StarPU-MPI

Task Programming over Clusters of Machines Enhanced with Accelerators

RUNTIME

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Task Scheduling on Accelerated Cluster Nodes

Clusters follow the general accelerator movement

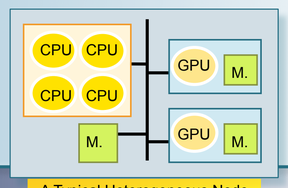
- Distributed Computing
- Node level heterogeneity
  - Multicore CPUs
  - Accelerator boards (GPU, etc)

Applications embrace the task-based approach

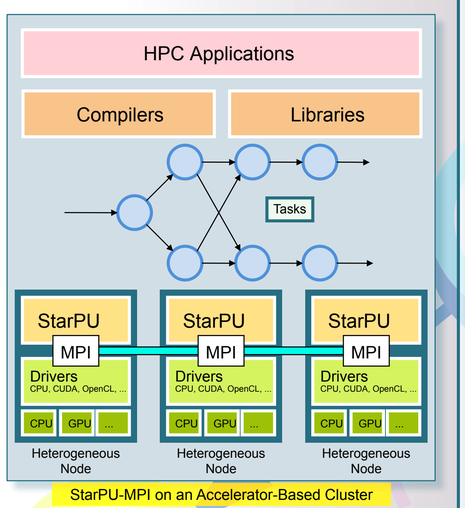
- Portability
- Flexibility
- Portability of Performances

Problem

- Design a task-based programming model for clusters



A Typical Heterogeneous Node



StarPU-MPI on an Accelerator-Based Cluster

The StarPU Paradigm

Process-level task scheduling

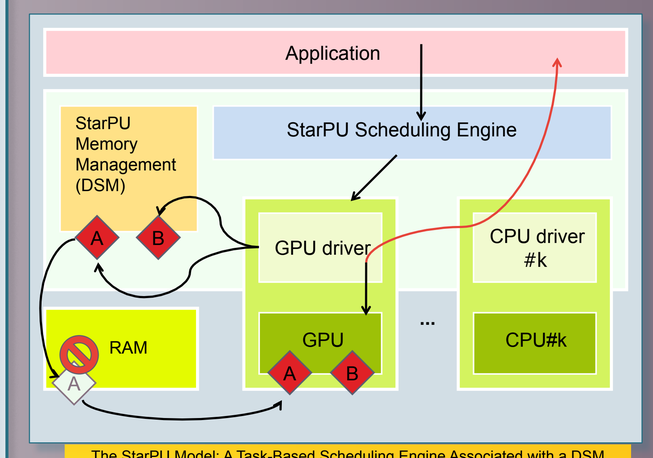
- Use every available computing units
  - CPU cores
  - Accelerated units (GPUs)

Data management using a DSM

- Data transfers to/from embedded memory
- Caching, replication
- Consistency management

Optimization

- Minimize a given cost function
  - Overall execution time
  - Power consumption
- Estimate the cost of upcoming tasks
  - History backlog
  - Parametric task-cost models
- Estimate the cost of upcoming transfers
  - Hardware buses calibration



The StarPU Model: A Task-Based Scheduling Engine Associated with a DSM

The StarPU-MPI Task Model

Goals

- Extend the StarPU model to clusters
- Avoid global cluster-wide scheduler
- Minimize changes to single node clusters

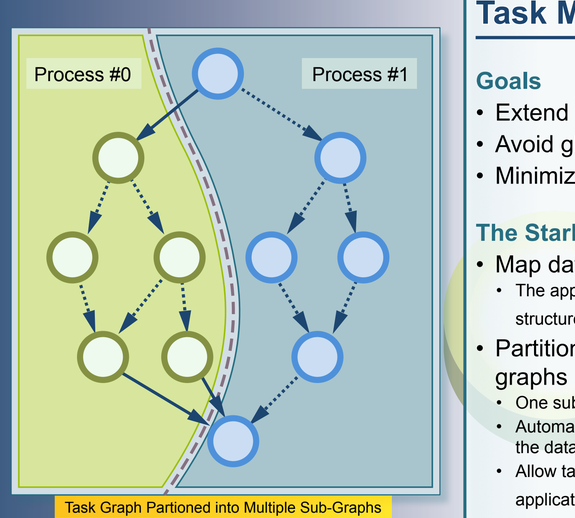
The StarPU-MPI Approach

- Map data onto cluster processes
  - The application controls the mapping of data structures
- Partition the graph into multiple sub-graphs
  - One sub-graph per StarPU instance
  - Automatically execute tasks on the process that own the data to be written to
  - Allow task execution location override by the application
- Handle inter-process dependencies
  - Automatically replace data dependencies across sub-graphs with MPI transfers
  - Implement an optional cache mechanism to eliminate redundant data transfers

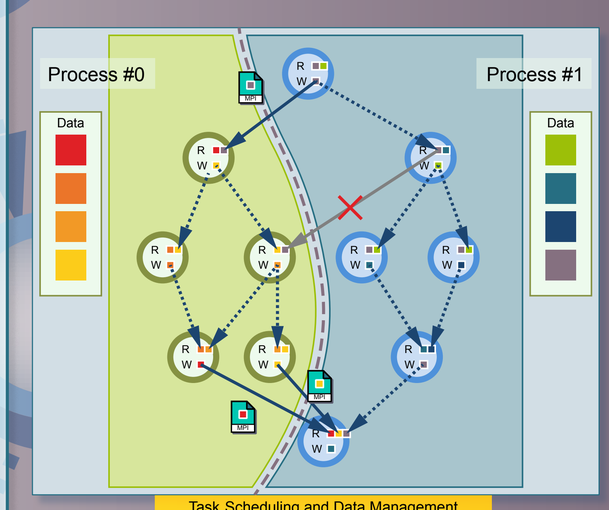
- Preserve the StarPU model within processes
  - StarPU-MPI inherits the scheduling capabilities of StarPU within a process
  - StarPU-MPI inherits the data management capabilities of StarPU within a process
  - StarPU Application codelets can seemlessly be reused for StarPU-MPI Applications
- Optimize data transfers
  - StarPU-MPI transparently overlaps MPI communication with computation

```
for(x = 0; x < X; x++)
    for(y = 0; y < Y; y++)
        starpu_matrix_data_register(&A[x][y], 0, &A_tile[x][y], ld, tile_s,tile_s);
        starpu_data_set_rank(A[x][y], (y%Y_BLK)*X_BLK + (x%X_BLK));

for (k = 0; k < Nt; k++)
    starpu_mpi_insert_task(MPI_COMM_WORLD, &potrf, RW, A[k][k], 0);
    for (m = k+1; m < Nt; m++)
        starpu_mpi_insert_task(MPI_COMM_WORLD, &trsm, R, A[k][k], RW, A[m][k], 0);

    for (m = k+1; m < Nt; m++)
        for (n = k+1; n < m; n++)
            starpu_mpi_insert_task(MPI_COMM_WORLD, &gemm, R, A[m][k], R, A[n][k], RW, A[m][n], 0);

        starpu_mpi_insert_task(MPI_COMM_WORLD, &syrk, R, A[m][k], RW, A[m][m], 0);

starpu_task_wait_for_all();
```

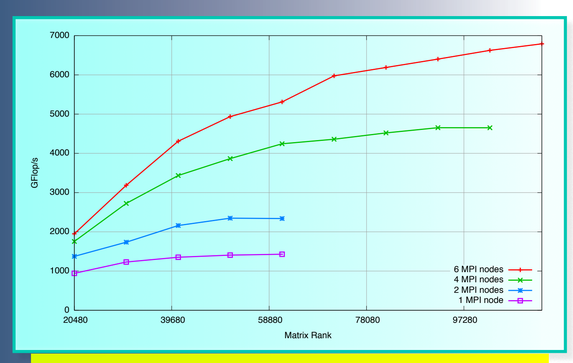
Example Code: Cholesky Decomposition using StarPU-MPI



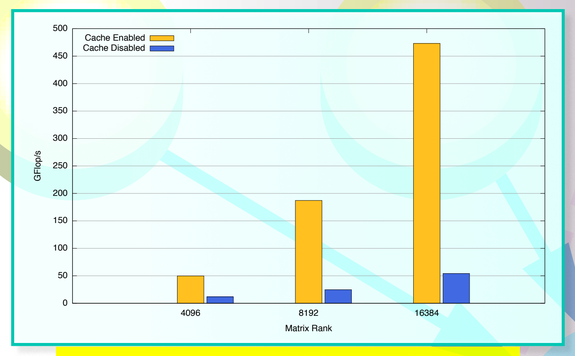
Task Graph Partioned into Multiple Sub-Graphs



Task Scheduling and Data Management



Strong scalability of a Cholesky decomposition over a cluster of machines accelerated with 3 GPUs and 12 CPU cores per MPI node



Effect of the StarPU-MPI cache mechanism on the efficiency of a Cholesky decomposition computation using two MPI nodes

Perspectives

Availability

- On-going work to include StarPU-MPI support in the MORSE software distribution

Scalability

- Optimize global graph traversal
- Prune submissions of non-local tasks that don't have cluster-wide impact

Granularity

- Automatically adapt task workload to available hardware
  - Aggregate tasks to improve the computation/overhead ratio
  - Split tasks to improve load balancing and accomodate many-core resources

Flexibility

- Adapt sessions to changing contexts
  - Changes in cores availability
  - Changes in nodes availability

Evaluation

Strong Scalability

The plot above shows the strong scalability obtained by the Cholesky decomposition on a cluster of machines enhanced with accelerators.

Each machine has two Intel Nehalem X5650 sockets with 6 cores each running at 2.67 GHz, as well as 3 NVIDIA Fermi M2070 GPUs each.

Effectiveness of the Cache Mechanism

The plot above shows the effectiveness of the cache mechanism implemented by the data management layer of StarPU-MPI.

The data cache dramatically improves the computation efficiency by avoiding unnecessary MPI transfers.

Contact

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- Grants
  - EU FP7 PEPPHER [contract num 248481]
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