Imperial College London

LSDS
Large-Scale Data & Systems Group

Slashing the Disaggregation Tax in Heterogeneous Data Centers with FractOS

Joint work with:

TECHNION Israel Institute of Technology

barkhausen institut

TECHNISCHE UNIVERSITÄT DRESDEN

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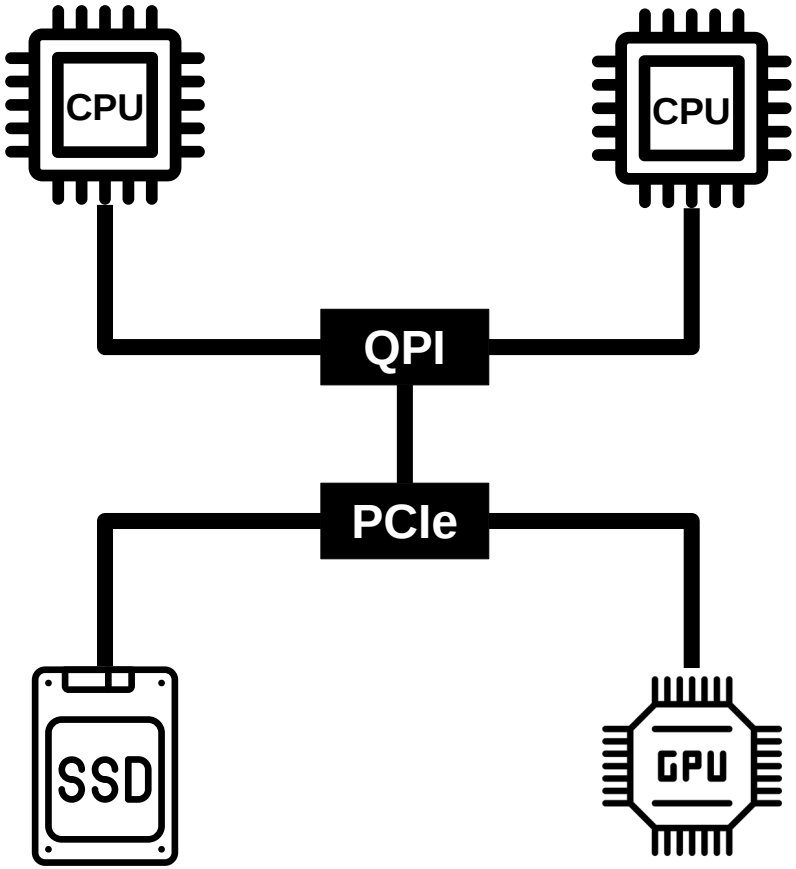
https://lsds.doc.ic.ac.uk/projects/fractos
<vilanova@imperial.ac.uk>

From PCIe to Disaggregation

PCIe

- ↓ Scale
- ↑ Performance (128GB/sec, 1µsec)
  (PCIe v6)
- ↓ Congestion and variability



From PCIe to Disaggregation

PCIe

- ↓ Scale
- ↑ Performance (128GB/sec, 1µsec)
  (PCIe v6)
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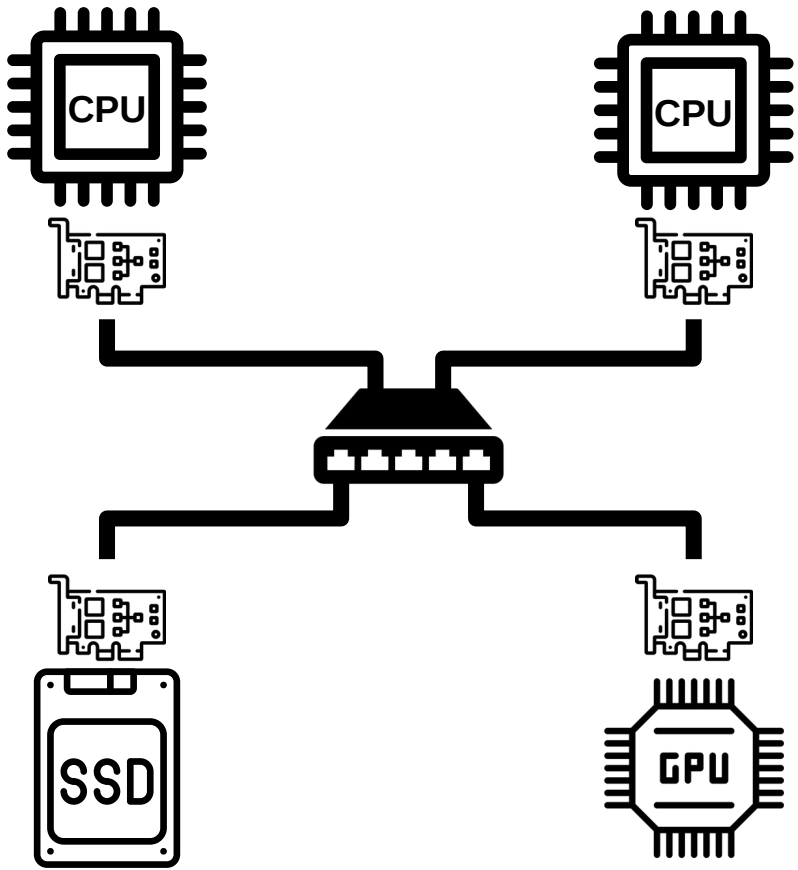
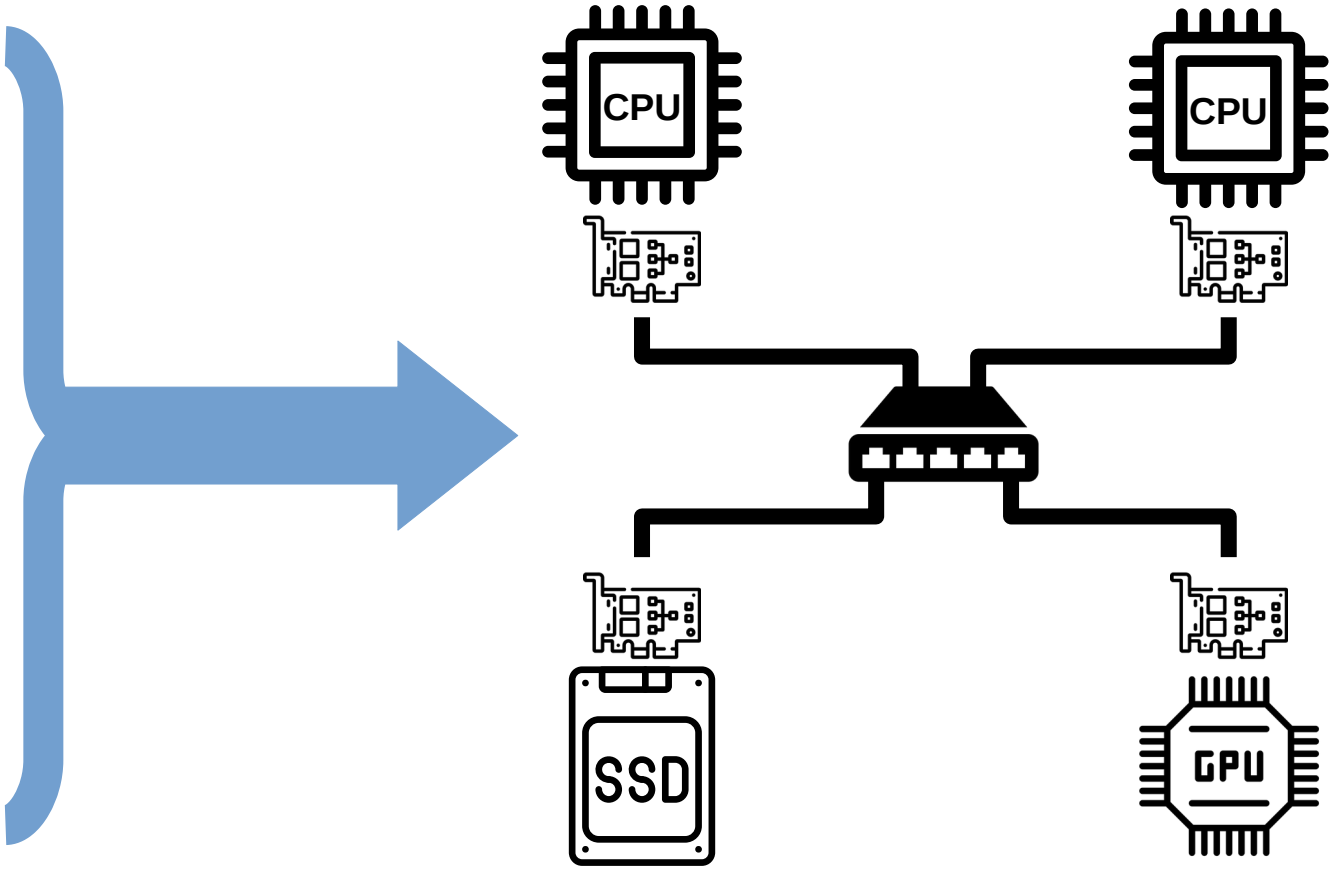
Disaggregation

- ↓ Data center cost
- ↑ Scale
- ↓ Performance (50GB/sec, 24µsec)
  (400 GbE + RoCE RDMA)
- ↑ Congestion and variability



Disaggregation brings new trade-offs

Application Example



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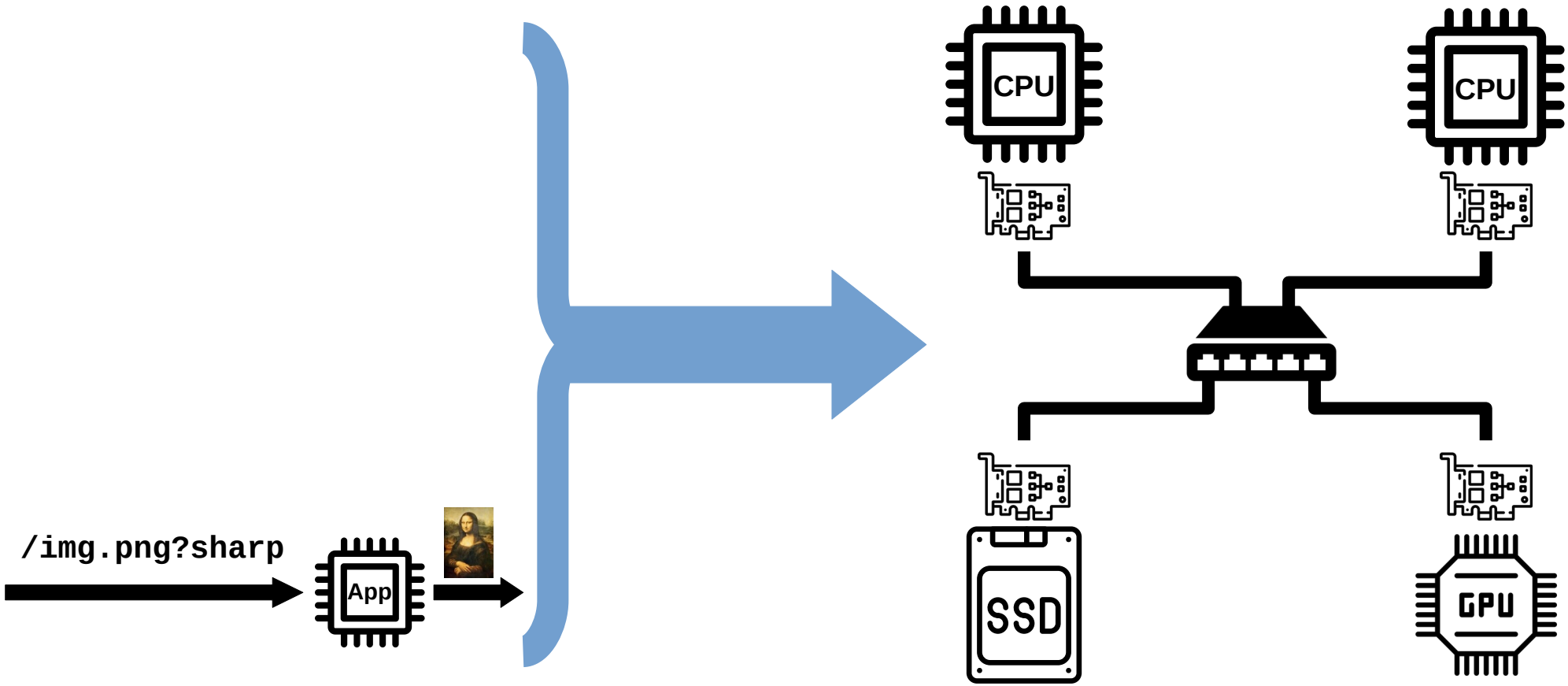

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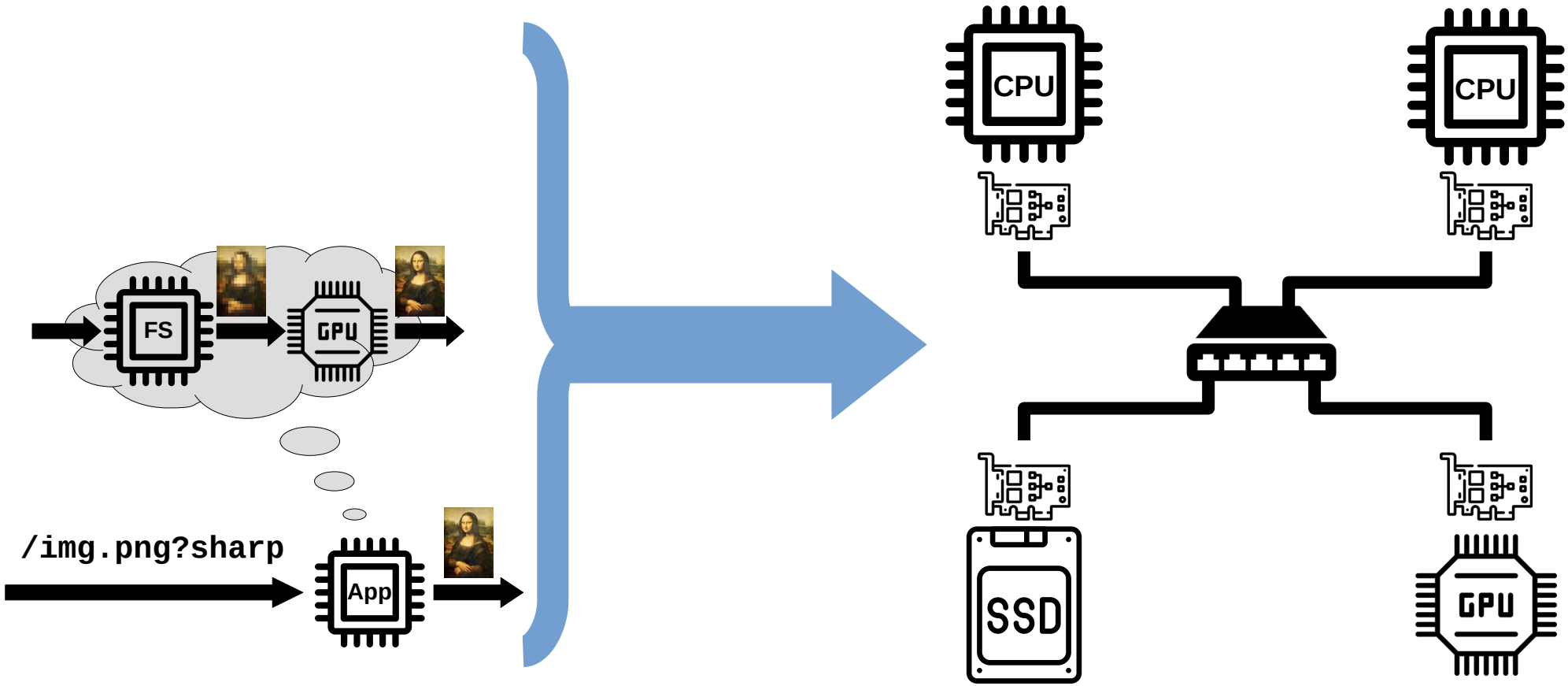

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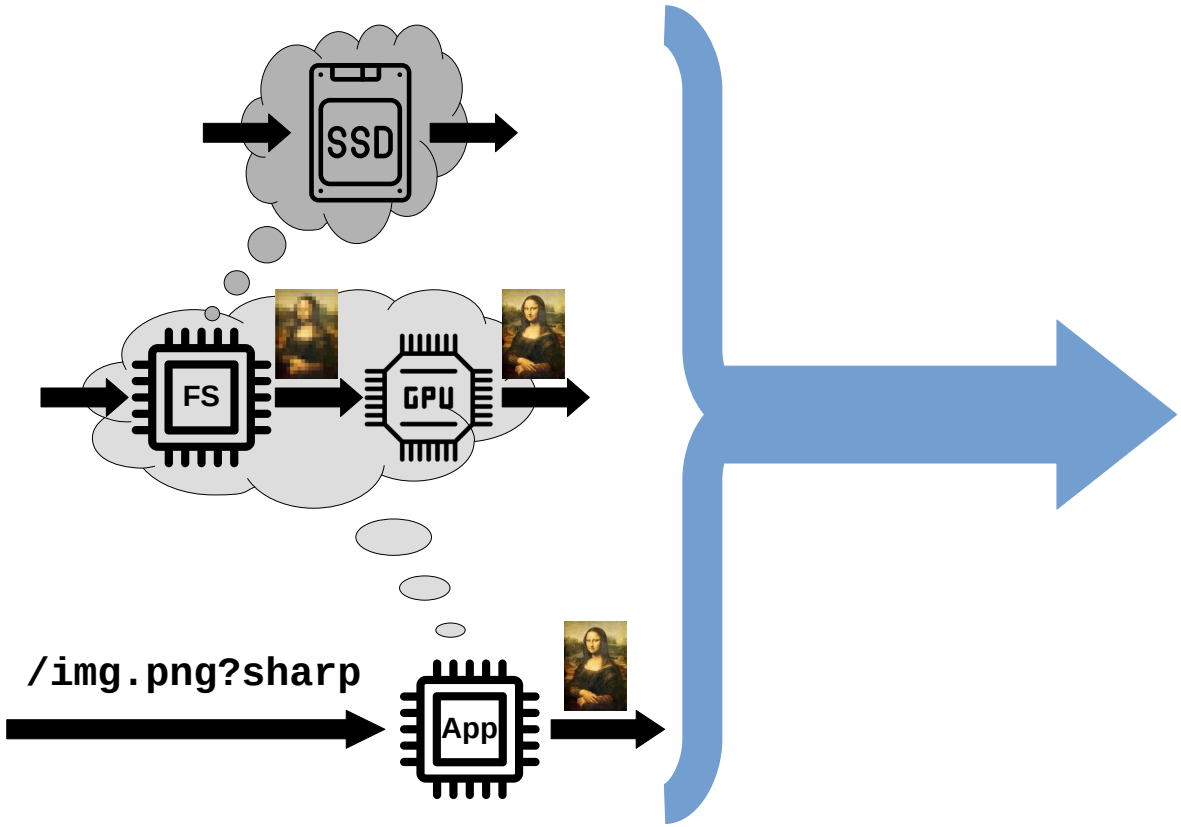

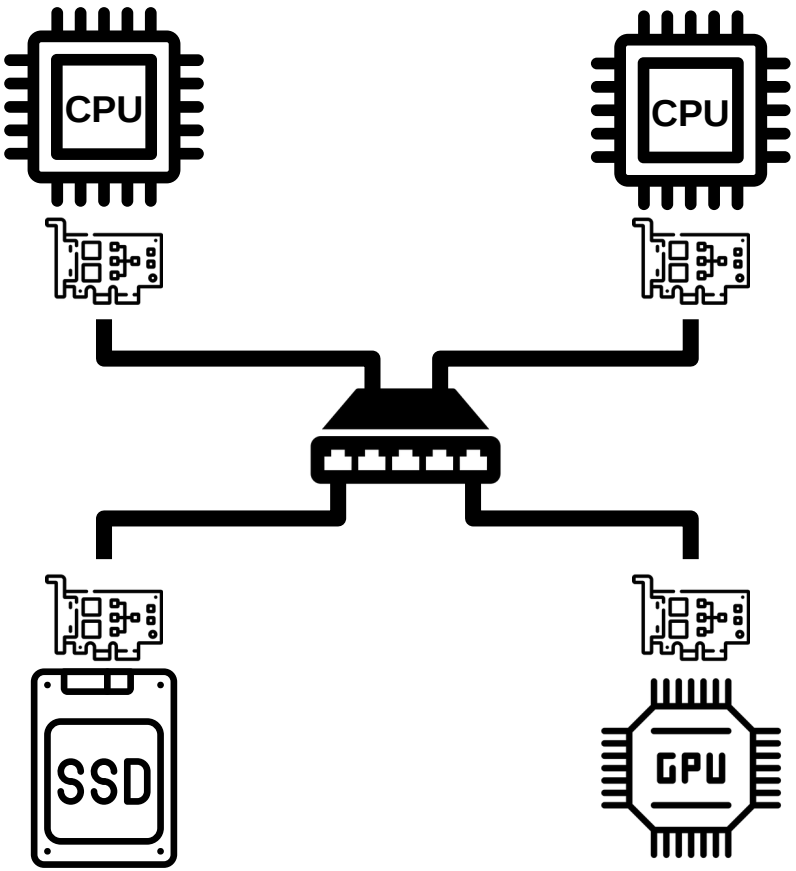

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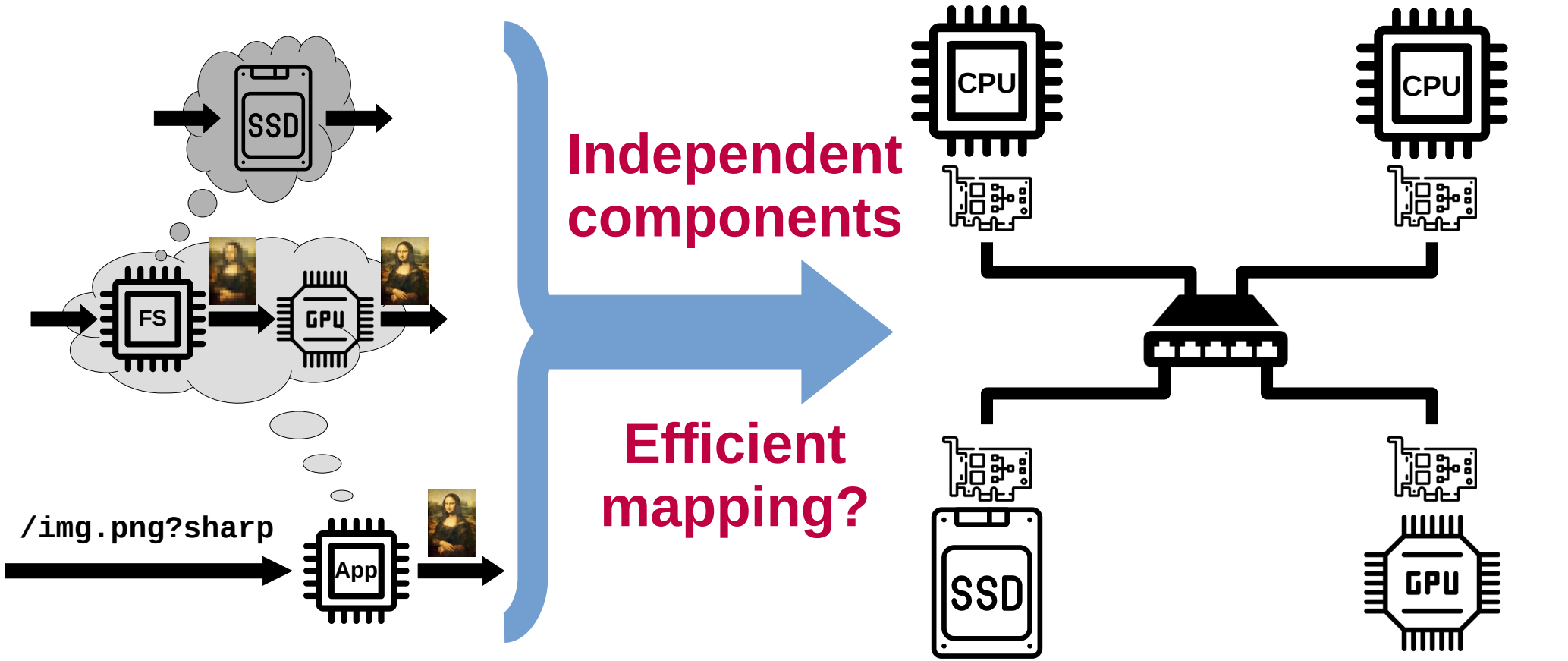
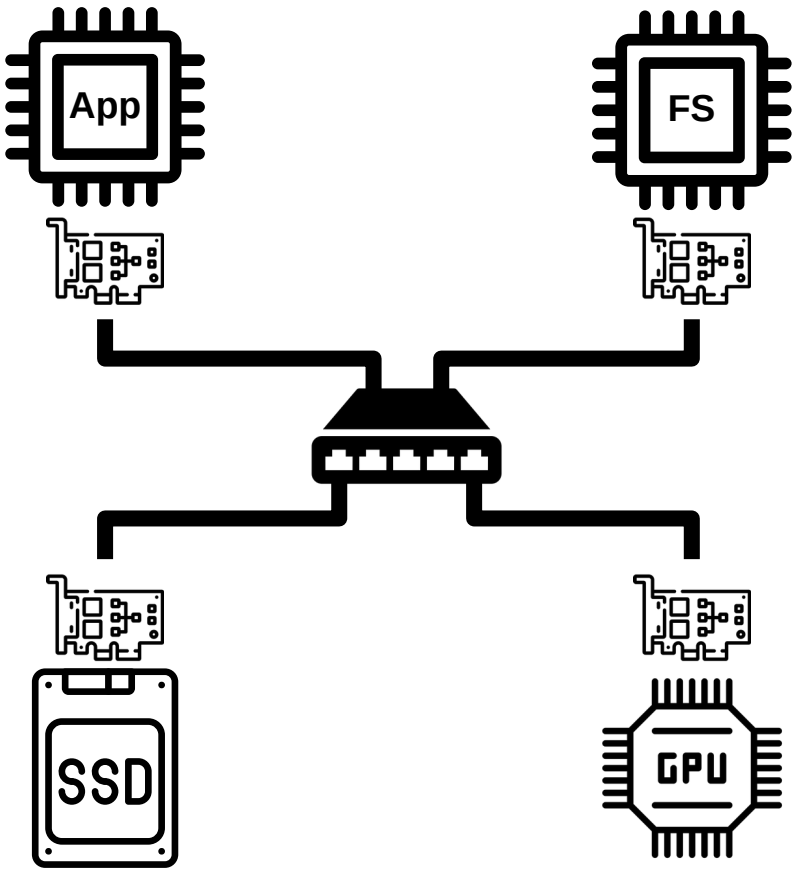
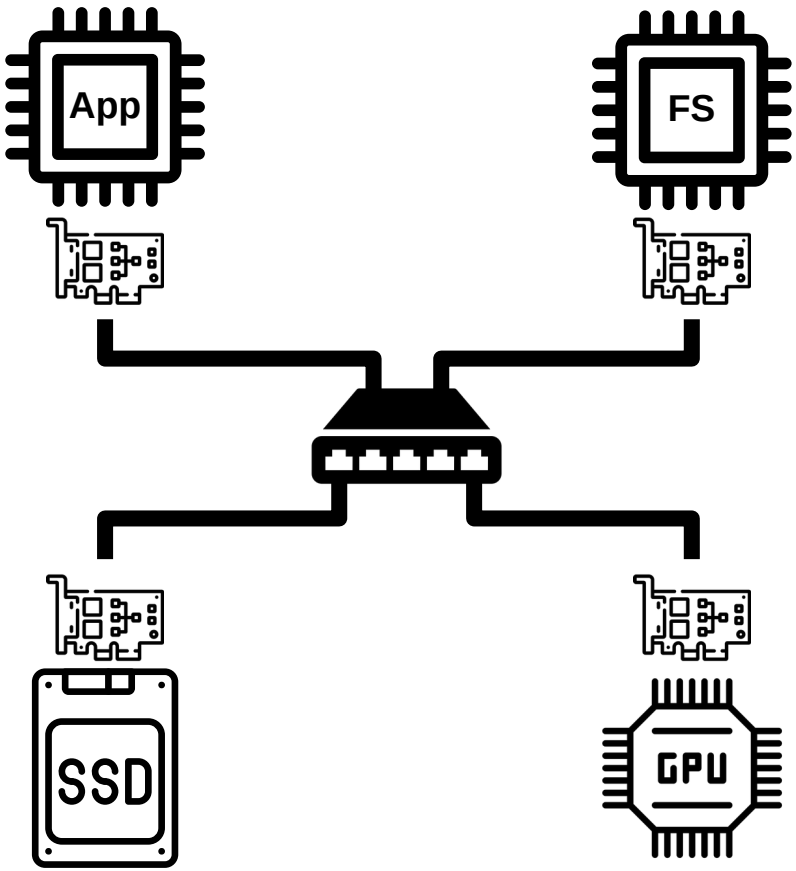


The Disaggregation Tax



The Disaggregation Tax

- Centralized application
  - Redundant transfers vs. shared network



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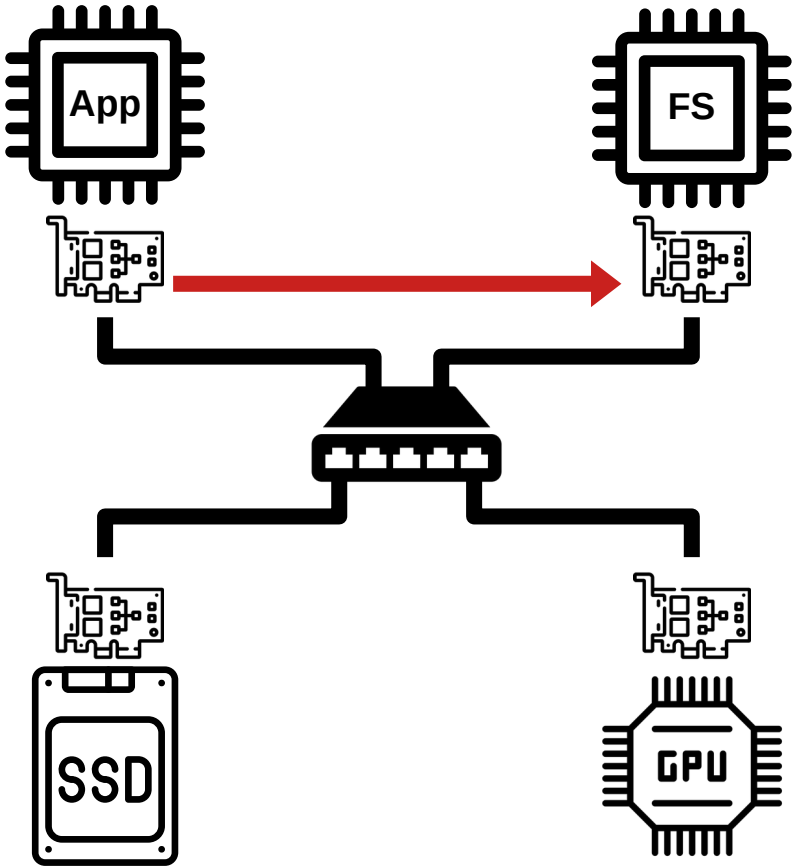

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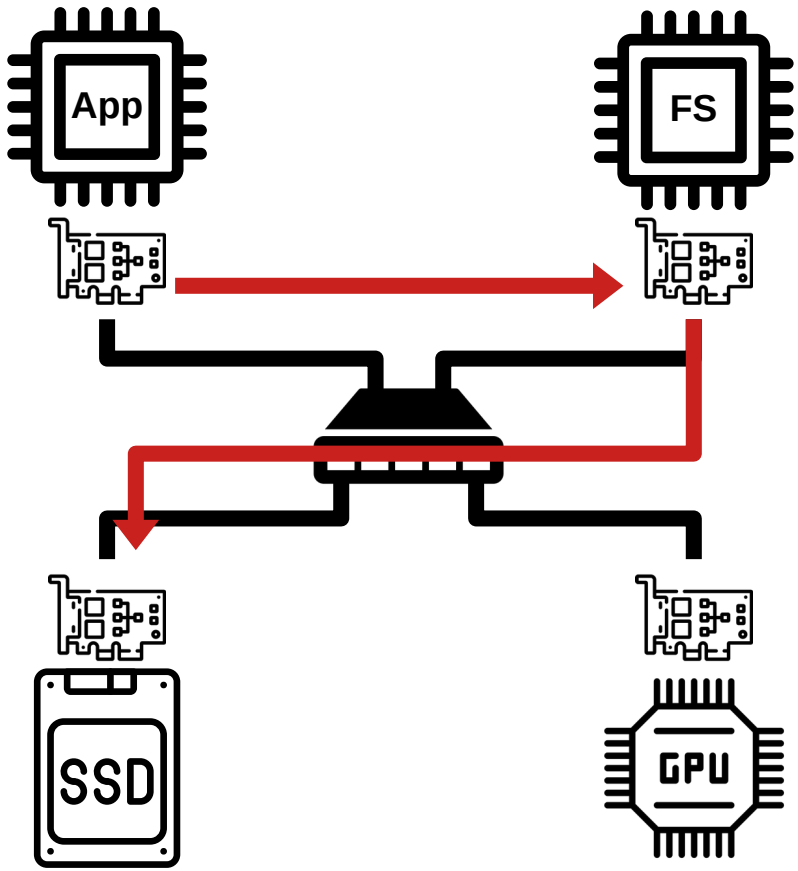

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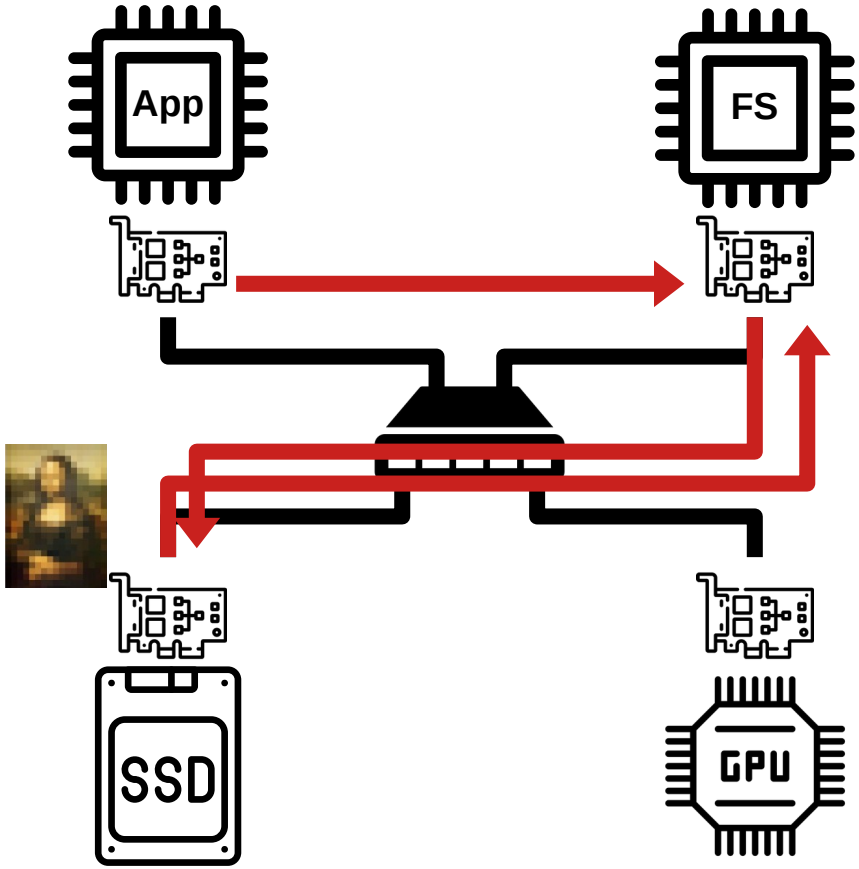

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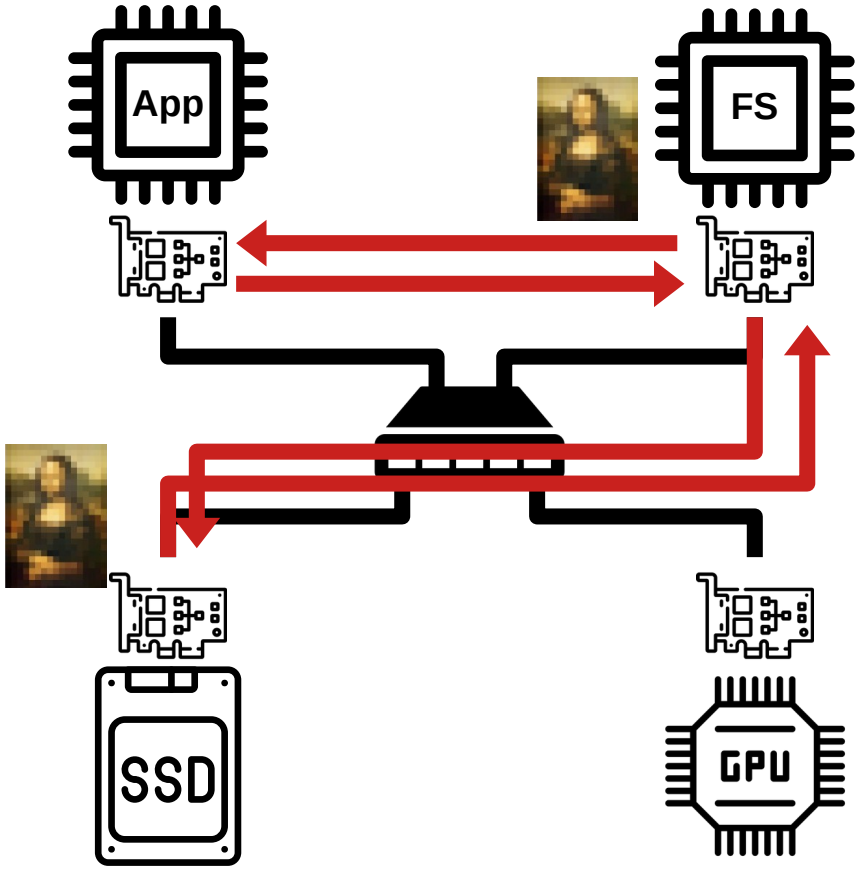

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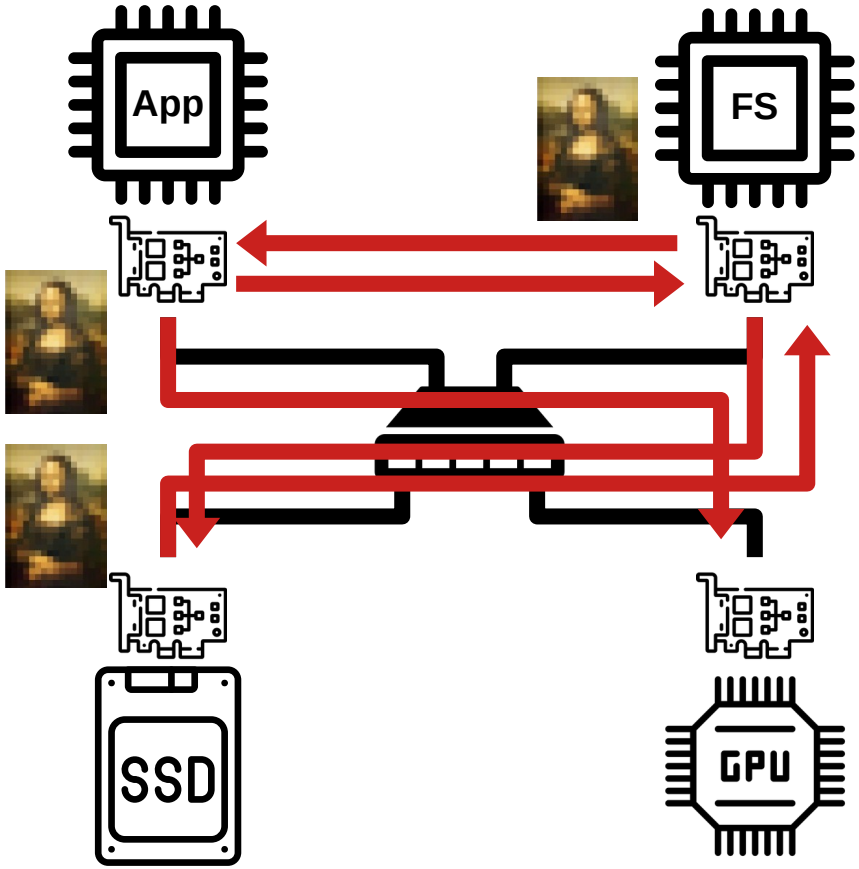

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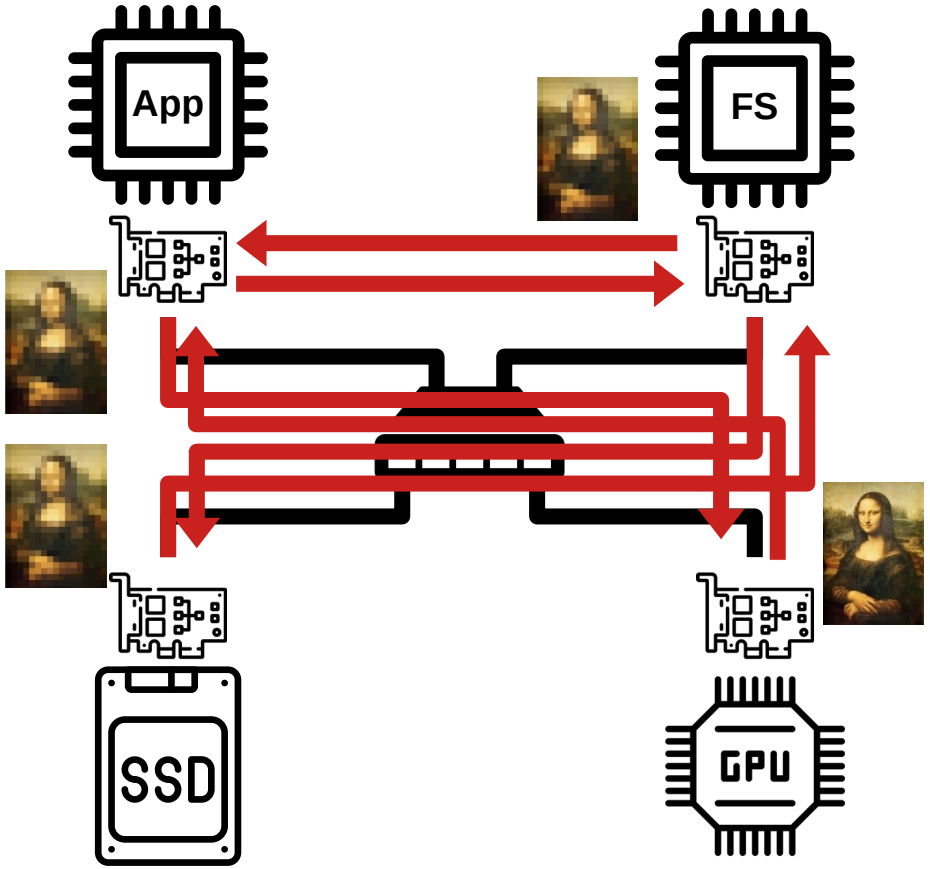

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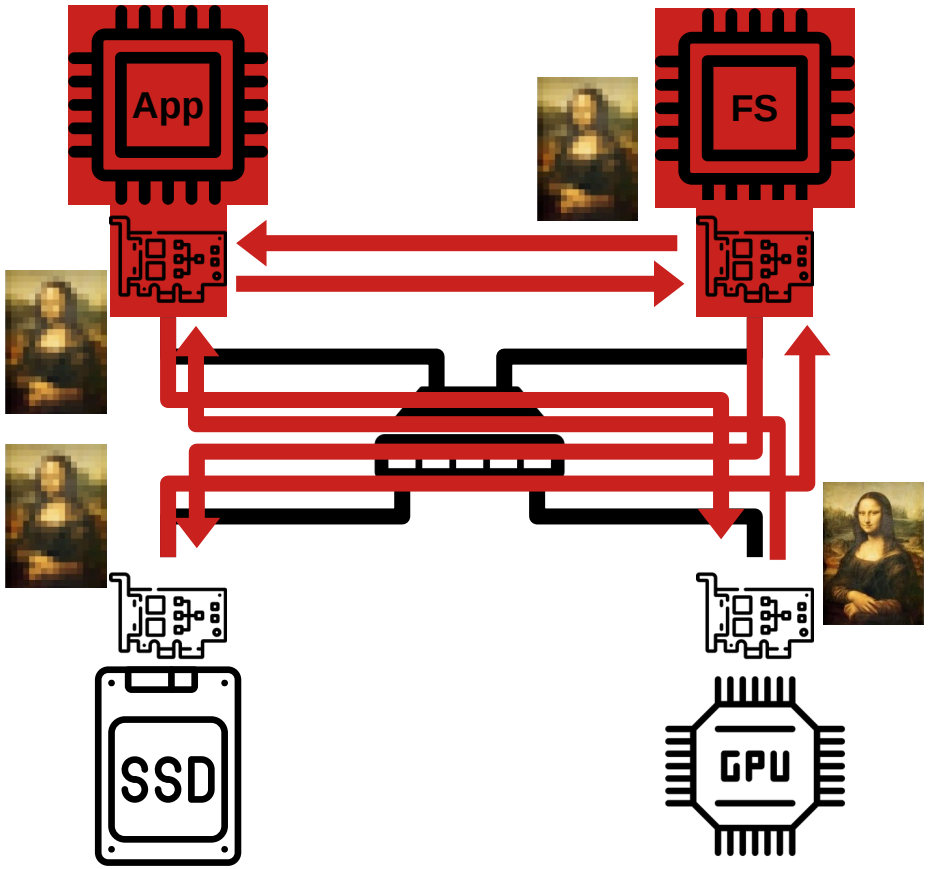

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- Centralized application
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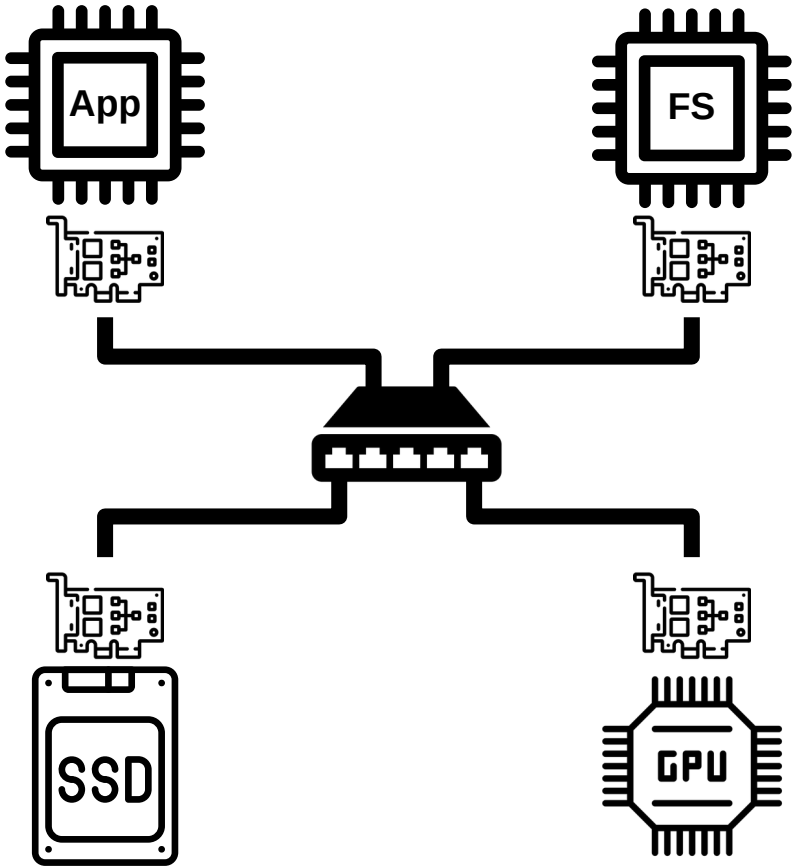

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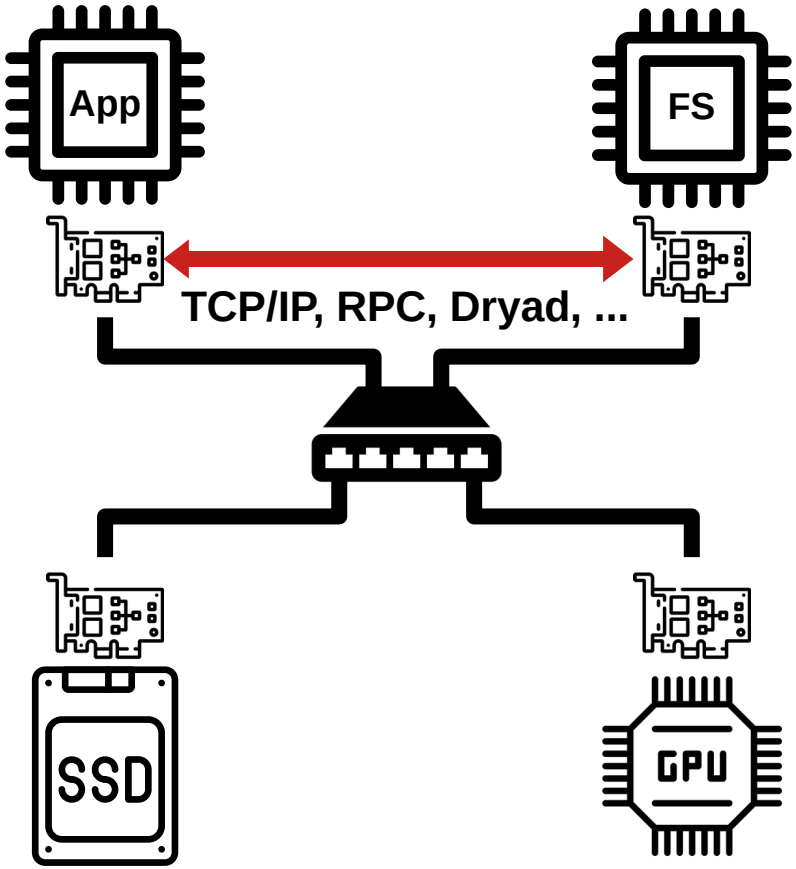

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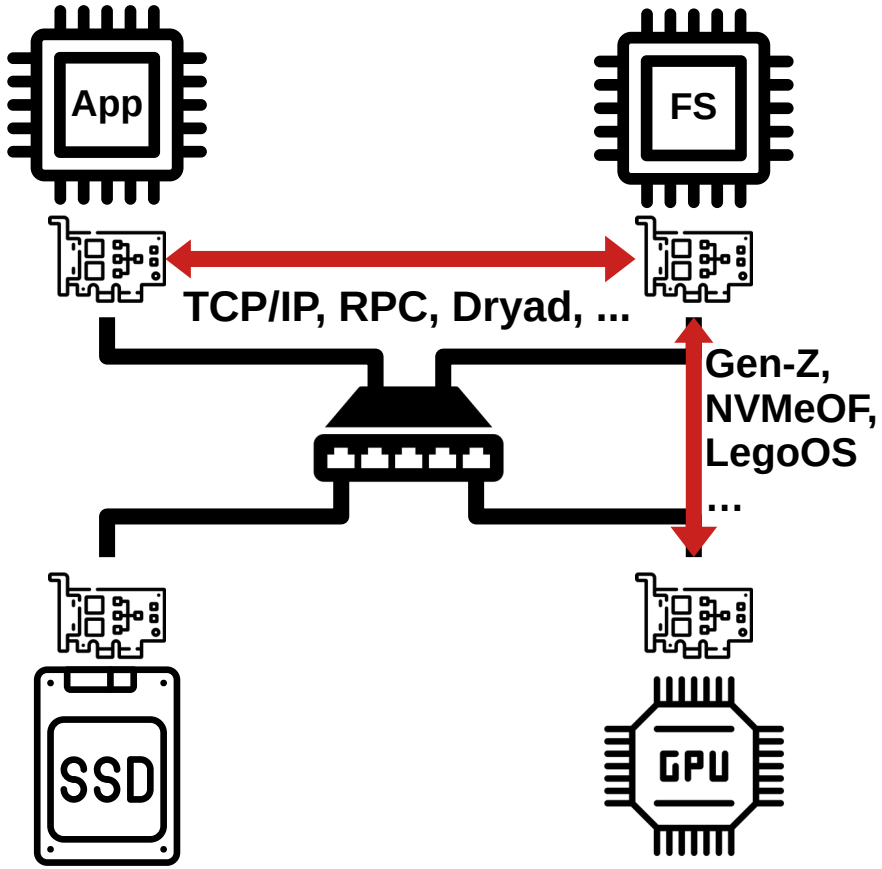

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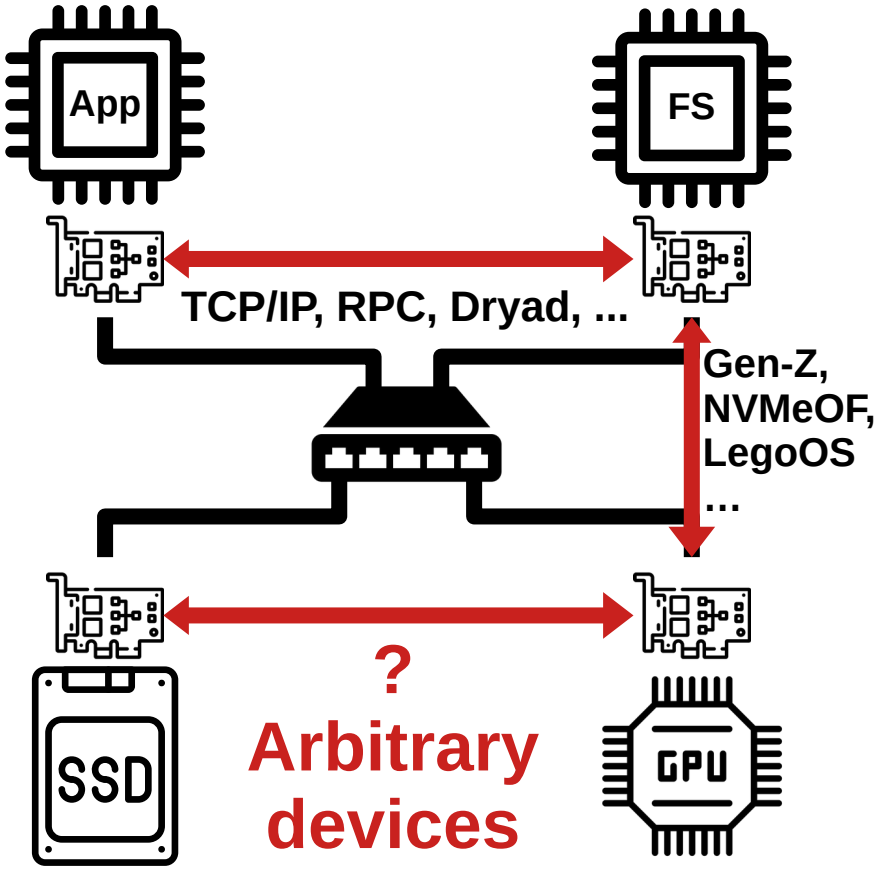

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- Naive app. distribution
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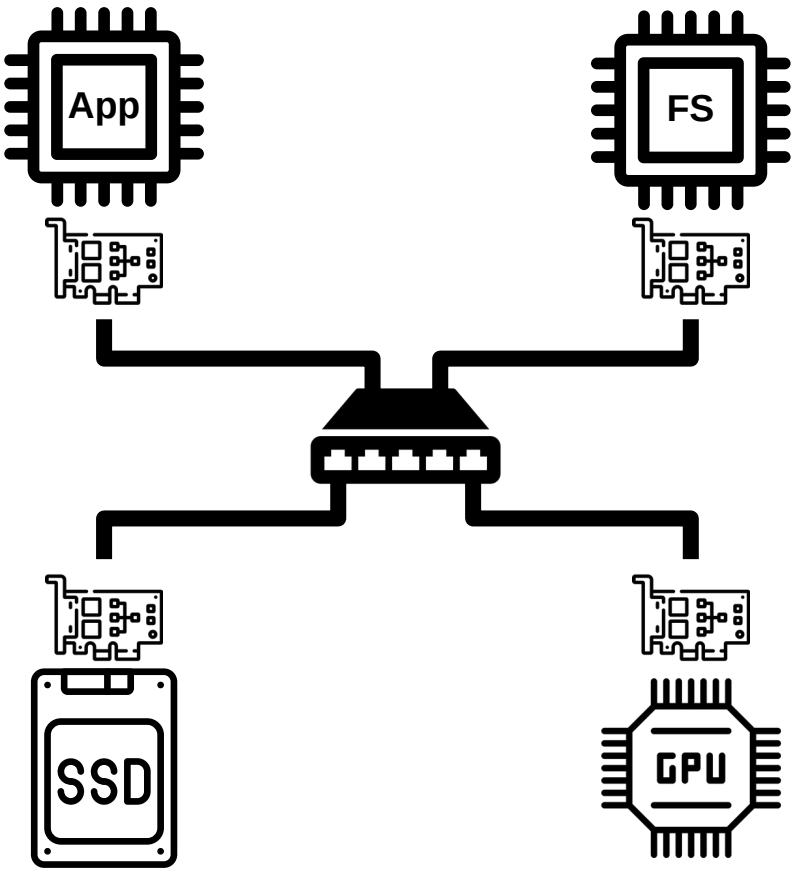

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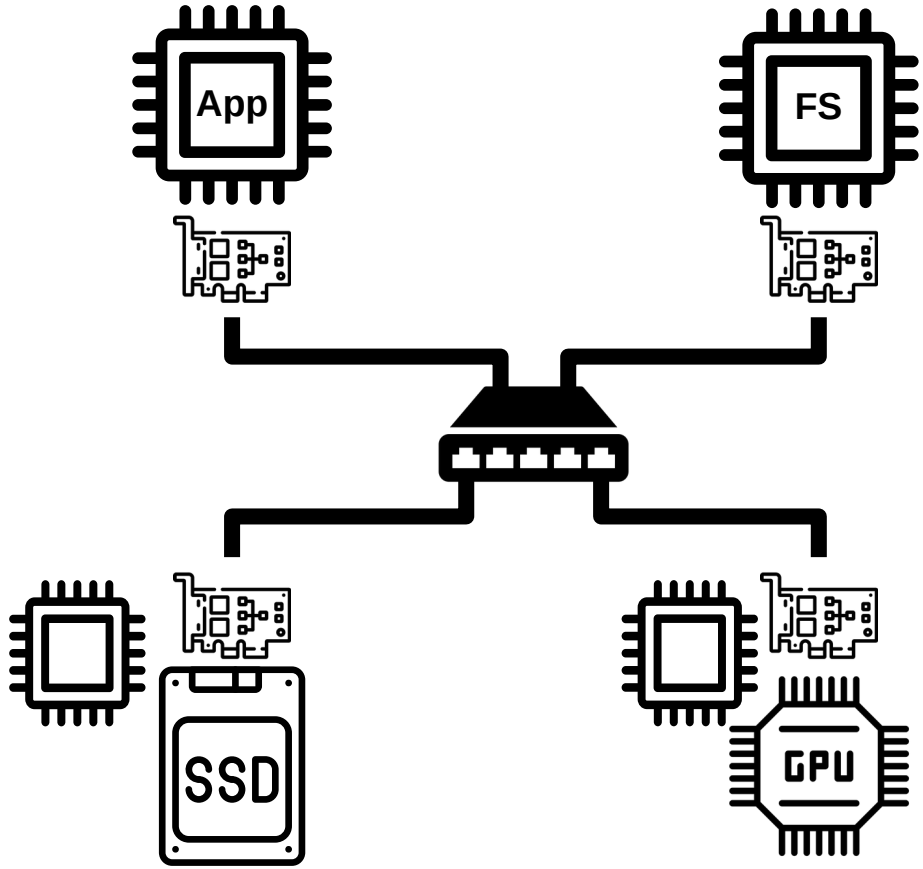

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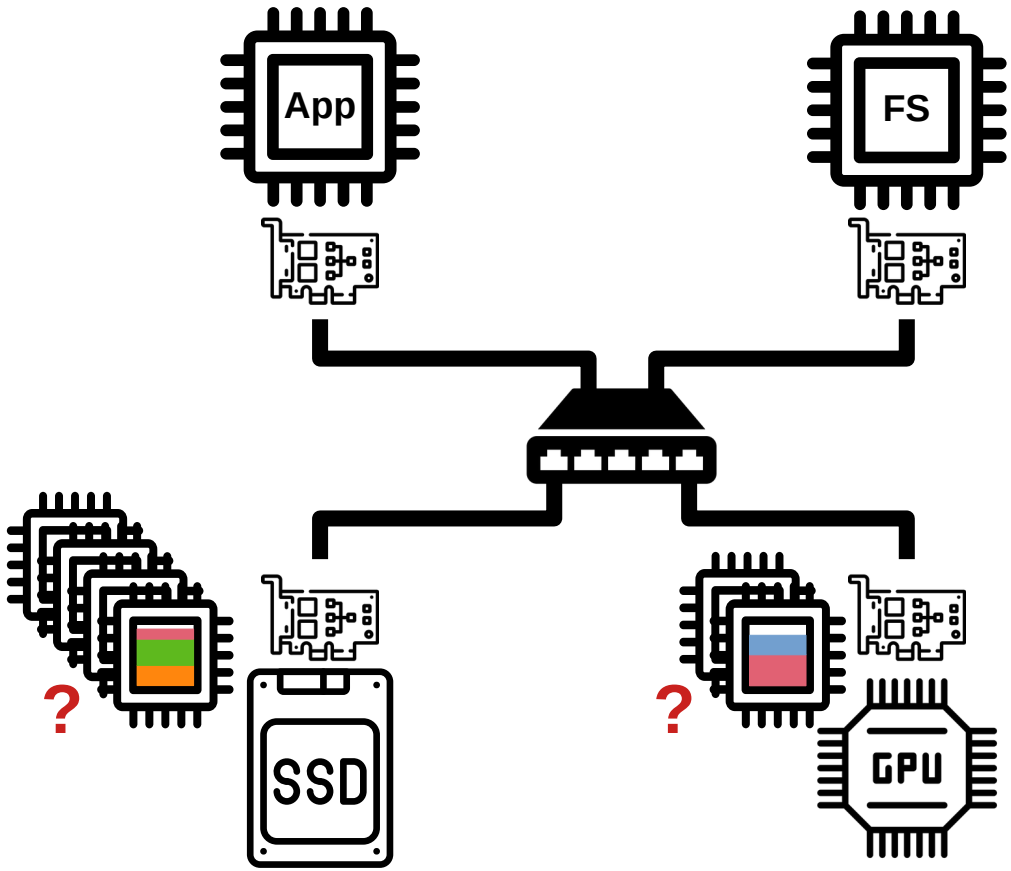
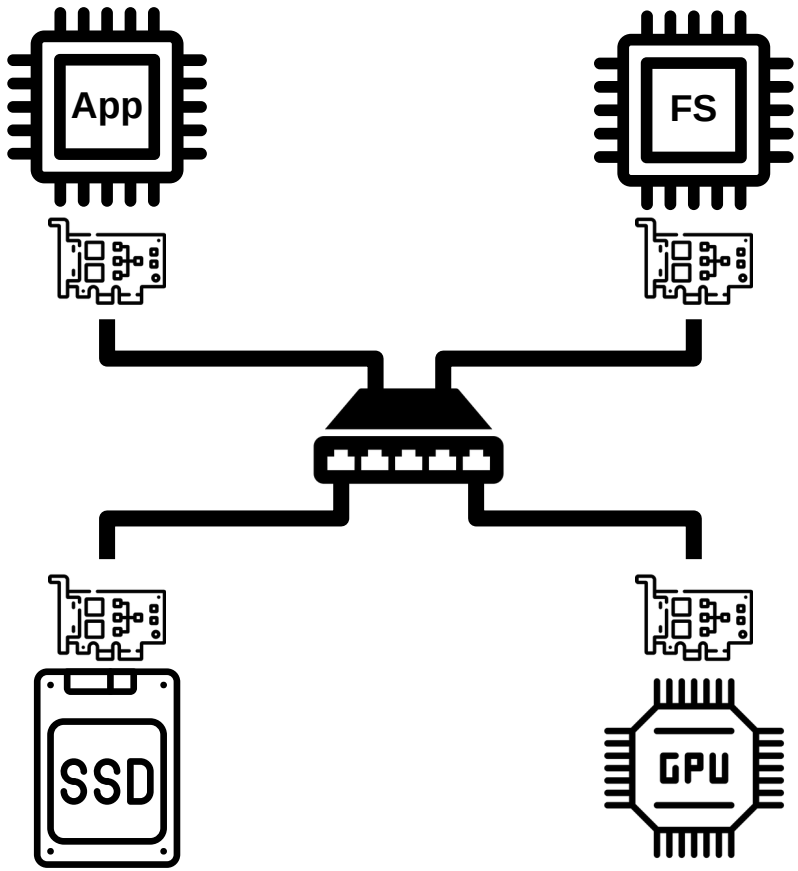
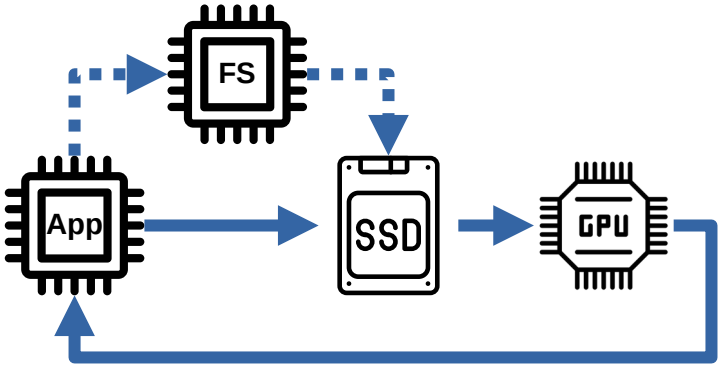


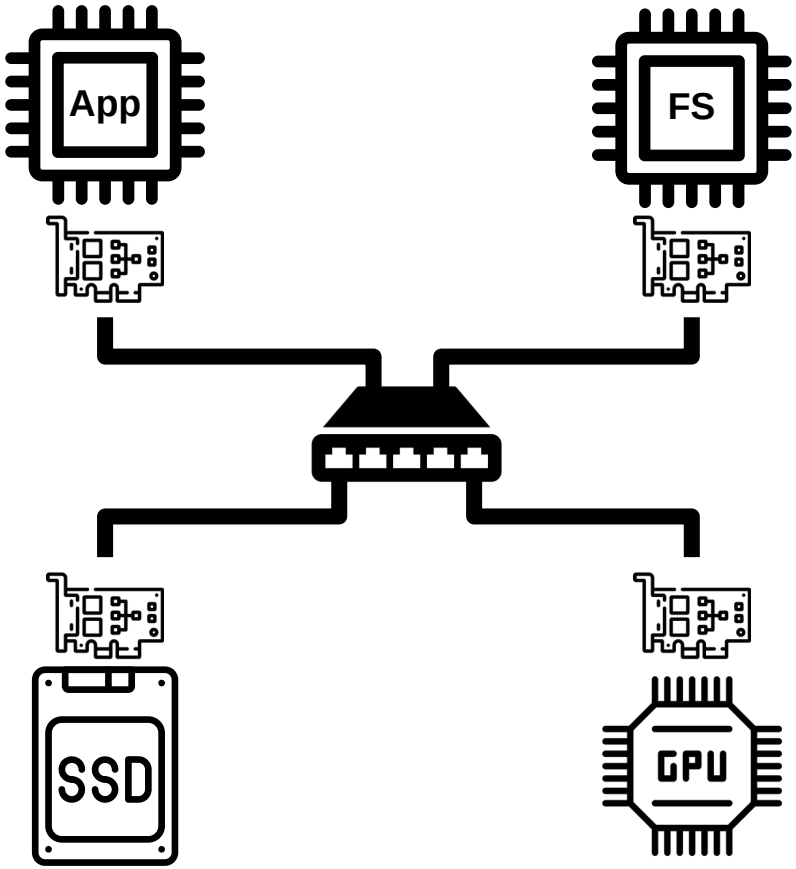
FractOS Goals



FractOS Goals

- Decentralized execution
  - Device-to-device, short-circuiting





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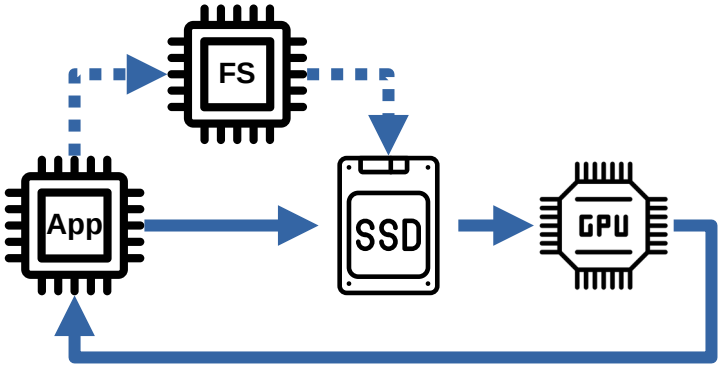
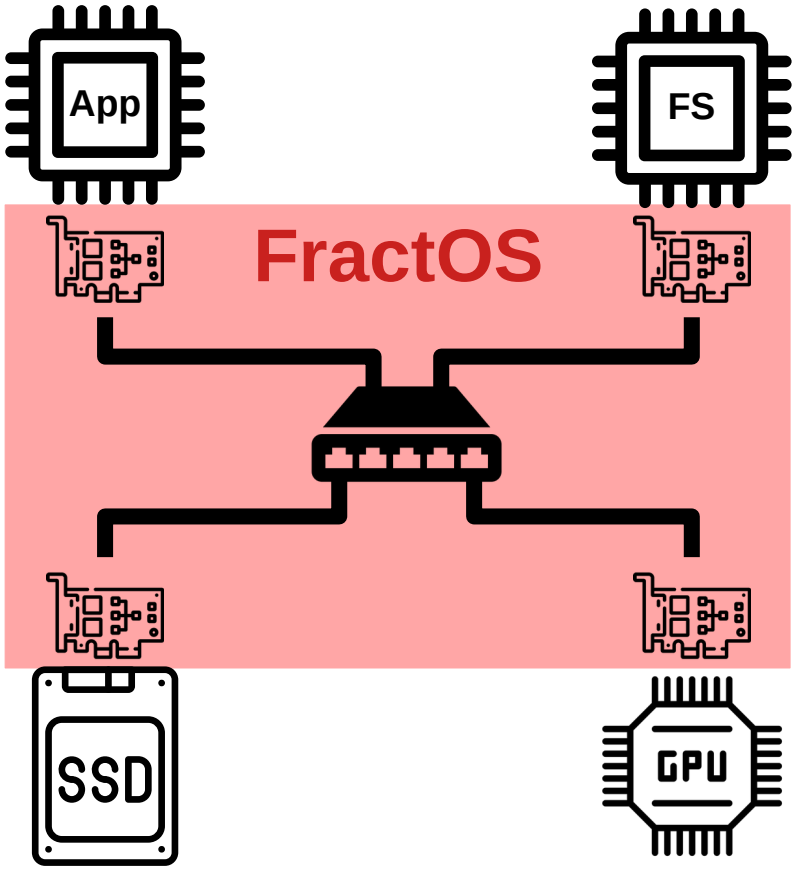
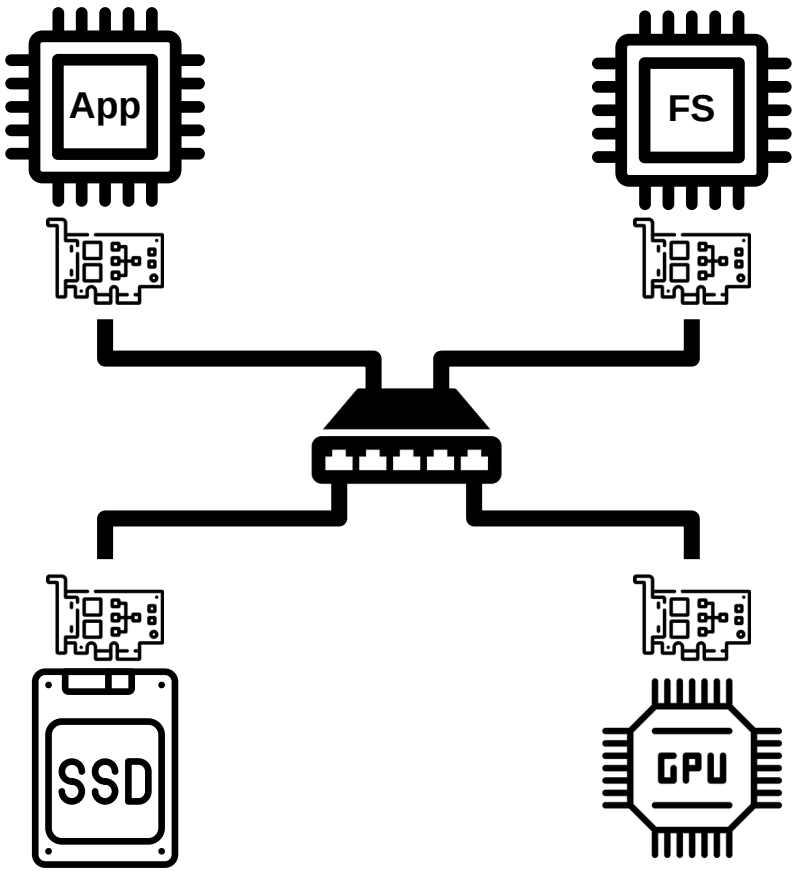


- First-class devices
  - Abstractions for device-agnostic P2P data and control operations

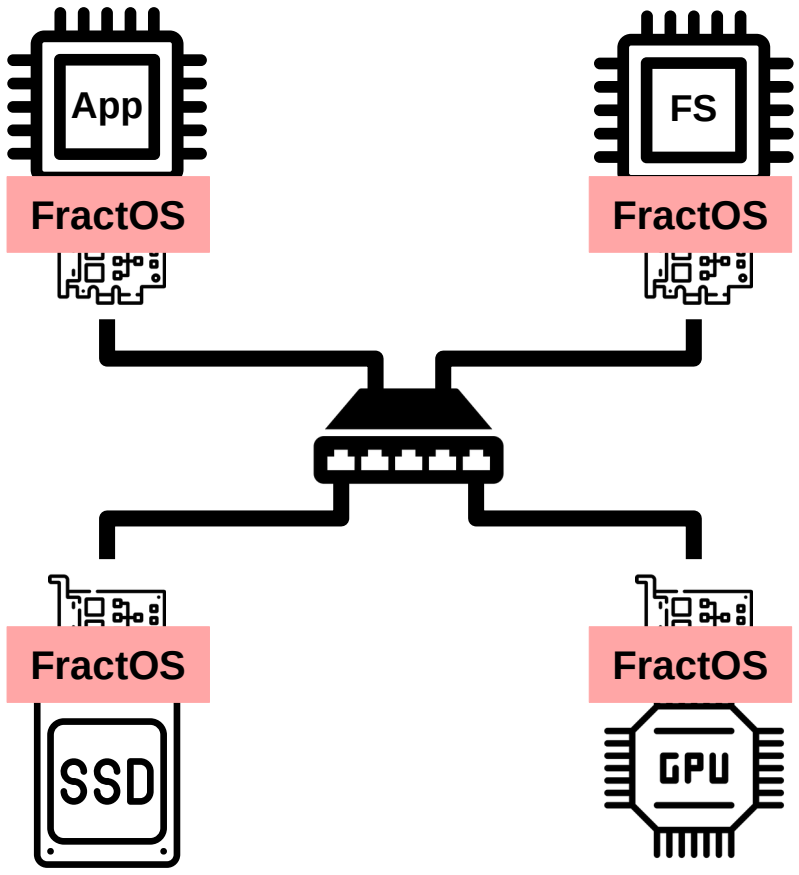


FractOS Design



FractOS Design

- Distributed “micro-kernel” architecture



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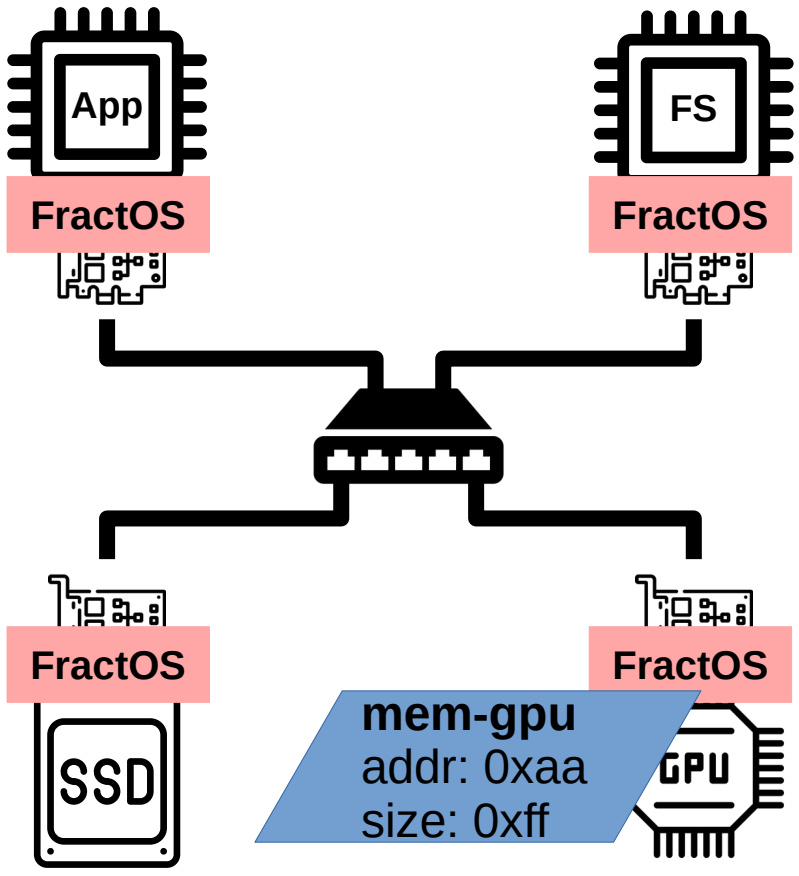

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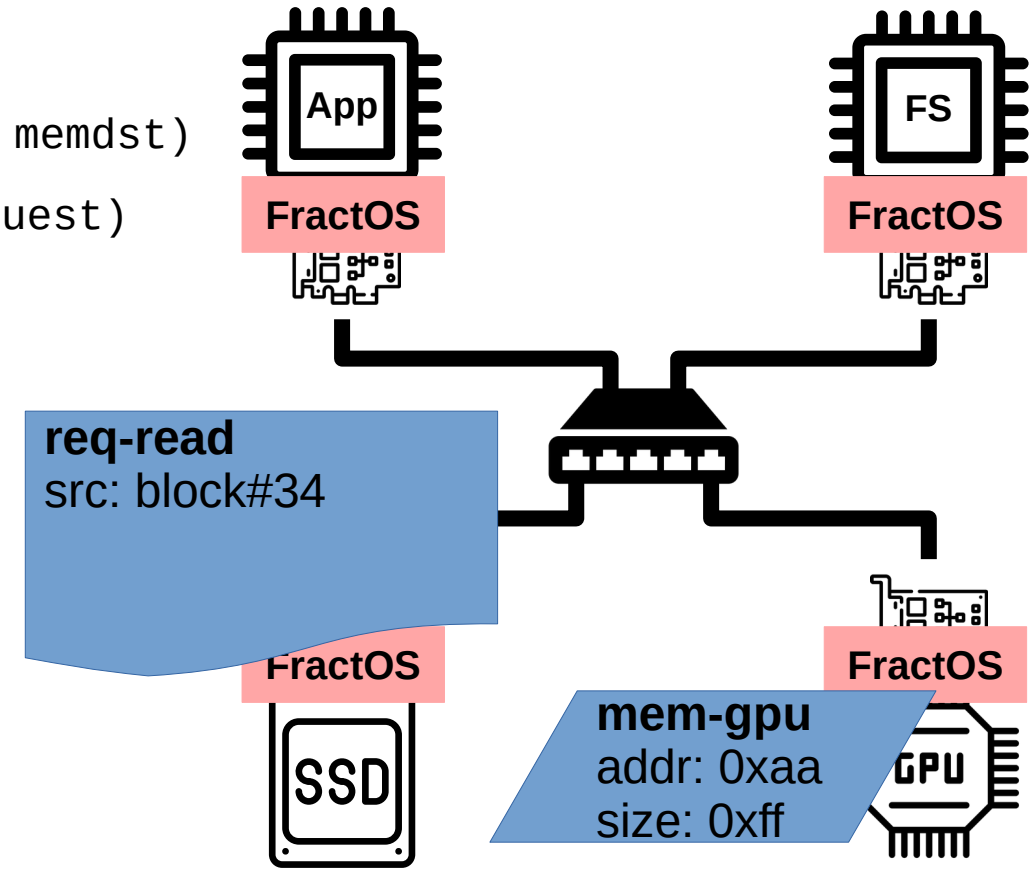

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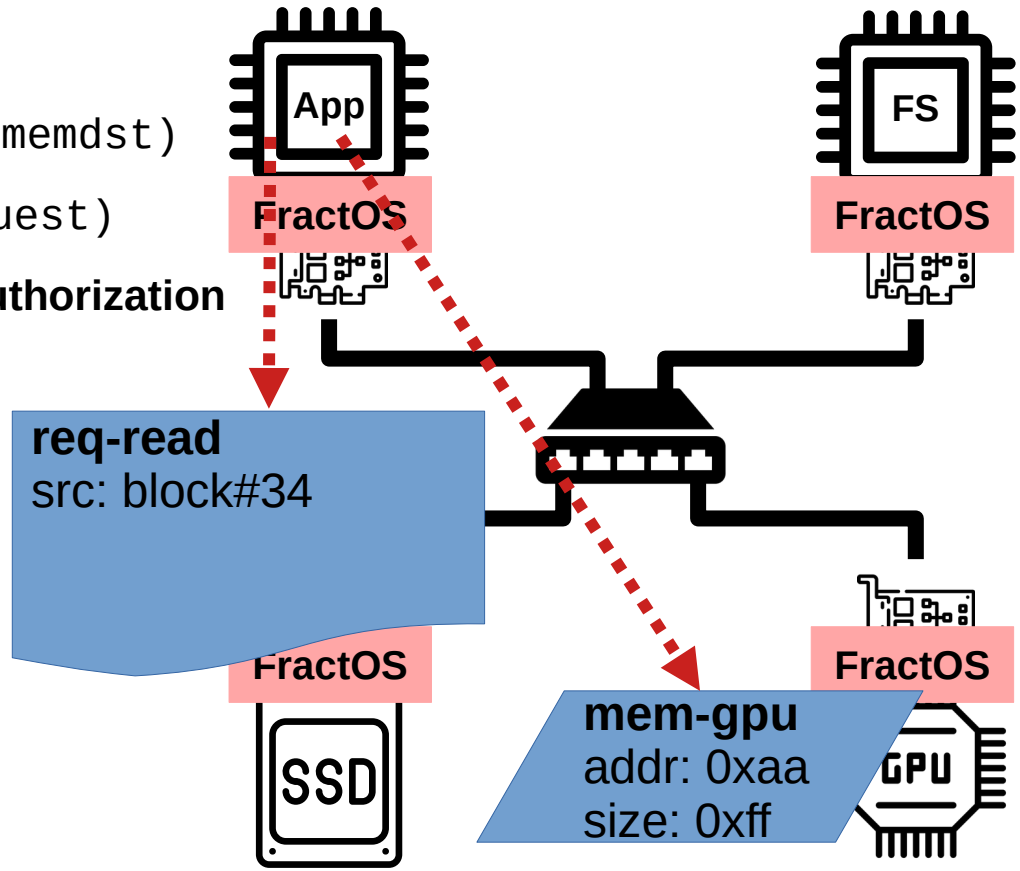

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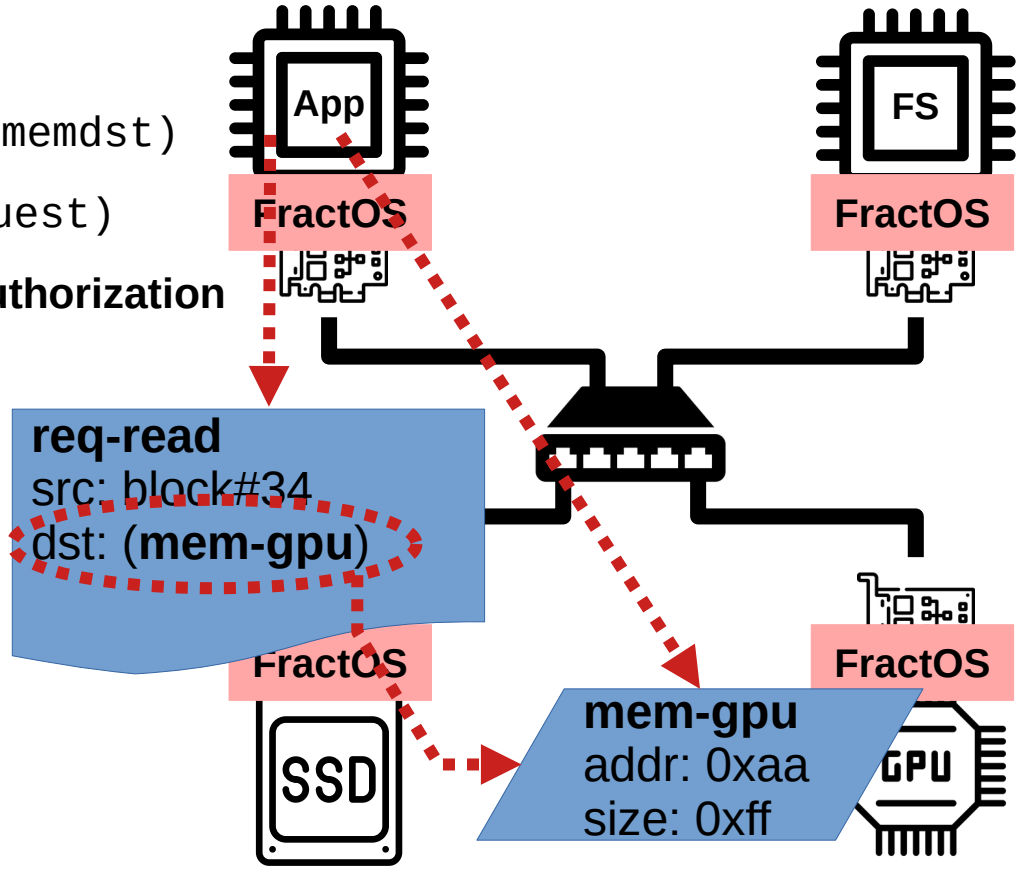

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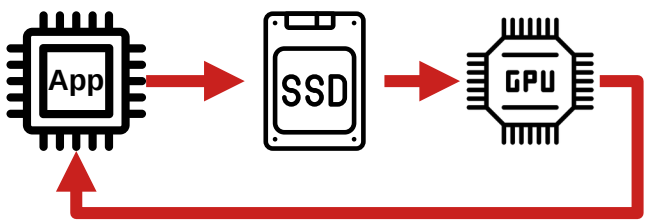

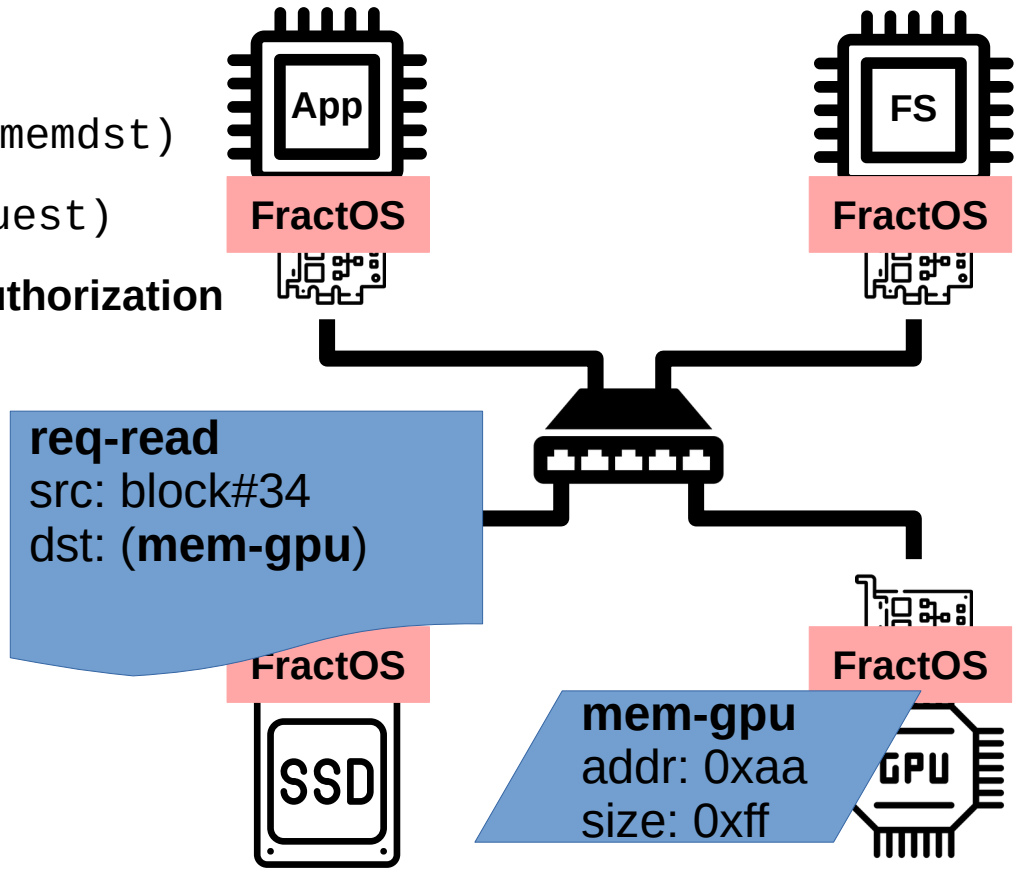

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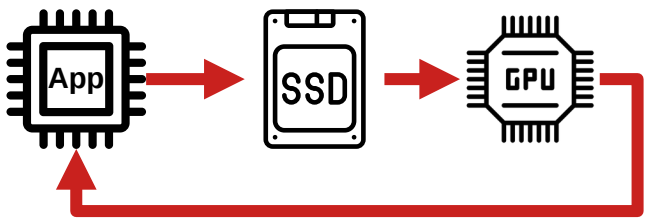

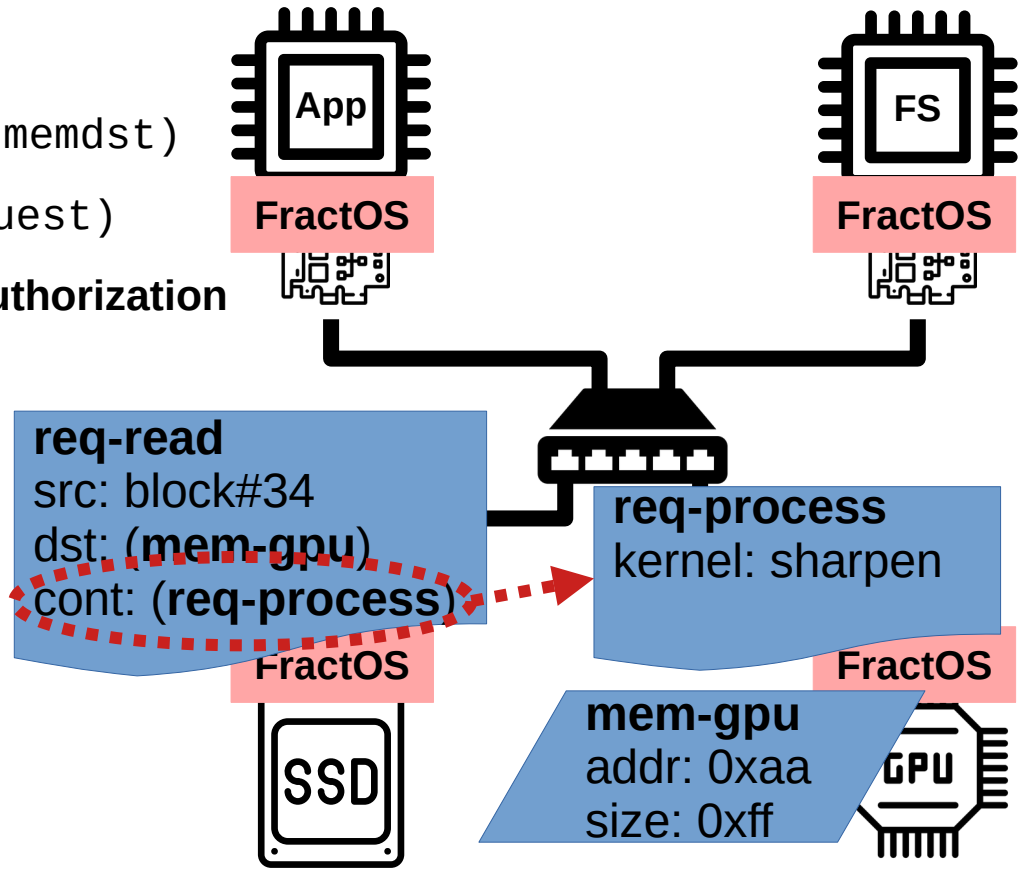

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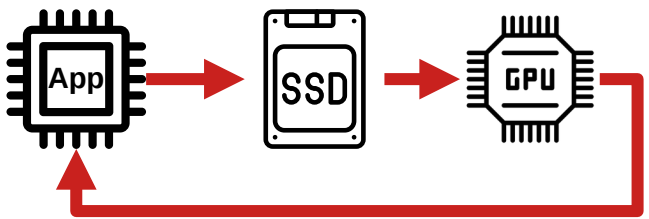
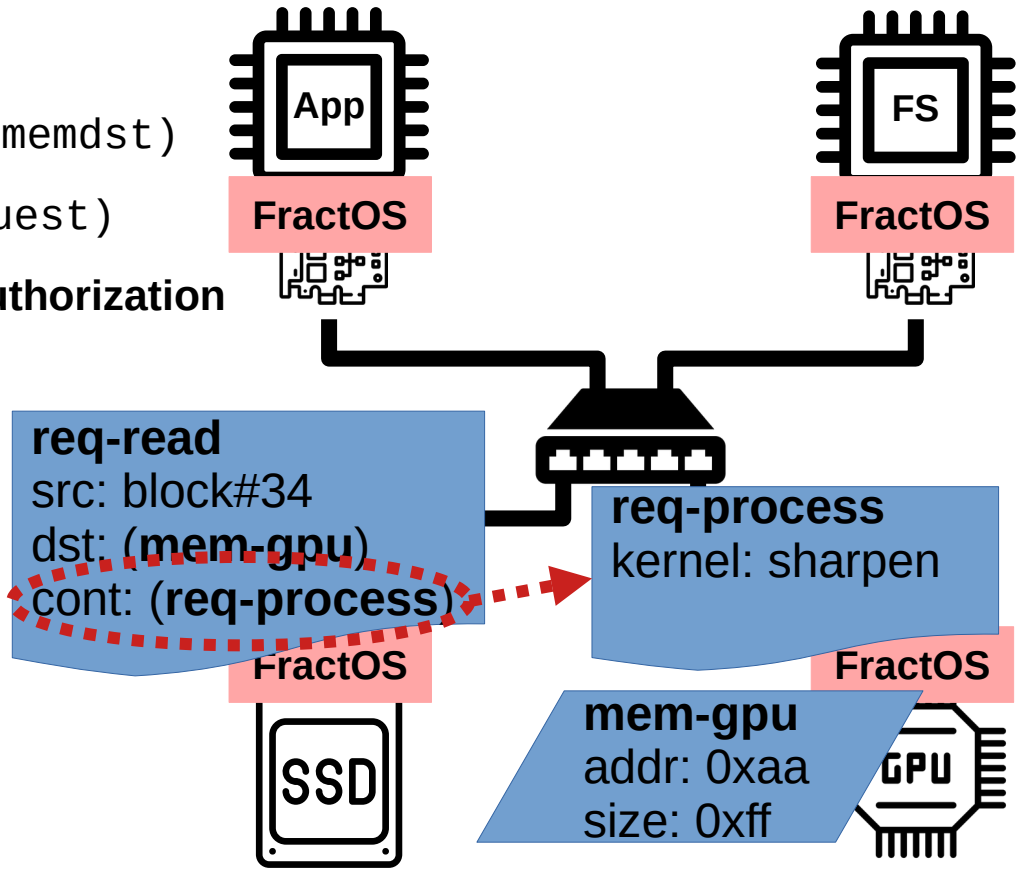
  - Requests as “continuations”
  - From RPCs to distributed dataflow





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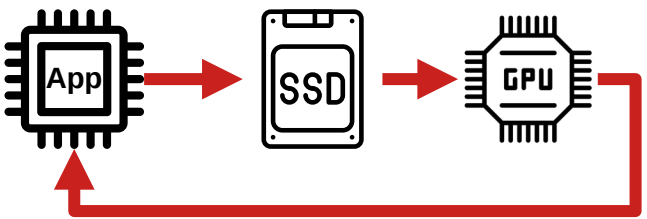

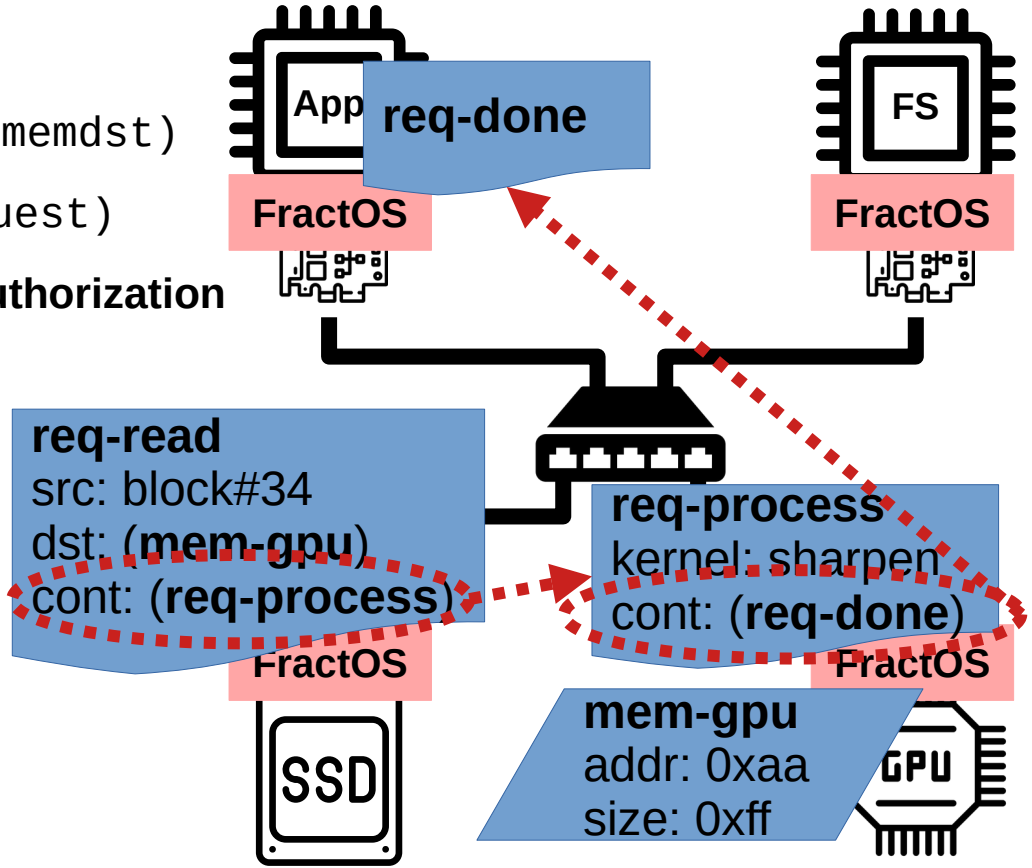

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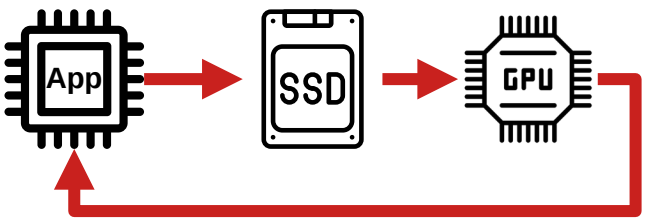

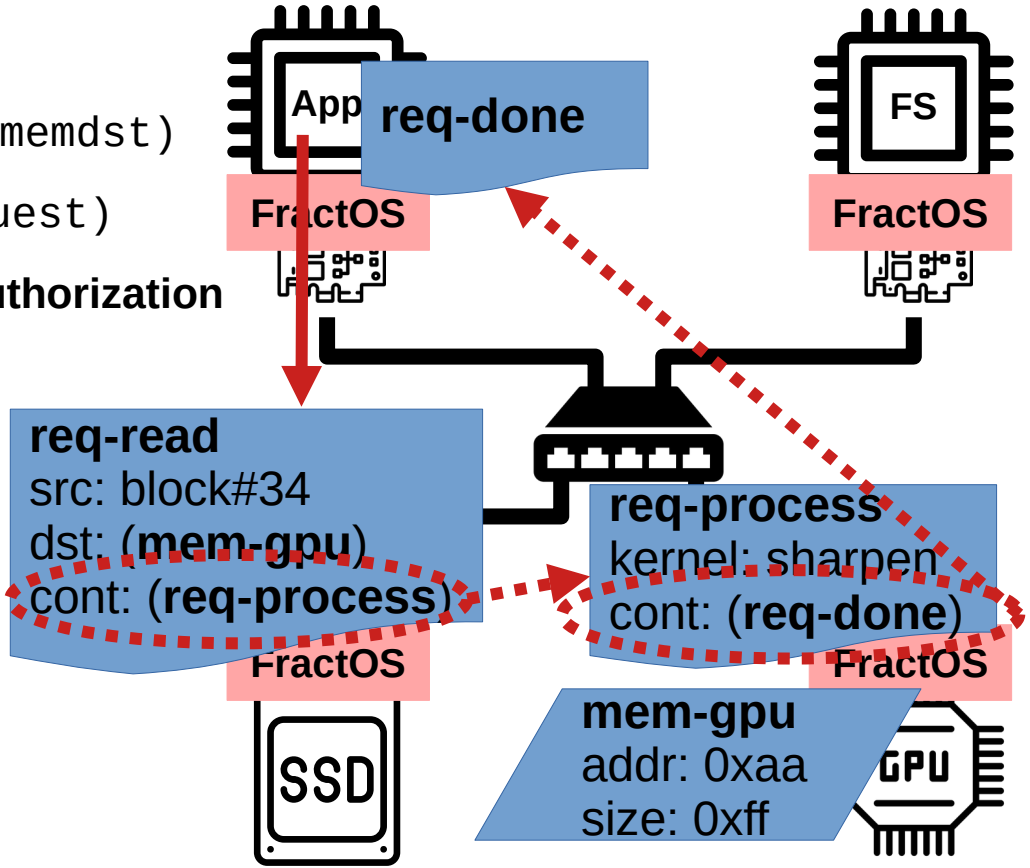

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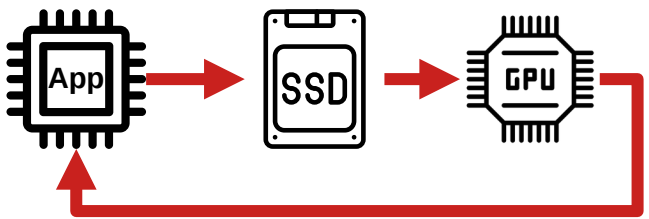

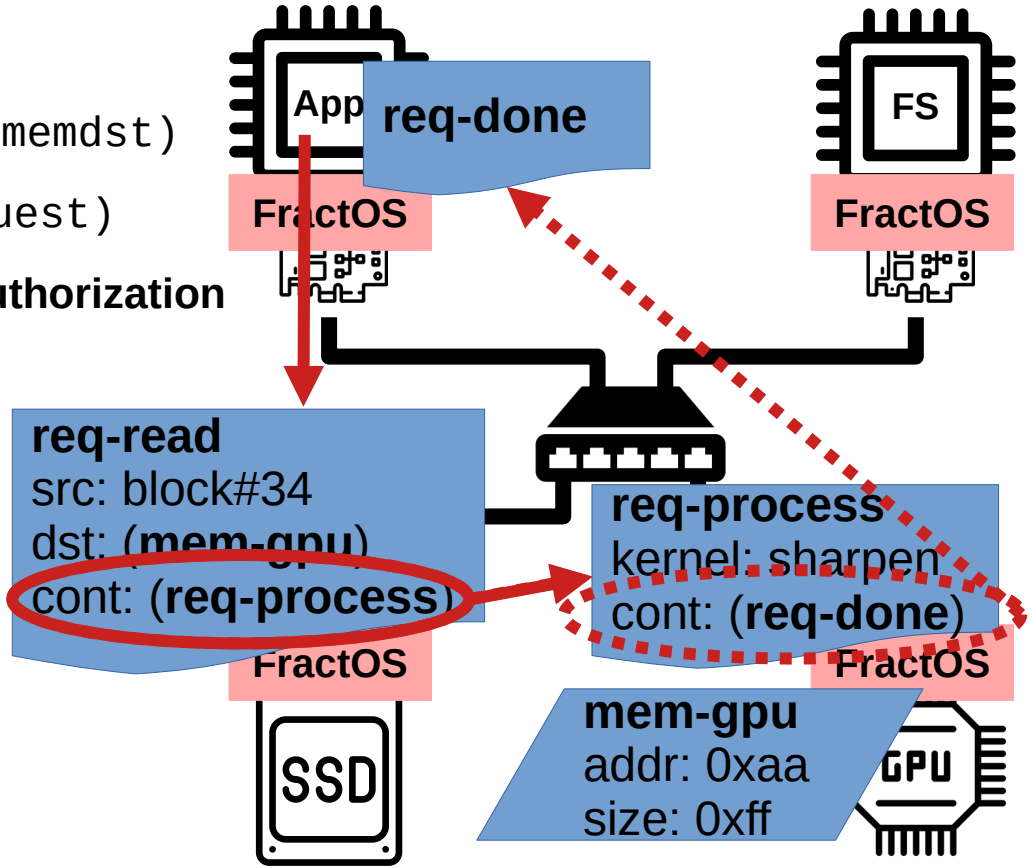

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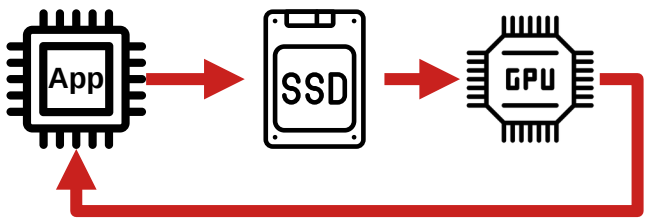
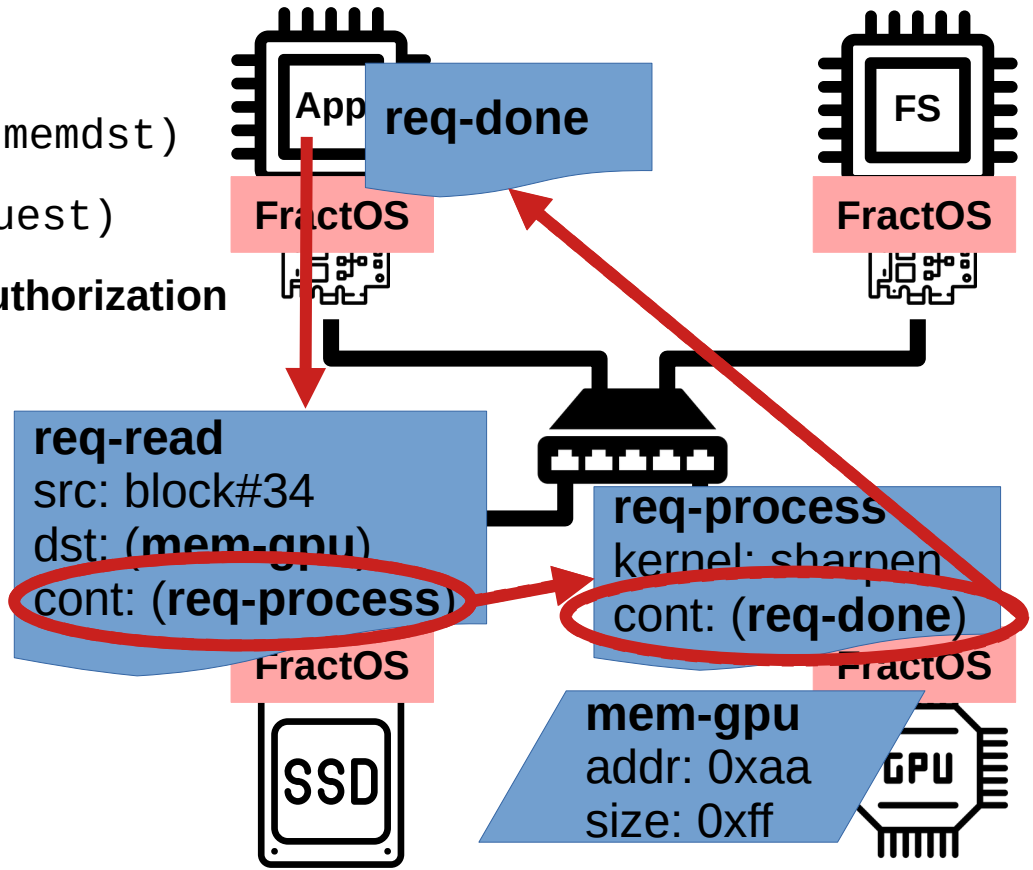
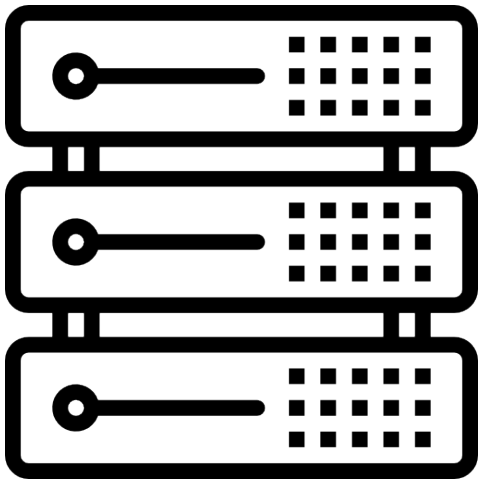


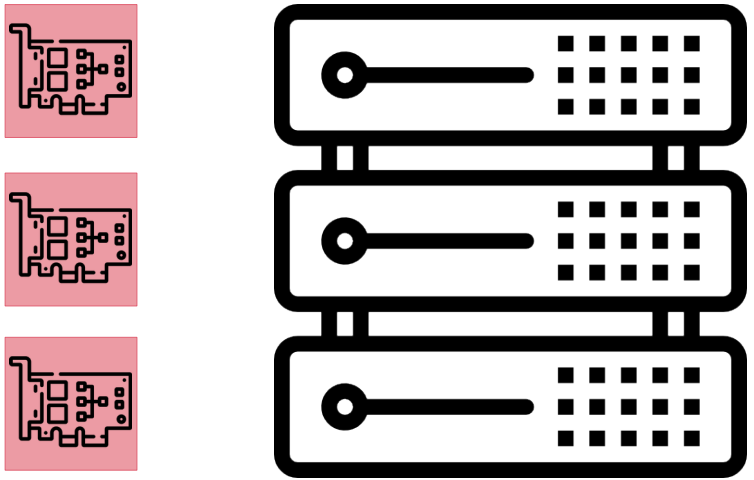


FractOS and Data Center Architecture



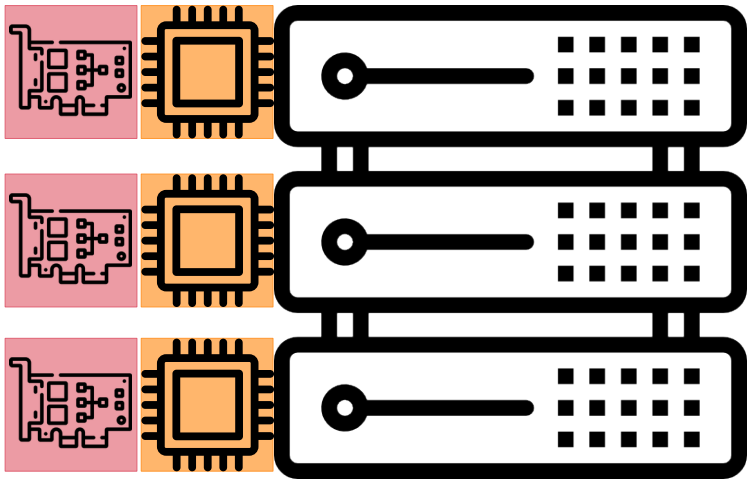
FractOS and Data Center Architecture

- Per-node FractOS Controller
  - Trusted “micro-kernel” instance
  - Serves **FractOS Processes** via asynchronous req/resp queues



FractOS and Data Center Architecture

- Per-node FractOS Controller
  - Trusted “micro-kernel” instance
  - Serves **FractOS Processes** via asynchronous req/resp queues
- Per-node device service adaptor
  - FractOS “device driver” Process
  - CPUs with Linux + existing drivers
  - **No client application code**



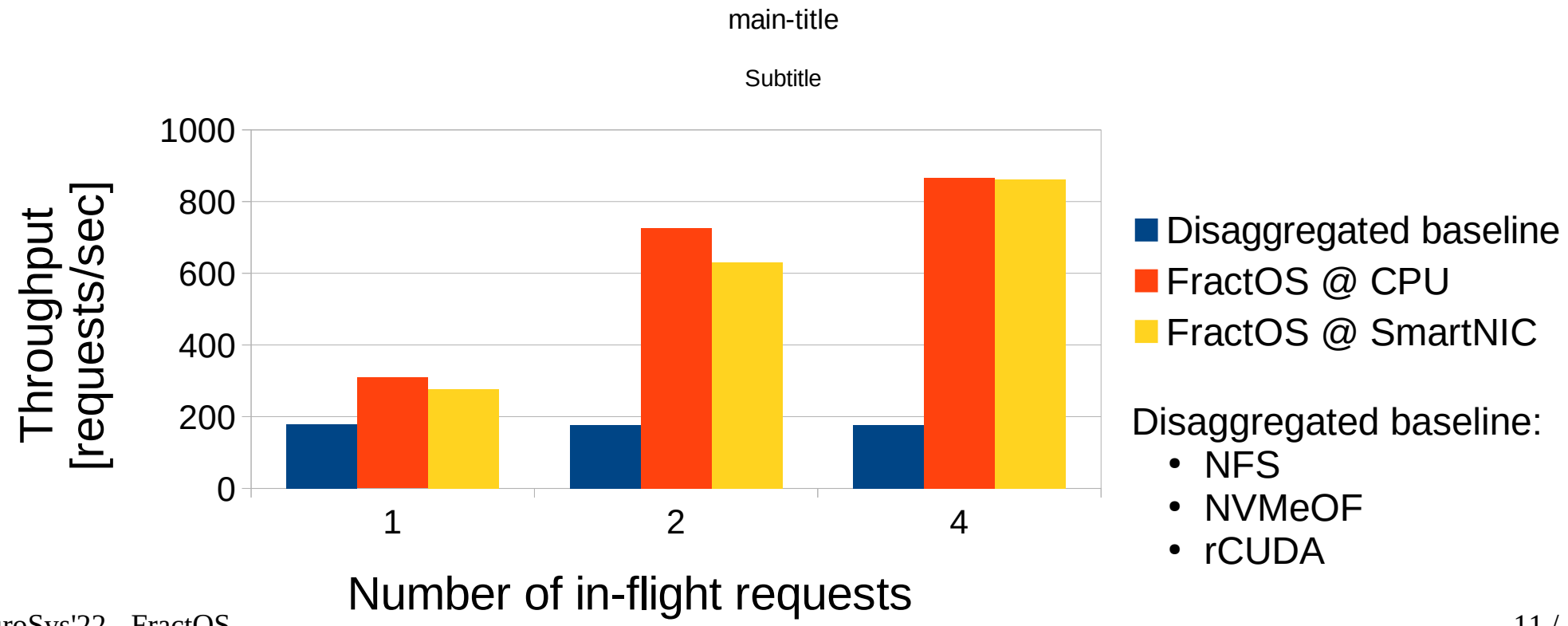
req-read
src: block#34
dst: (mem-gpu)
cont: (req-process)

cmd: NVME_CMD_READ
block: 34
buffer: 0xcafe
…

copy(0xcafe, req.dst)
invoke(req.cont)

Evaluation

- Face-verification application (similar to example)



Evaluation

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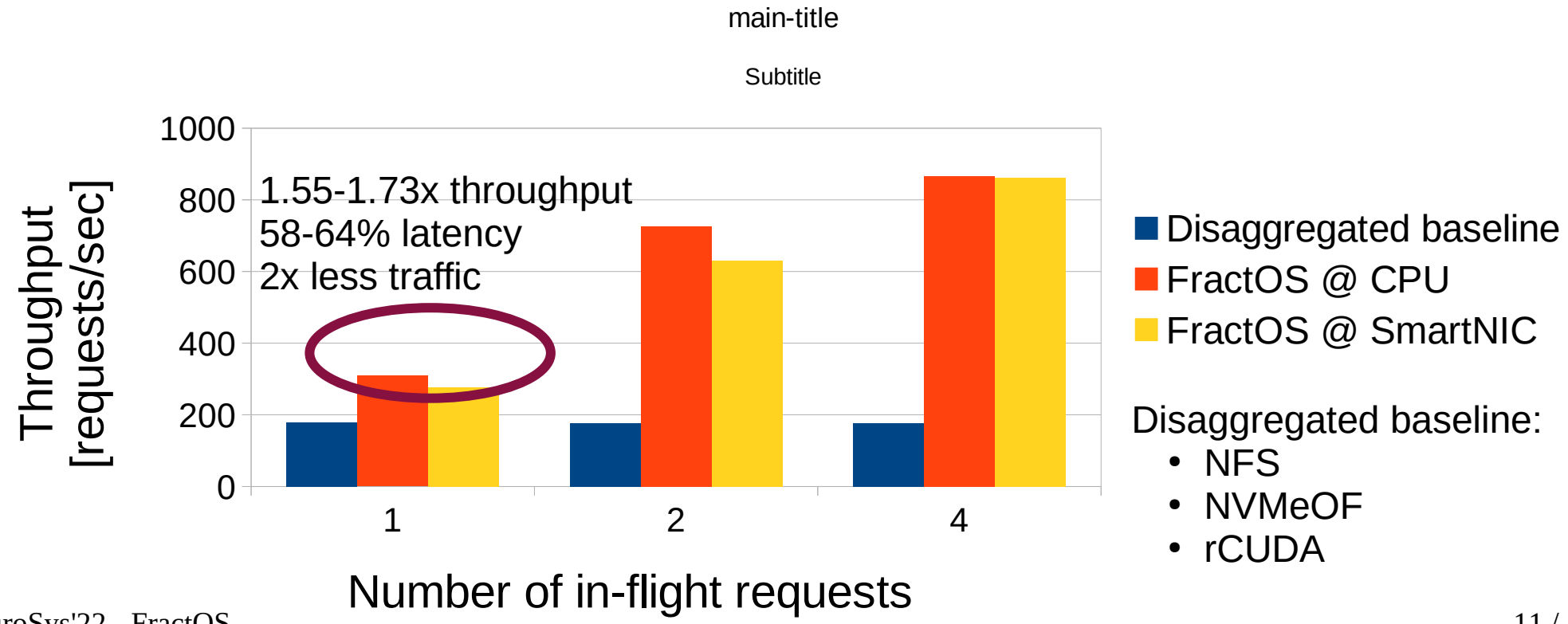
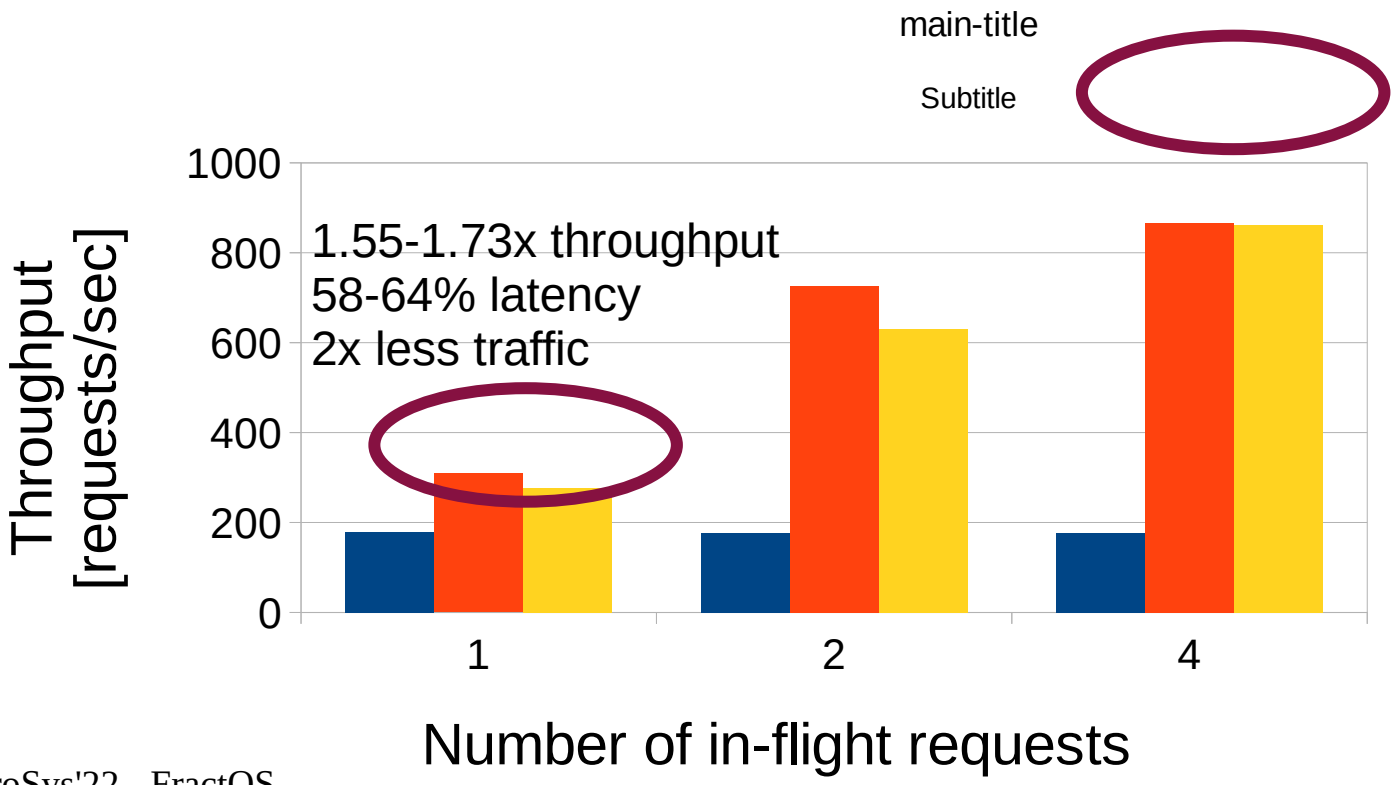


Evaluation

- Face-verification application (similar to example)



FractOS saturates GPU (vs. rCUDA: centralized + multiple messages)

- Disaggregated baseline
- FractOS @ CPU
- FractOS @ SmartNIC

Disaggregated baseline:

- NFS
- NVMeOF
- rCUDA

Conclusions

- A path to disaggregation-native systems
  - Device-to-device operations → latency speedups + network traffic reduction
  - Decoupled Controller and Process →CPUs/SmartNICs, FractOS-native devices, …
- More details on the paper
  - Secure and dynamic composition of third-party services
  - Application and deployment-specific optimizations
  - Distributed capability management algorithms
  - Micro-benchmark and application evaluation… and more!

A small step within a wide area of research, let's talk!

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https://lsds.doc.ic.ac.uk/projects/fractos