GNU Offloading and Multi Processing Runtime Library

The GNU OpenMP and OpenACC Implementation

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Short Contents

1 Enabling OpenMP . . . 1
2 OpenMP Implementation Status . . . 3
3 OpenMP Runtime Library Routines . . . 11
4 OpenMP Environment Variables . . . 49
5 Enabling OpenACC . . . 61
6 OpenACC Runtime Library Routines . . . 63
7 OpenACC Environment Variables . . . 81
8 CUDA Streams Usage . . . 83
9 OpenACC Library Interoperability . . . 85
10 OpenACC Profiling Interface . . . 89
11 OpenMP-Implementation Specifics . . . 95
12 Offload-Target Specifics . . . 99
13 The libgomp ABI . . . 103
14 Reporting Bugs . . . 109
GNU General Public License . . . 111
GNU Free Documentation License . . . 123
Funding Free Software . . . 131
Library Index . . . 133

Table of Contents

1 Enabling OpenMP 1

2 OpenMP Implementation Status 3

2.1 OpenMP 4.5 3
2.2 OpenMP 5.0 3
New features listed in Appendix B of the OpenMP specification . . . 3
Other new OpenMP 5.0 features 5
2.3 OpenMP 5.1 5
New features listed in Appendix B of the OpenMP specification . . . 5
Other new OpenMP 5.1 features 6
2.4 OpenMP 5.2 7
New features listed in Appendix B of the OpenMP specification . . . 7
Other new OpenMP 5.2 features 8
2.5 OpenMP Technical Report 12 8
New features listed in Appendix B of the OpenMP specification . . . 8
Other new TR 12 features 10

3 OpenMP Runtime Library Routines 11

3.1 Thread Team Routines 11
3.1.1 `omp_set_num_threads` – Set upper team size limit 11
3.1.2 `omp_get_num_threads` – Size of the active team 11
3.1.3 `omp_get_max_threads` – Maximum number of threads of parallel region 12
3.1.4 `omp_get_thread_num` – Current thread ID 12
3.1.5 `omp_in_parallel` – Whether a parallel region is active 12
3.1.6 `omp_set_dynamic` – Enable/disable dynamic teams 13
3.1.7 `omp_get_dynamic` – Dynamic teams setting 13
3.1.8 `omp_get_cancellation` – Whether cancellation support is enabled 13
3.1.9 `omp_set_nested` – Enable/disable nested parallel regions . . 14
3.1.10 `omp_get_nested` – Nested parallel regions 14
3.1.11 `omp_set_schedule` – Set the runtime scheduling method . . 15
3.1.12 `omp_get_schedule` – Obtain the runtime scheduling method . . 15
3.1.13 `omp_get_teams_thread_limit` – Maximum number of threads imposed by teams 16
3.1.14 `omp_get_supported_active_levels` – Maximum number of active regions supported 16
3.1.15 `omp_set_max_active_levels` – Limits the number of active parallel regions 16
3.1.16 `omp_get_max_active_levels` – Current maximum number of active regions 17
3.1.17 `omp_get_level` – Obtain the current nesting level 17

3.1.18 omp_get_ancestor_thread_num – Ancestor thread ID ... 17
3.1.19 omp_get_team_size – Number of threads in a team 18
3.1.20 omp_get_active_level – Number of parallel regions 18
3.2 Thread Affinity Routines 18
3.2.1 omp_get_proc_bind – Whether threads may be moved between CPUs 18
3.3 Teams Region Routines 19
3.3.1 omp_get_num_teams – Number of teams 19
3.3.2 omp_get_team_num – Get team number 19
3.3.3 omp_set_num_teams – Set upper teams limit for teams construct 19
3.3.4 omp_get_max_teams – Maximum number of teams of teams region 20
3.3.5 omp_set_teams_thread_limit – Set upper thread limit for teams construct 20
3.3.6 omp_get_thread_limit – Maximum number of threads ... 20
3.4 Tasking Routines 21
3.4.1 omp_get_max_task_priority – Maximum priority value .. 21
3.4.2 omp_in_explicit_task – Whether a given task is an explicit task 21
3.4.3 omp_in_final – Whether in final or included task region .. 21
3.5 Resource Relinquishing Routines 22
3.5.1 omp_pause_resource – Release OpenMP resources on a device 22
3.5.2 omp_pause_resource_all – Release OpenMP resources on all devices 22
3.6 Device Information Routines 23
3.6.1 omp_get_num_procs – Number of processors online 23
3.6.2 omp_set_default_device – Set the default device for target regions 23
3.6.3 omp_get_default_device – Get the default device for target regions 23
3.6.4 omp_get_num_devices – Number of target devices 24
3.6.5 omp_get_device_num – Return device number of current device 24
3.6.6 omp_is_initial_device – Whether executing on the host device 24
3.6.7 omp_get_initial_device – Return device number of initial device 24
3.7 Device Memory Routines 25
3.7.1 omp_target_alloc – Allocate device memory 25
3.7.2 omp_target_free – Free device memory 25
3.7.3 omp_target_is_present – Check whether storage is mapped .. 26
3.7.4 omp_target_is_accessible – Check whether memory is device accessible 27
3.7.5 omp_target_memcpy – Copy data between devices 27

3.7.6 omp_target_memcpy_async – Copy data between devices asynchronously . . . 28
3.7.7 omp_target_memcpy_rect – Copy a subvolume of data between devices . . . 29
3.7.8 omp_target_memcpy_rect_async – Copy a subvolume of data between devices asynchronously . . . 30
3.7.9 omp_target_associate_ptr – Associate a device pointer with a host pointer . . . 32
3.7.10 omp_target_disassociate_ptr – Remove device–host pointer association . . . 33
3.7.11 omp_get_mapped_ptr – Return device pointer to a host pointer . . . 33
3.8 Lock Routines . . . 34
3.8.1 omp_init_lock – Initialize simple lock . . . 34
3.8.2 omp_init_nest_lock – Initialize nested lock . . . 34
3.8.3 omp_destroy_lock – Destroy simple lock . . . 35
3.8.4 omp_destroy_nest_lock – Destroy nested lock . . . 35
3.8.5 omp_set_lock – Wait for and set simple lock . . . 35
3.8.6 omp_set_nest_lock – Wait for and set nested lock . . . 36
3.8.7 omp_unset_lock – Unset simple lock . . . 36
3.8.8 omp_unset_nest_lock – Unset nested lock . . . 36
3.8.9 omp_test_lock – Test and set simple lock if available . . . 37
3.8.10 omp_test_nest_lock – Test and set nested lock if available . . . 37
3.9 Timing Routines . . . 37
3.9.1 omp_get_wtick – Get timer precision . . . 38
3.9.2 omp_get_wtime – Elapsed wall clock time . . . 38
3.10 Event Routine . . . 38
3.10.1 omp_fulfill_event – Fulfill and destroy an OpenMP event . . . 38
3.11 Memory Management Routines . . . 39
3.11.1 omp_init_allocator – Create an allocator . . . 39
3.11.2 omp_destroy_allocator – Destroy an allocator . . . 39
3.11.3 omp_set_default_allocator – Set the default allocator . . . 40
3.11.4 omp_get_default_allocator – Get the default allocator . . . 40
3.11.5 omp_alloc – Memory allocation with an allocator . . . 41
3.11.6 omp_aligned_alloc – Memory allocation with an allocator and alignment . . . 41
3.11.7 omp_free – Freeing memory allocated with OpenMP routines . . . 42
3.11.8 omp_calloc – Allocate nullified memory with an allocator . . . 43
3.11.9 omp_aligned_calloc – Allocate aligned nullified memory with an allocator . . . 44
3.11.10 omp_realloc – Reallocate memory allocated with OpenMP routines . . . 45
3.12 Environment Display Routine . . . 46
3.12.1 omp_display_env – print the initial ICV values . . . 46

4 OpenMP Environment Variables 49

4.1 OMP_ALLOCATOR – Set the default allocator 49
4.2 OMP_AFFINITY_FORMAT – Set the format string used for affinity display 50
4.3 OMP_CANCELLATION – Set whether cancellation is activated 51
4.4 OMP_DISPLAY_AFFINITY – Display thread affinity information . . 51
4.5 OMP_DISPLAY_ENV – Show OpenMP version and environment variables 52
4.6 OMP_DEFAULT_DEVICE – Set the device used in target regions . . . 52
4.7 OMP_DYNAMIC – Dynamic adjustment of threads 52
4.8 OMP_MAX_ACTIVE_LEVELS – Set the maximum number of nested parallel regions 53
4.9 OMP_MAX_TASK_PRIORITY – Set the maximum priority 53
4.10 OMP_NESTED – Nested parallel regions 53
4.11 OMP_NUM_TEAMS – Specifies the number of teams to use by teams region 54
4.12 OMP_NUM_THREADS – Specifies the number of threads to use 54
4.13 OMP_PROC_BIND – Whether threads may be moved between CPUs . . 54
4.14 OMP_PLACES – Specifies on which CPUs the threads should be placed 55
4.15 OMP_STACKSIZE – Set default thread stack size 56
4.16 OMP_SCHEDULE – How threads are scheduled 56
4.17 OMP_TARGET_OFFLOAD – Controls offloading behavior 56
4.18 OMP_TEAMS_THREAD_LIMIT – Set the maximum number of threads imposed by teams 57
4.19 OMP_THREAD_LIMIT – Set the maximum number of threads 57
4.20 OMP_WAIT_POLICY – How waiting threads are handled 57
4.21 GOMP_CPU_AFFINITY – Bind threads to specific CPUs 58
4.22 GOMP_DEBUG – Enable debugging output 58
4.23 GOMP_STACKSIZE – Set default thread stack size 58
4.24 GOMP_SPINCOUNT – Set the busy-wait spin count 59
4.25 GOMP_RTEMS_THREAD_POOLS – Set the RTEMS specific thread pools 59

5 Enabling OpenACC 61

6 OpenACC Runtime Library Routines 63

6.1 acc_get_num_devices – Get number of devices for given device type 63
6.2 acc_set_device_type – Set type of device accelerator to use. . . 63
6.3 acc_get_device_type – Get type of device accelerator to be used. 63
6.4 acc_set_device_num – Set device number to use. 64
6.5 acc_get_device_num – Get device number to be used. 64
6.6 acc_get_property – Get device property. 64

6.7 `acc_async_test` – Test for completion of a specific asynchronous operation. 65
6.8 `acc_async_test_all` – Tests for completion of all asynchronous operations. 66
6.9 `acc_wait` – Wait for completion of a specific asynchronous operation. 66
6.10 `acc_wait_all` – Waits for completion of all asynchronous operations. 66
6.11 `acc_wait_all_async` – Wait for completion of all asynchronous operations. 67
6.12 `acc_wait_async` – Wait for completion of asynchronous operations. 67
6.13 `acc_init` – Initialize runtime for a specific device type. 67
6.14 `acc_shutdown` – Shuts down the runtime for a specific device type. 68
6.15 `acc_on_device` – Whether executing on a particular device . . . 68
6.16 `acc_malloc` – Allocate device memory. 68
6.17 `acc_free` – Free device memory. 69
6.18 `acc_copyin` – Allocate device memory and copy host memory to it. 69
6.19 `acc_present_or_copyin` – If the data is not present on the device, allocate device memory and copy from host memory. 70
6.20 `acc_create` – Allocate device memory and map it to host memory. 70
6.21 `acc_present_or_create` – If the data is not present on the device, allocate device memory and map it to host memory. 71
6.22 `acc_copyout` – Copy device memory to host memory. 72
6.23 `acc_delete` – Free device memory. 73
6.24 `acc_update_device` – Update device memory from mapped host memory. 74
6.25 `acc_update_self` – Update host memory from mapped device memory. 74
6.26 `acc_map_data` – Map previously allocated device memory to host memory. 75
6.27 `acc_unmap_data` – Unmap device memory from host memory. . . 75
6.28 `acc_deviceptr` – Get device pointer associated with specific host address. 76
6.29 `acc_hostptr` – Get host pointer associated with specific device address. 76
6.30 `acc_is_present` – Indicate whether host variable / array is present on device. 76
6.31 `acc_memcpy_to_device` – Copy host memory to device memory. . . 77
6.32 `acc_memcpy_from_device` – Copy device memory to host memory. 77
6.33 `acc_attach` – Let device pointer point to device-pointer target. . . 78
6.34 `acc_detach` – Let device pointer point to host-pointer target. . . 78
6.35 `acc_get_current_cuda_device` – Get CUDA device handle. . . 79

6.36 `acc_get_current_cuda_context` – Get CUDA context handle... 79
6.37 `acc_get_cuda_stream` – Get CUDA stream handle. 79
6.38 `acc_set_cuda_stream` – Set CUDA stream handle. 79
6.39 `acc_prof_register` – Register callbacks. 80
6.40 `acc_prof_unregister` – Unregister callbacks. 80
6.41 `acc_prof_lookup` – Obtain inquiry functions. 80
6.42 `acc_register_library` – Library registration. 80

7 OpenACC Environment Variables 81

7.1 `ACC_DEVICE_TYPE` 81
7.2 `ACC_DEVICE_NUM` 81
7.3 `ACC_PROFLIB` 81

8 CUDA Streams Usage 83

9 OpenACC Library Interoperability 85

9.1 Introduction 85
9.2 First invocation: NVIDIA CUBLAS library API 85
9.3 First invocation: OpenACC library API 86
9.4 OpenACC library and environment variables 87

10 OpenACC Profiling Interface 89

10.1 Implementation Status and Implementation-Defined Behavior .. 89

11 OpenMP-Implementation Specifics 95

11.1 Implementation-defined ICV Initialization 95
11.2 OpenMP Context Selectors 95
11.3 Memory allocation 95

12 Offload-Target Specifics 99

12.1 AMD Radeon (GCN) 99
12.2 nvptx 100

13 The libgomp ABI 103

13.1 Implementing MASTER construct 103
13.2 Implementing CRITICAL construct 103
13.3 Implementing ATOMIC construct 103
13.4 Implementing FLUSH construct 103
13.5 Implementing BARRIER construct 103
13.6 Implementing THREADPRIVATE construct 103
13.7 Implementing PRIVATE clause 104
13.8 Implementing FIRSTPRIVATE LASTPRIVATE
COPYIN and COPYPRIVATE clauses 104

13.9 Implementing REDUCTION clause 104
13.10 Implementing PARALLEL construct 104
13.11 Implementing FOR construct 105
13.12 Implementing ORDERED construct 106
13.13 Implementing SECTIONS construct 106
13.14 Implementing SINGLE construct 106
13.15 Implementing OpenACC's PARALLEL construct 107

14 Reporting Bugs 109

GNU General Public License 111

GNU Free Documentation License 123

ADDENDUM: How to use this License for your documents 130

Funding Free Software 131

Library Index 133

1 Enabling OpenMP

To activate the OpenMP extensions for C/C++ and Fortran, the compile-time flag `-fopenmp` must be specified. For C and C++, this enables the handling of the OpenMP directives using `#pragma omp` and the `[[omp::directive(...)]]`, `[[omp::sequence(...)]]` and `[[omp::decl(...)]]` attributes. For Fortran, it enables for free source form the `!$omp` sentinel for directives and the `!$` conditional compilation sentinel and for fixed source form the `c$omp`, `*$omp` and `!$omp` sentinels for directives and the `c$`, `*$` and `!$` conditional compilation sentinels. The flag also arranges for automatic linking of the OpenMP runtime library (Chapter 3 [Runtime Library Routines], page 11).

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

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

2 OpenMP Implementation Status

The `_OPENMP` preprocessor macro and Fortran's `openmp_version` parameter, provided by `omp_lib.h` and the `omp_lib` module, have the value `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 device provides `unified_shared_memory`
`teams` construct outside an enclosing target region	Y	
Non-rectangular loop nests	P	Full support for C/C++, partial for Fortran (PR110735 (`https://gcc.gnu.org/PR110735`))
`!=` as relational-op in canonical loop form for C/C++	Y	
`nonmonotonic` as default loop schedule modifier for worksharing-loop constructs	Y	
Collapse of associated loops that are imperfectly nested loops	Y	
Clauses `if`, `nontemporal` and `order(concurrent)` in `simd` construct	Y	
`atomic` constructs in `simd`	Y	
`loop` construct	Y	
`order(concurrent)` clause	Y	
`scan` directive and `in_scan` modifier for the `reduction` clause	Y	
`in_reduction` clause on `task` constructs	Y	
`in_reduction` clause on `target` constructs	P	`nowait` only stub

`task_reduction` clause with `taskgroup`	Y	
`task` modifier to `reduction` clause	Y	
`affinity` clause to `task` construct	Y	Stub only
`detach` clause to `task` construct	Y	
`omp_fulfill_event` runtime routine	Y	
`reduction` and `in_reduction` clauses on `taskloop` and `taskloop simd` constructs	Y	
`taskloop` construct cancelable by `cancel` construct	Y	
`mutexinoutset` *dependence-type* for `depend` clause	Y	
Predefined memory spaces, memory allocators, allocator traits	Y	See also Section 11.3 [Memory allocation], page 95,
Memory management routines	Y	
`allocate` directive	P	Only C for stack/automatic and Fortran for stack/automatic and allocatable/pointer variables
`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	Y	
C/C++'s lvalue expressions in `depend` clauses	Y	
Nested `declare target` directive	Y	
Combined `master` constructs	Y	
`depend` clause on `taskwait`	Y	
Weak memory ordering clauses on `atomic` and `flush` construct	Y	
`hint` clause on the `atomic` construct	Y	Stub only
`depobj` construct and depend objects	Y	
Lock hints were renamed to synchronization hints	Y	
`conditional` modifier to `lastprivate` clause	Y	
Map-order clarifications	P	
`close` *map-type-modifier*	Y	
Mapping C/C++ pointer variables and to assign the address of device memory mapped by an array section	P	
Mapping of Fortran pointer and allocatable variables, including pointer and allocatable components of variables	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	P	Only C and Fortran (and not for static variables)
`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	Y	

`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	Y
`omp_set_num_teams`, `omp_set_teams_thread_limit`, `omp_get_max_teams`, `omp_get_teams_thread_limit` runtime routines	Y
`omp_target_is_accessible` runtime routine	Y
`omp_target_memcpy_async` and `omp_target_memcpy_rect_async` runtime routines	Y
`omp_get_mapped_ptr` runtime routine	Y
`omp_calloc`, `omp_realloc`, `omp_aligned_alloc` and `omp_aligned_calloc` runtime routines	Y
`omp_alloctrait_key_t` enum: `omp_atv_serialized` added, `omp_atv_default` changed	Y
`omp_display_env` runtime routine	Y
`ompt_scope_endpoint_t` enum: `ompt_scope_beginend`	N
`ompt_sync_region_t` enum additions	N
`ompt_state_t` enum: `ompt_state_wait_barrier_implementation` and `ompt_state_wait_barrier_teams`	N
`ompt_callback_target_data_op_emi_t`, `ompt_callback_target_emi_t`, `ompt_callback_target_map_emi_t` and `ompt_callback_target_submit_emi_t`	N
`ompt_callback_error_t` type	N
`OMP_PLACES` syntax extensions	Y
`OMP_NUM_TEAMS` and `OMP_TEAMS_THREAD_LIMIT` environment variables	Y

Other new OpenMP 5.1 features

Description	Status	Comments
Support of strictly structured blocks in Fortran	Y	
Support of structured block sequences in C/C++	Y	
`unconstrained` and `reproducible` modifiers on `order` clause	Y	
Support `begin/end declare target` syntax in C/C++	Y	
Pointer predetermined firstprivate getting initialized to address of matching mapped list item per 5.1, Sect. 2.21.7.2	N	

For Fortran, diagnose placing declarative before/between `USE`, `IMPORT`, and `IMPLICIT` as invalid	N	
Optional comma between directive and clause in the `#pragma` form	Y	
`indirect` clause in `declare target`	Y	
`device_type(nohost)`/`device_type(host)` for variables	N	
`present` modifier to the `map`, `to` and `from` clauses	Y	

2.4 OpenMP 5.2

New features listed in Appendix B of the OpenMP specification

Description	Status	Comments
`omp_in_explicit_task` routine and *explicit-task-var* ICV	Y	
`omp`/`ompx`/`omx` sentinels and `omp_`/`ompx_` namespaces	N/A	warning for `ompx/omx` sentinels[1]
Clauses on `end` directive can be on directive	Y	
`destroy` clause with destroy-var argument on `depobj`	Y	
Deprecation of no-argument `destroy` clause on `depobj`	N	
`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	Y	
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	Y	
New `allocators` directive for Fortran	Y	
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	

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

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	
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`	Y	
`all` as *implicit-behavior* for `defaultmap`	Y	
interop_types in any position of the modifier list for the `init` clause of the `interop` construct	N	
Invoke virtual member functions of C++ objects created on the host device on other devices	N	

2.5 OpenMP Technical Report 12

Technical Report (TR) 12 is the second 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
Full support for C23 was added	P	
Full support for C++23 was added	P	
`_ALL` suffix to the device-scope environment variables	P	Host device number wrongly accepted
`num_threads` now accepts a list	N	
Supporting increments with abstract names in `OMP_PLACES`	N	
Extension of `OMP_DEFAULT_DEVICE` and new `OMP_AVAILABLE_DEVICES` environment vars	N	
New `OMP_THREADS_RESERVE` environment variable	N	

The `decl` attribute was added to the C++ attribute syntax	Y
The OpenMP directive syntax was extended to include C 23 attribute specifiers	Y
All inarguable clauses take now an optional Boolean argument	N
For Fortran, *locator list* can be also function reference with data pointer result	N
Concept of *assumed-size arrays* in C and C++	N
directive-name-modifier accepted in all clauses	N
For Fortran, atomic with BLOCK construct and, for C/C++, with unlimited curly braces supported	N
For Fortran, atomic compare with storing the comparison result	N
New `looprange` clause	N
Ref-count change for `use_device_ptr`/`use_device_addr`	N
Support for inductions	N
Implicit reduction identifiers of C++ classes	N
Change of the *map-type* property from *ultimate* to *default*	N
`self` modifier to `map` and `self` as `defaultmap` argument	N
Mapping of *assumed-size arrays* in C, C++ and Fortran	N
`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
`message` and `severity` clauses to `parallel` directive	N
`self` clause to `requires` directive	N
`no_openmp_constructs` assumptions clause	N
`reverse` loop-transformation construct	N
`interchange` loop-transformation construct	N
`fuse` loop-transformation construct	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
`atomic` permitted in a construct with `order(concurrent)`	N

`workdistribute` directive for Fortran	N	Renamed just after TR12; added in TR12 as `coexecute`
Fortran DO CONCURRENT as associated loop in a `loop` construct	N	
`threadset` clause in task-generating constructs	N	
`nowait` clause with reverse-offload `target` directives	N	
Boolean argument to `nowait` and `nogroup` may be non constant	N	
`memscope` clause to `atomic` and `flush`	N	
`omp_is_free_agent` and `omp_ancestor_is_free_agent` routines	N	
`omp_target_memset` and `omp_target_memset_rect_async` routines	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_target_data_transfer` and `ompt_target_data_transfer_async` values in `ompt_target_data_op_t` enum	N	
`ompt_get_buffer_limits` OMPT routine	N	

Other new TR 12 features

Canonical loop nest enclosed in (multiple) curly braces (C/C++) or BLOCK constructs (Fortran)	N	
Relaxed Fortran restrictions to the `aligned` clause	N	
Mapping lambda captures	N	
New `omp_pause_stop_tool` constant for omp_pause_resource	N	

3 OpenMP Runtime Library Routines

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

3.1 Thread Team Routines

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

3.1.1 `omp_set_num_threads` – Set upper team size limit

Description:

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

C/C++:

Prototype: `void omp_set_num_threads(int num_threads);`

Fortran:

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

See also: Section 4.12 [OMP_NUM_THREADS], page 54, Section 3.1.2 [omp_get_num_threads], page 11, Section 3.1.3 [omp_get_max_threads], page 12,

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

3.1.2 `omp_get_num_threads` – Size of the active team

Description:

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

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

C/C++:

Prototype: `int omp_get_num_threads(void);`

Fortran:

Interface: `integer function omp_get_num_threads()`

See also: Section 3.1.3 [omp_get_max_threads], page 12, Section 3.1.1 [omp_set_num_threads], page 11, Section 4.12 [OMP_NUM_THREADS], page 54,

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

3.1.3 omp_get_max_threads – Maximum number of threads of parallel region

Description:

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

C/C++:

Prototype: `int omp_get_max_threads(void);`

Fortran:

Interface: `integer function omp_get_max_threads()`

See also: Section 3.1.1 [omp_set_num_threads], page 11, Section 3.1.6 [omp_set_dynamic], page 13, Section 3.3.6 [omp_get_thread_limit], page 20,

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

3.1.4 omp_get_thread_num – Current thread ID

Description:

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

C/C++:

Prototype: `int omp_get_thread_num(void);`

Fortran:

Interface: `integer function omp_get_thread_num()`

See also: Section 3.1.2 [omp_get_num_threads], page 11, Section 3.1.18 [omp_get_ancestor_thread_num], page 17,

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

3.1.5 omp_in_parallel – Whether a parallel region is active

Description:

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

C/C++:

Prototype: `int omp_in_parallel(void);`

Fortran:

Interface: `logical function omp_in_parallel()`

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

3.1.6 omp_set_dynamic – Enable/disable dynamic teams

Description:

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

C/C++:

Prototype: `void omp_set_dynamic(int dynamic_threads);`

Fortran:

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

See also: Section 4.7 [OMP_DYNAMIC], page 52, Section 3.1.7 [omp_get_dynamic], page 13,

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

3.1.7 omp_get_dynamic – Dynamic teams setting

Description:

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

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

C/C++:

Prototype: `int omp_get_dynamic(void);`

Fortran:

Interface: `logical function omp_get_dynamic()`

See also: Section 3.1.6 [omp_set_dynamic], page 13, Section 4.7 [OMP_DYNAMIC], page 52,

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

3.1.8 omp_get_cancellation – Whether cancellation support is enabled

Description:

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

C/C++:

Prototype: `int omp_get_cancellation(void);`

Fortran:

Interface: `logical function omp_get_cancellation()`

See also: Section 4.3 [OMP_CANCELLATION], page 51,

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

3.1.9 omp_set_nested – Enable/disable nested parallel regions

Description:

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

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

Note that the `omp_set_nested` API routine was deprecated in the OpenMP specification 5.2 in favor of `omp_set_max_active_levels`.

C/C++:

Prototype: `void omp_set_nested(int nested);`

Fortran:

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

See also: Section 3.1.10 [omp_get_nested], page 14, Section 3.1.15 [omp_set_max_active_levels], page 16, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53, Section 4.10 [OMP_NESTED], page 53,

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

3.1.10 omp_get_nested – Nested parallel regions

Description:

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

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

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

Note that the `omp_get_nested` API routine was deprecated in the OpenMP specification 5.2 in favor of `omp_get_max_active_levels`.

C/C++:

Prototype: `int omp_get_nested(void);`

Fortran:

Interface: `logical function omp_get_nested()`

See also: Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.9 [omp_set_nested], page 14, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53, Section 4.10 [OMP_NESTED], page 53,

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

3.1.11 `omp_set_schedule` – Set the runtime scheduling method

Description:

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

C/C++

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

Fortran:

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

See also: Section 3.1.12 [omp_get_schedule], page 15, Section 4.16 [OMP_SCHEDULE], page 56,

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

3.1.12 `omp_get_schedule` – Obtain the runtime scheduling method

Description:

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

C/C++

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

Fortran:

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

See also: Section 3.1.11 [omp_set_schedule], page 15, Section 4.16 [OMP_SCHEDULE], page 56,

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

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

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

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

Fortran:
Interface: `integer function omp_get_teams_thread_limit()`

See also: Section 3.3.5 [omp_set_teams_thread_limit], page 20, Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 57,

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

3.1.14 `omp_get_supported_active_levels` – Maximum number of active regions supported

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

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

Fortran:
Interface: `integer function omp_get_supported_active_levels()`

See also: Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.15 [omp_set_max_active_levels], page 16,

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

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

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

C/C++
Prototype: `void omp_set_max_active_levels(int max_levels);`

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

See also: Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.20 [omp_get_active_level], page 18, Section 3.1.14 [omp_get_supported_active_levels], page 16,

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

3.1.16 omp_get_max_active_levels – Current maximum number of active regions

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

C/C++

Prototype: `int omp_get_max_active_levels(void);`

Fortran:

Interface: `integer function omp_get_max_active_levels()`

See also: Section 3.1.15 [omp_set_max_active_levels], page 16, Section 3.1.20 [omp_get_active_level], page 18,

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

3.1.17 omp_get_level – Obtain the current nesting level

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

C/C++

Prototype: `int omp_get_level(void);`

Fortran:

Interface: `integer function omp_level()`

See also: Section 3.1.20 [omp_get_active_level], page 18,

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

3.1.18 omp_get_ancestor_thread_num – Ancestor thread ID

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

C/C++

Prototype: `int omp_get_ancestor_thread_num(int level);`

Fortran:

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

See also: Section 3.1.17 [omp_get_level], page 17, Section 3.1.4 [omp_get_thread_num], page 12, Section 3.1.19 [omp_get_team_size], page 18,

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

3.1.19 omp_get_team_size – Number of threads in a team

Description:

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

C/C++:

Prototype: `int omp_get_team_size(int level);`

Fortran:

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

See also: Section 3.1.2 [omp_get_num_threads], page 11, Section 3.1.17 [omp_get_level], page 17, Section 3.1.18 [omp_get_ancestor_thread_num], page 17,

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

3.1.20 omp_get_active_level – Number of parallel regions

Description:

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

C/C++

Prototype: `int omp_get_active_level(void);`

Fortran:

Interface: `integer function omp_get_active_level()`

See also: Section 3.1.17 [omp_get_level], page 17, Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.15 [omp_set_max_active_levels], page 16,

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

3.2 Thread Affinity Routines

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

3.2.1 omp_get_proc_bind – Whether threads may be moved between CPUs

Description:

This functions returns the currently active thread affinity policy, which is set via `OMP_PROC_BIND`. Possible values are `omp_proc_bind_false`, `omp_proc_bind_true`, `omp_proc_bind_primary`, `omp_proc_bind_master`, `omp_proc_bind_close` and `omp_proc_bind_spread`, where `omp_proc_bind_master` is 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 4.13 [OMP_PROC_BIND], page 54, Section 4.14 [OMP_PLACES], page 55, Section 4.21 [GOMP_CPU_AFFINITY], page 58,

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

3.3 Teams Region Routines

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

3.3.1 `omp_get_num_teams` – Number of teams

Description:

Returns the number of teams in the current team region.

C/C++:

Prototype: `int omp_get_num_teams(void);`

Fortran:

Interface: `integer function omp_get_num_teams()`

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

3.3.2 `omp_get_team_num` – Get team number

Description:

Returns the team number of the calling thread.

C/C++:

Prototype: `int omp_get_team_num(void);`

Fortran:

Interface: `integer function omp_get_team_num()`

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

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

Description:

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

C/C++:

Prototype: `void omp_set_num_teams(int num_teams);`

Fortran:

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

See also: Section 4.11 [OMP_NUM_TEAMS], page 54, Section 3.3.1 [omp_get_num_teams], page 19, Section 3.3.4 [omp_get_max_teams], page 20,

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

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

Description:

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

C/C++:

Prototype: `int omp_get_max_teams(void);`

Fortran:

Interface: `integer function omp_get_max_teams()`

See also: Section 3.3.3 [omp_set_num_teams], page 19, Section 3.3.1 [omp_get_num_teams], page 19,

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

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

Description:

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

C/C++:

Prototype: `void omp_set_teams_thread_limit(int thread_limit);`

Fortran:

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

See also: Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 57, Section 3.1.13 [omp_get_teams_thread_limit], page 16, Section 3.3.6 [omp_get_thread_limit], page 20,

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

3.3.6 `omp_get_thread_limit` – Maximum number of threads

Description:

Return the maximum number of threads of the program.

C/C++:

Prototype: `int omp_get_thread_limit(void);`

Fortran:

Interface: `integer function omp_get_thread_limit()`

See also: Section 3.1.3 [omp_get_max_threads], page 12, Section 4.19 [OMP_THREAD_LIMIT], page 57,

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

3.4 Tasking Routines

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

3.4.1 `omp_get_max_task_priority` – Maximum priority value

that can be set for tasks.

Description:

This function obtains the maximum allowed priority number for tasks.

C/C++

Prototype: `int omp_get_max_task_priority(void);`

Fortran:

Interface: `integer function omp_get_max_task_priority()`

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

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

Description:

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

C/C++

Prototype: `int omp_in_explicit_task(void);`

Fortran:

Interface: `logical function omp_in_explicit_task()`

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

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

Description:

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

C/C++:

Prototype: `int omp_in_final(void);`

Fortran:

Interface: `logical function omp_in_final()`

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

3.5 Resource Relinquishing Routines

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

3.5.1 `omp_pause_resource` – Release OpenMP resources on a device

Description:

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

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

C/C++:

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

Fortran:

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

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

3.5.2 `omp_pause_resource_all` – Release OpenMP resources on all devices

Description:

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

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

C/C++:

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

Fortran:

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

See also: Section 3.5.1 [omp_pause_resource], page 22,

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

3.6 Device Information Routines

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

3.6.1 `omp_get_num_procs` – Number of processors online

Description:
Returns the number of processors online on that device.

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

Fortran:
Interface: `integer function omp_get_num_procs()`

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

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

Description:
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 4.6 [OMP_DEFAULT_DEVICE], page 52, Section 3.6.3 [omp_get_default_device], page 23,

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

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

Description:
Get the 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 4.6 [OMP_DEFAULT_DEVICE], page 52, Section 3.6.2 [omp_set_default_device], page 23,

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

3.6.4 omp_get_num_devices – Number of target devices

Description:
Returns the number of 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.

3.6.5 omp_get_device_num – Return device number of current device

Description:
This function returns a device number that represents the device that the current thread is executing on. 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 3.6.7 [omp_get_initial_device], page 24,

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

3.6.6 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.

3.6.7 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 3.6.4 [omp_get_num_devices], page 24,

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

3.7 Device Memory Routines

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

3.7.1 `omp_target_alloc` – Allocate device memory

Description:

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

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

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

C/C++

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

Fortran:

Interface:

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

See also: Section 3.7.2 [omp_target_free], page 25, Section 3.7.9 [omp_target_associate_ptr], page 32,

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

3.7.2 `omp_target_free` – Free device memory

Description:

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

by `omp_target_alloc` for the specified `device_num`. The device number *device_num* must be a conforming device number.

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

C/C++

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

Fortran:

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

See also: Section 3.7.1 [omp_target_alloc], page 25, Section 3.7.10 [omp_target_disassociate_ptr], page 33,

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

3.7.3 `omp_target_is_present` – Check whether storage is mapped

Description:

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

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

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

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

C/C++

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

Fortran:

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

See also: Section 3.7.9 [omp_target_associate_ptr], page 32,

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

3.7.4 `omp_target_is_accessible` – Check whether memory is device accessible

Description:

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

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

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

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

C/C++

Prototype:

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

Fortran:

Interface:

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

See also: Section 3.7.9 [omp_target_associate_ptr], page 32,

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

3.7.5 `omp_target_memcpy` – Copy data between devices

Description:

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

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

C/C++

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

Fortran:

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

See also: Section 3.7.6 [omp_target_memcpy_async], page 28, Section 3.7.7 [omp_target_memcpy_rect], page 29,

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

3.7.6 `omp_target_memcpy_async` – Copy data between devices asynchronously

Description:

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

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

C/C++

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

```
int depobj_count,
omp_depend_t *depobj_list)
```

Fortran:

Interface:

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

See also: Section 3.7.5 [omp_target_memcpy], page 27, Section 3.7.8 [omp_target_memcpy_rect_async], page 30,

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

3.7.7 `omp_target_memcpy_rect` – Copy a subvolume of data between devices

Description:

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

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

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

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

C/C++

Prototype:

```
int omp_target_memcpy_rect(void *dst,
```

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

Fortran:

Interface:

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

See also: Section 3.7.8 [omp_target_memcpy_rect_async], page 30, Section 3.7.5 [omp_target_memcpy], page 27,

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

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

Description:

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

The OpenMP specification only requires that *num_dims* up to three is supported. In order to find implementation-specific maximally supported number

of dimensions, the routine returns this value when invoked with a null pointer to both the *dst* and *src* arguments. As GCC supports arbitrary dimensions, it returns `INT_MAX`.

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

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

C/C++

Prototype:

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

Fortran:

Interface:

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

See also: Section 3.7.7 [omp_target_memcpy_rect], page 29, Section 3.7.6 [omp_target_memcpy_async], page 28,

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

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

Description:

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

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

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

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

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

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

C/C++

Prototype:

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

Fortran:

Interface:

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

See also: Section 3.7.10 [omp_target_disassociate_ptr], page 33, Section 3.7.3 [omp_target_is_present], page 26, Section 3.7.1 [omp_target_alloc], page 25,

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

3.7.10 `omp_target_disassociate_ptr` – Remove device–host pointer association

Description:

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

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

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

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

C/C++

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

Fortran:

Interface:

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

See also: Section 3.7.9 [omp_target_associate_ptr], page 32,

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

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

Description:

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

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

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

C/C++

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

Fortran:

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

See also: Section 3.7.9 [omp_target_associate_ptr], page 32,

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

3.8 Lock Routines

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

3.8.1 `omp_init_lock` – Initialize simple lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.3 [omp_destroy_lock], page 35,

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

3.8.2 `omp_init_nest_lock` – Initialize nested lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.4 [omp_destroy_nest_lock], page 35,

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

3.8.3 `omp_destroy_lock` – Destroy simple lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.1 [omp_init_lock], page 34,

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

3.8.4 `omp_destroy_nest_lock` – Destroy nested lock

Description:

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

C/C++:

Prototype: `void omp_destroy_nest_lock(omp_nest_lock_t *);`

Fortran:

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

See also: Section 3.8.1 [omp_init_lock], page 34,

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

3.8.5 `omp_set_lock` – Wait for and set simple lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.1 [omp_init_lock], page 34, Section 3.8.9 [omp_test_lock], page 37, Section 3.8.7 [omp_unset_lock], page 36,

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

3.8.6 omp_set_nest_lock – Wait for and set nested lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.2 [omp_init_nest_lock], page 34, Section 3.8.8 [omp_unset_nest_lock], page 36,

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

3.8.7 omp_unset_lock – Unset simple lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.5 [omp_set_lock], page 35, Section 3.8.9 [omp_test_lock], page 37,

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

3.8.8 omp_unset_nest_lock – Unset nested lock

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.6 [omp_set_nest_lock], page 36,

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

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

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.1 [omp_init_lock], page 34, Section 3.8.5 [omp_set_lock], page 35, Section 3.8.5 [omp_set_lock], page 35,

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

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

Description:

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

C/C++:

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

Fortran:

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

See also: Section 3.8.1 [omp_init_lock], page 34, Section 3.8.5 [omp_set_lock], page 35, Section 3.8.5 [omp_set_lock], page 35,

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

3.9 Timing Routines

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

3.9.1 omp_get_wtick – Get timer precision

Description:

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

C/C++:

Prototype: `double omp_get_wtick(void);`

Fortran:

Interface: `double precision function omp_get_wtick()`

See also: Section 3.9.2 [omp_get_wtime], page 38,

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

3.9.2 omp_get_wtime – Elapsed wall clock time

Description:

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

C/C++:

Prototype: `double omp_get_wtime(void);`

Fortran:

Interface: `double precision function omp_get_wtime()`

See also: Section 3.9.1 [omp_get_wtick], page 38,

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

3.10 Event Routine

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

3.10.1 omp_fulfill_event – Fulfill and destroy an OpenMP event

Description:

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

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

C/C++:

Prototype: `void omp_fulfill_event(omp_event_handle_t event);`

Fortran:

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

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

3.11 Memory Management Routines

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

3.11.1 omp_init_allocator – Create an allocator

Description:

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

The predefined memory spaces and available traits can be found at Section 4.1 [OMP_ALLOCATOR], page 49, where the trait names have to be prefixed by omp_atk_ (e.g. omp_atk_pinned) and the named trait values by omp_atv_ (e.g. omp_atv_true); additionally, omp_atv_default may be used as trait value to specify that the default value should be used.

C/C++:

Prototype:

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

Fortran:

Interface:

```
function omp_init_allocator(memspace, ntraits,
traits)
integer (omp_allocator_handle_kind) :: omp_init_
allocator
integer (omp_memspace_handle_kind), intent(in) ::
memspace
integer, intent(in) :: ntraits
type (omp_alloctrait), intent(in) :: traits(*)
```

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.2 [omp_destroy_allocator], page 39,

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

3.11.2 omp_destroy_allocator – Destroy an allocator

Description:

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

C/C++:

Prototype:

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

Fortran:

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

See also: Section 3.11.1 [omp_init_allocator], page 39,

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

3.11.3 `omp_set_default_allocator` – Set the default allocator

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

C/C++:

Prototype: `void omp_set_default_allocator(omp_allocator_handle_t allocator);`

Fortran:

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

See also: Section 3.11.4 [omp_get_default_allocator], page 40, Section 3.11.1 [omp_init_allocator], page 39, Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95,

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

3.11.4 `omp_get_default_allocator` – Get the default allocator

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

C/C++:

Prototype: `omp_allocator_handle_t omp_get_default_allocator();`

Fortran:

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

See also: Section 3.11.3 [omp_set_default_allocator], page 40, Section 4.1 [OMP_ALLOCATOR], page 49,

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

3.11.5 omp_alloc – Memory allocation with an allocator

Description:

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

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

Memory allocated by omp_alloc must be freed using omp_free.

C:

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

C++:

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

Fortran:

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

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

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

3.11.6 omp_aligned_alloc – Memory allocation with an allocator and alignment

Description:

Allocate memory with the specified allocator, which can either be a predefined allocator, an allocator handle or omp_null_allocator. If the allocators is omp_null_allocator, the allocator specified by the *def-allocator-var* ICV is used. *alignment* must be a positive power of two and *size* must be a nonnegative number that is a multiple of the alignment and denotes the number of bytes

to be allocated; if *size* is zero, `omp_aligned_alloc` will return a null pointer. The alignment will be at least the maximal value required by `alignment` trait of the allocator and the value of the passed *alignment* argument. If successful, a pointer to the allocated memory is returned, otherwise the `fallback` trait of the allocator determines the behavior. The content of the allocated memory is unspecified.

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

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

C:

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

C++:

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

Fortran:

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

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

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

3.11.7 `omp_free` – Freeing memory allocated with OpenMP routines

Description:

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

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

C:

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

C++:

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

Fortran:

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

See also: Section 3.11.5 [omp_alloc], page 41, Section 3.11.6 [omp_aligned_alloc], page 41, Section 3.11.8 [omp_calloc], page 43, Section 3.11.9 [omp_aligned_calloc], page 44, Section 3.11.10 [omp_realloc], page 45,

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

3.11.8 `omp_calloc` – Allocate nullified memory with an allocator

Description:

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

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

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

C:

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

C++:

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

Fortran:

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

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

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

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

Description:

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

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

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

C:

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

C++:

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

Fortran:

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

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

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

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

3.11.10 `omp_realloc` – Reallocate memory allocated with OpenMP routines

Description:

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

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

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

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

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

C:

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

C++:

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

```
omp_allocator_handle_t free_allocator=omp_null_
allocator)
```

Fortran:

Interface:

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

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

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

3.12 Environment Display Routine

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

3.12.1 `omp_display_env` – print the initial ICV values

Description:

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

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

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

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

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

same ICV might be printed multiple times for multiple devices, even if all have the same value.

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

C/C++:

Prototype: `void omp_display_env(int verbose)`

Fortran:

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

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

```
OPENMP DISPLAY ENVIRONMENT BEGIN
  _OPENMP = '201511'
  [host] OMP_DYNAMIC = 'FALSE'
  [host] OMP_NESTED = 'FALSE'
  [all] OMP_CANCELLATION = 'FALSE'
  ...
  [host] GOMP_SPINCOUNT = '300000'
OPENMP DISPLAY ENVIRONMENT END
```

See also: Section 4.5 [OMP_DISPLAY_ENV], page 52, Chapter 4 [Environment Variables], page 49, Section 11.1 [Implementation-defined ICV Initialization], page 95,

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

4 OpenMP Environment Variables

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

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

4.1 `OMP_ALLOCATOR` – Set the default allocator

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

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

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

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

Predefined allocators	**Associated predefined memory spaces**
omp_default_mem_alloc	omp_default_mem_space
omp_large_cap_mem_alloc	omp_large_cap_mem_space
omp_const_mem_alloc	omp_const_mem_space
omp_high_bw_mem_alloc	omp_high_bw_mem_space
omp_low_lat_mem_alloc	omp_low_lat_mem_space
omp_cgroup_mem_alloc	omp_low_lat_mem_space (implementation defined)
omp_pteam_mem_alloc	omp_low_lat_mem_space (implementation defined)
omp_thread_mem_alloc	omp_low_lat_mem_space (implementation defined)

The predefined allocators use the default values for the traits, as listed below. Except that the last three allocators have the `access` trait set to `cgroup`, `pteam`, and `thread`, respectively.

Trait	Allowed values	Default value
`sync_hint`	`contended`, `uncontended`, `serialized`, `private`	`contended`
`alignment`	Positive integer being a power of two	1 byte
`access`	`all`, `cgroup`, `pteam`, `thread`	`all`
`pool_size`	Positive integer	See Section 11.3 [Memory allocation], page 95,
`fallback`	`default_mem_fb`, `null_fb`, `abort_fb`, `allocator_fb`	See below
`fb_data`	*unsupported as it needs an allocator handle*	(none)
`pinned`	`true`, `false`	`false`
`partition`	`environment`, `nearest`, `blocked`, `interleaved`	`environment`

For the `fallback` trait, the default value is `null_fb` for the `omp_default_mem_alloc` allocator and any allocator that is associated with device memory; for all other allocators, it is `default_mem_fb` by default.

Examples:

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

See also: Section 11.3 [Memory allocation], page 95, Section 3.11.4 [omp_get_default_allocator], page 40, Section 3.11.3 [omp_set_default_allocator], page 40, Chapter 12 [Offload-Target Specifics], page 99,

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

4.2 `OMP_AFFINITY_FORMAT` – Set the format string used for affinity display

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

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

Supported field types are:

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

For instance, after setting

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

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

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

See also: Section 4.4 [OMP_DISPLAY_AFFINITY], page 51,

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

4.3 `OMP_CANCELLATION` – Set whether cancellation is activated

ICV: cancel-var
Scope: global
Description:

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

See also: Section 3.1.8 [omp_get_cancellation], page 13,

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

4.4 `OMP_DISPLAY_AFFINITY` – Display thread affinity information

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

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

See also: Section 4.2 [OMP_AFFINITY_FORMAT], page 50,

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

4.5 `OMP_DISPLAY_ENV` – Show OpenMP version and environment variables

ICV: none

Scope: not applicable

Description:

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

See also: Section 3.12.1 [omp_display_env], page 46,

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

4.6 `OMP_DEFAULT_DEVICE` – Set the device used in target regions

ICV: default-device-var

Scope: data environment

Description:

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

See also: Section 3.6.3 [omp_get_default_device], page 23, Section 3.6.2 [omp_set_default_device], page 23, Section 4.17 [OMP_TARGET_OFFLOAD], page 56,

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

4.7 `OMP_DYNAMIC` – Dynamic adjustment of threads

ICV: dyn-var

Scope: global

Description:

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

See also: Section 3.1.6 [omp_set_dynamic], page 13,

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

4.8 OMP_MAX_ACTIVE_LEVELS – Set the maximum number of nested parallel regions

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

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

See also: Section 3.1.15 [omp_set_max_active_levels], page 16, Section 4.10 [OMP_NESTED], page 53, Section 4.13 [OMP_PROC_BIND], page 54, Section 4.12 [OMP_NUM_THREADS], page 54,

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

4.9 OMP_MAX_TASK_PRIORITY – Set the maximum priority

number that can be set for a task.

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

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

See also: Section 3.4.1 [omp_get_max_task_priority], page 21,

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

4.10 OMP_NESTED – Nested parallel regions

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

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

Note that the OMP_NESTED environment variable was deprecated in the OpenMP specification 5.2 in favor of OMP_MAX_ACTIVE_LEVELS.

See also: Section 3.1.15 [omp_set_max_active_levels], page 16, Section 3.1.9 [omp_set_nested], page 14, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53,

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

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

ICV: nteams-var
Scope: device
Description:

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

See also: Section 3.3.3 [omp_set_num_teams], page 19,

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

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

ICV: nthreads-var
Scope: data environment
Description:

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

When a list with more than value is specified, it also affects the *max-active-levels-var* ICV as described in Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53.

See also: Section 3.1.1 [omp_set_num_threads], page 11, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53,

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

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

ICV: bind-var
Scope: data environment
Description:

Specifies whether threads may be moved between processors. If set to `TRUE`, OpenMP threads should not be moved; if set to `FALSE` they may be moved. Alternatively, a comma separated list with the values `PRIMARY`, `MASTER`, `CLOSE` and `SPREAD` can be used to specify the thread affinity policy for the corresponding nesting level. With `PRIMARY` and `MASTER` the worker threads are in the same place partition as the primary thread. With `CLOSE` those are kept close to the primary thread in contiguous place partitions. And with `SPREAD` a sparse

distribution across the place partitions is used. Specifying more than one item in the list automatically enables nesting by default.

When a list is specified, it also affects the *max-active-levels-var* ICV as described in Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53.

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

See also: Section 3.2.1 [omp_get_proc_bind], page 18, Section 4.21 [GOMP_CPU_AFFINITY], page 58, Section 4.14 [OMP_PLACES], page 55, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53,

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

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

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

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

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

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

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

See also: Section 4.13 [OMP_PROC_BIND], page 54, Section 4.21 [GOMP_CPU_AFFINITY], page 58, Section 3.2.1 [omp_get_proc_bind], page 18, Section 4.5 [OMP_DISPLAY_ENV], page 52,

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

4.15 `OMP_STACKSIZE` – Set default thread stack size

ICV: stacksize-var
Scope: device
Description:

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

See also: Section 4.23 [GOMP_STACKSIZE], page 58,

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

4.16 `OMP_SCHEDULE` – How threads are scheduled

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

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

See also: Section 3.1.11 [omp_set_schedule], page 15,

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

4.17 `OMP_TARGET_OFFLOAD` – Controls offloading behavior

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

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

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

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

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

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 52,

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

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

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

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

See also: Section 4.19 [OMP_THREAD_LIMIT], page 57, Section 3.3.5 [omp_set_teams_thread_limit], page 20,

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

4.19 `OMP_THREAD_LIMIT` – Set the maximum number of threads

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

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

See also: Section 4.12 [OMP_NUM_THREADS], page 54, Section 3.3.6 [omp_get_thread_limit], page 20,

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

4.20 `OMP_WAIT_POLICY` – How waiting threads are handled

Description:

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

See also: Section 4.24 [GOMP_SPINCOUNT], page 59,

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

4.21 GOMP_CPU_AFFINITY – Bind threads to specific CPUs

Description:

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

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

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

See also: Section 4.14 [OMP_PLACES], page 55, Section 4.13 [OMP_PROC_BIND], page 54,

4.22 GOMP_DEBUG – Enable debugging output

Description:

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

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

4.23 GOMP_STACKSIZE – Set default thread stack size

Description:

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

See also: Section 4.15 [OMP_STACKSIZE], page 56,

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

4.24 GOMP_SPINCOUNT – Set the busy-wait spin count

Description:

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

See also: Section 4.20 [OMP_WAIT_POLICY], page 57,

4.25 GOMP_RTEMS_THREAD_POOLS – Set the RTEMS specific thread pools

Description:

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

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

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

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

5 Enabling OpenACC

To activate the OpenACC extensions for C/C++ and Fortran, the compile-time flag `-fopenacc` must be specified. This enables the OpenACC directive '`#pragma acc`' in C/C++ and, in Fortran, the '`!$acc`' sentinel in free source form and the '`c$acc`', '`*$acc`' and '`!$acc`' sentinels in fixed source form. The flag also arranges for automatic linking of the OpenACC runtime library (Chapter 6 [OpenACC Runtime Library Routines], page 63).

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 89), that is, if the device is currently being initialized.

C/C++:

Prototype: `acc_device_t acc_get_device_type(void);`

Fortran:

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

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

6.4 `acc_set_device_num` – Set device number to use.

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

Prototype: `int acc_get_device_num(acc_device_t devicetype);`

Fortran:

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

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

6.6 `acc_get_property` – Get device property.

Description

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

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

C/C++:

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

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

Fortran:

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

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

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

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

Description

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

C/C++:

Prototype: `int acc_async_test(int arg);`

Fortran:

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

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

6.8 acc_async_test_all – Tests for completion of all asynchronous operations.

Description

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

C/C++:

Prototype: `int acc_async_test_all(void);`

Fortran:

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

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

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

Description

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

C/C++:

Prototype: `acc_wait(arg);`

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

Fortran:

Interface:
```
subroutine acc_wait(arg)
integer(acc_handle_kind) arg
```

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

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

6.10 acc_wait_all – Waits for completion of all asynchronous operations.

Description

This function waits for the completion of all asynchronous operations.

C/C++:

Prototype: `acc_wait_all(void);`

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

Fortran:

Interface: `subroutine acc_wait_all()`

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

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

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

Description

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

C/C++:

Prototype: `acc_wait_all_async(int async);`

Fortran:

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

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

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

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

Prototype: `acc_init(acc_device_t devicetype);`

Fortran:

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

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

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

Description

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

C/C++:

Prototype: `acc_shutdown(acc_device_t devicetype);`

Fortran:

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

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

6.15 acc_on_device – Whether executing on a particular device

Description:

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

C/C++:

Prototype: `acc_on_device(acc_device_t devicetype);`

Fortran:

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

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

6.16 acc_malloc – Allocate device memory.

Description

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

C/C++:

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

Fortran:

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

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

6.17 acc_free – Free device memory.

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

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

C/C++:

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

Fortran:

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

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

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

Description

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

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

Note that `acc_present_or_copyin` and `acc_pcopyin` exist for backward compatibility with OpenACC 2.0; use Section 6.18 [acc_copyin], page 69, 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, device memory is allocated and mapped to host memory. In C/C++, the device address of the newly allocated device memory is returned.

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

Note that `acc_present_or_create` and `acc_pcreate` exist for backward compatibility with OpenACC 2.0; use Section 6.20 [acc_create], page 70, 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 *data_dev*. The host memory is specified with the host address *data_arg* and a length of *bytes*.

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

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

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

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

Fortran:

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

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

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

Description

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

C/C++:

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

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

Fortran:

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

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

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

6.33 `acc_attach` – Let device pointer point to device-pointer target.

Description

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

C/C++:

Prototype: `void acc_attach(h_void **ptr_addr);`

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

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: `void acc_detach(h_void **ptr_addr);`

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

Prototype: `void acc_detach_finalize(h_void **ptr_addr);`

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

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 89,

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 89,

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 89,

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 89, Section 7.3 [ACC_PROFLIB], page 81,

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

7 OpenACC Environment Variables

The variables `ACC_DEVICE_TYPE` and `ACC_DEVICE_NUM` are defined by section 4 of the OpenACC specification in version 2.0. The variable `ACC_PROFLIB` is defined by section 4 of the OpenACC specification in version 2.6.

7.1 ACC_DEVICE_TYPE

Description:

Control the default device type to use when executing compute regions. If unset, the code can be run on any device type, favoring a non-host device type.

Supported values in GCC (if compiled in) are

- `host`
- `nvidia`
- `radeon`

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

7.2 ACC_DEVICE_NUM

Description:

Control which device, identified by device number, is the default device. The value must be a nonnegative integer less than the number of devices. If unset, device number zero is used.

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

7.3 ACC_PROFLIB

Description:

Semicolon-separated list of dynamic libraries that are loaded as profiling libraries. Each library must provide at least the `acc_register_library` routine. Each library file is found as described by the documentation of `dlopen` of your operating system.

See also: Section 6.42 [acc_register_library], page 80, Chapter 10 [OpenACC Profiling Interface], page 89,

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

8 CUDA Streams Usage

This applies to the `nvptx` plugin only.

The library provides elements that perform asynchronous movement of data and asynchronous operation of computing constructs. This asynchronous functionality is implemented by making use of CUDA streams[1].

The primary means by that the asynchronous functionality is accessed is through the use of those OpenACC directives which make use of the `async` and `wait` clauses. When the `async` clause is first used with a directive, it creates a CUDA stream. If an `async-argument` is used with the `async` clause, then the stream is associated with the specified `async-argument`.

Following the creation of an association between a CUDA stream and the `async-argument` of an `async` clause, both the `wait` clause and the `wait` directive can be used. When either the clause or directive is used after stream creation, it creates a rendezvous point whereby execution waits until all operations associated with the `async-argument`, that is, stream, have completed.

Normally, the management of the streams that are created as a result of using the `async` clause, is done without any intervention by the caller. This implies the association between the `async-argument` and the CUDA stream is maintained for the lifetime of the program. However, this association can be changed through the use of the library function `acc_set_cuda_stream`. When the function `acc_set_cuda_stream` is called, the CUDA stream that was originally associated with the `async` clause is destroyed. Caution should be taken when changing the association as subsequent references to the `async-argument` refer to a different CUDA stream.

[1] See "Stream Management" in "CUDA Driver API", TRM-06703-001, Version 5.5, for additional information

9 OpenACC Library Interoperability

9.1 Introduction

The OpenACC library uses the CUDA Driver API, and may interact with programs that use the Runtime library directly, or another library based on the Runtime library, e.g., CUBLAS[1]. This chapter describes the use cases and what changes are required in order to use both the OpenACC library and the CUBLAS and Runtime libraries within a program.

9.2 First invocation: NVIDIA CUBLAS library API

In this first use case (see below), a function in the CUBLAS library is called prior to any of the functions in the OpenACC library. More specifically, the function `cublasCreate()`.

When invoked, the function initializes the library and allocates the hardware resources on the host and the device on behalf of the caller. Once the initialization and allocation has completed, a handle is returned to the caller. The OpenACC library also requires initialization and allocation of hardware resources. Since the CUBLAS library has already allocated the hardware resources for the device, all that is left to do is to initialize the OpenACC library and acquire the hardware resources on the host.

Prior to calling the OpenACC function that initializes the library and allocate the host hardware resources, you need to acquire the device number that was allocated during the call to `cublasCreate()`. The invoking of the runtime library function `cudaGetDevice()` accomplishes this. Once acquired, the device number is passed along with the device type as parameters to the OpenACC library function `acc_set_device_num()`.

Once the call to `acc_set_device_num()` has completed, the OpenACC library uses the context that was created during the call to `cublasCreate()`. In other words, both libraries share the same context.

```
/* Create the handle */
s = cublasCreate(&h);
if (s != CUBLAS_STATUS_SUCCESS)
{
    fprintf(stderr, "cublasCreate failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Get the device number */
e = cudaGetDevice(&dev);
if (e != cudaSuccess)
{
    fprintf(stderr, "cudaGetDevice failed %d\n", e);
    exit(EXIT_FAILURE);
}

/* Initialize OpenACC library and use device 'dev' */
acc_set_device_num(dev, acc_device_nvidia);
```

Use Case 1

[1] See section 2.26, "Interactions with the CUDA Driver API" in "CUDA Runtime API", Version 5.5, and section 2.27, "VDPAU Interoperability", in "CUDA Driver API", TRM-06703-001, Version 5.5, for additional information on library interoperability.

9.3 First invocation: OpenACC library API

In this second use case (see below), a function in the OpenACC library is called prior to any of the functions in the CUBLAS library. More specifically, the function `acc_set_device_num()`.

In the use case presented here, the function `acc_set_device_num()` is used to both initialize the OpenACC library and allocate the hardware resources on the host and the device. In the call to the function, the call parameters specify which device to use and what device type to use, i.e., `acc_device_nvidia`. It should be noted that this is but one method to initialize the OpenACC library and allocate the appropriate hardware resources. Other methods are available through the use of environment variables and these is discussed in the next section.

Once the call to `acc_set_device_num()` has completed, other OpenACC functions can be called as seen with multiple calls being made to `acc_copyin()`. In addition, calls can be made to functions in the CUBLAS library. In the use case a call to `cublasCreate()` is made subsequent to the calls to `acc_copyin()`. As seen in the previous use case, a call to `cublasCreate()` initializes the CUBLAS library and allocates the hardware resources on the host and the device. However, since the device has already been allocated, `cublasCreate()` only initializes the CUBLAS library and allocates the appropriate hardware resources on the host. The context that was created as part of the OpenACC initialization is shared with the CUBLAS library, similarly to the first use case.

```
dev = 0;

acc_set_device_num(dev, acc_device_nvidia);

/* Copy the first set to the device */
d_X = acc_copyin(&h_X[0], N * sizeof (float));
if (d_X == NULL)
{
    fprintf(stderr, "copyin error h_X\n");
    exit(EXIT_FAILURE);
}

/* Copy the second set to the device */
d_Y = acc_copyin(&h_Y1[0], N * sizeof (float));
if (d_Y == NULL)
{
    fprintf(stderr, "copyin error h_Y1\n");
    exit(EXIT_FAILURE);
}

/* Create the handle */
s = cublasCreate(&h);
if (s != CUBLAS_STATUS_SUCCESS)
{
    fprintf(stderr, "cublasCreate failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Perform saxpy using CUBLAS library function */
s = cublasSaxpy(h, N, &alpha, d_X, 1, d_Y, 1);
if (s != CUBLAS_STATUS_SUCCESS)
{
```

```
    fprintf(stderr, "cublasSaxpy failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Copy the results from the device */
acc_memcpy_from_device(&h_Y1[0], d_Y, N * sizeof (float));
```

Use Case 2

9.4 OpenACC library and environment variables

There are two environment variables associated with the OpenACC library that may be used to control the device type and device number: `ACC_DEVICE_TYPE` and `ACC_DEVICE_NUM`, respectively. These two environment variables can be used as an alternative to calling `acc_set_device_num()`. As seen in the second use case, the device type and device number were specified using `acc_set_device_num()`. If however, the aforementioned environment variables were set, then the call to `acc_set_device_num()` would not be required.

The use of the environment variables is only relevant when an OpenACC function is called prior to a call to `cudaCreate()`. If `cudaCreate()` is called prior to a call to an OpenACC function, then you must call `acc_set_device_num()`[2]

[2] More complete information about `ACC_DEVICE_TYPE` and `ACC_DEVICE_NUM` can be found in sections 4.1 and 4.2 of the OpenACC (`https://www.openacc.org`) Application Programming Interface", Version 2.6.

10 OpenACC Profiling Interface

10.1 Implementation Status and Implementation-Defined Behavior

We're implementing the OpenACC Profiling Interface as defined by the OpenACC 2.6 specification. We're clarifying some aspects here as *implementation-defined behavior*, while they're still under discussion within the OpenACC Technical Committee.

This implementation is tuned to keep the performance impact as low as possible for the (very common) case that the Profiling Interface is not enabled. This is relevant, as the Profiling Interface affects all the *hot* code paths (in the target code, not in the offloaded code). Users of the OpenACC Profiling Interface can be expected to understand that performance is impacted to some degree once the Profiling Interface is enabled: for example, because of the *runtime* (libgomp) calling into a third-party *library* for every event that has been registered.

We're not yet accounting for the fact that *OpenACC events may occur during event processing*. We just handle one case specially, as required by CUDA 9.0 `nvprof`, that `acc_get_device_type` (Section 6.3 [acc_get_device_type], page 63)) may be called from `acc_ev_device_init_start`, `acc_ev_device_init_end` callbacks.

We're not yet implementing initialization via a `acc_register_library` function that is either statically linked in, or dynamically via `LD_PRELOAD`. Initialization via `acc_register_library` functions dynamically loaded via the `ACC_PROFLIB` environment variable does work, as does directly calling `acc_prof_register`, `acc_prof_unregister`, `acc_prof_lookup`.

As currently there are no inquiry functions defined, calls to `acc_prof_lookup` always returns `NULL`.

There aren't separate *start*, *stop* events defined for the event types `acc_ev_create`, `acc_ev_delete`, `acc_ev_alloc`, `acc_ev_free`. It's not clear if these should be triggered before or after the actual device-specific call is made. We trigger them after.

Remarks about data provided to callbacks:

`acc_prof_info.event_type`

It's not clear if for *nested* event callbacks (for example, `acc_ev_enqueue_launch_start` as part of a parent compute construct), this should be set for the nested event (`acc_ev_enqueue_launch_start`), or if the value of the parent construct should remain (`acc_ev_compute_construct_start`). In this implementation, the value generally corresponds to the innermost nested event type.

`acc_prof_info.device_type`

- For `acc_ev_compute_construct_start`, and in presence of an `if` clause with *false* argument, this still refers to the offloading device type. It's not clear if that's the expected behavior.
- Complementary to the item before, for `acc_ev_compute_construct_end`, this is set to `acc_device_host` in presence of an `if` clause with *false* argument. It's not clear if that's the expected behavior.

`acc_prof_info.thread_id`
: Always `-1`; not yet implemented.

`acc_prof_info.async`
: - Not yet implemented correctly for `acc_ev_compute_construct_start`.
  - In a compute construct, for host-fallback execution/`acc_device_host` it always is `acc_async_sync`. It is unclear if that is the expected behavior.
  - For `acc_ev_device_init_start` and `acc_ev_device_init_end`, it will always be `acc_async_sync`. It is unclear if that is the expected behavior.

`acc_prof_info.async_queue`
: There is no *limited number of asynchronous queues* in libgomp. This always has the same value as `acc_prof_info.async`.

`acc_prof_info.src_file`
: Always `NULL`; not yet implemented.

`acc_prof_info.func_name`
: Always `NULL`; not yet implemented.

`acc_prof_info.line_no`
: Always `-1`; not yet implemented.

`acc_prof_info.end_line_no`
: Always `-1`; not yet implemented.

`acc_prof_info.func_line_no`
: Always `-1`; not yet implemented.

`acc_prof_info.func_end_line_no`
: Always `-1`; not yet implemented.

`acc_event_info.event_type`, `acc_event_info.*.event_type`
: Relating to `acc_prof_info.event_type` discussed above, in this implementation, this will always be the same value as `acc_prof_info.event_type`.

`acc_event_info.*.parent_construct`
: - Will be `acc_construct_parallel` for all OpenACC compute constructs as well as many OpenACC Runtime API calls; should be the one matching the actual construct, or `acc_construct_runtime_api`, respectively.
  - Will be `acc_construct_enter_data` or `acc_construct_exit_data` when processing variable mappings specified in OpenACC *declare* directives; should be `acc_construct_declare`.
  - For implicit `acc_ev_device_init_start`, `acc_ev_device_init_end`, and explicit as well as implicit `acc_ev_alloc`, `acc_ev_free`, `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`, `acc_ev_enqueue_download_start`, and `acc_ev_enqueue_download_end`, will be `acc_construct_parallel`; should reflect the real parent construct.

`acc_event_info.*.implicit`
: For `acc_ev_alloc`, `acc_ev_free`, `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`, `acc_ev_enqueue_download_start`, and

`acc_ev_enqueue_download_end`, this currently will be `1` also for explicit usage.

`acc_event_info.data_event.var_name`
: Always `NULL`; not yet implemented.

`acc_event_info.data_event.host_ptr`
: For `acc_ev_alloc`, and `acc_ev_free`, this is always `NULL`.

`typedef union acc_api_info`
: . . . as printed in *5.2.3. Third Argument: API-Specific Information*. This should obviously be `typedef` *`struct`* `acc_api_info`.

`acc_api_info.device_api`
: Possibly not yet implemented correctly for `acc_ev_compute_construct_start`, `acc_ev_device_init_start`, `acc_ev_device_init_end`: will always be `acc_device_api_none` for these event types. For `acc_ev_enter_data_start`, it will be `acc_device_api_none` in some cases.

`acc_api_info.device_type`
: Always the same as `acc_prof_info.device_type`.

`acc_api_info.vendor`
: Always `-1`; not yet implemented.

`acc_api_info.device_handle`
: Always `NULL`; not yet implemented.

`acc_api_info.context_handle`
: Always `NULL`; not yet implemented.

`acc_api_info.async_handle`
: Always `NULL`; not yet implemented.

Remarks about certain event types:

`acc_ev_device_init_start`, `acc_ev_device_init_end`

- When a compute construct triggers implicit `acc_ev_device_init_start` and `acc_ev_device_init_end` events, they currently aren't *nested within* the corresponding `acc_ev_compute_construct_start` and `acc_ev_compute_construct_end`, but they're currently observed *before* `acc_ev_compute_construct_start`. It's not clear what to do: the standard asks us provide a lot of details to the `acc_ev_compute_construct_start` callback, without (implicitly) initializing a device before?
- Callbacks for these event types will not be invoked for calls to the `acc_set_device_type` and `acc_set_device_num` functions. It's not clear if they should be.

`acc_ev_enter_data_start`, `acc_ev_enter_data_end`, `acc_ev_exit_data_start`, `acc_ev_exit_data_end`

- Callbacks for these event types will also be invoked for OpenACC *host_data* constructs. It's not clear if they should be.

- Callbacks for these event types will also be invoked when processing variable mappings specified in OpenACC *declare* directives. It's not clear if they should be.

Callbacks for the following event types will be invoked, but dispatch and information provided therein has not yet been thoroughly reviewed:

- `acc_ev_alloc`
- `acc_ev_free`
- `acc_ev_update_start`, `acc_ev_update_end`
- `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`
- `acc_ev_enqueue_download_start`, `acc_ev_enqueue_download_end`

During device initialization, and finalization, respectively, callbacks for the following event types will not yet be invoked:

- `acc_ev_alloc`
- `acc_ev_free`

Callbacks for the following event types have not yet been implemented, so currently won't be invoked:

- `acc_ev_device_shutdown_start`, `acc_ev_device_shutdown_end`
- `acc_ev_runtime_shutdown`
- `acc_ev_create`, `acc_ev_delete`
- `acc_ev_wait_start`, `acc_ev_wait_end`

For the following runtime library functions, not all expected callbacks will be invoked (mostly concerning implicit device initialization):

- `acc_get_num_devices`
- `acc_set_device_type`
- `acc_get_device_type`
- `acc_set_device_num`
- `acc_get_device_num`
- `acc_init`
- `acc_shutdown`

Aside from implicit device initialization, for the following runtime library functions, no callbacks will be invoked for shared-memory offloading devices (it's not clear if they should be):

- `acc_malloc`
- `acc_free`
- `acc_copyin`, `acc_present_or_copyin`, `acc_copyin_async`
- `acc_create`, `acc_present_or_create`, `acc_create_async`
- `acc_copyout`, `acc_copyout_async`, `acc_copyout_finalize`, `acc_copyout_finalize_async`
- `acc_delete`, `acc_delete_async`, `acc_delete_finalize`, `acc_delete_finalize_async`

- `acc_update_device`, `acc_update_device_async`
- `acc_update_self`, `acc_update_self_async`
- `acc_map_data`, `acc_unmap_data`
- `acc_memcpy_to_device`, `acc_memcpy_to_device_async`
- `acc_memcpy_from_device`, `acc_memcpy_from_device_async`

11 OpenMP-Implementation Specifics

11.1 Implementation-defined ICV Initialization

affinity-format-var	See Section 4.2 [OMP_AFFINITY_FORMAT], page 50.
def-allocator-var	See Section 4.1 [OMP_ALLOCATOR], page 49.
max-active-levels-var	See Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53.
dyn-var	See Section 4.7 [OMP_DYNAMIC], page 52.
nthreads-var	See Section 4.12 [OMP_NUM_THREADS], page 54.
num-devices-var	Number of non-host devices found by GCC's run-time library
num-procs-var	The number of CPU cores on the initial device, except that affinity settings might lead to a smaller number. On non-host devices, the value of the *nthreads-var* ICV.
place-partition-var	See Section 4.14 [OMP_PLACES], page 55.
run-sched-var	See Section 4.16 [OMP_SCHEDULE], page 56.
stacksize-var	See Section 4.15 [OMP_STACKSIZE], page 56.
thread-limit-var	See Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 57,
wait-policy-var	See Section 4.20 [OMP_WAIT_POLICY], page 57, and Section 4.24 [GOMP_SPINCOUNT], page 59,

11.2 OpenMP Context Selectors

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

For the host compiler, `kind` always matches `host`; for the offloading architectures AMD GCN and Nvidia PTX, `kind` always matches `gpu`. For the x86 family of computers, AMD GCN and Nvidia PTX the following traits are supported in addition; while OpenMP is supported on more architectures, GCC currently does not match any `arch` or `isa` traits for those.

`arch`	`isa`
`x86`, `x86_64`, `i386`, `i486`, `i586`, `i686`, `ia32`	See `-m...` flags in "x86 Options" (without `-m`)
`amdgcn`, `gcn`	See `-march=` in "AMD GCN Options"[1]
`nvptx`, `nvptx64`	See `-march=` in "Nvidia PTX Options"

11.3 Memory allocation

The description below applies to:

- Explicit use of the OpenMP API routines, see Section 3.11 [Memory Management Routines], page 39.
- The `allocate` clause, except when the `allocator` modifier is a constant expression with value `omp_default_mem_alloc` and no `align` modifier has been specified. (In that case, the normal `malloc` allocation is used.)

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

- Using the `allocate` directive for automatic/stack variables, except when the `allocator` clause is a constant expression with value `omp_default_mem_alloc` and no `align` clause has been specified. (In that case, the normal allocation is used: stack allocation and, sometimes for Fortran, also `malloc` [depending on flags such as `-fstack-arrays`].)
- Using the `allocate` directive for variable in static memory is currently not supported (compile time error).
- In Fortran, the `allocators` directive and the executable `allocate` directive for Fortran pointers and allocatables is supported, but requires that files containing those directives has to be compiled with `-fopenmp-allocators`. Additionally, all files that might explicitly or implicitly deallocate memory allocated that way must also be compiled with that option.

For the available predefined allocators and, as applicable, their associated predefined memory spaces and for the available traits and their default values, see Section 4.1 [OMP_ALLOCATOR], page 49. Predefined allocators without an associated memory space use the `omp_default_mem_space` memory space.

For the memory spaces, the following applies:

- `omp_default_mem_space` is supported
- `omp_const_mem_space` maps to `omp_default_mem_space`
- `omp_low_lat_mem_space` is only available on supported devices, and maps to `omp_default_mem_space` otherwise.
- `omp_large_cap_mem_space` maps to `omp_default_mem_space`, unless the memkind library is available
- `omp_high_bw_mem_space` maps to `omp_default_mem_space`, unless the memkind library is available

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 `interleaved`; note that for `omp_large_cap_mem_space` the allocation will not be interleaved

On Linux systems, where the numa library (`https://github.com/numactl/numactl`) (`libnuma.so.1`) is available at runtime, it used when creating memory allocators requesting

- the `partition` trait `nearest`, except when both the libmemkind library is available and the memory space is either `omp_large_cap_mem_space` or `omp_high_bw_mem_space`

Note that the numa library will round up the allocation size to a multiple of the system page size; therefore, consider using it only with large data or by sharing allocations via the `pool_size` trait. Furthermore, the Linux kernel does not guarantee that an allocation will always be on the nearest NUMA node nor that after reallocation the same node will be used. Note additionally that, on Linux, the default setting of the memory placement policy is to use the current node; therefore, unless the memory placement policy has been

overridden, the `partition` trait `environment` (the default) will be effectively a `nearest` allocation.

Additional notes regarding the traits:

- The `pinned` trait is supported on Linux hosts, but is subject to the OS `ulimit/rlimit` locked memory settings.
- The default for the `pool_size` trait is no pool and for every (re)allocation the associated library routine is called, which might internally use a memory pool.
- For the `partition` trait, the partition part size will be the same as the requested size (i.e. `interleaved` or `blocked` has no effect), except for `interleaved` when the memkind library is available. Furthermore, for `nearest` and unless the numa library is available, the memory might not be on the same NUMA node as thread that allocated the memory; on Linux, this is in particular the case when the memory placement policy is set to preferred.
- The `access` trait has no effect such that memory is always accessible by all threads.
- The `sync_hint` trait has no effect.

See also: Chapter 12 [Offload-Target Specifics], page 99,

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_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.
- Low-latency memory (`omp_low_lat_mem_space`) is supported when the the `access` trait is set to `cgroup`. The default pool size is automatically scaled to share the 64 kiB

LDS memory between the number of teams configured to run on each compute-unit, but may be adjusted at runtime by setting environment variable `GOMP_GCN_LOWLAT_POOL=bytes`.

- `omp_low_lat_mem_alloc` cannot be used with true low-latency memory because the definition implies the `omp_atv_all` trait; main graphics memory is used instead.
- `omp_cgroup_mem_alloc`, `omp_pteam_mem_alloc`, and `omp_thread_mem_alloc`, all use low-latency memory as first preference, and fall back to main graphics memory when the low-latency pool is exhausted.

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_shared_memory` will remove any nvptx device from the list of available devices ("host fallback").
- The default per-warp stack size is 128 kiB; see also `-msoft-stack` in the GCC manual.
- The OpenMP routines `omp_target_memcpy_rect` and `omp_target_memcpy_rect_async` and the `target update` directive for non-contiguous list items will use the 2D and 3D memory-copy functions of the CUDA library. Higher dimensions will call those functions in a loop and are therefore supported.
- Low-latency memory (`omp_low_lat_mem_space`) is supported when the the `access` trait is set to `cgroup`, the ISA is at least `sm_53`, and the PTX version is at least 4.1. The default pool size is 8 kiB per team, but may be adjusted at runtime by setting environment variable `GOMP_NVPTX_LOWLAT_POOL=`*`bytes`*. The maximum value is limited by the available hardware, and care should be taken that the selected pool size does not unduly limit the number of teams that can run simultaneously.
- `omp_low_lat_mem_alloc` cannot be used with true low-latency memory because the definition implies the `omp_atv_all` trait; main graphics memory is used instead.
- `omp_cgroup_mem_alloc`, `omp_pteam_mem_alloc`, and `omp_thread_mem_alloc`, all use low-latency memory as first preference, and fall back to main graphics memory when the low-latency pool is exhausted.

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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Library Index

A

acc_get_property 64
acc_get_property_string 64

E

Environment Variable . . . 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59

F

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I

Implementation specific setting . . 53, 54, 56, 58, 59, 95