KVM FORUM

Sharing IOMMU page tables with TDP in KVM

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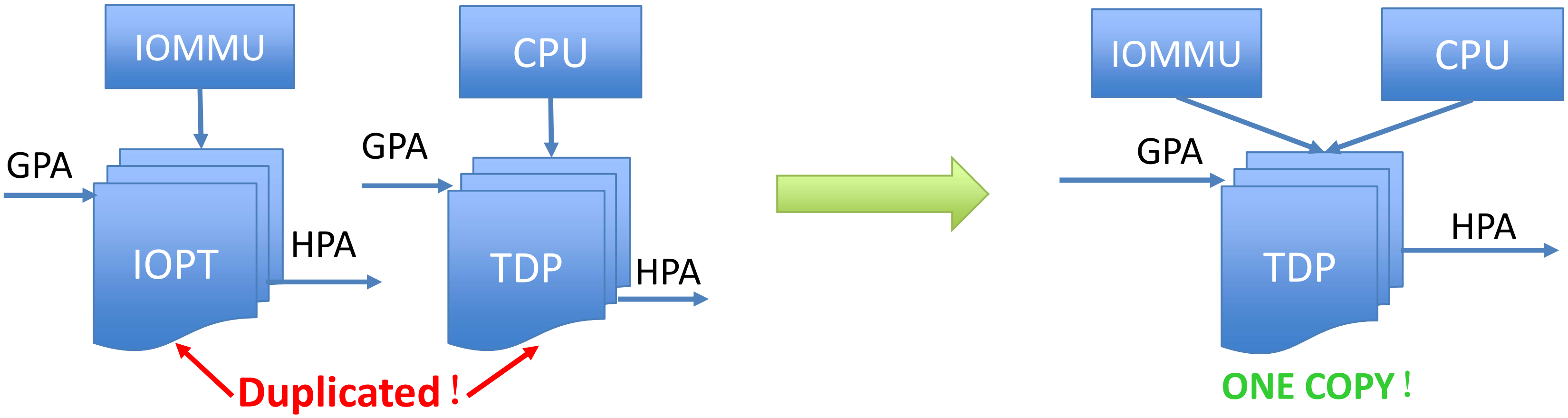
Agenda

- Goal
- Sharing Advantages
- Sharing Prerequisites
- Sharing Interfaces
- Page & Page table Pinning
- Shared Page Table Root Update
- Bootup Performance
- TODOs

Goal


IOMMU
CPU
GPA
IOPT
HPA
GPA
TDP
HPA
Duplicated !
IOMMU
CPU
GPA
TDP
HPA
ONE COPY !

Sharing Advantages

- Reduced memory footprint

- Unified page table management
  - Dirty page tracking, page fault handling, etc.

- Probably higher performance by reducing unnecessary EPT/NPT zap

Sharing Prerequisites

- The same address space
- Compatible page table format
- Non-conflicting page table content

The Same Address Space

- Address space is GPA (L1) → HPA

- Qemu
  - KVM side
    - check TDP is enabled
    - vCPU model does not include EPT/NPT feature
  - IOMMU side
    - no vIOMMU
    - vIOMMU is not in shadow mode. (nested mode on GPA is ok)

.

The Same Address Space (Cont.)

- Nested VM
  - TBD currently

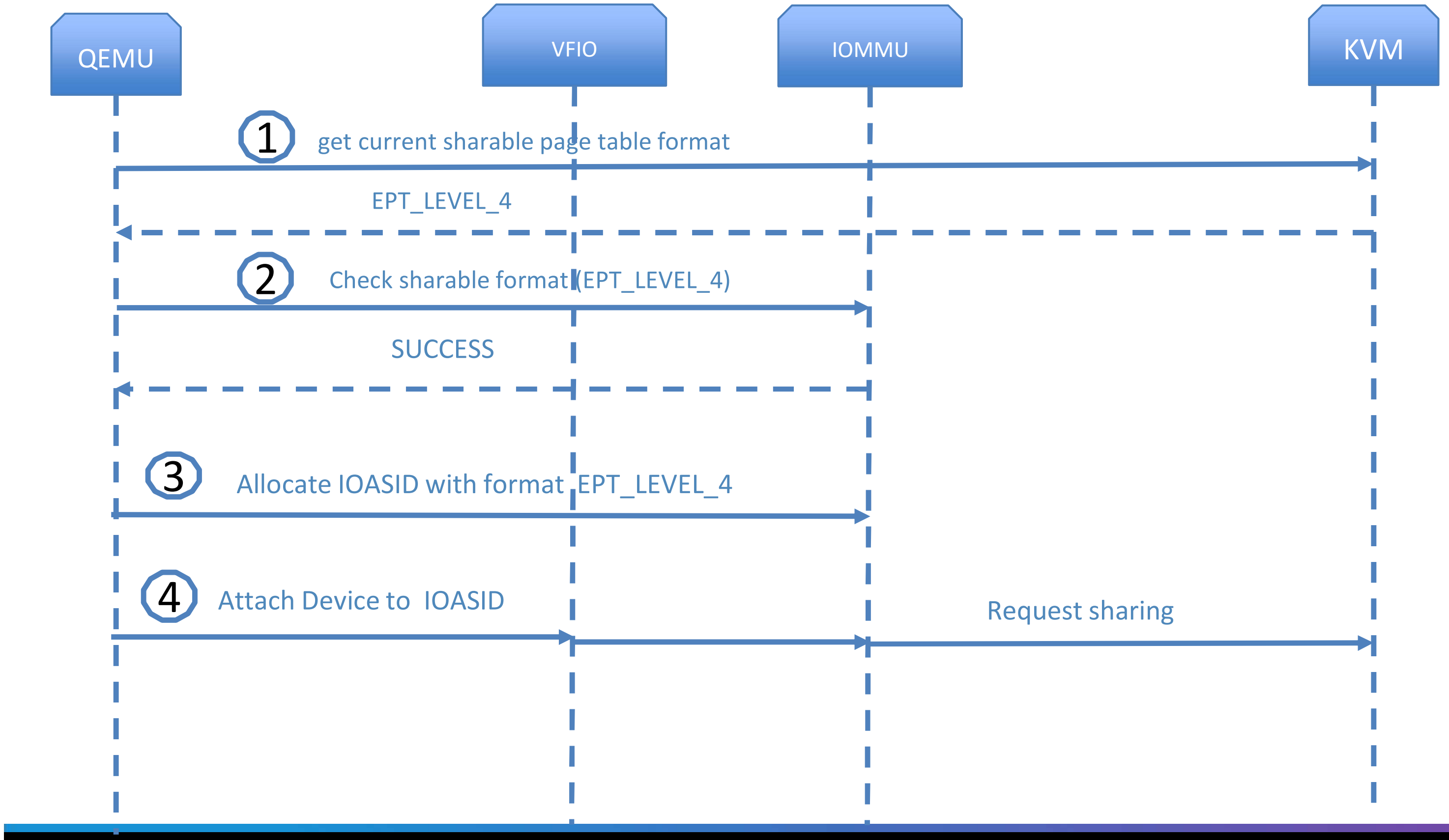
- SMM in x86
  - A different address space. Cannot be shared to IOMMU.
  - Non-SMM mode EPT must be kept for sharing when vCPU is in SMM mode.

Compatible Page Table Formats

- Unified compatible page table format definition across KVM and IOMMU

- Compatible page table formats
  - FORMAT_EPT_LEVEL_4
  - FORMAT_EPT_LEVEL_5
  - FORMAT_NPT_LEVEL_4
  - FORMAT_NPT_LEVEL_5
  - …

Sharing Handshake Sequence


QEMU
VFIO
IOMMU
KVM
1
get current sharable page table format
EPT_LEVEL_4
2
Check sharable format (EPT_LEVEL_4)
SUCCESS
3
Allocate IOASID with format EPT_LEVEL_4
4
Attach Device to IOASID
Request sharing

Note:

1. device pass-through is based on the /dev/iommu proposal, which is IOASID oriented.
2. KVM shares TDP used by vCPU 0

Non-conflicting Page Table Content

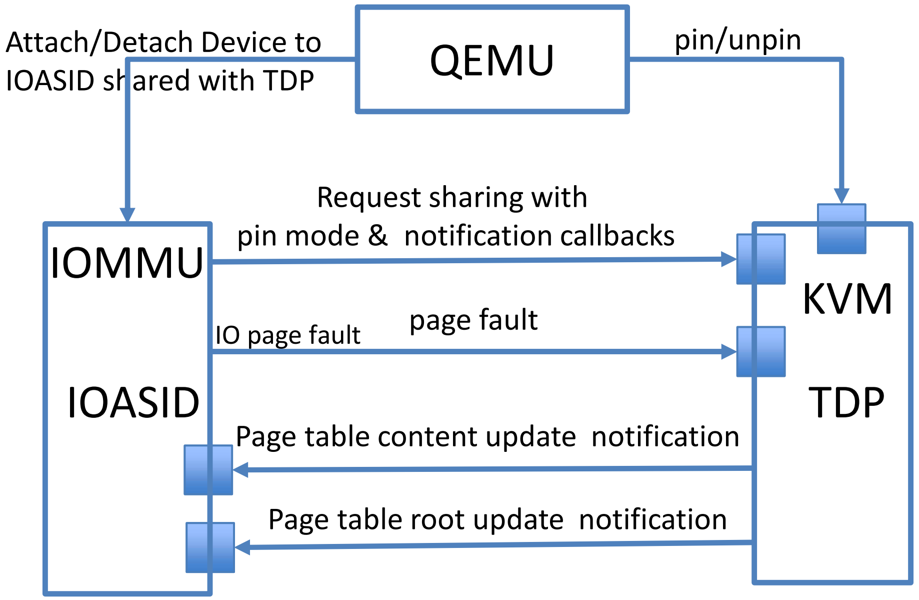
- Presence of page table entry
  - For KVM user memslots
    - must be present and pinned (staying present) for DMA pages when IO page fault is not supported.
    - Can be present or zapped for non-DMA pages or when IO page fault supported
  - For KVM private memslots
    - Not present in IOPT before sharing
    - Safe to be present in IOPT after sharing
    - Local APIC
      - DMA write to 0xfeexxxxx doesn’t go through DMA remapping.
    - TSS and IDENTITY_PAGETABLE
      - for !enable_unrestricted_guest, E820 Reserved

Non-conflicting Page Table Content (Cont.)

- Read/Write/Execute bit
  - RO for RO memslots
  - RW for other memslots
  - Execute bit
    - currently ignored in IOMMU and no device uses it.
  - Write protection for live migration
    - Allowed when IO page fault is supported
    - Must be disabled otherwise
      - All pinned ranges are dirty or
      - traversal for Dirty bit

Sharing Interfaces

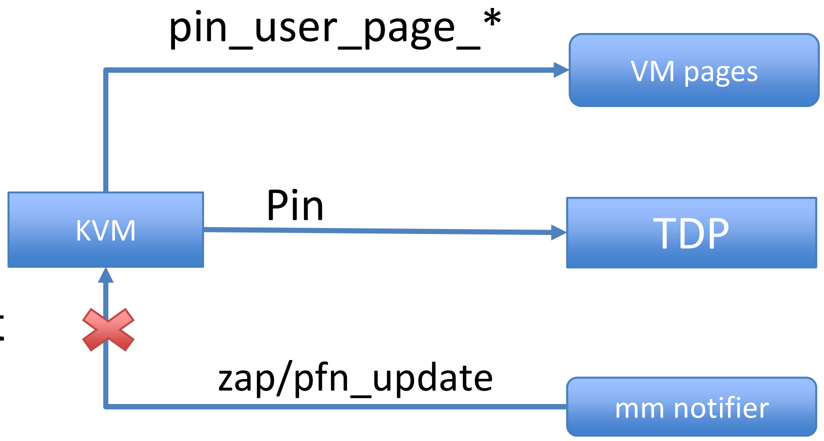
- Request/stop sharing
- Page/page table pinning for DMAs without IO page fault
- Page fault for IO page fault support
- Notification
  - Page table content update notification
  - Page table root update notification


QEMU
Attach/Detach Device to IOASID shared with TDP
pin/unpin
IOMMU
IOASID
KVM
TDP
Request sharing with pin mode & notification callbacks
IO page fault
page fault
Page table content update notification
Page table root update notification

Page & Page Table Pinning

For sharing without IO page fault,

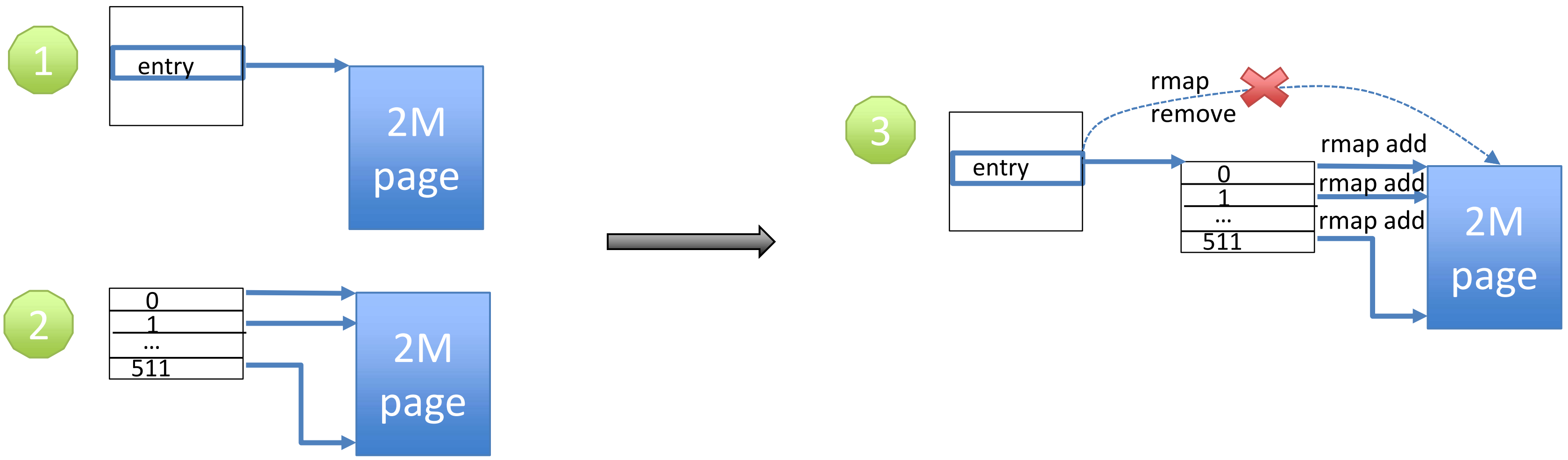
- Pinning of VM pages
  - pin_user_pages_* (FOLL_LONGTERM)
- Pinning of TDP entries
  - Pre-population of pinned ranges
  - No zap/pfn update
  - No reclaiming of mmu pages with parent linked
  - Atomic update of TDP entries when permission or page size change



Atomic Update for TDP Entries

Atomic update is required for TDP entries for pinned ranges, when

- Splitting huge pages
- Updating of PTE permission



TDP entry being atomically updated from non-zero value to another non-zero value.

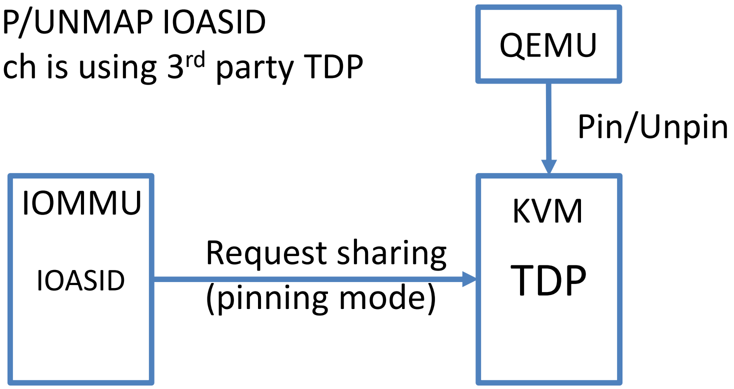
Page & Page Table Pinning Interfaces

- For sharing without IO page fault,
  - Pinning of all ranges in user memslots: memslot add
  - Pinning a specific range: extra interface

Pin/Unpin from Qemu

Pros:

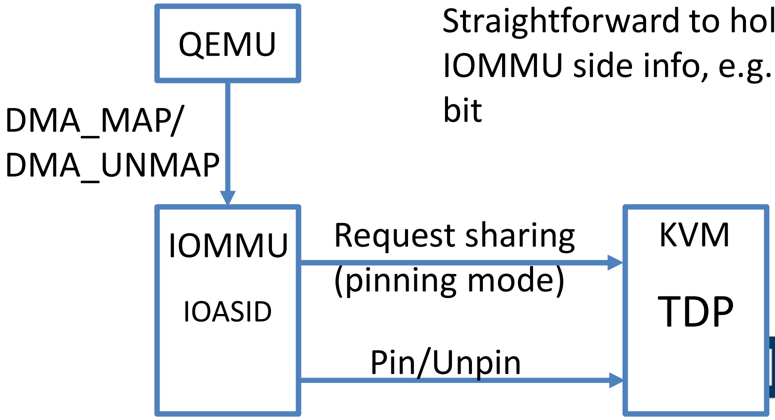
QEMU doesn't need to MAP/UNMAP IOASID which is using 3rd party TDP



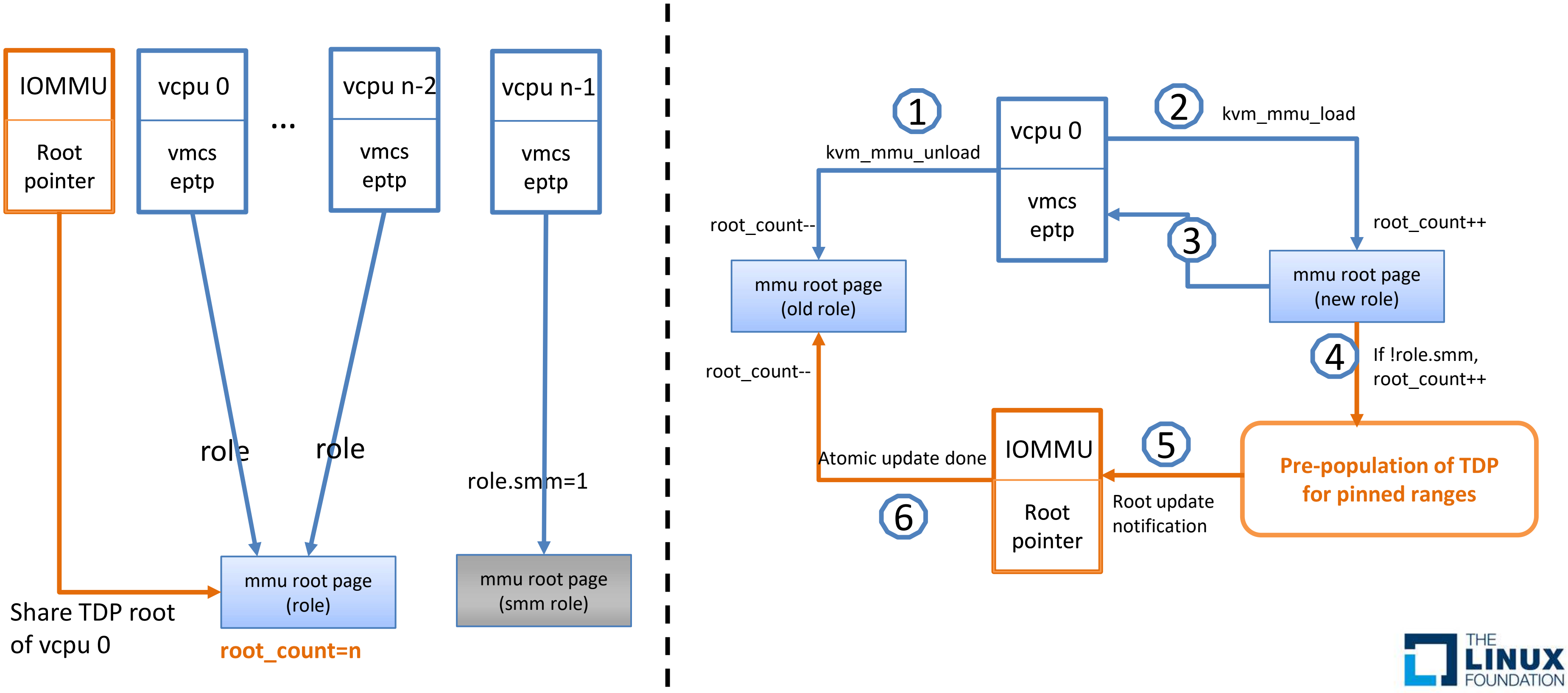
Pin/Unpin from IOMMU

Pros:

Straightforward to hold more IOMMU side info, e.g. snoop bit



Shared Page Table Root Update



Bootup Performance

Rough performance data without any optimization yet.

8G memory	Bootup Time	Pre-population count
Base (no sharing)	29s	0
Sharing (huge page enabled)	32s	132
Sharing (huge page disabled)	63s	132

- All VM pages were pinned/unpinned on user memslots creation/deletion.
- TDP was pre-populated on page table changes (when switching to new root, memslot add, and huge page splitting)
- IOTLB was flushed on page table root/content update notification (~1s)

- Quite a lot of time spend on TDP pre-population
  - ~2s with huge page
  - ~32s when huge page is disabled
- In concept can reach equal boot time performance as before sharing by reducing TDP root update count.

TODOs

- Snoop bit handling
- Unified dirty page tracking
- Nested VM (vIOMMU, virtual EPT/NPT)
- Performance optimization
  - Page table root update reduction,
  - Huge page support for P2P, etc.

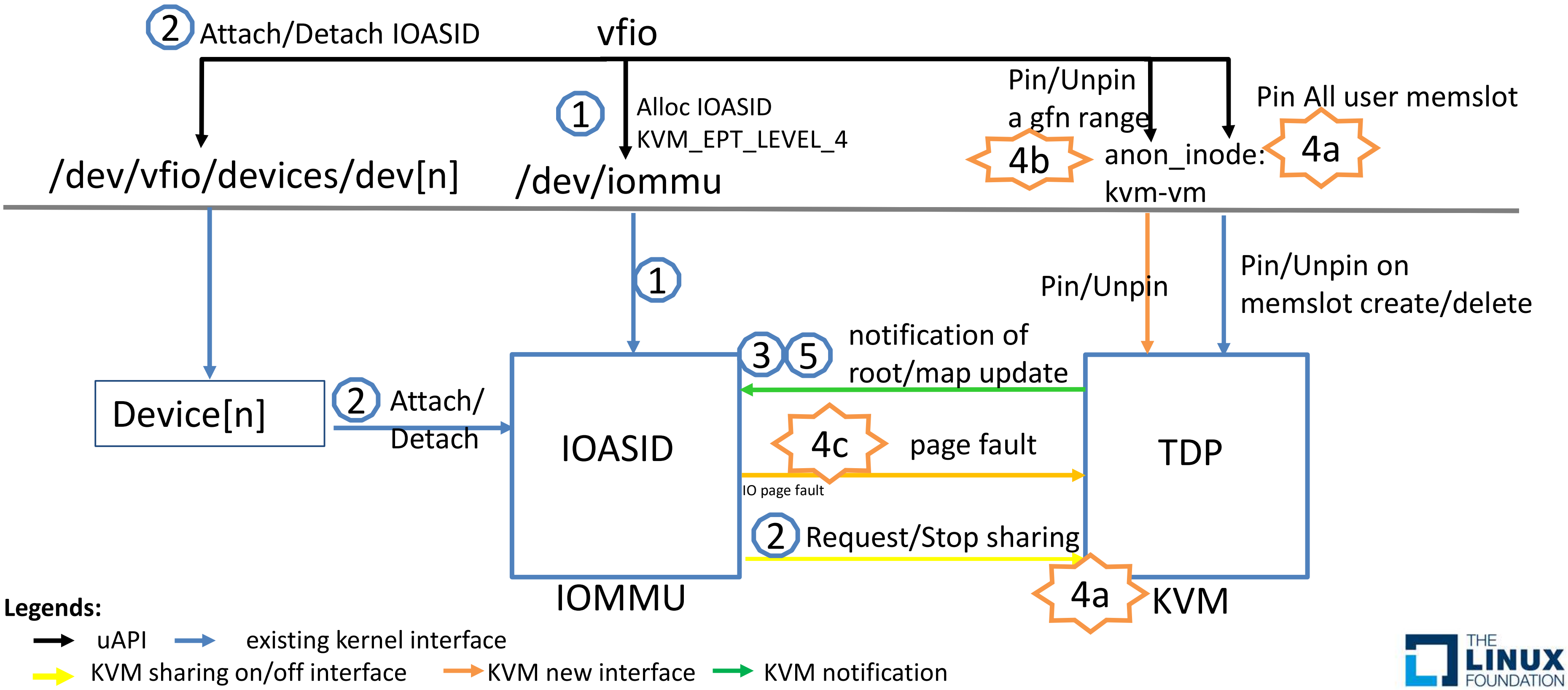
KVM

FORUM

Why it is KVM manages the shared table

- CPU side has more restrictions in page size
  - Check guest MTRR
  - NX huge page workaround
- CPU side has extra GFN ranges to access
  - Private memslots in kernel space
- IOMMU page tables are not always present.

Overall Design



2 Attach/Detach IOASID

vfio

1 Alloc IOASID KVM_EPT_LEVEL_4

Pin/Unpin a gfn range

Pin All user memslot

/dev/vfio/devices/dev[n]

/dev/iommu

4b anon_inode: kvm-vm 4a

1

Pin/Unpin

Pin/Unpin on memslot create/delete

Device[n]

2 Attach/ Detach

IOASID

IOMMU

3 5 notification of root/map update

4c page fault

IO page fault

2 Request/Stop sharing

4a

TDP

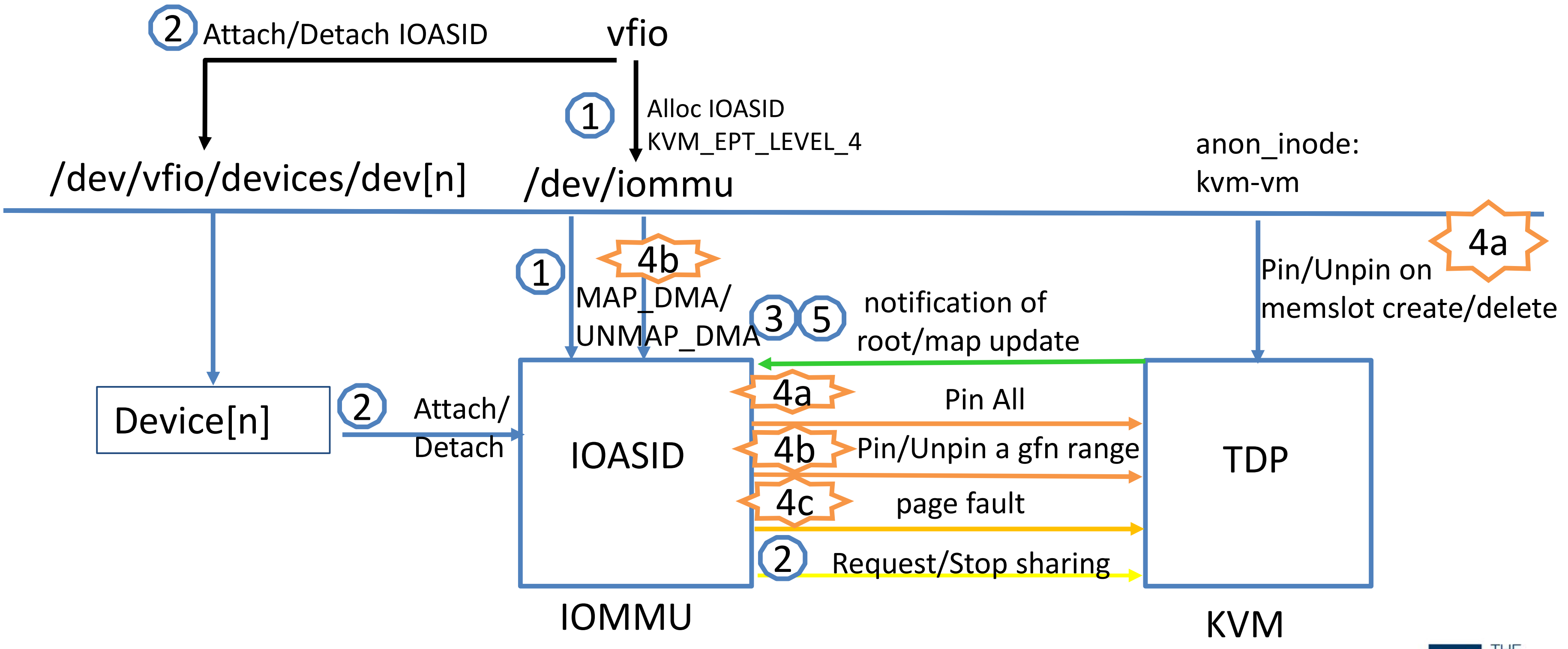
KVM

Legends:

→ uAPI → existing kernel interface

→ KVM sharing on/off interface → KVM new interface → KVM notification

Overall Design (alternative)


2 Attach/Detach IOASID
vfio
1 Alloc IOASID
KVM_EPT_LEVEL_4
/dev/vfio/devices/dev[n]
/dev/iommu
anon_inode:
kvm-vm
4a
1
4b
MAP_DMA/
UNMAP_DMA
3 5 notification of
root/map update
Pin/Unpin on
memslot create/delete
Device[n]
2 Attach/
Detach
IOASID
4a Pin All
4b Pin/Unpin a gfn range
4c page fault
2 Request/Stop sharing
TDP
IOMMU
KVM