thread Affinity Routines

Routines controlling and accessing thread-affinity policies. They have C linkage and do not throw exceptions.

3.2.1 omp_get_proc_bind – Whether threads may be moved between CPUs

Description:

This functions returns the currently active thread affinity policy, which is set via OMP_PROC_BIND. Possible values are omp_proc_bind_false, omp_proc_bind_true, omp_proc_bind_primary, omp_proc_bind_master, omp_proc_bind_close and omp_proc_bind_spread, where omp_proc_bind_master is a deprecated alias for omp_proc_bind_primary.

C/C++:

Prototype: `omp_proc_bind_t omp_get_proc_bind(void);`

Fortran:

Interface: `integer(kind=omp_proc_bind_kind) function omp_get_proc_bind()`

See also: Section 4.13 [OMP_PROC_BIND], page 64, Section 4.14 [OMP_PLACES], page 64, Section 4.21 [GOMP_CPU_AFFINITY], page 67,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.22.

3.3 Teams Region Routines

Routines controlling the league of teams that are executed in a `teams` region. They have C linkage and do not throw exceptions.

3.3.1 `omp_get_num_teams` – Number of teams

Description:

Returns the number of teams in the current team region.

C/C++:

Prototype: `int omp_get_num_teams(void);`

Fortran:

Interface: `integer function omp_get_num_teams()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.32.

3.3.2 `omp_get_team_num` – Get team number

Description:

Returns the team number of the calling thread.

C/C++:

Prototype: `int omp_get_team_num(void);`

Fortran:

Interface: `integer function omp_get_team_num()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.33.

3.3.3 `omp_set_num_teams` – Set upper teams limit for teams construct

Description:

Specifies the upper bound for number of teams created by the teams construct which does not specify a `num_teams` clause. The argument of `omp_set_num_teams` shall be a positive integer.

C/C++:

Prototype: `void omp_set_num_teams(int num_teams);`

Fortran:

Interface:

```
subroutine omp_set_num_teams(num_teams)
integer, intent(in) :: num_teams
```

See also: Section 4.11 [OMP_NUM_TEAMS], page 63, Section 3.3.1 [omp_get_num_teams], page 23, Section 3.3.4 [omp_get_max_teams], page 24,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.4.3.

3.3.4 `omp_get_max_teams` – Maximum number of teams of teams region

Description:
Return the maximum number of teams used for the teams region that does not use the clause `num_teams`.

C/C++:

Prototype: `int omp_get_max_teams(void);`

Fortran:

Interface: `integer function omp_get_max_teams()`

See also: Section 3.3.3 [omp_set_num_teams], page 23, Section 3.3.1 [omp_get_num_teams], page 23,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.4.4.

3.3.5 `omp_set_teams_thread_limit` – Set upper thread limit for teams construct

Description:
Specifies the upper bound for number of threads that are available for each team created by the teams construct which does not specify a `thread_limit` clause. The argument of `omp_set_teams_thread_limit` shall be a positive integer.

C/C++:

Prototype: `void omp_set_teams_thread_limit(int thread_limit);`

Fortran:

Interface:
```
subroutine omp_set_teams_thread_limit(thread_
limit)
integer, intent(in) :: thread_limit
```

See also: Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 66, Section 3.1.13 [omp_get_teams_thread_limit], page 20, Section 3.3.6 [omp_get_thread_limit], page 24,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.4.5.

3.3.6 `omp_get_thread_limit` – Maximum number of threads

Description:
Return the maximum number of threads of the program.

C/C++:

Prototype: `int omp_get_thread_limit(void);`

Fortran:

Interface: `integer function omp_get_thread_limit()`

See also: Section 3.1.3 [omp_get_max_threads], page 16, Section 4.19 [OMP_THREAD_LIMIT], page 67,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.14.

3.4 Tasking Routines

Routines relating to explicit tasks. They have C linkage and do not throw exceptions.

3.4.1 `omp_get_max_task_priority` – Maximum priority value

that can be set for tasks.

Description:

This function obtains the maximum allowed priority number for tasks.

C/C++

Prototype: `int omp_get_max_task_priority(void);`

Fortran:

Interface: `integer function omp_get_max_task_priority()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.29.

3.4.2 `omp_in_explicit_task` – Whether a given task is an explicit task

Description:

The function returns the *explicit-task-var* ICV; it returns true when the encountering task was generated by a task-generating construct such as `target`, `task` or `taskloop`. Otherwise, the encountering task is in an implicit task region such as generated by the implicit or explicit `parallel` region and `omp_in_explicit_task` returns false.

C/C++

Prototype: `int omp_in_explicit_task(void);`

Fortran:

Interface: `logical function omp_in_explicit_task()`

Reference: OpenMP specification v5.2 (`https://www.openmp.org`), Section 18.5.2.

3.4.3 `omp_in_final` – Whether in final or included task region

Description:

This function returns `true` if currently running in a final or included task region, `false` otherwise. Here, `true` and `false` represent their language-specific counterparts.

C/C++:

Prototype: `int omp_in_final(void);`

Fortran:

Interface: `logical function omp_in_final()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.21.

3.5 Resource Relinquishing Routines

Routines releasing resources used by the OpenMP runtime. They have C linkage and do not throw exceptions.

3.5.1 `omp_pause_resource` – Release OpenMP resources on a device

Description:

Free resources used by the OpenMP program and the runtime library on and for the device specified by *device_num*; on success, zero is returned and non-zero otherwise.

The value of *device_num* must be a conforming device number. The routine may not be called from within any explicit region and all explicit threads that do not bind to the implicit parallel region have finalized execution.

C/C++:

Prototype:
```
int omp_pause_resource(omp_pause_resource_t kind,
int device_num);
```

Fortran:

Interface:
```
integer function omp_pause_resource(kind,
device_num)
integer (kind=omp_pause_resource_kind) kind
integer device_num
```

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.2.43.

3.5.2 `omp_pause_resource_all` – Release OpenMP resources on all devices

Description:

Free resources used by the OpenMP program and the runtime library on all devices, including the host. On success, zero is returned and non-zero otherwise.

The routine may not be called from within any explicit region and all explicit threads that do not bind to the implicit parallel region have finalized execution.

C/C++:

Prototype:
```
int omp_pause_resource(omp_pause_resource_t kind);
```

Fortran:

Interface:
```
integer function omp_pause_resource(kind)
integer (kind=omp_pause_resource_kind) kind
```

See also: Section 3.5.1 [omp_pause_resource], page 26,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.2.44.

3.6 Device Information Routines

Routines related to devices available to an OpenMP program. They have C linkage and do not throw exceptions.

3.6.1 `omp_get_num_procs` – Number of processors online

Description:

Returns the number of processors online on that device.

C/C++:

Prototype: `int omp_get_num_procs(void);`

Fortran:

Interface: `integer function omp_get_num_procs()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.5.

3.6.2 `omp_set_default_device` – Set the default device for target regions

Description:

Get the value of the *default-device-var* ICV, which is used for target regions without a device clause. The argument shall be a nonnegative device number, `omp_initial_device`, or `omp_invalid_device`.

The effect of running this routine in a `target` region is unspecified.

C/C++:

Prototype: `void omp_set_default_device(int device_num);`

Fortran:

Interface:
```
subroutine omp_set_default_device(device_num)
integer device_num
```

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 61, Section 3.6.3 [omp_get_default_device], page 27,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.29.

3.6.3 `omp_get_default_device` – Get the default device for target regions

Description:

Get the value of the *default-device-var* ICV, which is used for target regions without a device clause. The value is either a nonnegative device number, `omp_initial_device` or `omp_invalid_device`. Note that for the host, the ICV can have two values: either the value of the named constant `omp_initial_device` or the value returned by the `omp_get_num_devices` routine.

The effect of running this routine in a `target` region is unspecified.

C/C++:

Prototype: `int omp_get_default_device(void);`

Fortran:

Interface: `integer function omp_get_default_device()`

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 61, Section 3.6.2 [omp_set_default_device], page 27, Section 3.6.9 [omp_get_initial_device], page 30,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.30.

3.6.4 `omp_get_num_devices` – Number of target devices

Description:

Returns the number of available non-host devices.

The effect of running this routine in a `target` region is unspecified.

Note that in GCC the function is marked pure, i.e. as returning always the same number. When GCC was not configured to support offloading, it is replaced by zero; compile with `-fno-builtin-omp_get_num_devices` if a run-time function is desired.

C/C++:

Prototype: `int omp_get_num_devices(void);`

Fortran:

Interface: `integer function omp_get_num_devices()`

See also: Section 3.6.9 [omp_get_initial_device], page 30,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.31.

3.6.5 `omp_get_device_num` – Return device number of current device

Description:

This function returns a device number that represents the device that the current thread is executing on. When called on the host, it returns the same value as returned by the `omp_get_initial_device` function as required since OpenMP 5.0.

C/C++

Prototype: `int omp_get_device_num(void);`

Fortran:

Interface: `integer function omp_get_device_num()`

See also: Section 3.6.9 [omp_get_initial_device], page 30,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.2.37.

3.6.6 `omp_get_device_from_uid` – Obtain the device number to a unique id

Description:

This function returns the device number associated with the passed unique-identifier (UID) string. If no device with this UID is available, the value `omp_` invalid_device is returned. The effect of running this routine in a target region is unspecified.

GCC treats the UID string case sensitive; for the initial device, GCC currently only accepts the value OMP_INITIAL_DEVICE and returns for it the value of omp_initial_device.

C/C++:

Prototype: `int omp_get_device_from_uid(const char *uid);`

Fortran:

Interface: `integer function omp_get_device_from_uid(uid)`
`character(len=*), intent(in) :: uid`

See also: Section 3.6.7 [omp_get_uid_from_device], page 29, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v6.0 (https://www.openmp.org), Section 24.7

3.6.7 omp_get_uid_from_device – Obtain the unique id of a device

Description:

This function returns a pointer to a string that represents a unique identifier (UID) for the device specified by *device_num*. It returns a NULL (C/C++) or a disassociated pointer (Fortran) for omp_invalid_device. The effect of running this routine in a target region is unspecified.

GCC currently returns for initial device the value OMP_INITIAL_DEVICE.

C/C++:

Prototype: `const char *omp_get_uid_from_device(int device_num);`

Fortran:

Interface: `character(:) function omp_get_uid_from_device(device_num)`

Interface: `pointer :: omp_get_uid_from_device`
`integer, intent(in) :: device_num`

See also: Section 3.6.7 [omp_get_uid_from_device], page 29, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v6.0 (https://www.openmp.org), Section 24.8

3.6.8 omp_is_initial_device – Whether executing on the host device

Description:

This function returns true if currently running on the host device, false otherwise. Here, true and false represent their language-specific counterparts.

Note that in GCC this function call is already folded to a constant in the compiler; compile with -fno-builtin-omp_is_initial_device if a run-time function is desired.

C/C++:

Prototype: `int omp_is_initial_device(void);`

Fortran:

Interface: `logical function omp_is_initial_device()`

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.34.

3.6.9 `omp_get_initial_device` – Return device number of initial device

Description:

This function returns a device number that represents the host device. Since OpenMP 5.1, this is equal to the value returned by the `omp_get_num_devices` function; since OpenMP 6.0 it may also return the value of `omp_initial_device`.

The effect of running this routine in a `target` region is unspecified.

Note that GCC inlines this function unless you compile with `-fno-builtin-omp_get_initial_device`. If GCC was not configured to support offloading, it expands to constant zero; in non-host code it expands to `omp_initial_device`; and otherwise it is replaced with a call to `omp_get_num_devices`.

C/C++

Prototype: `int omp_get_initial_device(void);`

Fortran:

Interface: `integer function omp_get_initial_device()`

See also: Section 3.6.4 [omp_get_num_devices], page 28,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.2.35.

3.7 Device Memory Routines

Routines related to memory allocation and managing corresponding pointers on devices. They have C linkage and do not throw exceptions.

3.7.1 `omp_target_alloc` – Allocate device memory

Description:

This routine allocates *size* bytes of memory in the device environment associated with the device number *device_num*. If successful, a device pointer is returned, otherwise a null pointer.

In GCC, when the device is the host or the device shares memory with the host, the memory is allocated on the host; in that case, when *size* is zero, either NULL or a unique pointer value that can later be successfully passed to `omp_target_free` is returned. When the allocation is not performed on the host, a null pointer is returned when *size* is zero; in that case, additionally a diagnostic might be printed to standard error (stderr).

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype: `void *omp_target_alloc(size_t size, int device_num)`

Fortran:

Interface:
```
type(c_ptr) function omp_target_alloc(size,
device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int,
c_size_t
integer(c_size_t), value :: size
integer(c_int), value :: device_num
```

See also: Section 3.7.2 [omp_target_free], page 31, Section 3.7.11 [omp_target_associate_ptr], page 39,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.1

3.7.2 `omp_target_free` – Free device memory

Description:

This routine frees memory allocated by the `omp_target_alloc` routine. The *device_ptr* argument must be either a null pointer or a device pointer returned by `omp_target_alloc` for the specified `device_num`. The device number *device_num* must be a conforming device number.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:
```
void omp_target_free(void *device_ptr, int
device_num)
```

Fortran:

Interface:
```
subroutine omp_target_free(device_ptr, device_num)
bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: device_ptr
integer(c_int), value :: device_num
```

See also: Section 3.7.1 [omp_target_alloc], page 30, Section 3.7.12 [omp_target_disassociate_ptr], page 40,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.2

3.7.3 `omp_target_is_present` – Check whether storage is mapped

Description:

This routine tests whether storage, identified by the host pointer *ptr* is mapped to the device specified by *device_num*. If so, it returns a nonzero value and otherwise zero.

In GCC, this includes self mapping such that `omp_target_is_present` returns *true* when *device_num* specifies the host or when the host and the device share memory. If *ptr* is a null pointer, *true* is returned and if *device_num* is an invalid device number, *false* is returned.

If those conditions do not apply, *true* is returned if the association has been established by an explicit or implicit `map` clause, the `declare target` directive or a call to the `omp_target_associate_ptr` routine.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:
```
int omp_target_is_present(const void *ptr,
 int device_num)
```

Fortran:

Interface:
```
integer(c_int) function omp_target_is_present(ptr,
&
 device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: ptr
integer(c_int), value :: device_num
```

See also: Section 3.7.11 [omp_target_associate_ptr], page 39,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.3

3.7.4 `omp_target_is_accessible` – Check whether memory is device accessible

Description:

This routine tests whether memory, starting at the address given by *ptr* and extending *size* bytes, is accessibly on the device specified by *device_num*. If so, it returns a nonzero value and otherwise zero.

The address given by *ptr* is interpreted to be in the address space of the device and *size* must be positive.

Note that GCC's current implementation assumes that *ptr* is a valid host pointer. Therefore, all addresses given by *ptr* are assumed to be accessible on the initial device. And, to err on the safe side, this memory is only available on a non-host device that can access all host memory ([uniform] shared memory access).

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:
```
int omp_target_is_accessible(const void *ptr,
 size_t size,
 int device_num)
```

Fortran:

Interface:
```
integer(c_int) function omp_target_is_
accessible(ptr, &
```

```
 size, device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: ptr
integer(c_size_t), value :: size
integer(c_int), value :: device_num
```

See also: Section 3.7.11 [omp_target_associate_ptr], page 39,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.4

3.7.5 `omp_target_memcpy` – Copy data between devices

Description:

This routine copies *length* of bytes of data from the device identified by device number *src_device_num* to device *dst_device_num*. The data is copied from the source device from the address provided by *src*, shifted by the offset of *src_offset* bytes, to the destination device's *dst* address shifted by *dst_offset*. The routine returns zero on success and non-zero otherwise.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:

```
int omp_target_memcpy(void *dst,
 const void *src,
 size_t length,
 size_t dst_offset,
 size_t src_offset,
 int dst_device_num,
 int src_device_num)
```

Fortran:

Interface:

```
integer(c_int) function omp_target_memcpy( &
 dst, src, length, dst_offset, src_offset, &
 dst_device_num, src_device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: length, dst_offset,
src_offset
integer(c_int), value :: dst_device_num, src_
device_num
```

See also: Section 3.7.6 [omp_target_memcpy_async], page 34, Section 3.7.7 [omp_target_memcpy_rect], page 35,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.5

3.7.6 `omp_target_memcpy_async` – Copy data between devices asynchronously

Description:

This routine copies asynchronously *length* of bytes of data from the device identified by device number *src_device_num* to device *dst_device_num*. The data is copied from the source device from the address provided by *src*, shifted by the offset of *src_offset* bytes, to the destination device's *dst* address shifted by *dst_offset*. Task dependence is expressed by passing an array of depend objects to *depobj_list*, where the number of array elements is passed as *depobj_count*; if the count is zero, the *depobj_list* argument is ignored. In C++ and Fortran, the *depobj_list* argument can also be omitted in that case. The routine returns zero if the copying process has successfully been started and non-zero otherwise.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:
```
int omp_target_memcpy_async(void *dst,
 const void *src,
 size_t length,
 size_t dst_offset,
 size_t src_offset,
 int dst_device_num,
 int src_device_num,
 int depobj_count,
 omp_depend_t *depobj_list)
```

Fortran:

Interface:
```
integer(c_int) function omp_target_memcpy_async( &
 dst, src, length, dst_offset, src_offset, &
 dst_device_num, src_device_num, &
 depobj_count, depobj_list) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: length, dst_offset,
src_offset
integer(c_int), value :: dst_device_num, src_
device_num, depobj_count
integer(omp_depend_kind), optional :: depobj_
list(*)
```

See also: Section 3.7.5 [omp_target_memcpy], page 33, Section 3.7.8 [omp_target_memcpy_rect_async], page 36,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.7

3.7.7 omp_target_memcpy_rect – Copy a subvolume of data between devices

Description:

This routine copies a subvolume of data from the device identified by device number *src_device_num* to device *dst_device_num*. The array has *num_dims* dimensions and each array element has a size of *element_size* bytes. The *volume* array specifies how many elements per dimension are copied. The full sizes of the destination and source arrays are given by the *dst_dimensions* and *src_dimensions* arguments, respectively. The offset per dimension to the first element to be copied is given by the *dst_offset* and *src_offset* arguments. The routine returns zero on success and non-zero otherwise.

The OpenMP specification only requires that *num_dims* up to three is supported. In order to find implementation-specific maximally supported number of dimensions, the routine returns this value when invoked with a null pointer to both the *dst* and *src* arguments. As GCC supports arbitrary dimensions, it returns `INT_MAX`.

The device-number arguments must be conforming device numbers, the *src* and *dst* must be either both null pointers or all of the following must be fulfilled: *element_size* and *num_dims* must be positive and the *volume*, offset and dimension arrays must have at least *num_dims* dimensions.

Running this routine in a `target` region is not supported except on the initial device.

C/C++

Prototype:

```
int omp_target_memcpy_rect(void *dst,
 const void *src,
 size_t element_size,
 int num_dims,
 const size_t *volume,
 const size_t *dst_offset,
 const size_t *src_offset,
 const size_t *dst_dimensions,
 const size_t *src_dimensions,
 int dst_device_num,
 int src_device_num)
```

Fortran:

Interface:

```
integer(c_int) function omp_target_memcpy_rect( &
 dst, src, element_size, num_dims, volume, &
 dst_offset, src_offset, dst_dimensions, &
 src_dimensions, dst_device_num, src_device_num)
bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: element_size,
dst_offset, src_offset
```

```
integer(c_size_t), value :: volume, dst_dimensions,
src_dimensions
integer(c_int), value :: num_dims, dst_device_num,
src_device_num
```

See also: Section 3.7.8 [omp_target_memcpy_rect_async], page 36, Section 3.7.5 [omp_target_memcpy], page 33, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.6

3.7.8 `omp_target_memcpy_rect_async` – Copy a subvolume of data between devices asynchronously

Description:

This routine copies asynchronously a subvolume of data from the device identified by device number *src_device_num* to device *dst_device_num*. The array has *num_dims* dimensions and each array element has a size of *element_size* bytes. The *volume* array specifies how many elements per dimension are copied. The full sizes of the destination and source arrays are given by the *dst_dimensions* and *src_dimensions* arguments, respectively. The offset per dimension to the first element to be copied is given by the *dst_offset* and *src_offset* arguments. Task dependence is expressed by passing an array of depend objects to *depobj_list*, where the number of array elements is passed as *depobj_count*; if the count is zero, the *depobj_list* argument is ignored. In C++ and Fortran, the *depobj_list* argument can also be omitted in that case. The routine returns zero on success and non-zero otherwise.

The OpenMP specification only requires that *num_dims* up to three is supported. In order to find implementation-specific maximally supported number of dimensions, the routine returns this value when invoked with a null pointer to both the *dst* and *src* arguments. As GCC supports arbitrary dimensions, it returns `INT_MAX`.

The device-number arguments must be conforming device numbers, the *src* and *dst* must be either both null pointers or all of the following must be fulfilled: *element_size* and *num_dims* must be positive and the *volume*, offset and dimension arrays must have at least *num_dims* dimensions.

Running this routine in a `target` region is not supported except on the initial device.

C/C++

Prototype:

```
int omp_target_memcpy_rect_async(void *dst,
 const void *src,
 size_t element_size,
 int num_dims,
 const size_t *volume,
 const size_t *dst_offset,
 const size_t *src_offset,
 const size_t *dst_dimensions,
```

```
const size_t *src_dimensions,
int dst_device_num,
int src_device_num,
int depobj_count,
omp_depend_t *depobj_list)
```

Fortran:

Interface:

```
integer(c_int) function omp_target_memcpy_rect_
async( &
 dst, src, element_size, num_dims, volume, &
 dst_offset, src_offset, dst_dimensions, &
 src_dimensions, dst_device_num, src_device_num, &
 depobj_count, depobj_list) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: element_size,
dst_offset, src_offset
integer(c_size_t), value :: volume, dst_dimensions,
src_dimensions
integer(c_int), value :: num_dims, dst_device_num,
src_device_num
integer(c_int), value :: depobj_count
integer(omp_depend_kind), optional :: depobj_
list(*)
```

See also: Section 3.7.7 [omp_target_memcpy_rect], page 35, Section 3.7.6 [omp_target_memcpy_async], page 34, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.8

3.7.9 `omp_target_memset` – Set bytes in device memory

Description:

This routine fills memory on the device identified by device number *device_num*. Starting from the device address *ptr*, the first *count* bytes are set to the value *val*, converted to `unsigned char`. If *count* is zero, the routine has no effect; if *ptr* is `NULL`, the behavior is unspecified. The function returns *ptr*.

The *device_num* must be a conforming device number and *ptr* must be a valid device pointer for that device. Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:

```
void *omp_target_memcpy(void *ptr,
 int val,
 size_t count,
 int device_num)
```

Fortran:

Interface:
```
type(c_ptr) function omp_target_memset( &
 ptr, val, count, device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: ptr
integer(c_size_t), value :: count
integer(c_int), value :: val, device_num
```

See also: Section 3.7.10 [omp_target_memset_async], page 38,

Reference: OpenMP specification v6.0 (`https://www.openmp.org`), Section 25.8.1

3.7.10 `omp_target_memset` – Set bytes in device memory asynchronously

Description:

This routine fills memory on the device identified by device number *device_num*. Starting from the device address *ptr*, the first *count* bytes are set to the value *val*, converted to `unsigned char`. If *count* is zero, the routine has no effect; if *ptr* is `NULL`, the behavior is unspecified. Task dependence is expressed by passing an array of depend objects to *depobj_list*, where the number of array elements is passed as *depobj_count*; if the count is zero, the *depobj_list* argument is ignored. In C++ and Fortran, the *depobj_list* argument can also be omitted in that case. The function returns *ptr*.

The *device_num* must be a conforming device number and *ptr* must be a valid device pointer for that device. Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:
```
void *omp_target_memcpy_async(void *ptr,
 int val,
 size_t count,
 int device_num,
 int depobj_count,
 omp_depend_t *depobj_list)
```

Fortran:

Interface:
```
type(c_ptr) function omp_target_memset_async( &
 ptr, val, count, device_num, &
 depobj_count, depobj_list) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: ptr
integer(c_size_t), value :: count
integer(c_int), value :: val, device_num, depobj_
count
integer(omp_depend_kind), optional :: depobj_
list(*)
```

See also: Section 3.7.9 [omp_target_memset], page 37,

Reference: OpenMP specification v6.0 (`https://www.openmp.org`), Section 25.8.2

3.7.11 `omp_target_associate_ptr` – Associate a device pointer with a host pointer

Description:

This routine associates storage on the host with storage on a device identified by *device_num*. The device pointer is usually obtained by calling `omp_target_alloc` or by other means (but not by using the `map` clauses or the `declare target` directive). The host pointer should point to memory that has a storage size of at least *size*.

The *device_offset* parameter specifies the offset into *device_ptr* that is used as the base address for the device side of the mapping; the storage size should be at least *device_offset* plus *size*.

After the association, the host pointer can be used in a `map` clause and in the `to` and `from` clauses of the `target update` directive to transfer data between the associated pointers. The reference count of such associated storage is infinite. The association can be removed by calling `omp_target_disassociate_ptr` which should be done before the lifetime of either storage ends.

The routine returns nonzero (`EINVAL`) when the *device_num* invalid, for when the initial device or the associated device shares memory with the host. `omp_target_associate_ptr` returns zero if *host_ptr* points into already associated storage that is fully inside of a previously associated memory. Otherwise, if the association was successful zero is returned; if none of the cases above apply, nonzero (`EINVAL`) is returned.

The `omp_target_is_present` routine can be used to test whether associated storage for a device pointer exists.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:

```
int omp_target_associate_ptr(const void *host_ptr,
 const void *device_ptr,
 size_t size,
 size_t device_offset,
 int device_num)
```

Fortran:

Interface:

```
integer(c_int) function omp_target_associate_
ptr(host_ptr, &
 device_ptr, size, device_offset, device_num)
bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int,
c_size_t
type(c_ptr), value :: host_ptr, device_ptr
```

```
integer(c_size_t), value :: size, device_offset
integer(c_int), value :: device_num
```

See also: Section 3.7.12 [omp_target_disassociate_ptr], page 40, Section 3.7.3 [omp_target_is_present], page 31, Section 3.7.1 [omp_target_alloc], page 30,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.9

3.7.12 `omp_target_disassociate_ptr` – Remove device–host pointer association

Description:

This routine removes the storage association established by calling `omp_target_associate_ptr` and sets the reference count to zero, even if `omp_target_associate_ptr` was invoked multiple times for for host pointer `ptr`. If applicable, the device memory needs to be freed by the user.

If an associated device storage location for the *device_num* was found and has infinite reference count, the association is removed and zero is returned. In all other cases, nonzero (`EINVAL`) is returned and no other action is taken.

Note that passing a host pointer where the association to the device pointer was established with the `declare target` directive yields undefined behavior.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype:
```
int omp_target_disassociate_ptr(const void *ptr,
 int device_num)
```

Fortran:

Interface:
```
integer(c_int) function omp_target_disassociate_
ptr(ptr, &
 device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: ptr
integer(c_int), value :: device_num
```

See also: Section 3.7.11 [omp_target_associate_ptr], page 39,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.10

3.7.13 `omp_get_mapped_ptr` – Return device pointer to a host pointer

Description:

If the device number is refers to the initial device or to a device with memory accessible from the host (shared memory), the `omp_get_mapped_ptr` routines returns the value of the passed *ptr*. Otherwise, if associated storage to the passed host pointer *ptr* exists on device associated with *device_num*, it returns that pointer. In all other cases and in cases of an error, a null pointer is returned.

The association of storage location is established either via an explicit or implicit `map` clause, the `declare target` directive or the `omp_target_associate_ptr` routine.

Running this routine in a `target` region except on the initial device is not supported.

C/C++

Prototype: `void *omp_get_mapped_ptr(const void *ptr, int device_num);`

Fortran:

Interface:
```
type(c_ptr) function omp_get_mapped_ptr(ptr,
device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: ptr
integer(c_int), value :: device_num
```

See also: Section 3.7.11 [omp_target_associate_ptr], page 39,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.8.11

3.8 Lock Routines

Initialize, set, test, unset and destroy simple and nested locks. The routines have C linkage and do not throw exceptions.

3.8.1 `omp_init_lock` – Initialize simple lock

Description:

Initialize a simple lock. After initialization, the lock is in an unlocked state.

C/C++:

Prototype: `void omp_init_lock(omp_lock_t *lock);`

Fortran:

Interface:
```
subroutine omp_init_lock(svar)
integer(omp_lock_kind), intent(out) :: svar
```

See also: Section 3.8.3 [omp_destroy_lock], page 42,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.1.

3.8.2 `omp_init_nest_lock` – Initialize nested lock

Description:

Initialize a nested lock. After initialization, the lock is in an unlocked state and the nesting count is set to zero.

C/C++:

Prototype: `void omp_init_nest_lock(omp_nest_lock_t *lock);`

Fortran:

Interface:
```
subroutine omp_init_nest_lock(nvar)
integer(omp_nest_lock_kind), intent(out) :: nvar
```

See also: Section 3.8.4 [omp_destroy_nest_lock], page 42,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.1.

3.8.3 `omp_destroy_lock` – Destroy simple lock

Description:
Destroy a simple lock. In order to be destroyed, a simple lock must be in the unlocked state.

C/C++:
Prototype: `void omp_destroy_lock(omp_lock_t *lock);`

Fortran:
Interface:
```
subroutine omp_destroy_lock(svar)
integer(omp_lock_kind), intent(inout) :: svar
```

See also: Section 3.8.1 [omp_init_lock], page 41,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.3.

3.8.4 `omp_destroy_nest_lock` – Destroy nested lock

Description:
Destroy a nested lock. In order to be destroyed, a nested lock must be in the unlocked state and its nesting count must equal zero.

C/C++:
Prototype: `void omp_destroy_nest_lock(omp_nest_lock_t *);`

Fortran:
Interface:
```
subroutine omp_destroy_nest_lock(nvar)
integer(omp_nest_lock_kind), intent(inout) :: nvar
```

See also: Section 3.8.1 [omp_init_lock], page 41,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.3.

3.8.5 `omp_set_lock` – Wait for and set simple lock

Description:
Before setting a simple lock, the lock variable must be initialized by `omp_init_lock`. The calling thread is blocked until the lock is available. If the lock is already held by the current thread, a deadlock occurs.

C/C++:
Prototype: `void omp_set_lock(omp_lock_t *lock);`

Fortran:
Interface:
```
subroutine omp_set_lock(svar)
integer(omp_lock_kind), intent(inout) :: svar
```

See also: Section 3.8.1 [omp_init_lock], page 41, Section 3.8.9 [omp_test_lock], page 44, Section 3.8.7 [omp_unset_lock], page 43,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.4.

3.8.6 `omp_set_nest_lock` – Wait for and set nested lock

Description:
Before setting a nested lock, the lock variable must be initialized by `omp_init_nest_lock`. The calling thread is blocked until the lock is available. If the lock is already held by the current thread, the nesting count for the lock is incremented.

C/C++:
Prototype: `void omp_set_nest_lock(omp_nest_lock_t *lock);`

Fortran:
Interface: `subroutine omp_set_nest_lock(nvar)`
`integer(omp_nest_lock_kind), intent(inout) :: nvar`

See also: Section 3.8.2 [omp_init_nest_lock], page 41, Section 3.8.8 [omp_unset_nest_lock], page 43,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.4.

3.8.7 `omp_unset_lock` – Unset simple lock

Description:
A simple lock about to be unset must have been locked by `omp_set_lock` or `omp_test_lock` before. In addition, the lock must be held by the thread calling `omp_unset_lock`. Then, the lock becomes unlocked. If one or more threads attempted to set the lock before, one of them is chosen to, again, set the lock to itself.

C/C++:
Prototype: `void omp_unset_lock(omp_lock_t *lock);`

Fortran:
Interface: `subroutine omp_unset_lock(svar)`
`integer(omp_lock_kind), intent(inout) :: svar`

See also: Section 3.8.5 [omp_set_lock], page 42, Section 3.8.9 [omp_test_lock], page 44,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.5.

3.8.8 `omp_unset_nest_lock` – Unset nested lock

Description:
A nested lock about to be unset must have been locked by `omp_set_nested_lock` or `omp_test_nested_lock` before. In addition, the lock must be held by the thread calling `omp_unset_nested_lock`. If the nesting count drops to zero, the lock becomes unlocked. If one ore more threads attempted to set the lock before, one of them is chosen to, again, set the lock to itself.

C/C++:
Prototype: `void omp_unset_nest_lock(omp_nest_lock_t *lock);`

Fortran:

Interface: `subroutine omp_unset_nest_lock(nvar)`
`integer(omp_nest_lock_kind), intent(inout) :: nvar`

See also: Section 3.8.6 [omp_set_nest_lock], page 43,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.5.

3.8.9 `omp_test_lock` – Test and set simple lock if available

Description:

Before setting a simple lock, the lock variable must be initialized by `omp_init_lock`. Contrary to `omp_set_lock`, `omp_test_lock` does not block if the lock is not available. This function returns `true` upon success, `false` otherwise. Here, `true` and `false` represent their language-specific counterparts.

C/C++:

Prototype: `int omp_test_lock(omp_lock_t *lock);`

Fortran:

Interface: `logical function omp_test_lock(svar)`
`integer(omp_lock_kind), intent(inout) :: svar`

See also: Section 3.8.1 [omp_init_lock], page 41, Section 3.8.5 [omp_set_lock], page 42, Section 3.8.5 [omp_set_lock], page 42,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.6.

3.8.10 `omp_test_nest_lock` – Test and set nested lock if available

Description:

Before setting a nested lock, the lock variable must be initialized by `omp_init_nest_lock`. Contrary to `omp_set_nest_lock`, `omp_test_nest_lock` does not block if the lock is not available. If the lock is already held by the current thread, the new nesting count is returned. Otherwise, the return value equals zero.

C/C++:

Prototype: `int omp_test_nest_lock(omp_nest_lock_t *lock);`

Fortran:

Interface: `logical function omp_test_nest_lock(nvar)`
`integer(omp_nest_lock_kind), intent(inout) :: nvar`

See also: Section 3.8.1 [omp_init_lock], page 41, Section 3.8.5 [omp_set_lock], page 42, Section 3.8.5 [omp_set_lock], page 42,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.3.6.

3.9 Timing Routines

Portable, thread-based, wall clock timer. The routines have C linkage and do not throw exceptions.

3.9.1 `omp_get_wtick` – Get timer precision

Description:

Gets the timer precision, i.e., the number of seconds between two successive clock ticks.

C/C++:

Prototype: `double omp_get_wtick(void);`

Fortran:

Interface: `double precision function omp_get_wtick()`

See also: Section 3.9.2 [omp_get_wtime], page 45,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.4.2.

3.9.2 `omp_get_wtime` – Elapsed wall clock time

Description:

Elapsed wall clock time in seconds. The time is measured per thread, no guarantee can be made that two distinct threads measure the same time. Time is measured from some "time in the past", which is an arbitrary time guaranteed not to change during the execution of the program.

C/C++:

Prototype: `double omp_get_wtime(void);`

Fortran:

Interface: `double precision function omp_get_wtime()`

See also: Section 3.9.1 [omp_get_wtick], page 45,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 3.4.1.

3.10 Event Routine

Support for event objects. The routine has C linkage and do not throw exceptions.

3.10.1 `omp_fulfill_event` – Fulfill and destroy an OpenMP event

Description:

Fulfill the event associated with the event handle argument. Currently, it is only used to fulfill events generated by detach clauses on task constructs - the effect of fulfilling the event is to allow the task to complete.

The result of calling `omp_fulfill_event` with an event handle other than that generated by a detach clause is undefined. Calling it with an event handle that has already been fulfilled is also undefined.

C/C++:

Prototype: `void omp_fulfill_event(omp_event_handle_t event);`

Fortran:

Interface:

```
subroutine omp_fulfill_event(event)
integer (kind=omp_event_handle_kind) :: event
```

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.5.1.

3.11 Interoperability Routines

Routines to obtain properties from an object of OpenMP interop type. They have C linkage and do not throw exceptions.

3.11.1 `omp_get_num_interop_properties` – Get the number of implementation-specific properties

Description:

The `omp_get_num_interop_properties` function returns the number of implementation-defined interoperability properties available for the passed *interop*, extending the OpenMP-defined properties. The available OpenMP interop_property-type values range from `omp_ipr_first` to the value returned by `omp_get_num_interop_properties` minus one.

No implementation-defined properties are currently defined in GCC.

C/C++:

Prototype: `int omp_get_num_interop_properties(const omp_interop_t interop)`

Fortran:

Interface: `integer function omp_get_num_interop_properties(interop)`
`integer(omp_interop_kind), intent(in) :: interop`

See also: Section 3.11.5 [omp_get_interop_name], page 48, Section 3.11.6 [omp_get_interop_type_desc], page 49,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.12.1, OpenMP specification v6.0 (`https://www.openmp.org`), Section 26.1

3.11.2 `omp_get_interop_int` – Obtain integer-valued interoperability property

Description:

The `omp_get_interop_int` function returns the integer value associated with the *property_id* interoperability property of the passed *interop* object. The *ret_code* argument is optional, i.e. it can be omitted in C++ and Fortran or used with `NULL` as argument in C and C++. If successful, *ret_code* (if present) is set to `omp_irc_success`.

In GCC, the effect of running this routine in a `target` region that is not the initial device is unspecified.

GCC implements the OpenMP 6.0 version of this function for C and C++, which is not compatible with its type signature in previous versions of the OpenMP specification. In older versions, the type `int*` was used for the *ret_code* argument in place of a pointer to the enumerated type `omp_interop_rc_t`.

C/C++:

Prototype: `omp_intptr_t omp_get_interop_int(const omp_interop_t interop, omp_interop_property_t property_id, omp_interop_rc_t *ret_code)`

Fortran:

Interface:
```
integer(c_intptr_t) function omp_get_interop_
int(interop, property_id, ret_code)
use, intrinsic :: iso_c_binding, only : c_intptr_t
integer(omp_interop_kind), intent(in) :: interop
integer(omp_interop_property_kind) property_id
integer(omp_interop_rc_kind), optional,
intent(out) :: ret_code
```

See also: Section 3.11.3 [omp_get_interop_ptr], page 47, Section 3.11.4 [omp_get_interop_str], page 48, Section 3.11.7 [omp_get_interop_rc_desc], page 49, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.12.2, OpenMP specification v6.0 (`https://www.openmp.org`), Section 26.2

3.11.3 `omp_get_interop_ptr` – Obtain pointer-valued interoperability property

Description:

The `omp_get_interop_int` function returns the pointer value associated with the *property_id* interoperability property of the passed *interop* object. The *ret_code* argument is optional, i.e. it can be omitted in C++ and Fortran or used with `NULL` as argument in C and C++. If successful, *ret_code* (if present) is set to `omp_irc_success`.

In GCC, the effect of running this routine in a `target` region that is not the initial device is unspecified.

GCC implements the OpenMP 6.0 version of this function for C and C++, which is not compatible with its type signature in previous versions of the OpenMP specification. In older versions, the type `int*` was used for the *ret_code* argument in place of a pointer to the enumerated type `omp_interop_rc_t`.

C/C++:

Prototype:
```
void *omp_get_interop_ptr(const omp_interop_t
interop, omp_interop_property_t property_id,
omp_interop_rc_t *ret_code)
```

Fortran:

Interface:
```
type(c_ptr) function omp_get_interop_int(interop,
property_id, ret_code)
use, intrinsic :: iso_c_binding, only : c_ptr
integer(omp_interop_kind), intent(in) :: interop
integer(omp_interop_property_kind) property_id
integer(omp_interop_rc_kind), optional,
intent(out) :: ret_code
```

See also: Section 3.11.2 [omp_get_interop_int], page 46, Section 3.11.4 [omp_get_interop_str], page 48, Section 3.11.7 [omp_get_interop_rc_desc], page 49, Chapter 12 [Offload-Target Specifics], page 113, *Reference*: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.12.3, OpenMP specification v6.0 (`https://www.openmp.org`), Section 26.3

3.11.4 `omp_get_interop_str` – Obtain string-valued interoperability property

Description:

The `omp_get_interop_str` function returns the string value associated with the *property_id* interoperability property of the passed *interop* object. The *ret_code* argument is optional, i.e. it can be omitted in C++ and Fortran or used with `NULL` as argument in C and C++. If successful, *ret_code* (if present) is set to `omp_irc_success`.

In GCC, the effect of running this routine in a `target` region that is not the initial device is unspecified.

GCC implements the OpenMP 6.0 version of this function for C and C++, which is not compatible with its type signature in previous versions of the OpenMP specification. In older versions, the type `int*` was used for the *ret_code* argument in place of a pointer to the enumerated type `omp_interop_rc_t`.

C/C++:

Prototype:
```
const char *omp_get_interop_str(const omp_interop_t
interop, omp_interop_property_t property_id,
omp_interop_rc_t *ret_code)
```

Fortran:

Interface:
```
character(:) function omp_get_interop_str(interop,
property_id, ret_code)
pointer :: omp_get_interop_str
integer(omp_interop_kind), intent(in) :: interop
integer(omp_interop_property_kind) property_id
integer(omp_interop_rc_kind), optional,
intent(out) :: ret_code
```

See also: Section 3.11.2 [omp_get_interop_int], page 46, Section 3.11.3 [omp_get_interop_ptr], page 47, Section 3.11.7 [omp_get_interop_rc_desc], page 49, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.12.4, OpenMP specification v6.0 (`https://www.openmp.org`), Section 26.4

3.11.5 `omp_get_interop_name` – Obtain the name of an `interop_property` value as string

Description:

The `omp_get_interop_name` function returns the name of the property itself as string; for the properties specified by the OpenMP specification, the name matches the name of the named constant with the '`omp_ipr_`' prefix removed.

C/C++:

Prototype:
```
const char *omp_get_interop_name(const omp_interop_
t interop, omp_interop_property_t property_id)
```

Fortran:

Interface: `character(:) function omp_get_interop_name(interop, property_id)`
`pointer :: omp_get_interop_name`
`integer(omp_interop_kind), intent(in) :: interop`
`integer(omp_interop_property_kind) property_id`

See also: Section 3.11.1 [omp_get_num_interop_properties], page 46, Section 3.11.6 [omp_get_interop_type_desc], page 49,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.12.5, OpenMP specification v6.0 (https://www.openmp.org), Section 26.5

3.11.6 omp_get_interop_type_desc – Obtain type and description to an interop_property

Description:

The `omp_get_interop_type_desc` function returns a string that describes in human-readable form the data type associated with the *property_id* interoperability property of the passed *interop* object.

In GCC, this function returns the name of the C/C++ data type for this property or 'N/A' if this property is not available for the given foreign runtime. If *interop* is `omp_interop_none` or for invalid property values, a null pointer is returned. The effect of running this routine in a `target` region that is not the initial device is unspecified.

C/C++:

Prototype: `const char *omp_get_interop_type_desc(const omp_interop_t interop, omp_interop_property_t property_id)`

Fortran:

Interface: `character(:) function omp_get_interop_type_desc(interop, property_id)`
`pointer :: omp_get_interop_type_desc`
`integer(omp_interop_kind), intent(in) :: interop`
`integer(omp_interop_property_kind) property_id`

See also: Section 3.11.1 [omp_get_num_interop_properties], page 46, Section 3.11.5 [omp_get_interop_name], page 48, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.12.6, OpenMP specification v6.0 (https://www.openmp.org), Section 26.6

3.11.7 omp_get_interop_rc_desc – Obtain error string to an interop_rc error code

Description:

The `omp_get_interop_rc_desc` function returns a string value describing the *ret_code* in human-readable form.

The behavior is unspecified if value of *ret_code* was not set by an interoperability routine invoked for *interop*.

GCC implements the OpenMP 6.0 version of this function for C and C++, which is not compatible with its type signature in previous versions of the OpenMP specification. In older versions, the type `int` was used for the *ret_code* argument in place of the enumerated type `omp_interop_rc_t`.

C/C++:

Prototype: `const char *omp_get_interop_rc_desc(const omp_interop_t interop, omp_interop_rc_t ret_code)`

Fortran:

Interface:
```
character(:) function omp_get_interop_rc_desc(interop, property_id, ret_code)
pointer :: omp_get_interop_rc_desc
integer(omp_interop_kind), intent(in) :: interop
integer (omp_interop_rc_kind) ret_code
```

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.12.7, OpenMP specification v6.0 (`https://www.openmp.org`), Section 26.7

3.12 Memory Management Routines

Routines to manage and allocate memory on the current device. They have C linkage and do not throw exceptions.

3.12.1 `omp_init_allocator` – Create an allocator

Description:

Create an allocator that uses the specified memory space and has the specified traits; if an allocator that fulfills the requirements cannot be created, `omp_null_allocator` is returned.

The predefined memory spaces and available traits can be found at Section 11.3 [Memory allocation], page 107, where the trait names have to be prefixed by `omp_atk_` (e.g. `omp_atk_pinned`) and the named trait values by `omp_atv_` (e.g. `omp_atv_true`); additionally, `omp_atv_default` may be used as trait value to specify that the default value should be used.

C/C++:

Prototype:
```
omp_allocator_handle_t omp_init_allocator(
 omp_memspace_handle_t memspace,
 int ntraits,
 const omp_alloctrait_t traits[]);
```

Fortran:

Interface:
```
function omp_init_allocator(memspace, ntraits, traits)
integer (omp_allocator_handle_kind) :: omp_init_allocator
```

```
integer (omp_memspace_handle_kind), intent(in) ::
memspace
integer, intent(in) :: ntraits
type (omp_alloctrait), intent(in) :: traits(*)
```

See also: Section 11.3 [Memory allocation], page 107, Section 4.1 [OMP_ALLOCATOR], page 59, Section 3.12.2 [omp_destroy_allocator], page 51,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.2

3.12.2 `omp_destroy_allocator` – Destroy an allocator

Description:

Releases all resources used by a memory allocator, which must not represent a predefined memory allocator. Accessing memory after its allocator has been destroyed has unspecified behavior. Passing `omp_null_allocator` to the routine is permitted but has no effect.

C/C++:

Prototype:
```
void omp_destroy_allocator (omp_allocator_handle_t
allocator);
```

Fortran:

Interface:
```
subroutine omp_destroy_allocator(allocator)
integer (omp_allocator_handle_kind), intent(in) ::
allocator
```

See also: Section 3.12.1 [omp_init_allocator], page 50,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.3

3.12.3 `omp_set_default_allocator` – Set the default allocator

Description:

Sets the default allocator that is used when no allocator has been specified in the `allocate` or `allocator` clause or if an OpenMP memory routine is invoked with the `omp_null_allocator` allocator.

C/C++:

Prototype:
```
void omp_set_default_allocator(omp_allocator_
handle_t allocator);
```

Fortran:

Interface:
```
subroutine omp_set_default_allocator(allocator)
integer (omp_allocator_handle_kind), intent(in) ::
allocator
```

See also: Section 3.12.4 [omp_get_default_allocator], page 52, Section 3.12.1 [omp_init_allocator], page 50, Section 4.1 [OMP_ALLOCATOR], page 59, Section 11.3 [Memory allocation], page 107,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.4

3.12.4 `omp_get_default_allocator` – Get the default allocator

Description:

The routine returns the default allocator that is used when no allocator has been specified in the `allocate` or `allocator` clause or if an OpenMP memory routine is invoked with the `omp_null_allocator` allocator.

C/C++:

Prototype: `omp_allocator_handle_t omp_get_default_allocator();`

Fortran:

Interface:
```
function omp_get_default_allocator()
integer (omp_allocator_handle_kind) :: omp_get_default_allocator
```

See also: Section 3.12.3 [omp_set_default_allocator], page 51, Section 4.1 [OMP_ALLOCATOR], page 59,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.5

3.12.5 `omp_alloc` – Memory allocation with an allocator

Description:

Allocate memory with the specified allocator, which can either be a predefined allocator, an allocator handle or `omp_null_allocator`. If the allocators is `omp_null_allocator`, the allocator specified by the *def-allocator-var* ICV is used. *size* must be a nonnegative number denoting the number of bytes to be allocated; if *size* is zero, `omp_alloc` will return a null pointer. If successful, a pointer to the allocated memory is returned, otherwise the `fallback` trait of the allocator determines the behavior. The content of the allocated memory is unspecified.

In `target` regions, either the `dynamic_allocators` clause must appear on a `requires` directive in the same compilation unit – or the *allocator* argument may only be a constant expression with the value of one of the predefined allocators and may not be `omp_null_allocator`.

Memory allocated by `omp_alloc` must be freed using `omp_free`.

C:

Prototype:
```
void* omp_alloc(size_t size,
 omp_allocator_handle_t allocator)
```

C++:

Prototype:
```
void* omp_alloc(size_t size,
 omp_allocator_handle_t allocator=omp_null_allocator)
```

Fortran:

Interface:
```
type(c_ptr) function omp_alloc(size, allocator)
bind(C)
```

```
use, intrinsic :: iso_c_binding, only : c_ptr,
c_size_t
integer (c_size_t), value :: size
integer (omp_allocator_handle_kind), value ::
allocator
```

See also: Section 4.1 [OMP_ALLOCATOR], page 59, Section 11.3 [Memory allocation], page 107, Section 3.12.3 [omp_set_default_allocator], page 51, Section 3.12.7 [omp_free], page 54, Section 3.12.1 [omp_init_allocator], page 50,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.6

3.12.6 `omp_aligned_alloc` – Memory allocation with an allocator and alignment

Description:

Allocate memory with the specified allocator, which can either be a predefined allocator, an allocator handle or `omp_null_allocator`. If the allocators is `omp_null_allocator`, the allocator specified by the *def-allocator-var* ICV is used. *alignment* must be a positive power of two and *size* must be a nonnegative number that is a multiple of the alignment and denotes the number of bytes to be allocated; if *size* is zero, `omp_aligned_alloc` will return a null pointer. The alignment will be at least the maximal value required by `alignment` trait of the allocator and the value of the passed *alignment* argument. If successful, a pointer to the allocated memory is returned, otherwise the `fallback` trait of the allocator determines the behavior. The content of the allocated memory is unspecified.

In `target` regions, either the `dynamic_allocators` clause must appear on a `requires` directive in the same compilation unit – or the *allocator* argument may only be a constant expression with the value of one of the predefined allocators and may not be `omp_null_allocator`.

Memory allocated by `omp_aligned_alloc` must be freed using `omp_free`.

C:

Prototype:
```
void* omp_aligned_alloc(size_t alignment,
 size_t size,
 omp_allocator_handle_t allocator)
```

C++:

Prototype:
```
void* omp_aligned_alloc(size_t alignment,
 size_t size,
 omp_allocator_handle_t allocator=omp_null_
allocator)
```

Fortran:

Interface:
```
type(c_ptr) function omp_aligned_alloc(alignment,
size, allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr,
c_size_t
```

```
integer (c_size_t), value :: alignment, size
integer (omp_allocator_handle_kind), value ::
allocator
```

See also: Section 4.1 [OMP_ALLOCATOR], page 59, Section 11.3 [Memory allocation], page 107, Section 3.12.3 [omp_set_default_allocator], page 51, Section 3.12.7 [omp_free], page 54, Section 3.12.1 [omp_init_allocator], page 50,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.13.6

3.12.7 `omp_free` – Freeing memory allocated with OpenMP routines

Description:

The `omp_free` routine deallocates memory previously allocated by an OpenMP memory-management routine. The *ptr* argument must point to such memory or be a null pointer; if it is a null pointer, no operation is performed. If specified, the *allocator* argument must be either the memory allocator that was used for the allocation or `omp_null_allocator`; if it is `omp_null_allocator`, the implementation will determine the value automatically.

Calling `omp_free` invokes undefined behavior if the memory was already deallocated or when the used allocator has already been destroyed.

C:

Prototype:
```
void omp_free(void *ptr,
 omp_allocator_handle_t allocator)
```

C++:

Prototype:
```
void omp_free(void *ptr,
 omp_allocator_handle_t allocator=omp_null_
allocator)
```

Fortran:

Interface:
```
subroutine omp_free(ptr, allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr
type (c_ptr), value :: ptr
integer (omp_allocator_handle_kind), value ::
allocator
```

See also: Section 3.12.5 [omp_alloc], page 52, Section 3.12.6 [omp_aligned_alloc], page 53, Section 3.12.8 [omp_calloc], page 54, Section 3.12.9 [omp_aligned_calloc], page 55, Section 3.12.10 [omp_realloc], page 56,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.7

3.12.8 `omp_calloc` – Allocate nullified memory with an allocator

Description:

Allocate zero-initialized memory with the specified allocator, which can either be a predefined allocator, an allocator handle or `omp_null_allocator`. If the allocators is `omp_null_allocator`, the allocator specified by the *def-allocator-var* ICV is used. The to-be allocated memory is for an array with *nmemb* elements, each having a size of *size* bytes. Both *nmemb* and *size* must be nonnegative numbers; if either of them is zero, `omp_calloc` will return a null pointer. If successful, a pointer to the zero-initialized allocated memory is returned, otherwise the `fallback` trait of the allocator determines the behavior.

In `target` regions, either the `dynamic_allocators` clause must appear on a `requires` directive in the same compilation unit – or the *allocator* argument may only be a constant expression with the value of one of the predefined allocators and may not be `omp_null_allocator`.

Memory allocated by `omp_calloc` must be freed using `omp_free`.

C:

Prototype:
```
void* omp_calloc(size_t nmemb, size_t size,
 omp_allocator_handle_t allocator)
```

C++:

Prototype:
```
void* omp_calloc(size_t nmemb, size_t size,
 omp_allocator_handle_t allocator=omp_null_
allocator)
```

Fortran:

Interface:
```
type(c_ptr) function omp_calloc(nmemb, size,
allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr,
c_size_t
integer (c_size_t), value :: nmemb, size
integer (omp_allocator_handle_kind), value ::
allocator
```

See also: Section 4.1 [OMP_ALLOCATOR], page 59, Section 11.3 [Memory allocation], page 107, Section 3.12.3 [omp_set_default_allocator], page 51, Section 3.12.7 [omp_free], page 54, Section 3.12.1 [omp_init_allocator], page 50,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.13.8

3.12.9 `omp_aligned_calloc` – Allocate aligned nullified memory with an allocator

Description:

Allocate zero-initialized memory with the specified allocator, which can either be a predefined allocator, an allocator handle or `omp_null_allocator`. If the allocators is `omp_null_allocator`, the allocator specified by the *def-allocator-var* ICV is used. The to-be allocated memory is for an array with *nmemb* elements, each having a size of *size* bytes. Both *nmemb* and *size* must be non-negative numbers; if either of them is zero, `omp_aligned_calloc` will return a null pointer. *alignment* must be a positive power of two and *size* must be a multiple of the alignment; the alignment will be at least the maximal value required by `alignment` trait of the allocator and the value of the passed *alignment* argument. If successful, a pointer to the zero-initialized allocated memory is returned, otherwise the `fallback` trait of the allocator determines the behavior.

In `target` regions, either the `dynamic_allocators` clause must appear on a `requires` directive in the same compilation unit – or the *allocator* argument may only be a constant expression with the value of one of the predefined allocators and may not be `omp_null_allocator`.

Memory allocated by `omp_aligned_calloc` must be freed using `omp_free`.

C:

Prototype: `void* omp_aligned_calloc(size_t nmemb, size_t size, omp_allocator_handle_t allocator)`

C++:

Prototype: `void* omp_aligned_calloc(size_t nmemb, size_t size, omp_allocator_handle_t allocator=omp_null_allocator)`

Fortran:

Interface:
```
type(c_ptr) function omp_aligned_calloc(nmemb,
size, allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr,
c_size_t
integer (c_size_t), value :: nmemb, size
integer (omp_allocator_handle_kind), value ::
allocator
```

See also: Section 4.1 [OMP_ALLOCATOR], page 59, Section 11.3 [Memory allocation], page 107, Section 3.12.3 [omp_set_default_allocator], page 51, Section 3.12.7 [omp_free], page 54, Section 3.12.1 [omp_init_allocator], page 50,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.13.8

3.12.10 `omp_realloc` – Reallocate memory allocated with OpenMP routines

Description:

The `omp_realloc` routine deallocates memory to which *ptr* points to and allocates new memory with the specified *allocator* argument; the new memory will have the content of the old memory up to the minimum of the old size and the new *size*, otherwise the content of the returned memory is unspecified. If the new allocator is the same as the old one, the routine tries to resize the existing memory allocation, returning the same address as *ptr* if successful. *ptr* must point to memory allocated by an OpenMP memory-management routine.

The *allocator* and *free_allocator* arguments must be a predefined allocator, an allocator handle or `omp_null_allocator`. If *free_allocator* is `omp_null_allocator`, the implementation automatically determines the allocator used for the allocation of *ptr*. If *allocator* is `omp_null_allocator` and *ptr* is not a null pointer, the same allocator as `free_allocator` is used and when *ptr* is a null pointer the allocator specified by the *def-allocator-var* ICV is used.

The *size* must be a nonnegative number denoting the number of bytes to be allocated; if *size* is zero, `omp_realloc` will return free the memory and return a null pointer. When *size* is nonzero: if successful, a pointer to the allocated memory is returned, otherwise the `fallback` trait of the allocator determines the behavior.

In `target` regions, either the `dynamic_allocators` clause must appear on a `requires` directive in the same compilation unit – or the *free_allocator* and *allocator* arguments may only be a constant expression with the value of one of the predefined allocators and may not be `omp_null_allocator`.

Memory allocated by `omp_realloc` must be freed using `omp_free`. Calling `omp_free` invokes undefined behavior if the memory was already deallocated or when the used allocator has already been destroyed.

C:

Prototype:
```
void* omp_realloc(void *ptr, size_t size,
 omp_allocator_handle_t allocator,
 omp_allocator_handle_t free_allocator)
```

C++:

Prototype:
```
void* omp_realloc(void *ptr, size_t size,
 omp_allocator_handle_t allocator=omp_null_
allocator,
 omp_allocator_handle_t free_allocator=omp_null_
allocator)
```

Fortran:

Interface:
```
type(c_ptr) function omp_realloc(ptr, size,
allocator, free_allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr,
c_size_t
type(C_ptr), value :: ptr
integer (c_size_t), value :: size
integer (omp_allocator_handle_kind), value ::
allocator, free_allocator
```

See also: Section 4.1 [OMP_ALLOCATOR], page 59, Section 11.3 [Memory allocation], page 107, Section 3.12.3 [omp_set_default_allocator], page 51, Section 3.12.7 [omp_free], page 54, Section 3.12.1 [omp_init_allocator], page 50,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 3.7.9

3.13 Environment Display Routine

Routine to display the OpenMP version number and the initial value of ICVs. It has C linkage and does not throw exceptions.

3.13.1 `omp_display_env` – print the initial ICV values

Description:

Each time this routine is invoked, the OpenMP version number and initial value of internal control variables (ICVs) is printed on `stderr`. The displayed values are those at startup after evaluating the environment variables; later calls to API routines or clauses used in enclosing constructs do not affect the output.

If the *verbose* argument is `false`, only the OpenMP version and standard OpenMP ICVs are shown; if it is `true`, additionally, the GCC-specific ICVs are shown.

The output consists of multiple lines and starts with '`OPENMP DISPLAY ENVIRONMENT BEGIN`' followed by the name-value lines and ends with '`OPENMP DISPLAY ENVIRONMENT END`'. The *name* is followed by an equal sign and the *value* is enclosed in single quotes.

The first line has as *name* either '`_OPENMP`' or '`openmp_version`' and shows as value the supported OpenMP version number (4-digit year, 2-digit month) of the implementation, matching the value of the `_OPENMP` macro and, in Fortran, the named constant `openmp_version`.

In each of the succeeding lines, the *name* matches the environment-variable name of an ICV and shows its value. Those line are might be prefixed by pair of brackets and a space, where the brackets enclose a comma-separated list of devices to which the ICV-value combination applies to; the value can either be a numeric device number or an abstract name denoting all devices (`all`), the initial host device (`host`) or all devices but the host (`device`). Note that the same ICV might be printed multiple times for multiple devices, even if all have the same value.

The effect when invoked from within a `target` region is unspecified.

C/C++:

Prototype: `void omp_display_env(int verbose)`

Fortran:

Interface: `subroutine omp_display_env(verbose)`
`logical, intent(in) :: verbose`

Example: Note that the GCC-specific ICVs, such as the shown `GOMP_SPINCOUNT`, are only printed when *verbose* set to `true`.

```
OPENMP DISPLAY ENVIRONMENT BEGIN
  _OPENMP = '202111'
  [host] OMP_DYNAMIC = 'FALSE'
  [host] OMP_NESTED = 'FALSE'
  [all] OMP_CANCELLATION = 'FALSE'
  ...
  [host] GOMP_SPINCOUNT = '300000'
OPENMP DISPLAY ENVIRONMENT END
```

See also: Section 4.5 [OMP_DISPLAY_ENV], page 61, Chapter 4 [Environment Variables], page 59, Section 11.1 [Implementation-defined ICV Initialization], page 107,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 3.15

4 OpenMP Environment Variables

The environment variables which beginning with `OMP_` are defined by section 4 of the OpenMP specification in version 4.5 or in a later version of the specification, while those beginning with `GOMP_` are GNU extensions. Most `OMP_` environment variables have an associated internal control variable (ICV).

For any OpenMP environment variable that sets an ICV and is neither `OMP_DEFAULT_DEVICE` nor has global ICV scope, associated device-specific environment variables exist. For them, the environment variable without suffix affects the host. The suffix `_DEV_` followed by a non-negative device number less that the number of available devices sets the ICV for the corresponding device. The suffix `_DEV` sets the ICV of all non-host devices for which a device-specific corresponding environment variable has not been set while the `_ALL` suffix sets the ICV of all host and non-host devices for which a more specific corresponding environment variable is not set.

4.1 `OMP_ALLOCATOR` – Set the default allocator

ICV: def-allocator-var
Scope: data environment
Description:

Sets the default allocator that is used when no allocator has been specified in the `allocate` or `allocator` clause or if an OpenMP memory routine is invoked with the `omp_null_allocator` allocator. If unset, `omp_default_mem_alloc` is used.

The value can either be a predefined allocator or a predefined memory space or a predefined memory space followed by a colon and a comma-separated list of memory trait and value pairs, separated by `=`.

See Section 11.3 [Memory allocation], page 107, for a list of supported prefedined allocators, memory spaces, and traits.

Note: The corresponding device environment variables are currently not supported. Therefore, the non-host *def-allocator-var* ICVs are always initialized to `omp_default_mem_alloc`. However, on all devices, the `omp_set_default_allocator` API routine can be used to change value.

Examples:

```
OMP_ALLOCATOR=omp_high_bw_mem_alloc
OMP_ALLOCATOR=omp_large_cap_mem_space
OMP_ALLOCATOR=omp_low_lat_mem_space:pinned=true,partition=nearest
```

See also: Section 11.3 [Memory allocation], page 107, Section 3.12.4 [omp_get_default_allocator], page 52, Section 3.12.3 [omp_set_default_allocator], page 51, Chapter 12 [Offload-Target Specifics], page 113,

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 6.21

4.2 OMP_AFFINITY_FORMAT – Set the format string used for affinity display

ICV: affinity-format-var
Scope: device
Description:

Sets the format string used when displaying OpenMP thread affinity information. Special values are output using % followed by an optional size specification and then either the single-character field type or its long name enclosed in curly braces; using %% displays a literal percent. The size specification consists of an optional 0. or . followed by a positive integer, specifying the minimal width of the output. With 0. and numerical values, the output is padded with zeros on the left; with ., the output is padded by spaces on the left; otherwise, the output is padded by spaces on the right. If unset, the value is "level %L thread %i affinity %A".

Supported field types are:

t	team_num	value returned by omp_get_team_num
T	num_teams	value returned by omp_get_num_teams
L	nesting_level	value returned by omp_get_level
n	thread_num	value returned by omp_get_thread_num
N	num_threads	value returned by omp_get_num_threads
a	ancestor_tnum	value returned by omp_get_ancestor_thread_num(omp_get_level()-1)
H	host	name of the host that executes the thread
P	process_id	process identifier
i	native_thread_id	native thread identifier
A	thread_affinity	comma separated list of integer values or ranges, representing the processors on which a process might execute, subject to affinity mechanisms

For instance, after setting

```
OMP_AFFINITY_FORMAT="%0.2a!%n!%.4L!%N;%.2t;%0.2T;%{team_num};%{num_teams};%A"
```

with either OMP_DISPLAY_AFFINITY being set or when calling omp_display_affinity with NULL or an empty string, the program might display the following:

```
00!0!   1!4; 0;01;0;1;0-11
00!3!   1!4; 0;01;0;1;0-11
00!2!   1!4; 0;01;0;1;0-11
00!1!   1!4; 0;01;0;1;0-11
```

See also: Section 4.4 [OMP_DISPLAY_AFFINITY], page 61,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 6.14

4.3 OMP_CANCELLATION – Set whether cancellation is activated

ICV: cancel-var
Scope: global
Description:

If set to TRUE, the cancellation is activated. If set to FALSE or if unset, cancellation is disabled and the cancel construct is ignored.

See also: Section 3.1.8 [omp_get_cancellation], page 17,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.11

4.4 OMP_DISPLAY_AFFINITY – Display thread affinity information

ICV: display-affinity-var
Scope: global
Description:

If set to FALSE or if unset, affinity displaying is disabled. If set to TRUE, the runtime displays affinity information about OpenMP threads in a parallel region upon entering the region and every time any change occurs.

See also: Section 4.2 [OMP_AFFINITY_FORMAT], page 60,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 6.13

4.5 OMP_DISPLAY_ENV – Show OpenMP version and environment variables

ICV: none

Scope: not applicable
Description:

If set to TRUE, the runtime displays the same information to stderr as shown by the omp_display_env routine invoked with *verbose* argument set to false. If set to VERBOSE, the same information is shown as invoking the routine with *verbose* set to true. If unset or set to FALSE, this information is not shown. The result for any other value is unspecified.

See also: Section 3.13.1 [omp_display_env], page 57,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.12

4.6 OMP_DEFAULT_DEVICE – Set the device used in target regions

ICV: default-device-var
Scope: data environment
Description:

Set to choose the device which is used in a target region, unless the value is overridden by omp_set_default_device or by a device clause. The value shall be the nonnegative device number. If no device with the given device number exists, the code is executed on the host. If unset, `OMP_TARGET_OFFLOAD` is `mandatory` and no non-host devices are available, it is set to `omp_invalid_device`. Otherwise, if unset, device number 0 is used.

See also: Section 3.6.3 [omp_get_default_device], page 27, Section 3.6.2 [omp_set_default_device], page 27, Section 4.17 [OMP_TARGET_OFFLOAD], page 66,

Reference: OpenMP specification v5.2 (`https://www.openmp.org`), Section 21.2.7

4.7 `OMP_DYNAMIC` – Dynamic adjustment of threads

ICV: dyn-var
Scope: global
Description:

Enable or disable the dynamic adjustment of the number of threads within a team. The value of this environment variable shall be `TRUE` or `FALSE`. If undefined, dynamic adjustment is disabled by default.

See also: Section 3.1.6 [omp_set_dynamic], page 17,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.3

4.8 `OMP_MAX_ACTIVE_LEVELS` – Set the maximum number of nested parallel regions

ICV: max-active-levels-var
Scope: data environment
Description:

Specifies the initial value for the maximum number of nested parallel regions. The value of this variable shall be a positive integer. If undefined, then if `OMP_NESTED` is defined and set to true, or if `OMP_NUM_THREADS` or `OMP_PROC_BIND` are defined and set to a list with more than one item, the maximum number of nested parallel regions is initialized to the largest number supported, otherwise it is set to one.

See also: Section 3.1.15 [omp_set_max_active_levels], page 20, Section 4.10 [OMP_NESTED], page 63, Section 4.13 [OMP_PROC_BIND], page 64, Section 4.12 [OMP_NUM_THREADS], page 63,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.9

4.9 `OMP_MAX_TASK_PRIORITY` – Set the maximum priority

number that can be set for a task.

ICV: max-task-priority-var
Scope: global
Description:

Specifies the initial value for the maximum priority value that can be set for a task. The value of this variable shall be a non-negative integer, and zero is allowed. If undefined, the default priority is 0.

See also: Section 3.4.1 [omp_get_max_task_priority], page 25,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.14

4.10 `OMP_NESTED` – Nested parallel regions

ICV: max-active-levels-var
Scope: data environment
Description:

Enable or disable nested parallel regions, i.e., whether team members are allowed to create new teams. The value of this environment variable shall be `TRUE` or `FALSE`. If set to `TRUE`, the number of maximum active nested regions supported is by default set to the maximum supported, otherwise it is set to one. If `OMP_MAX_ACTIVE_LEVELS` is defined, its setting overrides this setting. If both are undefined, nested parallel regions are enabled if `OMP_NUM_THREADS` or `OMP_PROC_BINDS` are defined to a list with more than one item, otherwise they are disabled by default.

Note that the `OMP_NESTED` environment variable was deprecated in the OpenMP specification 5.0 in favor of `OMP_MAX_ACTIVE_LEVELS`.

See also: Section 3.1.15 [omp_set_max_active_levels], page 20, Section 3.1.9 [omp_set_nested], page 18, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.6

4.11 `OMP_NUM_TEAMS` – Specifies the number of teams to use by teams region

ICV: nteams-var
Scope: device
Description:

Specifies the upper bound for number of teams to use in teams regions without explicit `num_teams` clause. The value of this variable shall be a positive integer. If undefined it defaults to 0 which means implementation defined upper bound.

See also: Section 3.3.3 [omp_set_num_teams], page 23,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 6.23

4.12 `OMP_NUM_THREADS` – Specifies the number of threads to use

ICV: nthreads-var
Scope: data environment
Description:

Specifies the default number of threads to use in parallel regions. The value of this variable shall be a comma-separated list of positive integers; the value specifies the number of threads to use for the corresponding nested level. Specifying more than one item in the list automatically enables nesting by default. If undefined one thread per CPU is used.

When a list with more than value is specified, it also affects the *max-active-levels-var* ICV as described in Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62.

See also: Section 3.1.1 [omp_set_num_threads], page 15, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.2

4.13 `OMP_PROC_BIND` – Whether threads may be moved between CPUs

ICV: bind-var
Scope: data environment
Description:

Specifies whether threads may be moved between processors. If set to `TRUE`, OpenMP threads should not be moved; if set to `FALSE` they may be moved. Alternatively, a comma separated list with the values `PRIMARY`, `MASTER` (deprecated since OpenMP 5.1), `CLOSE` and `SPREAD` can be used to specify the thread affinity policy for the corresponding nesting level. With `PRIMARY` and `MASTER` the worker threads are in the same place partition as the primary thread. With `CLOSE` those are kept close to the primary thread in contiguous place partitions. And with `SPREAD` a sparse distribution across the place partitions is used. Specifying more than one item in the list automatically enables nesting by default.

When a list is specified, it also affects the *max-active-levels-var* ICV as described in Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62.

When undefined, `OMP_PROC_BIND` defaults to `TRUE` when `OMP_PLACES` or `GOMP_CPU_AFFINITY` is set and `FALSE` otherwise.

See also: Section 3.2.1 [omp_get_proc_bind], page 22, Section 4.21 [GOMP_CPU_AFFINITY], page 67, Section 4.14 [OMP_PLACES], page 64, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.4

4.14 `OMP_PLACES` – Specifies on which CPUs the threads should be placed

ICV: place-partition-var
Scope: implicit tasks
Description:

The thread placement can be either specified using an abstract name or by an explicit list of the places. The abstract names `threads`, `cores`, `sockets`, `ll_caches` and `numa_domains` can be optionally followed by a positive number in parentheses, which denotes the how many places shall be created. With `threads` each place corresponds to a single hardware thread; `cores` to a single core with the corresponding number of hardware threads; with `sockets` the place corresponds to a single socket; with `ll_caches` to a set of cores that shares the last level cache on the device; and `numa_domains` to a set of cores for which their closest memory on the device is the same memory and at a similar distance from the cores. The resulting placement can be shown by setting the `OMP_DISPLAY_ENV` environment variable.

Alternatively, the placement can be specified explicitly as comma-separated list of places. A place is specified by set of nonnegative numbers in curly braces, denoting the hardware threads. The curly braces can be omitted when only a single number has been specified. The hardware threads belonging to a place can either be specified as comma-separated list of nonnegative thread numbers or using an interval. Multiple places can also be either specified by a comma-separated list of places or by an interval. To specify an interval, a colon followed by the count is placed after the hardware thread number or the place. Optionally, the length can be followed by a colon and the stride number – otherwise a unit stride is assumed. Placing an exclamation mark (`!`) directly before a curly brace or numbers inside the curly braces (excluding intervals) excludes those hardware threads.

For instance, the following specifies the same places list: `"{0,1,2}, {3,4,6}, {7,8,9}, {10,11,12}"`; `"{0:3}, {3:3}, {7:3}, {10:3}"`; and `"{0:2}:4:3"`.

If `OMP_PLACES` and `GOMP_CPU_AFFINITY` are unset and `OMP_PROC_BIND` is either unset or `false`, threads may be moved between CPUs following no placement policy.

See also: Section 4.13 [OMP_PROC_BIND], page 64, Section 4.21 [GOMP_CPU_AFFINITY], page 67, Section 3.2.1 [omp_get_proc_bind], page 22, Section 4.5 [OMP_DISPLAY_ENV], page 61,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.5

4.15 `OMP_STACKSIZE` – Set default thread stack size

ICV: stacksize-var
Scope: device
Description:

Set the default thread stack size in kilobytes, unless the number is suffixed by `B`, `K`, `M` or `G`, in which case the size is, respectively, in bytes, kilobytes, megabytes or gigabytes. This is different from `pthread_attr_setstacksize` which gets the number of bytes as an argument. If the stack size cannot be set due to system constraints, an error is reported and the initial stack size is left unchanged. If undefined, the stack size is system dependent.

See also: Section 4.23 [GOMP_STACKSIZE], page 68,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.7

4.16 `OMP_SCHEDULE` – How threads are scheduled

ICV: run-sched-var
Scope: data environment
Description:

Allows to specify `schedule type` and `chunk size`. The value of the variable shall have the form: `type[,chunk]` where `type` is one of `static`, `dynamic`, `guided` or `auto` The optional `chunk` size shall be a positive integer. If undefined, dynamic scheduling and a chunk size of 1 is used.

See also: Section 3.1.11 [omp_set_schedule], page 19,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Sections 2.7.1.1 and 4.1

4.17 `OMP_TARGET_OFFLOAD` – Controls offloading behavior

ICV: target-offload-var
Scope: global
Description:

Specifies the behavior with regard to offloading code to a device. This variable can be set to one of three values - `MANDATORY`, `DISABLED` or `DEFAULT`.

If set to `MANDATORY`, the program terminates with an error if any device construct or device memory routine uses a device that is unavailable or not supported by the implementation, or uses a non-conforming device number. If set to `DISABLED`, then offloading is disabled and all code runs on the host. If set to `DEFAULT`, the program tries offloading to the device first, then falls back to running code on the host if it cannot.

If undefined, then the program behaves as if `DEFAULT` was set.

Note: Even with `MANDATORY`, no run-time termination is performed when the device number in a `device` clause or argument to a device memory routine is for host, which includes using the device number in the *default-device-var* ICV. However, the initial value of the *default-device-var* ICV is affected by `MANDATORY`.

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 61,

Reference: OpenMP specification v5.2 (`https://www.openmp.org`), Section 21.2.8

4.18 `OMP_TEAMS_THREAD_LIMIT` – Set the maximum number of threads imposed by teams

ICV: teams-thread-limit-var
Scope: device
Description:

Specifies an upper bound for the number of threads to use by each contention group created by a teams construct without explicit `thread_limit` clause. The value of this variable shall be a positive integer. If undefined, the value of 0 is used which stands for an implementation defined upper limit.

See also: Section 4.19 [OMP_THREAD_LIMIT], page 67, Section 3.3.5 [omp_set_teams_thread_limit], page 24,

Reference: OpenMP specification v5.1 (`https://www.openmp.org`), Section 6.24

4.19 `OMP_THREAD_LIMIT` – Set the maximum number of threads

ICV: thread-limit-var
Scope: data environment
Description:

Specifies the number of threads to use for the whole program. The value of this variable shall be a positive integer. If undefined, the number of threads is not limited.

See also: Section 4.12 [OMP_NUM_THREADS], page 63, Section 3.3.6 [omp_get_thread_limit], page 24,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.10

4.20 `OMP_WAIT_POLICY` – How waiting threads are handled

Description:

Specifies whether waiting threads should be active or passive. If the value is `PASSIVE`, waiting threads should not consume CPU power while waiting; while the value is `ACTIVE` specifies that they should. If undefined, threads wait actively for a short time before waiting passively.

See also: Section 4.24 [GOMP_SPINCOUNT], page 68,

Reference: OpenMP specification v4.5 (`https://www.openmp.org`), Section 4.8

4.21 `GOMP_CPU_AFFINITY` – Bind threads to specific CPUs

Description:

Binds threads to specific CPUs. The variable should contain a space-separated or comma-separated list of CPUs. This list may contain different kinds of entries: either single CPU numbers in any order, a range of CPUs (M-N) or a range with some stride (M-N:S). CPU numbers are zero based. For example, `GOMP_CPU_AFFINITY="0 3 1-2 4-15:2"` binds the initial thread to CPU 0, the second to CPU 3, the third to CPU 1, the fourth to CPU 2, the fifth to CPU 4, the sixth through tenth to CPUs 6, 8, 10, 12, and 14 respectively and then starts assigning back from the beginning of the list. `GOMP_CPU_AFFINITY=0` binds all threads to CPU 0.

There is no libgomp library routine to determine whether a CPU affinity specification is in effect. As a workaround, language-specific library functions, e.g., `getenv` in C or `GET_ENVIRONMENT_VARIABLE` in Fortran, may be used to query the setting of the `GOMP_CPU_AFFINITY` environment variable. A defined CPU affinity on startup cannot be changed or disabled during the runtime of the application.

If both `GOMP_CPU_AFFINITY` and `OMP_PROC_BIND` are set, `OMP_PROC_BIND` has a higher precedence. If neither has been set and `OMP_PROC_BIND` is unset, or when `OMP_PROC_BIND` is set to `FALSE`, the host system handles the assignment of threads to CPUs.

See also: Section 4.14 [OMP_PLACES], page 64, Section 4.13 [OMP_PROC_BIND], page 64,

4.22 `GOMP_DEBUG` – Enable debugging output

Description:

Enable debugging output. The variable should be set to `0` (disabled, also the default if not set), or `1` (enabled).

If enabled, some debugging output is printed during execution. This is currently not specified in more detail, and subject to change.

4.23 `GOMP_STACKSIZE` – Set default thread stack size

Description:

Set the default thread stack size in kilobytes. This is different from `pthread_attr_setstacksize` which gets the number of bytes as an argument. If the stack size cannot be set due to system constraints, an error is reported and the initial stack size is left unchanged. If undefined, the stack size is system dependent.

See also: Section 4.15 [OMP_STACKSIZE], page 65,

Reference: GCC Patches Mailinglist (`https://gcc.gnu.org/ml/gcc-patches/2006-06/msg00493.html`), GCC Patches Mailinglist (`https://gcc.gnu.org/ml/gcc-patches/2006-06/msg00496.html`)

4.24 `GOMP_SPINCOUNT` – Set the busy-wait spin count

Description:

Determines how long a threads waits actively with consuming CPU power before waiting passively without consuming CPU power. The value may be either `INFINITE`, `INFINITY` to always wait actively or an integer which gives the number of spins of the busy-wait loop. The integer may optionally be followed by the following suffixes acting as multiplication factors: `k` (kilo, thousand), `M` (mega, million), `G` (giga, billion), or `T` (tera, trillion). If undefined, 0 is used when `OMP_WAIT_POLICY` is `PASSIVE`, 300,000 is used when `OMP_WAIT_POLICY` is undefined and 30 billion is used when `OMP_WAIT_POLICY` is `ACTIVE`. If there are more OpenMP threads than available CPUs, 1000 and 100 spins are used for `OMP_WAIT_POLICY` being `ACTIVE` or undefined, respectively; unless the `GOMP_SPINCOUNT` is lower or `OMP_WAIT_POLICY` is `PASSIVE`.

See also: Section 4.20 [OMP_WAIT_POLICY], page 67,

4.25 GOMP_RTEMS_THREAD_POOLS – Set the RTEMS specific thread pools

Description:

This environment variable is only used on the RTEMS real-time operating system. It determines the scheduler instance specific thread pools. The format for GOMP_RTEMS_THREAD_POOLS is a list of optional <thread-pool-count>[$<priority>]@<scheduler-name> configurations separated by : where:

- <thread-pool-count> is the thread pool count for this scheduler instance.
- $<priority> is an optional priority for the worker threads of a thread pool according to pthread_setschedparam. In case a priority value is omitted, then a worker thread inherits the priority of the OpenMP primary thread that created it. The priority of the worker thread is not changed after creation, even if a new OpenMP primary thread using the worker has a different priority.
- @<scheduler-name> is the scheduler instance name according to the RTEMS application configuration.

In case no thread pool configuration is specified for a scheduler instance, then each OpenMP primary thread of this scheduler instance uses its own dynamically allocated thread pool. To limit the worker thread count of the thread pools, each OpenMP primary thread must call omp_set_num_threads.

Example: Lets suppose we have three scheduler instances IO, WRK0, and WRK1 with GOMP_RTEMS_THREAD_POOLS set to "1@WRK0:3$4@WRK1". Then there are no thread pool restrictions for scheduler instance IO. In the scheduler instance WRK0 there is one thread pool available. Since no priority is specified for this scheduler instance, the worker thread inherits the priority of the OpenMP primary thread that created it. In the scheduler instance WRK1 there are three thread pools available and their worker threads run at priority four.

5 Enabling OpenACC

To activate the OpenACC extensions for C/C++ and Fortran, the compile-time flag `-fopenacc` must be specified. This enables the OpenACC directive '`#pragma acc`' in C/C++ and, in Fortran, the '`!$acc`' sentinel in free source form and the '`c$acc`', '`*$acc`' and '`!$acc`' sentinels in fixed source form. The flag also arranges for automatic linking of the OpenACC runtime library (Chapter 6 [OpenACC Runtime Library Routines], page 73).

See `https://gcc.gnu.org/wiki/OpenACC` for more information.

A complete description of all OpenACC directives accepted may be found in the OpenACC (`https://www.openacc.org`) Application Programming Interface manual, version 2.6.

6 OpenACC Runtime Library Routines

The runtime routines described here are defined by section 3 of the OpenACC specifications in version 2.6. They have C linkage, and do not throw exceptions. Generally, they are available only for the host, with the exception of `acc_on_device`, which is available for both the host and the acceleration device.

6.1 `acc_get_num_devices` – Get number of devices for given device type

Description

This function returns a value indicating the number of devices available for the device type specified in *devicetype*.

C/C++:

Prototype: `int acc_get_num_devices(acc_device_t devicetype);`

Fortran:

Interface:
```
integer function acc_get_num_devices(devicetype)
integer(kind=acc_device_kind) devicetype
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.1.

6.2 `acc_set_device_type` – Set type of device accelerator to use.

Description

This function indicates to the runtime library which device type, specified in *devicetype*, to use when executing a parallel or kernels region.

C/C++:

Prototype: `acc_set_device_type(acc_device_t devicetype);`

Fortran:

Interface:
```
subroutine acc_set_device_type(devicetype)
integer(kind=acc_device_kind) devicetype
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.2.

6.3 `acc_get_device_type` – Get type of device accelerator to be used.

Description

This function returns what device type will be used when executing a parallel or kernels region.

This function returns `acc_device_none` if `acc_get_device_type` is called from `acc_ev_device_init_start`, `acc_ev_device_init_end` callbacks of the OpenACC Profiling Interface (Chapter 10 [OpenACC Profiling Interface], page 101), that is, if the device is currently being initialized.

C/C++:

Prototype: `acc_device_t acc_get_device_type(void);`

Fortran:

Interface: `function acc_get_device_type(void)`
`integer(kind=acc_device_kind) acc_get_device_type`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.3.

6.4 `acc_set_device_num` – Set device number to use.

Description

This function will indicate to the runtime which device number, specified by *devicenum*, associated with the specified device type *devicetype*.

C/C++:

Prototype: `acc_set_device_num(int devicenum, acc_device_t devicetype);`

Fortran:

Interface: `subroutine acc_set_device_num(devicenum, devicetype)`
`integer devicenum`
`integer(kind=acc_device_kind) devicetype`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.4.

6.5 `acc_get_device_num` – Get device number to be used.

Description

This function returns which device number associated with the specified device type *devicetype*, will be used when executing a parallel or kernels region.

C/C++:

Prototype: `int acc_get_device_num(acc_device_t devicetype);`

Fortran:

Interface: `function acc_get_device_num(devicetype)`
`integer(kind=acc_device_kind) devicetype`
`integer acc_get_device_num`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.5.

6.6 `acc_get_property` – Get device property.

Description

These routines return the value of the specified *property* for the device being queried according to *devicenum* and *devicetype*. Integer-valued and string-valued properties are returned by `acc_get_property` and `acc_get_property_string` respectively. The Fortran `acc_get_property_string` subroutine returns the string retrieved in its fourth argument while the remaining entry points are functions, which pass the return value as their result.

Note for Fortran, only: the OpenACC technical committee corrected and, hence, modified the interface introduced in OpenACC 2.6. The kind-value parameter `acc_device_property` has been renamed to `acc_device_property_kind` for consistency and the return type of the `acc_get_property` function is now a `c_size_t` integer instead of a `acc_device_property` integer. The parameter `acc_device_property` is still provided, but might be removed in a future version of GCC.

C/C++:

Prototype: `size_t acc_get_property(int devicenum, acc_device_t devicetype, acc_device_property_t property);`

Prototype: `const char *acc_get_property_string(int devicenum, acc_device_t devicetype, acc_device_property_t property);`

Fortran:

Interface: `function acc_get_property(devicenum, devicetype, property)`

Interface: `subroutine acc_get_property_string(devicenum, devicetype, property, string)`

```
use ISO_C_Binding, only: c_size_t
integer devicenum
integer(kind=acc_device_kind) devicetype
integer(kind=acc_device_property_kind) property
integer(kind=c_size_t) acc_get_property
character(*) string
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.6.

6.7 `acc_async_test` – Test for completion of a specific asynchronous operation.

Description

This function tests for completion of the asynchronous operation specified in *arg*. In C/C++, a non-zero value is returned to indicate the specified asynchronous operation has completed while Fortran returns `true`. If the asynchronous operation has not completed, C/C++ returns zero and Fortran returns `false`.

C/C++:

Prototype: `int acc_async_test(int arg);`

Fortran:

Interface:

```
function acc_async_test(arg)
integer(kind=acc_handle_kind) arg
logical acc_async_test
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.9.

6.8 `acc_async_test_all` – Tests for completion of all asynchronous operations.

Description

This function tests for completion of all asynchronous operations. In C/C++, a non-zero value is returned to indicate all asynchronous operations have completed while Fortran returns `true`. If any asynchronous operation has not completed, C/C++ returns zero and Fortran returns `false`.

C/C++:

Prototype: `int acc_async_test_all(void);`

Fortran:

Interface: `function acc_async_test()`
`logical acc_get_device_num`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.10.

6.9 `acc_wait` – Wait for completion of a specific asynchronous operation.

Description

This function waits for completion of the asynchronous operation specified in *arg*.

C/C++:

Prototype: `acc_wait(arg);`
Prototype (OpenACC 1.0 compatibility): `acc_async_wait(arg);`

Fortran:

Interface: `subroutine acc_wait(arg)`
`integer(acc_handle_kind) arg`
Interface (OpenACC 1.0 compatibility): `subroutine acc_async_wait(arg)`
`integer(acc_handle_kind) arg`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.11.

6.10 `acc_wait_all` – Waits for completion of all asynchronous operations.

Description

This function waits for the completion of all asynchronous operations.

C/C++:

Prototype: `acc_wait_all(void);`
Prototype (OpenACC 1.0 compatibility): `acc_async_wait_all(void);`

Fortran:

Interface:	`subroutine acc_wait_all()`
Interface (OpenACC 1.0 compatibility):	`subroutine acc_async_wait_all()`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.13.

6.11 `acc_wait_all_async` – Wait for completion of all asynchronous operations.

Description

This function enqueues a wait operation on the queue *async* for any and all asynchronous operations that have been previously enqueued on any queue.

C/C++:

Prototype:	`acc_wait_all_async(int async);`

Fortran:

Interface:	`subroutine acc_wait_all_async(async)` `integer(acc_handle_kind) async`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.14.

6.12 `acc_wait_async` – Wait for completion of asynchronous operations.

Description

This function enqueues a wait operation on queue *async* for any and all asynchronous operations enqueued on queue *arg*.

C/C++:

Prototype:	`acc_wait_async(int arg, int async);`

Fortran:

Interface:	`subroutine acc_wait_async(arg, async)` `integer(acc_handle_kind) arg, async`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.12.

6.13 `acc_init` – Initialize runtime for a specific device type.

Description

This function initializes the runtime for the device type specified in *devicetype*.

C/C++:

Prototype:	`acc_init(acc_device_t devicetype);`

Fortran:

Interface:	`subroutine acc_init(devicetype)` `integer(acc_device_kind) devicetype`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.7.

6.14 acc_shutdown – Shuts down the runtime for a specific device type.

Description
This function shuts down the runtime for the device type specified in *devicetype*.

C/C++:
Prototype: `acc_shutdown(acc_device_t devicetype);`

Fortran:
Interface: `subroutine acc_shutdown(devicetype)`
`integer(acc_device_kind) devicetype`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.8.

6.15 acc_on_device – Whether executing on a particular device

Description:
This function returns whether the program is executing on a particular device specified in *devicetype*. In C/C++ a non-zero value is returned to indicate the device is executing on the specified device type. In Fortran, `true` is returned. If the program is not executing on the specified device type C/C++ returns zero, while Fortran returns `false`.

Note that in GCC, depending on *devicetype*, the function call might be folded to a constant in the compiler; compile with `-fno-builtin-acc_on_device` if a run-time function is desired.

C/C++:
Prototype: `acc_on_device(acc_device_t devicetype);`

Fortran:
Interface: `function acc_on_device(devicetype)`
`integer(acc_device_kind) devicetype`
`logical acc_on_device`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.17.

6.16 acc_malloc – Allocate device memory.

Description
This function allocates *bytes* bytes of device memory. It returns the device address of the allocated memory.

C/C++:
Prototype: `d_void* acc_malloc(size_t bytes);`

Fortran:
Interface: `type(c_ptr) function acc_malloc(bytes)`
`integer(c_size_t), value :: bytes`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.18. openacc specification v3.3 (https://www.openacc.org), section 3.2.16.

6.17 `acc_free` – Free device memory.

Description

Free previously allocated device memory at the device address `data_dev`.

C/C++:

Prototype: `void acc_free(d_void *data_dev);`

Fortran:

Interface:
```
subroutine acc_free(data_dev)
type(c_ptr), value :: data_dev
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.19. openacc specification v3.3 (`https://www.openacc.org`), section 3.2.17.

6.18 `acc_copyin` – Allocate device memory and copy host memory to it.

Description

In C/C++, this function allocates *len* bytes of device memory and maps it to the specified host address in *a*. The device address of the newly allocated device memory is returned.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

C/C++:

Prototype: `void *acc_copyin(h_void *a, size_t len);`

Prototype: `void *acc_copyin_async(h_void *a, size_t len, int async);`

Fortran:

Interface:
```
subroutine acc_copyin(a)
type(*), dimension(..) :: a
```

Interface:
```
subroutine acc_copyin(a, len)
type(*), dimension(..) :: a
integer len
```

Interface:
```
subroutine acc_copyin_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```

Interface:
```
subroutine acc_copyin_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.20.

6.19 `acc_present_or_copyin` – If the data is not present on the device, allocate device memory and copy from host memory.

Description

This function tests if the host data specified by *a* and of length *len* is present or not. If it is not present, device memory is allocated and the host memory copied. The device address of the newly allocated device memory is returned.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

Note that `acc_present_or_copyin` and `acc_pcopyin` exist for backward compatibility with OpenACC 2.0; use Section 6.18 [acc_copyin], page 79, instead.

C/C++:

Prototype: `void *acc_present_or_copyin(h_void *a, size_t len);`
Prototype: `void *acc_pcopyin(h_void *a, size_t len);`

Fortran:

Interface:
```
subroutine acc_present_or_copyin(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_present_or_copyin(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_pcopyin(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_pcopyin(a, len)
type(*), dimension(..) :: a
integer len
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.20.

6.20 `acc_create` – Allocate device memory and map it to host memory.

Description

This function allocates device memory and maps it to host memory specified by the host address *a* with a length of *len* bytes. In C/C++, the function returns the device address of the allocated device memory.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

C/C++:

Prototype: `void *acc_create(h_void *a, size_t len);`
Prototype: `void *acc_create_async(h_void *a, size_t len, int async);`

Fortran:

Interface:
```
subroutine acc_create(a)
```

Interface:
```
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_create(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_create_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_create_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.21.

6.21 `acc_present_or_create` – If the data is not present on the device, allocate device memory and map it to host memory.

Description

This function tests if the host data specified by *a* and of length *len* is present or not. If it is not present, device memory is allocated and mapped to host memory. In C/C++, the device address of the newly allocated device memory is returned.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

Note that `acc_present_or_create` and `acc_pcreate` exist for backward compatibility with OpenACC 2.0; use Section 6.20 [acc_create], page 80, instead.

C/C++:

Prototype: `void *acc_present_or_create(h_void *a, size_t len)`
Prototype: `void *acc_pcreate(h_void *a, size_t len)`

Fortran:

Interface:
```
subroutine acc_present_or_create(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_present_or_create(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_pcreate(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_pcreate(a, len)
type(*), dimension(..) :: a
integer len
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.21.

6.22 `acc_copyout` – Copy device memory to host memory.

Description

This function copies mapped device memory to host memory which is specified by host address *a* for a length *len* bytes in C/C++.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

C/C++:

Prototype: `acc_copyout(h_void *a, size_t len);`
Prototype: `acc_copyout_async(h_void *a, size_t len, int async);`
Prototype: `acc_copyout_finalize(h_void *a, size_t len);`
Prototype: `acc_copyout_finalize_async(h_void *a, size_t len, int async);`

Fortran:

Interface:
```
subroutine acc_copyout(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_copyout(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_copyout_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_copyout_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_copyout_finalize(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_copyout_finalize(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_copyout_finalize_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_copyout_finalize_async(a, len,
async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.22.

6.23 acc_delete – Free device memory.

Description

This function frees previously allocated device memory specified by the device address *a* and the length of *len* bytes.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

C/C++:

Prototype: `acc_delete(h_void *a, size_t len);`
Prototype: `acc_delete_async(h_void *a, size_t len, int async);`
Prototype: `acc_delete_finalize(h_void *a, size_t len);`
Prototype: `acc_delete_finalize_async(h_void *a, size_t len, int async);`

Fortran:

Interface:
```
subroutine acc_delete(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_delete(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_delete_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_delete_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_delete_finalize(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_delete_finalize(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_delete_finalize_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_delete_finalize_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.23.

6.24 `acc_update_device` – Update device memory from mapped host memory.

Description

This function updates the device copy from the previously mapped host memory. The host memory is specified with the host address *a* and a length of *len* bytes.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

C/C++:

Prototype: `acc_update_device(h_void *a, size_t len);`
Prototype: `acc_update_device(h_void *a, size_t len, async);`

Fortran:

Interface:
```
subroutine acc_update_device(a)
type(*), dimension(..) :: a
```
Interface:
```
subroutine acc_update_device(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_update_device_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_update_device_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.24.

6.25 `acc_update_self` – Update host memory from mapped device memory.

Description

This function updates the host copy from the previously mapped device memory. The host memory is specified with the host address *a* and a length of *len* bytes.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes.

C/C++:

Prototype: `acc_update_self(h_void *a, size_t len);`
Prototype: `acc_update_self_async(h_void *a, size_t len, int async);`

Fortran:

Interface:
```
subroutine acc_update_self(a)
type(*), dimension(..) :: a
```

Interface:
```
subroutine acc_update_self(a, len)
type(*), dimension(..) :: a
integer len
```
Interface:
```
subroutine acc_update_self_async(a, async)
type(*), dimension(..) :: a
integer(acc_handle_kind) :: async
```
Interface:
```
subroutine acc_update_self_async(a, len, async)
type(*), dimension(..) :: a
integer len
integer(acc_handle_kind) :: async
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.25.

6.26 `acc_map_data` – Map previously allocated device memory to host memory.

Description

This function maps previously allocated device and host memory. The device memory is specified with the device address *data_dev*. The host memory is specified with the host address *data_arg* and a length of *bytes*.

C/C++:

Prototype:
```
void acc_map_data(h_void *data_arg, d_void
*data_dev, size_t bytes);
```

Fortran:

Interface:
```
subroutine acc_map_data(data_arg, data_dev, bytes)
type(*), dimension(*) :: data_arg
type(c_ptr), value :: data_dev
integer(c_size_t), value :: bytes
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.26. OpenACC specification v3.3 (`https://www.openacc.org`), section 3.2.21.

6.27 `acc_unmap_data` – Unmap device memory from host memory.

Description

This function unmaps previously mapped device and host memory. The latter specified by *data_arg*.

C/C++:

Prototype:
```
void acc_unmap_data(h_void *data_arg);
```

Fortran:

Interface:
```
subroutine acc_unmap_data(data_arg)
type(*), dimension(*) :: data_arg
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.27. OpenACC specification v3.3 (`https://www.openacc.org`), section 3.2.22.

6.28 acc_deviceptr – Get device pointer associated with specific host address.

Description

This function returns the device address that has been mapped to the host address specified by *data_arg*.

C/C++:

Prototype: `void *acc_deviceptr(h_void *data_arg);`

Fortran:

Interface: `type(c_ptr) function acc_deviceptr(data_arg)`
`type(*), dimension(*) :: data_arg`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.28. OpenACC specification v3.3 (https://www.openacc.org), section 3.2.23.

6.29 acc_hostptr – Get host pointer associated with specific device address.

Description

This function returns the host address that has been mapped to the device address specified by *data_dev*.

C/C++:

Prototype: `void *acc_hostptr(d_void *data_dev);`

Fortran:

Interface: `type(c_ptr) function acc_hostptr(data_dev)`
`type(c_ptr), value :: data_dev`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.29. OpenACC specification v3.3 (https://www.openacc.org), section 3.2.24.

6.30 acc_is_present – Indicate whether host variable / array is present on device.

Description

This function indicates whether the specified host address in *a* and a length of *len* bytes is present on the device. In C/C++, a non-zero value is returned to indicate the presence of the mapped memory on the device. A zero is returned to indicate the memory is not mapped on the device.

In Fortran, two (2) forms are supported. In the first form, *a* specifies a contiguous array section. The second form *a* specifies a variable or array element and *len* specifies the length in bytes. If the host memory is mapped to device memory, then a `true` is returned. Otherwise, a `false` is return to indicate the mapped memory is not present.

C/C++:

Prototype: `int acc_is_present(h_void *a, size_t len);`

Fortran:

Interface: `function acc_is_present(a)`
`type(*), dimension(..) :: a`
`logical acc_is_present`
Interface: `function acc_is_present(a, len)`
`type(*), dimension(..) :: a`
`integer len`
`logical acc_is_present`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.30.

6.31 `acc_memcpy_to_device` – Copy host memory to device memory.

Description

This function copies host memory specified by host address of *data_host_src* to device memory specified by the device address *data_dev_dest* for a length of *bytes* bytes.

C/C++:

Prototype: `void acc_memcpy_to_device(d_void* data_dev_dest,`
`h_void* data_host_src, size_t bytes);`
Prototype: `void acc_memcpy_to_device_async(d_void* data_dev_`
`dest,`
`h_void* data_host_src, size_t bytes, int async_arg);`

Fortran:

Interface: `subroutine acc_memcpy_to_device(data_dev_dest, &`
`data_host_src, bytes)`
Interface: `subroutine acc_memcpy_to_device_async(data_dev_`
`dest, &`
`data_host_src, bytes, async_arg)`
`type(c_ptr), value :: data_dev_dest`
`type(*), dimension(*) :: data_host_src`
`integer(c_size_t), value :: bytes`
`integer(acc_handle_kind), value :: async_arg`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.31
OpenACC specification v3.3 (`https://www.openacc.org`), section 3.2.26.

6.32 `acc_memcpy_from_device` – Copy device memory to host memory.

Description

This function copies device memory specified by device address of *data_dev_src* to host memory specified by the host address *data_host_dest* for a length of *bytes* bytes.

C/C++:

Prototype: `void acc_memcpy_from_device(h_void* data_host_dest, d_void* data_dev_src, size_t bytes);`

Prototype: `void acc_memcpy_from_device_async(h_void* data_host_dest, d_void* data_dev_src, size_t bytes, int async_arg);`

Fortran:

Interface: `subroutine acc_memcpy_from_device(data_host_dest, & data_dev_src, bytes)`

Interface: `subroutine acc_memcpy_from_device_async(data_host_dest, & data_dev_src, bytes, async_arg)`

```
type(*), dimension(*) :: data_host_dest
type(c_ptr), value :: data_dev_src
integer(c_size_t), value :: bytes
integer(acc_handle_kind), value :: async_arg
```

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.32. OpenACC specification v3.3 (`https://www.openacc.org`), section 3.2.27.

6.33 `acc_memcpy_device` – Copy memory within a device.

Description

This function copies device memory from one memory location to another on the current device. It copies *bytes* bytes of data from the device address, specified by *data_dev_src*, to the device address *data_dev_dest*. The `_async` version performs the transfer asynchronously using the queue associated with *async_arg*.

C/C++:

Prototype: `void acc_memcpy_device(d_void* data_dev_dest, d_void* data_dev_src, size_t bytes);`

Prototype: `void acc_memcpy_device_async(d_void* data_dev_dest, d_void* data_dev_src, size_t bytes, int async_arg);`

Fortran:

Interface: `subroutine acc_memcpy_device(data_dev_dest, & data_dev_src, bytes)`

Interface: `subroutine acc_memcpy_device_async(data_dev_dest, & data_dev_src, bytes, async_arg)`

```
type(c_ptr), value :: data_dev_dest
type(c_ptr), value :: data_dev_src
integer(c_size_t), value :: bytes
integer(acc_handle_kind), value :: async_arg
```

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.33. OpenACC specification v3.3 (https://www.openacc.org), section 3.2.28.

6.34 acc_attach – Let device pointer point to device-pointer target.

Description
This function updates a pointer on the device from pointing to a host-pointer address to pointing to the corresponding device data.

C/C++:

Prototype: `void acc_attach(h_void **ptr_addr);`
Prototype: `void acc_attach_async(h_void **ptr_addr, int async);`

Fortran:

Interface: `subroutine acc_attach(ptr_addr)`
Interface: `subroutine acc_attach_async(ptr_addr, async_arg)`
`type(*), dimension(..) :: ptr_addr`
`integer(acc_handle_kind), value :: async_arg`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.34. OpenACC specification v3.3 (https://www.openacc.org), section 3.2.29.

6.35 acc_detach – Let device pointer point to host-pointer target.

Description
This function updates a pointer on the device from pointing to a device-pointer address to pointing to the corresponding host data.

C/C++:

Prototype: `void acc_detach(h_void **ptr_addr);`
Prototype: `void acc_detach_async(h_void **ptr_addr, int async);`
Prototype: `void acc_detach_finalize(h_void **ptr_addr);`
Prototype: `void acc_detach_finalize_async(h_void **ptr_addr, int async);`

Fortran:

Interface: `subroutine acc_detach(ptr_addr)`
Interface: `subroutine acc_detach_async(ptr_addr, async_arg)`
Interface: `subroutine acc_detach_finalize(ptr_addr)`
Interface: `subroutine acc_detach_finalize_async(ptr_addr, async_arg)`
`type(*), dimension(..) :: ptr_addr`
`integer(acc_handle_kind), value :: async_arg`

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.35. OpenACC specification v3.3 (https://www.openacc.org), section 3.2.29.

6.36 `acc_get_current_cuda_device` – Get CUDA device handle.

Description

This function returns the CUDA device handle. This handle is the same as used by the CUDA Runtime or Driver API's.

C/C++:

Prototype: `void *acc_get_current_cuda_device(void);`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section A.2.1.1.

6.37 `acc_get_current_cuda_context` – Get CUDA context handle.

Description

This function returns the CUDA context handle. This handle is the same as used by the CUDA Runtime or Driver API's.

C/C++:

Prototype: `void *acc_get_current_cuda_context(void);`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section A.2.1.2.

6.38 `acc_get_cuda_stream` – Get CUDA stream handle.

Description

This function returns the CUDA stream handle for the queue *async*. This handle is the same as used by the CUDA Runtime or Driver API's.

C/C++:

Prototype: `void *acc_get_cuda_stream(int async);`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section A.2.1.3.

6.39 `acc_set_cuda_stream` – Set CUDA stream handle.

Description

This function associates the stream handle specified by *stream* with the queue *async*.

This cannot be used to change the stream handle associated with `acc_async_sync`.

The return value is not specified.

C/C++:

Prototype: `int acc_set_cuda_stream(int async, void *stream);`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section A.2.1.4.

6.40 `acc_prof_register` – Register callbacks.

Description:
This function registers callbacks.

C/C++:
Prototype: `void acc_prof_register (acc_event_t, acc_prof_callback, acc_register_t);`

See also: Chapter 10 [OpenACC Profiling Interface], page 101,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

6.41 `acc_prof_unregister` – Unregister callbacks.

Description:
This function unregisters callbacks.

C/C++:
Prototype: `void acc_prof_unregister (acc_event_t, acc_prof_callback, acc_register_t);`

See also: Chapter 10 [OpenACC Profiling Interface], page 101,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

6.42 `acc_prof_lookup` – Obtain inquiry functions.

Description:
Function to obtain inquiry functions.

C/C++:
Prototype: `acc_query_fn acc_prof_lookup (const char *);`

See also: Chapter 10 [OpenACC Profiling Interface], page 101,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

6.43 `acc_register_library` – Library registration.

Description:
Function for library registration.

C/C++:
Prototype: `void acc_register_library (acc_prof_reg, acc_prof_reg, acc_prof_lookup_func);`

See also: Chapter 10 [OpenACC Profiling Interface], page 101, Section 7.3 [ACC_PROFLIB], page 93,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

7 OpenACC Environment Variables

The variables ACC_DEVICE_TYPE and ACC_DEVICE_NUM are defined by section 4 of the OpenACC specification in version 2.0. The variable ACC_PROFLIB is defined by section 4 of the OpenACC specification in version 2.6.

7.1 ACC_DEVICE_TYPE

Description:

Control the default device type to use when executing compute regions. If unset, the code can be run on any device type, favoring a non-host device type.

Supported values in GCC (if compiled in) are

- host
- nvidia
- radeon

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 4.1.

7.2 ACC_DEVICE_NUM

Description:

Control which device, identified by device number, is the default device. The value must be a nonnegative integer less than the number of devices. If unset, device number zero is used.

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 4.2.

7.3 ACC_PROFLIB

Description:

Semicolon-separated list of dynamic libraries that are loaded as profiling libraries. Each library must provide at least the acc_register_library routine. Each library file is found as described by the documentation of dlopen of your operating system.

See also: Section 6.43 [acc_register_library], page 91, Chapter 10 [OpenACC Profiling Interface], page 101,

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 4.3.

8 CUDA Streams Usage

This applies to the `nvptx` plugin only.

The library provides elements that perform asynchronous movement of data and asynchronous operation of computing constructs. This asynchronous functionality is implemented by making use of CUDA streams[1].

The primary means by that the asynchronous functionality is accessed is through the use of those OpenACC directives which make use of the `async` and `wait` clauses. When the `async` clause is first used with a directive, it creates a CUDA stream. If an `async-argument` is used with the `async` clause, then the stream is associated with the specified `async-argument`.

Following the creation of an association between a CUDA stream and the `async-argument` of an `async` clause, both the `wait` clause and the `wait` directive can be used. When either the clause or directive is used after stream creation, it creates a rendezvous point whereby execution waits until all operations associated with the `async-argument`, that is, stream, have completed.

Normally, the management of the streams that are created as a result of using the `async` clause, is done without any intervention by the caller. This implies the association between the `async-argument` and the CUDA stream is maintained for the lifetime of the program. However, this association can be changed through the use of the library function `acc_set_cuda_stream`. When the function `acc_set_cuda_stream` is called, the CUDA stream that was originally associated with the `async` clause is destroyed. Caution should be taken when changing the association as subsequent references to the `async-argument` refer to a different CUDA stream.

---

[1] See "Stream Management" in "CUDA Driver API", TRM-06703-001, Version 5.5, for additional information

9 OpenACC Library Interoperability

9.1 Introduction

The OpenACC library uses the CUDA Driver API, and may interact with programs that use the Runtime library directly, or another library based on the Runtime library, e.g., CUBLAS[1]. This chapter describes the use cases and what changes are required in order to use both the OpenACC library and the CUBLAS and Runtime libraries within a program.

9.2 First invocation: NVIDIA CUBLAS library API

In this first use case (see below), a function in the CUBLAS library is called prior to any of the functions in the OpenACC library. More specifically, the function `cublasCreate()`.

When invoked, the function initializes the library and allocates the hardware resources on the host and the device on behalf of the caller. Once the initialization and allocation has completed, a handle is returned to the caller. The OpenACC library also requires initialization and allocation of hardware resources. Since the CUBLAS library has already allocated the hardware resources for the device, all that is left to do is to initialize the OpenACC library and acquire the hardware resources on the host.

Prior to calling the OpenACC function that initializes the library and allocate the host hardware resources, you need to acquire the device number that was allocated during the call to `cublasCreate()`. The invoking of the runtime library function `cudaGetDevice()` accomplishes this. Once acquired, the device number is passed along with the device type as parameters to the OpenACC library function `acc_set_device_num()`.

Once the call to `acc_set_device_num()` has completed, the OpenACC library uses the context that was created during the call to `cublasCreate()`. In other words, both libraries share the same context.

```
/* Create the handle */
s = cublasCreate(&h);
if (s != CUBLAS_STATUS_SUCCESS)
{
    fprintf(stderr, "cublasCreate failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Get the device number */
e = cudaGetDevice(&dev);
if (e != cudaSuccess)
{
    fprintf(stderr, "cudaGetDevice failed %d\n", e);
    exit(EXIT_FAILURE);
}

/* Initialize OpenACC library and use device 'dev' */
acc_set_device_num(dev, acc_device_nvidia);
```

Use Case 1

[1] See section 2.26, "Interactions with the CUDA Driver API" in "CUDA Runtime API", Version 5.5, and section 2.27, "VDPAU Interoperability", in "CUDA Driver API", TRM-06703-001, Version 5.5, for additional information on library interoperability.

9.3 First invocation: OpenACC library API

In this second use case (see below), a function in the OpenACC library is called prior to any of the functions in the CUBLAS library. More specifically, the function `acc_set_device_num()`.

In the use case presented here, the function `acc_set_device_num()` is used to both initialize the OpenACC library and allocate the hardware resources on the host and the device. In the call to the function, the call parameters specify which device to use and what device type to use, i.e., `acc_device_nvidia`. It should be noted that this is but one method to initialize the OpenACC library and allocate the appropriate hardware resources. Other methods are available through the use of environment variables and these is discussed in the next section.

Once the call to `acc_set_device_num()` has completed, other OpenACC functions can be called as seen with multiple calls being made to `acc_copyin()`. In addition, calls can be made to functions in the CUBLAS library. In the use case a call to `cublasCreate()` is made subsequent to the calls to `acc_copyin()`. As seen in the previous use case, a call to `cublasCreate()` initializes the CUBLAS library and allocates the hardware resources on the host and the device. However, since the device has already been allocated, `cublasCreate()` only initializes the CUBLAS library and allocates the appropriate hardware resources on the host. The context that was created as part of the OpenACC initialization is shared with the CUBLAS library, similarly to the first use case.

```
dev = 0;

acc_set_device_num(dev, acc_device_nvidia);

/* Copy the first set to the device */
d_X = acc_copyin(&h_X[0], N * sizeof (float));
if (d_X == NULL)
{
    fprintf(stderr, "copyin error h_X\n");
    exit(EXIT_FAILURE);
}

/* Copy the second set to the device */
d_Y = acc_copyin(&h_Y1[0], N * sizeof (float));
if (d_Y == NULL)
{
    fprintf(stderr, "copyin error h_Y1\n");
    exit(EXIT_FAILURE);
}

/* Create the handle */
s = cublasCreate(&h);
if (s != CUBLAS_STATUS_SUCCESS)
{
    fprintf(stderr, "cublasCreate failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Perform saxpy using CUBLAS library function */
s = cublasSaxpy(h, N, &alpha, d_X, 1, d_Y, 1);
if (s != CUBLAS_STATUS_SUCCESS)
{
```

```
        fprintf(stderr, "cublasSaxpy failed %d\n", s);
        exit(EXIT_FAILURE);
    }

    /* Copy the results from the device */
    acc_memcpy_from_device(&h_Y1[0], d_Y, N * sizeof (float));
```

Use Case 2

9.4 OpenACC library and environment variables

There are two environment variables associated with the OpenACC library that may be used to control the device type and device number: `ACC_DEVICE_TYPE` and `ACC_DEVICE_NUM`, respectively. These two environment variables can be used as an alternative to calling `acc_set_device_num()`. As seen in the second use case, the device type and device number were specified using `acc_set_device_num()`. If however, the aforementioned environment variables were set, then the call to `acc_set_device_num()` would not be required.

The use of the environment variables is only relevant when an OpenACC function is called prior to a call to `cudaCreate()`. If `cudaCreate()` is called prior to a call to an OpenACC function, then you must call `acc_set_device_num()`[2]

[2] More complete information about `ACC_DEVICE_TYPE` and `ACC_DEVICE_NUM` can be found in sections 4.1 and 4.2 of the OpenACC (`https://www.openacc.org`) Application Programming Interface", Version 2.6.

10 OpenACC Profiling Interface

10.1 Implementation Status and Implementation-Defined Behavior

We're implementing the OpenACC Profiling Interface as defined by the OpenACC 2.6 specification. We're clarifying some aspects here as *implementation-defined behavior*, while they're still under discussion within the OpenACC Technical Committee.

This implementation is tuned to keep the performance impact as low as possible for the (very common) case that the Profiling Interface is not enabled. This is relevant, as the Profiling Interface affects all the *hot* code paths (in the target code, not in the offloaded code). Users of the OpenACC Profiling Interface can be expected to understand that performance is impacted to some degree once the Profiling Interface is enabled: for example, because of the *runtime* (libgomp) calling into a third-party *library* for every event that has been registered.

We're not yet accounting for the fact that *OpenACC events may occur during event processing*. We just handle one case specially, as required by CUDA 9.0 `nvprof`, that `acc_get_device_type` (Section 6.3 [acc_get_device_type], page 73)) may be called from `acc_ev_device_init_start`, `acc_ev_device_init_end` callbacks.

We're not yet implementing initialization via a `acc_register_library` function that is either statically linked in, or dynamically via `LD_PRELOAD`. Initialization via `acc_register_library` functions dynamically loaded via the `ACC_PROFLIB` environment variable does work, as does directly calling `acc_prof_register`, `acc_prof_unregister`, `acc_prof_lookup`.

As currently there are no inquiry functions defined, calls to `acc_prof_lookup` always returns `NULL`.

There aren't separate *start*, *stop* events defined for the event types `acc_ev_create`, `acc_ev_delete`, `acc_ev_alloc`, `acc_ev_free`. It's not clear if these should be triggered before or after the actual device-specific call is made. We trigger them after.

Remarks about data provided to callbacks:

`acc_prof_info.event_type`
: It's not clear if for *nested* event callbacks (for example, `acc_ev_enqueue_launch_start` as part of a parent compute construct), this should be set for the nested event (`acc_ev_enqueue_launch_start`), or if the value of the parent construct should remain (`acc_ev_compute_construct_start`). In this implementation, the value generally corresponds to the innermost nested event type.

`acc_prof_info.device_type`

- For `acc_ev_compute_construct_start`, and in presence of an `if` clause with *false* argument, this still refers to the offloading device type. It's not clear if that's the expected behavior.
- Complementary to the item before, for `acc_ev_compute_construct_end`, this is set to `acc_device_host` in presence of an `if` clause with *false* argument. It's not clear if that's the expected behavior.

`acc_prof_info.thread_id`
: Always `-1`; not yet implemented.

`acc_prof_info.async`
- Not yet implemented correctly for `acc_ev_compute_construct_start`.
- In a compute construct, for host-fallback execution/`acc_device_host` it always is `acc_async_sync`. It is unclear if that is the expected behavior.
- For `acc_ev_device_init_start` and `acc_ev_device_init_end`, it will always be `acc_async_sync`. It is unclear if that is the expected behavior.

`acc_prof_info.async_queue`
: There is no *limited number of asynchronous queues* in libgomp. This always has the same value as `acc_prof_info.async`.

`acc_prof_info.src_file`
: Always `NULL`; not yet implemented.

`acc_prof_info.func_name`
: Always `NULL`; not yet implemented.

`acc_prof_info.line_no`
: Always `-1`; not yet implemented.

`acc_prof_info.end_line_no`
: Always `-1`; not yet implemented.

`acc_prof_info.func_line_no`
: Always `-1`; not yet implemented.

`acc_prof_info.func_end_line_no`
: Always `-1`; not yet implemented.

`acc_event_info.event_type`, `acc_event_info.*.event_type`
: Relating to `acc_prof_info.event_type` discussed above, in this implementation, this will always be the same value as `acc_prof_info.event_type`.

`acc_event_info.*.parent_construct`
- Will be `acc_construct_parallel` for all OpenACC compute constructs as well as many OpenACC Runtime API calls; should be the one matching the actual construct, or `acc_construct_runtime_api`, respectively.
- Will be `acc_construct_enter_data` or `acc_construct_exit_data` when processing variable mappings specified in OpenACC *declare* directives; should be `acc_construct_declare`.
- For implicit `acc_ev_device_init_start`, `acc_ev_device_init_end`, and explicit as well as implicit `acc_ev_alloc`, `acc_ev_free`, `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`, `acc_ev_enqueue_download_start`, and `acc_ev_enqueue_download_end`, will be `acc_construct_parallel`; should reflect the real parent construct.

`acc_event_info.*.implicit`
: For `acc_ev_alloc`, `acc_ev_free`, `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`, `acc_ev_enqueue_download_start`, and

acc_ev_enqueue_download_end, this currently will be 1 also for explicit usage.

acc_event_info.data_event.var_name
: Always NULL; not yet implemented.

acc_event_info.data_event.host_ptr
: For acc_ev_alloc, and acc_ev_free, this is always NULL.

typedef union acc_api_info
: . . . as printed in *5.2.3. Third Argument: API-Specific Information*. This should obviously be typedef *struct* acc_api_info.

acc_api_info.device_api
: Possibly not yet implemented correctly for acc_ev_compute_construct_start, acc_ev_device_init_start, acc_ev_device_init_end: will always be acc_device_api_none for these event types. For acc_ev_enter_data_start, it will be acc_device_api_none in some cases.

acc_api_info.device_type
: Always the same as acc_prof_info.device_type.

acc_api_info.vendor
: Always -1; not yet implemented.

acc_api_info.device_handle
: Always NULL; not yet implemented.

acc_api_info.context_handle
: Always NULL; not yet implemented.

acc_api_info.async_handle
: Always NULL; not yet implemented.

Remarks about certain event types:

acc_ev_device_init_start, acc_ev_device_init_end

- When a compute construct triggers implicit acc_ev_device_init_start and acc_ev_device_init_end events, they currently aren't *nested within* the corresponding acc_ev_compute_construct_start and acc_ev_compute_construct_end, but they're currently observed *before* acc_ev_compute_construct_start. It's not clear what to do: the standard asks us provide a lot of details to the acc_ev_compute_construct_start callback, without (implicitly) initializing a device before?
- Callbacks for these event types will not be invoked for calls to the acc_set_device_type and acc_set_device_num functions. It's not clear if they should be.

acc_ev_enter_data_start, acc_ev_enter_data_end, acc_ev_exit_data_start, acc_ev_exit_data_end

- Callbacks for these event types will also be invoked for OpenACC *host_data* constructs. It's not clear if they should be.

- Callbacks for these event types will also be invoked when processing variable mappings specified in OpenACC *declare* directives. It's not clear if they should be.

Callbacks for the following event types will be invoked, but dispatch and information provided therein has not yet been thoroughly reviewed:

- `acc_ev_alloc`
- `acc_ev_free`
- `acc_ev_update_start`, `acc_ev_update_end`
- `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`
- `acc_ev_enqueue_download_start`, `acc_ev_enqueue_download_end`

During device initialization, and finalization, respectively, callbacks for the following event types will not yet be invoked:

- `acc_ev_alloc`
- `acc_ev_free`

Callbacks for the following event types have not yet been implemented, so currently won't be invoked:

- `acc_ev_device_shutdown_start`, `acc_ev_device_shutdown_end`
- `acc_ev_runtime_shutdown`
- `acc_ev_create`, `acc_ev_delete`
- `acc_ev_wait_start`, `acc_ev_wait_end`

For the following runtime library functions, not all expected callbacks will be invoked (mostly concerning implicit device initialization):

- `acc_get_num_devices`
- `acc_set_device_type`
- `acc_get_device_type`
- `acc_set_device_num`
- `acc_get_device_num`
- `acc_init`
- `acc_shutdown`

Aside from implicit device initialization, for the following runtime library functions, no callbacks will be invoked for shared-memory offloading devices (it's not clear if they should be):

- `acc_malloc`
- `acc_free`
- `acc_copyin`, `acc_present_or_copyin`, `acc_copyin_async`
- `acc_create`, `acc_present_or_create`, `acc_create_async`
- `acc_copyout`, `acc_copyout_async`, `acc_copyout_finalize`, `acc_copyout_finalize_async`
- `acc_delete`, `acc_delete_async`, `acc_delete_finalize`, `acc_delete_finalize_async`

- `acc_update_device`, `acc_update_device_async`
- `acc_update_self`, `acc_update_self_async`
- `acc_map_data`, `acc_unmap_data`
- `acc_memcpy_to_device`, `acc_memcpy_to_device_async`
- `acc_memcpy_from_device`, `acc_memcpy_from_device_async`

11 OpenMP-Implementation Specifics

11.1 Implementation-defined ICV Initialization

affinity-format-var	See Section 4.2 [OMP_AFFINITY_FORMAT], page 60.
def-allocator-var	See Section 4.1 [OMP_ALLOCATOR], page 59.
max-active-levels-var	See Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 62.
dyn-var	See Section 4.7 [OMP_DYNAMIC], page 62.
nthreads-var	See Section 4.12 [OMP_NUM_THREADS], page 63.
num-devices-var	Number of non-host devices found by GCC's run-time library
num-procs-var	The number of CPU cores on the initial device, except that affinity settings might lead to a smaller number. On non-host devices, the value of the *nthreads-var* ICV.
place-partition-var	See Section 4.14 [OMP_PLACES], page 64.
run-sched-var	See Section 4.16 [OMP_SCHEDULE], page 66.
stacksize-var	See Section 4.15 [OMP_STACKSIZE], page 65.
thread-limit-var	See Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 66,
wait-policy-var	See Section 4.20 [OMP_WAIT_POLICY], page 67, and Section 4.24 [GOMP_SPINCOUNT], page 68,

11.2 OpenMP Context Selectors

`vendor` is always `gnu`. References are to the GCC manual.

For the host compiler, `kind` always matches `host`, `cpu` and `any`; for the offloading architectures AMD GCN and Nvidia PTX, `kind` always matches `nohost`, `gpu` and `any`. For the x86 family of computers, AMD GCN and Nvidia PTX the following traits are supported in addition; while OpenMP is supported on more architectures, GCC currently does not match any `arch` or `isa` traits for those.

Note that for AMD GCN and Nvidia PTX, the `isa` is currently an exact match between the compiled-for ISA architecture and the matching `isa` trait value. For instance, when compiling for `gfx942`, the `isa` trait value `gfx9-4-generic` is not matched and, likewise, `gfx942` is not matched when compiling for its generic architecture.

`arch`	`isa`
`x86`, `x86_64`, `i386`, `i486`, `i586`, `i686`, `ia32`	See `-m...` flags in "x86 Options" (without `-m`)
`amdgcn`, `gcn`	See `-march=` in "AMD GCN Options"
`nvptx`, `nvptx64`	See `-march=` in "Nvidia PTX Options"

11.3 Memory allocation

The description below applies to:

- Explicit use of the OpenMP API routines, see Section 3.12 [Memory Management Routines], page 50.

- The `allocate` clause, except when the `allocator` modifier is a constant expression with value `omp_default_mem_alloc` and no `align` modifier has been specified. (In that case, the normal `malloc` allocation is used.)
- The `allocate` directive for variables in static memory; while the alignment is honored, the normal static memory is used.
- Using the `allocate` directive for automatic/stack variables, except when the `allocator` clause is a constant expression with value `omp_default_mem_alloc` and no `align` clause has been specified. (In that case, the normal allocation is used: stack allocation and, sometimes for Fortran, also `malloc` [depending on flags such as `-fstack-arrays`].)
- In Fortran, the `allocators` directive and the executable `allocate` directive for Fortran pointers and allocatables is supported, but requires that files containing those directives has to be compiled with `-fopenmp-allocators`. Additionally, all files that might explicitly or implicitly deallocate memory allocated that way must also be compiled with that option.
- The used alignment is the maximum of the value the `align` clause and the alignment of the type after honoring, if present, the `aligned` (`GNU::aligned`) attribute and C's `_Alignas` and C++'s `alignas`. However, the `align` clause of the `allocate` directive has no effect on the value of C's `_Alignof` and C++'s `alignof`.

GCC supports the following predefined allocators and predefined memory spaces:

Predefined allocators	**Associated predefined memory spaces**
omp_default_mem_alloc	omp_default_mem_space
omp_large_cap_mem_alloc	omp_large_cap_mem_space
omp_const_mem_alloc	omp_const_mem_space
omp_high_bw_mem_alloc	omp_high_bw_mem_space
omp_low_lat_mem_alloc	omp_low_lat_mem_space
omp_cgroup_mem_alloc	omp_low_lat_mem_space (implementation defined)
omp_pteam_mem_alloc	omp_low_lat_mem_space (implementation defined)
omp_thread_mem_alloc	omp_low_lat_mem_space (implementation defined)
ompx_gnu_pinned_mem_alloc	omp_default_mem_space (GNU extension)
ompx_gnu_managed_mem_alloc	ompx_gnu_managed_mem_space (GNU extension)

Each predefined allocator, including `omp_null_allocator`, has a corresponding allocator class template that meet the C++ allocator completeness requirements. These are located in the `omp::allocator` namespace, and the `ompx::allocator` namespace for gnu extensions. This allows the allocator-aware C++ standard library containers to use OpenMP allocation routines; for instance:

```
std::vector<int, omp::allocator::cgroup_mem<int>> vec;
```

The following allocator templates are supported:

Predefined allocators	**Associated allocator template**
omp_null_allocator	omp::allocator::null_allocator

omp_default_mem_alloc	omp::allocator::default_mem
omp_large_cap_mem_alloc	omp::allocator::large_cap_mem
omp_const_mem_alloc	omp::allocator::const_mem
omp_high_bw_mem_alloc	omp::allocator::high_bw_mem
omp_low_lat_mem_alloc	omp::allocator::low_lat_mem
omp_cgroup_mem_alloc	omp::allocator::cgroup_mem
omp_pteam_mem_alloc	omp::allocator::pteam_mem
omp_thread_mem_alloc	omp::allocator::thread_mem
ompx_gnu_pinned_mem_alloc	ompx::allocator::gnu_pinned_mem
ompx_gnu_managed_mem_alloc	ompx::allocator::gnu_managed_mem

The following traits are available when constructing a new allocator; if a trait is not specified or with the value `default`, the specified default value is used for that trait. The predefined allocators use the default values of each trait, except that the `omp_cgroup_mem_alloc`, `omp_pteam_mem_alloc`, and `omp_thread_mem_alloc` allocators have the `access` trait set to `cgroup`, `pteam`, and `thread`, respectively. For each trait, a named constant prefixed by `omp_atk_` exists; for each non-numeric value, a named constant prefixed by `omp_atv_` exists.

Trait	**Allowed values**	**Default value**
`sync_hint`	`contended`, `uncontended`, `serialized`, `private`	`contended`
`alignment`	Positive integer being a power of two	1 byte
`access`	`all`, `cgroup`, `pteam`, `thread`	`all`
`pool_size`	Positive integer (bytes)	See below.
`fallback`	`default_mem_fb`, `null_fb`, `abort_fb`, `allocator_fb`	See below
`fb_data`	*allocator handle*	(none)
`pinned`	`true`, `false`	See below
`partition`	`environment`, `nearest`, `blocked`, `interleaved`	`environment`

For the `fallback` trait, the default value is `null_fb` for the `omp_default_mem_alloc` allocator and any allocator that is associated with device memory; for all other allocators, it is `default_mem_fb` by default.

For the `pinned` trait, the default value is `true` for predefined allocator `ompx_gnu_pinned_mem_alloc` (a GNU extension), and `false` for all others.

The following description applies to the initial device (the host) and largely also to non-host devices; for the latter, also see Chapter 12 [Offload-Target Specifics], page 113.

For the memory spaces, the following applies:

- `omp_default_mem_space` is supported
- `omp_const_mem_space` maps to `omp_default_mem_space`
- `omp_low_lat_mem_space` is only available on supported devices, and maps to `omp_default_mem_space` otherwise.
- `omp_large_cap_mem_space` maps to `omp_default_mem_space`, unless the memkind library is available
- `omp_high_bw_mem_space` maps to `omp_default_mem_space`, unless the memkind library is available

- `ompx_gnu_managed_mem_space` is a GNU extension that provides managed memory accessible by both host and devices. The memory space is available if the offload target associated with the *default-device-var* ICV supports managed memory (see Chapter 12 [Offload-Target Specifics], page 113). This memory is accessible by both the host and the device at the same address, so it need not be mapped with `map` clauses. Instead, use the `is_device_ptr` clause or `has_device_addr` clause to indicate that the pointer is already accessible on the device. If managed memory is not supported by the default device, as configured at the moment the allocator is called, then the allocator will use the fall-back setting. If the default device is configured differently when the memory is freed, via `omp_free` or `omp_realloc`, the result may be undefined.

On Linux systems, where the memkind library (`https://github.com/memkind/memkind`) (`libmemkind.so.0`) is available at runtime and the respective memkind kind is supported, it is used when creating memory allocators requesting

- the `partition` trait `interleaved` except when the memory space is `omp_large_cap_mem_space` (uses `MEMKIND_HBW_INTERLEAVE`)
- the memory space is `omp_high_bw_mem_space` (uses `MEMKIND_HBW_PREFERRED`)
- the memory space is `omp_large_cap_mem_space` (uses `MEMKIND_DAX_KMEM_ALL` or, if not available, `MEMKIND_DAX_KMEM`)

On Linux systems, where the numa library (`https://github.com/numactl/numactl`) (`libnuma.so.1`) is available at runtime, it used when creating memory allocators requesting

- the `partition` trait `nearest`, except when both the libmemkind library is available and the memory space is either `omp_large_cap_mem_space` or `omp_high_bw_mem_space`

Note that the numa library will round up the allocation size to a multiple of the system page size; therefore, consider using it only with large data or by sharing allocations via the `pool_size` trait. Furthermore, the Linux kernel does not guarantee that an allocation will always be on the nearest NUMA node nor that after reallocation the same node will be used. Note additionally that, on Linux, the default setting of the memory placement policy is to use the current node; therefore, unless the memory placement policy has been overridden, the `partition` trait `environment` (the default) will be effectively a `nearest` allocation.

Additional notes regarding the traits:

- The `pinned` trait is supported on Linux hosts, but is usually subject to the OS `ulimit/rlimit` locked memory settings (see Chapter 12 [Offload-Target Specifics], page 113, for exceptions). The implementation uses a custom allocator to try to use as few memory pages as possible. At present, freed pinned memory is not returned to the OS (although it may be reused by subsequent pinned allocations).
- The default for the `pool_size` trait is no pool and for every (re)allocation the associated library routine is called, which might internally use a memory pool. Currently, the same applies when a `pool_size` has been specified, except that once allocations exceed the the pool size, the action of the `fallback` trait applies.
- For the `partition` trait, the partition part size will be the same as the requested size (i.e. `interleaved` or `blocked` has no effect), except for `interleaved` when the memkind library is available. Furthermore, for `nearest` and unless the numa library is available, the memory might not be on the same NUMA node as thread that allocated

the memory; on Linux, this is in particular the case when the memory placement policy is set to preferred.

- The `access` trait has no effect such that memory is always accessible by all threads. (Except on supported no-host devices.)
- The `sync_hint` trait has no effect.

See also: Chapter 12 [Offload-Target Specifics], page 113,

12 Offload-Target Specifics

The following sections present notes on the offload-target specifics

12.1 AMD Radeon (GCN)

On the hardware side, there is the hierarchy (fine to coarse):

- work item (thread)
- wavefront
- work group
- compute unit (CU)

All OpenMP and OpenACC levels are used, i.e.

- OpenMP's simd and OpenACC's vector map to work items (thread)
- OpenMP's threads ("parallel") and OpenACC's workers map to wavefronts
- OpenMP's teams and OpenACC's gang use a threadpool with the size of the number of teams or gangs, respectively.

The used sizes are

- Number of teams is the specified `num_teams` (OpenMP) or `num_gangs` (OpenACC) or otherwise the number of CU. It is limited by two times the number of CU.
- Number of wavefronts is 4 for gfx900 and 16 otherwise; `num_threads` (OpenMP) and `num_workers` (OpenACC) overrides this if smaller.
- The wavefront has 102 scalars and 64 vectors
- Number of workitems is always 64
- The hardware permits maximally 40 workgroups/CU and 16 wavefronts/workgroup up to a limit of 40 wavefronts in total per CU.
- 80 scalars registers and 24 vector registers in non-kernel functions (the chosen procedure-calling API).
- For the kernel itself: as many as register pressure demands (number of teams and number of threads, scaled down if registers are exhausted)

The implementation remark:

- I/O within OpenMP target regions and OpenACC compute regions is supported using the C library `printf` functions and the Fortran `print`/`write` statements.
- Reverse offload regions (i.e. `target` regions with `device(ancestor:1)`) are processed serially per `target` region such that the next reverse offload region is only executed after the previous one returned.
- OpenMP code that has a `requires` directive with `self_maps` or `unified_shared_memory` is only supported if *all* the AMD GPUs present have the `HSA_AMD_SYSTEM_INFO_SVM_ACCESSIBLE_BY_DEFAULT` property; some systems require the "xnack" feature enabled for this to be true, in which case the runtime will attempt to set the `HSA_XNACK` environment variable to '`1`' automatically (user-set values are not overridden, and the setting only affects the executable itself and any child processes). If any AMD GPU device is not supported, all AMD GPUs are removed from the list of available devices ("host fallback").

- The available stack size can be changed using the `GCN_STACK_SIZE` environment variable; the default is 32 kiB per thread.
- Low-latency memory (`omp_low_lat_mem_space`) is supported when the the `access` trait is set to `cgroup`. The default pool size is automatically scaled to share the 64 kiB LDS memory between the number of teams configured to run on each compute-unit, but may be adjusted at runtime by setting environment variable `GOMP_GCN_LOWLAT_POOL=`*`bytes`*.
- `omp_low_lat_mem_alloc` cannot be used with true low-latency memory because the definition implies the `omp_atv_all` trait; main graphics memory is used instead.
- `omp_cgroup_mem_alloc`, `omp_pteam_mem_alloc`, and `omp_thread_mem_alloc`, all use low-latency memory as first preference, and fall back to main graphics memory when the low-latency pool is exhausted.
- Pinned memory allocated using `omp_alloc` with the `ompx_gnu_pinned_mem_alloc` allocator or the `pinned` trait is obtained via the CUDA API when an NVPTX device is present. This provides a performance boost for NVPTX offload code and also allows unlimited use of pinned memory regardless of the OS `ulimit`/`rlimit` settings.
- Managed memory allocated on the host with the `ompx_gnu_managed_mem_alloc` allocator or in the `ompx_gnu_managed_mem_space` (both GNU extensions) allocate memory equivalent to HIP Managed Memory, although *not* actually allocated using `hipMallocManaged`. This memory is accessible by both the host and the device at the same address, so it need not be mapped with `map` clauses. Instead, use the `is_device_ptr` clause or `has_device_addr` clause to indicate that the pointer is already accessible on the device. The ROCm runtime will automatically handle data migration between host and device as needed. Not all AMD GPU devices support this feature, and many that do require that `-mxnack=on` is configured at compile time. If managed memory is not supported by the default device, as configured at the moment the allocator is called, then the allocator will use the fall-back setting. If the default device is configured differently when the memory is freed, via `omp_free` or `omp_realloc`, the result may be undefined. If the current device does not support Unified Shared Memory (or it is not enabled with `HSA_XNACK=1`) then Managed Memory might still work, but allocations may only be visible to a single device (whichever was the default device when the *first* allocation was made).
- The OpenMP routines `omp_target_memcpy_rect` and `omp_target_memcpy_rect_async` and the `target update` directive for non-contiguous list items use the 3D memory-copy function of the HSA library. Higher dimensions call this functions in a loop and are therefore supported.
- The unique identifier (UID), used with OpenMP's API UID routines, is the value returned by the HSA runtime library for `HSA_AMD_AGENT_INFO_UUID`. For GPUs, it is currently '`GPU-`' followed by 16 lower-case hex digits, yielding a string like `GPU-f914a2142fc3413a`. The output matches the one used by `rocminfo`.

12.1.1 OpenMP `interop` – Foreign-Runtime Support for AMD GPUs

On AMD GPUs, the foreign runtimes are HIP (C++ Heterogeneous-Compute Interface for Portability) and HSA (Heterogeneous System Architecture), where HIP is the default. The interop object is created using OpenMP's `interop` directive or, implicitly, when invoking a `declare variant` procedure that has the `append_args` clause. In either case, the `prefer_type` modifier determines whether HIP or HSA is used.

When specifying the `targetsync` modifier: For HIP, a stream is created using `hipStreamCreate`. For HSA, a queue is created of type `HSA_QUEUE_TYPE_MULTI` with a queue size of 64.

Invoke the Section 3.11 [Interoperability Routines], page 46, on an interop object to obtain the following properties. For properties with integral (int), pointer (ptr), or string (str) data type, call `omp_get_interop_int`, `omp_get_interop_ptr`, or `omp_get_interop_str`, respectively. Note that `device_num` is the OpenMP device number while `device` is the HIP device number or HSA device handle.

When using HIP with C and C++, the `__HIP_PLATFORM_AMD__` preprocessor macro must be defined before including the HIP header files.

For the API routine call, add the prefix `omp_ipr_` to the property name; for instance:

```
omp_interop_rc_t ret;
int device_num = omp_get_interop_int (my_interop_obj, omp_ipr_device_num, &ret);
```

Available properties for an HIP interop object:

Property	**C data type**	**API routine**	**value (if constant)**
`fr_id`	`omp_interop_fr_t`	int	`omp_fr_hip`
`fr_name`	`const char *`	str	`"hip"`
`vendor`	`int`	int	`1`
`vendor_name`	`const char *`	str	`"amd"`
`device_num`	`int`	int	
`platform`	N/A		
`device`	`hipDevice_t`	int	
`device_context`	`hipCtx_t`	ptr	
`targetsync`	`hipStream_t`	ptr	

Available properties for an HSA interop object:

Property	**C data type**	**API routine**	**value (if constant)**
`fr_id`	`omp_interop_fr_t`	int	`omp_fr_hsa`
`fr_name`	`const char *`	str	`"hsa"`
`vendor`	`int`	int	`1`
`vendor_name`	`const char *`	str	`"amd"`
`device_num`	`int`	int	
`platform`	N/A		
`device`	`hsa_agent *`	ptr	
`device_context`	N/A		
`targetsync`	`hsa_queue *`	ptr	

12.2 nvptx

On the hardware side, there is the hierarchy (fine to coarse):

- thread

- warp
- thread block
- streaming multiprocessor

All OpenMP and OpenACC levels are used, i.e.

- OpenMP's simd and OpenACC's vector map to threads
- OpenMP's threads ("parallel") and OpenACC's workers map to warps
- OpenMP's teams and OpenACC's gang use a threadpool with the size of the number of teams or gangs, respectively.

The used sizes are

- The `warp_size` is always 32
- CUDA kernel launched: `dim={#teams,1,1}, blocks={#threads,warp_size,1}`.
- The number of teams is limited by the number of blocks the device can host simultaneously.

Additional information can be obtained by setting the environment variable to `GOMP_DEBUG=1` (very verbose; grep for `kernel.*launch` for launch parameters).

GCC generates generic PTX ISA code, which is just-in-time compiled by CUDA, which caches the JIT in the user's directory (see CUDA documentation; can be tuned by the environment variables `CUDA_CACHE_{DISABLE,MAXSIZE,PATH}`.

Note: While PTX ISA is generic, the `-mptx=` and `-march=` commandline options still affect the used PTX ISA code and, thus, the requirements on CUDA version and hardware.

The implementation remark:

- I/O within OpenMP target regions and OpenACC compute regions is supported using the C library `printf` functions. Additionally, the Fortran `print`/`write` statements are supported within OpenMP target regions, but not yet within OpenACC compute regions.
- Compilation OpenMP code that contains `requires reverse_offload` requires at least `-march=sm_35`, compiling for `-march=sm_30` is not supported.
- For code containing reverse offload (i.e. `target` regions with `device(ancestor:1)`), there is a slight performance penalty for *all* target regions, consisting mostly of shutdown delay Per device, reverse offload regions are processed serially such that the next reverse offload region is only executed after the previous one returned.
- OpenMP code that has a `requires` directive with `self_maps` or `unified_shared_memory` runs on nvptx devices if and only if all of those support the `pageableMemoryAccess` property;[1] otherwise, all nvptx device are removed from the list of available devices ("host fallback").
- The default per-warp stack size is 128 kiB; see also `-msoft-stack` in the GCC manual.
- Low-latency memory (`omp_low_lat_mem_space`) is supported when the the `access` trait is set to `cgroup`, and libgomp has been built for PTX ISA version 4.1 or higher (such as in GCC's default configuration). The default pool size is 8 kiB per team,

[1] `https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html#um-requirements`

but may be adjusted at runtime by setting environment variable GOMP_NVPTX_LOWLAT_POOL=*bytes*. The maximum value is limited by the available hardware, and care should be taken that the selected pool size does not unduly limit the number of teams that can run simultaneously.

- omp_low_lat_mem_alloc cannot be used with true low-latency memory because the definition implies the omp_atv_all trait; main graphics memory is used instead.
- omp_cgroup_mem_alloc, omp_pteam_mem_alloc, and omp_thread_mem_alloc, all use low-latency memory as first preference, and fall back to main graphics memory when the low-latency pool is exhausted.
- Managed memory allocated on the host with the ompx_gnu_managed_mem_alloc allocator or in the ompx_gnu_managed_mem_space (both GNU extensions) allocate memory in the CUDA Managed Memory space using cuMemAllocManaged. This memory is accessible by both the host and the device at the same address, so it need not be mapped with map clauses. Instead, use the is_device_ptr clause or has_device_addr clause to indicate that the pointer is already accessible on the device. The CUDA runtime will automatically handle data migration between host and device as needed. If managed memory is not supported by the default device, as configured at the moment the allocator is called, then the allocator will use the fall-back setting. If the default device is configured differently when the memory is freed, via omp_free or omp_realloc, the result may be undefined.
- The OpenMP routines omp_target_memcpy_rect and omp_target_memcpy_rect_async and the target update directive for non-contiguous list items use the 2D and 3D memory-copy functions of the CUDA library. Higher dimensions call those functions in a loop and are therefore supported.
- The unique identifier (UID), used with OpenMP's API UID routines, consists of the 'GPU-' prefix followed by the 16-bytes UUID as returned by the CUDA runtime library. This UUID is output in grouped lower-case hex digits; the grouping of those 32 digits is: 8 digits, hyphen, 4 digits, hyphen, 4 digits, hyphen, 16 digits. This leads to a string like GPU-a8081c9e-f03e-18eb-1827-bf5ba95afa5d. The output matches the format used by nvidia-smi.

12.2.1 OpenMP interop – Foreign-Runtime Support for Nvidia GPUs

On Nvidia GPUs, the foreign runtimes APIs are the CUDA runtime API, the CUDA driver API, and HIP, the C++ Heterogeneous-Compute Interface for Portability that is—on CUDA-based systems—a very thin layer on top of the CUDA API. By default, CUDA is used. The interop object is created using OpenMP's interop directive or, implicitly, when invoking a declare variant procedure that has the append_args clause. In either case, the prefer_type modifier determines whether CUDA, CUDA driver, or HSA is used.

When specifying the targetsync modifier, a CUDA stream is created using the CU_STREAM_DEFAULT flag.

Invoke the Section 3.11 [Interoperability Routines], page 46, on an interop object to obtain the following properties. For properties with integral (int), pointer (ptr), or string (str) data type, call omp_get_interop_int, omp_get_interop_ptr, or omp_get_interop_ str, respectively. Note that device_num is the OpenMP device number while device is the CUDA, CUDA Driver, or HIP device number.

When using HIP with C and C++, the __HIP_PLATFORM_NVIDIA__ preprocessor macro must be defined before including the HIP header files.

For the API routine call, add the prefix omp_ipr_ to the property name; for instance:

```
omp_interop_rc_t ret;
int device_num = omp_get_interop_int (my_interop_obj, omp_ipr_device_num, &ret);
```

Available properties for a CUDA runtime API interop object:

Property	**C data type**	**API routine**	**value (if constant)**
fr_id	omp_interop_fr_t	int	omp_fr_cuda
fr_name	const char *	str	"cuda"
vendor	int	int	11
vendor_name	const char *	str	"nvidia"
device_num	int	int	
platform	N/A		
device	int	int	
device_context	N/A		
targetsync	cudaStream_t	ptr	

Available properties for a CUDA driver API interop object:

Property	**C data type**	**API routine**	**value (if constant)**
fr_id	omp_interop_fr_t	int	omp_fr_cuda_driver
fr_name	const char *	str	"cuda_driver"
vendor	int	int	11
vendor_name	const char *	str	"nvidia"
device_num	int	int	
platform	N/A		
device	CUdevice	int	
device_context	CUcontext	ptr	
targetsync	CUstream	ptr	

Available properties for an HIP interop object:

Property	**C data type**	**API routine**	**value (if constant)**
fr_id	omp_interop_fr_t	int	omp_fr_hip
fr_name	const char *	str	"hip"
vendor	int	int	11
vendor_name	const char *	str	"nvidia"
device_num	int	int	
platform	N/A		
device	hipDevice_t	int	
device_context	hipCtx_t	ptr	
targetsync	hipStream_t	ptr	

13 The libgomp ABI

The following sections present notes on the external ABI as presented by libgomp. Only maintainers should need them.

13.1 Implementing MASKED and MASTER construct

```
if (omp_get_thread_num () == thread_num)
  block
```

Hereby, *thread_num* has the value of the argument to the `filter` clause or zero if not specified.

Alternately, we generate two copies of the parallel subfunction and only include this in the version run by the *thread_num* thread. Surely this is not worthwhile though...

13.2 Implementing CRITICAL construct

Without a specified name,

```
void GOMP_critical_start (void);
void GOMP_critical_end (void);
```

so that we don't get COPY relocations from libgomp to the main application.

With a specified name, use omp_set_lock and omp_unset_lock with name being transformed into a variable declared like

```
omp_lock_t gomp_critical_user_<name> __attribute__((common))
```

Ideally the ABI would specify that all zero is a valid unlocked state, and so we wouldn't need to initialize this at startup.

13.3 Implementing ATOMIC construct

The target should implement the `__sync` builtins.

Failing that we could add

```
void GOMP_atomic_enter (void)
void GOMP_atomic_exit (void)
```

which reuses the regular lock code, but with yet another lock object private to the library.

13.4 Implementing FLUSH construct

Expands to the `__sync_synchronize` builtin.

13.5 Implementing BARRIER construct

```
void GOMP_barrier (void)
```

13.6 Implementing THREADPRIVATE construct

In _most_ cases we can map this directly to `__thread`. Except that OMP allows constructors for C++ objects. We can either refuse to support this (how often is it used?) or we can implement something akin to .ctors.

Even more ideally, this ctor feature is handled by extensions to the main pthreads library. Failing that, we can have a set of entry points to register ctor functions to be called.

13.7 Implementing PRIVATE clause

In association with a PARALLEL, or within the lexical extent of a PARALLEL block, the variable becomes a local variable in the parallel subfunction.

In association with FOR or SECTIONS blocks, create a new automatic variable within the current function. This preserves the semantic of new variable creation.

13.8 Implementing FIRSTPRIVATE LASTPRIVATE COPYIN and COPYPRIVATE clauses

This seems simple enough for PARALLEL blocks. Create a private struct for communicating between the parent and subfunction. In the parent, copy in values for scalar and "small" structs; copy in addresses for others TREE_ADDRESSABLE types. In the subfunction, copy the value into the local variable.

It is not clear what to do with bare FOR or SECTION blocks. The only thing I can figure is that we do something like:

```
#pragma omp for firstprivate(x) lastprivate(y)
for (int i = 0; i < n; ++i)
  body;
```

which becomes

```
{
  int x = x, y;

  // for stuff

  if (i == n)
    y = y;
}
```

where the "x=x" and "y=y" assignments actually have different uids for the two variables, i.e. not something you could write directly in C. Presumably this only makes sense if the "outer" x and y are global variables.

COPYPRIVATE would work the same way, except the structure broadcast would have to happen via SINGLE machinery instead.

13.9 Implementing REDUCTION clause

The private struct mentioned in the previous section should have a pointer to an array of the type of the variable, indexed by the thread's *team_id*. The thread stores its final value into the array, and after the barrier, the primary thread iterates over the array to collect the values.

13.10 Implementing PARALLEL construct

```
#pragma omp parallel
{
  body;
}
```

becomes

```
void subfunction (void *data)
{
```

```
  use data;
  body;
}

setup data;
GOMP_parallel_start (subfunction, &data, num_threads);
subfunction (&data);
GOMP_parallel_end ();
```

```
void GOMP_parallel_start (void (*fn)(void *), void *data, unsigned num_threads)
```

The *FN* argument is the subfunction to be run in parallel.

The *DATA* argument is a pointer to a structure used to communicate data in and out of the subfunction, as discussed above with respect to FIRSTPRIVATE et al.

The *NUM_THREADS* argument is 1 if an IF clause is present and false, or the value of the NUM_THREADS clause, if present, or 0.

The function needs to create the appropriate number of threads and/or launch them from the dock. It needs to create the team structure and assign team ids.

```
void GOMP_parallel_end (void)
```

Tears down the team and returns us to the previous `omp_in_parallel()` state.

13.11 Implementing FOR construct

```
#pragma omp parallel for
for (i = lb; i <= ub; i++)
  body;
```

becomes

```
void subfunction (void *data)
{
  long _s0, _e0;
  while (GOMP_loop_static_next (&_s0, &_e0))
  {
    long _e1 = _e0, i;
    for (i = _s0; i < _e1; i++)
      body;
  }
  GOMP_loop_end_nowait ();
}

GOMP_parallel_loop_static (subfunction, NULL, 0, lb, ub+1, 1, 0);
subfunction (NULL);
GOMP_parallel_end ();
```

```
#pragma omp for schedule(runtime)
for (i = 0; i < n; i++)
  body;
```

becomes

```
{
  long i, _s0, _e0;
  if (GOMP_loop_runtime_start (0, n, 1, &_s0, &_e0))
    do {
      long _e1 = _e0;
      for (i = _s0, i < _e0; i++)
        body;
    } while (GOMP_loop_runtime_next (&_s0, _&e0));
```

```
  GOMP_loop_end ();
}
```

Note that while it looks like there is trickiness to propagating a non-constant STEP, there isn't really. We're explicitly allowed to evaluate it as many times as we want, and any variables involved should automatically be handled as PRIVATE or SHARED like any other variables. So the expression should remain evaluable in the subfunction. We can also pull it into a local variable if we like, but since its supposed to remain unchanged, we can also not if we like.

If we have SCHEDULE(STATIC), and no ORDERED, then we ought to be able to get away with no work-sharing context at all, since we can simply perform the arithmetic directly in each thread to divide up the iterations. Which would mean that we wouldn't need to call any of these routines.

There are separate routines for handling loops with an ORDERED clause. Bookkeeping for that is non-trivial...

13.12 Implementing ORDERED construct

```
void GOMP_ordered_start (void)
void GOMP_ordered_end (void)
```

13.13 Implementing SECTIONS construct

A block as

```
#pragma omp sections
{
  #pragma omp section
  stmt1;
  #pragma omp section
  stmt2;
  #pragma omp section
  stmt3;
}
```

becomes

```
for (i = GOMP_sections_start (3); i != 0; i = GOMP_sections_next ())
  switch (i)
    {
    case 1:
      stmt1;
      break;
    case 2:
      stmt2;
      break;
    case 3:
      stmt3;
      break;
    }
GOMP_barrier ();
```

13.14 Implementing SINGLE construct

A block like

```
#pragma omp single
```

```
{
  body;
}
```

becomes

```
if (GOMP_single_start ())
  body;
GOMP_barrier ();
```

while

```
#pragma omp single copyprivate(x)
  body;
```

becomes

```
datap = GOMP_single_copy_start ();
if (datap == NULL)
  {
    body;
    data.x = x;
    GOMP_single_copy_end (&data);
  }
else
  x = datap->x;
GOMP_barrier ();
```

13.15 Implementing OpenACC's PARALLEL construct

```
void GOACC_parallel ()
```

14 Reporting Bugs

Bugs in the GNU Offloading and Multi Processing Runtime Library should be reported via Bugzilla (`https://gcc.gnu.org/bugzilla/`). Please add "openacc", or "openmp", or both to the keywords field in the bug report, as appropriate.

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Version 3, 29 June 2007

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