IOSEC: Protection and Memory Safety for Input/Output Security

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Protection and Memory Safety for Input/Output Security

Thunderbolt 2

Thunderbolt 3 over USB-C

- Modern systems are composed of all kinds of processors; some of them aren't trustworthy
- A notable case is input/output (I/O) – for example USB, smart network cards, GPUs
- Even worse, the rise of pluggable Thunderbolt and USB-C
  - is my charger trustworthy?
- Can we be secure in the face of adversarial devices?

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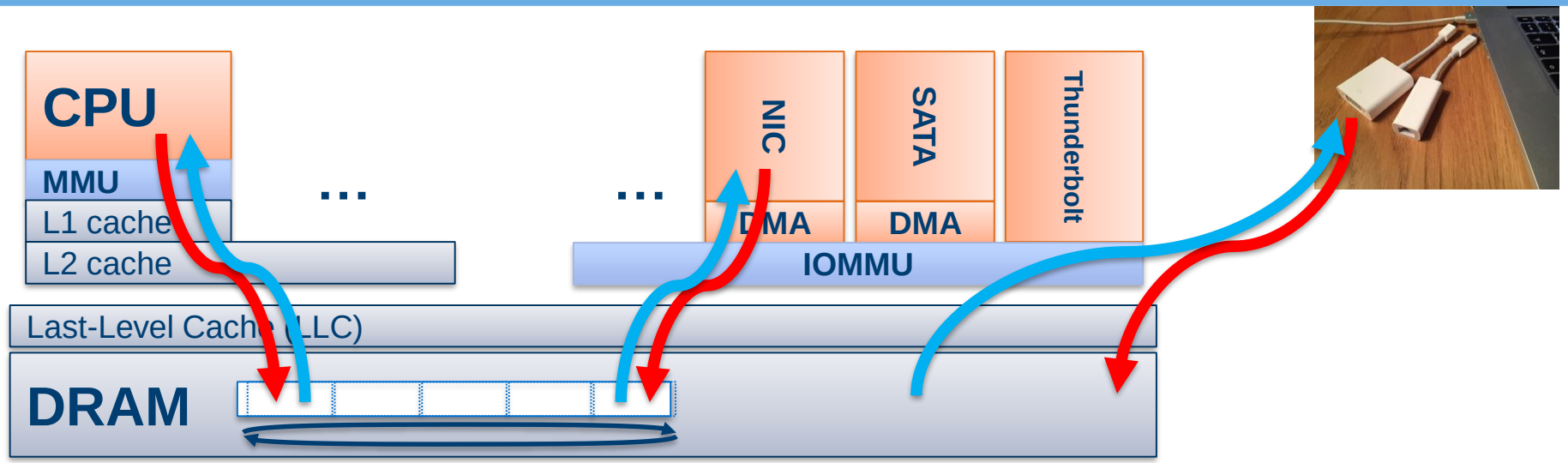
Current architectures

- Message-passing I/O
  - packet-based interconnect
  - copying of packets to and from memory
  - often packets interpreted by software
  - packetisation can be a bottleneck
  - e.g. USB, SATA, SAS
- Shared-memory I/O
  - I/O devices have rights to read and write system memory (DMA)
  - communicate with CPU by passing pointers to memory blocks
  - more efficient
  - e.g. NVMe, GPUs, PCIe network cards
  - safe?

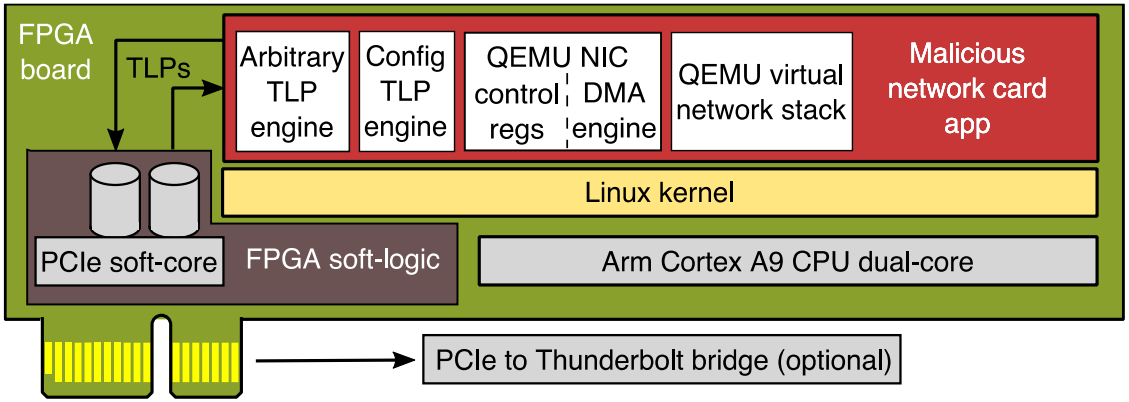
Shared-memory I/O architectures



- Are we doing the right things architecturally?
- State of the art: Input/Output Memory Management Unit (IOMMU)
- How is it used in modern systems?

Thunderclap: an I/O research platform

- Talking to industry, they lament the lack of tools for evaluating I/O protections - so we built some
- Thunderclap - FPGA-based research platform
  - able to run a complex software model of a PCIe network card, interact with the OS and driver stack
  - see what data is exposed to a malicious device
  - explore vulnerability space



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IOMMU use and misuse

- The IOMMU is supposed to defend against malicious DMA from peripherals – but does it?
- The IOMMU has fundamental limitations, and many operating systems only use it to a limited extent
- The IOMMU interface has a lot of similarities with the kernel system-call interface in operating systems, but had little attention
- We discovered multiple new vulnerabilities in Windows, MacOS, FreeBSD and Linux
- Substantial work with vendors regarding mitigations
- Patches now shipped, including major changes in Windows 10 release 1803

Coming soon...

- *“Thunderclap: Exploring Vulnerabilities in Operating-System IOMMU Protection with DMA from Untrustworthy Peripherals”*
  Markettos, Moore, Watson, et. al

  to appear in
  Network and Distributed Systems Security Symposium, February 2019

The future

- Things were bad, how can we make them better?
- Is there a better way to implement an IOMMU to avoid such vulnerabilities?
- Or is there another way to structure I/O?
  - more message-passing I/O?
  - how to share compute safely?
- Can we achieve security *and* performance?
- Lots of hard questions...