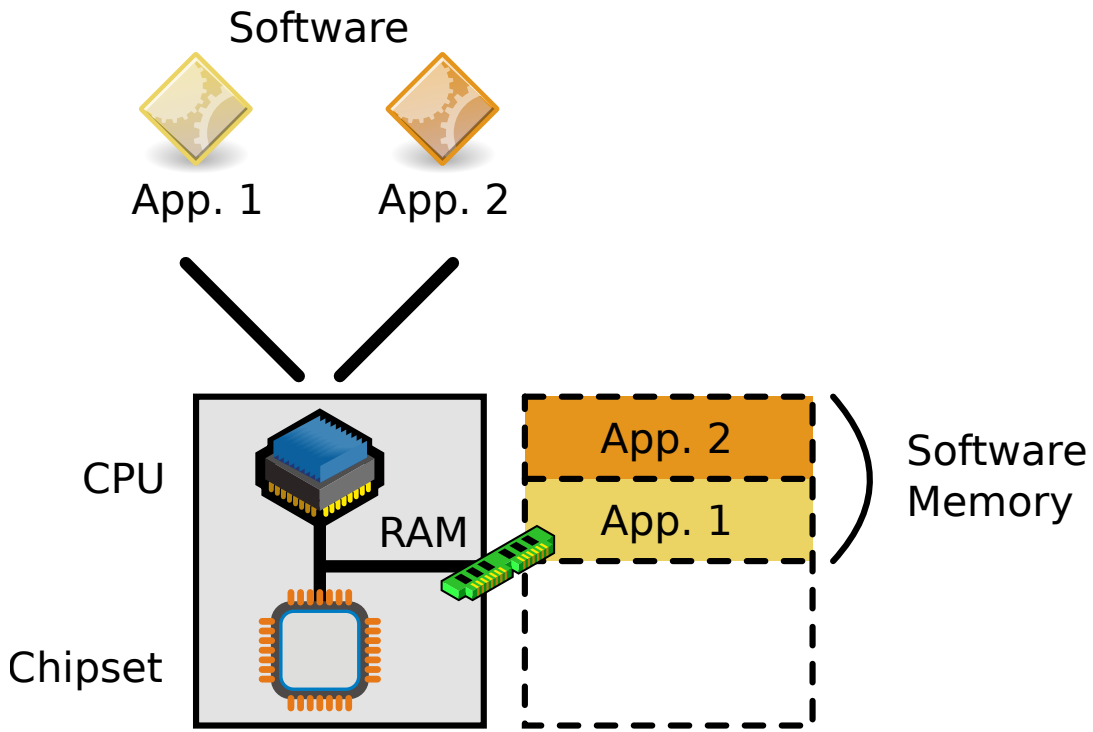
Bypassing IOMMU protection against I/O Attacks

Benoît Morgan, Éric Alata,
Vincent Nicomette and Mohamed Kaâniche

LAAS-CNRS, INSA Toulouse, University of Toulouse

October 19, 2016

Memory protection in modern architectures



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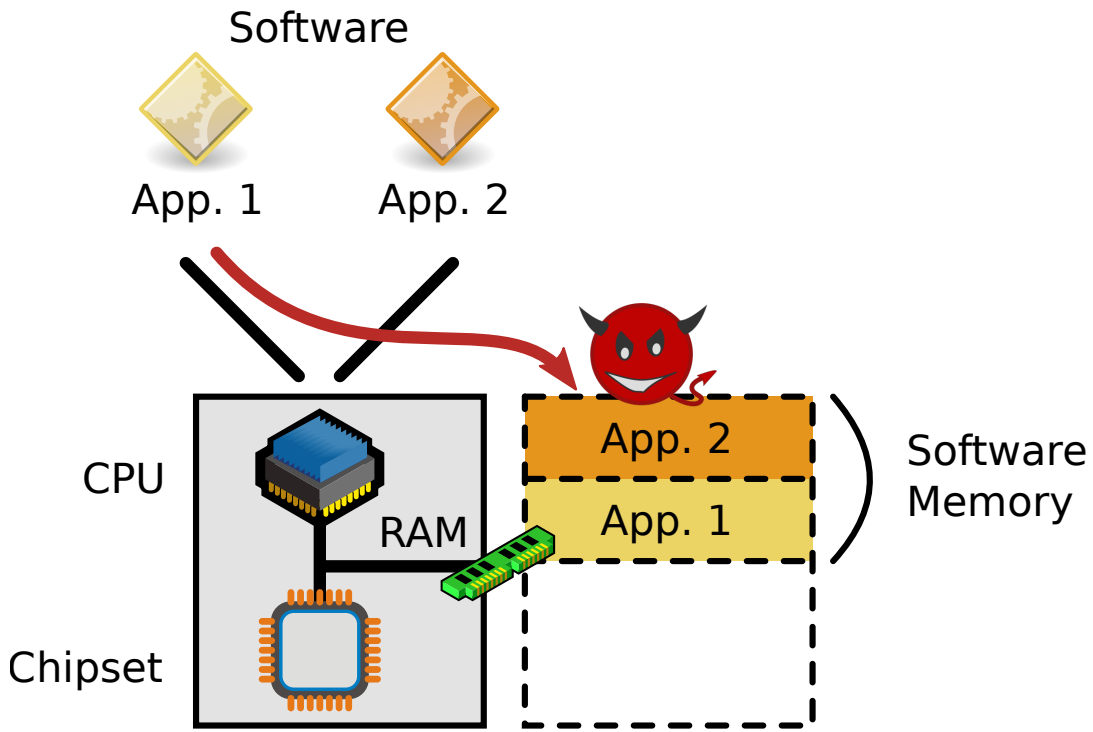

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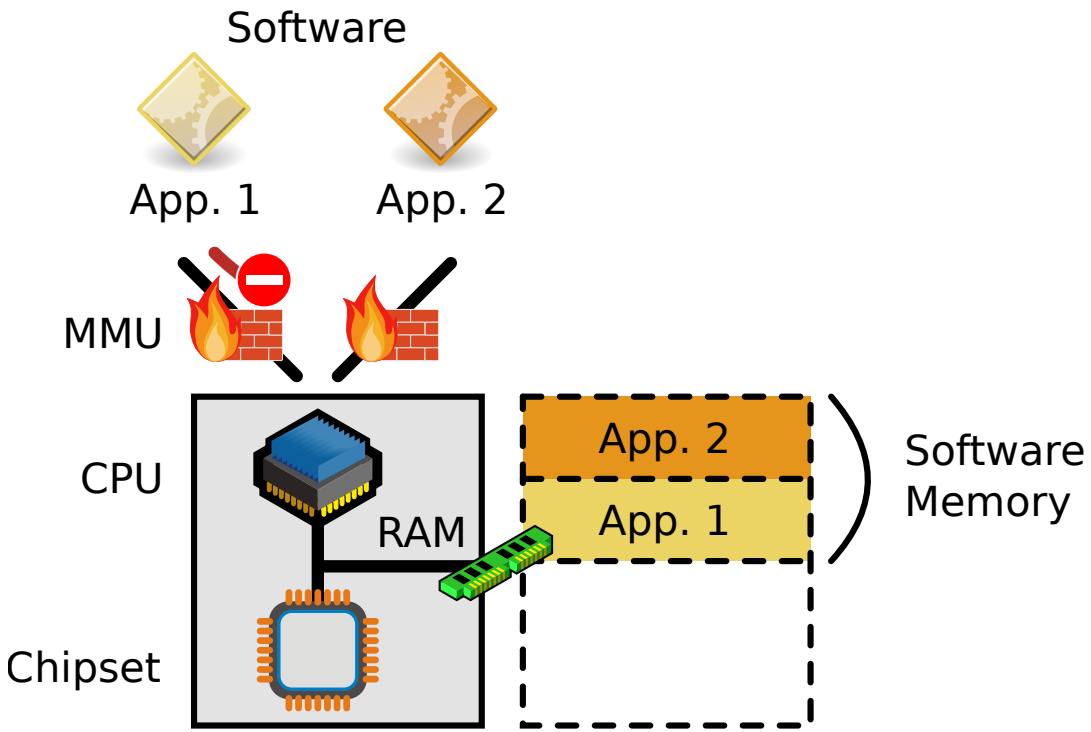

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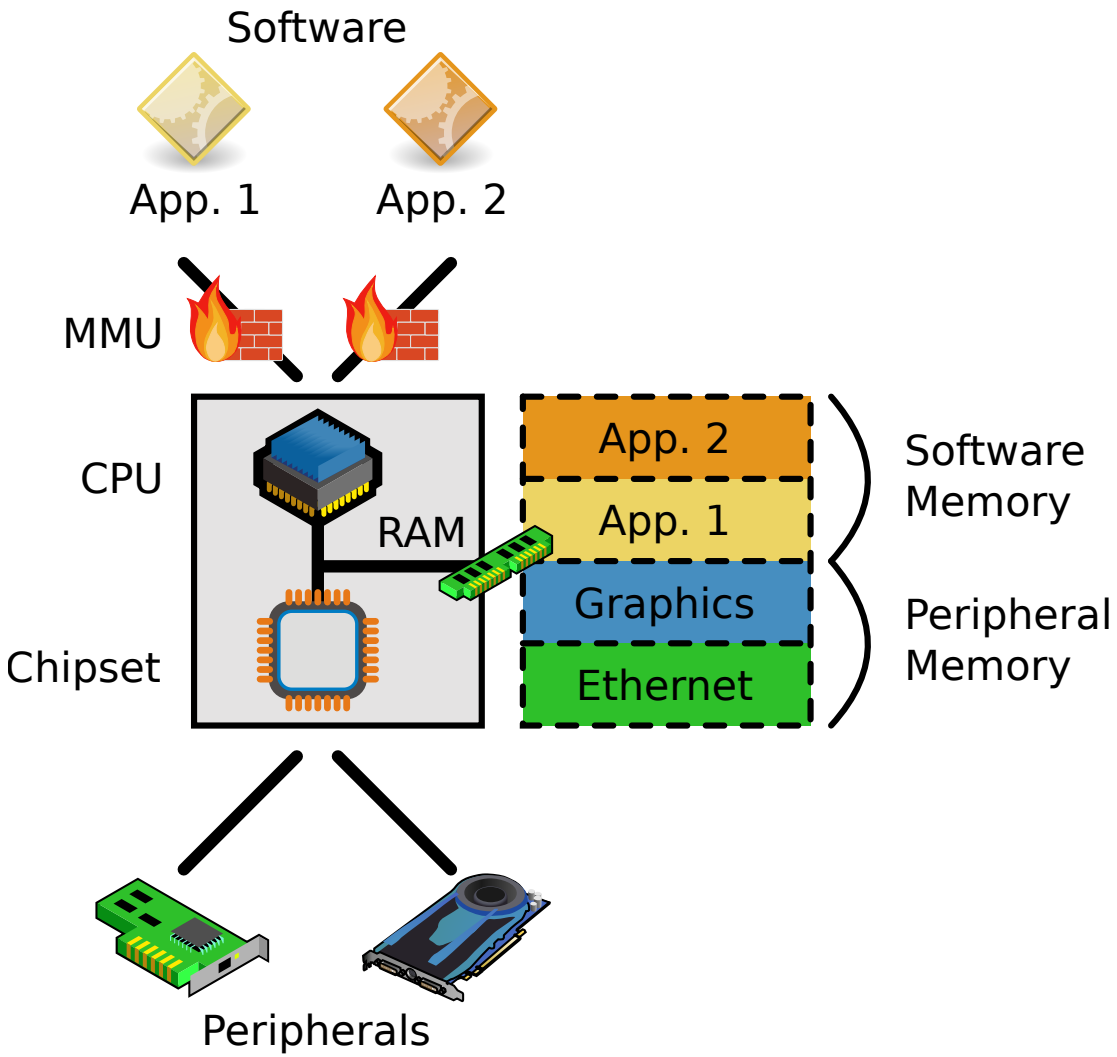

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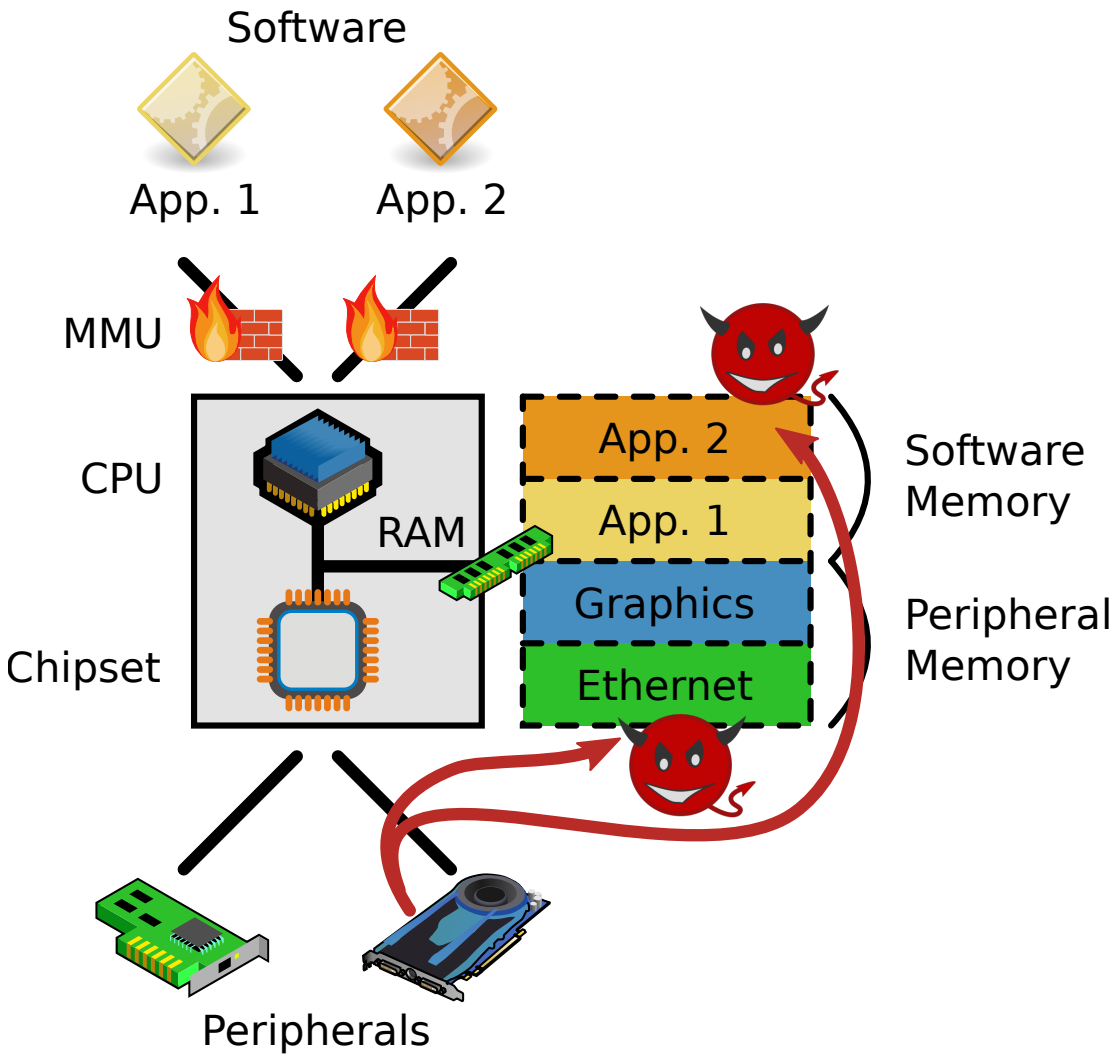

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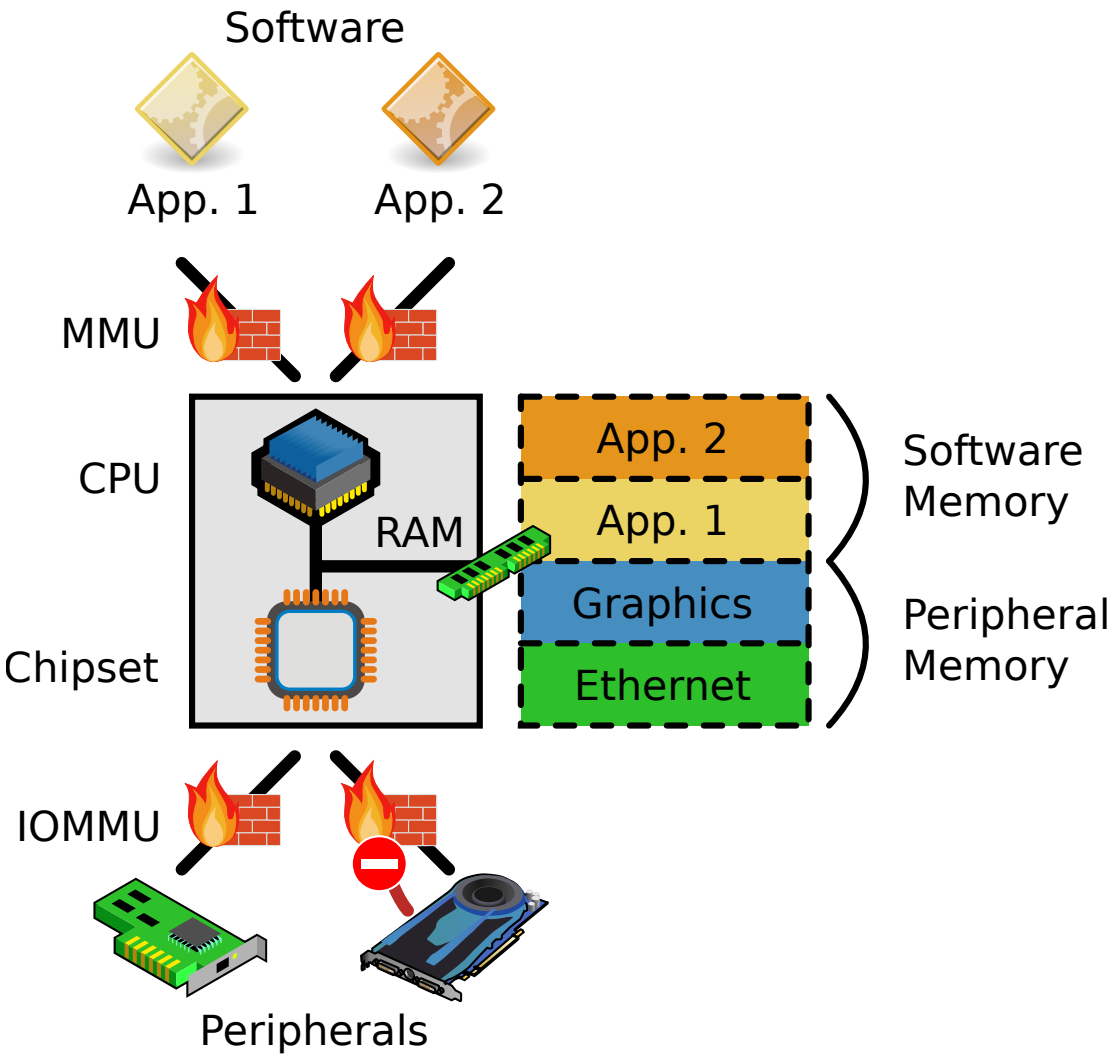


IOMMU security issues

- Do modern operating systems use this component by default ?
- Is it used correctly ?
- Is it active all the time ?

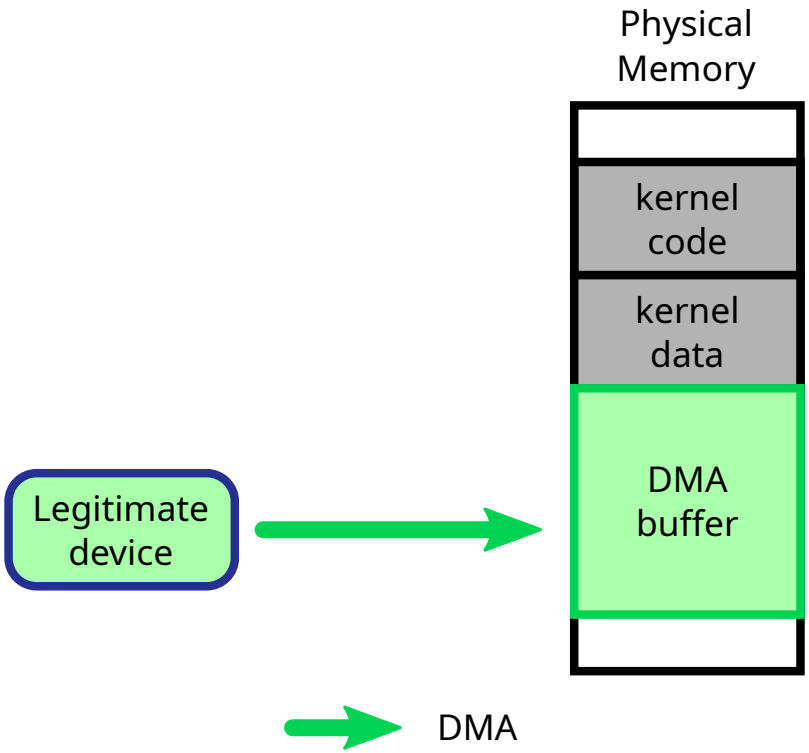
Contribution

- Vulnerability in the IOMMU configuration and exploitation proof of concept

Outline

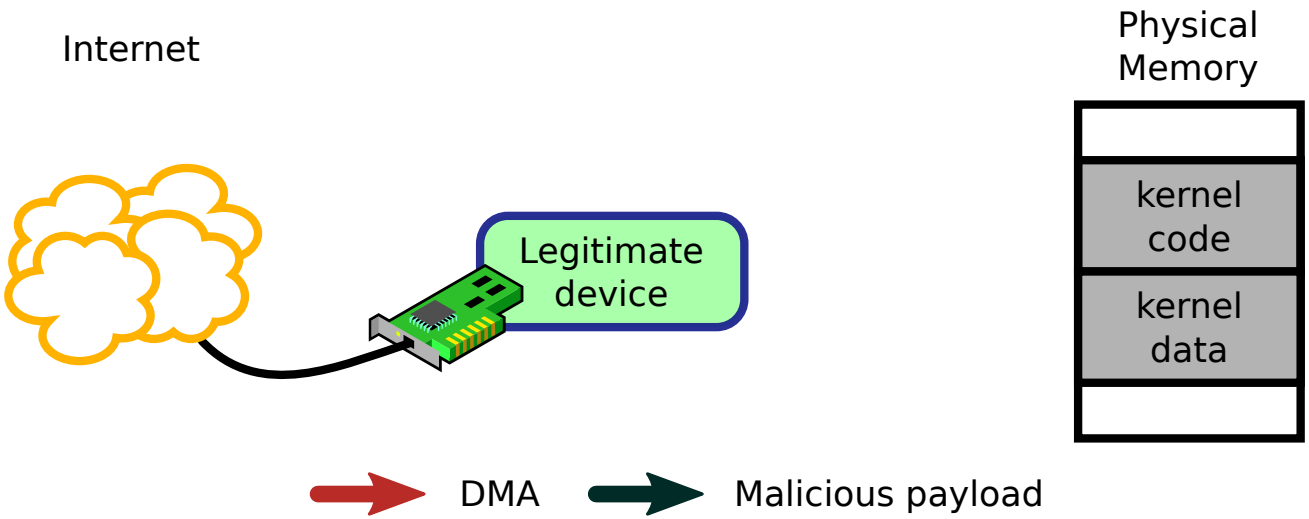
1. Background
   - DMA principles
   - IOMMU principles
2. A vulnerability in the IOMMU configuration
3. Conclusion

Direct Memory Access



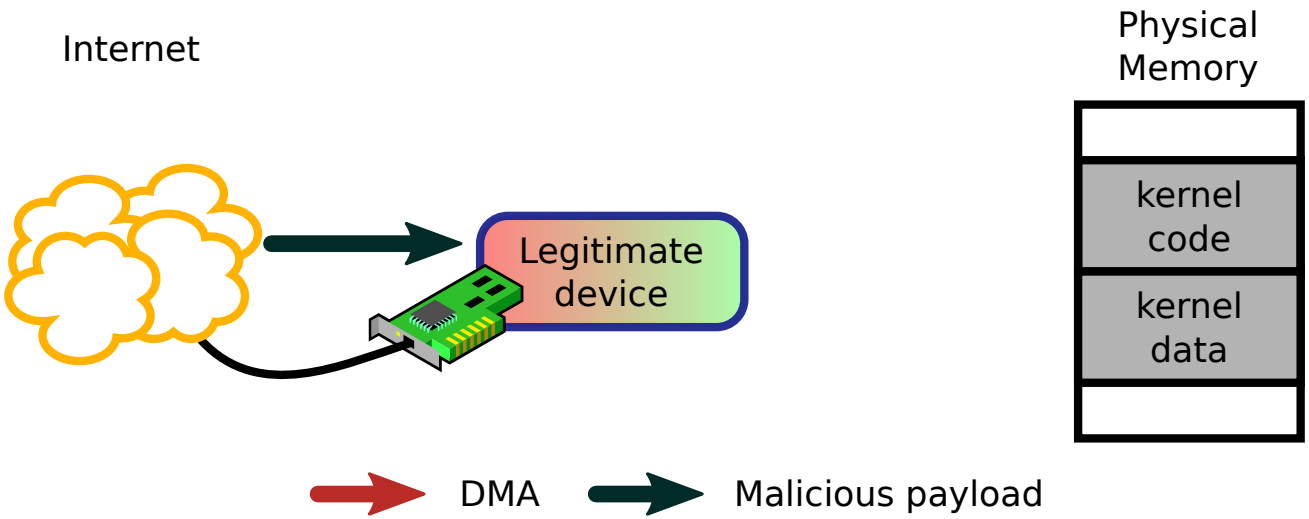
- Peripheral access to the main memory
- Independent from the CPU

DMA threats



- Some peripherals are vulnerable and remotely exploitable (*Duflot et al.* [1])

DMA threats



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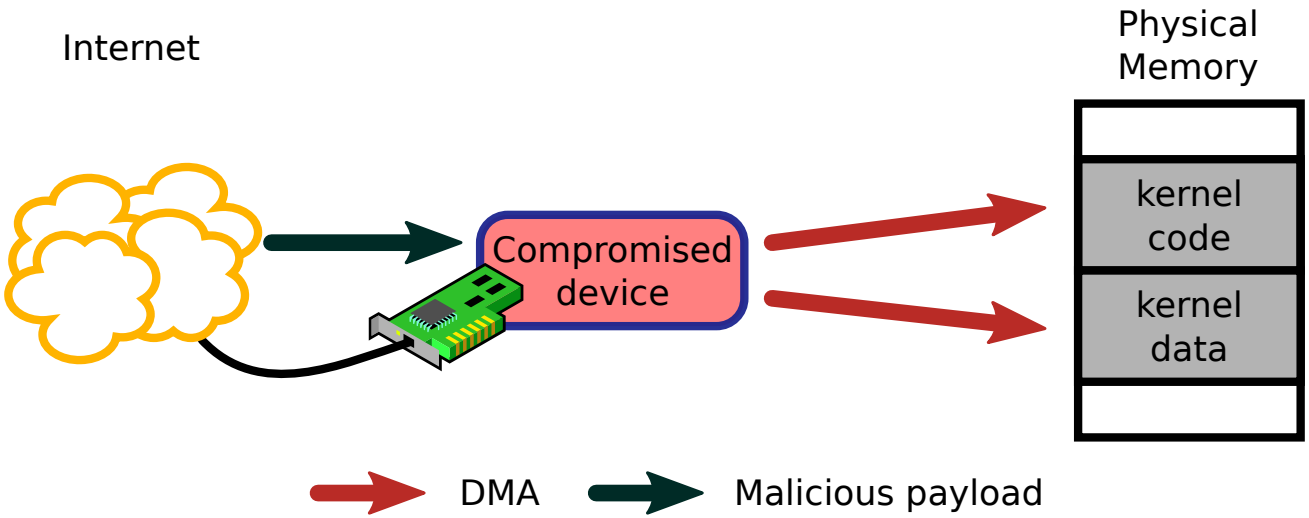

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$\Rightarrow$ Remote malicious arbitrary reads and writes of privileged data

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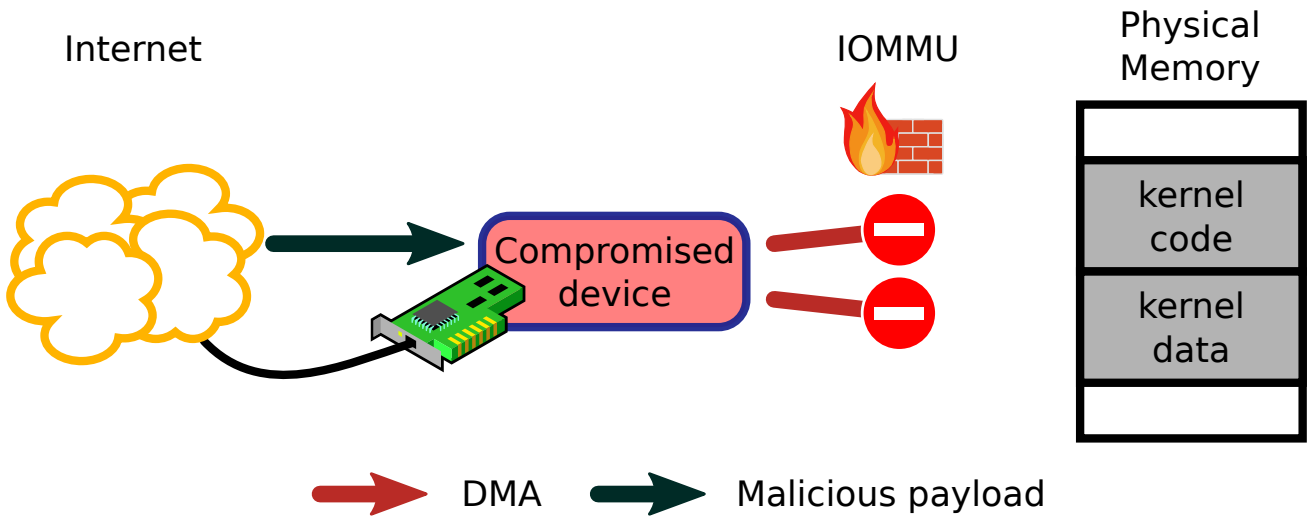


- Some peripherals are vulnerable and remotely exploitable (*Duflot et al.* [1])

$\Rightarrow$ Remote malicious arbitrary reads and writes of privileged data

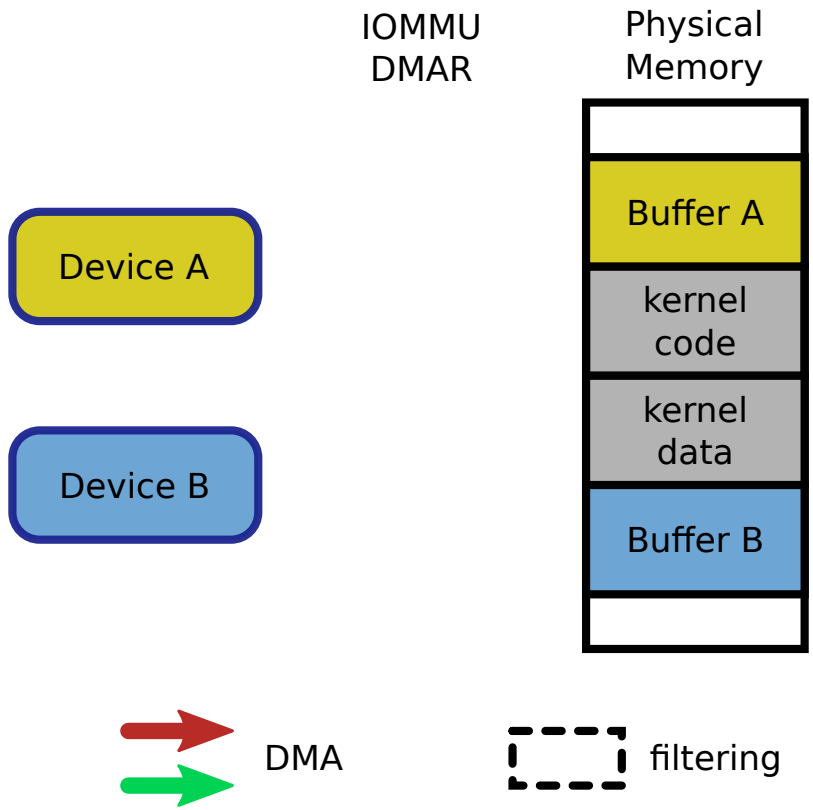
$\Rightarrow$ Access control is essential

Input Output Memory Management Unit

Services

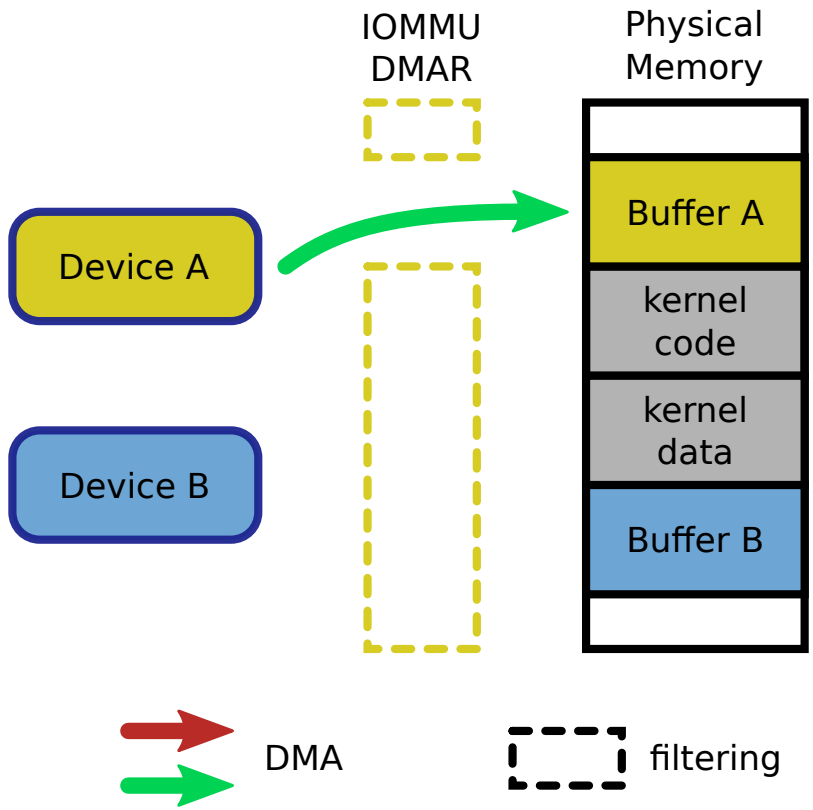
- DMA Remapping (**DMAR**) : Peripheral address space virtualization thanks to translation and filtering
- Interrupt Remapping

DMAR access control



- Multiple memory protection domain
- Unlimited configuration possibilities

DMAR access control



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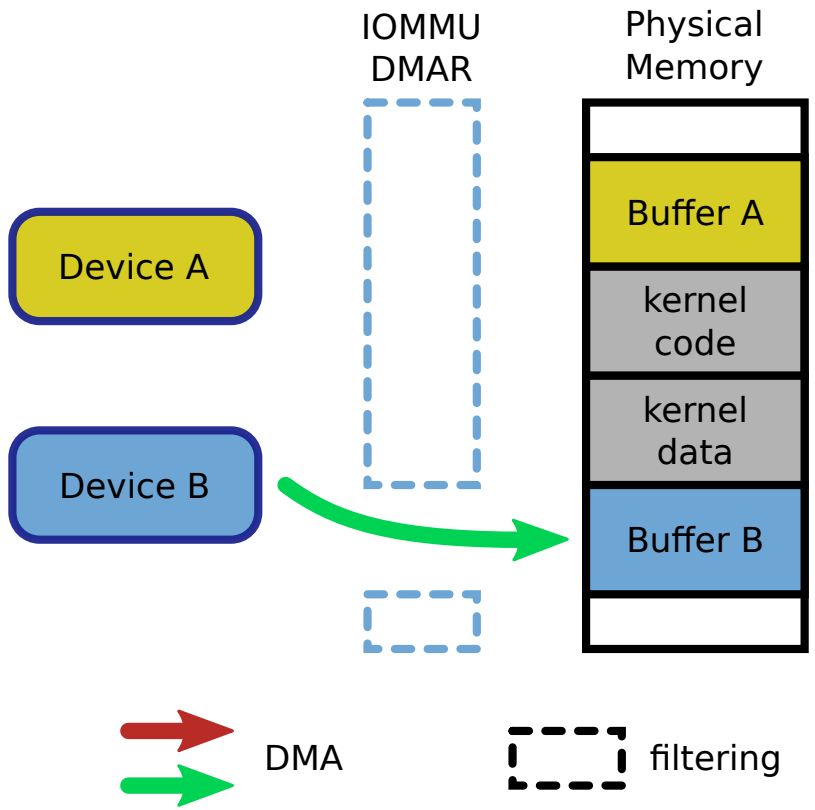

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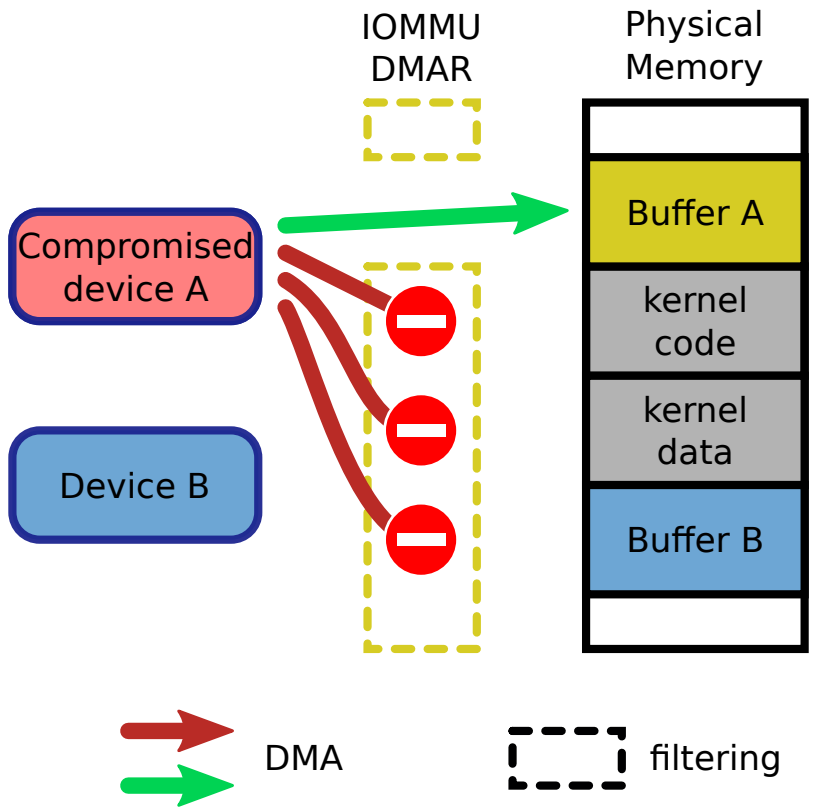

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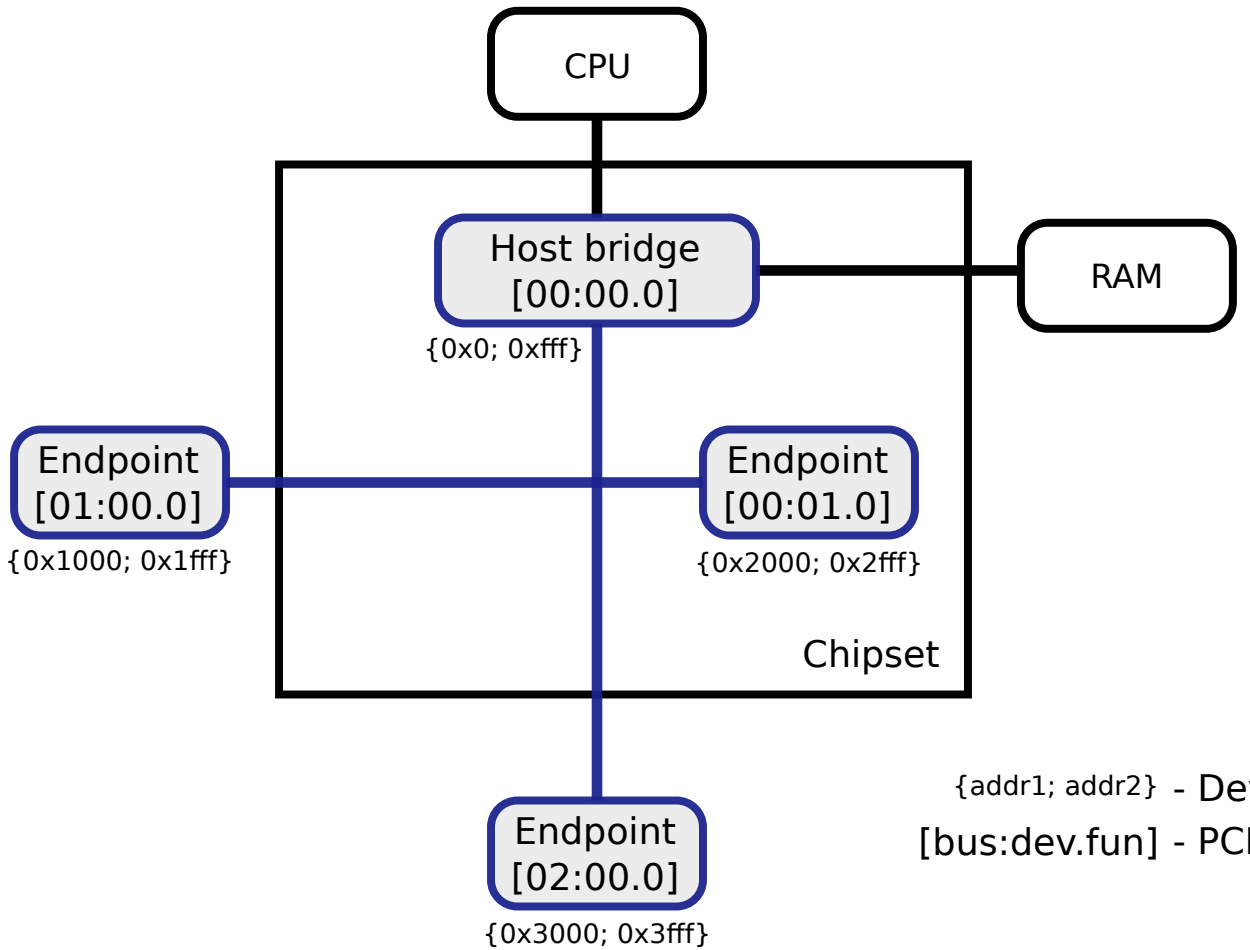
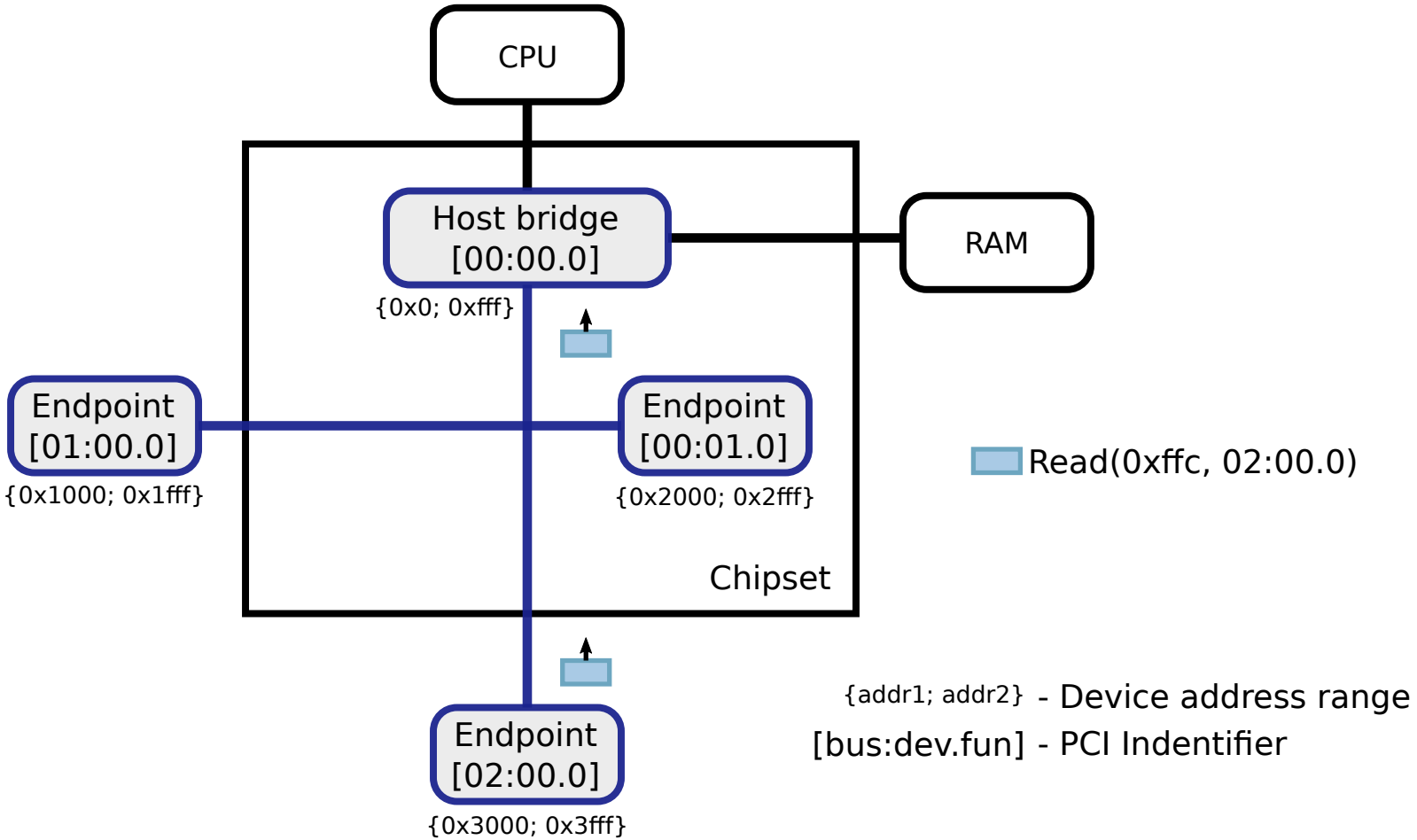
PCI Express bus



{addr1; addr2} - Device address range

[bus:dev.fun] - PCI Indentifier

PCI Express Memory Read



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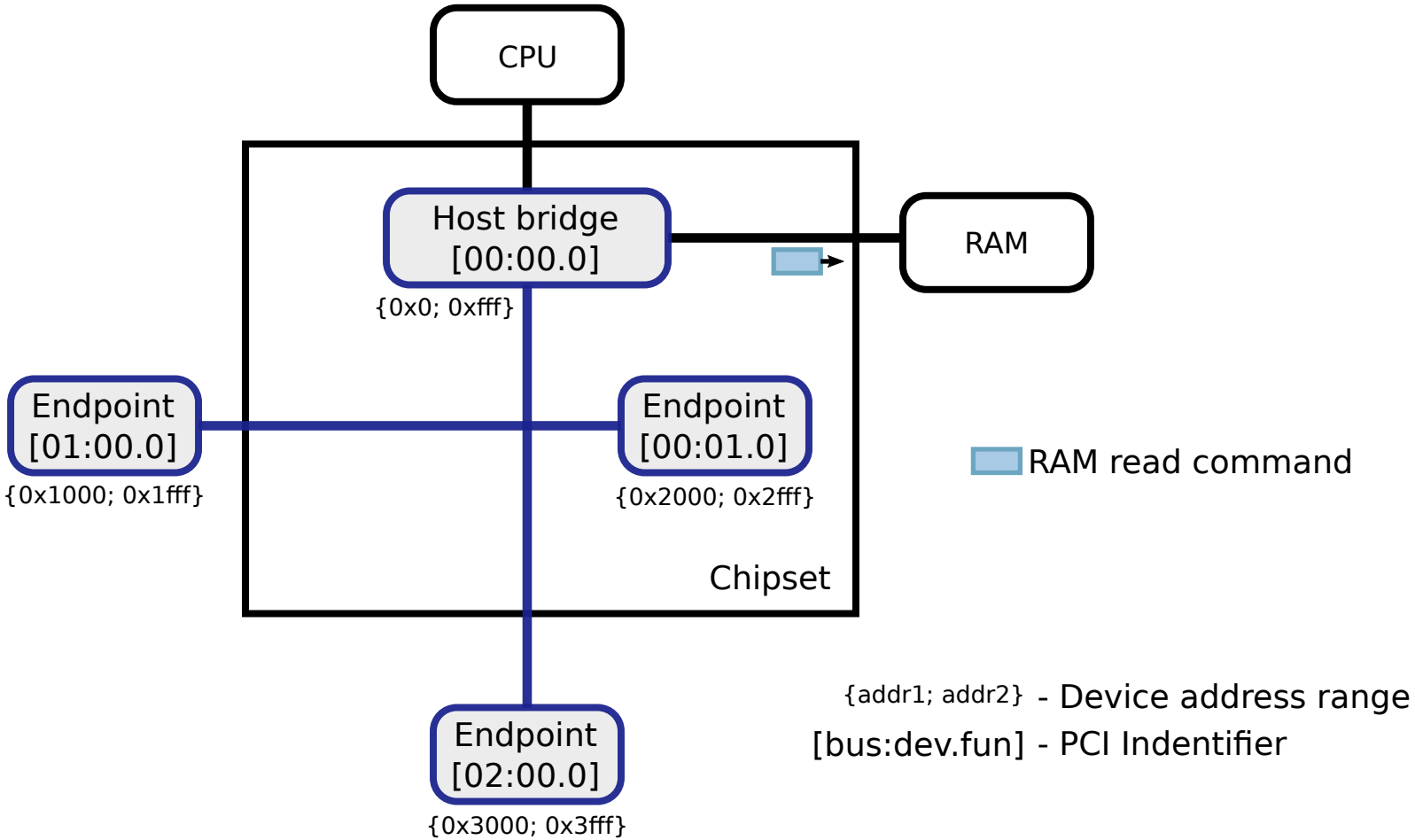

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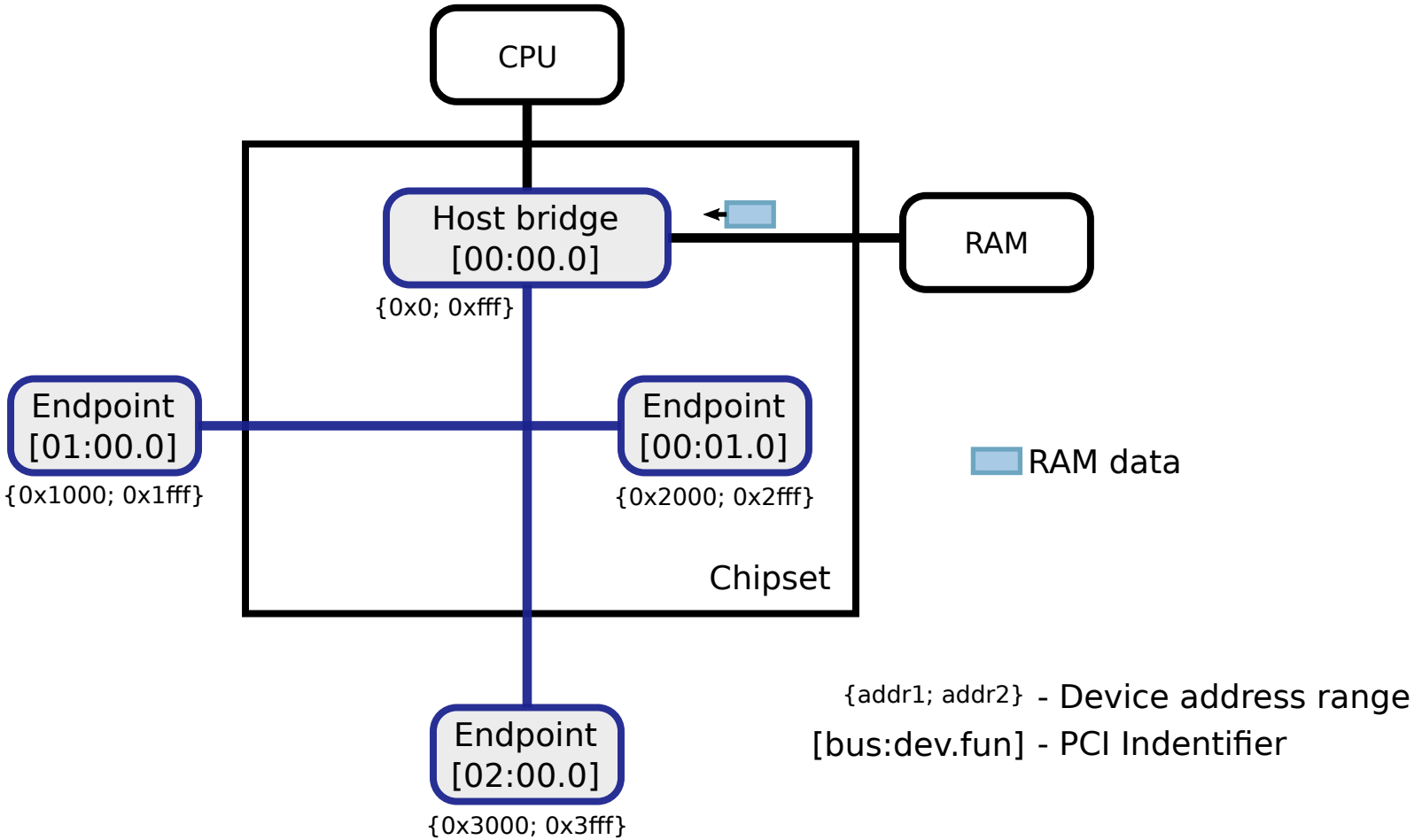

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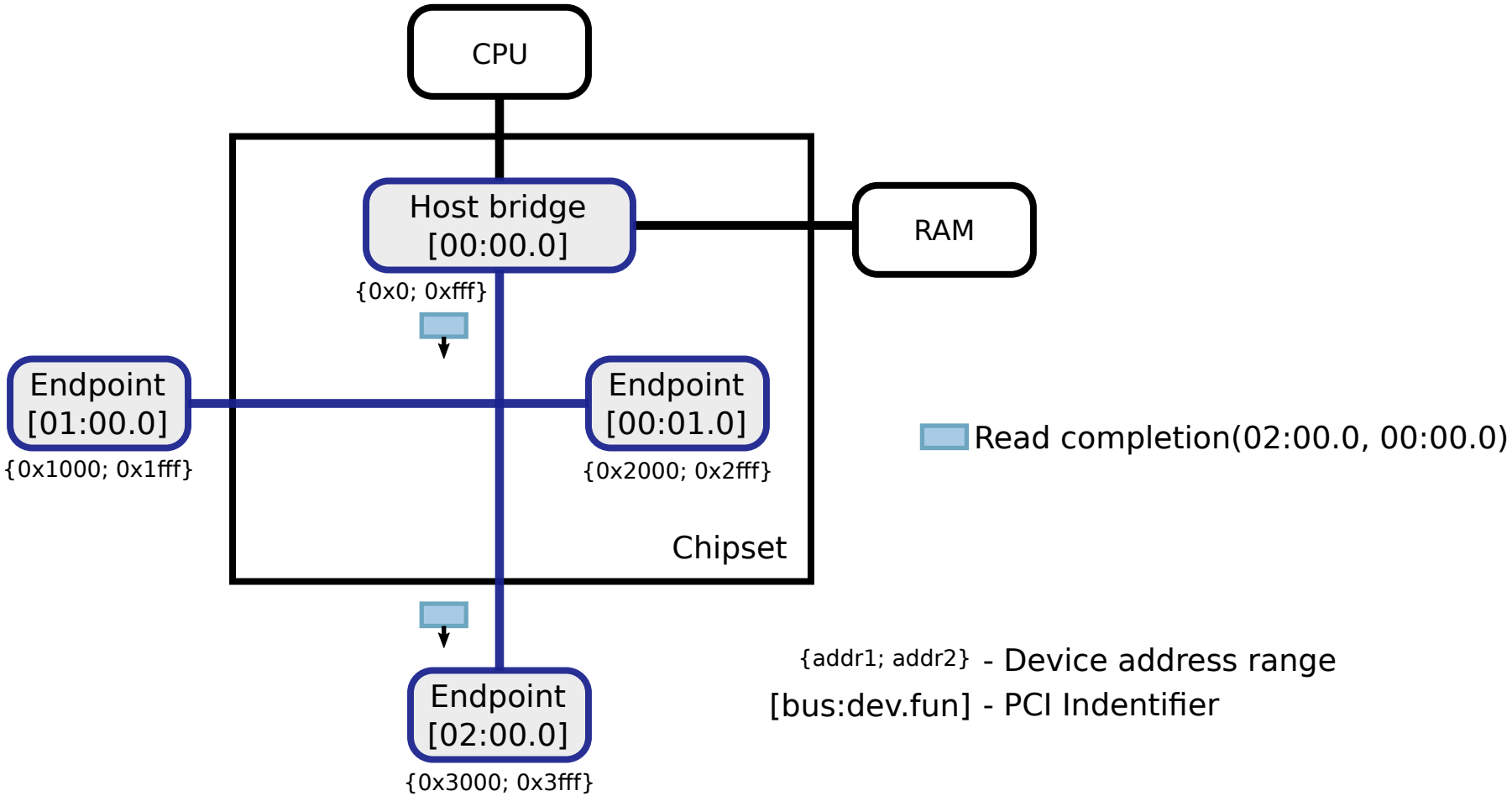
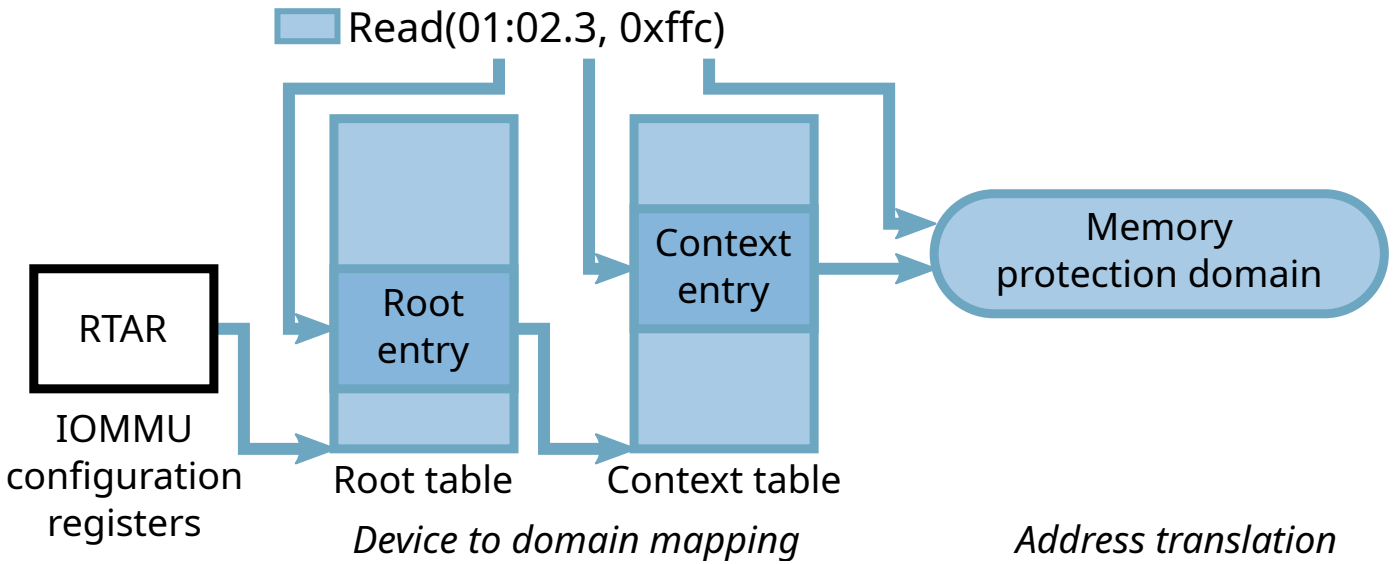


DMAR configuration

- A two phases process for translation and filtering with two sets of translation tables
  - Device to domain mapping : identifies the peripheral
  - Address translation : applies access control domain
- Memory structures are placed in RAM and read by the IOMMU located in the host bridge



Outline

1 Background

2 A vulnerability in the IOMMU configuration
- Observations
- Attack

3 Conclusion

Attack goal

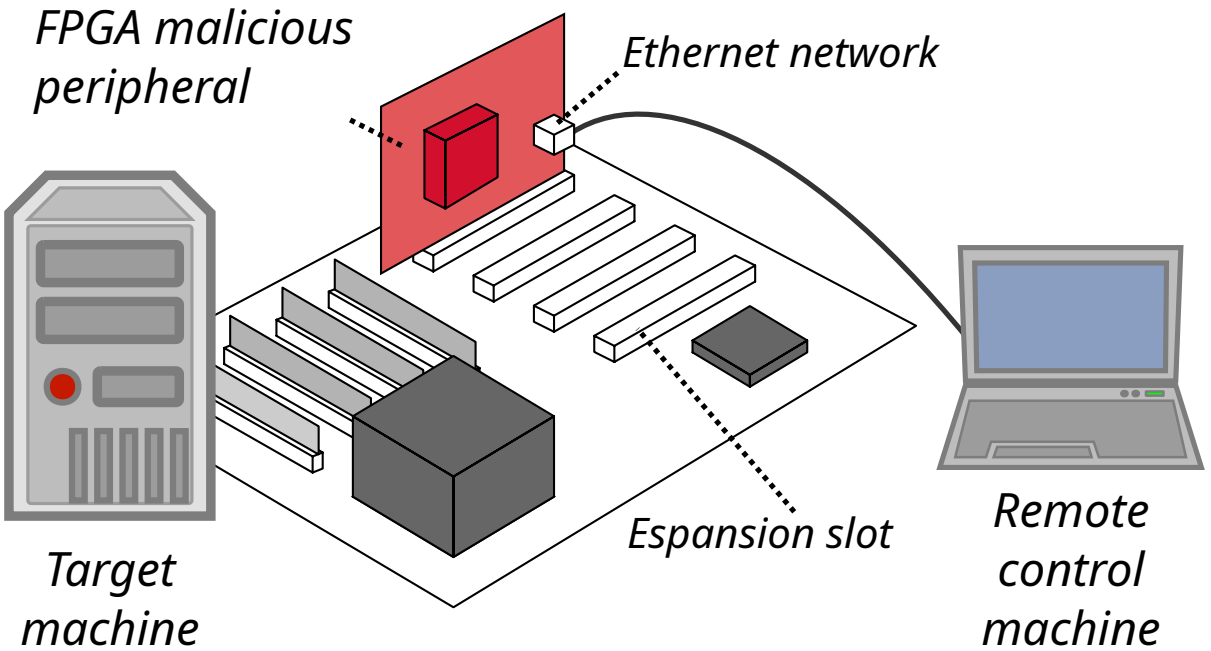
- Keep the DMA rights after the activation of the IOMMU

$\Rightarrow$ Overwrite legitimate IOMMU configuration using DMA

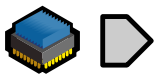
Experimentation setup

- Standard configuration

Linux 4.3.4 (IOMMU Intel)	Intel i7-4770
grub 2.02.beta2	Intel PCH c226



IOMMU vulnerability

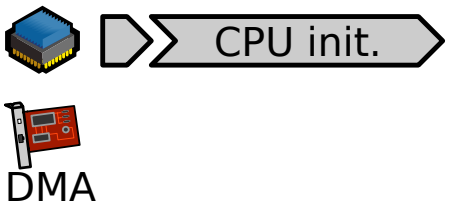


DMA

Our goal : Overwrite legitimate IOMMU configuration using DMA

1. When is DMA available ?

IOMMU vulnerability



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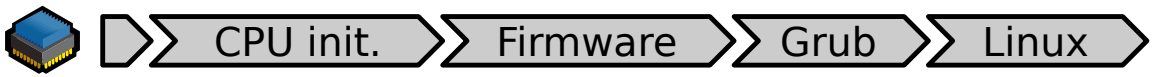


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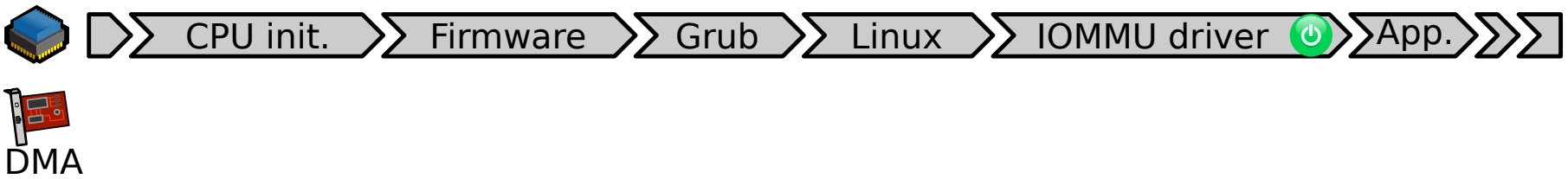

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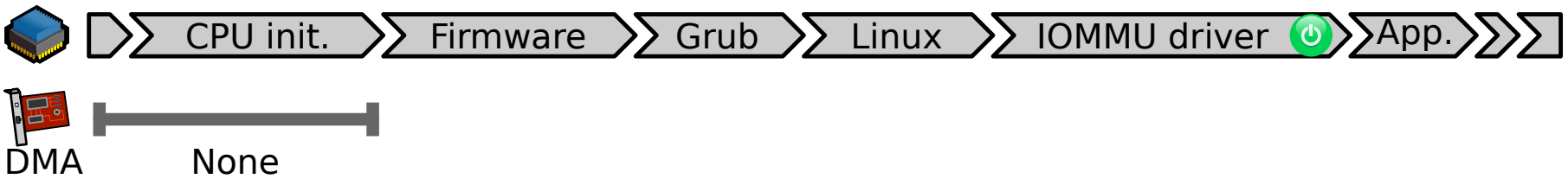

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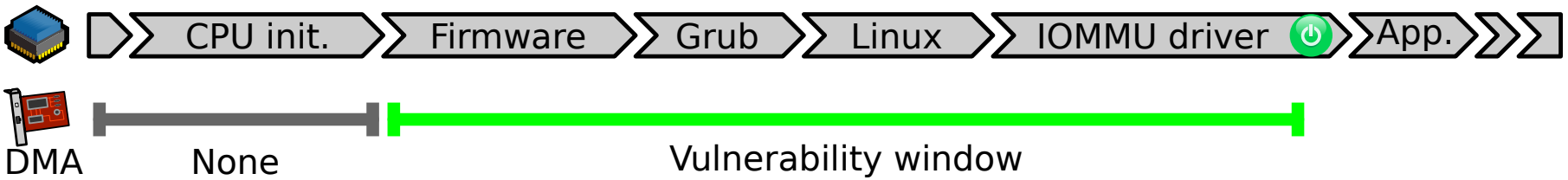

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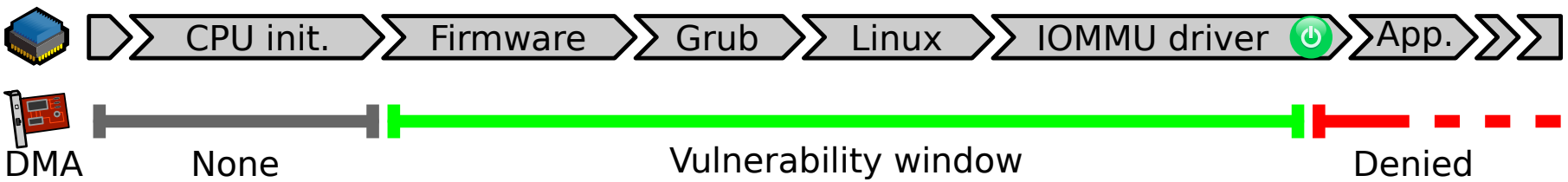
1. When is DMA available ? $\Rightarrow$ Vulnerability window

IOMMU vulnerability



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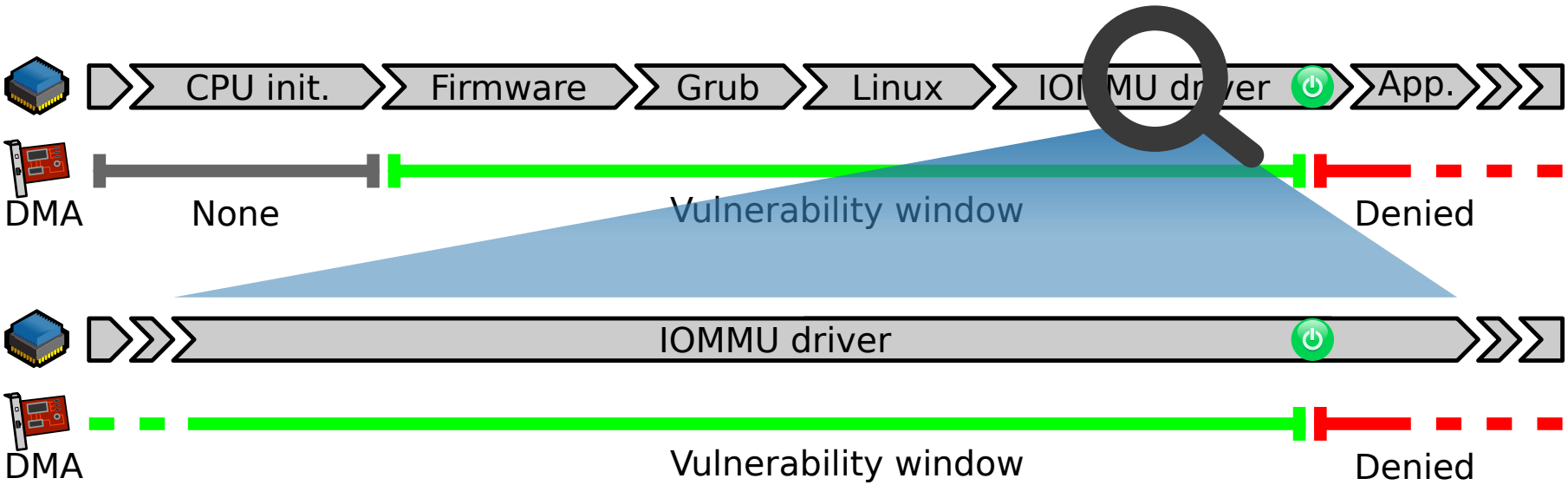
1. When is DMA available ? $\Rightarrow$ Vulnerability window
2. When is the configuration actually in memory ?

IOMMU vulnerability



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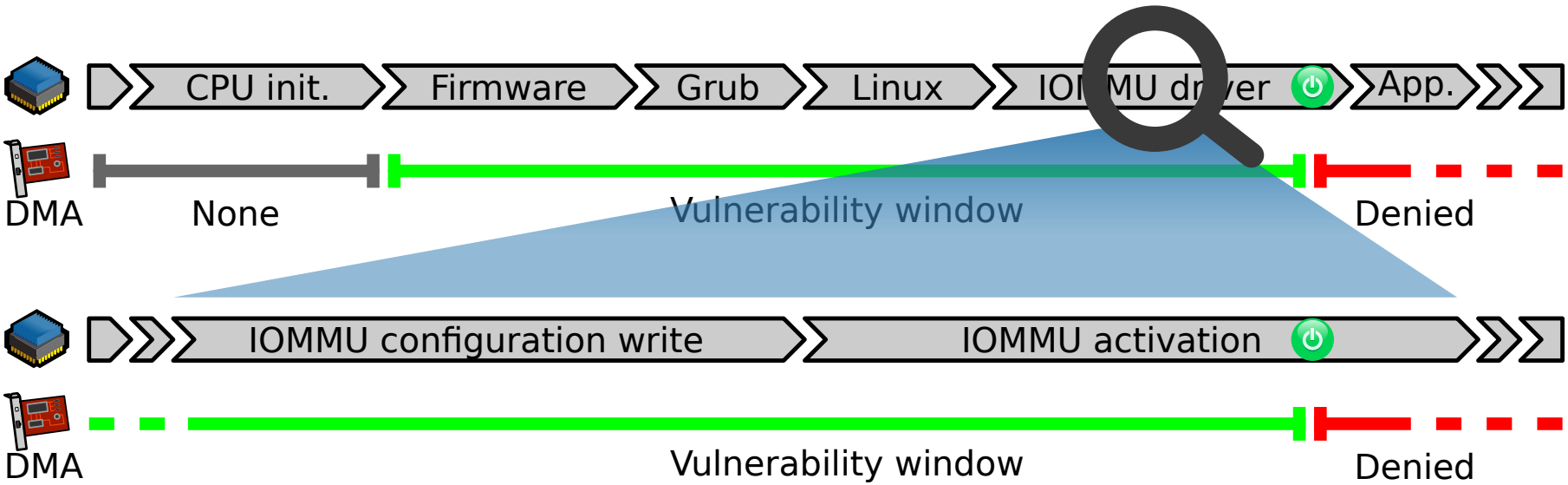

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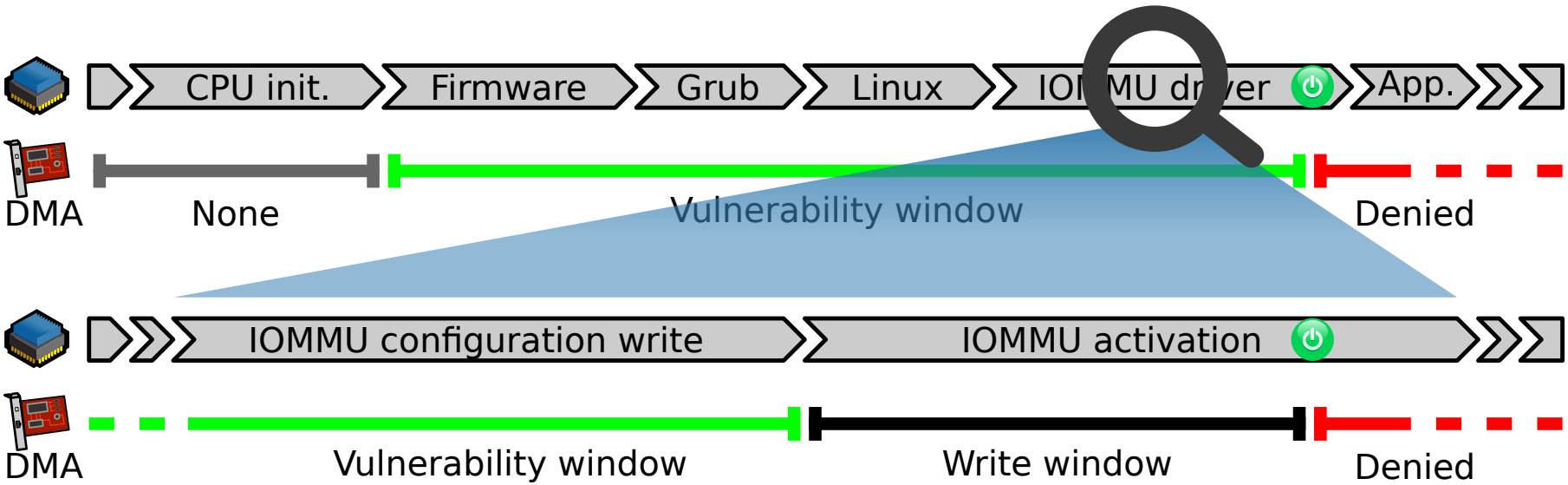
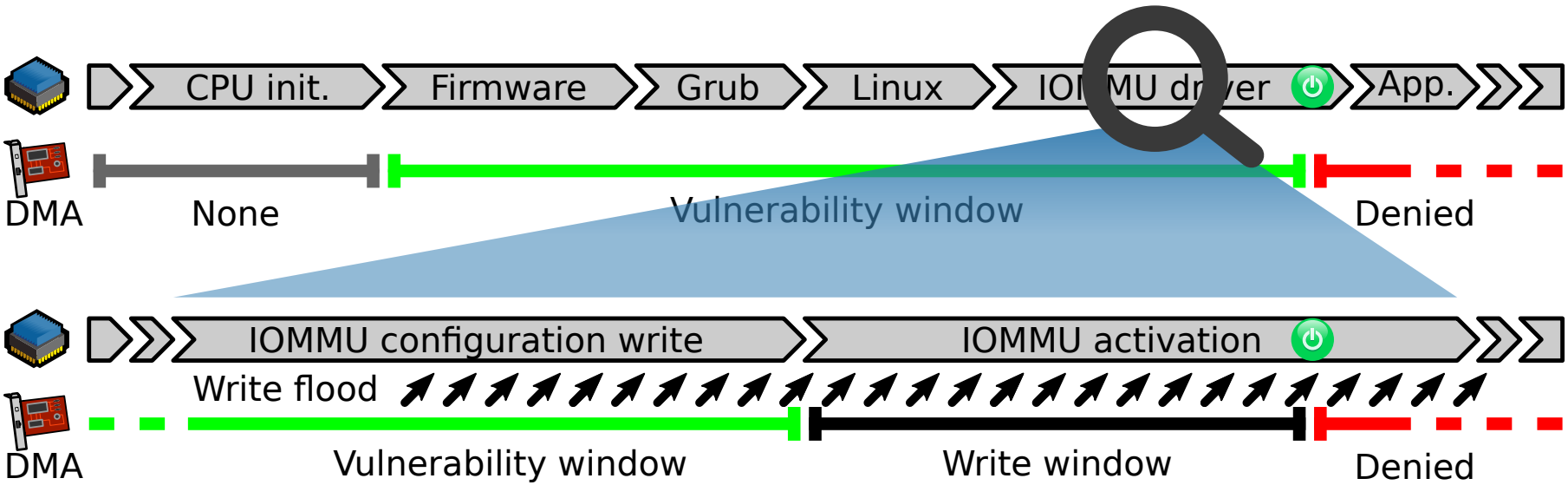


Our goal : Overwrite legitimate IOMMU configuration using DMA

1. When is DMA available ? ⇒ Vulnerability window
2. When is the configuration actually in memory ? ⇒ Write window
3. How to be sure not to miss the write window ?

IOMMU vulnerability



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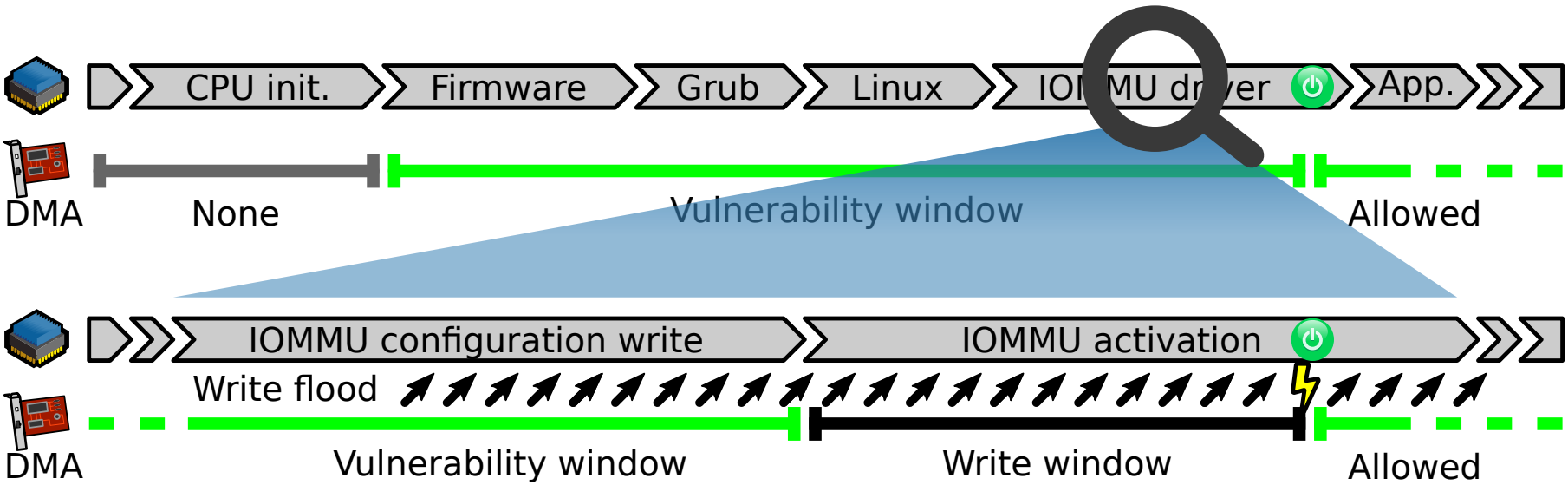

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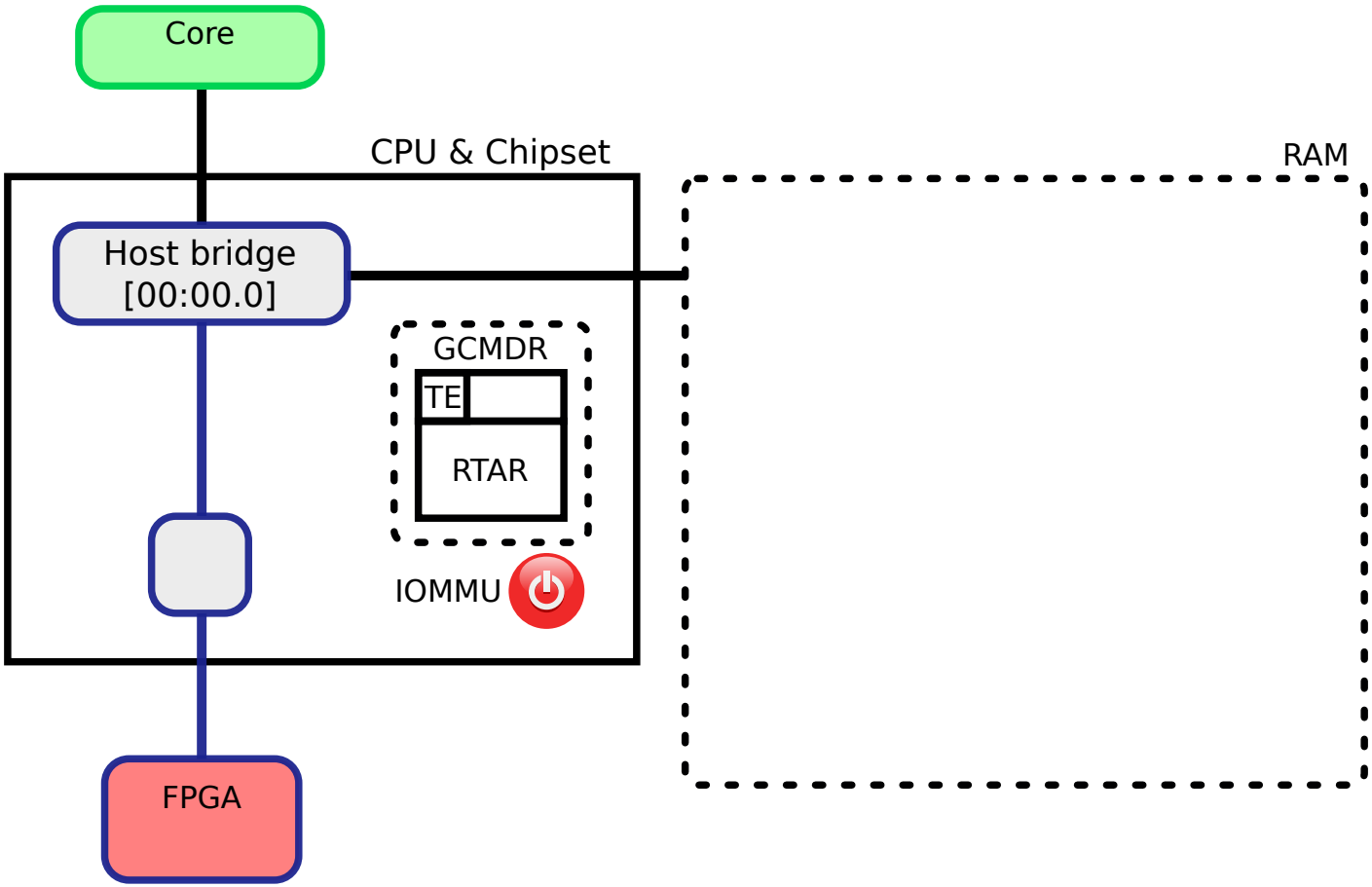
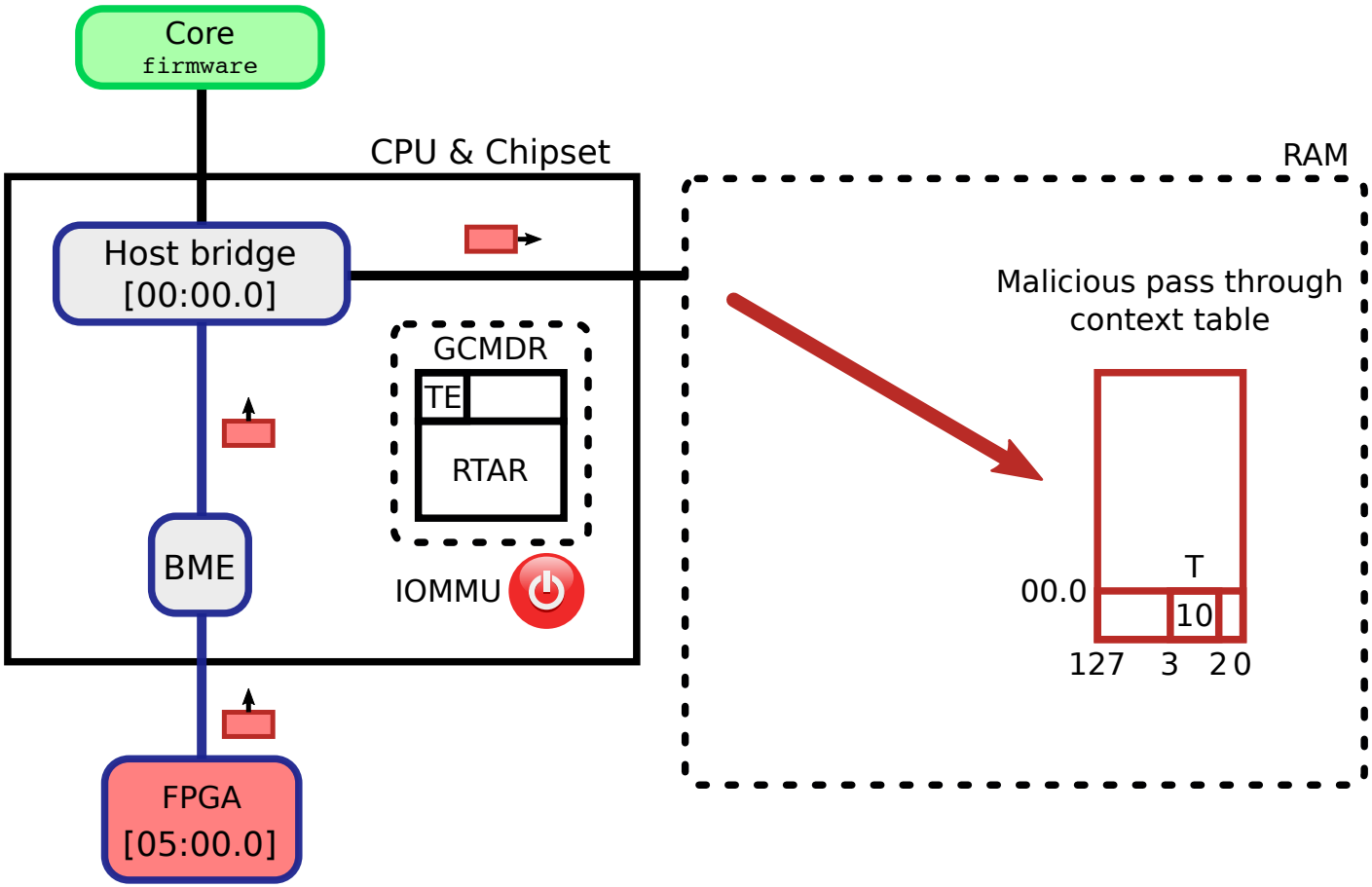
Linux driver attack



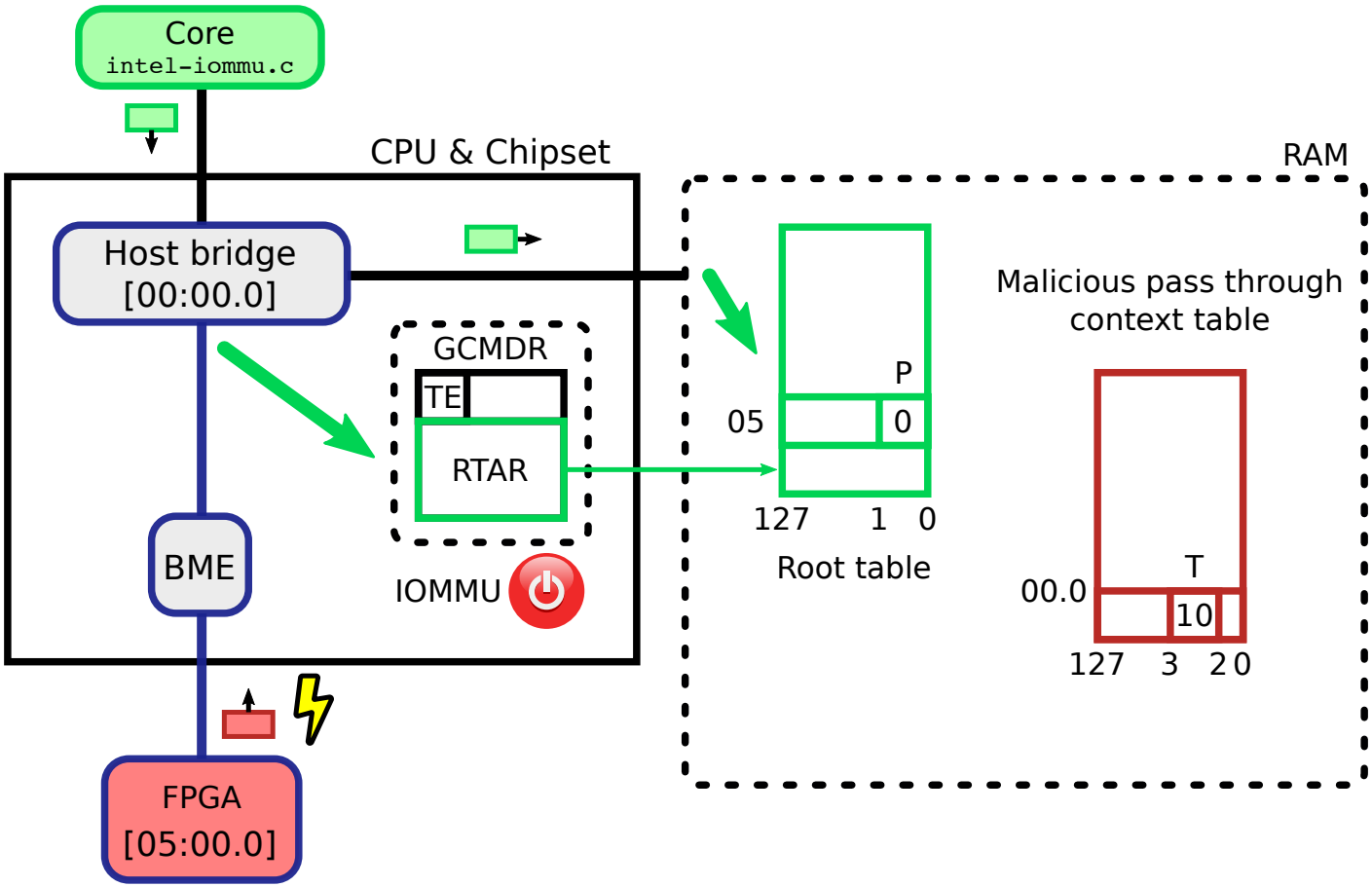
- Platform boot up

Linux driver attack



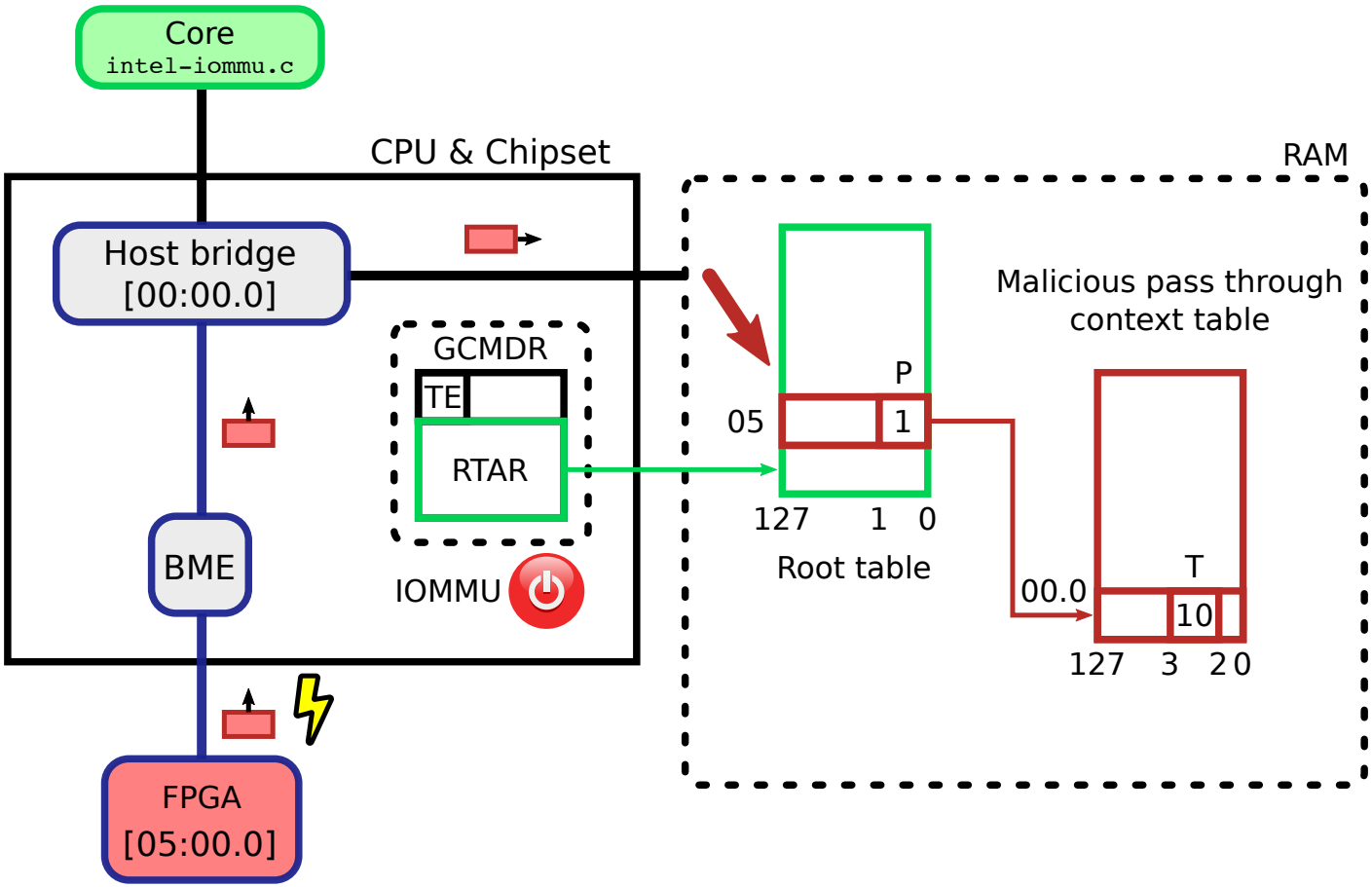
- Copy of a malicious context table in pass through mode

Linux driver attack



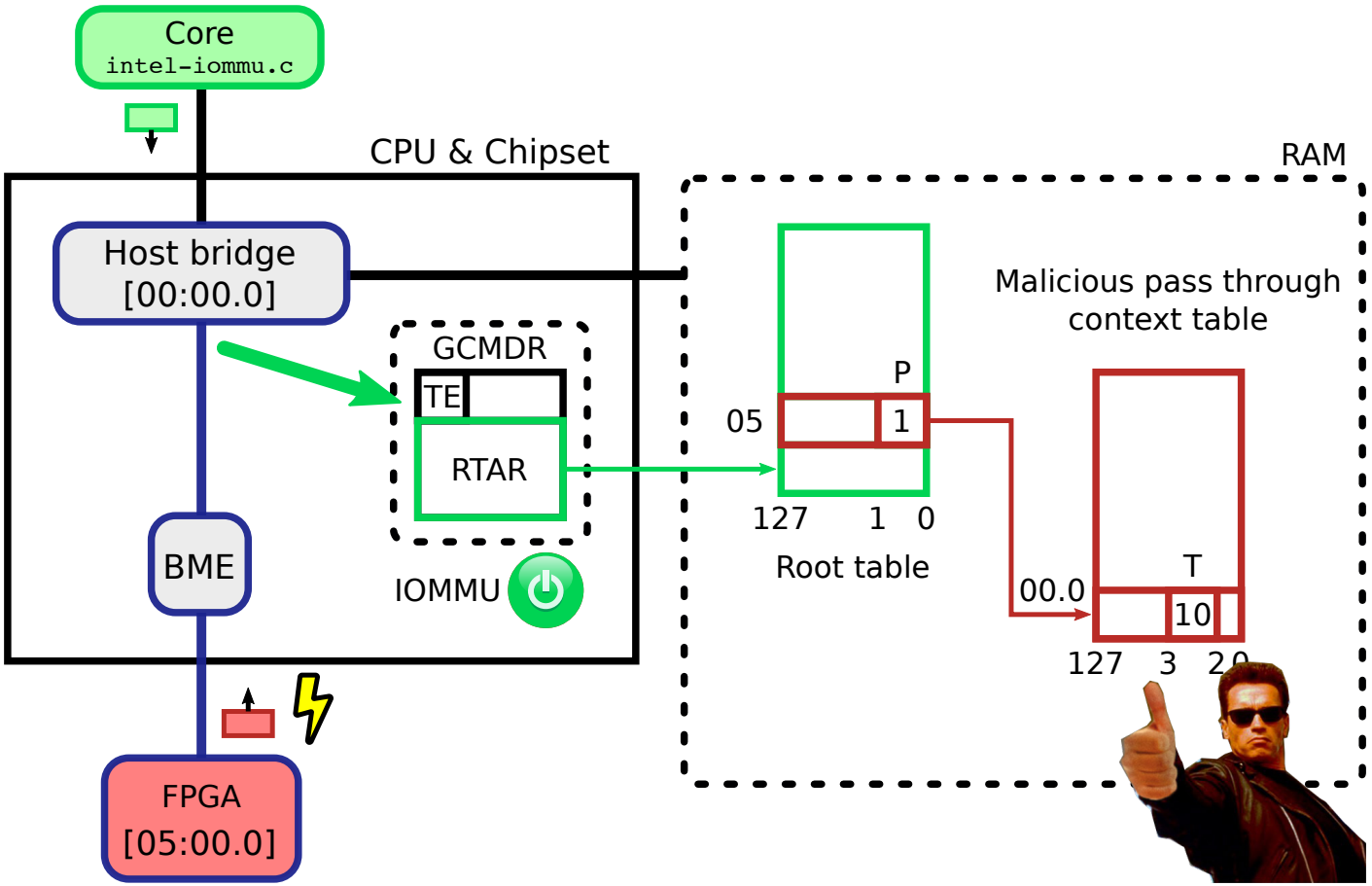
- Legitimate root table configuration by the driver

Linux driver attack



- Overwriting of the Malicious FPGA root entry

Linux driver attack

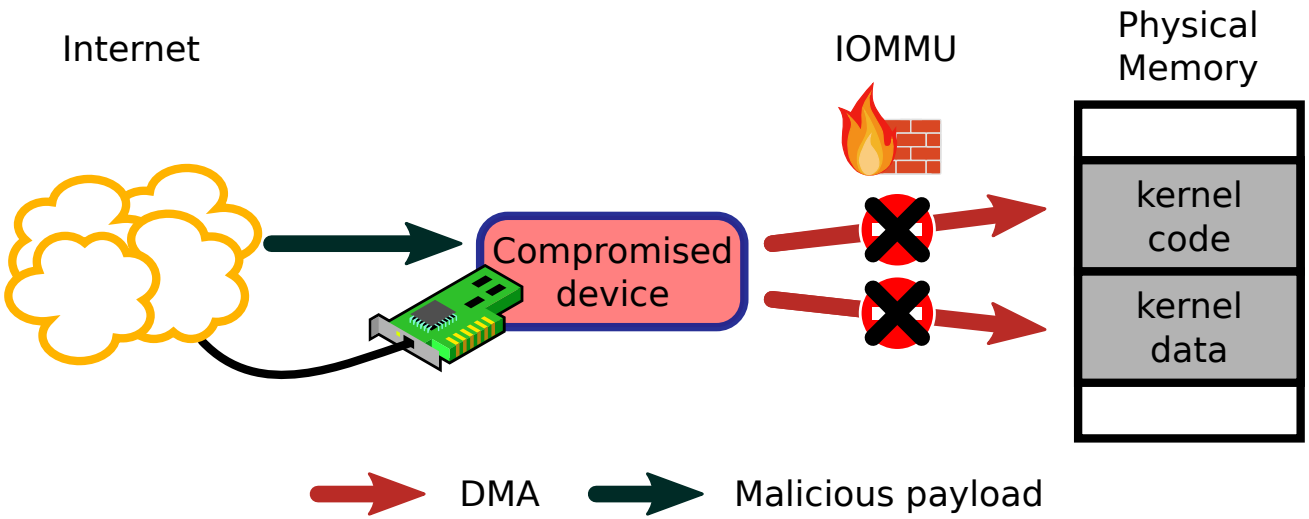


- Legitimate DMAR activation by the linux IOMMU driver

Attack : demonstration

- `http://homepages.laas.fr/nicomett/LADC2016/iommu-pwn-sstic.webm`

Consequences of the attack



⇒ DMA is still available for a remotely controlled compromised device, even with the IOMMU activated

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2 A vulnerability in the IOMMU configuration

3 Conclusion

Conclusion et countermeasures

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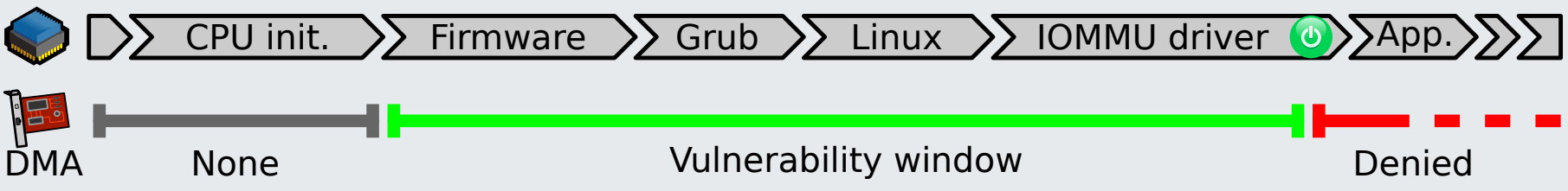

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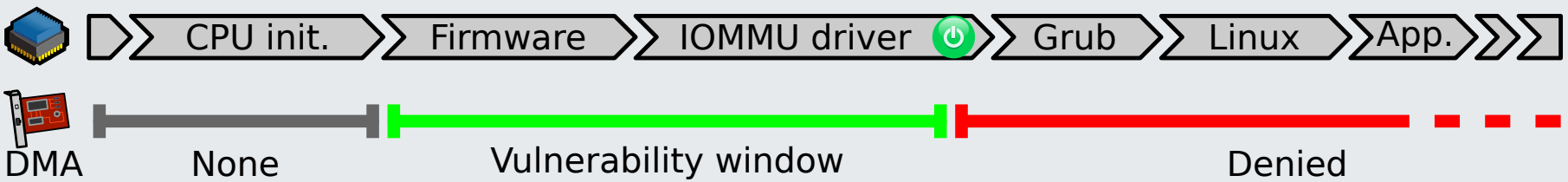

- Change the firmware / OS responsibilities in activating DMAR

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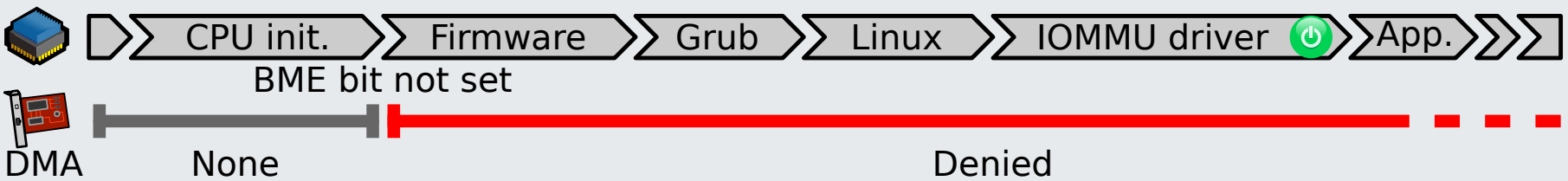
Countermeasures



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- Use PCI to PCI bridges access control (BME bit)

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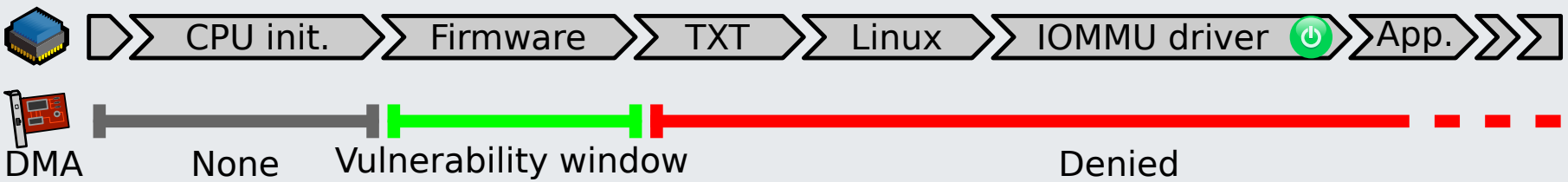

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- Use PCI to PCI bridges access control (BME bit)
- Secured boot with TXT ?

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Références

[1] Duflot, L., Perez, Y. A., Valadon, G., & Levillain, O. (2010). Can you still trust your network card. CanSecWest/core10, 24-26.