MLIR open meeting

[RFC] Adding support for OpenMP GPU target offload

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Background
Target attributes determine how to compile GPU modules

- There is compilation support for NVIDIA #nvvm.target, AMD #rocdl.target and Intel #spirv.target
- With some caveats, the same GPU module can be compiled for different vendors. GPU binaries can hold objects from any target.

## Listing: GPU compilation operations and attributes

```mlir
gpu.module @moduleName [  
  #nvvm.target<chip = "sm_90", libs=[  
    "libomptarget-nvptx-sm_90.bc"
  ]>,
  #rocdl.target<chip = "gfx90a", libs=[  
    "libomptarget-amdgpu-gfx90a.bc"
  ]>,
] {
...
}

// mlir-opt --gpu-module-to-binary
gpu.binary @moduleName [  
  #gpu.object<  
    #nvvm.target<chip = "sm_90">, "Binary blob"
  >,
  #gpu.object<  
    #rocdl.target<chip = "gfx90a">, "Binary blob"
  >
]
```
Target attributes determine how to compile GPU modules

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- With some caveats, the same GPU module can be compiled for different vendors. GPU binaries can hold objects from any target.

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  #nvvm.target<chip = "sm_90", libs=[  
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  ]>,  
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  ]>,  
] {
...
}
// mlir-opt --gpu-module-to-binary
gpu.binary @moduleName [  
  #gpu.object<  
    #nvvm.target<chip = "sm_90">, "Binary blob"
  >,  
  #gpu.object<  
    #rocdl.target<chip = "gfx90a">, "Binary blob"
  >
]
```

Listing: GPU compilation operations and attributes
MLIR’s GPU compilation infrastructure: serialization

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7   ]>,  
8 ] {  
9   ...  
10  }
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15     >,  
16     #gpu.object<  
17     #rocdl.target<chip = "gfx90a">, "Binary blob"  
18     >  
19 ]
```

Listing: GPU compilation operations and attributes
Offloading attributes determine how to translate binaries and kernel launches

#gpu.select_object is the only offload attribute upstream

It supports embedding only one binary in the host module

**Listing: Translation of GPU operations**

```mlir
1 gpu.binary @kernels [#gpu.object<#nvvm.target, 
   offload = "BIN">]  
2 llvm.func @main () {  
3   %0 = llvm.mlir.constant (1 : index) : i64  
4   gpu.launch_func @kernels::@hello blocks in  
   (%0, %0, %0) threads in (%0, %0, %0) : i64  
5   llvm.return  
6 }  
7 // mlir-translate --mlir-to-llvmir  
8 @kernels_bin_cst = internal constant [3 x i8] c"BIN", align 8  
9 @kernels_hello_kernel_name = private unnamed_addr  
   constant [6 x i8] c"hello\00", align 1  
10 define void @main () {  
11   %3 = call ptr @mgpuModuleLoad (ptr @kernels_bin_cst, i64 3)  
12   %4 = call ptr @mgpuModuleGetFunction (ptr %3,  
      ptr @kernels_hello_kernel_name)  
13   call void @mgpuLaunchKernel (%4, ...)  
14   call void @mgpuModuleUnload (ptr %3)  
15   ret void  
16 }
```
MLIR’s GPU compilation infrastructure: embedding

- Offloading attributes determine how to translate binaries and kernel launches
- `#gpu.select_object` is the only offload attribute upstream
  - It supports embedding only one binary in the host module

```mlir
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@kernels_bin_cst = internal constant [3 x i8] c"BIN", align 8
@kernels_hello_kernel_name = private unnamed_addr constant [6 x i8] c"hello\00", align 1
define void @main() {
  %3 = call ptr @mgpuModuleLoad(ptr @kernels_bin_cst, i64 3)
  %4 = call ptr @mgpuModuleGetFunction(ptr %3, ptr @kernels_hello_kernel_name)
  call void @mgpuLaunchKernel(%4, ...) call void @mgpuModuleUnload(ptr %3)
  ret void
}
```

Listing: Translation of GPU operations
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 15 ret void
 16 }
```
Proposal
Offload embedding attribute

- `#gpu.offload_embedding` a new offload attribute, PR: #78117
- Instead of loading the binaries and kernels every time, everything gets registered into a runtime at startup.
- The CUDA, HIP, and LibOMPTarget runtimes become usable, PR: #78116.
- The CUDA runtime provides automatic context management, and it’s interoperable with the driver.

```mlir
// mlir-translate --mlir-to-llvmir
@gpu.binary @kernels
<#gpu.offload_embedding<CUDA>>
[#gpu.object<#nvvm.target, offload = "BIN">]
llvm.func @main() { ... }
// mlir-translate --mlir-to-llvmir
@__dev_image = ... [3 x i8] c"BIN" ...
@__kernel_id = weak constant i8 0
@__kernel_name = ... [6 x i8] c"hello\00"
@__bin_descriptor = internal constant ...
@llvm.global_ctors = ... [@__register_fn]
define void @__register_fn() {
define void @__register_lib(
define void @main() {
define void @mgpuLaunchKernel(@__kernel_id, ...)
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**Proposal**

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3  ([#gpu.object<nvvm.target, offload = "BIN">]
4  llvm.func @main() { ... }
5  // mlir-translate --mlir-to-llvmir
6  @_dev_image = ... [3 x i8] c"BIN" ...
7  @_kernel_id = weak constant i8 0
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9  @_bin_descriptor = internal constant ...
10  @llvm.global_ctors = ... [@__register_fn]
11  define void @_register_fn() {
12   call void @_register_lib(
13     ptr @_bin_descriptor)
14  ret void
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Main point: Enable GPU compilation for OMP target constructs

The OpenMPIRBuilder is still used; the proposal is only about adding a compilation driver

Addition of an outlining pass for omp.target ops similar to “gpu-kernel-outlining”, PR: #78328

This would allow testing the OMP dialect within MLIR, JIT-ting OMP offload code, mixing GPU and OMP, and developing the OMP dialect independently from flang and clang

Link: GH gist with a real-world example

Listing: MLIR with host and offload modules. Instead of having 2 MLIR files (host & dev), everything is embedded in a single file.
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```mlir
gpu.module @ompModule ... {
  func.func @main_outlined(...) {
    omp.target ... {
      // Target region
      omp.terminator
    }
  }
}
func.func @main(...) {
  omp.target ... {
    // Target region
    omp.terminator
  }
} 
```
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Future work
LLVM project offload

- Is an initiative proposed by Johannes Doerfert to make an official LLVM offload runtime, RFC: #74302
- The starting point is LibOMPTarget, and it will be transformed into a vendor-agnostic runtime API for GPU constructs
- The plan is to support NVIDIA, AMD, and Intel
- It could allow multi-vendor fat binaries
- It would allow JIT-compiling for AMD targets
- #gpu.offload_embedding is the starting point for supporting it in MLIR
- Eventually, we should consider dropping our GPU vendor wrappers in favor of LLVM offload
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