OpenMP

Portable Performance in Numerical Linear Algebra Software with OpenMP

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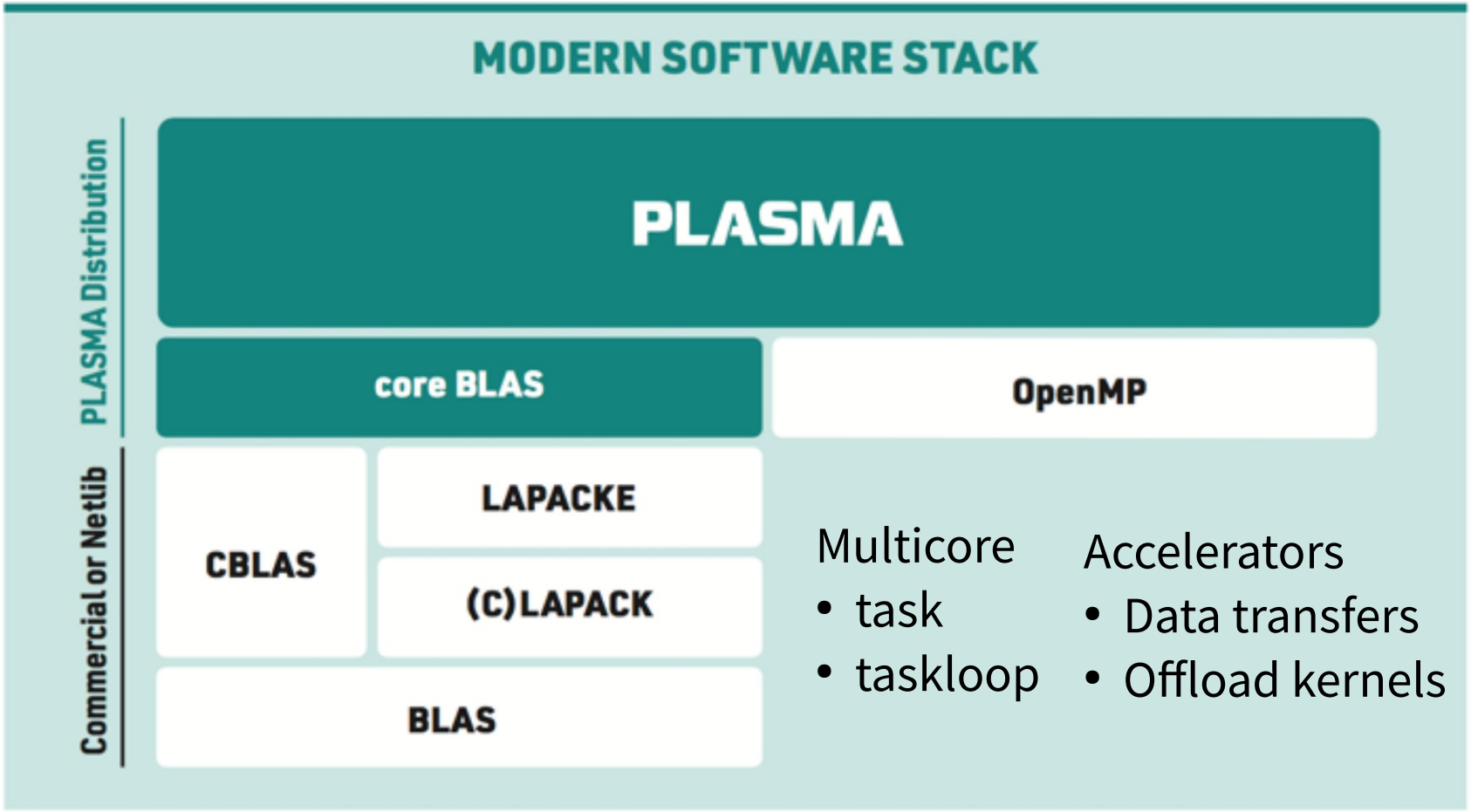
PLASMA:
Paralllel Linear Algebra for Scalable Multicores & Accelerators

- Dense: linear, least-squares, EIG/SVD (with vectors)
- Tile matrix layout and OpenMP 4 tasking
- Threading variants
  - POSIX (obsolete)
  - WinThreads (obsolete)
  - OpenMP 4+ (currently supported)
- Targeted Compilers and Software Stacks
  - OSS
    - LLVM Clang 11, GNU GCC 10+
  - Accelerator vendors
    - AMD AOMP 11, Intel OneAPI, NVIDIA NVHPC SDK 20+
  - Integrators
    - IBM XL 16, HPE/Cray 9

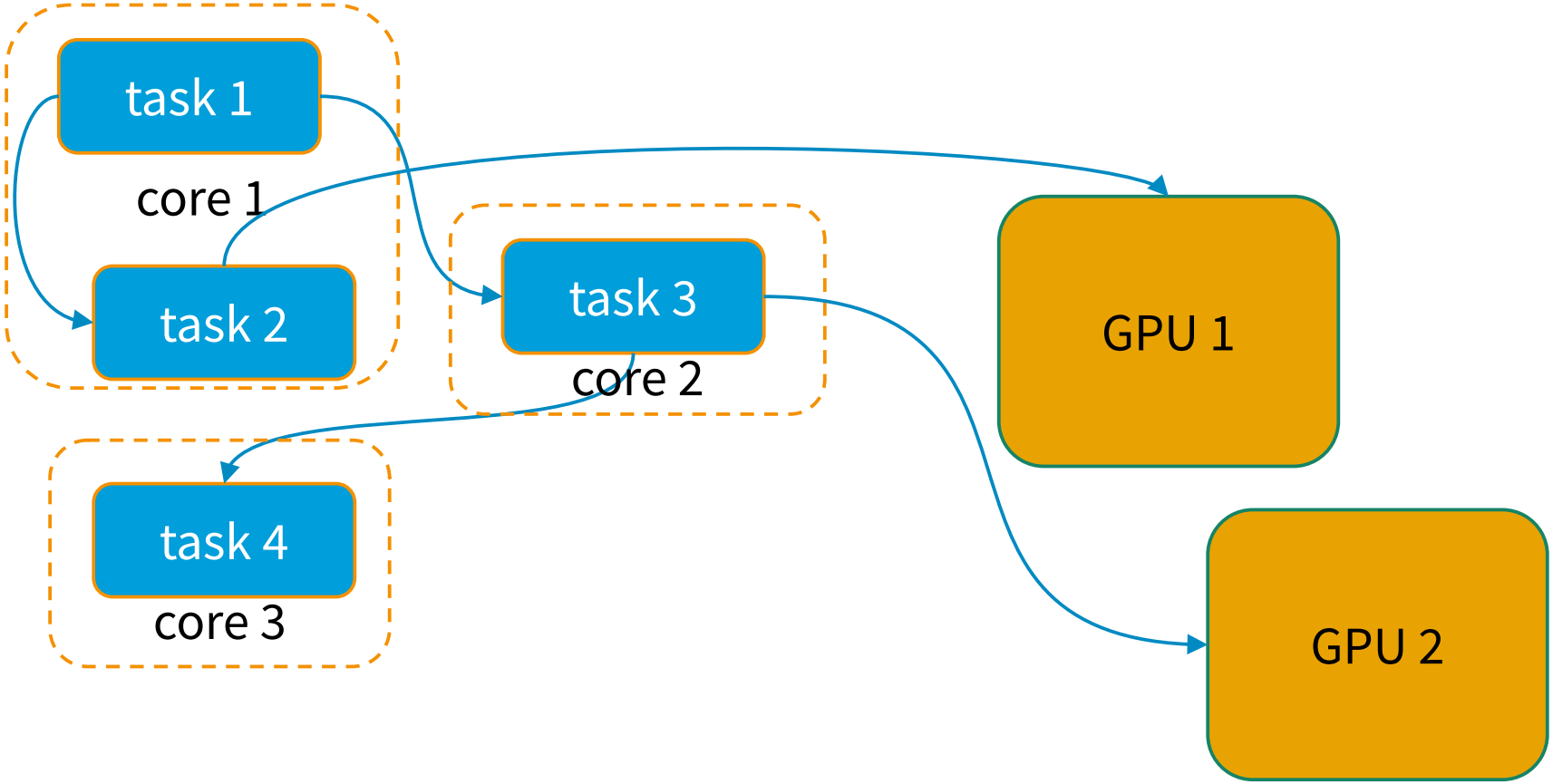
PLASMA with OpenMP Tasking and Offload



PLASMA

BLAS & LAPACK	BLAS++ & LAPACK++	OpenMP	Software Defined Events
ARM Math Lib.	cuBLAS	ECP SOLLVE	ExaPAPI
ESSL	oneMKL	IBM XL	Exascale Hardware
MKL	rocBLAS	Intel OpenMP	

PLASMA Task Scheduling



On-Device Performance From Vendor Libraries

```
int dev = omp_get_default_device();
double *a = mkl_malloc(a_ld * n * 8, 64);
#pragma omp target data map(to:a,b) map(tofrom:c)
{
#pragma omp target variant dispatch use_device_ptr(a,b,c) device(dev) \
 nowait
mkl_dgemm(tA, tB, m, n, k, alpha, a, a_ld, b, b_ld, beta, c, c_ld);
#pragma omp taskwait
}
```

- Common interfaces that Reuse or emulate established interfaces (optimized by vendors)
  - DGEMM(), cuDgemm(), hipDgemm(), rocDgemm(), mkl_dgemm()

On-Device Storage with Device-Resident Allocations

```
double *a = omp_target_alloc(device, a_ld * n * 8, 64);
omp_target_memcpy(..., a);
omp_target_free(a);
```

- Abstractions that are well defined for practical structure of objects formed from users' data
  - Focusing on user experience
  - Object hierarchy for matrix, vector, execution policy (host or device)

Device-Specific Dispatch with Vendor Runtime Integration

```
#pragma omp target data map(a[0:n*n],b[0:n*n]) map(alloc:c[0:n*n])
#pragma omp target data use_device_ptr(a,b,c)
{
  cudaStream_t ompStream = (cudaStream_t)omp_get_cuda_stream(dev);
  cublasSetStream(handle, stream);
  cublasDgemm(handle, CUBLAS_OP_N, CUBLAS_OP_N, m, n, k,
    &alpha, a, a_ldim, b, b_ld, &beta, c, c_ldim);
}
```

SLATE: Scalable Linear Algebra Targeting Exascale

- Compute targets
  - Distributed memory
  - Multicore
  - Multi-GPU systems
- Flexible tile storage with affinity tracking
- Generic algorithms
  - Programming against generic types
  - Testing on concrete types

SLATE: dense and low-rank algorithms

- Large scope in terms of hardware
  - Multicore
    - ARM, POWER, x86
  - GPUs
    - CUDA, HIP, SYCL
  - Distributed memory
    - MPI (multithreaded)
- Large algorithmic scope
  - Dense algorithms: linear, least-squares, eigenvalue, SVD
  - Matrix types and storages: rectangular, square, triangular, trapezoidal
  - Low-rank algorithms (ACA, low-rank tiles, …)
- OpenMP coordinates with MPI, use of cores, and launching kernles on devices

Reusable Portability Layers

- Dense and batched kernels hiding HPC compute code
  - BLAS++
  - LAPACK++
- Randomized kernels and algorithms hiding HPC randomization, projections, and iteration
  - RandBLAS
  - RandLAPACK