Software-Based Networks: Leveraging high-performance NFV platforms to meet future communication challenges

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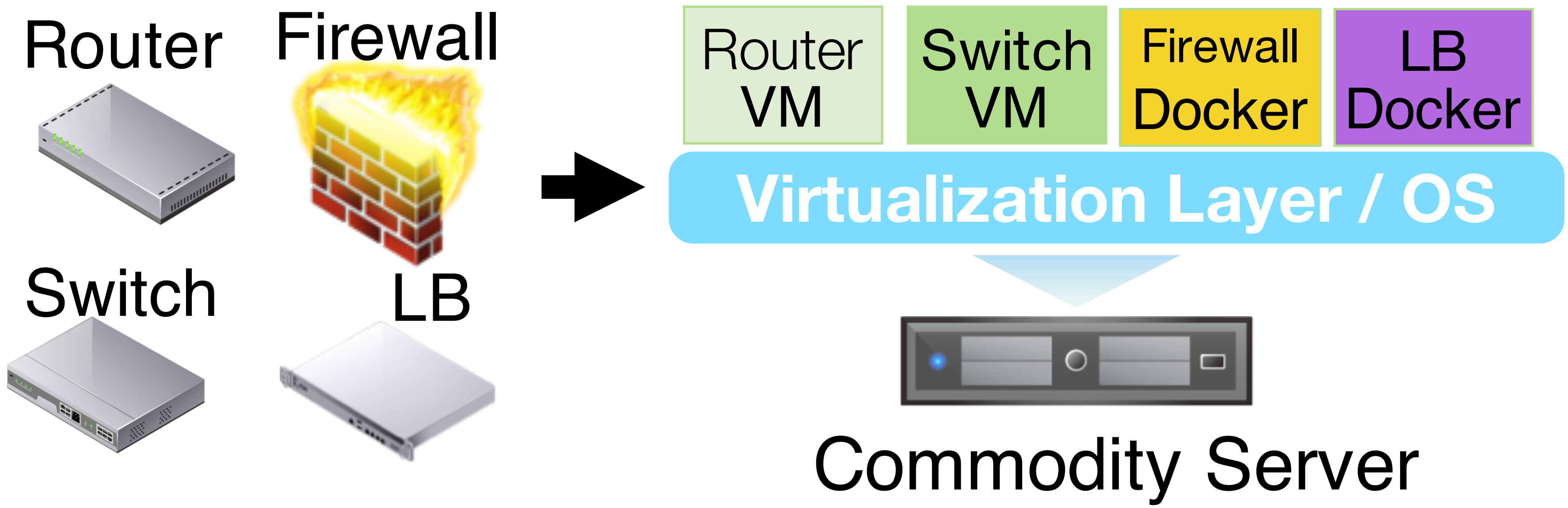
Joint work with: Timothy Wood (GWU) , our students, collaborators

Network Function Virtualization

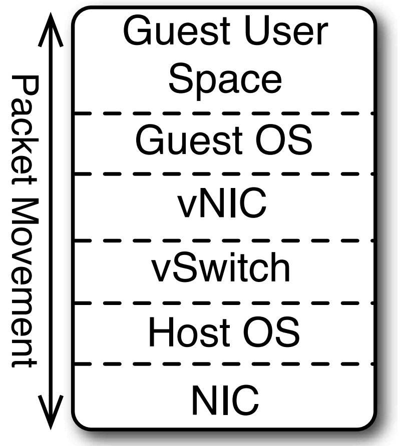
- Run network functions in software



- More flexible than hardware
  - Easy to instantiate new NFs
  - Easy to deploy NFs; Easier to manage NFs
- Network Service Providers are migrating towards a software based networking infrastructure

Virtualization Overheads

- **Virtualization layer** provides (resource and performance) isolation among virtual machines
- **Isolation** involves many functions such as access permissions (security), ability to schedule and share etc.
- **Network overhead** (packet delivery) is one of the most critical concerns
- A generic virtualization architecture includes several critical boundaries – host OS, virtual NIC, guest OS, and guest user space–getting packet data there includes **memory copies**



Jinho Hwang, K.K. Ramakrishnan, and Timothy Wood, "NetVM: High Performance and Flexible Networking using Virtualization on Commodity Platforms," NSDI '14.

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Our Contributions with NetVM

1. **A virtualization-based high-speed packet delivery platform**

   - for flexible network service deployment that can meet the performance of customized hardware, especially when involving complex packet processing

2. **Network shared-memory framework**

   - that truly exploits the DPDK (data plane development kit) library to provide zero-copy delivery to VMs and between VMs (containers)

3. **A hypervisor-based switching algorithm**

   - that can dynamically adjust a flow's destination in a state-dependent and/or data-dependent manner

4. **High speed inter-VM communication**

   - enabling complex network services to be spread across multiple VMs

5. **Security domains**

   - that restrict access of packet data to only trusted VMs

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OpenNetVM – NFV Open Source Platform

http://sdnfv.github.io

- Network Functions run in Docker containers
- DPDK based design, to achieve zero-copy, high-speed I/O
  - Key: Shared memory across NFs and NF Manager
- Created an open source version
- Multiple industrial partners evaluating use of OpenNetVM
  - Of course, there are many competitors (e.g., Fast Data Project (fd.io), etc.)

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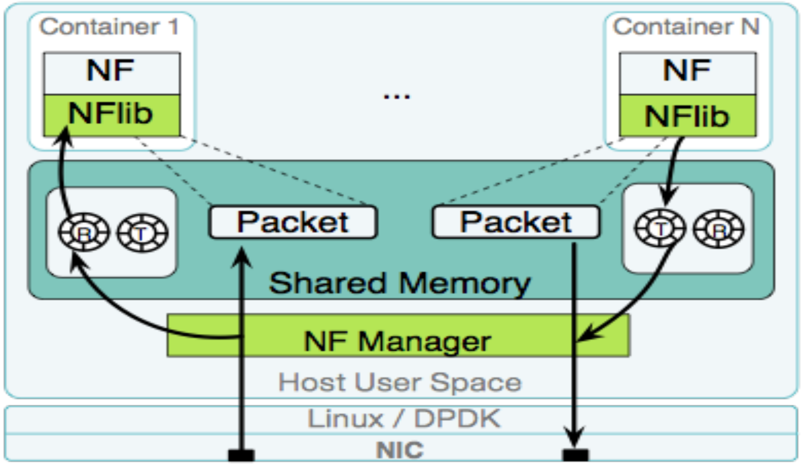
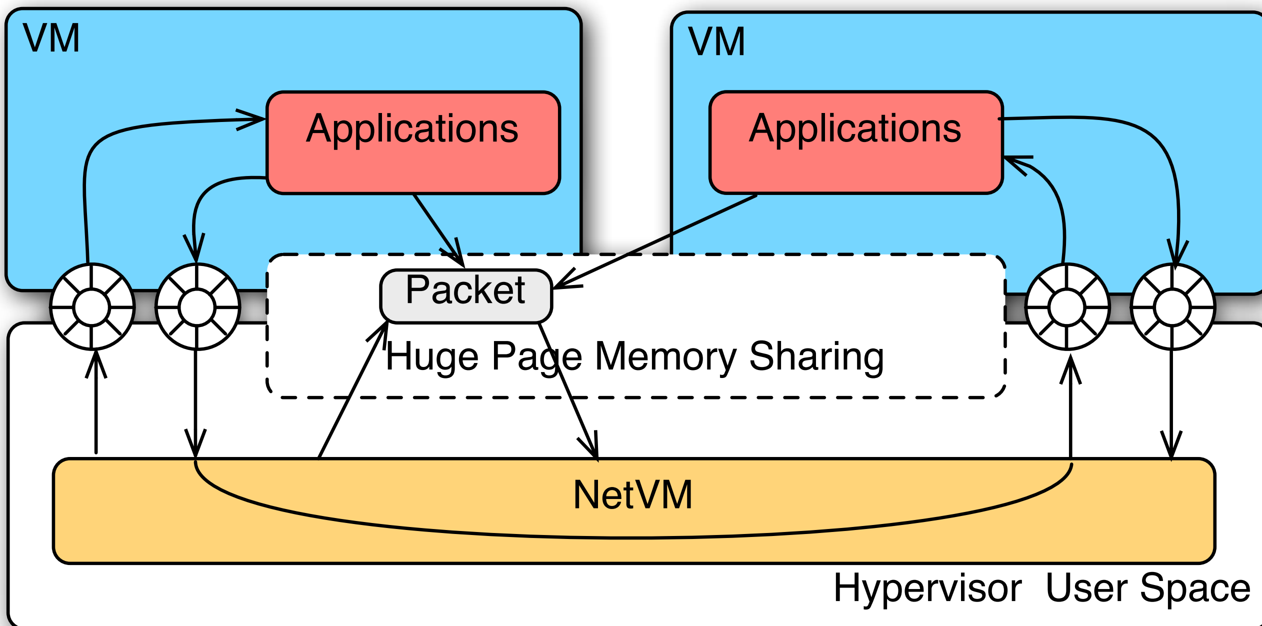
OpenNetVM Architecture



- **NF Manager** (with DPDK) runs in host's User Space
- **NFs** run inside Docker containers
  - **NUMA-aware** processing
  - **Zero-copy** data transfer to and between NFs
  - **No Interrupts** using DPDK poll-mode driver
  - **Scalable** RX and TX threads in manager
  - Each NF has its own ring to receive/transmit a packet descriptor
  - NFs start in 0.5 seconds; throughput of 68 Gbps w/ 6 cores

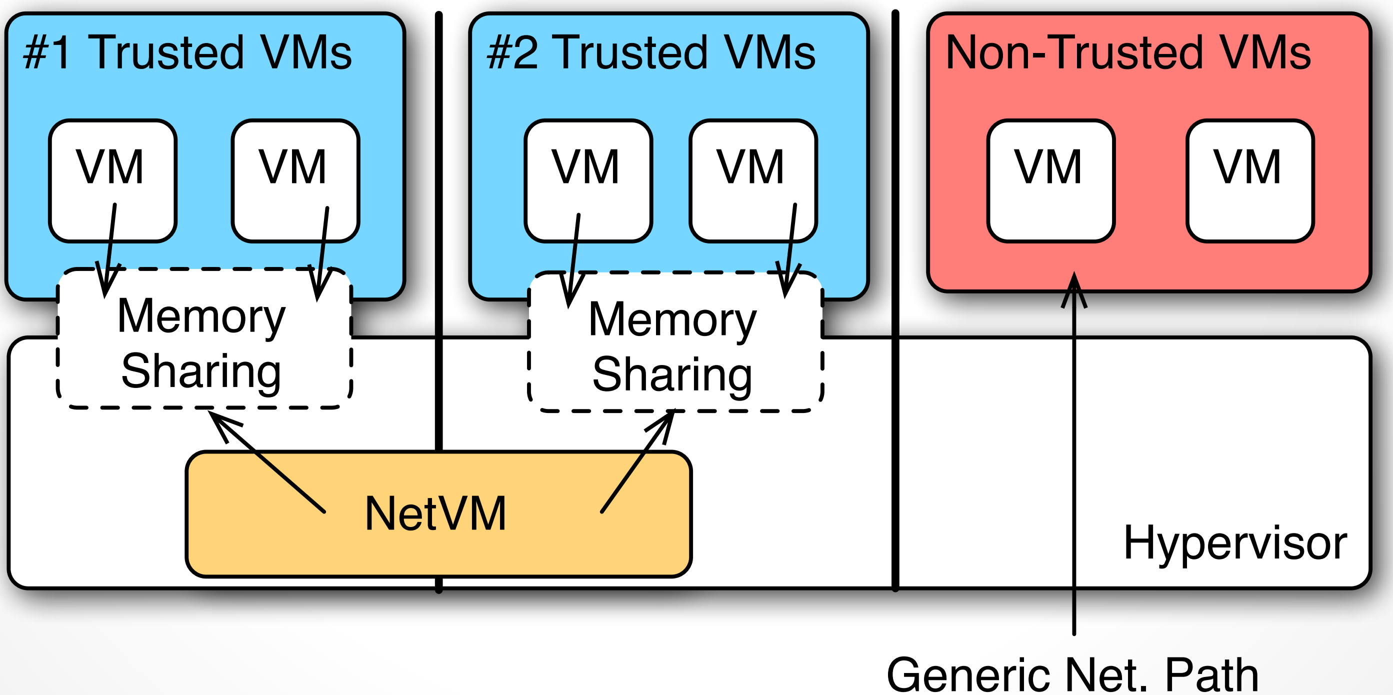
Chained Packet Delivery

- Packets in memory do not have to be copied
- Applications in containers pass packet references to other NFs – through the descriptor ring
- Only one application can access a given packet at any time for writing – avoid locks



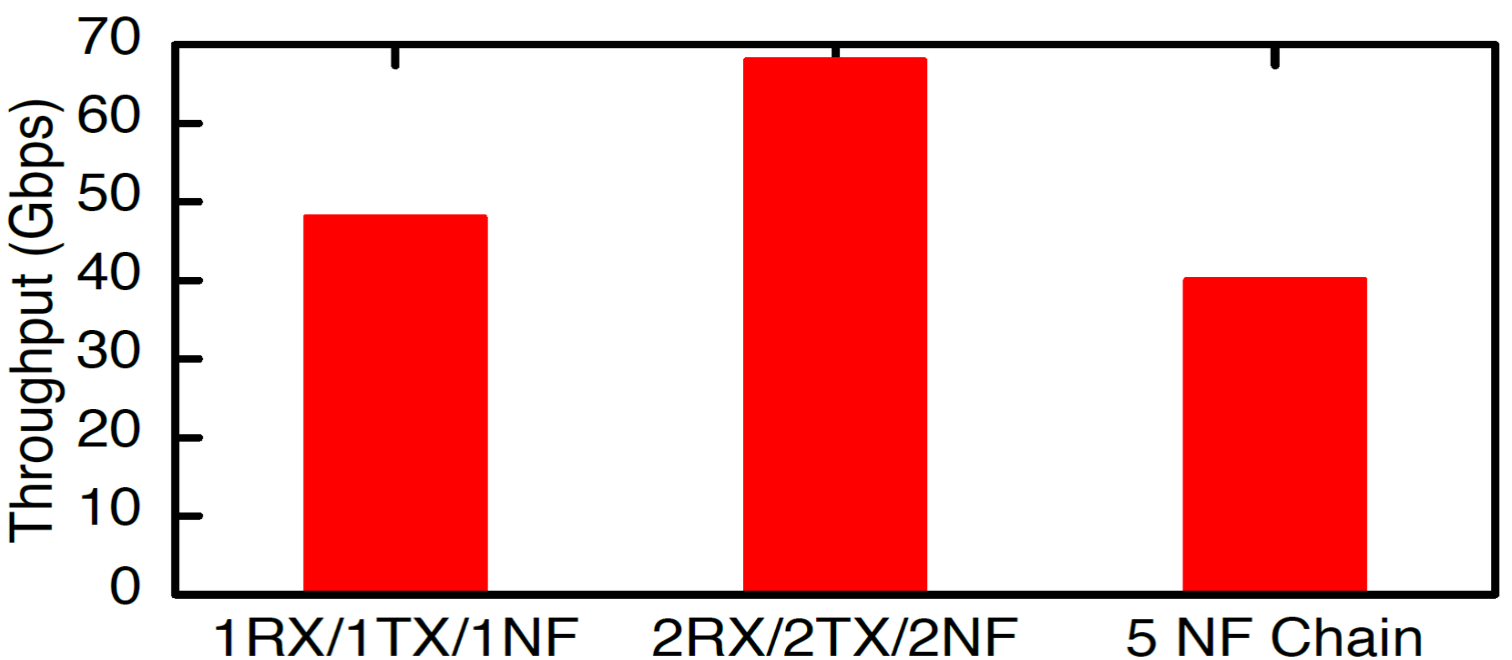
Trusted and Untrusted Domains

- Virtualization should provide security guarantees among VMs
- OpenNetVM provides a security boundary between trusted and untrusted NFs
- Untrusted NFs cannot see packets from OpenNetVM
- Grouping of trusted NFs via huge page separation



Performance w/ Real Traffic

- Send HTTP traffic through OpenNetVM
  - 1 RX thread, 1 TX thread, 1 NF = 48Gbps
  - 2 RX threads, 2 TX threads, 2 NFs = 68Gbps (NIC bottleneck?)
  - 2 RX threads, 5 TX threads, chain of 5 NFs = 38Gbps
- Fast enough to run a software-based core router; Middleboxes that function as a ‘bump-in-the-wire’



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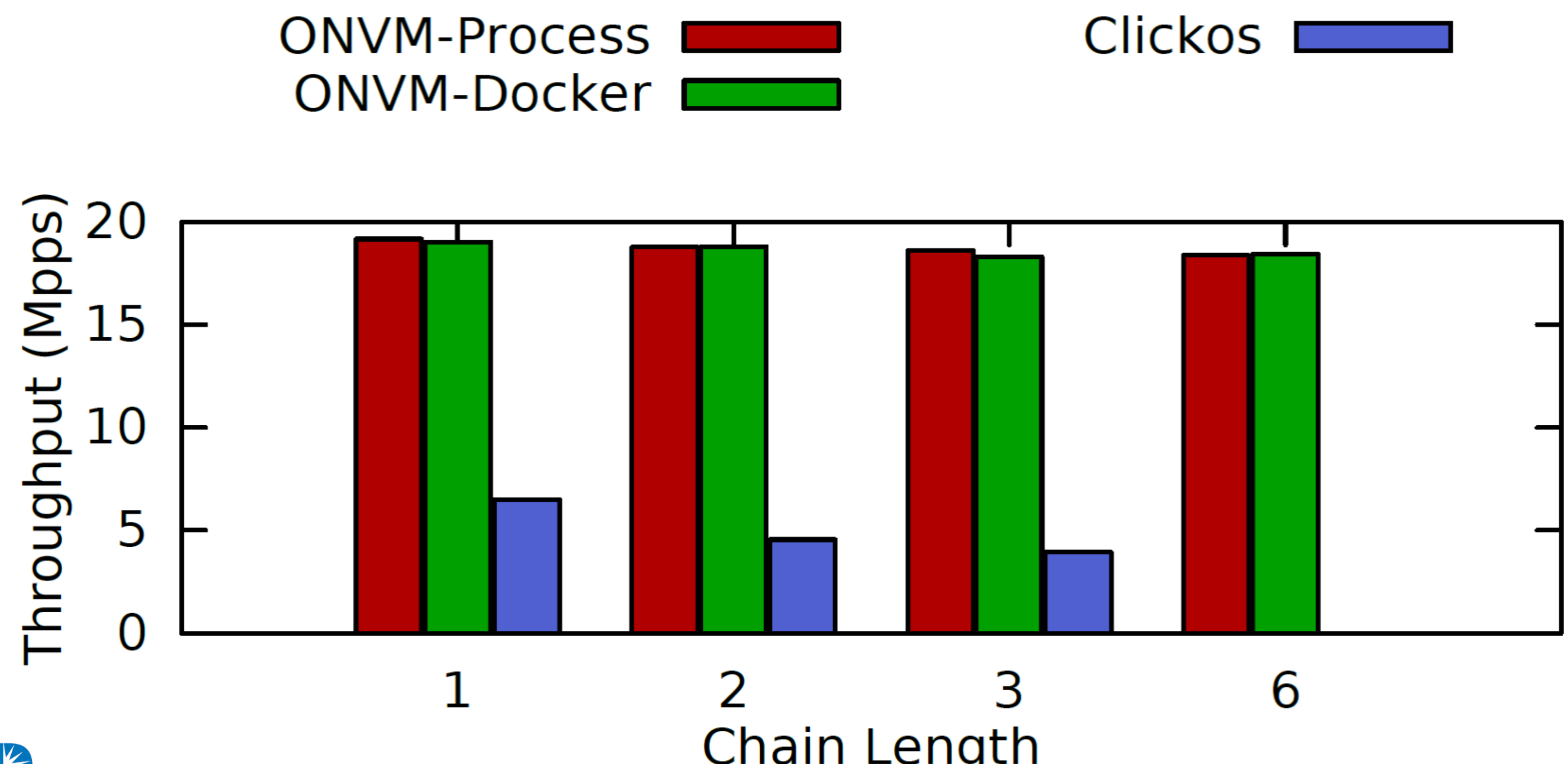
Service Chain Performance

- Negligible performance difference between processes and containers.
  - OpenNetVM sees only a 4% drop in throughput for a six NF chain, while ClickOS falls by 39% with a chain of three NFs.



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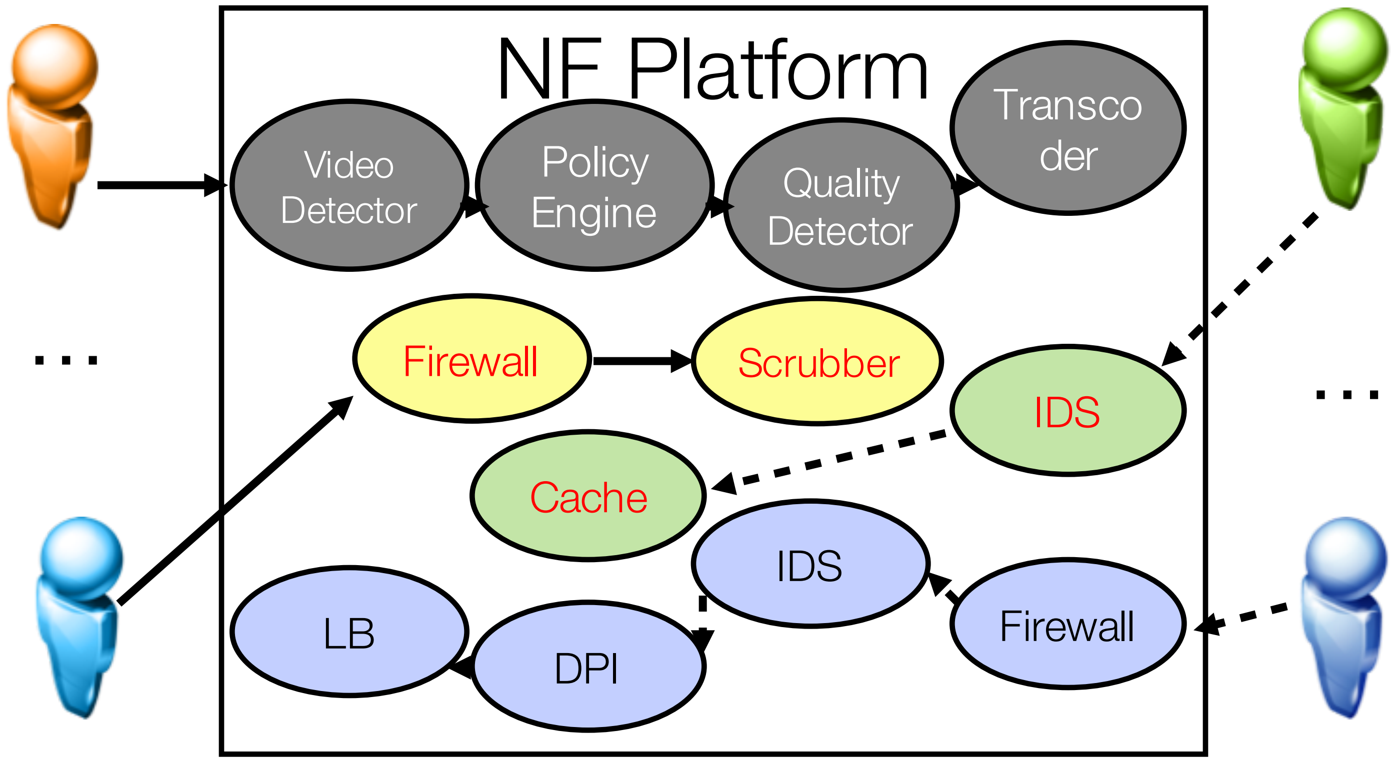
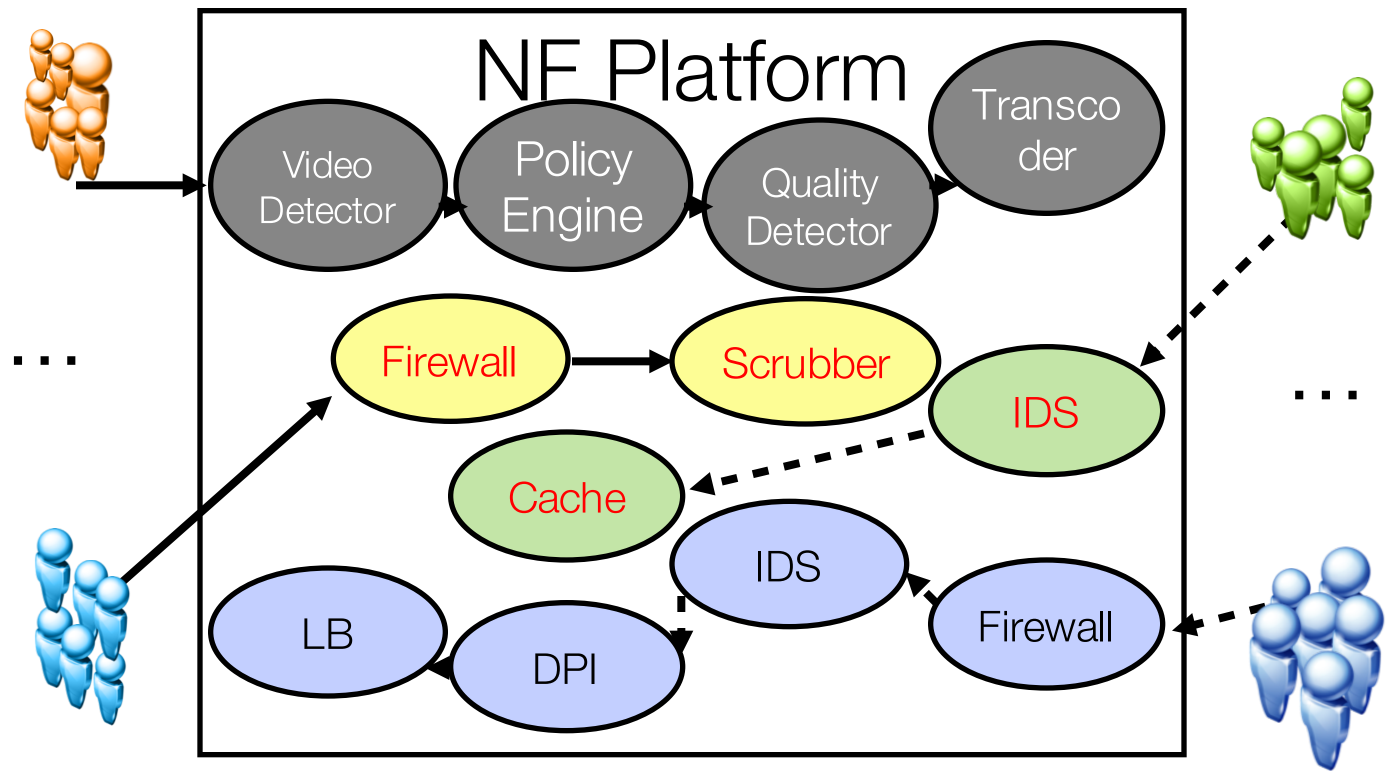
Service Diversity & Multiple Flows

- A typical NF platform may host NFs for many different service chains
- Each flow may need customized services



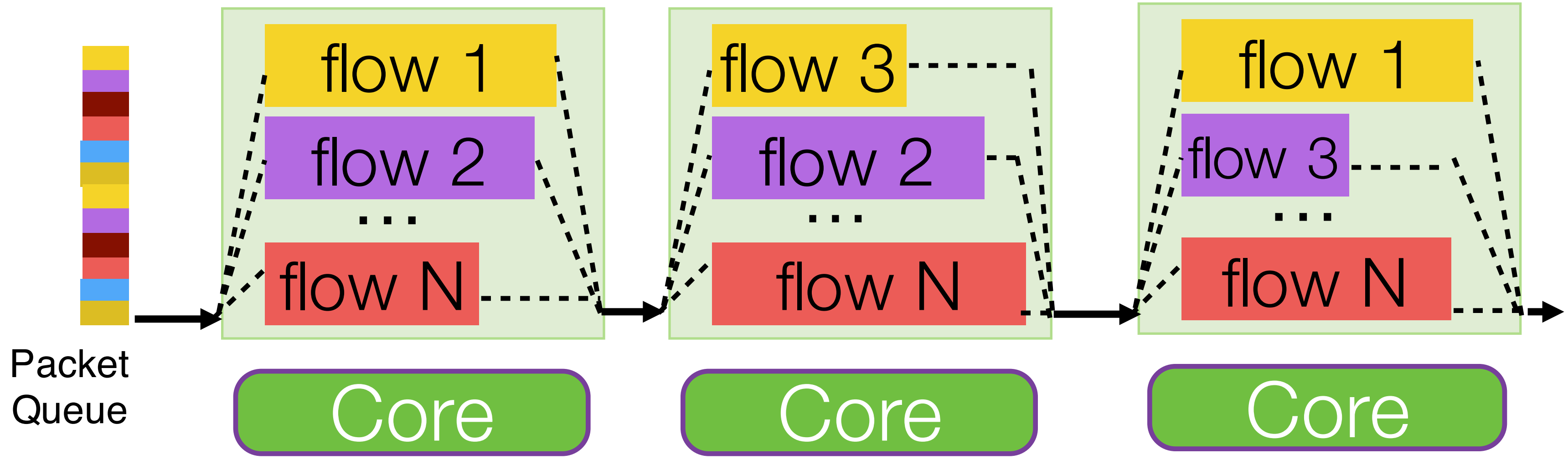
Service Diversity & Multi-Flows

- NF platforms host NFs for many different service chains
- Each flow may need customized services
- Many different flows, each with slightly different need



Monolithic NFs

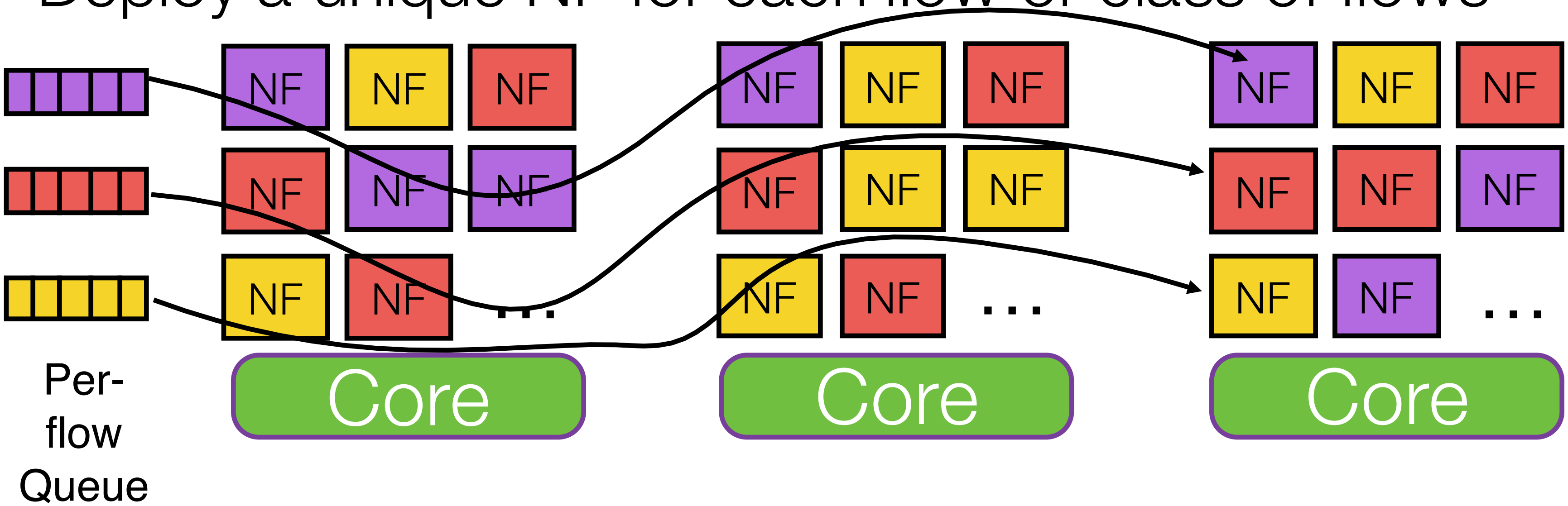
- Multiple flows have to go through an NF
  - Scheduling packets: complex, multiple flows share packet queues
  - NF must classify flows? NF manager?
  - Manage flow interference
  - Scalability: avoid restriction of 1 core per NF



Need a **high speed** platform which can **isolate** and process flows with **fine granularity** *and* **efficiently** use resources

Goal: Per-Flow NFs

- Make the flow the scheduling entity
- Deploy a unique NF for each flow or class of flows



Flurries

- A **scalable** platform for **unique, short-lived** NFs
- (ACM CoNext 2016)
- **Run unique NFs per flow or per class of flows**
- **Benefits:**
  - **do flow-level performance management**
  - **Flexible and customized flow processing**

Flurries

- A **scalable** platform for **unique, short-lived** NFs

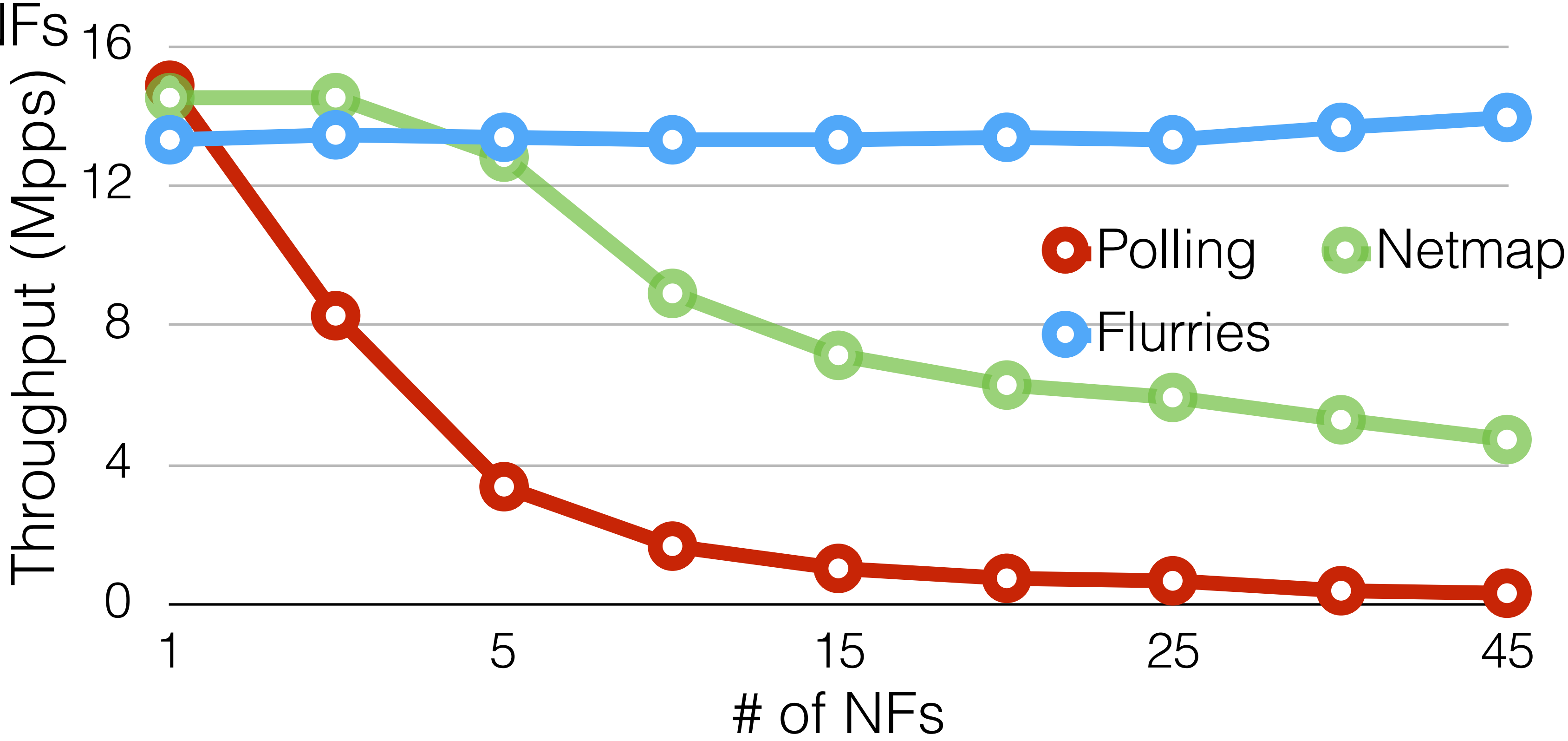
Flurries contributions:

- Hybrid polling and interrupts to efficiently run 1000s of NFs
- Flow director maps flows to NFs; NFlib recycles NFs
- Adaptive wakeup system and prioritized NF scheduling

- Challenges
  - How to move packets efficiently across service chains?
  - How to run large numbers of NFs on a host?
  - How to manage the mapping of flows to NFs?
  - How to schedule NFs?

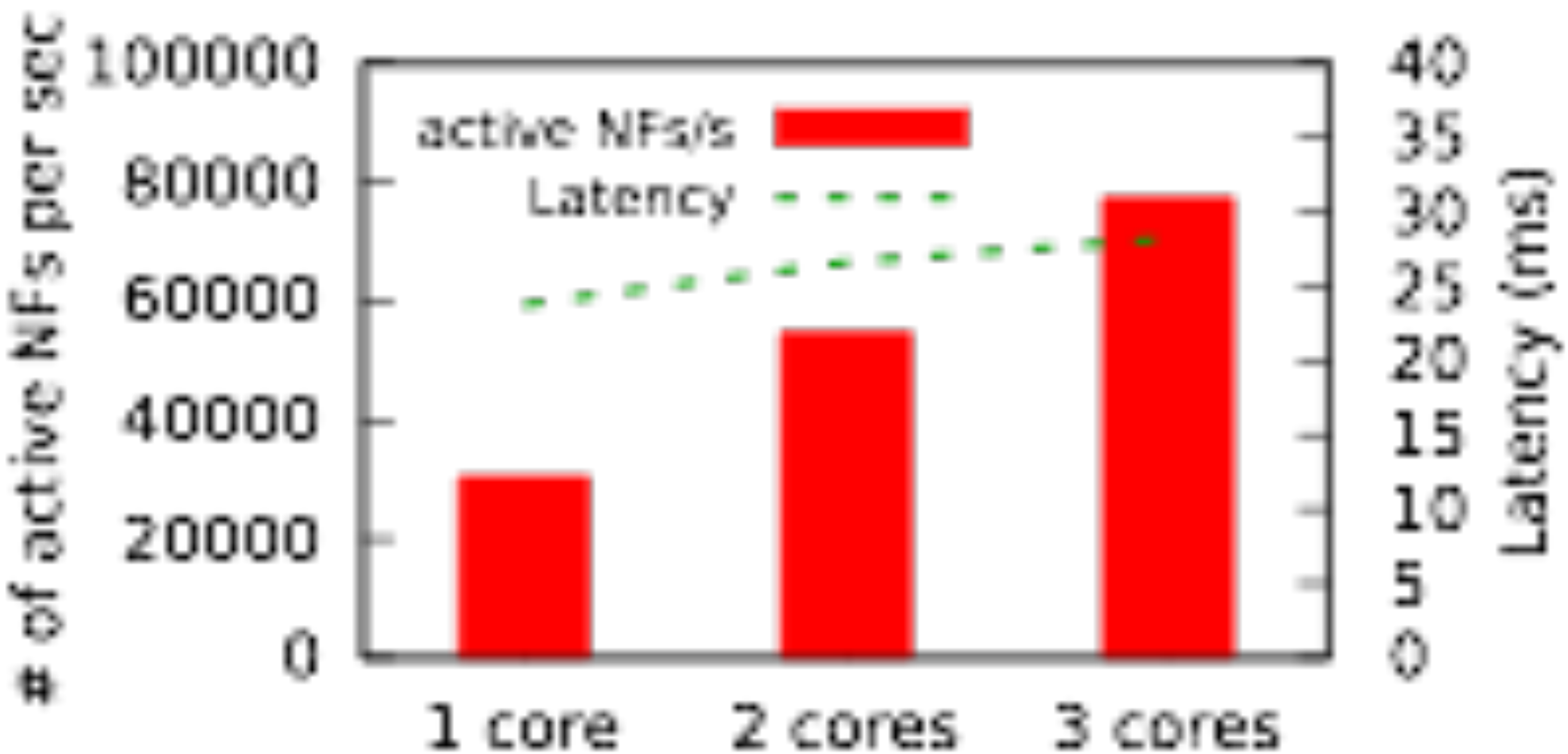
Flurries Performance: Benefit of Hybrid Polling & Interrupts

- Throughput drops as the number of NFs increases on the core for polling and netmap
- Flurries achieves good performance even with large number of NFs



Scale Out

- Run up to 80,000 NFs in a one second interval per host
- Achieve 30Gbps traffic rate and incur minimal added latency to web traffic

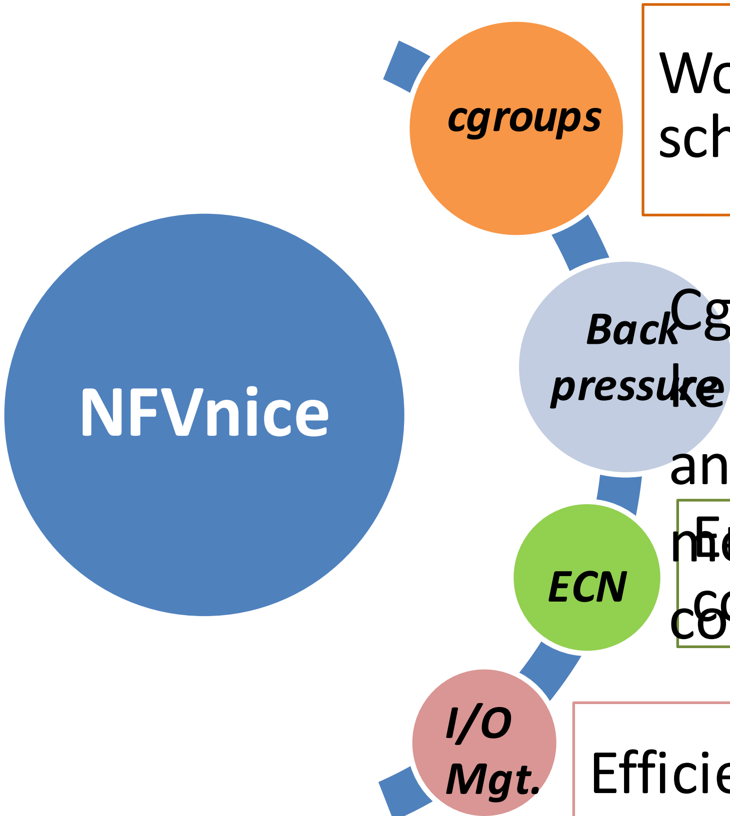


NFVnice

A user space control framework for scheduling NFV chains.
ACM Sigcomm 2017

- NFVnice in a nutshell:
  - Complements the existing kernel task schedulers.
    - Integrates “Rate proportional scheduling” from hardware schedulers.
    - Integrates “Cost Proportional scheduling” from software schedulers.
  - Built on OpenNetVM[HMBox’16, NSDI’14]: *A DPDK based NFV platform.*
    - Enables deployment of containerized (Docker) or process based NFs.
  - Improves NF Throughput, Fairness and CPU Utilization through:
    - Proportional and Fair share of CPU to NFs: ***Tuning Scheduler***.
    - Avoid wasted work and isolate bottlenecks: ***Backpressure***.
    - ***Efficient I/O management*** framework for NFs.

NFVnice: Building Blocks



Work-conserving and proportional scheduling *(within each core)*

Chain-aware scheduling; Avoid wasted work *(within and across cores)*

Cgroups: (control groups) is a Linux kernel feature that limits, accounts for and isolates the resource usage (CPU, memory, disk I/O, network, etc.) of a collection of processes.

End-2-End Bottleneck/congestion control *(across nodes)*

Efficient Disk I/O Mgmt. Library

cgroups

Rate-Cost Proportional Fairness

- **What is Rate-Cost Proportional Fairness?**
  - Determines the NFs CPU share by accounting for both:
    - NF Load (Avg. packet arrival rate, instantaneous queue length)
    - NF Priority and per-packet computation cost (Median)

- **Why?**
  - Efficient and fair allocation of CPU to the contending NFs.
  - *Provides upper bound on the wait/Idle time for each NF.*
  - Flexible & Extensible approach to adapt any QOS policy.

Summary

- Networks are changing – moving to a software base
  - SDN's centralized control
  - NFV's software based implementations
- NetVM/OpenNetVM efforts enhance industry direction
  - NFV platform provides significant performance improvement
  - A more coherent and effective software network architecture

Getting OpenNetVM

- Source code and NSF CloudLab images at

http://sdnfv.github.io/

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