Peer-to-Peer & Unified Virtual Addressing

CUDA Webinar

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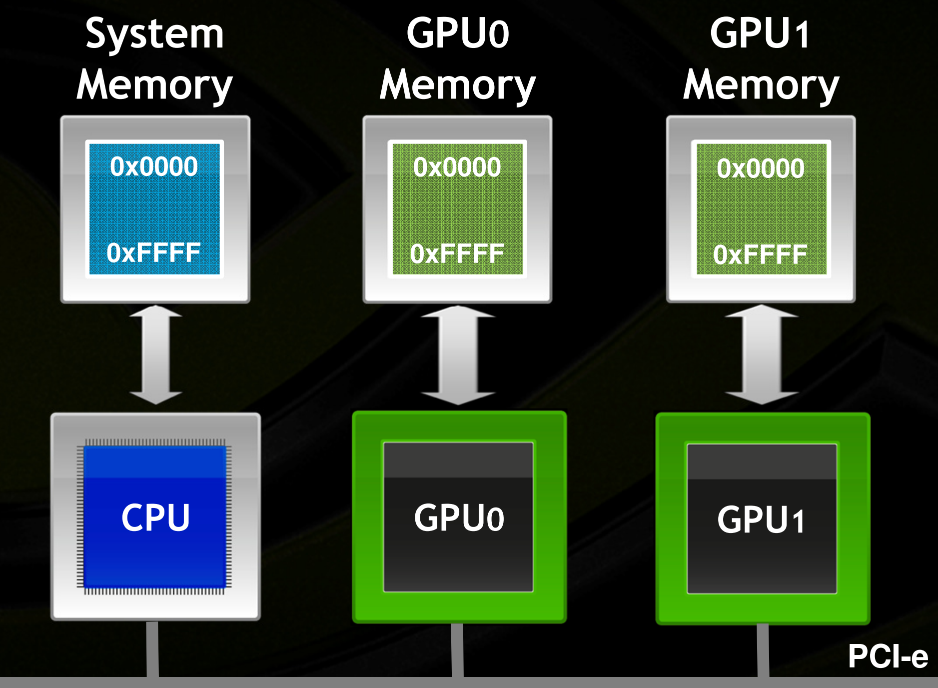
Outline

- Overview: P2P & UVA
- UVA Memory Copy
- UVA Zero-Copy
- P2P Memory Copy
- P2P Direct Addressing
- Summary, Further Reading and Questions

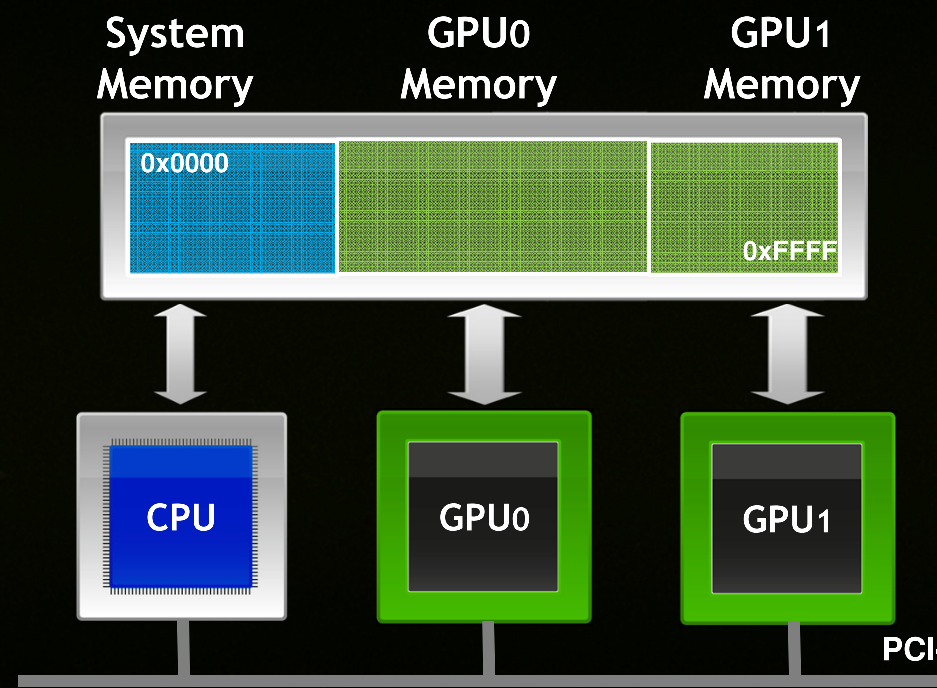
Unified Virtual Addressing

Easier to Program with Single Address Space

lo UVA: Multiple Memory Spaces

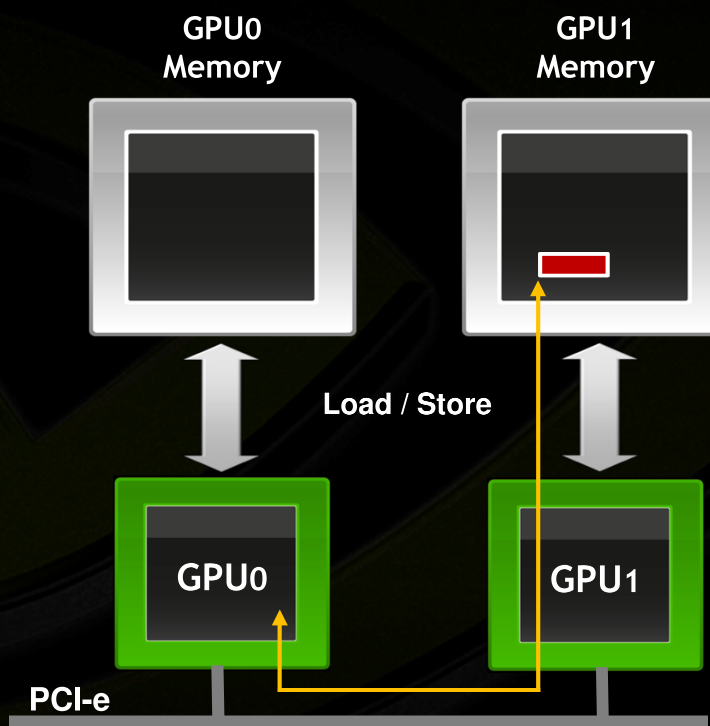


UVA: Single Address Space

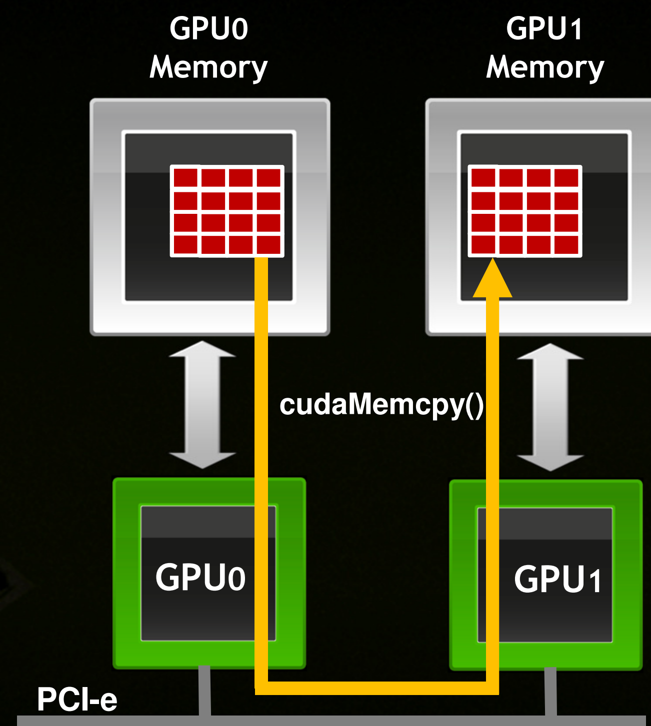


Peer-to-Peer (P2P) Communication

Direct Access



Direct Transfers



Eliminates system memory allocation & copy overhead

More convenient multi-GPU programming

What we're focusing on today

- **Lots of different use cases for P2P & UVA, we're going to go through the following:**
  - UVA Memory Copy - cudaMemcpy(…, cudaMemcpyDefault)
  - P2P Memory Copy (GPU to GPU)
  - P2P Memory Access from a CUDA kernel
  - …as demonstrated by the simpleP2P sample

Unified Virtual Addressing (UVA)

- **One address space for all CPU and GPU memory**
  - Determine physical memory location from pointer value
  - Enables libraries to simplify their interfaces (e.g. cudaMemcpy)

Before UVA	With UVA
Separate options for each permutation	One function handles all cases
cudaMemcpyHostToHost cudaMemcpyHostToDevice cudaMemcpyDeviceToHost cudaMemcpyDeviceToDevice	cudaMemcpyDefault (data location becomes an implementation detail)

UVA Memory Copy Step-by-Step (1/2)

- **Copy without specifying in which memory space src / dst are**
- **Requirements**
  - Needs to be a 64bit application
  - Fermi-class GPU
  - Linux or Windows TCC
  - CUDA 4.0
- **Call cudaGetDeviceProperties() for all participating devices, check cudaDeviceProp::unifiedAddressing flag**

UVA Memory Copy Step-by-Step (2/2)

- **Between host and multiple devices:**

```
cudaMemcpy(gpu0_buf, host_buf, buf_size, cudaMemcpyDefault)
cudaMemcpy(gpu1_buf, host_buf, buf_size, cudaMemcpyDefault)
cudaMemcpy(host_buf, gpu0_buf, buf_size, cudaMemcpyDefault)
cudaMemcpy(host_buf, gpu1_buf, buf_size, cudaMemcpyDefault)
```

- **Between two devices:**

```
cudaMemcpy(gpu0_buf, gpu1_buf, buf_size, cudaMemcpyDefault)
```

Zero-Copy Memory With UVA

- Pointers returned by cudaHostAlloc() can be used directly from within kernels running on UVA enabled devices (i.e. there is no need to obtain a device pointer via cudaHostGetDevicePointer())

Peer-to-Peer Communication Between GPUs

- **Direct Transfers**
  - cudaMemcpy() initiates DMA copy from GPU_0 memory to GPU_1 memory
  - Works transparently with CUDA Unified Virtual Addressing (UVA)

- **Direct Access**
  - GPU_0 reads or writes GPU_1 memory (load/store)
  - Data cached in L2 of the target GPU

- **Performance Expectations**
  - High bandwidth: saturates PCIe (> 6GB/s observed)
  - Low latency: 1 PCIe transaction + 1 memory fetch (~2.5us)

P2P Memory Copy Step-by-Step (1/4)

- **Copy data between GPUs without going through host memory**

- **Requirements**
  - Needs to be a 64bit application
  - Fermi-class Tesla GPU
  - Linux or Windows TCC
  - CUDA 4.0
  - Drivers v270.41.19 or later
  - GPUs need to be on same IOH

P2P Memory Copy Step-by-Step (2/4)

- **Check for peer access between participating GPUs:**

```
cudaDeviceCanAccessPeer(&can_access_peer_0_1, gpuid_0, gpuid_1);
cudaDeviceCanAccessPeer(&can_access_peer_1_0, gpuid_1, gpuid_0);
```

- **Enable peer access between participating GPUs:**

```
cudaSetDevice(gpuid_0);
cudaDeviceEnablePeerAccess(gpuid_1, 0);
cudaSetDevice(gpuid_1);
cudaDeviceEnablePeerAccess(gpuid_0, 0);
```

P2P Memory Copy Step-by-Step (3/4)

- **Now we can do a UVA memory copy just like before:**

```
cudaMemcpy(gpu0_buf, gpu1_buf, buf_size, cudaMemcpyDefault)
```

- **cudaMemcpy() knows that our buffers are on different devices (UVA), will do a P2P copy now**

- **Note that this will transparently fall back to a normal copy through the host if P2P is not available**

P2P Memory Copy Step-by-Step (4/4)

- **Shutdown peer access at the end:**

```
cudaSetDevice(gpuid_0);
cudaDeviceDisablePeerAccess(gpuid_1);
cudaSetDevice(gpuid_1);
cudaDeviceDisablePeerAccess(gpuid_0);
```

- **Optional**

  No need to shutdown if you’re requiring the same peer access throughout your program, but if it’s limited to a specific phase you can potentially reduce overhead and free resources by explicitly disabling it once you’re done

P2P Direct Access Step-by-Step (1/3)

- **Starting point – same as for P2P memory copy**
- **Same initialization**
  - cudaDeviceCanAccessPeer()
  - cudaDeviceEnablePeerAccess()
- **Same shutdown**
  - cudaDeviceDisablePeerAccess()
- **Same system requirements**

P2P Direct Access Step-by-Step (2/3)

- **Basic copy kernel as example, taking two buffers:**

```
__global__ void SimpleKernel(float *src, float *dst)
{
    const int idx = blockIdx.x * blockDim.x + threadIdx.x;
    dst[idx] = src[idx];
}
```

P2P Direct Access Step-by-Step (3/3)

- **After P2P initialization, this kernel can now read and write data in the memory of multiple GPUs:**

```
cudaSetDevice(gpuid_0); SimpleKernel<<<blocks, threads>>> (gpu0_buf, gpu1_buf);
cudaSetDevice(gpuid_0); SimpleKernel<<<blocks, threads>>> (gpu1_buf, gpu0_buf);

cudaSetDevice(gpuid_1); SimpleKernel<<<blocks, threads>>> (gpu0_buf, gpu1_buf);
cudaSetDevice(gpuid_1); SimpleKernel<<<blocks, threads>>> (gpu1_buf, gpu0_buf);
```

- **UVA makes sure the kernel knows whether its argument is from local memory, another GPU or zero-copy from the host**

Summary

- P2P and UVA can be used to both simplify and accelerate your CUDA programs
- Faster memory copies between GPUs with less host overhead
- Kernels can directly read and write memory of other GPUs
- Transparent addressing of memory on different devices

Further reading

- simpleP2P Sample, SDK 4.0 (Demonstrates both P2P & UVA)

- CUDA Programming Guide 4.0
  - 3.2.6.4 Peer-to-Peer Memory Access
  - 3.2.6.5 Peer-to-Peer Memory Copy
  - 3.2.7 Unified Virtual Address Space

Questions?