



Software Defined Networking

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In this course, you will learn about software defined networking and how it is changing the way communications networks are managed, maintained, and secured.

This Module: Programmable Data Plane

- ◎ Two Lessons
 - Programming the data plane: Click
 - **Scaling programmable data planes**
 - Making software faster
 - **Making hardware more programmable**
- ◎ **Optional** programming assignment (in Click)
- ◎ Quiz on Concepts

What Do We Want From SDN?

- ⦿ Protocol-independent processing
- ⦿ Control and repurpose in the field
- ⦿ Implemented by fast, low-power chips

Today: Still Real Hardware Constraints

- ⦿ OpenFlow is protocol dependent because of constraints of traditional switching chips.
- ⦿ Mapping to existing switching chips enabled quick adoption.
- ⦿ What if we could re-design the data plane?

Insight: Few Data Plane Primitives

- ◎ The set of functions that we want to perform on packets are pretty limited
 - Bit shifting
 - Parsing and rewriting header fields
 - ...
- ◎ Can build a flexible data plane by developing modules + ways to integrate them.

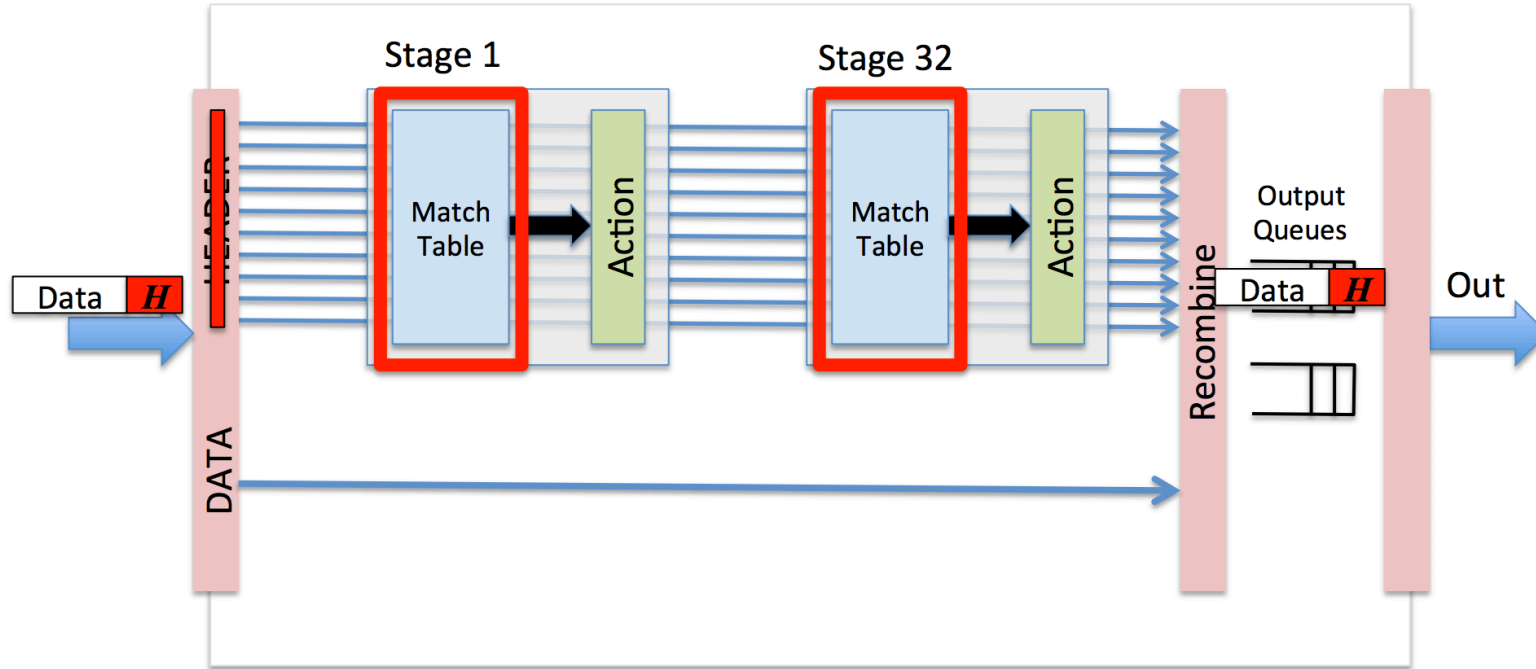
Two Examples of Modular Programmable Hardware Data Planes

- ⦿ An “OpenFlow Chip”
 - Generalizable, programmable match-action primitives
- ⦿ SwitchBlade
 - Programmable, modularizable FPGA-based data plane

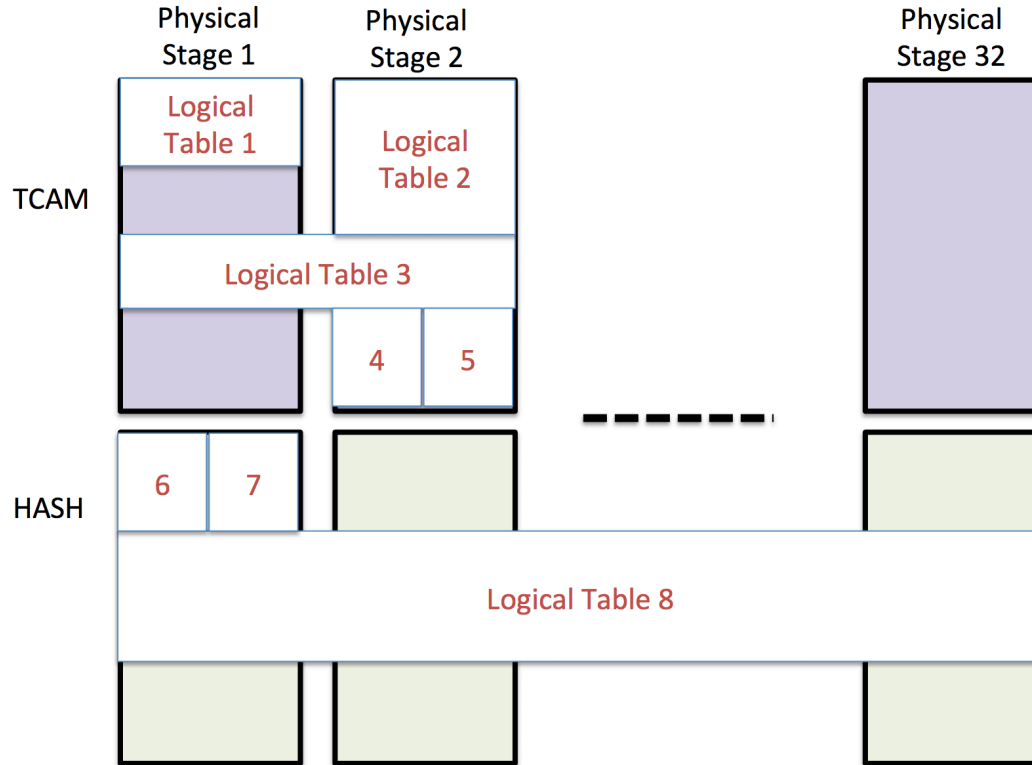
OpenFlow Chip

- ⦿ 64 x10GE OpenFlow-optimized ASIC
- ⦿ Industry-standard 28nm design process
- ⦿ Parse existing + custom packet headers
- ⦿ 32 stages of match-action
- ⦿ Large tables (1M x 40b TCAM, 370 Mb SRAM)
- ⦿ VLIW Action processing

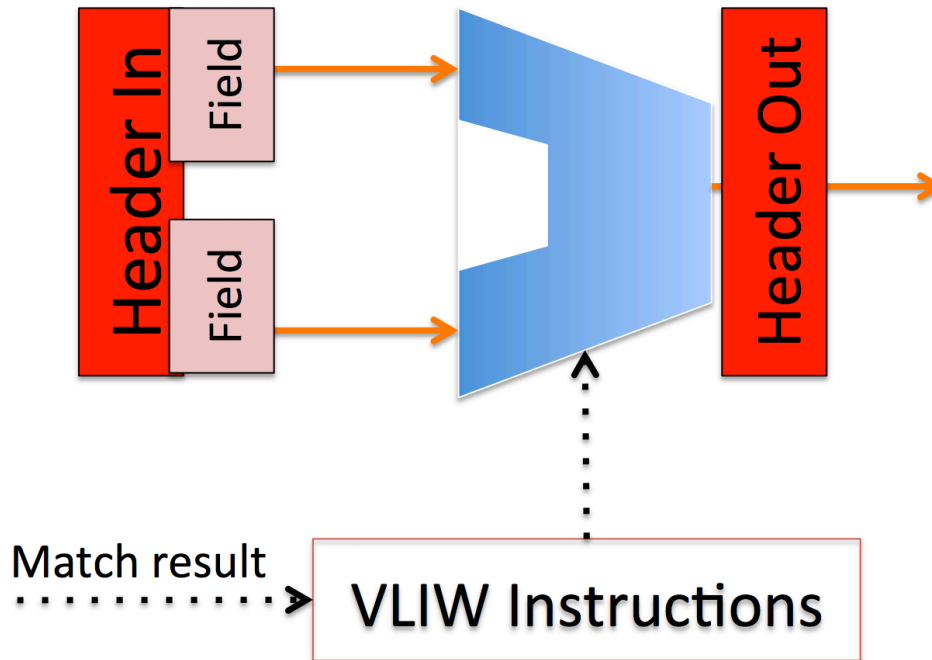
RISC-Like Architecture



Flexible Match Tables

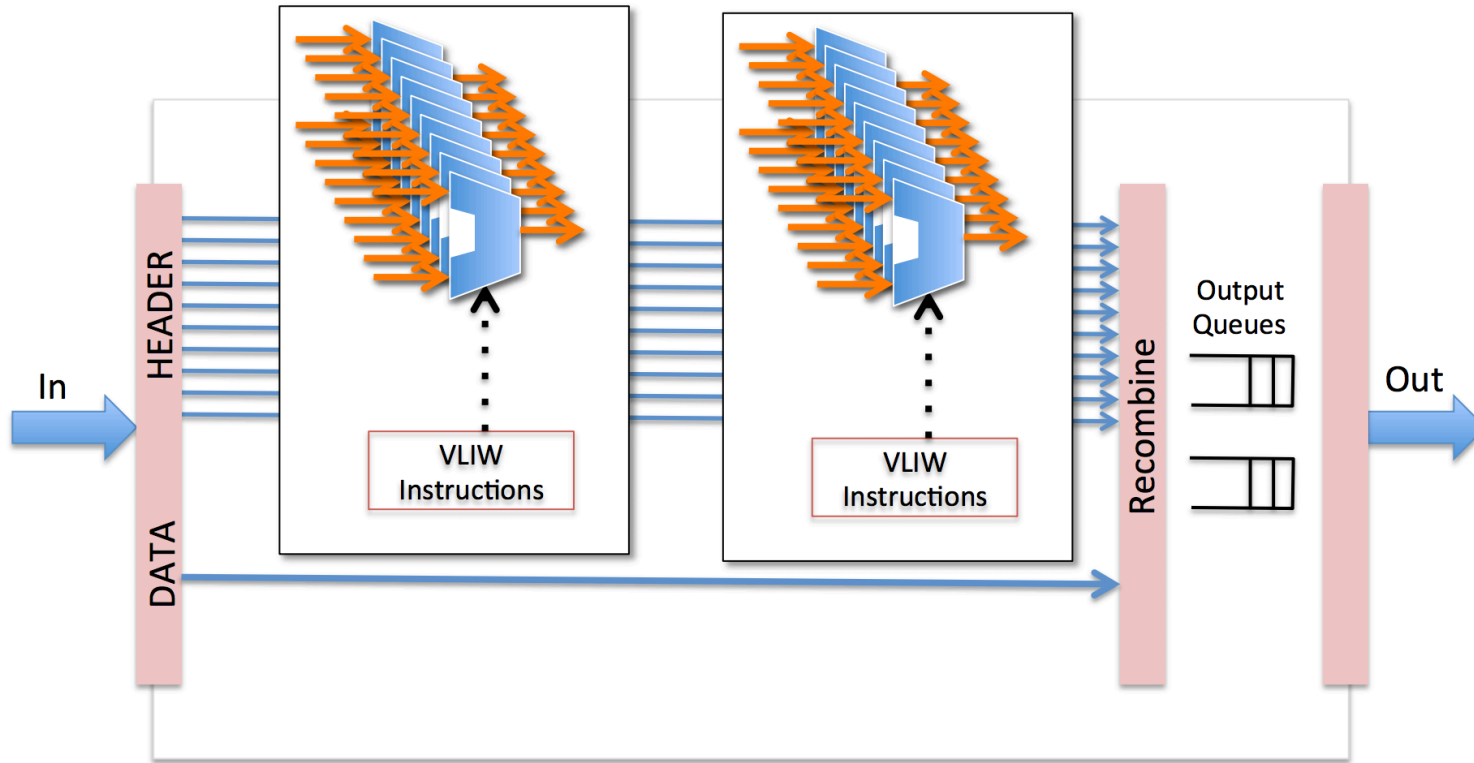


Action Processor



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Actions Built into Stages



Two Examples of Modular Programmable Hardware Data Planes

⦿ An “OpenFlow Chip”

- Generalizable, programmable match-action primitives

⦿ SwitchBlade

- Programmable, modularizable FPGA-based data plane

SwitchBlade: Main Idea

- ⦿ Identify **modular hardware building blocks** that implement a variety of data-plane functions
- ⦿ Allow a developer to **enable and connect various building blocks in a hardware pipeline** from software
- ⦿ Allow multiple custom data planes to operate **in parallel** on the same hardware

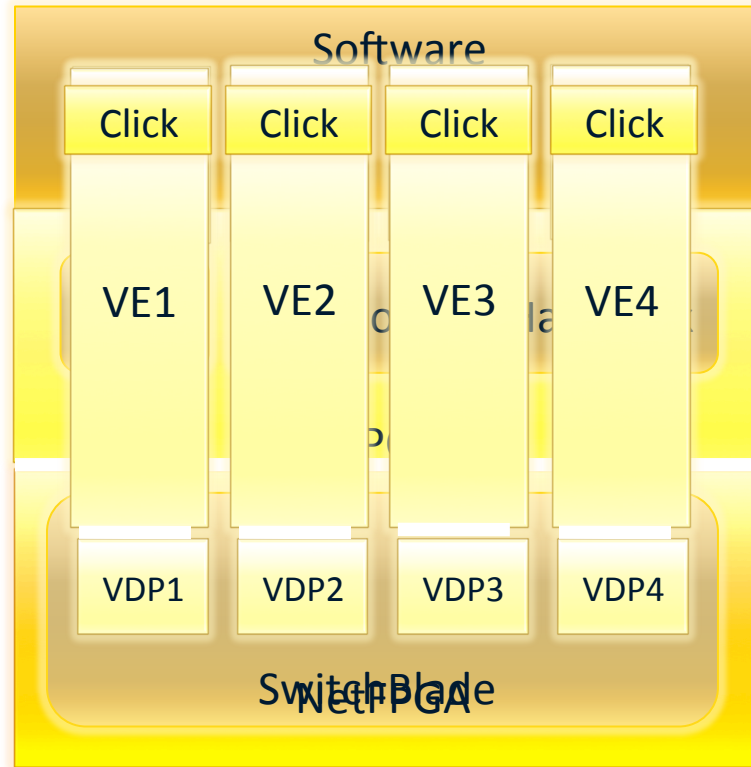
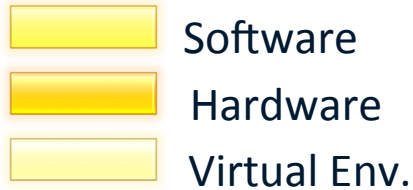
Flexible, fast, and easy to program.

Advantages of hardware and software with minimal overhead.

Anwer, Muhammad Bilal, et al. "Switchblade: a platform for rapid deployment of network protocols on programmable hardware." *ACM SIGCOMM Computer Communication Review* 40.4 (2010): 183-194.

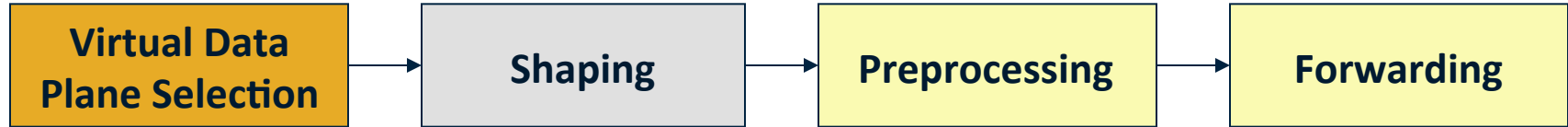
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SwitchBlade: Push Custom Forwarding Planes into Hardware



VDP = Virtual Data Plane
Click = Click Software Router
VE = Virtual Environment

Virtual Data Planes (VDPs)

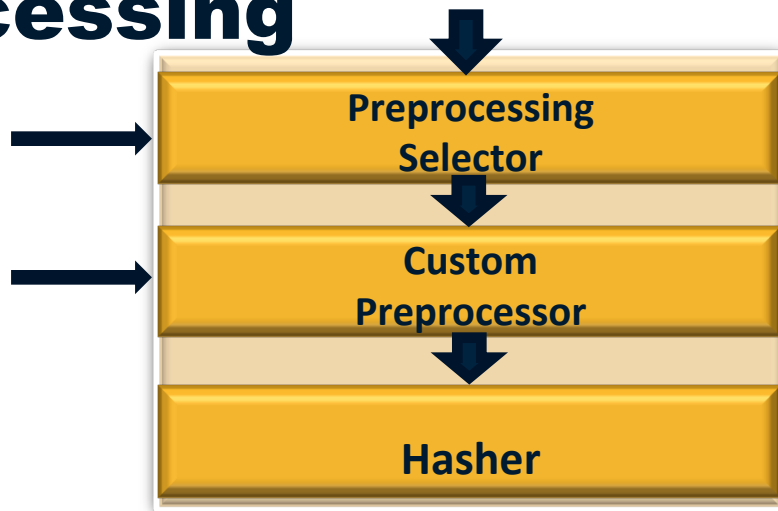


- ⦿ Separate packet processing pipeline, lookup tables, and forwarding modules per VDP
- ⦿ Stored table maps MAC address to VDP identifier
- ⦿ VDP Selection step
 - Identifies VDP based on MAC address
 - Attaches 64-bit *platform header* that controls functions in later stages
 - Register interface controls this header per VDP

SwitchBlade Features

- ◎ Parallel custom data planes
 - Ability to **demultiplex** into existing data planes and maintain **isolation** on common hardware platform.
- ◎ Rapid development and deployment
 - **Pluggable preprocessor** modules to enable a range of customizable functions at hardware rates.
- ◎ Customizability and programmability
 - Dynamic **selection of modules**, and ability to operate in several different **forwarding modes**.

Preprocessing



- ⊙ Select processing functions from **library of reusable modules**
 - Fast customization without resynthesis
 - Example implementations: Path Splicing, IPv6, OpenFlow
- ⊙ **Hash custom bits in packet header** and insert value in *hash* field in platform header
 - Enables custom forwarding

Example: OpenFlow

- Limited implementation (no VLANs, wildcards)
- Preprocessing Steps
 - Parse packet and extracts relevant tuples
 - 240-bit OpenFlow “bitstream” passed to **hasher** module in the preprocessor
 - Hasher outputs 32-bit hash value on which custom forwarding could take place
 - **Mode field** set to perform *exact match*

Adding New Modules

- ⦿ Adding a new module at any stage requires Verilog programming
- ⦿ User writes preprocessing (and postprocessing) modules to extract the bits used for lookup
- ⦿ Resynthesize hardware
- ⦿ Enable module from register interface in software

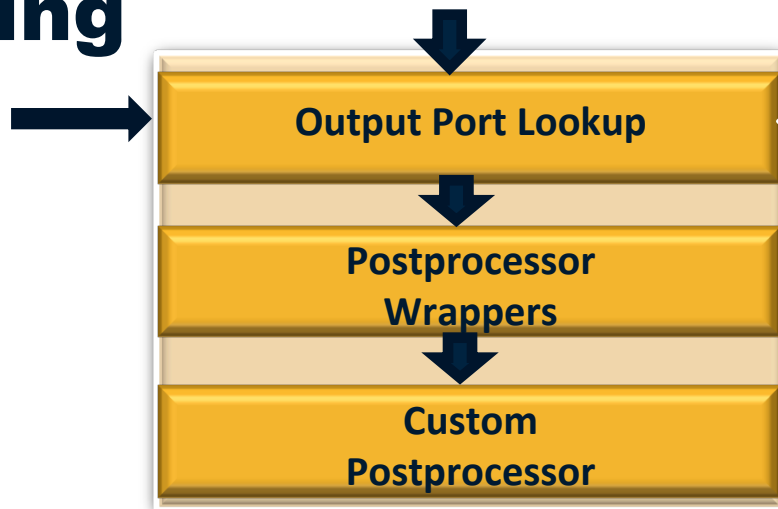
Virtual Data
Plane Selection

Shaping

Preprocessing

Forwarding

Forwarding

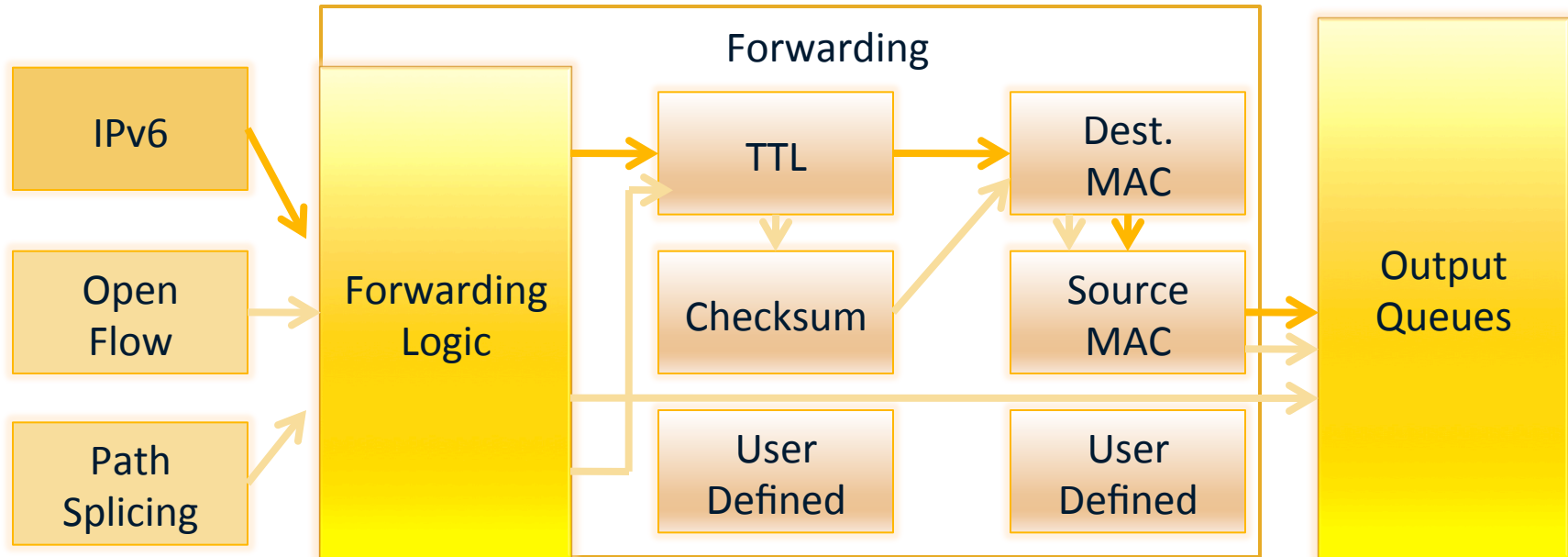


- **Output port lookup** performs custom forwarding depending on the mode bits in the platform header
- **Wrapper modules** allow matching on custom bit offsets
- **Custom post processors** allow other functions to be enabled/disabled on the fly

Software Exceptions

- ⦿ Ability to redirect some packets to CPU
- ⦿ Packets are passed with VDP (and platform header), to allow for VDP-based software exceptions

Custom Postprocessing Paths



Summary

- ⦿ **Scalability: Make hardware programmable**
- ⦿ Insight: Optimize a few primitives, provide composition
- ⦿ OpenFlow Chip: Extreme flexibility, 15%+ area
- ⦿ SwitchBlade: Programmable hardware, customizable data planes