Passthrough/Headless GPU Gets A Head

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Sep. 15th 2021

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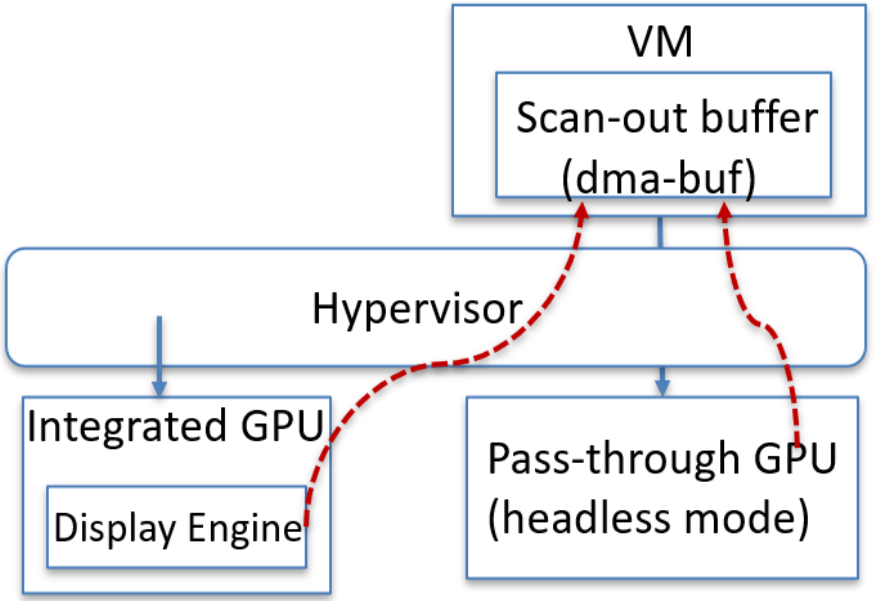
Agenda

- Motivation & Background
- Architecture
- Implementation
- Summary

Motivation & Background

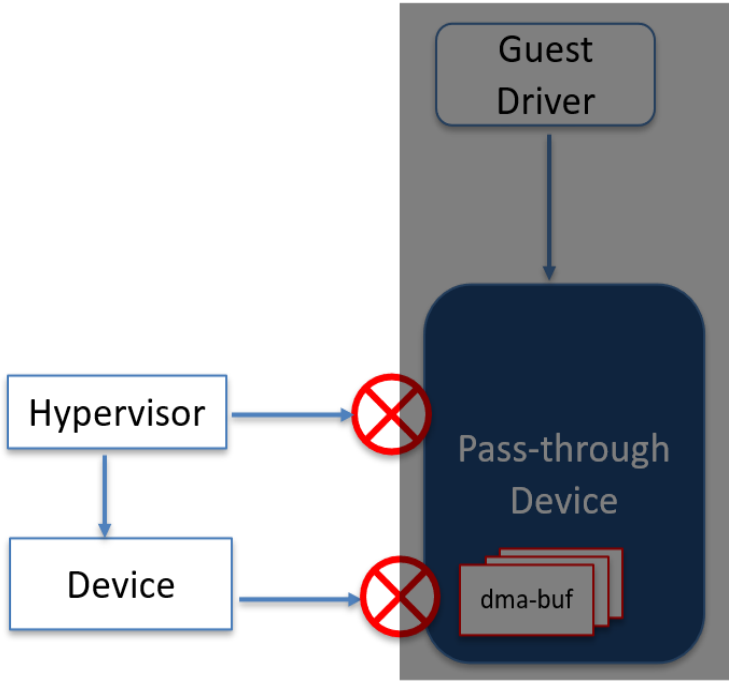
- Multi-GPU platform
  - More than one GPU is provided
  - Power & performance benefits
- A multi-GPU use case in client virtualization field
  - Pass-through GPU:
    - Best GPU performance within VM
  - Integrated GPU for host display and render
    - Power-saving
  - Need scan-out buffer sharing mechanism between iGPU and pass-through GPU
    - **cross-domain dma-buf sharing**



Share guest scan-out buffer between pass-through GPU & integrated GPU

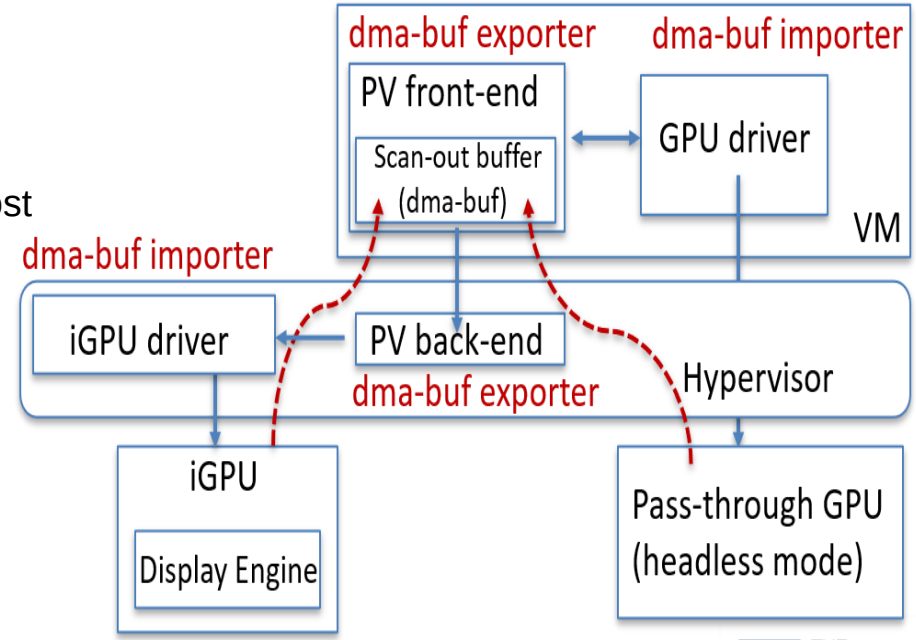
Cross-Domain DMA-BUF Sharing

- Sharing dma-buf owned by a pass-through device might not be feasible
  - Hypervisor has no visibility of dma-buf resource of a pass-through device
  - The backing storage of a pass-through device's dma-buf may be its private local memory which may not be accessible to other devices
- Proposal: para-virtualization based dma-buf exporter

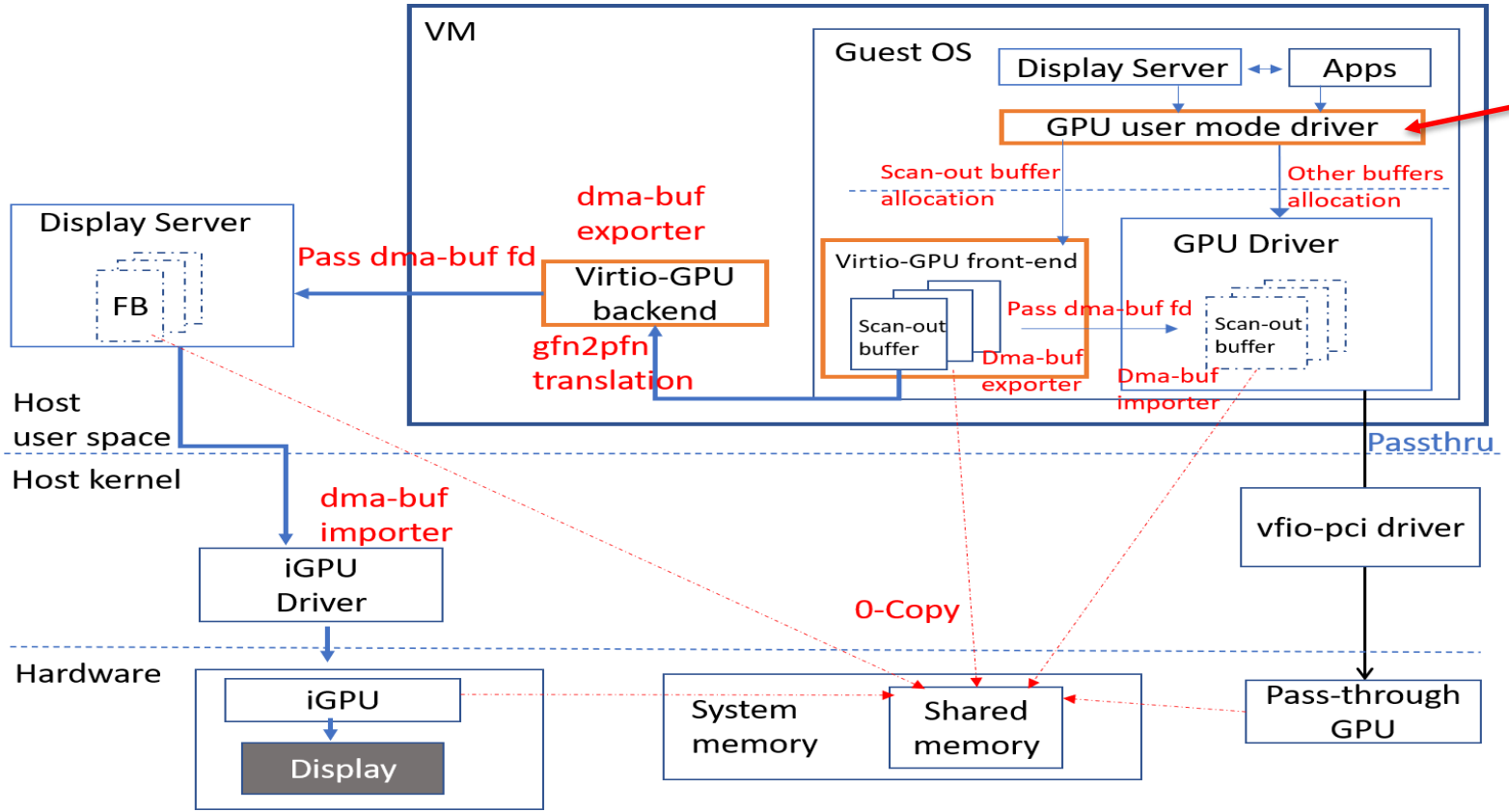


PV Based DMA-BUF Exporter

- VIRTIO-based cross-domain dma-buf sharing mechanism
  - Front-end: page-backed dma-buf owner and exposer in guest
  - Back-end: dma-buf owner and exposer on host
  - Equipped with a buffer producer-consumer synchronization mechanism
- Vdma-buf was proposed
  - RFC patch-set: https://lwn.net/Articles/846810/
- Choose virtio-gpu at last
  - Has cross-domain dma-buf sharing support
  - Supported by Linux user space graphic stack



Architecture Picture



From guest p.o.v:

- Multi-GPU case, if virtio-gpu 2d/3d is enabled;
- Virtio-gpu display + pass-through GPU render-only, if virtio-gpu 2d is enabled.

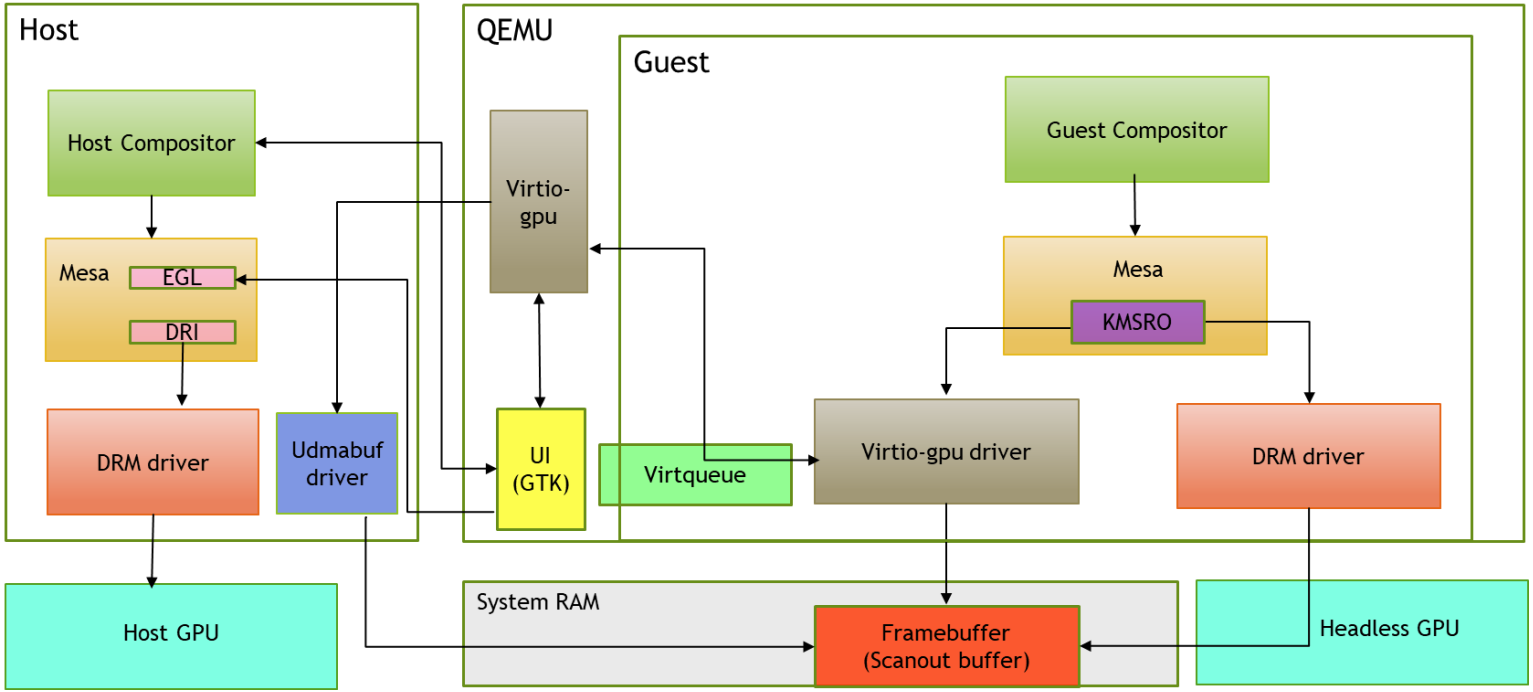
Virtio-gpu: Performance challenges

- More headless GPUs coming up: Intel XeHP SDV, SRIOV VFs, etc.
- Noticed that there was one CPU copy and multiple GPU copies done for transferring the Guest framebuffer data to the Host.
- Solution to eliminate the CPU copy was already available: Blob resources.
- Virtio-gpu and Qemu UI maintainer (Gerd Hoffmann) created initial patches to implement this feature more than a year ago.
- Refactored and augmented these initial patches and added few more and finally got them merged.

Virtio-gpu: Blob resources

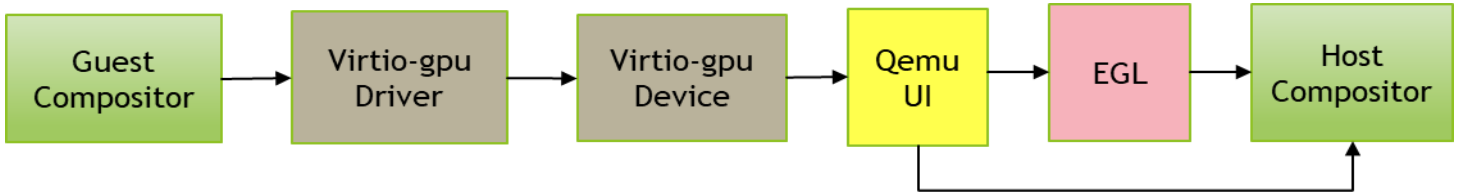
- It is based on Linux dma-buf buffer sharing framework.
- Before this feature, the resource data was (mem) copied from the IOV to a shadow buffer (pixman) and then a texture was created.
- We now associate a dma-buf fd with the resource (FB) by passing the IOV entries to the Udmabuf driver and getting an fd in return.
- A texture can be created directly using the fd thereby eliminating the need for a CPU copy.
- The Udmabuf driver was also augmented to work if Qemu's memory backend was backed up by memfd + Hugepages.

Virtio-gpu: Blob resources



Virtio-gpu: Blob resource synchronization

- Synchronization (i.e., prevent Host and Guest from accessing a buffer at the same time) was never a problem before this feature.
- And guests would render frames at a rate faster than what the Host can consume -- wasting GPU cycles.
- Fix both these issues by introducing sync objects.
- A file descriptor (fd) is extracted from a sync object and can be added to Qemu's main event loop.
- The Guest would be blocked -- from rendering new frames -- until the relevant fd is signaled.



Virtio-gpu: Blob resource synchronization

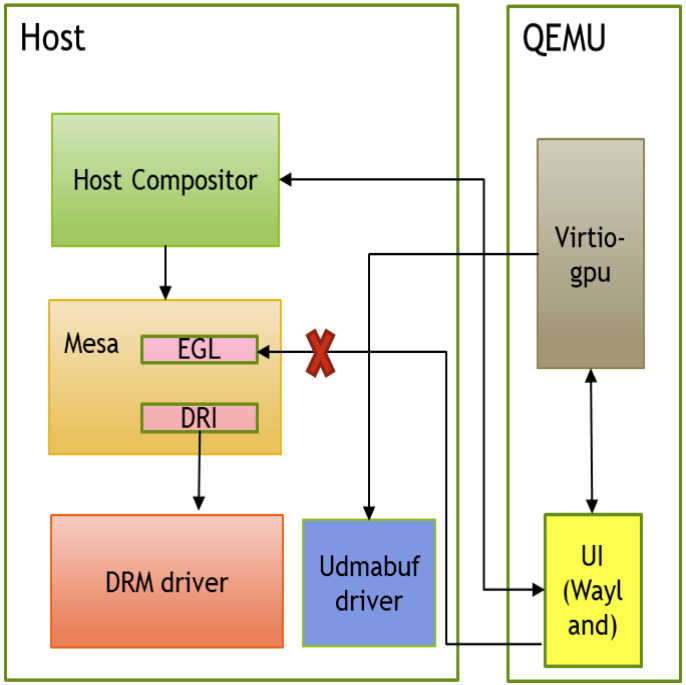
- Sync objects and fds are created using EGL APIs:

  EGLSyncKHR sync = eglCreateSyncKHR();

  int fd = eglDupNativeFenceFDANDROID(…, sync);
- Qemu UI backends such as GTK (default) and SDL that use EGL for presenting Guest frames can make use of these sync objects.
- Once an fd associated with a sync object is signaled, it means the Host is done using the buffer and it can be reused by the Guest.
- This also ensures that the Guest rendering rate is not higher than the monitor refresh rate.
- Most of the patches associated with synchronization are already reviewed and ready to be merged.

Qemu UI: New Wayland UI backend

- Qemu currently supports multiple UI backends: GTK, SDL, Cocoa, Spice, etc.
- All these backends make a copy of the Guest framebuffer -- using either the CPU or the GPU -- before presenting it.
- This can lead to performance issues if multiple Qemu instances are running and presenting Guest frames simultaneously.
- Using Blob resources would eliminate the need for a CPU copy but a GPU copy (aka Blit) cannot be eliminated if EGL is used.
- Only way to eliminate the Blit is to submit the Guest framebuffer directly to the Host display server/compositor.
- A Wayland UI backend makes this possible.



Qemu UI: New Wayland UI backend

- With this backend, it is possible to have the Guest framebuffer be placed directly on a hardware plane (zero copy).
- If a hardware plane is not available, then the Host compositor would inevitably Blit the Guest framebuffer onto its scanout buffer.
- In addition to limiting the (GPU) copies to a maximum of one, this backend is very lightweight and has a smaller footprint.
- Drawbacks include no window decorations (menus, etc.) and its efficacy is limited to iGPUs and Guests that do double-buffer rendering.
- Patches are posted but a non-trivial overhaul (dbus) of Qemu UI modules is underway after which this can be reviewed.

Summary

- Dma-buf exported by passthrough device may not be accessible to other devices controlled in other domains.
- Para-virtualization based solution provides an efficient and generic way for sharing cross-domain dma-buf.
- Using Blob resources would eliminate the need for CPU copies.
- Wayland UI backend would limit the GPU copies to a max of one.

Acknowledgements

- Gerd Hoffmann (Virtio-gpu and Qemu UI maintainer)
- Daniel Vetter (DRM subsystem maintainer)

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