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P51: High Performance Networking

Lecture 2: Programmable network devices

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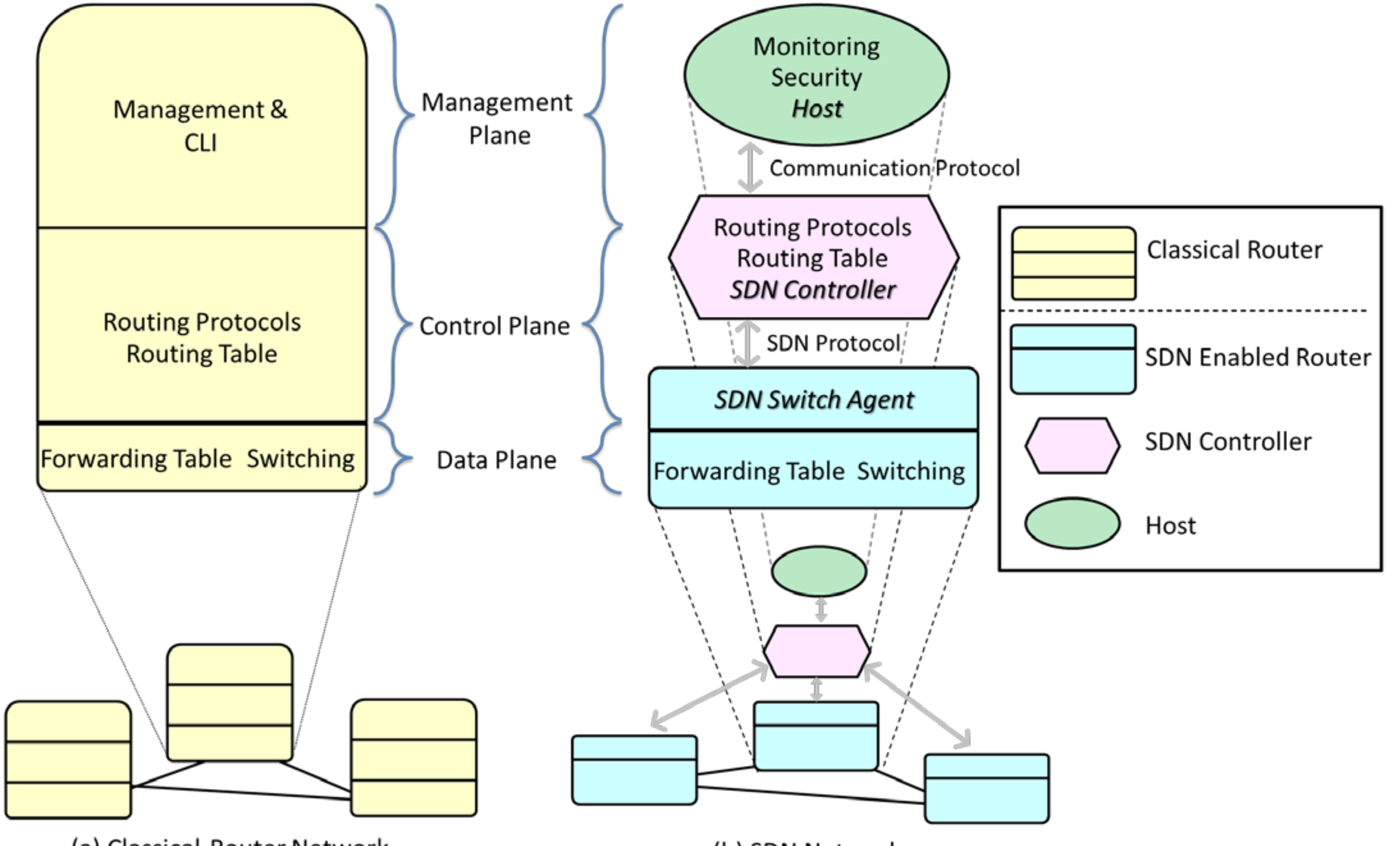
Software Defined Networks

We will not discuss SDN…

Software Defined Networking (SDN)

Key Idea: Separation of Data and Control Planes



(a) Classical-Router Network

(b) SDN Network

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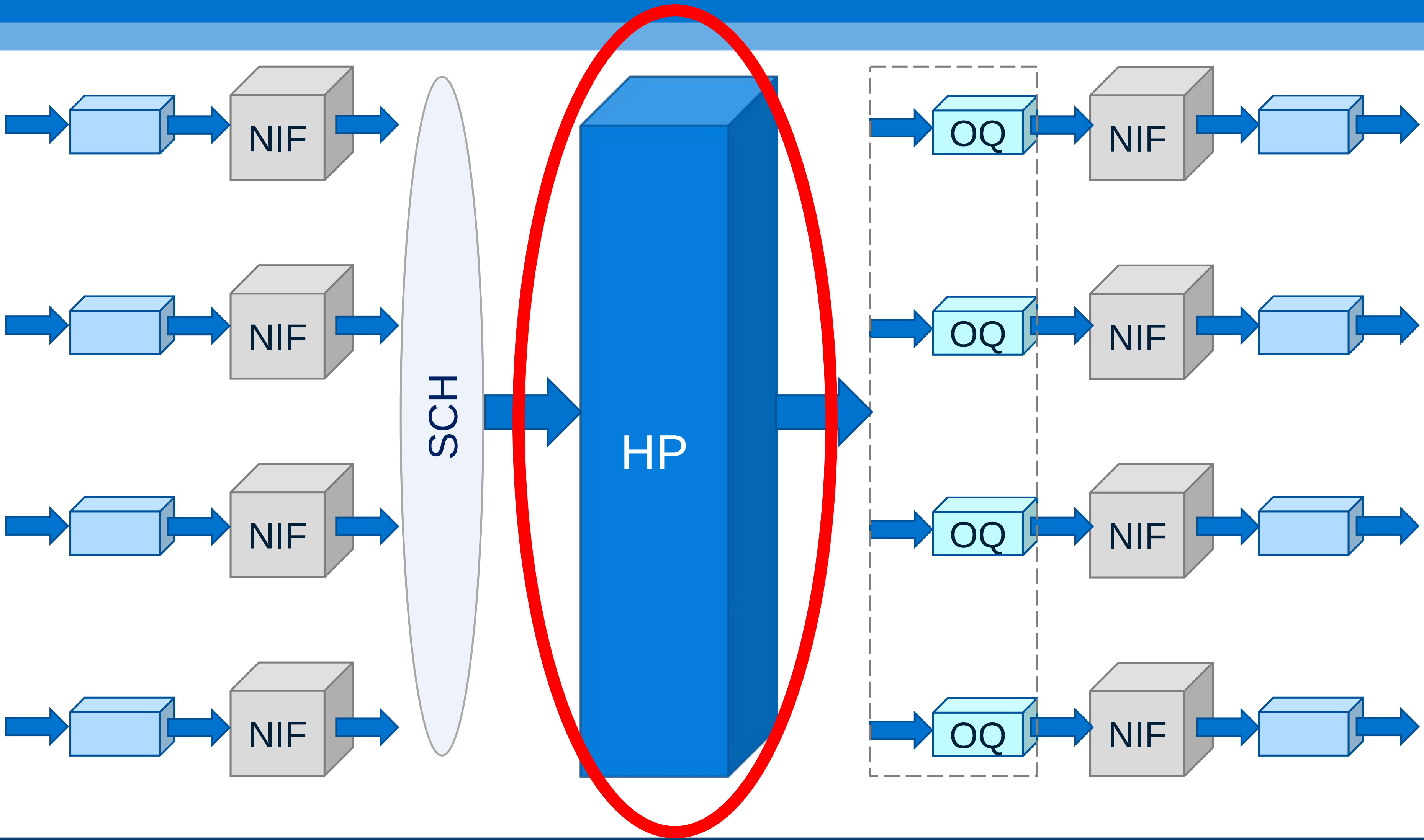
Switch Architecture and SDN



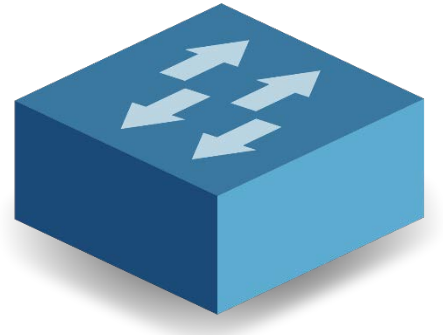
Software Defined Networking (SDN)

- SDN is about control and manageability
- Attending to challenges in:
  - Controlling large scale networks
  - Different underlying hardware
  - Device complexity
  - …
- The data plane is simple, the “smartness” is in the control plane
  - Focused on the packet processing

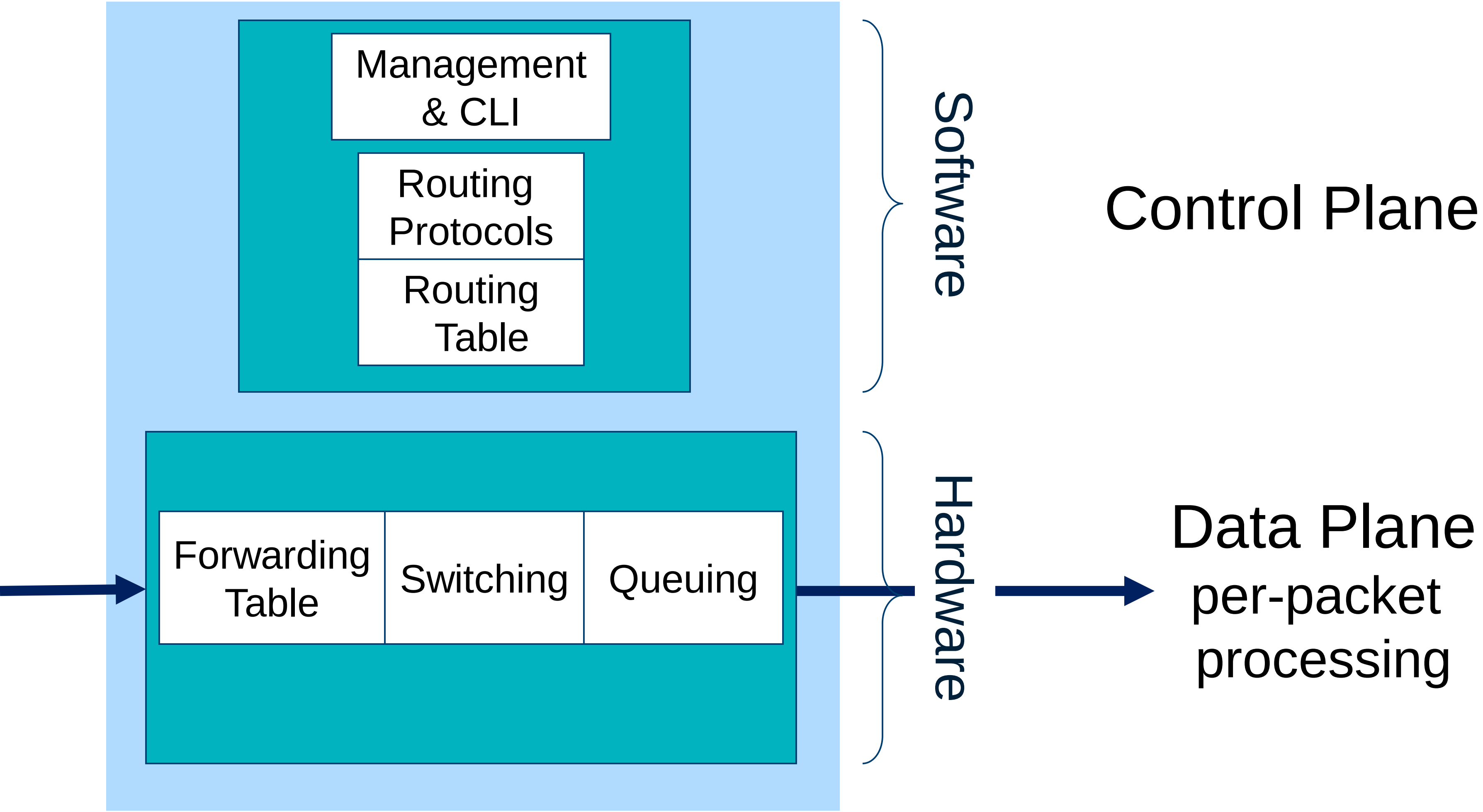
Programmable Network Devices

A bit of history…

- The role of a switch is to connect multiple LAN segments
- Operates on Layer 2
- Supports a single operation: Forwarding
- If you want to do more:
  - Layer 3 is handled by the software
  - Protocol processing is handled by another device (NPU / PPU)
- Valid until mid-2000’s
  - E.g. 2002’s “state of the art” Broadcom Strata XGS, 8x10GE



Basic components of an IP router (originally)

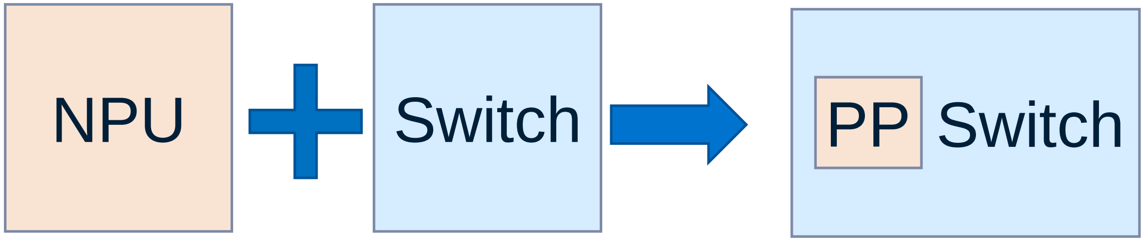


Control Plane

Data Plane
per-packet processing

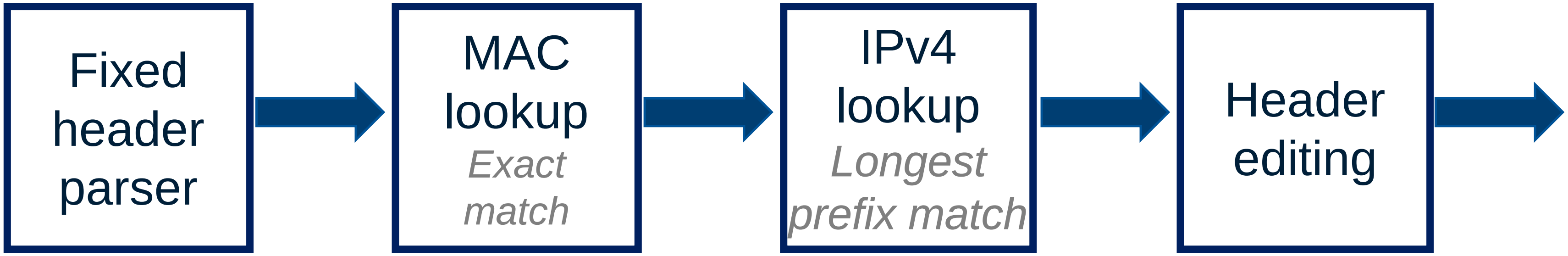
A bit of recent history…

- Mid-2000’s to start-2010’s:
  - Fixed function switches
  - Integration of functions: same trend as with CPUs
    - Why use NPU + Switch if you can use just a switch?
    - For limited applications



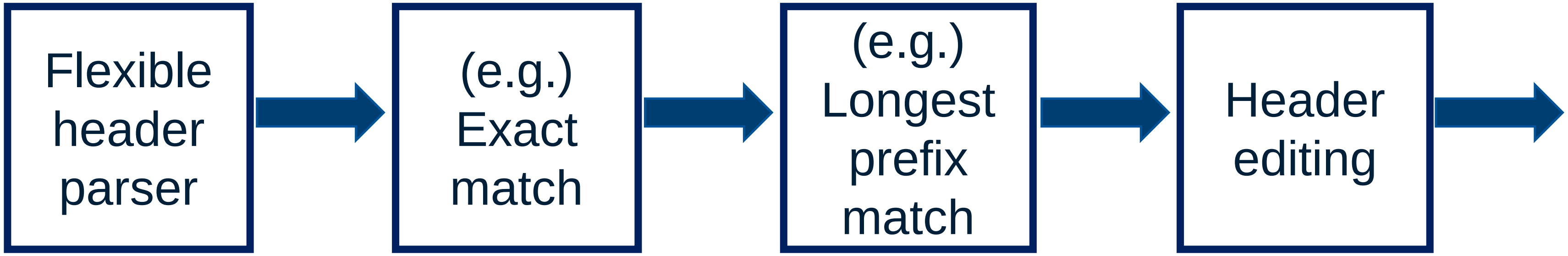
A bit of recent history…

- Mid-2000's to start-2010's:
  - Fixed function switches
  - Supporting multiple (pre-defined) protocols
    - E.g. Layer 3 switching
  - Fixed pipeline (example only):



A bit of recent history…

- Start-2010's – Recent years:
  - Partly / fully flexible switches
  - Support *many* protocols
  - Flexibility in selecting the protocols, memories used, header size,…



Programmable network devices

- Partly / fully programmable
  - Mostly focused on the header processing
  - But starting to attend also to queueing / switching / TM / …
- Support ANY protocol
- Pipeline is “programmable”
  - But within given resource limitations

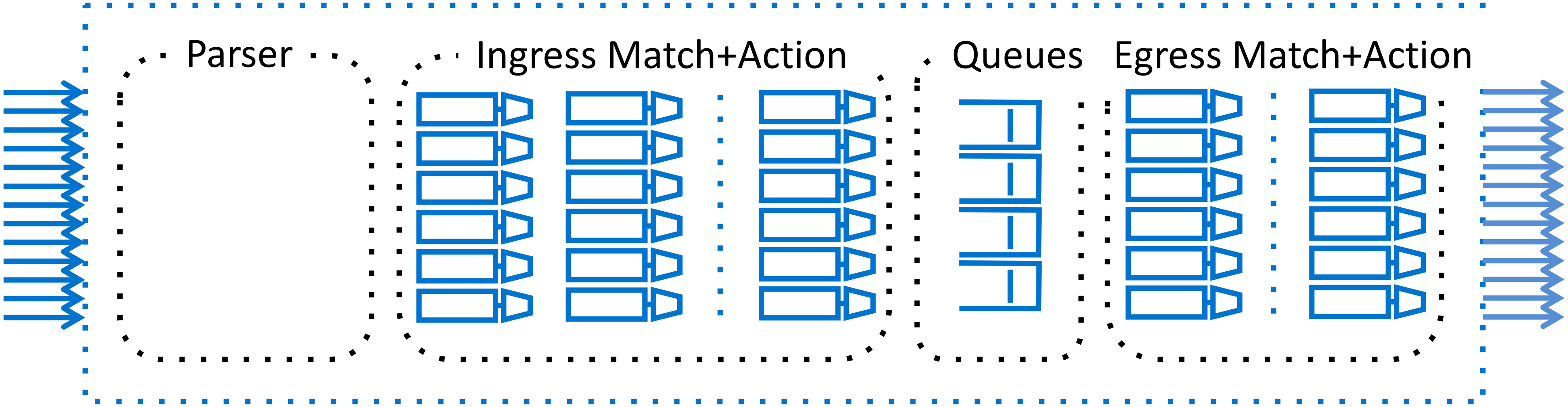
Programmable network devices

Advantages:

- New Features – Add new protocols
- Reduce device complexity – e.g., Implement only required protocols.
- Flexible use of resources
- SW style development – better innovation, fix data-plane bugs in the field

Reconfigurable Match-Action Model

- RMT – Reconfigurable Match-Action Model



- Bosshart, Pat, et al. "Forwarding metamorphosis: Fast programmable match-action processing in hardware for SDN." *SIGCOMM* 2013.

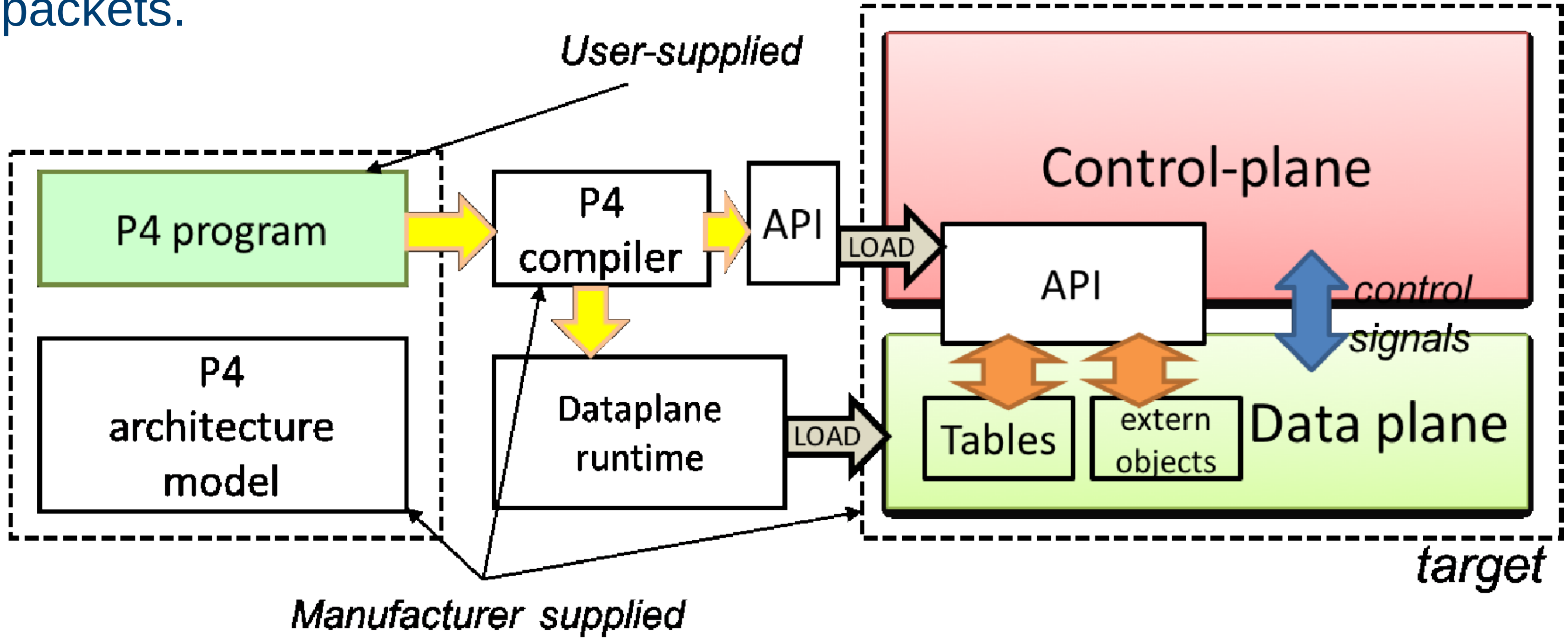
Programmable network devices

- How do you programme a network device?
- Requires:
  - Programming language
  - Compilers
  - Architecture
    - Underlying hardware support

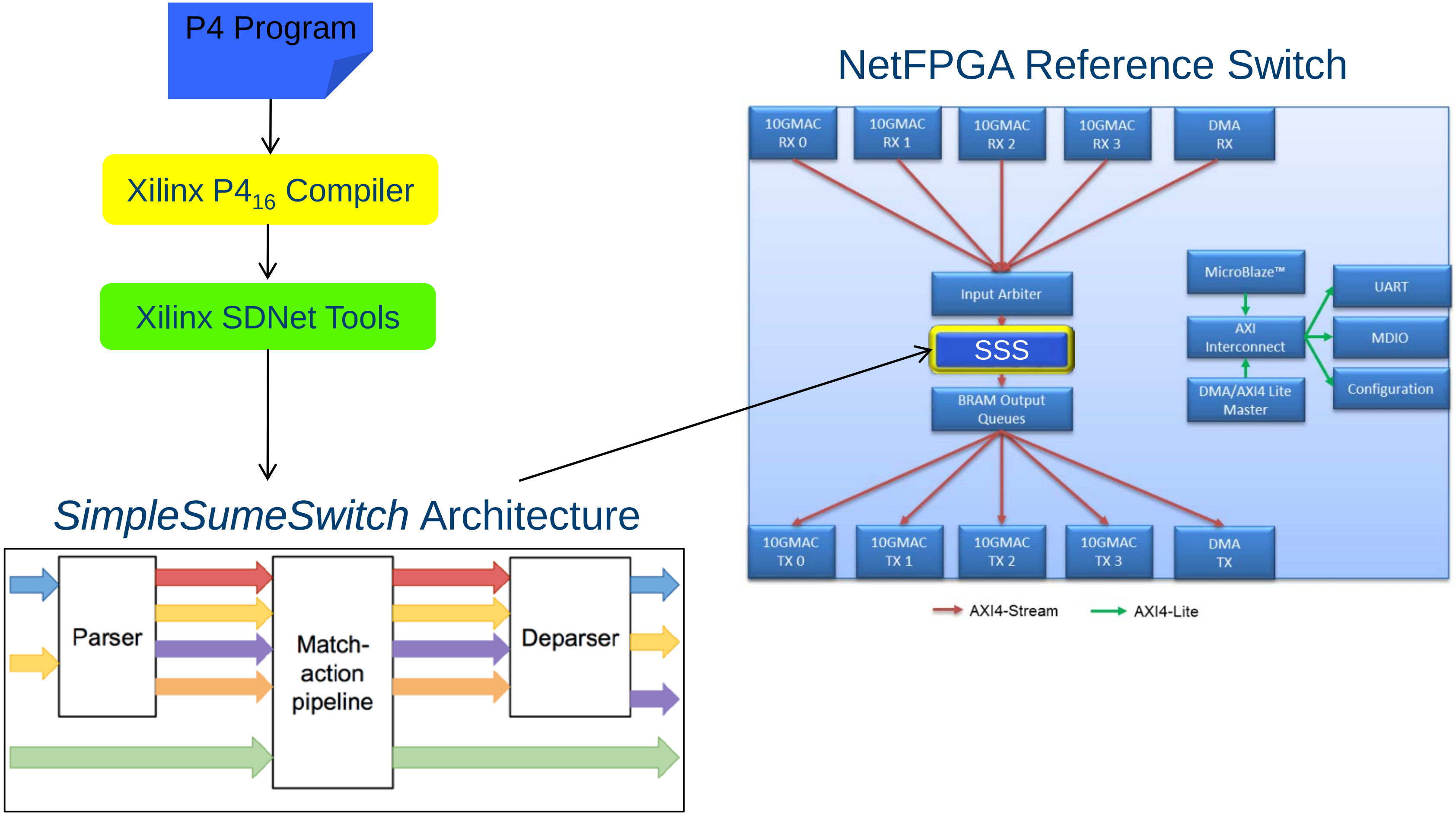
- We will discuss one popular option, but there are more

P4

- www.p4.org
- A declarative language
- Telling forwarding-plane devices (switches, NICs, …) how to process packets.



Example: P4 on NetFPGA (P4-NetFPGA)



P4 Program

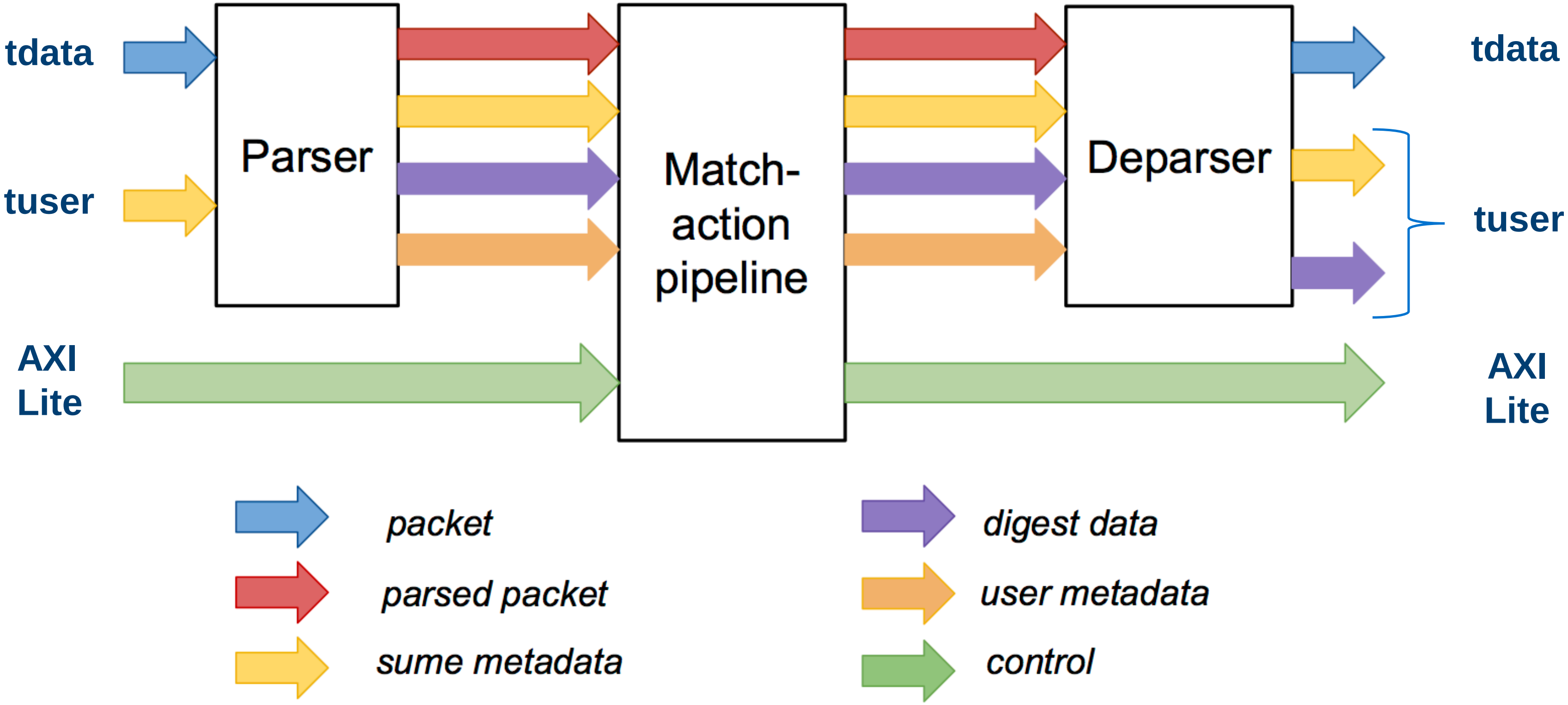
Xilinx $P4_{16}$ Compiler

Xilinx SDNet Tools

SimpleSumeSwitch Architecture

NetFPGA Reference Switch

SimpleSumeSwitch Architecture Model for SUME Target

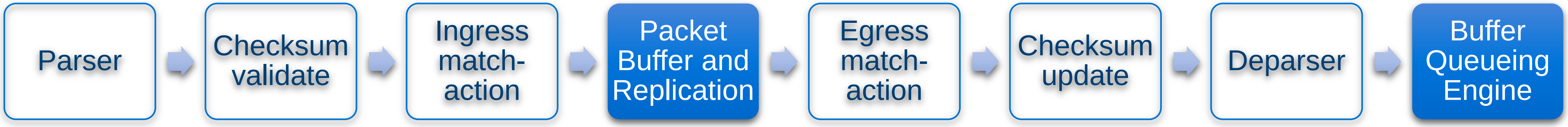


P4 used to describe parser, match-action pipeline, and deparser

P4 PSA: Portable Switch Architecture

- Composability
  - Example: Multiple functions in a single pipeline
- Portability
  - Example: Apply a function consistently across a network
- Comparability
  - Example: Compare functions implementation, A vs. B

Pipeline



Parser → Checksum validate → Ingress match-action → Packet Buffer and Replication → Egress match-action → Checksum update → Deparser → Buffer Queueing Engine

Externs

- Checksum
- Register
- Counter
- Meter
- Action Profile
- Action Selector
- Random

P4 – Examples Use Cases

- Network telemetry (INT)
- New protocols (e.g., NDP)
- Layer 4 load balancing
- In Network Caching (NetCache) – ×10 throughput
- Consensus Protocols (NetPaxos) – ×10,000 throughput
- Tic-Tac-Toe

In Network Computing

- Idea: move services and applications from the host to the network
- Somewhat similar terms:
  - Network as a Service (NaaS)
  - Hardware acceleration (but network specific)
- Implementations:
  - Smart NICs
  - Programmable Switches
- Different platforms support different languages

In Network Computing - Examples

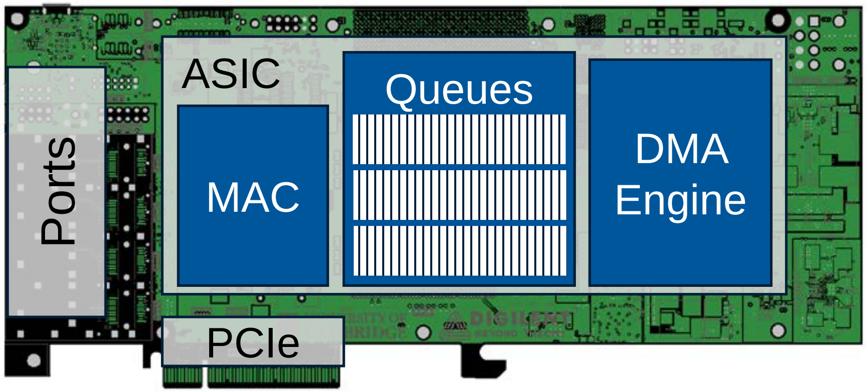
- Machine learning
- Graph processing
- Key-value store
- Security (e.g., DDoS detection)
- Big data analytics
- Stream processing

- But nothing is for free (cost, power, space, …)

NICs

Classic Network Interface Cards (NIC):

- Get packets from the network to the host
- Get packets from the host to the network
- DMA – manage getting packets to/from host over the interconnect
  - Not trivial! (Lecture 5)
- Manage queues
  - Mostly toward the host
- ….

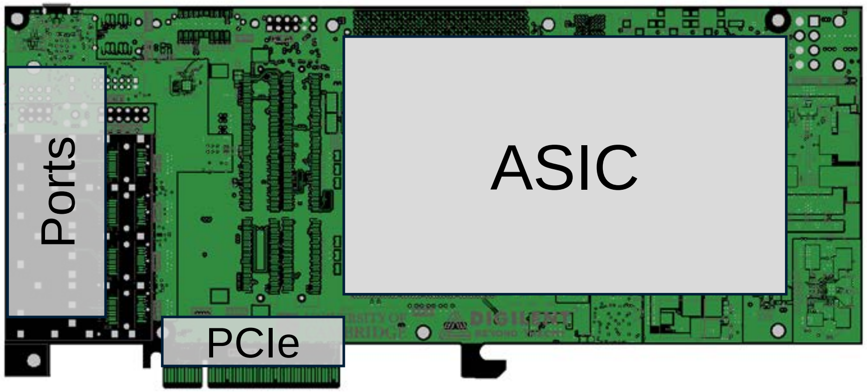


SmartNICs

Offload host functionality to the NIC:

- Virtualization
- Checksum
- TCP segmentation
- IPSec, MACSec

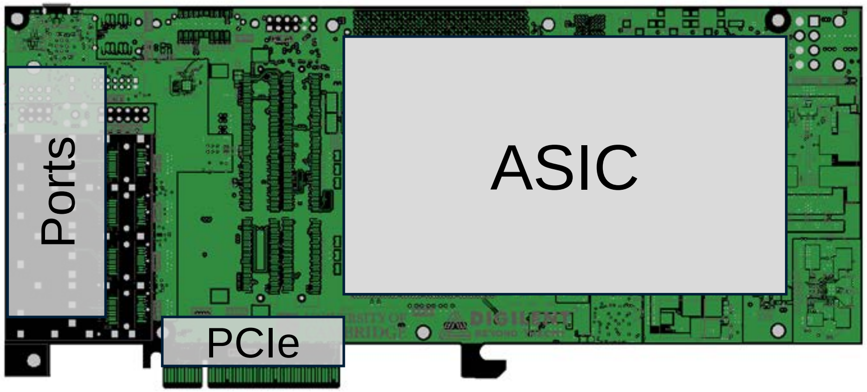
Even in “simple” NICs as X520



More SmartNICs!

Offload host functionality to the NIC:

- Programmable data planes
- Data transport acceleration
  - NVMe, RoCE, DPDK…
- Security
- Network function virtualiztion (NFV)
- Application acceleration

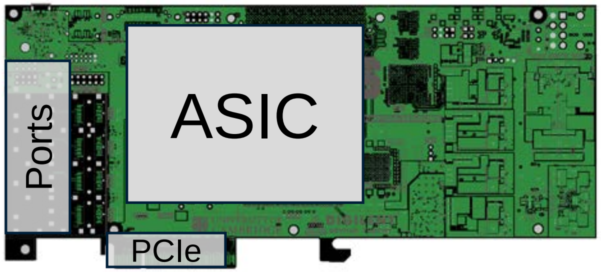


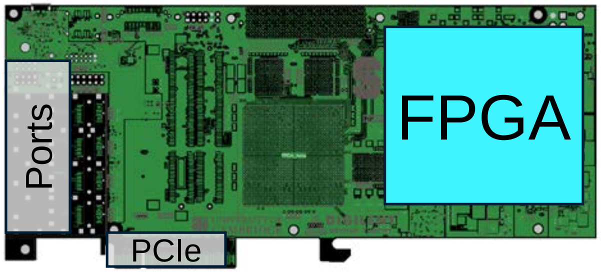
SmartNICs Models

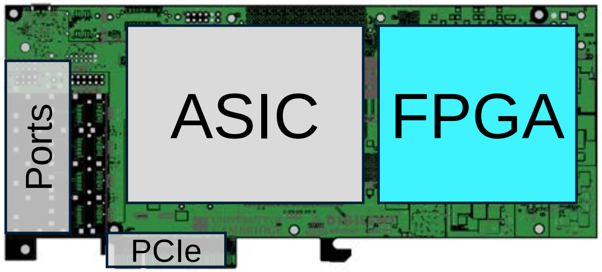
- ASIC based (e.g., Intel, Netronome, Solarflare)
- FPGA based (e.g., Microsoft, Exablaze)
- ASIC + FPGA based (inline or not, e.g., Mellanox)
- SoC (ASIC w/ CPU) based (e.g., Mellanox)

Everyone are doing SmartNICs today!

Evolution, not revolution


Ports
ASIC
PCIe


Ports
FPGA
PCIe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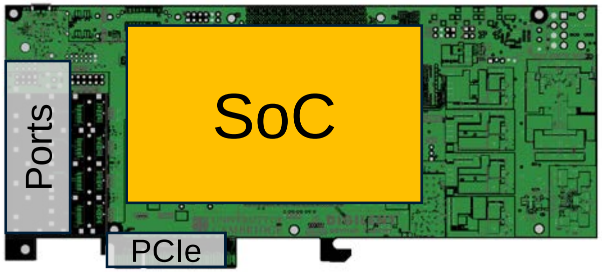
Ports
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