A Modern Memory Management System for OpenMP

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Motivation: Variety in Memory Hierarchies

Platform	Memory Kind							
	Constant	Texture	SPM	DDR	eDRAM	GDDR	HBM	NVRAM
Intel® Xeon® Processor	-	-	-	✓	-	-	-	-
Intel® Xeon Phi™ Coprocessor	-	-	-	-	-	✓	-	-
Intel® Xeon Phi™ Processor	-	-	-	✓	-	-	✓	-
Future System w/ 3D XPoint™ Technology	-	-	-	✓	-	-	-	✓
Intel® HD Graphics	-	-	✓	✓	✓	-	-	-
Intel® Iris™ Graphics	-	-	✓	✓	✓	-	-	-
Current Generation NVIDIA* GPU	✓	✓	✓	-	-	✓	-	-
Future Generation NVIDIA* GPU	✓	✓	✓	-	-	✓	✓	-

Motivation: Inadequate Allocation Interfaces

- Language standards are not keeping pace with modern hardware:
  - Legacy `malloc`, `new`/`delete`, `ALLOCATE` take one parameter: size.
  - Later additions have focused primarily on alignment.

- A growing number of incompatible and overlapping options in development:
  - Proprietary allocators (e.g. `_mm_malloc`, `cudaMalloc`)
  - Scalable threaded allocators (e.g. `jemalloc`, `TBBmalloc`)
  - OS functionality (e.g. `LD_PRELOAD`, `numactl`)
  - Environment variables (e.g. `MKL_FAST_MEMORY_LIMIT`)

Design: Key Principles

- Three driving principles:
  1. Support as many existing memories as possible.
  2. Support future memories without requiring significant changes.
  3. Support all types of user allocations (e.g. static, stack, heap).

- We believe that a successful interface for HPC should also:
  - Be simple to integrate into large codes.
  - Be aware of (and make allowances for) legacy interfaces that cannot be changed.
  - Be compatible with existing HPC programming models.

Proposal: Key Concepts

- **Traits**
  - Descriptive characteristics that can be queried and specified by the user.
- **Memory Space**
  - A particular system-level storage resource.
  - Example Traits: “Kind”; Page Size; Permissions; Persistence; Capacity
- **Allocator**
  - An object that manages memory allocations from a given memory space.
  - Example Traits: Thread Safety; Default Alignment; Pinning; Fallback Behavior

Proposal: Example Usage of the API

```
omp_memtrait_t lbm_traits[] = { {OMP_MTK_BANDWIDTH, OMP_MTV_LOWEST}, {OMP_MT_PAGESIZE, 2*1024*1024} };
omp_memtrait_t hbm_traits[] = { {OMP_MTK_BANDWIDTH, OMP_MTV_HIGHEST}, {OMP_MT_PAGESIZE, 2*1024*1024} };

omp_memtrait_set_t lbmset, hbmset;

omp_init_memtrait_set(&lbmset, 2, lbm_traits);
omp_init_memtrait_set(&hbmset, 2, hbm_traits);

omp_memspace_t* ddr_mem = omp_init_memspace(&lbmset);
omp_memspace_t* hbw_mem = omp_init_memspace(&hbmset);

omp_alloctrait_set smallset, largeset;

omp_alloctrait_t small_traits[] = { {OMP_ATK_ALIGNMENT, 64}, {OMP_ATK_FALLBACK, OMP_ATV_ABORT} };
omp_init_alloctrait_set(&smallset, 2, small_traits);
omp_allocator_t* small_allocator = omp_init_allocator(ddr_mem, &smallset);

omp_alloctrait_t large_traits[] = { {OMP_ATK_ALIGNMENT, 64}, {OMP_ATK_FALLBACK, OMP_ATV_ALLOCATOR},
                                    {OMP_ATK_FBDATA, small_allocator} };
omp_init_alloctrait_set(&largeset, 3, large_traits);
omp_allocator_t* large_allocator = omp_init_allocator(hbw_mem, &largeset);

…

void foo(omp_allocator_t* allocator)
{
        double* array = (double*) omp_allocate(allocator, sizeof(double)*N);
        …
        omp_free(allocator, array);
}
```

Key
type
trait
API

Proposal: Example Usage of the Directives/Clauses

```
double a[N];
#pragma omp allocate(a) memtraits(bandwidth=lowest, pagesize=2*1024*1024) // allocate directive

void foo(omp_allocator_t* allocator)
{
      double b[N];
      #pragma omp allocate(b) allocator(allocator)

      double c[M];
      #pragma omp parallel firstprivate(b) private(c) \
      allocate(memtraits(bandwidth=highest, pagesize=2*1024*1024):b,c) // allocate clause
      {
            …
      } // private copies of c are automatically deallocated at the exit of this scope

} // b and c are automatically deallocated at the exit of this scope
```

Key
type
trait
directive
clause

Proposal: Support for Special Instructions

```
#pragma omp declare version(foo_persistent) memtraits(persistence=true:v)
#pragma omp declare version(foo_scratch) memtraits(location=core:v)
void foo(double* v) { … }

#pragma omp declare version implements(foo) memtraits(optimized=latency:v)
void foo_fancy(double* v) { … }

void bar (double* a)
{
      double b[N];
      #pragma omp allocate(b) memtraits(location=core)

      #pragma omp dispatch(b)
      foo(b); // compiler can see static memtraits of ‘b’ so can call foo_scratch

      #pragma omp dispatch(a)
      foo(a); // compiler must perform reflection on ‘a’ for dynamic dispatch

      foo_fancy(a); // user can call foo_fancy manually, based on program knowledge
}
```

Key
type
trait
directive

Summary

- We have proposed a novel mechanism for memory management that:
  - Separates **storage resources** from **allocation behavior**.
  - Provides a **platform-agnostic interface** for querying and managing memory.
  - Is **compatible with OpenMP*** directives.

- Working on an OpenMP TR with newest candidate directives/API for release by end of 2016.

- Future work:
  - Continue to refine and iterate over our proposal until it's accepted by the standard. ☺

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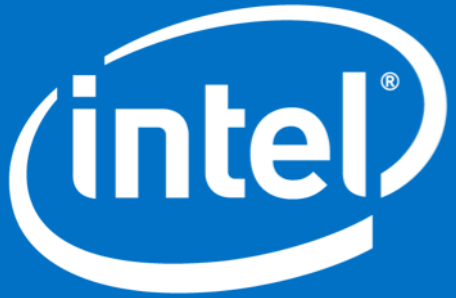
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