Life of a frame

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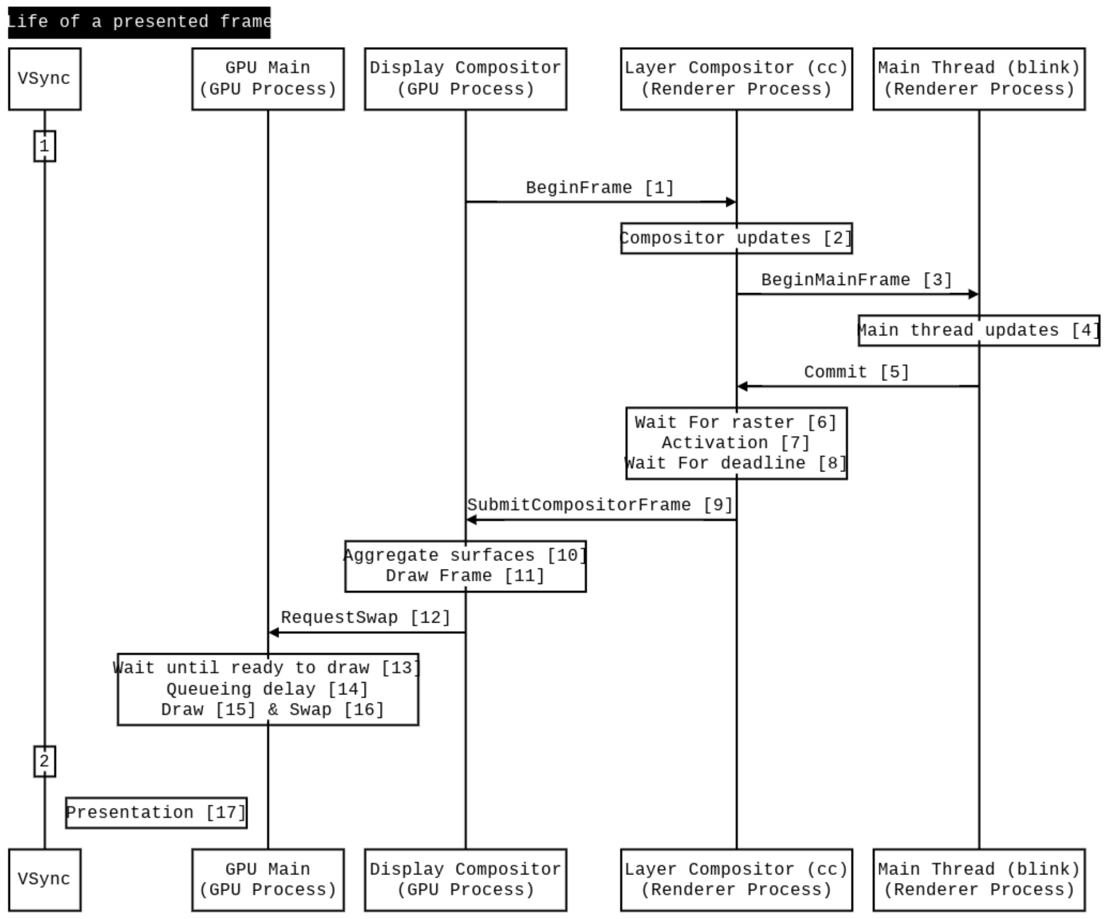
Pipeline flow diagram



[1] **BeginFrame**:

BeginImplFrame starts a compositor frame (with each vsync) that will wait up until a deadline for a BeginMainFrame plus activation to complete before it times out and draws any asynchronous animation and scroll/pinch updates. (cs)

[2] **Compositor updates**:

All updates on Impl thread such as scrolls (`cc::ScrollbarController`), zoom animation (`cc::PageScaleAnimation`).

[3] **BeginMainFrame**:

If there is main thread damage, BeginMainFrame will be sent and if there is no main thread damage steps 3,4 & 5 will be skipped (ShouldSendBeginMainFrame()).

[4] **MainThreadUpdates**:

All updates on the Main thread. Latency of this stage is also reported for each of the blink breakdowns (HandleInputEvents, Animate, StyleUpdate, LayoutUpdate, ...).

[5] **Commit**:

Commits updates back to Impl thread for activation.

Specifically, the main thread copies its own version of Layer tree onto the pending tree (`pending_tree_`) on the impl thread. The main thread is **blocked** during the copying process.

[6] **Wait for raster**

Rasterization may occur asynchronously on separate threads, or even another process (OOP-R, or out-of-process rasterization). If rasterization cannot be finished before the deadline for activation, the pipeline will not perform the copying from pending tree to the active tree in step [7], and will instead proceed to step [8] with whatever is already in the active tree.

[7] **Activation**

Activation is the process of pushing layer trees and properties from the pending tree to the active tree (`active_tree_`). Note that Impl thread can also directly manipulate the activate tree to reflect updates the impl thread makes in step [2].

[8] **Wait for deadline**

The deadline for compositor frame submission is provided by the GPU process. See also Scheduler::**`BeginImplFrameWithDeadline`**().

[9] **SubmitCompositorFrame**:

All activated updates will be submitted to the GPU process as a compositor frame that is produced based on the content of the active tree. If any of the steps [2], [3], [4], [5], [6] takes so long that the update that step is responsible for cannot be delivered to the active tree by deadline, the pipeline will proceed to submit with the existing active tree without said update. This is a possible source of a dropped **frame**.

[10] **AggregateSurfaces**:

After each client submitted CompositorFrame (or signalled that it DidNotProduceFrame) the Display Compositor can proceed with the draw (Note: If the DisplayScheduler hits a deadline it will still draw if any client has submitted a new CompositorFrame, even if it's still waiting on a response for other clients.). Before the actual draw could happen SurfaceAggregator will recursively walk over compositor frames and replace SurfaceQuads (quads produced by SurfaceLayer) with contents of the embedded compositor frame. This step produces single CompositorFrame in the end that can be drawn by the Display Compositor

[11] **Draw Frame**:

During draw Display Compositor will go over quads and render passes in the aggregated compositor frame and produce draw commands. For GLRenderer it's gl calls recorded by InProcessCommandBuffer and for SkiaRenderer it's recording of Deferred Display Lists (DDL).

[12] **RequestSwap**:

After commands are recorded they will be submitted to the GPU thread to replay along with SwapBuffers request to show the result on screen.

[13] **Wait until ready to draw**:

When the draw was submitted to GPU Main Thread some of the resources may not be ready yet. Chrome uses SyncTokens to ensure this type of synchronization. GPU Task submitted at step [12] won't be scheduled until all associated SyncTokens will be signaled.

[14] **Queueing delay**:

GPU Main Thread does all the GPU work and by the time the display compositor is ready to draw it might still be busy doing other tasks (e.g raster for next frame). gpu::Scheduler uses cooperative multi-tasking and can't preempt the current task unless it yields, so the task submitted by the display compositor might have to wait until the current task (and potentially some other high priority tasks) are finished.

[15] **GPU draw:**

Finally tasks that DisplayCompositor posted to GPU Main thread executed and we replay draw commands recorded during Draw Frame [11]. For GLRenderer InProcessCommand buffer will be issuing recorded GL calls, for SkiaRenderer Skia will be replaying DDLs and issue commands to the GPU. This step is when we finally submit the job to the GPU (not GPU thread on CPU).

[16] **Swap**:

The GPU work has been submitted and we signal that we want to present the result (Submits commands to request displaying framebuffer and/or overlays after drawing new content into them). Depending on the platform this step can be blocking or not and take a substantial amount of time (eg. if we have too many queued swaps sometimes this will just block until the next vblank).

[17] **Presentation**:

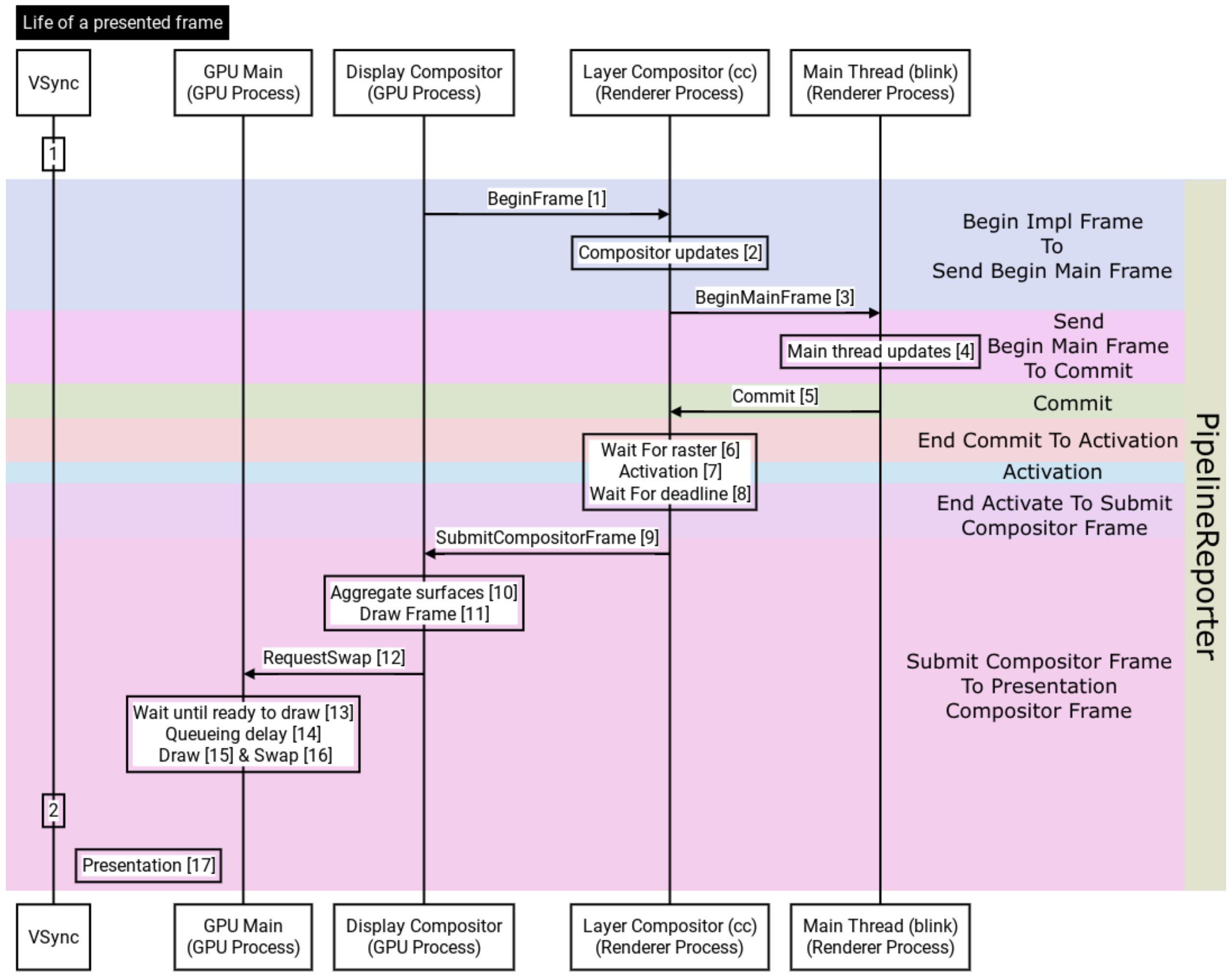
This is when the GPU has finished all the work and the display controller started scanning out the results. The pixels are finally visible on the screen. Depending on the platform, before this could happen the system compositor might need to do its work. Unfortunately it's not possible to get the exact timestamp on every platform and Chrome makes best efforts to estimate it. This estimation can be something like the swap time (on mac where we don't have any better information), the completion time for work on the GPU aligned to the next vblank as a good estimate, or a signal from the OS with the exact time the content was displayed.

PipelineReporter trace events

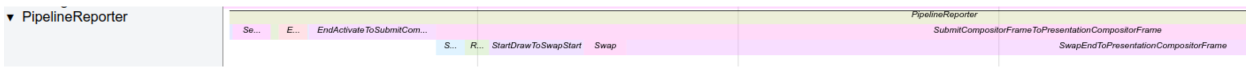
Multiple stages of the pipeline are highlighted for each frame in the traces titled **PipelineReporter**. Stages that are tracked in PipelineReporter events are:

- BeginImplFrameToSendBeginMainFrame
- SendBeginMainFrameToCommit
- Commit
- EndCommitToActivation
- Activation
- EndActivateToSubmitCompositorFrame
- SubmitCompositorFrameToPresentationCompositorFrame

Image below shows how each segment of the Pipeline is tracked in PipelineReporter trace events.


Life of a presented frame
VSync
GPU Main (GPU Process)
Display Compositor (GPU Process)
Layer Compositor (cc) (Renderer Process)
Main Thread (blink) (Renderer Process)
1
BeginFrame [1]
Compositor updates [2]
BeginMainFrame [3]
Begin Impl Frame To Send Begin Main Frame
Main thread updates [4]
Send Begin Main Frame To Commit
Commit [5]
Commit
Wait For raster [6]
Activation [7]
Wait For deadline [8]
End Commit To Activation
Activation
End Activate To Submit Compositor Frame
SubmitCompositorFrame [9]
Aggregate surfaces [10]
Draw Frame [11]
RequestSwap [12]
Wait until ready to draw [13]
Queueing delay [14]
Draw [15] & Swap [16]
Submit Compositor Frame To Presentation Compositor Frame
2
Presentation [17]
PipelineReporter

In the traces these pipeline reporters would look like


PipelineReporter
PipelineReporter
Se...
E...
EndActivateToSubmitCom...
SubmitCompositorFrameToPresentationCompositorFrame
S...
R...
StartDrawToSwapStart
Swap
SwapEndToPresentationCompositorFrame

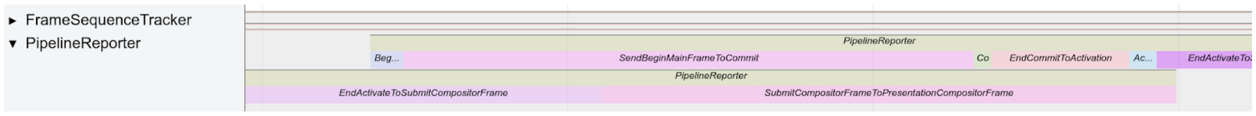
In which the length of each segment demonstrates the latency of that stage.
Also **SubmitCompositorFrameToPresentationCompositorFrame** would have its own, which are:

- SubmitToReceiveCompositorFrame: The time of communicating the submit (step [9])
- ReceiveCompositorFrameToStartDraw: The time it takes for steps [10] to [14]
- StartDrawToSwapStart: The time that “Draw” takes in GPU Main (step [15])
- Swap: The time that “Swap” takes in GPU Main (step [16])
- SwapEndToPresentationCompositorFrame: The remaining time until presentation (step [17])

Overlapping pipeline reporter events

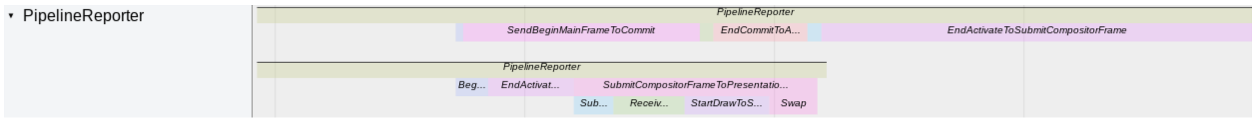
One advantage of having multiple processes handling the frame is that multiple frames can be worked on simultaneously. This might create some overlapping pipeline reporter events. In this section we would explore a few examples of these cases.

Example 1:



In this example the PipelineReporter(PR) on the bottom started earlier and while it was in the *EndActivateToSubmitCompositorFrame,* vsync for the next frame is reached. In this stage, the compositor thread is already done with activation and is waiting for the deadline to submit the compositor frame, so it can start working on the second frame (top PR).
Then we reach the deadline for submission of the frame while the second frame is in the stage of *SendBeginMainFrameToCommit* (on the main thread) so frame#1 will be submitted while frame#2 will continue on its stages and will be submitted in the next vsync.

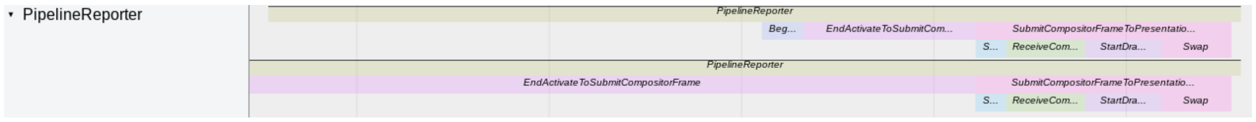
Example 2:



In this example the two PipelineReporters start at the same time but would not end at the same time. If we look into the arguments of each we would notice that they both correspond to the same sequence number (this would be expected for PRs that start at the same time corresponding to the same vsync).
In this case, the PR on top has been in middle of *SendBeginMainFrameToCommit* that the second PR moves to *EndActivateToSubmitCompositorFrame* and then

SubmitCompositorFrameToPresentationCompositorFrame. That means that while the main thread work was taking place we reached the deadline and submitted the compositor updates that were ready (bottom PR), and the PR on top would do the same with main thread updates on the next vsync.

Example 3:


PipelineReporter
PipelineReporter
Beg...
EndActivateToSubmitCom...
SubmitCompositorFrameToPresentatio...
S...
ReceiveCom...
StartDra...
Swap
PipelineReporter
EndActivateToSubmitCompositorFrame
SubmitCompositorFrameToPresentatio...
S...
ReceiveCom...
StartDra...
Swap

In this example the two PRs started at different times but are ending at the same time. This would often happen when a PR takes longer than one vsync and its last stage (e.g. *SubmitCompositorFrameToPresentationCompositorFrame*) would be synced with the next PR (top PR on the image).
In such cases the combined update from two PRs would be submitted to the GPU process and be presented together.