
Advanced OpenMP
Newer Features
archer2
epcc

OpenMP 4.0 and later

- Version 4.0 was released in July 2013
  - accelerator offloading, thread affinity, more task support
- Version 4.5 was released in Nov 2015
  - corrections and a few new features
  - now available in most production compilers (apart from the accelerator offloading features)
- Version 5.0 was released in Nov 2018
  - some extra features, extensions to offloading, new memory model, recent base language version support
  - some implementations support this
- Version 5.1 was released in Nov 2020 and 5.2 was released in Nov 2021
  - mostly minor changes
  - implementation mostly work-in-progress

Overview

- User defined reductions
- Construct cancellation
- Portable SIMD directives
- Extensions to tasking
- Thread affinity

User defined reductions

- As of 3.1 cannot do reductions on objects or structures.
- UDR extensions in 4.0 added support for this.

- Use **`declare reduction`** directive to define new reduction operators
- New operators can then be used in reduction clause.

```
#pragma omp declare reduction (reduction-identifier :
typename-list : combiner) [identity(identity-expr)]
```

- `reduction-identifier` gives a name to the operator
  - Can be overloaded for different types
  - Can be redefined in inner scopes
- `typename-list` is a list of types to which it applies
- `combiner` expression specifies how to combine values
- `identity` can specify the identity value of the operator
  - Can be an expression or a brace initializer

Example: merging vectors

```
#pragma omp declare reduction (merge : std::vector<int>
: omp_out.insert(omp_out.end(), omp_in.begin(), omp_in.end()))
```

- Private copies created for a reduction are initialized to the identity that was specified for the operator and type
  - Default identity defined if identity clause not present
- Compiler uses combiner to combine private copies
- **`omp_out`** refers to private copy that holds combined values
- **`omp_in`** refers to the other private copy
- Can now use **`merge`** as a reduction operator.

Construct cancellation

- Clean way to signal early termination of an OpenMP construct.
  - one thread signals
  - other threads jump to the end of the construct

```
!$omp cancel construct [if (expr)]
```

where *construct* is **`parallel`**, **`sections`**, **`do`** or **`taskgroup`** cancels the construct

```
!$omp cancellation point construct
```

checks for cancellation (also happens implicitly at cancel directive, barriers etc.)

Example

```
!$omp parallel do private(eureka)
do i=1,n
   eureka = testing(i,...)
!$omp cancel parallel if(eureka)
end do
```

- First thread for which `eureka` is true will cancel the parallel region and exit.
- Other threads exit next time they hit the `cancel` directive

Portable SIMD directives

- Many compilers support SIMD directives to aid vectorisation of loops.
  - compiler can struggle to generate SIMD code without these
- OpenMP 4.0 provides a standardised set
- Use **`simd`** directive to indicate a loop should be SIMDized

```
#pragma omp simd [clauses]
```

- Executes iterations of following loop in SIMD chunks
- Loop is not divided across threads
- SIMD chunk is set of iterations executed concurrently by SIMD lanes

- Clauses control data environment, how loop is partitioned
- `safelen(length)` limits the number of iterations in a SIMD chunk.
- `linear` lists variables with a linear relationship to the iteration space
- `aligned` specifies byte alignments of a list of variables
- `private`, `lastprivate`, `reduction` and `collapse` have usual meanings.
- Also `declare simd` directive to generate SIMDised versions of functions.
- Can be combined with loop constructs (parallelise and SIMDise)

Extensions to tasking

`taskloop` directive provides a convenient way to turn loop iterations into tasks

```
#pragma omp taskloop grainsize(16)
for (int i=0; i<n; i++){
   a[i] = somefunc(i);
}
```

- Each set of 16 consecutive iterations will form a task
- Can specify the number of tasks with the **`num_tasks`** clause instead of grainsize

Task dependencies

- **`depend`** clause on task construct

`!$omp task depend(`*type*`:`***list*`)`**

where *type* is **`in`**, **`out`** or **`inout`** and *list* is a list of variables.

  - list may contain subarrays: OpenMP 4.0 includes a syntax for C/C++

- **`in`**: the generated task will be a dependent task of all previously generated sibling tasks that reference at least one of the list items in an **`out`** or **`inout`** clause.
- **`out`** or **`inout`**: the generated task will be a dependent task of all previously generated sibling tasks that reference at least one of the list items in **`in`**, **`out`** or **`inout`** clause.

Example

```
#pragma omp task depend (out:a)
    { ... }
#pragma omp task depend (out:b)
    { ... }
#pragma omp task depend (in:a,b)
    { ... }
```

- The first two tasks can execute in parallel
- The third task cannot start until both the first two are complete

Thread affinity

- OpenMP 4.0 gives much more control

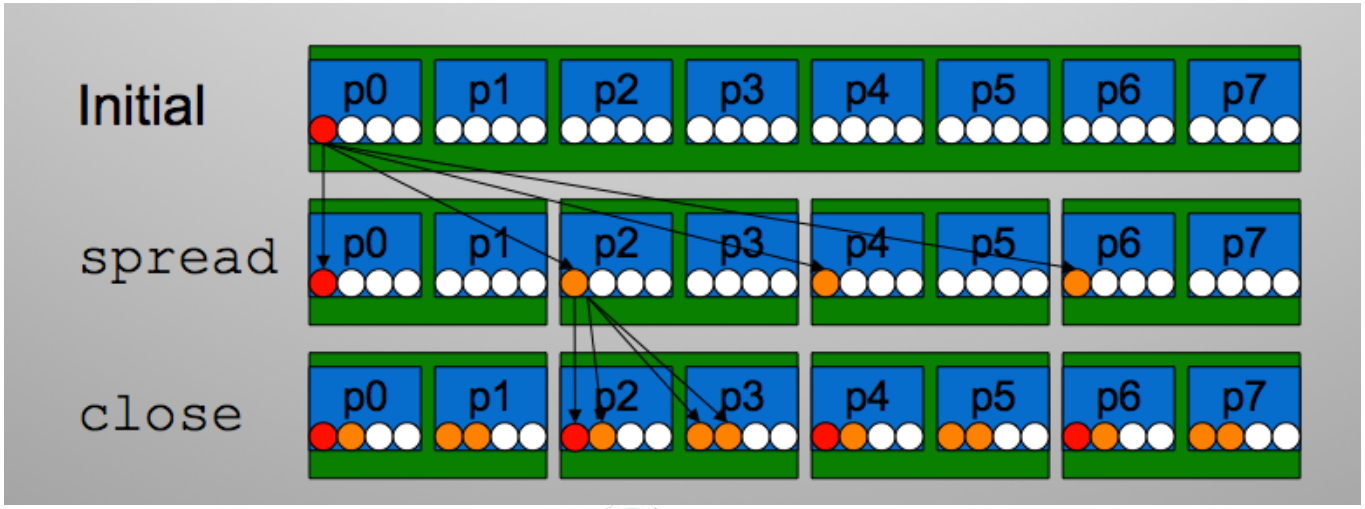
Affinity environment

- Since many systems are now NUMA and SMT, placement of threads on the hardware can have a big effect on performance.
- Increased choices for `OMP_PROC_BIND`
- Can still specify `true` or `false`
- Can now provide a list (possible item values: `master`, `close` or `spread`) to specify how to bind parallel regions at different nesting levels.
- Added `OMP_PLACES` environment variable
- Can specify abstract names including threads, cores and sockets
- Can specify an explicit ordered list of places
- Place numbering is implementation defined

Example

- Two levels of nested parallel regions
- Hardware with 8 cores and 4 hardware threads per core

```
export OMP_NUM_THREADS=4,2
export OMP_PLACES=threads
export OMP_PROC_BIND="spread,close"
```



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