NVIDIA Tools For Profiling And Monitoring

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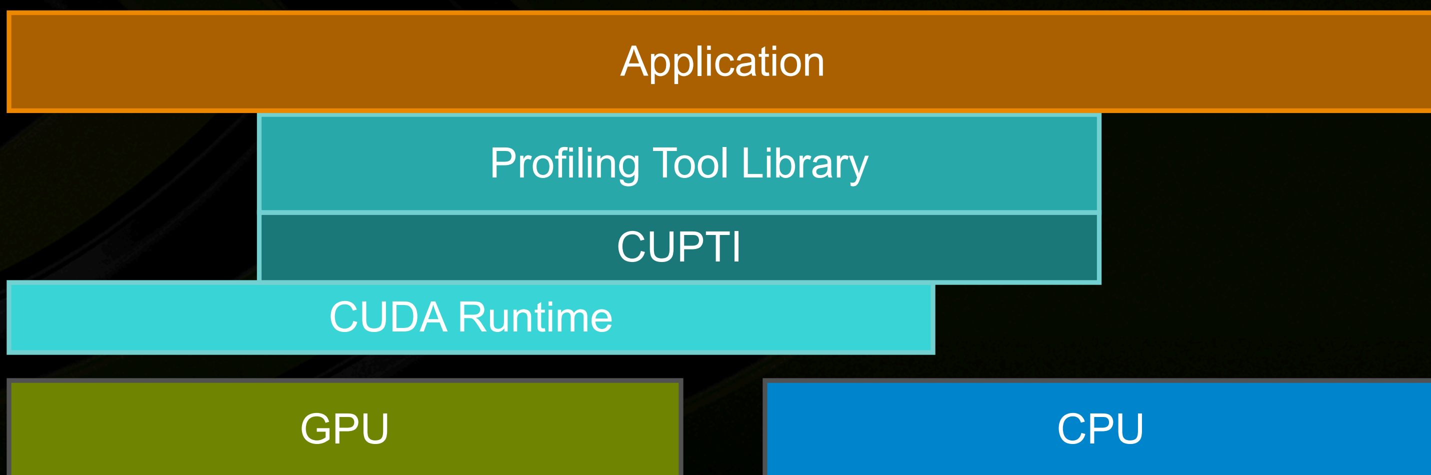
Outline

- CUDA Profiling and Monitoring
  - Libraries
  - Tools
- Technologies
- Directions

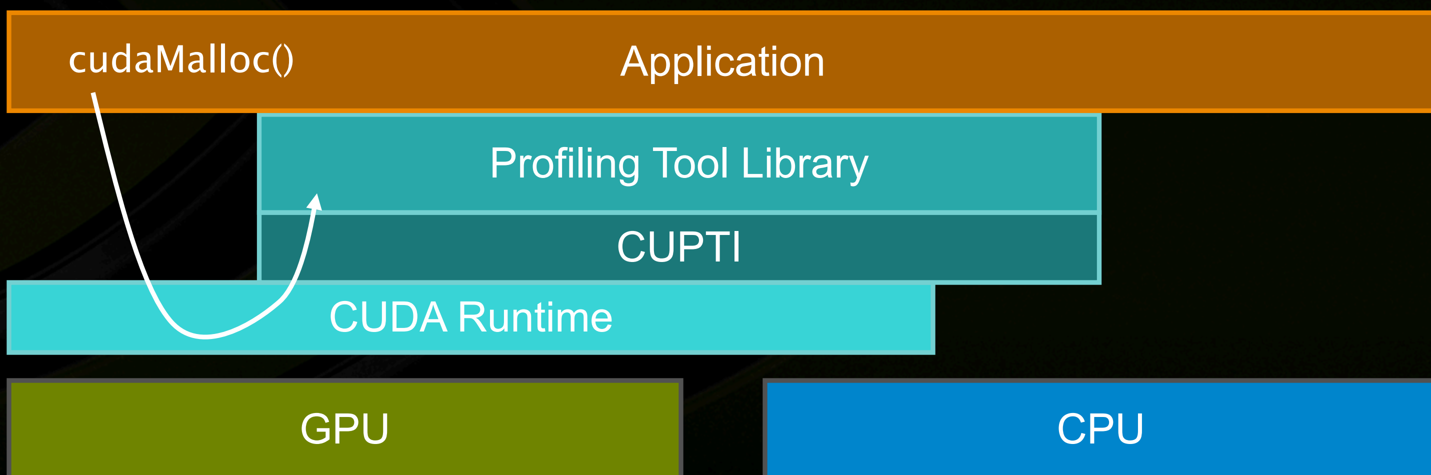
CUDA Profiling Tools Interface (CUPTI)

- CUPTI only supported interface for CUDA profiling
  - 3rd party profilers: Vampir, Tau, PAPI, …
  - Internal: NVIDIA Visual Profiler, nvprof



CUPTI Callbacks

- Profiling tool can register for callback on every CUDA API call
  - Callback at entry and exit
  - Callback get access to function parameters and return code
- Also for CUDA object create/destroy, synchronization

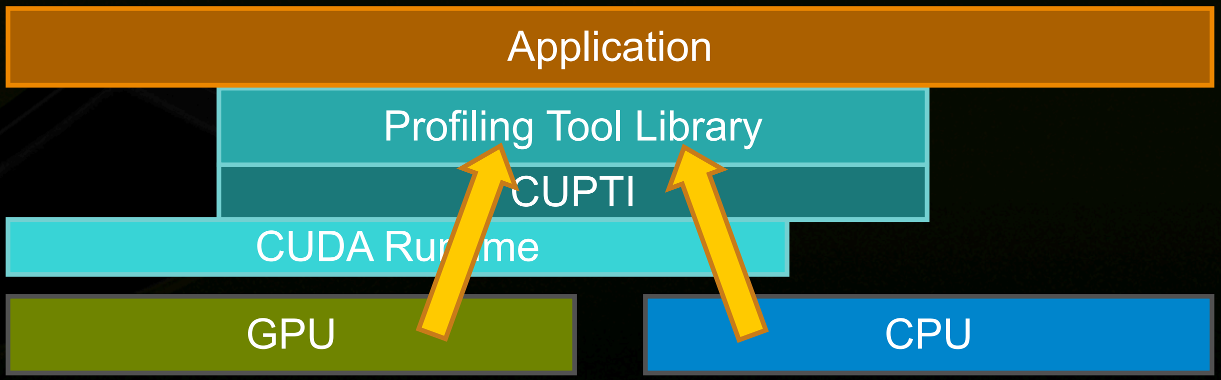


CUPTI Events and Metrics

- Events: low-level raw counts
  - Sample
  - Collect over duration of kernel execution
  - HW counters
  - SW patches
  - Replay kernel execution to collect large amount of data
- Metrics: typical profiling values
  - E.g. IPC, throughput, hit-rate, etc.
  - Derived from event values and system properties
  - More actionable

CUPTI Activity Trace

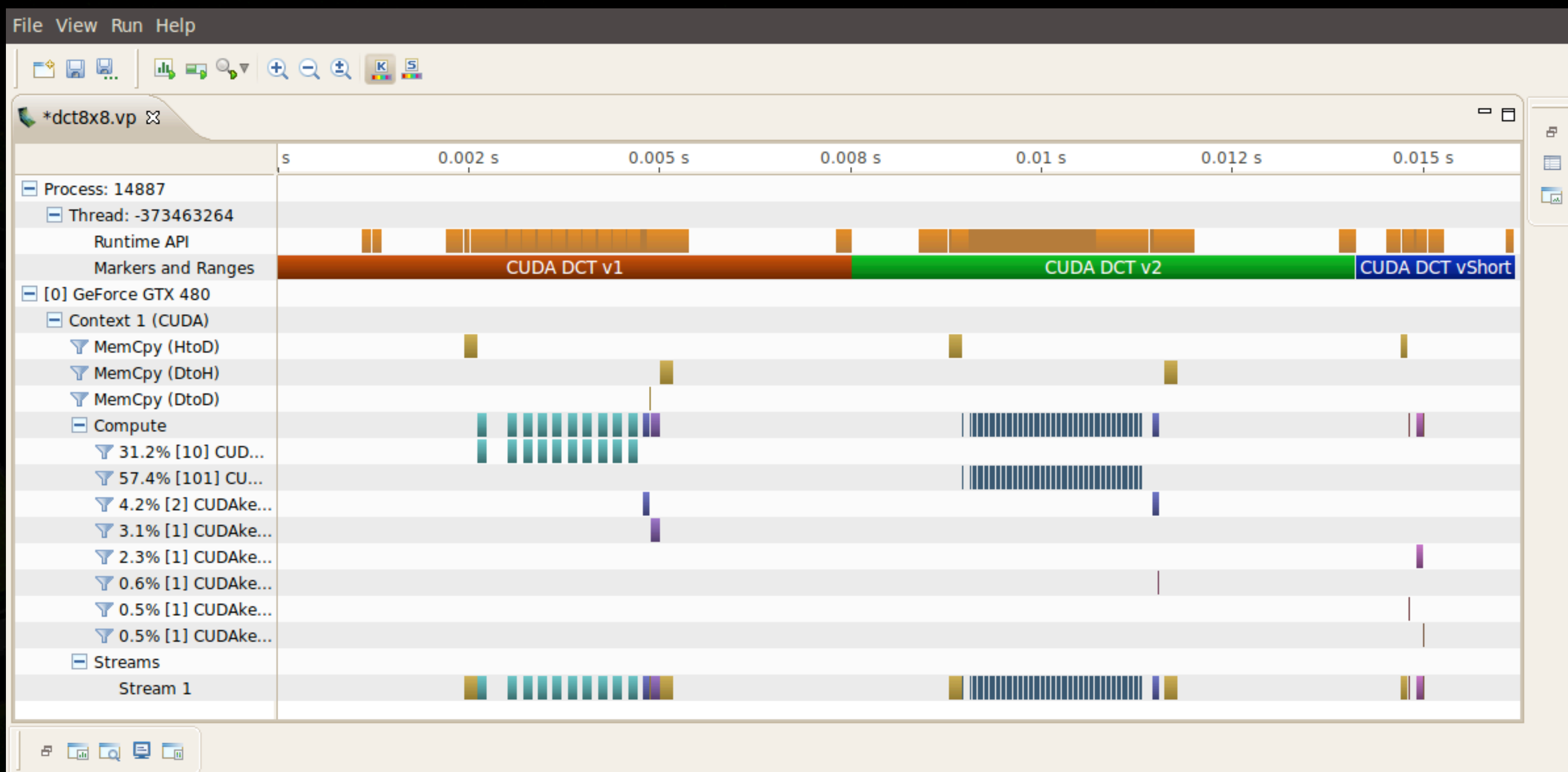
- Deliver asynchronous stream of system activity
  - GPU Kernel, memset, memcpy
  - CUDA API invocations
  - Developer-defined activity
  - Dynamic, Per-PC activity
    - Behavior of individual branches
    - Behavior of individual loads/stores



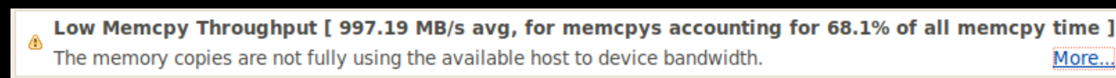
NVIDIA Profiling Tools

- Visual Profiler
  - Graphical, Eclipse-based
  - Timeline
  - Automated Analysis
- nvprof
  - Command-line
  - Backend for Visual Profiler
  - Built on CUPTI

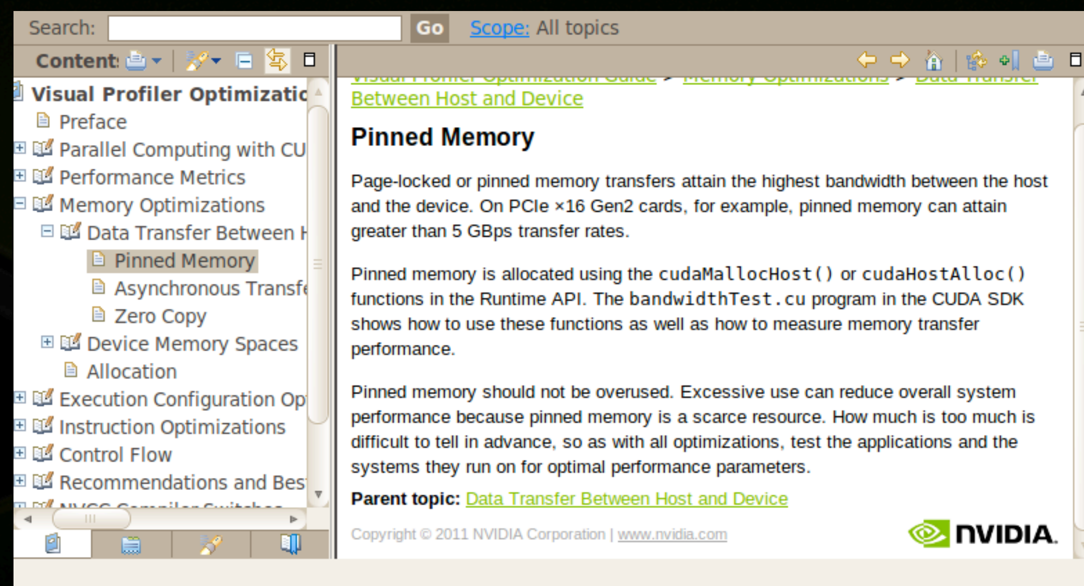
Visual Profiler - Timeline



Automated Analysis



- Actionable feedback
- Direct link to more extensive documentation
- Based on both trace and profile information



Automated Analysis - Expert System

- Identify bottlenecks
- Multiprocessor
  - Compute, latency, memory bound
  - FU, register, etc. resource limiters
- Memory subsytems
  - Global, Shared
  - Texture, Constant
  - Caches

Analysis Examples

- "Occupancy can potentially be improved by increasing the number of threads per block."
- "Global memory loads may have a bad access pattern, leading to inefficient use of global memory bandwidth."
- "The kernel is likely memory bound, but it is not fully utilizing the available DRAM bandwidth."
- "Divergent branches are causing significant instruction issue overhead."

nvprof

- Command-line interface to most CUPTI functionality
- Summary and full trace outputs
- Collect on headless node, visualize with Visual Profiler

```
$ nvprof dct8x8

======== Profiling result:
 Time(%)      Time   Calls       Avg       Min       Max  Name
   49.52    9.36ms     101   92.68us   92.31us   94.31us  CUDAkernel2DCT(float*, float*, int)
   37.47    7.08ms      10  708.31us  707.99us  708.50us  CUDAkernel1DCT(float*,int, int,int)
    3.75  708.42us       1  708.42us  708.42us  708.42us  CUDAkernel1IDCT(float*,int,int,int)
    1.84  347.99us       2  173.99us  173.59us  174.40us  CUDAkernelQuantizationFloat()
    1.75  331.37us       2  165.69us  165.67us  165.70us  [CUDA memcpy DtoH]
    1.41  266.70us       2  133.35us   89.70us  177.00us  [CUDA memcpy HtoD]
    1.00  189.64us       1  189.64us  189.64us  189.64us  CUDAkernelShortDCT(short*, int)
    0.94  176.87us       1  176.87us  176.87us  176.87us  [CUDA memcpy HtoA]
```

Future (Profiling)

- Tighter integration of CPU/GPU profiling
- Expand expert system
  - “upward” – help identify and extract data parallelism
  - “downward” – more precise feedback
- Auto tuning
- PC Sampling
- Expose expert system through CUPTI so 3rd party tools can take advantage
- Standards for higher-level profiling
  - OpenACC

Monitoring

- Cluster, not individual nodes
- Coarser measurement and control
- Zero or little overhead

- NVIDIA Monitoring Library
  - In-band
- Proprietary bus protocol
  - Out-of-band

NVIDIA Monitoring Library (NVML)

- GPU aggregate utilizations
  - Compute
  - Bandwidth
  - Memory usage

- Power
  - Temperature
  - Clocks
  - Power draw
  - Power states

Future (Monitoring)

- Power management
  - Improved control over clock speeds, power budget
  - Integration with power balancing solutions
  - Exploit variations in GPU power efficiencies
- Improved profiling capabilities
  - Support concurrent workloads (per-process reporting vs. per-GPU)
  - System level metrics: network bottlenecks, communication locality, …
  - Higher accuracy utilization measurement
  - Cluster-level profiling expert system

Future (Monitoring) – cont.

- In-band vs. out-of-band
- Proprietary vs. standard

Questions?