CHAPEL-ON-HSA: TOWARDS SEAMLESS ACCELERATION OF CHAPEL PROGRAMS USING HSA

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THE HETEROGENEOUS SYSTEM ARCHITECTURE (HSA)
OPEN STANDARD PLATFORM SPECIFICATION

- Enables efficient, portable management of heterogeneous systems
- Shared address space abstraction
  - No explicit data movement
  - Single pointer across all devices
- Fast user-mode task dispatch
  - Shared memory queues for user-space direct packet enqueue
  - Fast user-space synchronization
- Multi-device support: GPUs, DSPs, FPGAs, NICs, PIM, etc.
  - A single task dispatch packet format across all devices
- Pre-emptive context-switching
- Open-source implementation
- Support for multiple higher-level languages
EXECUTING A GPU KERNEL

Host Application (C/C++)
1. Discover devices, create queues
2. Read & finalize kernel object code
3. Create HSA packet (kernel handle, argument ptrs)
4. Enqueue packet
5. Wait on completion signal

Device Kernel (OpenCL)
1. Compile to object code
Native single-source GPU execution support

Expose GPU execution capabilities in the language
- Expose GPU as a sublocale
- New “HSA” hierarchical locale with CPU and GPU sublocales
- Any operation executed on a GPU sublocale gets executed on a GPU

```plaintext
on Locales[0] do {
    var A: [1..3] int = (1,2,3);
    on (Locales[0]:LocaleModel).GPU do {
        //Data-parallel constructs
        var sum = + reduce A;
    }
}
```
GPU EXECUTION IN CHAPEL

Runtime

- Discover devices, create queues
- Read & finalize kernel object code
- Create HSA packet (kernel handle, argument ptrs)
- Enqueue packet
- Wait on completion signal

Compiler

- Generate OpenCL code
- Interface with runtime to execute kernel

Build System

- Compile to object code
COMPILER MODIFICATIONS
CODE GENERATION AND KERNEL EXECUTION

- Parse
- Create Task Functions
- Parallel Transforms
- Optimizations
- C-Codegen
COMPILER MODIFICATIONS

Parse

- Insert new Chapel block for GPU offload
- Conditional execution of GPU code if sublocale is GPU

Create Task Functions

- Create new task functions for GPU blocks

Create GPU Functions

- Bundle core GPU executable in a new GPU function
- Maintain unique ids
- Capture arguments and bundle into 1 parameter

Parallel Transforms

- Generate OpenCL code for GPU functions in .cl file
- Use runtime enqueue calls to enqueue functions using ids

Optimizations

C-Codegen
OFFLOADING NODE-LOCAL REDUCTIONS

- Predefined reduction operators to reduce aggregate expressions to a single result
  
  ```chapel
  var A: [1..3] int = (1,2,3);
  var sum = + reduce A;
  ```

- CPU reductions are pre-defined in the ChapelReduce module

- Similarly, we use precompiled OpenCL kernels
  - Separate OpenCL kernel for every <operator, data-type> pair

- Parser replaces a reduction expression with a call to the Chapel runtime routine

- GPU reductions are tricky!
  - Multiple calls to the kernels followed by processing on the CPU
  - Runtime orchestrates execution of multiple kernels
  - Direct translation of CPU code not appropriate
REDUCTION RESULTS

A10-7850K WITH RADEON™ R7 SERIES (4 CPU CORES @3.7 GHZ, 512 GPU CORES@720MHZ)

HSA Integer Reductions

Time in ms

Data items

256K 1M 4M 16M

GPU-Unoptimized CPU GPU-Optimized
OFFLOADING NODE-LOCAL FORALLS

Data-parallelism

```
var A: [1..256] int;
forall i in {1..256} do
  A[i] = i;
```

CPU task-parallelism

```
var A: [1..256] int;
coforall j in {1..4} do {
  const lo = 1+(i-1)*64;
  const hi = lo + 63;
  for i in {lo..hi}
    A[i] = i;
}
```

4 tasks in parallel
Each task does 64 serial iterations

GPU thread-parallelism

```
var A: [1..256] int;
size_t i = get_global_id(0)
A[i] = i;
```

256 work-items in parallel
4 workgroups
Each workgroup has 64 workitems
## OFFLOADING NODE-LOCAL FORALLS

<table>
<thead>
<tr>
<th>COMPILER</th>
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</thead>
<tbody>
<tr>
<td>▶ Bundle the loop body in a new GPU-targeted function</td>
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<tr>
<td>▶ Estimate work-items and work group size</td>
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<tr>
<td>▶ Replace loop variables with OpenCL calls to obtain thread id</td>
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<tr>
<td>▶ Insert OpenCL specific keywords (&quot;kernel&quot;, &quot;global&quot;)</td>
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<tr>
<td>▶ Emit kernel code in .cl file</td>
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<th>BUILD</th>
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<td>▶ Build system compiles the kernels to a GPU ISA using a llvm-based tool-chain</td>
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<td>▶ Kernel execution requests are sent to the runtime using the kernel-id</td>
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FUTURE WORK

- Multi-node reductions and coforalls
- Multi-dimensional arrays
- Expose workgroup based resources
  - Local memory
  - Barriers
- Benchmarking
- Testing
We Are Hiring!
Abhisek Pan Abhisek.Pan@amd.com
Mike Chu Mike.Chu@amd.com
Interns, Co-ops, Post-docs
(Fall 2016, Spring 2017,...)

Thank You!
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