HYDRA: Extending Shared Address Programming for Accelerator Clusters

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Highlights
- HYDRA: extending shared address programming to accelerator clusters
- Programmer only specifies parallel regions
- Fully automatic translation system generates MPI + accelerator code
- Optimized accelerator data placement and transfer
- High-level IR supports multiple accelerator architectures
- Average 64-node cluster speedups: 24.54x on Xeon Phi, 27.56x on GPU

HYDRA Programming Model
HYDRA is a directive-based shared address programming model offering a single parallel loop construct.

```
#pragma hydra parallel for [clauses]
```

All available clauses for the HYDRA parallel loop directive are listed in Table 1. These clauses are syntactically optional but might be needed for program semantics.

### Table 1:HYDRA Parallel Loop Clauses

<table>
<thead>
<tr>
<th>Clauses</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>shared</td>
<td>shared(varlist)</td>
</tr>
<tr>
<td>private</td>
<td>private(varlist)</td>
</tr>
<tr>
<td>firstprivate</td>
<td>firstprivate(varlist)</td>
</tr>
<tr>
<td>reduction</td>
<td>reduction(op:varlist)</td>
</tr>
</tbody>
</table>

![Figure 1: HYDRA Program Example](image)

Extending Shared Address Programming Beyond CPU Clusters

Data Transfer Analysis
- Precise data transfer between host and accelerator memory is critical. Excessive transfer overhead can limit scalability

Algorithm
- Perform local analysis of shared data access
- First step: Identify necessary shared data for a program block
  - Use LUSE information to determine a live-in and live-out data
- Second step: Determine the transfer range of the shared data
  - Transfer range can be defined by the minimum lower bound and the maximum upper bound of local accesses

Memory Allocation Optimization
- Full data allocation could exceed its capacity
- Failure of single accelerator execution
- Inability to scale to multiple nodes

Algorithm
- Perform global analysis to summarize all accesses of the shared data
- The allocation size can be found using the minimum lower bound and maximum upper bound of all accesses
- Compiler deal with the misalignment of the newly allocated and old shared data

HYDRA Translation System
- Compiler: Translate HYDRA programs to accelerated MPI programs
- Support multiple target accelerator architectures

![Figure 2: HYDRA Compiler Translation Process](image)

Evaluation

Strong Scaling - Scalability

![Strong Scalling - Memory Allocation](image)

Weak Scaling - Scalability

![Weak Scalling - Memory Allocation](image)

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