Performance Monitoring & Queries on Intel GPUs

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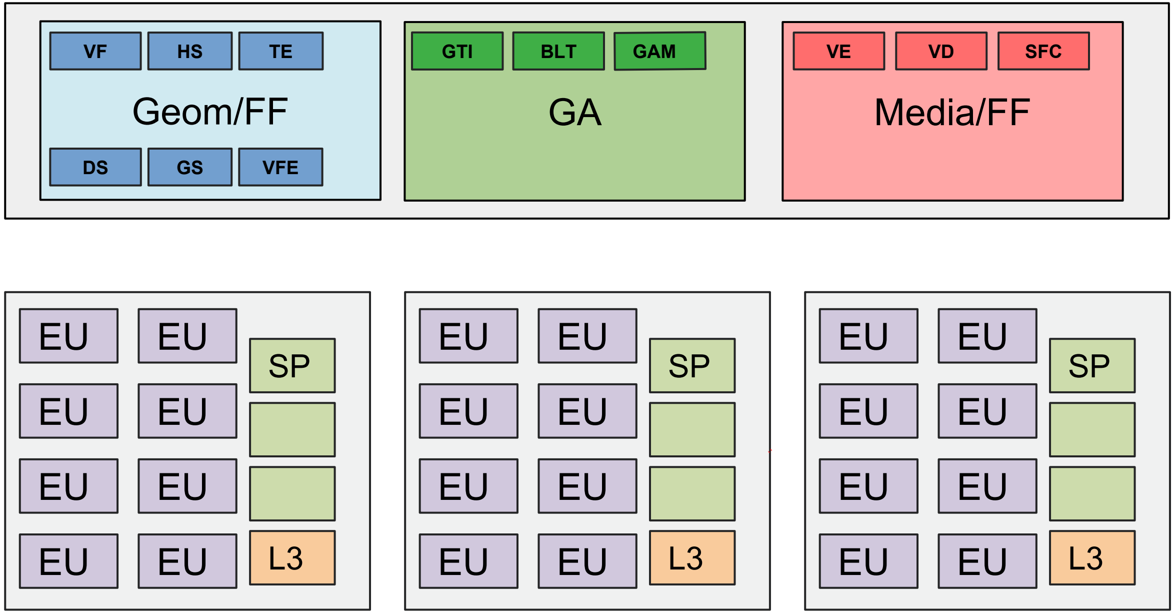
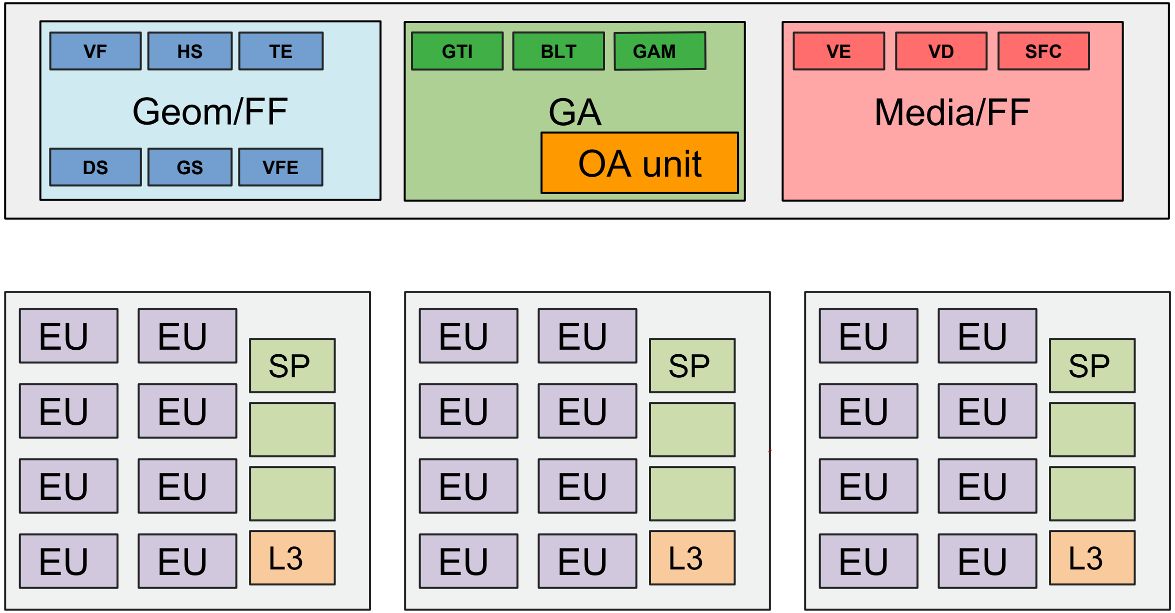
Hardware overview
i915 interface
Userspace tools

Hardware overview



https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol04-configurations.pdf

Hardware overview



https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol04-configurations.pdf

Hardware overview

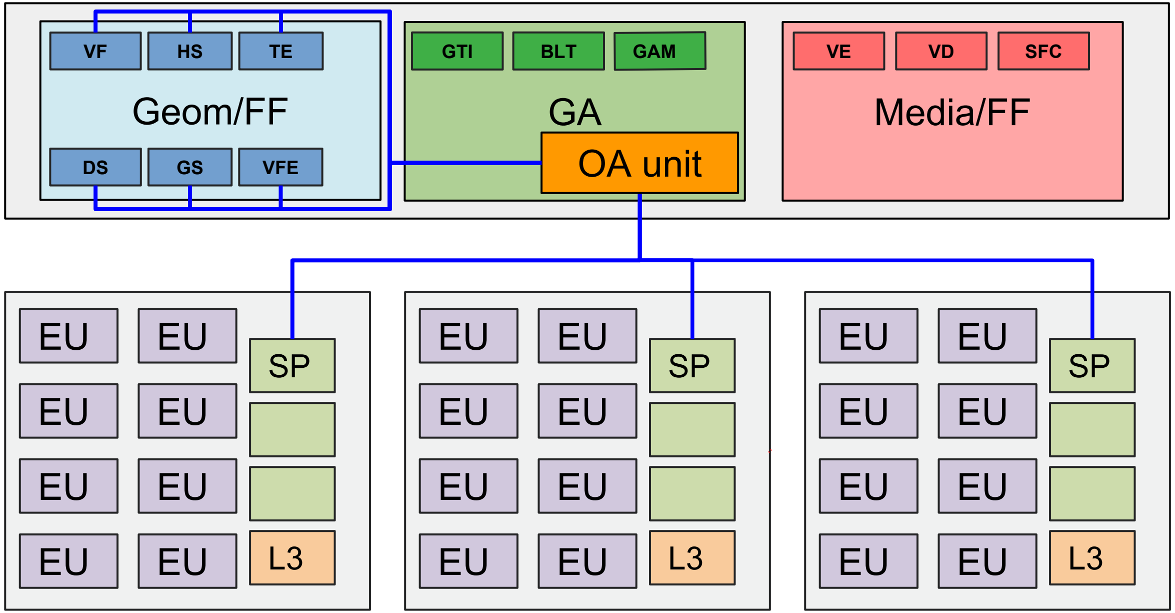
OA unit :

- Writes snapshots of multiple registers to memory on :
    - context switch
    - programmed timer
    - frequency changes
    - request from command streamer (only on 3D engine)

- Snapshots written to :
    - OA buffer (circular buffer up to 16Mb)
    - application address space

https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol14-observability.pdf

Hardware overview



▬ : direct connections

https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol04-configurations.pdf

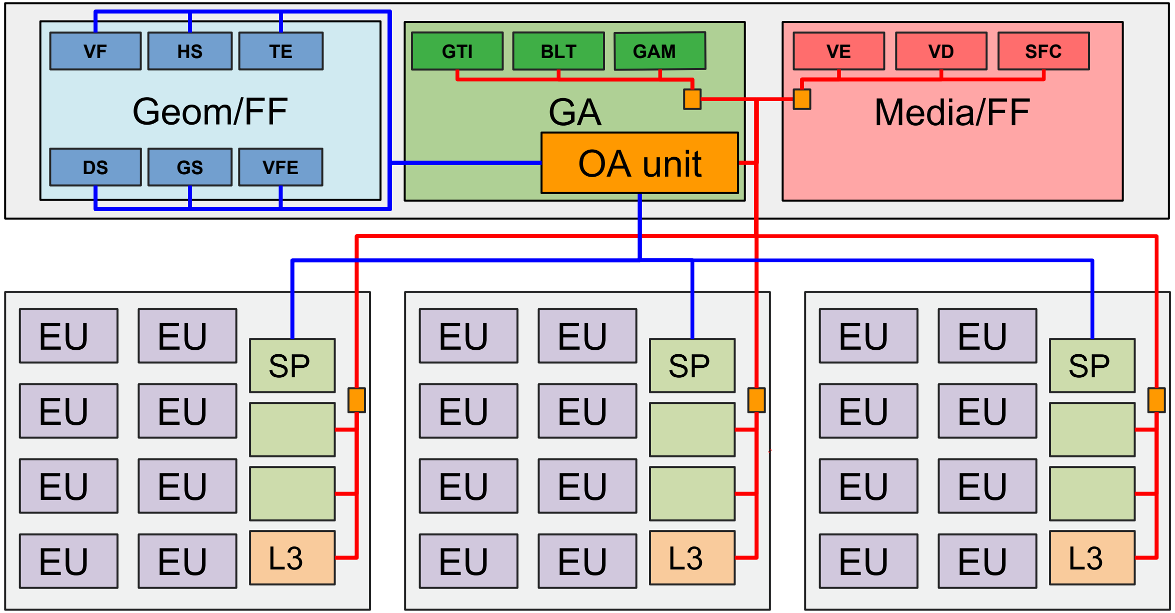
Hardware overview

- Direct connections examples :
  - Vertex Shader Threads Dispatched
  - Hull Shader Threads Dispatched
  - Pixel Shader Threads Dispatched
  - 2x2s Rasterized Pixels
  - 2x2s Killed in PS (discard in fragment shader)
  - 2x2s Written To Render Target
  - Blended 2x2s Written to Render Target
  - 2x2s Requested from Sampler
  - Sampler L1 Cache Misses
  - Flexible EU counters
  - …

Mostly 3D counters

https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol14-observability.pdf

Introduction



🟧 : OA nodes ▬ : direct connections ▬ : indirect connections

https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol04-configurations.pdf

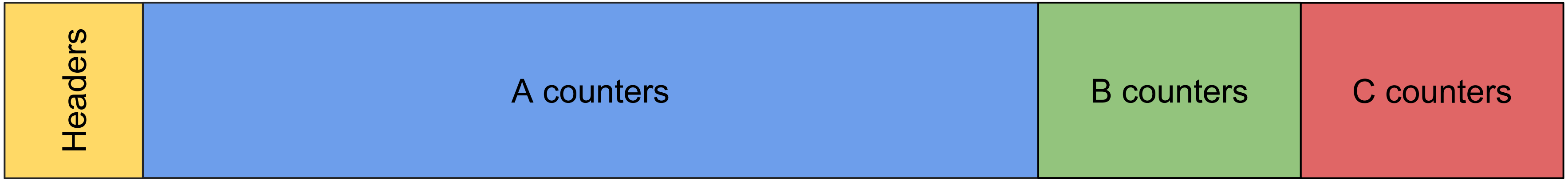
Hardware overview

- Indirect connections examples :
  - GTI Depth Throughput
  - Sampler 0/1 Busy
  - L3 Cache Misses
  - Early Depth Bottleneck
  - Hi-Depth Cache Misses
  - Multisampling Color Cache misses
  - Stencil Cache misses
  - …
- HW programming needed to get specific information

https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol14-observability.pdf

OA reports

256 bytes (Broadwell and above)



Headers

A counters

B counters

C counters

- Headers : timestamp + context ID + reason
- A counters : 32 (40 bits) + 4 (32 bits)
    - Mostly 3D counters
- B counters : 8 (32 bits)
- C counters : 8 (32 bits)

https://01.org/sites/default/files/documentation/intel-gfx-prm-osrc-kbl-vol14-observability.pdf

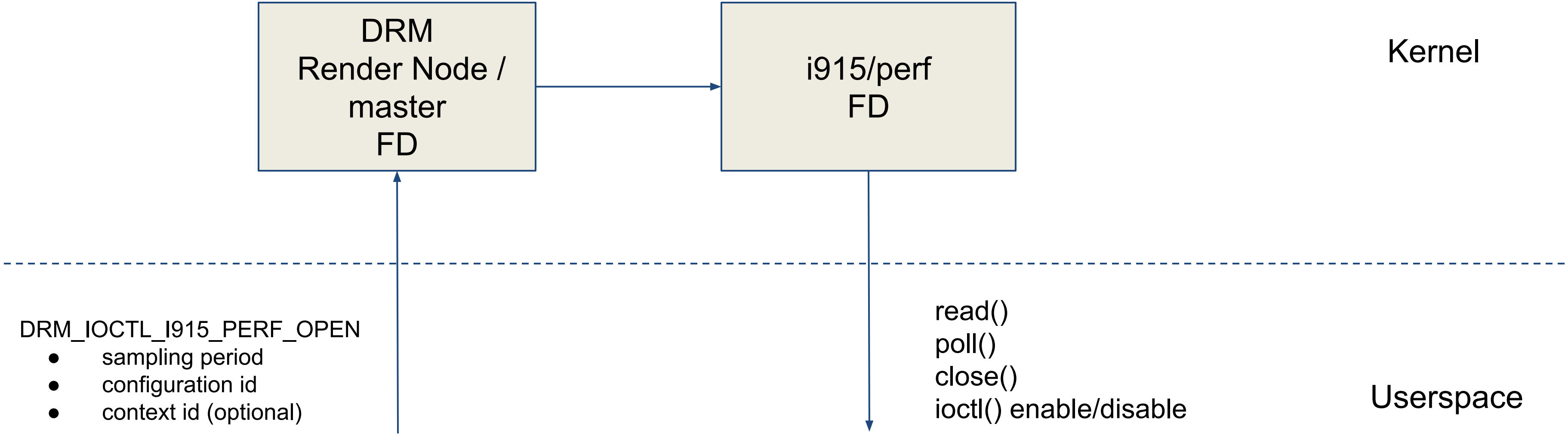
i915 Interface

Exclusive access to the OA unit because of B/C counters programming.

2 ways to use the i915 API :

- Query mode :
  - Have snapshots filtered by context ID
  - Use in addition to the MI_REPORT_PERF_COUNT instruction
- Monitoring mode :
  - All snapshots available (privileged access)

i915 Interface



DRM
Render Node /
master
FD

i915/perf
FD

Kernel

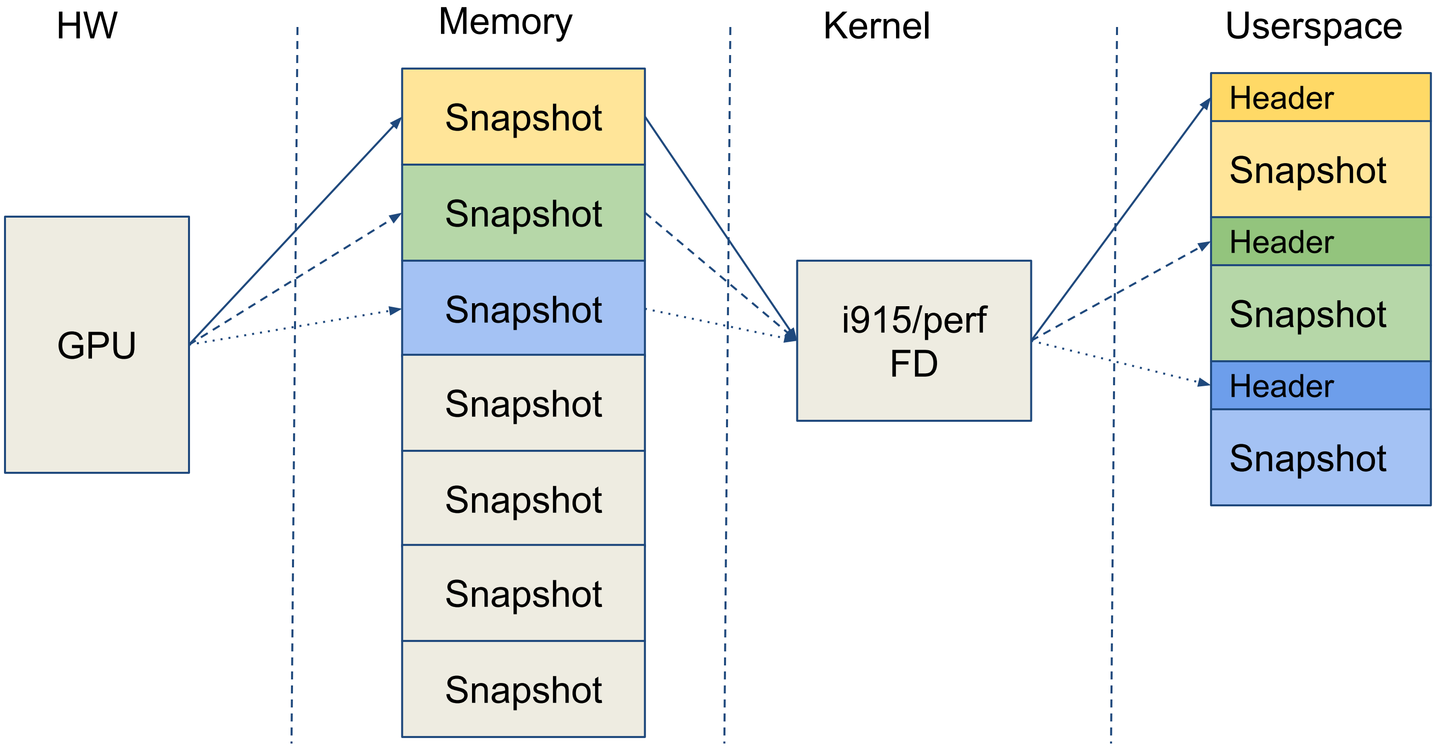
DRM_IOCTL_I915_PERF_OPEN

- sampling period
- configuration id
- context id (optional)

read()
poll()
close()
ioctl() enable/disable

Userspace

i915 Interface



Userspace

- Metrics Discovery (used by Graphics Performance Analyzers / VTUNE)
  - https://github.com/intel/metrics-discovery
- GL_INTEL_performance_query extension
  - https://www.khronos.org/registry/OpenGL/extensions/INTEL/INTEL_performance_query.txt
- GPUTop
  - https://github.com/rib/gputop

OpenGL performance queries

We can’t extract all the performance counters in one pass.

Counters are grouped in query IDs :

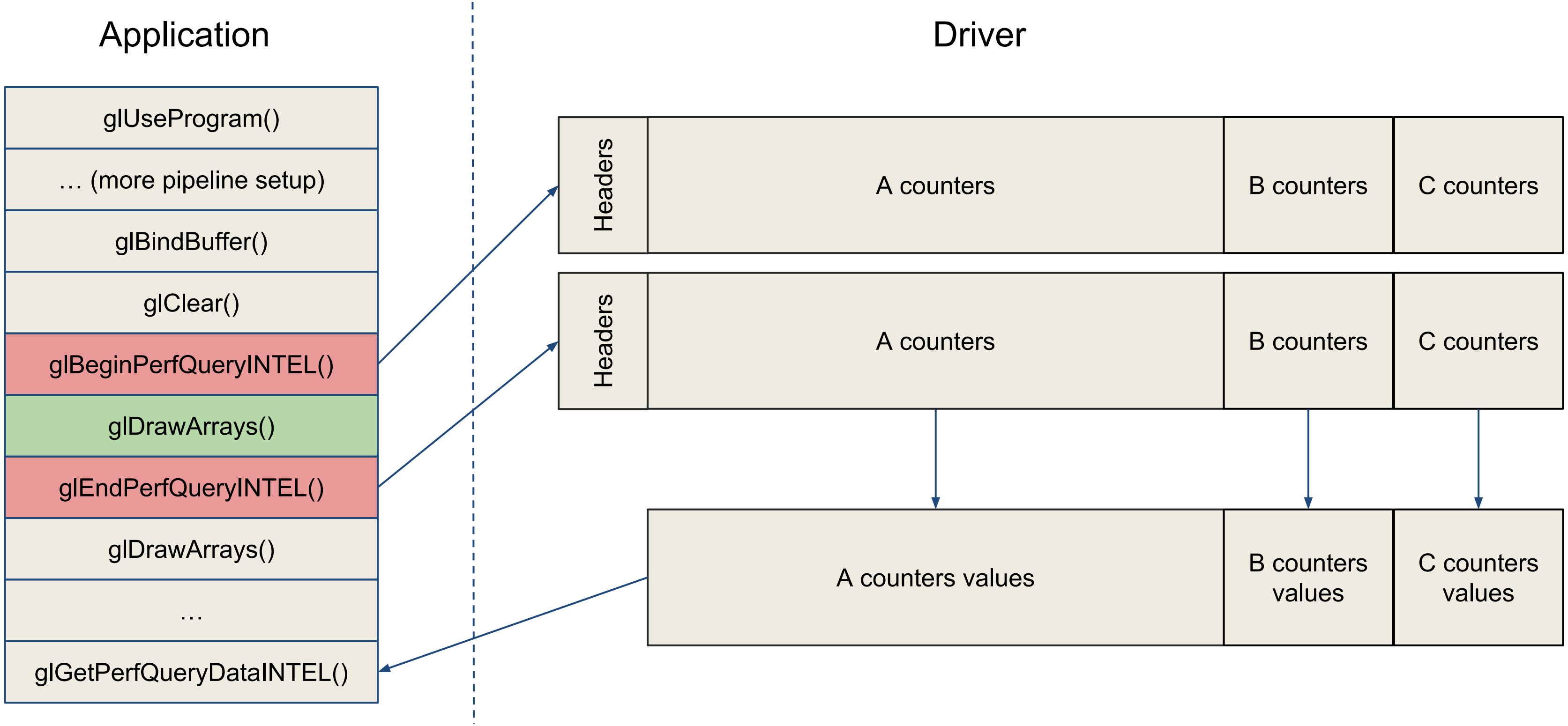
- Render Metrics Basic
- Compute Metrics Basic
- Render Metrics for 3D Pipeline Profile
- Memory Reads Distribution
- Memory Writes Distribution
- Compute Metrics Extended
- Compute Metrics L3 Cache
- Metric set HDCAndSF
- Metric set L3_1
- Metric set L3_2
- Metric set L3_3
- Metric set RasterizerAndPixelBackend
- Metric set Sampler
- Metric set TDL_1
- Metric set TDL_2
- Compute Metrics Extra
- Media Vme Pipe
- Gpu Rings Busyness

OpenGL performance queries

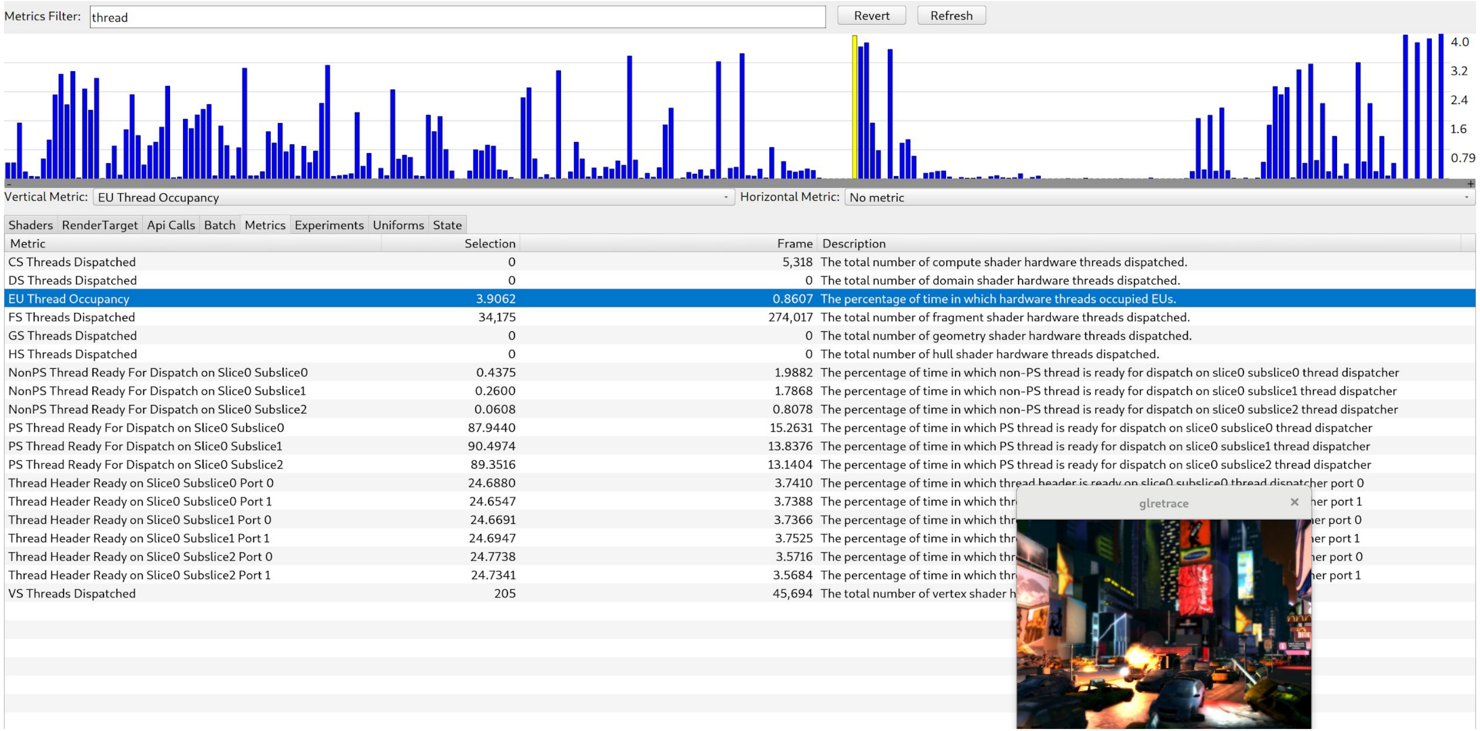
GL_INTEL_performance_query :

- List query IDs :
  - **`glGetFirstPerfQueryIdINTEL()  / glGetNextPerfQueryIdINTEL()`**
- List counters for a given query ID :
  - **`glGetPerfCounterInfoINTEL()`**
- Query data :
  - **`glCreatePerfQueryINTEL() / glBeginPerfQueryINTEL() / glEndPerfQueryINTEL()`**
- Get data :
  - **`glGetPerfQueryDataINTEL()`**

OpenGL performance queries



OpenGL performance queries



Metrics Filter: thread

Vertical Metric: EU Thread Occupancy

Horizontal Metric: No metric

Metric	Selection	Frame	Description
CS Threads Dispatched	0	5,318	The total number of compute shader hardware threads dispatched.
DS Threads Dispatched	0	0	The total number of domain shader hardware threads dispatched.
EU Thread Occupancy	3.9062	0.8607	The percentage of time in which hardware threads occupied EUs.
FS Threads Dispatched	34,175	274,017	The total number of fragment shader hardware threads dispatched.
GS Threads Dispatched	0	0	The total number of geometry shader hardware threads dispatched.
HS Threads Dispatched	0	0	The total number of hull shader hardware threads dispatched.
NonPS Thread Ready For Dispatch on Slice0 Subslice0	0.4375	1.9882	The percentage of time in which non-PS thread is ready for dispatch on slice0 subslice0 thread dispatcher
NonPS Thread Ready For Dispatch on Slice0 Subslice1	0.2600	1.7868	The percentage of time in which non-PS thread is ready for dispatch on slice0 subslice1 thread dispatcher
NonPS Thread Ready For Dispatch on Slice0 Subslice2	0.0608	0.8078	The percentage of time in which non-PS thread is ready for dispatch on slice0 subslice2 thread dispatcher
PS Thread Ready For Dispatch on Slice0 Subslice0	87.9440	15.2631	The percentage of time in which PS thread is ready for dispatch on slice0 subslice0 thread dispatcher
PS Thread Ready For Dispatch on Slice0 Subslice1	90.4974	13.8376	The percentage of time in which PS thread is ready for dispatch on slice0 subslice1 thread dispatcher
PS Thread Ready For Dispatch on Slice0 Subslice2	89.3516	13.1404	The percentage of time in which PS thread is ready for dispatch on slice0 subslice2 thread dispatcher
Thread Header Ready on Slice0 Subslice0 Port 0	24.6880	3.7410	The percentage of time in which thread header is ready on slice0 subslice0 thread dispatcher port 0
Thread Header Ready on Slice0 Subslice0 Port 1	24.6547	3.7388	The percentage of time in which thr her port 1
Thread Header Ready on Slice0 Subslice1 Port 0	24.6691	3.7366	The percentage of time in which thr her port 0
Thread Header Ready on Slice0 Subslice1 Port 1	24.6947	3.7525	The percentage of time in which thr her port 1
Thread Header Ready on Slice0 Subslice2 Port 0	24.7738	3.5716	The percentage of time in which thr her port 0
Thread Header Ready on Slice0 Subslice2 Port 1	24.7341	3.5684	The percentage of time in which thr her port 1
VS Threads Dispatched	205	45,694	The total number of vertex shader h

https://github.com/janesma/apitrace

GPUTop

- Client/Server model :
    - Server runs on the target system to monitor
    - Clients connects to the server and process the extracted data
- 2 clients :
    - Command line tool :
        - records accumulated samples in CSV format
        - track an application’s usage
    - User interface :
        - Observe global usage
        - Draw timelines

GPUTop

Server :

```
$ sudo gputop
```

Global monitoring :

```
$ gputop-wrapper -m RenderBasic -c AvgGpuCoreFrequency,RasterizedPixels,Sampler0Busy
```

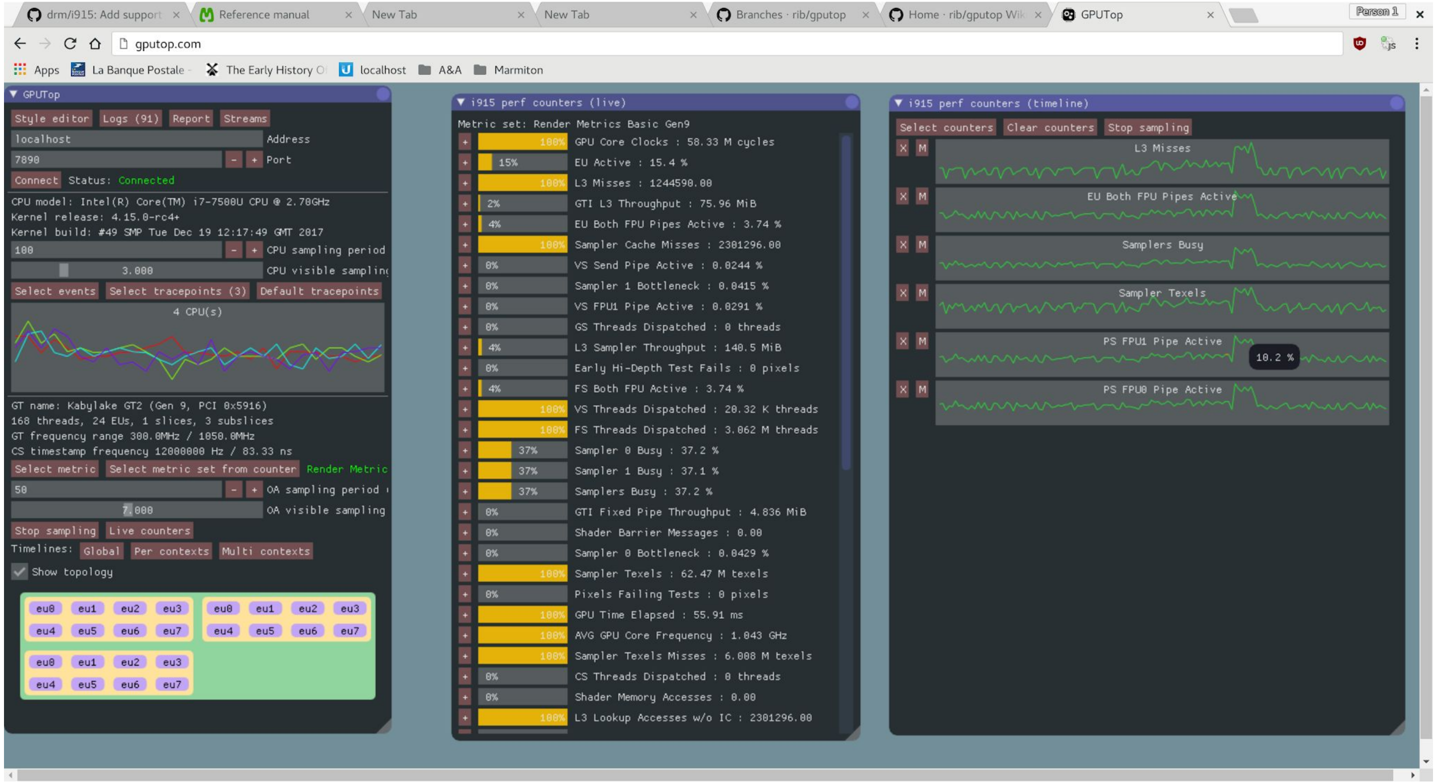
Application monitoring :

```
$ gputop-wrapper -m RenderBasic -c AvgGpuCoreFrequency,RasterizedPixels,Sampler0Busy -- glxgears
```

Output :

```
AvgGpuCoreFrequency,  RasterizedPixels, Sampler0Busy
               (Hz),          (pixels),          (%)
          295.3 MHz,    145.6 M pixels,       6.44 %
          295.6 MHz,    119.5 M pixels,       4.84 %
          295.8 MHz,    169.4 M pixels,       7.02 %
          295.6 MHz,    97.31 M pixels,       3.97 %
          295.6 MHz,    120.1 M pixels,       4.87 %
```

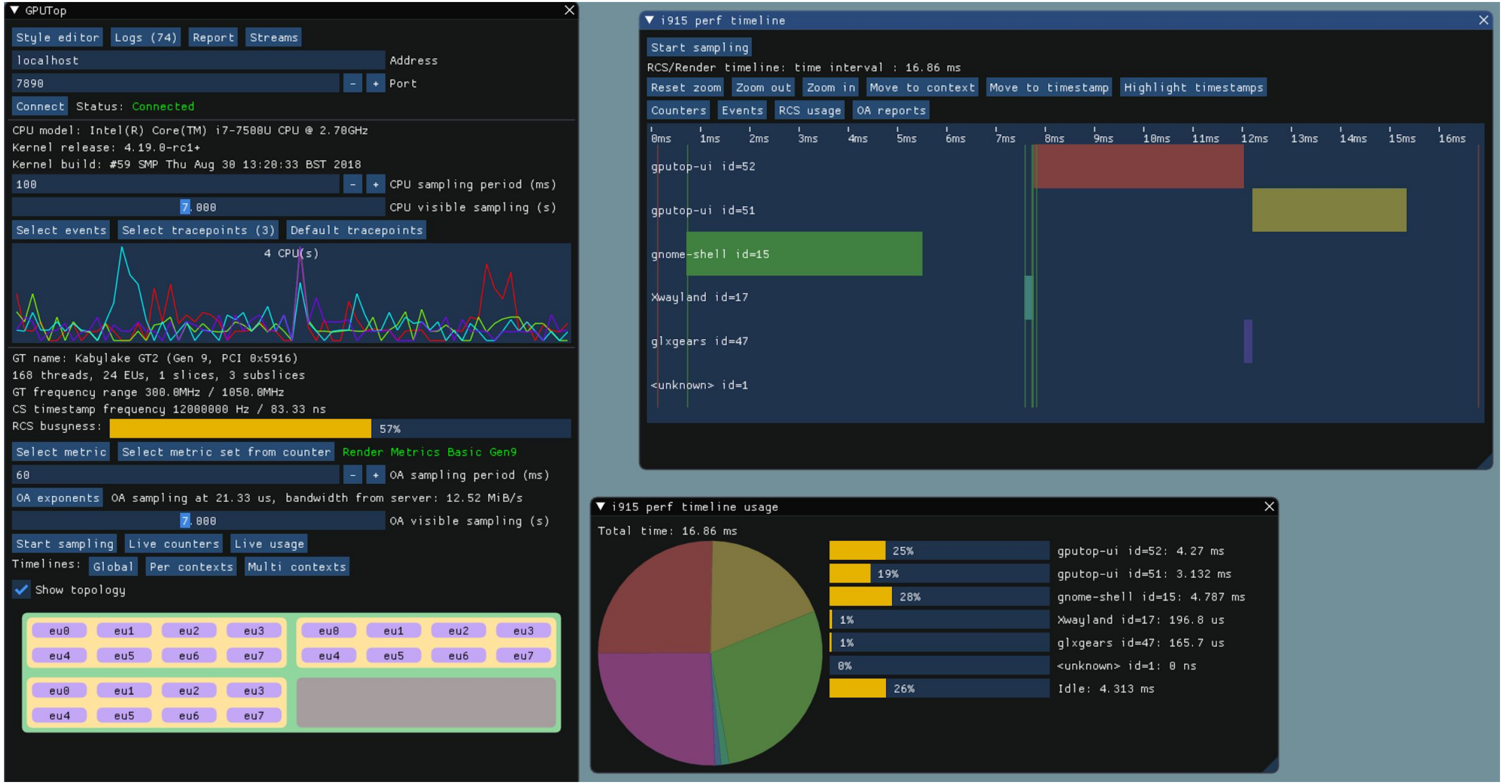
GPUTop



```
localhost                Address
7890              - +    Port
Connect  Status: Connected
CPU model: Intel(R) Core(TM) i7-7500U CPU @ 2.70GHz
Kernel release: 4.15.0-rc4+
Kernel build: #49 SMP Tue Dec 19 12:17:49 GMT 2017
100               - +    CPU sampling period
        3.000            CPU visible samplinç
GT name: Kabylake GT2 (Gen 9, PCI 0x5916)
168 threads, 24 EUs, 1 slices, 3 subslices
GT frequency range 300.0MHz / 1050.0MHz
CS timestamp frequency 12000000 Hz / 83.33 ns
Select metric  Select metric set from counter  Render Metric
50                - +    OA sampling period
        7.000            OA visible sampling
Timelines:  Global  Per contexts  Multi contexts
☑ Show topology
```

```
Metric set: Render Metrics Basic Gen9
+ 100%  GPU Core Clocks : 58.33 M cycles
+ 15%   EU Active : 15.4 %
+ 100%  L3 Misses : 1244590.00
+ 2%    GTI L3 Throughput : 75.96 MiB
+ 4%    EU Both FPU Pipes Active : 3.74 %
+ 100%  Sampler Cache Misses : 2301296.00
+ 0%    VS Send Pipe Active : 0.0244 %
+ 0%    Sampler 1 Bottleneck : 0.0415 %
+ 0%    VS FPU1 Pipe Active : 0.0291 %
+ 0%    GS Threads Dispatched : 0 threads
+ 4%    L3 Sampler Throughput : 140.5 MiB
+ 0%    Early Hi-Depth Test Fails : 0 pixels
+ 4%    FS Both FPU Active : 3.74 %
+ 100%  VS Threads Dispatched : 20.32 K threads
+ 100%  FS Threads Dispatched : 3.062 M threads
+ 37%   Sampler 0 Busy : 37.2 %
+ 37%   Sampler 1 Busy : 37.1 %
+ 37%   Samplers Busy : 37.2 %
+ 0%    GTI Fixed Pipe Throughput : 4.836 MiB
+ 0%    Shader Barrier Messages : 0.00
+ 0%    Sampler 0 Bottleneck : 0.0429 %
+ 100%  Sampler Texels : 62.47 M texels
+ 0%    Pixels Failing Tests : 0 pixels
+ 100%  GPU Time Elapsed : 55.91 ms
+ 100%  AVG GPU Core Frequency : 1.043 GHz
+ 100%  Sampler Texels Misses : 6.008 M texels
+ 0%    CS Threads Dispatched : 0 threads
+ 0%    Shader Memory Accesses : 0.00
+ 100%  L3 Lookup Accesses w/o IC : 2301296.00
```

GPUTop - timelines



localhost Address

7890 Port

Status: Connected

CPU model: Intel(R) Core(TM) i7-7500U CPU @ 2.70GHz
Kernel release: 4.19.0-rc1+
Kernel build: #59 SMP Thu Aug 30 13:20:33 BST 2018

100 CPU sampling period (ms)

7.000 CPU visible sampling (s)

GT name: Kabylake GT2 (Gen 9, PCI 0x5916)
168 threads, 24 EUs, 1 slices, 3 subslices
GT frequency range 300.0MHz / 1050.0MHz
CS timestamp frequency 12000000 Hz / 83.33 ns
RCS busyness: 57%

Render Metrics Basic Gen9

60 OA sampling period (ms)

OA sampling at 21.33 us, bandwidth from server: 12.52 MiB/s

7.000 OA visible sampling (s)

Timelines:

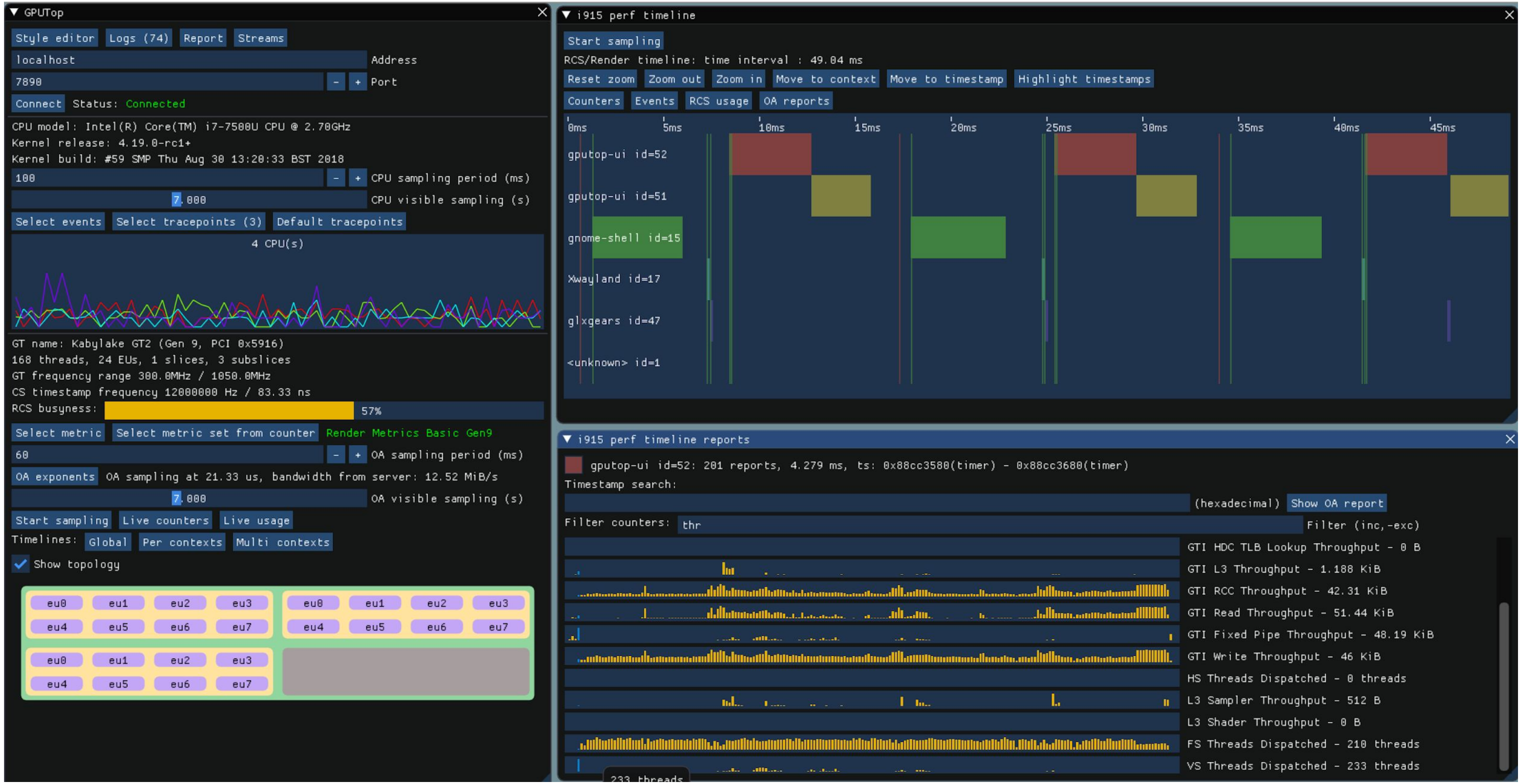
☑ Show topology

RCS/Render timeline: time interval : 16.86 ms

Total time: 16.86 ms

25% gputop-ui id=52: 4.27 ms
19% gputop-ui id=51: 3.132 ms
28% gnome-shell id=15: 4.787 ms
1% Xwayland id=17: 196.8 us
1% glxgears id=47: 165.7 us
0% <unknown> id=1: 0 ns
26% Idle: 4.313 ms

GPUTop - high frequency sampling



```
localhost                         Address
7890                              Port
Status: Connected
CPU model: Intel(R) Core(TM) i7-7500U CPU @ 2.70GHz
Kernel release: 4.19.0-rc1+
Kernel build: #59 SMP Thu Aug 30 13:20:33 BST 2018
100                               CPU sampling period (ms)
7.000                             CPU visible sampling (s)
GT name: Kabylake GT2 (Gen 9, PCI 0x5916)
168 threads, 24 EUs, 1 slices, 3 subslices
GT frequency range 300.0MHz / 1050.0MHz
CS timestamp frequency 12000000 Hz / 83.33 ns
RCS busyness: 57%
Render Metrics Basic Gen9
60                                OA sampling period (ms)
OA sampling at 21.33 us, bandwidth from server: 12.52 MiB/s
7.000                             OA visible sampling (s)
```

```
RCS/Render timeline: time interval : 49.04 ms
```

```
gputop-ui id=52: 201 reports, 4.279 ms, ts: 0x88cc3580(timer) - 0x88cc3680(timer)
Timestamp search:                 (hexadecimal)
Filter counters: thr              Filter (inc,-exc)
GTI HDC TLB Lookup Throughput - 0 B
GTI L3 Throughput - 1.188 KiB
GTI RCC Throughput - 42.31 KiB
GTI Read Throughput - 51.44 KiB
GTI Fixed Pipe Throughput - 48.19 KiB
GTI Write Throughput - 46 KiB
HS Threads Dispatched - 0 threads
L3 Sampler Throughput - 512 B
L3 Shader Throughput - 0 B
FS Threads Dispatched - 210 threads
VS Threads Dispatched - 233 threads
```

Give performance queries a try :

https://github.com/janesma/apitrace

Give GPUTop a try (kernel 4.14 recommended) :

https://github.com/rib/gputop

http://gputop.com

Questions?