Paravirtualized DMA using IOMMU emulation

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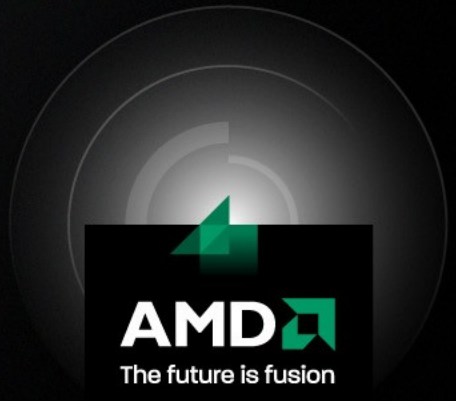


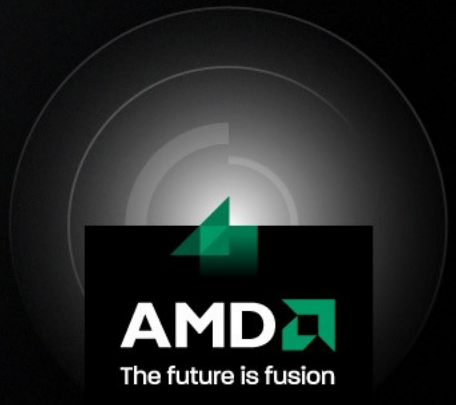
Overview

- State of KVM Device Passthrough
- IOMMU architectures
- The Idea: A Paravirtual IOMMU
- Guest Kernel Changes

State of KVM Device Passthrough

- KVM allows DMA for a passthrough device
- Device can access any guest physical address
- Implemented using newer hardware IOMMUs
- Problem: PCI DMA has no concept of demand paging
  - Requires that all guest memory is mapped (and **pinned**) in advance
  - Prevents that any guest memory is moved or swapped out
- This talk is about an idea that limits the amount of guest ram to pin

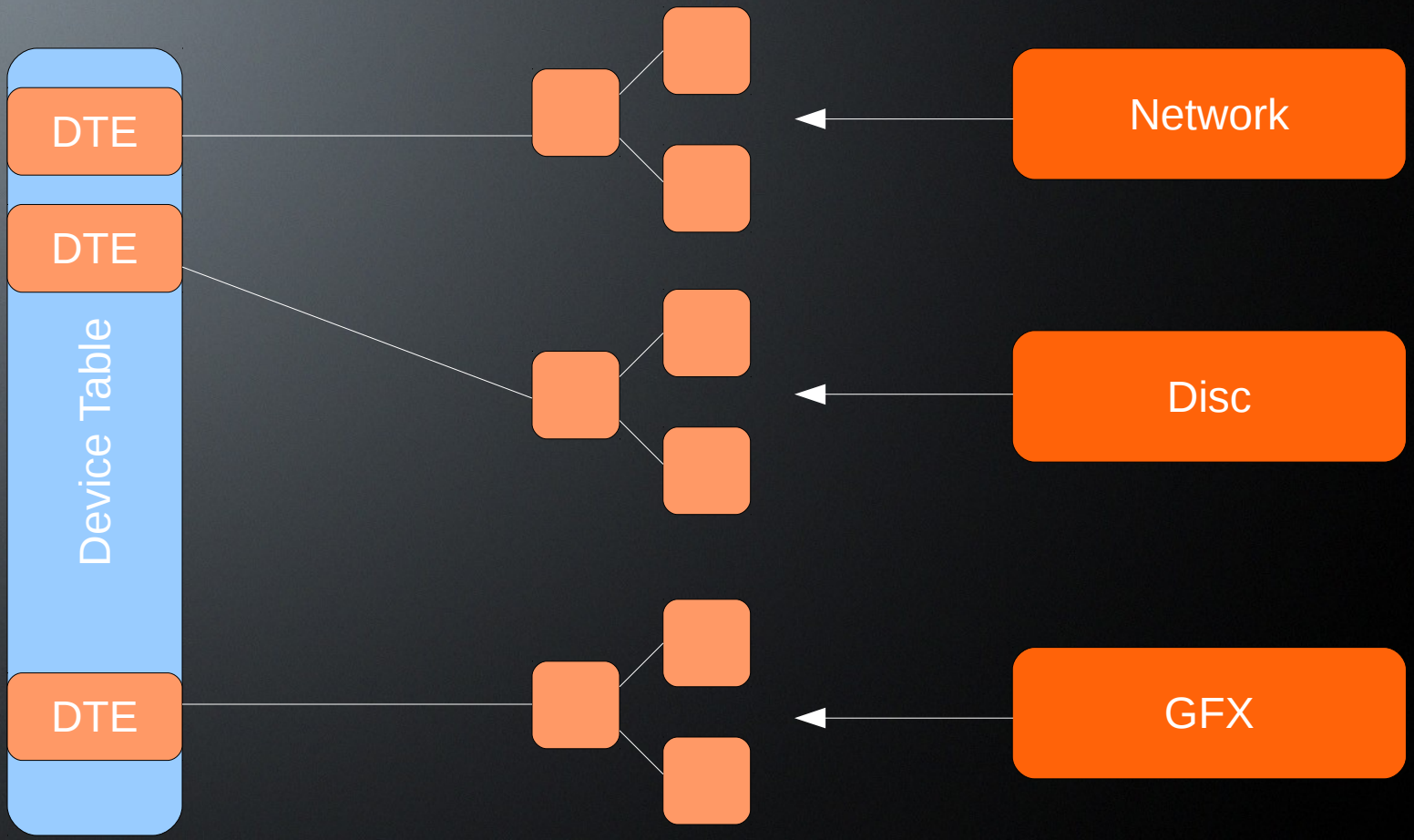
IOMMU architectures



State-of-the-Art IOMMU Architecture

- Modern IOMMUs have a large feature set
  - Can differentiate between devices
  - Support remapping of full 64-bit address space
  - Protect main memory by assigning access permissions to DMA mappings
- Support many use-cases
  - DMA remapping for legacy devices
  - Protection against misbehaving devices
  - Virtualization
- Difficult to emulate

State-of-the-Art IOMMU architecture example: AMD-Vi



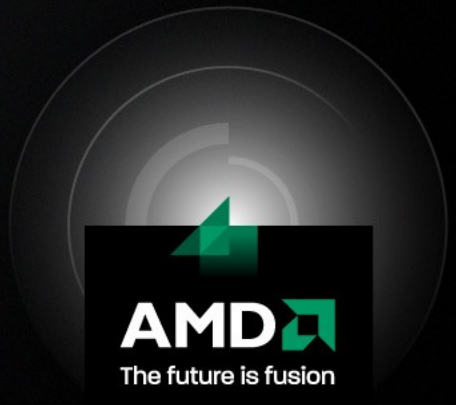
Legacy IOMMUs

- Support only one scenario:
  - DMA remapping for legacy devices
- Cannot differentiate between all devices
- Different flavors available
- All use the same principles
  - Provide an aperture
  - Mapping is implemented by a single-level linear page table

Legacy IOMMU Example: AMD GART

- Basic principle: Remaps physical memory
- Implements an address range, which is remapped: The Aperture
  - Remapping destination configured in a page table
  - Access outside the aperture range is not remapped
- TLB can only be flushed completely
- Can be emulated with an State-of-the-Art IOMMU

The Idea: A Paravirtual IOMMU



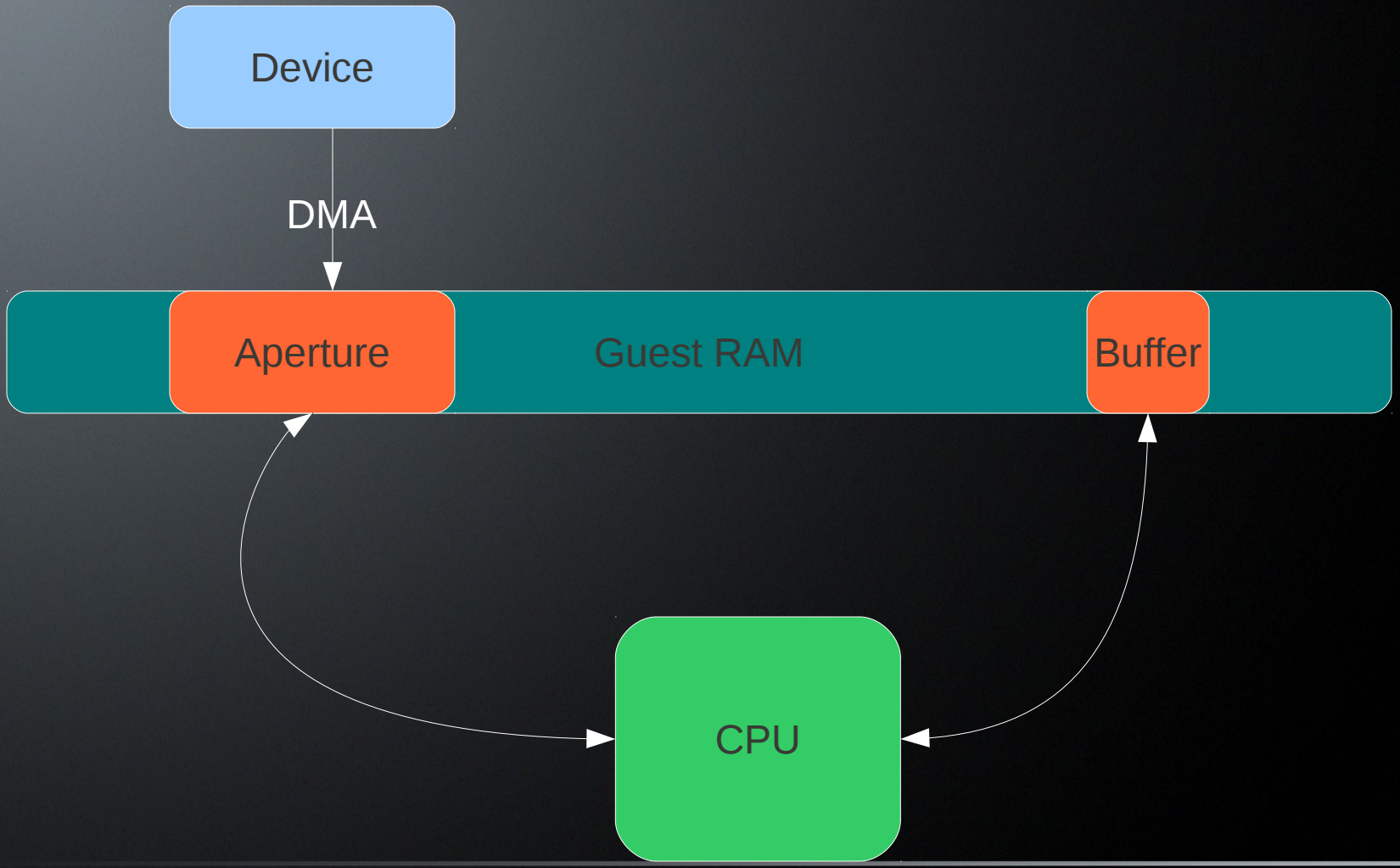
Basic Idea for Paravirtualized DMA

- Idea: Emulate a legacy-type IOMMU
- Emulate an IOMMU with the following properties
  - Fixed size aperture for exclusive DMA access
  - Passthrough device can only access the aperture address range
- Guest cannot pin more memory than provided in the aperture
- Could be implemented even with a legacy IOMMU on the host side (when trusting the guest)
- Two variants to evaluate

First Variant

- Use guest RAM for the aperture
- Passthrough device can DMA into the aperture
- Kernel bounce buffers the data to/from the destination buffer
- Pros:
  - No hypercalls needed for mapping/unmapping
  - Could reuse SWIOTLB code with minor modifications
- Cons:
  - Guest could not use the aperture RAM otherwise
  - Bounce buffering expensive

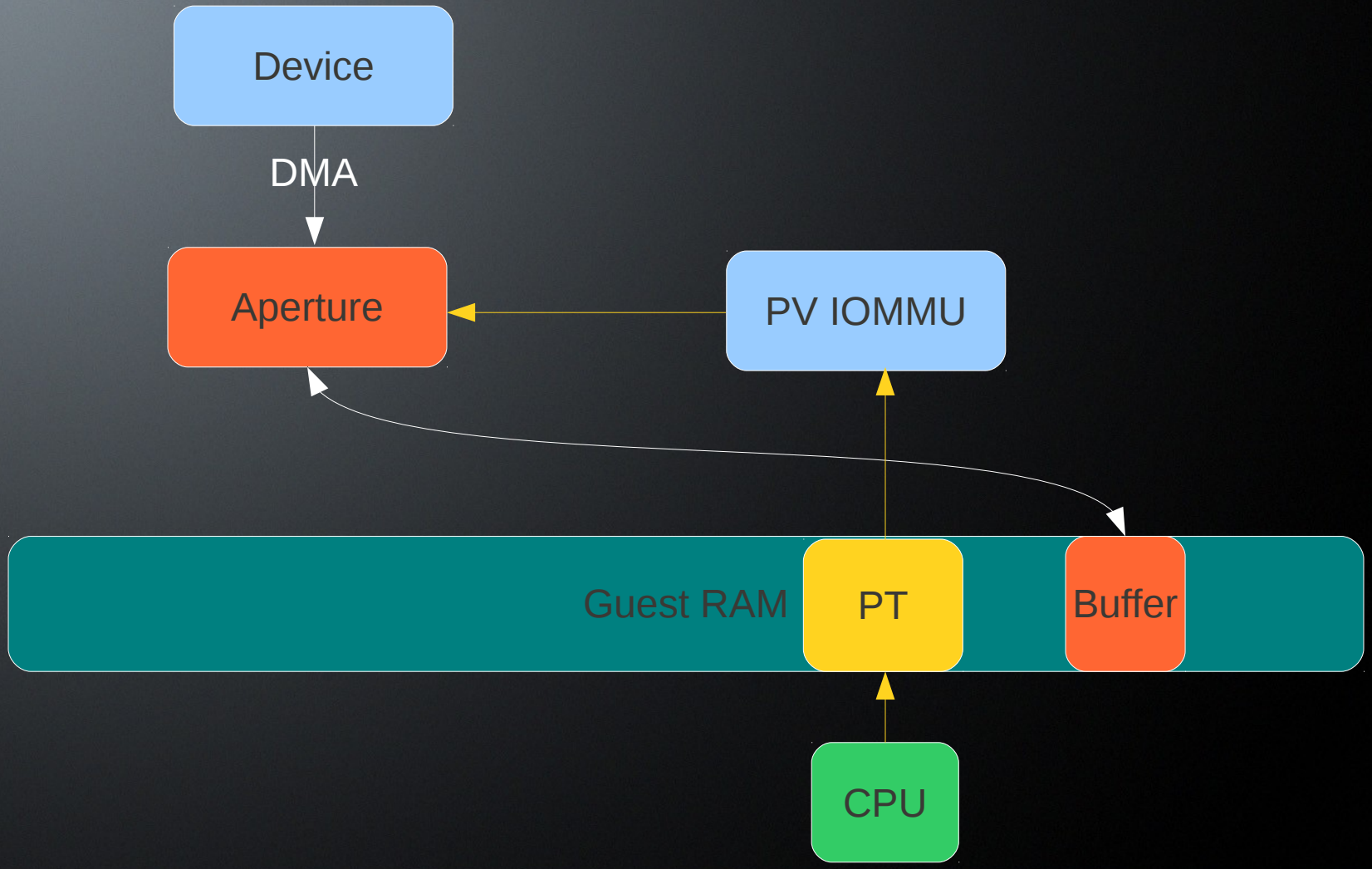
First Variant - Illustrated



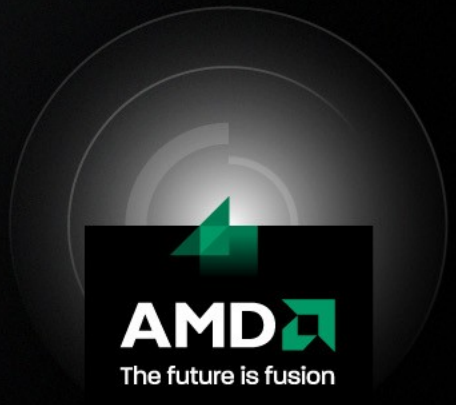
Second Variant

- Guest provides a remapping table for the aperture
- TLB range flush hypercall to sync guest remapping table with host IOMMU page table
- Host IOMMU is used to emulate the paravirtual IOMMU
- Pros:
  - Offloads remapping from software to hardware (no bounce buffering)
  - Can reuse most parts of the GART code
  - Guest does not need to reserve aperture range in RAM
- Cons:
  - Requires TLB-sync hypercall for every mapping operation
  - More difficult to implement than first variant

Second Variant - Illustrated



Guest Kernel Changes



Guest Kernel Changes

- Infrastructure needed in the guest kernel:
  - Per-device DMA-ops
  - Paravirtual IOMMU driver
- Per-device DMA-ops already available in Linux
- A paravirtual IOMMU driver for Linux could reuse existing code in the kernel
  - SWIOTLB for first variant
  - PCI-GART for second variant
- Guest kernel changes not expected to be very intrusive

Thanks for listening!