GNU Offloading and Multi Processing Runtime Library

The GNU OpenMP and OpenACC Implementation

Published by the Free Software Foundation
51 Franklin Street, Fifth Floor
Boston, MA 02110-1301, USA

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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. This enables the OpenMP directive `#pragma omp` in C/C++ and `!$omp` directives in free form, `c$omp`, `*$omp` and `!$omp` directives in fixed form, `!$` conditional compilation sentinels in free form and `c$`, `*$` and `!$` sentinels in fixed form, for Fortran. The flag also arranges for automatic linking of the OpenMP runtime library (Chapter 3 [Runtime Library Routines], page 11).

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 `201511` (i.e. OpenMP 4.5).

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	N	
`declare variant` directive	P	*simd* traits not handled correctly
target-offload-var ICV and `OMP_TARGET_OFFLOAD` env variable	Y	
Nested-parallel changes to *max-active-levels-var* ICV	Y	
`requires` directive	P	complete but no non-host devices provides `unified_address` or `unified_shared_memory`
`teams` construct outside an enclosing target region	Y	
Non-rectangular loop nests	P	Full support for C/C++, partial for Fortran
`!=` 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	N	
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	Some are only stubs
Memory management routines	Y	
`allocate` directive	N	
`allocate` clause	P	Initial support
`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	N	
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	P	Mapping of vars with allocatable components unsupported
`defaultmap` extensions	Y	
`declare mapper` directive	N	
`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	N	
`target_device` selector set in context selectors	N	
C/C++'s `declare variant` directive: elision support of preprocessed code	N	
`declare variant`: new clauses `adjust_args` and `append_args`	N	
`dispatch` construct	N	
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	N	
`strict` modifier in the `grainsize` and `num_tasks` clauses of the `taskloop` construct	Y	
`align` clause in `allocate` directive	N	
`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	N	
Indirect calls to the device version of a procedure or function in `target` regions	N	
`interop` directive	N	
`omp_interop_t` object support in runtime routines	N	
`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	N	

`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`	N	
`device_type(nohost)`/`device_type(host)` for variables	N	

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	
Deprecation of no-argument `destroy` clause on `depobj`	N	
`linear` clause syntax changes and `step` modifier	Y	
Deprecation of minus operator for reductions	N	
Deprecation of separating `map` modifiers without comma	N	
`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	N	
New `enter` clause as alias for `to` on declare target directive	Y	
Deprecation of `to` clause on declare target directive	N	
Extended list of directives permitted in Fortran pure procedures	N	
New `allocators` directive for Fortran	N	
Deprecation of `allocate` directive for Fortran allocatables/pointers	N	
Optional paired `end` directive with `dispatch`	N	
New `memspace` and `traits` modifiers for `uses_allocators`	N	
Deprecation of traits array following the allocator_handle expression in `uses_allocators`	N	
New `otherwise` clause as alias for `default` on metadirectives	N	
Deprecation of `default` clause on metadirectives	N	
Deprecation of delimited form of `declare target`	N	
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	

[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 with `-Wsurprising` (enabled by `-Wall`). Unknown clauses are always rejected with an error.

New doacross clause as alias for depend with source/sink modifier	Y	
Deprecation of depend with source/sink modifier	N	
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	N	
interop_types in any position of the modifier list for the init clause of the interop construct	N	

2.5 OpenMP Technical Report 11

Technical Report (TR) 11 is the first preview for OpenMP 6.0.

New features listed in Appendix B of the OpenMP specification

Features deprecated in versions 5.2, 5.1 and 5.0 were removed	N/A	Backward compatibility
The decl attribute was added to the C++ attribute syntax	N	
_ALL suffix to the device-scope environment variables	P	Host device number wrongly accepted
For Fortran, *locator list* can be also function reference with data pointer result	N	
Ref-count change for use_device_ptr/use_device_addr	N	
Implicit reduction identifiers of C++ classes	N	
Change of the *map-type* property from *ultimate* to *default*	N	
Concept of *assumed-size arrays* in C and C++	N	
Mapping of *assumed-size arrays* in C, C++ and Fortran	N	
groupprivate directive	N	
local clause to declare target directive	N	
part_size allocator trait	N	
pin_device, preferred_device and target_access allocator traits	N	
access allocator trait changes	N	
Extension of interop operation of append_args, allowing all modifiers of the init clause	N	
interop clause to dispatch	N	
apply code to loop-transforming constructs	N	

`omp_curr_progress_width` identifier	N
`safesync` clause to the `parallel` construct	N
`omp_get_max_progress_width` runtime routine	N
`strict` modifier keyword to `num_threads`	N
`memscope` clause to `atomic` and `flush`	N
Routines for obtaining memory spaces/allocators for shared/device memory	N
`omp_get_memspace_num_resources` routine	N
`omp_get_submemspace` routine	N
`ompt_get_buffer_limits` OMPT routine	N
Extension of `OMP_DEFAULT_DEVICE` and new `OMP_AVAILABLE_DEVICES` environment vars	N
Supporting increments with abstract names in `OMP_PLACES`	N

Other new TR 11 features

Relaxed Fortran restrictions to the `aligned` clause	N
Mapping lambda captures	N
For Fortran, atomic compare with storing the comparison result	N
`aligned` clause changes for `simd` and `declare simd`	N

3 OpenMP Runtime Library Routines

The runtime routines described here are defined by Section 3 of the OpenMP specification in version 4.5. The routines are structured in following three parts:

3.1 `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 3.8 [omp_get_level], page 13, Section 3.9 [omp_get_max_active_levels], page 13, Section 3.31 [omp_set_max_active_levels], page 21,

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

3.2 `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 3.8 [omp_get_level], page 13, Section 3.25 [omp_get_thread_num], page 19, Section 3.22 [omp_get_team_size], page 18,

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

3.3 `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 4.1 [OMP_CANCELLATION], page 29,

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

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

Description:

Get the default device for target regions without device clause.

C/C++:

Prototype: `int omp_get_default_device(void);`

Fortran:

Interface: `integer function omp_get_default_device()`

See also: Section 4.3 [OMP_DEFAULT_DEVICE], page 29, Section 3.29 [omp_set_default_device], page 20,

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

3.5 `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. For OpenMP 5.0, this must be equal to the value returned by the `omp_get_initial_device` function when called from the host.

C/C++

Prototype: `int omp_get_device_num(void);`

Fortran:

Interface: `integer function omp_get_device_num()`

See also: Section 3.7 [omp_get_initial_device], page 13,

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

3.6 `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 3.30 [omp_set_dynamic], page 21, Section 4.4 [OMP_DYNAMIC], page 29,

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

3.7 `omp_get_initial_device` – Return device number of initial device

Description:

This function returns a device number that represents the host device. For OpenMP 5.1, this must be equal to the value returned by the `omp_get_num_devices` function.

C/C++

Prototype: `int omp_get_initial_device(void);`

Fortran:

Interface: `integer function omp_get_initial_device()`

See also: Section 3.14 [omp_get_num_devices], page 15,

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

3.8 `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 [omp_get_active_level], page 11,

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

3.9 `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 3.31 [omp_set_max_active_levels], page 21, Section 3.1 [omp_get_active_level], page 11,

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

3.10 `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.

3.11 `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 3.33 [omp_set_num_teams], page 22, Section 3.16 [omp_get_num_teams], page 16,

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

3.12 `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 3.34 [omp_set_num_threads], page 22, Section 3.30 [omp_set_dynamic], page 21, Section 3.24 [omp_get_thread_limit], page 19,

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

3.13 `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.

C/C++:

Prototype: `int omp_get_nested(void);`

Fortran:

Interface: `logical function omp_get_nested()`

See also: Section 3.31 [omp_set_max_active_levels], page 21, Section 3.32 [omp_set_nested], page 21, Section 4.5 [OMP_MAX_ACTIVE_LEVELS], page 30, Section 4.7 [OMP_NESTED], page 30,

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

3.14 `omp_get_num_devices` – Number of target devices

Description:

Returns the number of target devices.

C/C++:

Prototype: `int omp_get_num_devices(void);`

Fortran:

Interface: `integer function omp_get_num_devices()`

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

3.15 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.

3.16 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.

3.17 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 3.12 [omp_get_max_threads], page 14, Section 3.34 [omp_set_num_threads], page 22, Section 4.9 [OMP_NUM_THREADS], page 31,

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

3.18 `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 an 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 4.10 [OMP_PROC_BIND], page 31, Section 4.11 [OMP_PLACES], page 31, Section 4.18 [GOMP_CPU_AFFINITY], page 34,

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

3.19 `omp_get_schedule` – Obtain the runtime scheduling method

Description:

Obtain the runtime scheduling method. The *kind* argument will be set to the value `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 3.35 [omp_set_schedule], page 23, Section 4.13 [OMP_SCHEDULE], page 32,

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

3.20 `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 3.9 [omp_get_max_active_levels], page 13, Section 3.31 [omp_set_max_active_levels], page 21,

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

3.21 `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.

3.22 `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 3.17 [omp_get_num_threads], page 16, Section 3.8 [omp_get_level], page 13, Section 3.2 [omp_get_ancestor_thread_num], page 11,

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

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

Description:

Return the maximum number of threads that will be 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 3.36 [omp_set_teams_thread_limit], page 23, Section 4.15 [OMP_TEAMS_THREAD_LIMIT], page 33,

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

3.24 `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 3.12 [omp_get_max_threads], page 14, Section 4.16 [OMP_THREAD_LIMIT], page 33,

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

3.25 `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 3.17 [omp_get_num_threads], page 16, Section 3.2 [omp_get_ancestor_thread_num], page 11,

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

3.26 `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.

3.27 `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.

3.28 `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.

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.

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

Description:

Set the default device for target regions without device clause. The argument shall be a nonnegative device number.

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 4.3 [OMP_DEFAULT_DEVICE], page 29, Section 3.4 [omp_get_default_device], page 12,

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

3.30 `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 4.4 [OMP_DYNAMIC], page 29, Section 3.6 [omp_get_dynamic], page 12,

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

3.31 `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 3.9 [omp_get_max_active_levels], page 13, Section 3.1 [omp_get_active_level], page 11, Section 3.20 [omp_get_supported_active_levels], page 17,

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

3.32 `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 will also set the maximum number of active nested regions to the maximum supported. Disabling nested parallel regions will set the maximum number of active nested regions to one.

C/C++:

Prototype: `void omp_set_nested(int nested);`

Fortran:

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

See also: Section 3.13 [omp_get_nested], page 15, Section 3.31 [omp_set_max_active_levels], page 21, Section 4.5 [OMP_MAX_ACTIVE_LEVELS], page 30, Section 4.7 [OMP_NESTED], page 30,

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

3.33 `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 4.8 [OMP_NUM_TEAMS], page 30, Section 3.16 [omp_get_num_teams], page 16, Section 3.11 [omp_get_max_teams], page 14,

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

3.34 `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 4.9 [OMP_NUM_THREADS], page 31, Section 3.17 [omp_get_num_threads], page 16, Section 3.12 [omp_get_max_threads], page 14,

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

3.35 `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 3.19 [omp_get_schedule], page 17, Section 4.13 [OMP_SCHEDULE], page 32,

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

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

Description:
Specifies the upper bound for number of threads that will be 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 4.15 [OMP_TEAMS_THREAD_LIMIT], page 33, Section 3.23 [omp_get_teams_thread_limit], page 18, Section 3.24 [omp_get_thread_limit], page 19,

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

3.37 `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 3.41 [omp_destroy_lock], page 25,

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

3.38 `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 3.37 [omp_init_lock], page 23, Section 3.39 [omp_test_lock], page 24, Section 3.40 [omp_unset_lock], page 25,

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

3.39 `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 3.37 [omp_init_lock], page 23, Section 3.38 [omp_set_lock], page 24, Section 3.38 [omp_set_lock], page 24,

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

3.40 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 3.38 [omp_set_lock], page 24, Section 3.39 [omp_test_lock], page 24,

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

3.41 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 3.37 [omp_init_lock], page 23,

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

3.42 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 3.46 [omp_destroy_nest_lock], page 27,

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

3.43 `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 3.42 [omp_init_nest_lock], page 25, Section 3.45 [omp_unset_nest_lock], page 26,

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

3.44 `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 3.37 [omp_init_lock], page 23, Section 3.38 [omp_set_lock], page 24, Section 3.38 [omp_set_lock], page 24,

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

3.45 `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 3.43 [omp_set_nest_lock], page 26,

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

3.46 `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 3.37 [omp_init_lock], page 23,

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

3.47 `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 3.48 [omp_get_wtime], page 27,

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

3.48 `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 3.47 [omp_get_wtick], page 27,

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

3.49 `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.

4 OpenMP Environment Variables

The environment variables which beginning with OMP_ are defined by section 4 of the OpenMP specification in version 4.5, while those beginning with GOMP_ are GNU extensions.

4.1 OMP_CANCELLATION – Set whether cancellation is activated

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 3.3 [omp_get_cancellation], page 11,

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

4.2 OMP_DISPLAY_ENV – Show OpenMP version and environment variables

Description:
If set to TRUE, the OpenMP version number and the values associated with the OpenMP environment variables are printed to stderr. If set to VERBOSE, it additionally shows the value of the environment variables which are GNU extensions. If undefined or set to FALSE, this information will not be shown.

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

4.3 OMP_DEFAULT_DEVICE – Set the device used in target regions

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, device number 0 will be used.

See also: Section 3.4 [omp_get_default_device], page 12, Section 3.29 [omp_set_default_device], page 20,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.13

4.4 OMP_DYNAMIC – Dynamic adjustment of threads

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 3.30 [omp_set_dynamic], page 21,

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

4.5 OMP_MAX_ACTIVE_LEVELS – Set the maximum number of nested parallel regions

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 will be initialized to the largest number supported, otherwise it will be set to one.

See also: Section 3.31 [omp_set_max_active_levels], page 21, Section 4.7 [OMP_NESTED], page 30,

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

4.6 OMP_MAX_TASK_PRIORITY – Set the maximum priority

number that can be set for a task.

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 3.10 [omp_get_max_task_priority], page 14,

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

4.7 OMP_NESTED – Nested parallel regions

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 will by default be set to the maximum supported, otherwise it will be set to one. If OMP_MAX_ACTIVE_LEVELS is defined, its setting will override 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.

See also: Section 3.31 [omp_set_max_active_levels], page 21, Section 3.32 [omp_set_nested], page 21,

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

4.8 OMP_NUM_TEAMS – Specifies the number of teams to use by teams region

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 3.33 [omp_set_num_teams], page 22,

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

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

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 will automatically enable nesting by default. If undefined one thread per CPU is used.

See also: Section 3.34 [omp_set_num_threads], page 22, Section 4.7 [OMP_NESTED], page 30,

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

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

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`, `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 will automatically enable nesting by default.

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

See also: Section 3.18 [omp_get_proc_bind], page 17, Section 4.18 [GOMP_CPU_AFFINITY], page 34, Section 4.7 [OMP_NESTED], page 30, Section 4.11 [OMP_PLACES], page 31,

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

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

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) will exclude 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 4.10 [OMP_PROC_BIND], page 31, Section 4.18 [GOMP_CPU_AFFINITY], page 34, Section 3.18 [omp_get_proc_bind], page 17, Section 4.2 [OMP_DISPLAY_ENV], page 29,

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

4.12 `OMP_STACKSIZE` – Set default thread stack size

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.

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

4.13 `OMP_SCHEDULE` – How threads are scheduled

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 3.35 [omp_set_schedule], page 23,

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

4.14 `OMP_TARGET_OFFLOAD` – Controls offloading behaviour

Description:

Specifies the behaviour 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 will terminate with an error if the offload device is not present or is not supported. If set to `DISABLED`, then offloading is disabled and all code will run on the host. If set to `DEFAULT`, the program will try offloading to the device first, then fall back to running code on the host if it cannot.

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

Reference: OpenMP specification v5.0 (`https://www.openmp.org`), Section 6.17

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

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 4.16 [OMP_THREAD_LIMIT], page 33, Section 3.36 [omp_set_teams_thread_limit], page 23,

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

4.16 `OMP_THREAD_LIMIT` – Set the maximum number of threads

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 4.9 [OMP_NUM_THREADS], page 31, Section 3.24 [omp_get_thread_limit], page 19,

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

4.17 `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 4.21 [GOMP_SPINCOUNT], page 35,

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

4.18 `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"` will bind 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 start 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 will handle the assignment of threads to CPUs.

See also: Section 4.11 [OMP_PLACES], page 31, Section 4.10 [OMP_PROC_BIND], page 31,

4.19 `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 will be printed during execution. This is currently not specified in more detail, and subject to change.

4.20 `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 4.12 [OMP_STACKSIZE], page 32,

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)

4.21 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 4.17 [OMP_WAIT_POLICY], page 33,

4.22 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 will inherit 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 will use 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 `!$acc` directives in free form, `c$acc`, `*$acc` and `!$acc` directives in fixed form, `!$` conditional compilation sentinels in free form and `c$`, `*$` and `!$` sentinels in fixed form, for Fortran. The flag also arranges for automatic linking of the OpenACC runtime library (Chapter 6 [OpenACC Runtime Library Routines], page 39).

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 65), 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` will continue to be 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 will be returned to indicate the specified asynchronous operation has completed. While Fortran will return a `true`. If the asynchronous operation has not completed, C/C++ returns a zero and Fortran returns a `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 will be returned to indicate all asynchronous operations have completed. While Fortran will return a `true`. If any asynchronous operation has not completed, C/C++ returns a zero and Fortran returns a `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` will be returned. If the program is not executing on the specified device type C/C++ will return a zero, while Fortran will return `false`.

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 *len* bytes of device memory. It returns the device address of the allocated memory.

C/C++:

Prototype: `d_void* acc_malloc(size_t len);`

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

6.17 `acc_free` – Free device memory.

Description

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

C/C++:

Prototype: `acc_free(d_void *a);`

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

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, then device memory will be 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 45, 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)
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, then device memory will be 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 46, 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_async_finalize(a, async)`
	`type, dimension(:[,:]...) :: a`
	`integer(acc_handle_kind) :: async`

Interface:	`subroutine acc_delete_async_finalize(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 *d*. The host memory is specified with the host address *h* and a length of *len*.

C/C++:

Prototype: `acc_map_data(h_void *h, d_void *d, size_t len);`

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

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 *h*.

C/C++:

Prototype: `acc_unmap_data(h_void *h);`

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

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 *h*.

C/C++:

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

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

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 *d*.

C/C++:

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

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

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 *src* to device memory specified by the device address *dest* for a length of *bytes* bytes.

C/C++:

Prototype: `acc_memcpy_to_device(d_void *dest, h_void *src, size_t bytes);`

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

6.32 acc_memcpy_from_device – Copy device memory to host memory.

Description

This function copies host memory specified by host address of *src* from device memory specified by the device address *dest* for a length of *bytes* bytes.

C/C++:

Prototype: `acc_memcpy_from_device(d_void *dest, h_void *src, size_t bytes);`

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

6.33 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: `acc_attach(h_void **ptr);`

Prototype: `acc_attach_async(h_void **ptr, int async);`

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

6.34 `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:	`acc_detach(h_void **ptr);`
Prototype:	`acc_detach_async(h_void **ptr, int async);`
Prototype:	`acc_detach_finalize(h_void **ptr);`
Prototype:	`acc_detach_finalize_async(h_void **ptr, int async);`

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 3.2.35.

6.35 `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.

6.36 `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.

6.37 `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.

6.38 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.

6.39 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 65,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

6.40 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 65,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

6.41 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 65,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 5.3.

6.42 `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 65, Section 7.3 [ACC_PROFLIB], page 57,

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. The variable `GCC_ACC_NOTIFY` is used for diagnostic purposes.

7.1 ACC_DEVICE_TYPE

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 4.1.

7.2 ACC_DEVICE_NUM

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 4.2.

7.3 ACC_PROFLIB

See also: Section 6.42 [acc_register_library], page 55, Chapter 10 [OpenACC Profiling Interface], page 65,

Reference: OpenACC specification v2.6 (`https://www.openacc.org`), section 4.3.

7.4 GCC_ACC_NOTIFY

Description:
Print debug information pertaining to the accelerator.

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 will be 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 will be 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 will be sharing 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 will be 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()` will only initialize the CUBLAS library and allocate 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 will be impacted to some degree once the Profiling Interface has gotten 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 39)) 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` will always return `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 will generally correspond 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 will still refer 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 will always be acc_async_sync. It's not clear if that's the expected behavior.
- For acc_ev_device_init_start and acc_ev_device_init_end, it will always be acc_async_sync. It's not clear if that's the expected behavior.

acc_prof_info.async_queue
: There is no *limited number of asynchronous queues* in libgomp. This will always have 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 OpenMP Context Selectors

`vendor` is always `gnu`. References are to the GCC manual.

arch	kind	isa
`x86`, `x86_64`, `i386`, `i486`, `i586`, `i686`, `ia32`	`host`	See `-m...` flags in "x86 Options" (without `-m`)
`amdgcn`, `gcn`	`gpu`	See `-march=` in "AMD GCN Options"[1]
`nvptx`	`gpu`	See `-march=` in "Nvidia PTX Options"

11.2 Memory allocation with libmemkind

On Linux systems, where the memkind library (`https://github.com/memkind/memkind`) (`libmemkind.so.0`) is available at runtime, it is used when creating memory allocators requesting

- the memory space `omp_high_bw_mem_space`
- the memory space `omp_large_cap_mem_space`
- the partition trait `omp_atv_interleaved`

[1] Additionally, `gfx803` is supported as an alias for `fiji`.

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 parallel/kernels 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 `unified_address` or `unified_shared_memory` will remove any GCN device 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.

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 parallel/kernels is supported using the C library `printf` functions. Note that the Fortran `print`/`write` statements are not supported, yet.
- 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 `unified_address` or `unified_shared_memory` will remove any nvptx device from the list of available devices ("host fallback").

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 MASTER construct

```
if (omp_get_thread_num () == 0)
  block
```

Alternately, we generate two copies of the parallel subfunction and only include this in the version run by the primary 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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