Network Interface Cards

ECE/CS598HPN

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Network Interface Card (NIC)

- Physical layer processing
- Link layer processing
- Direct Memory Access (DMA) for copying data.
- Mechanism to trigger interrupts.

Modern NICs do much more than this

NIC Features: Protocol Offload

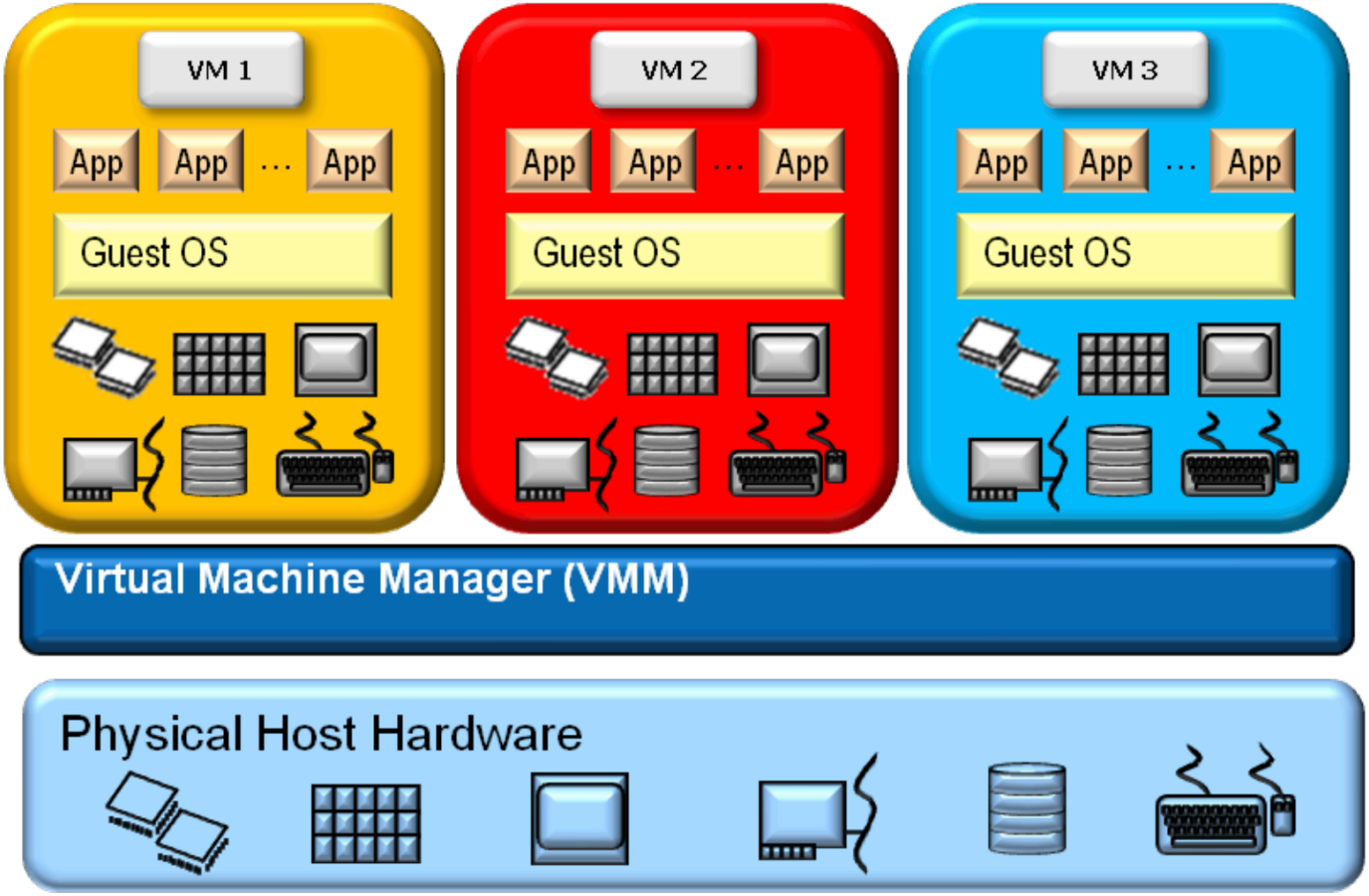
- TCP Segmentation offload
  - Split a large outgoing packet into MTU-sized packets and assign appropriate headers.
- Checksum Offload
  - TCP / UDP / IPv4 checksum computation.
- Large Receive Offload
  - Combine multiple MTU-sized packets for the same connection into a single large packet.

NIC Features: Packet Steering

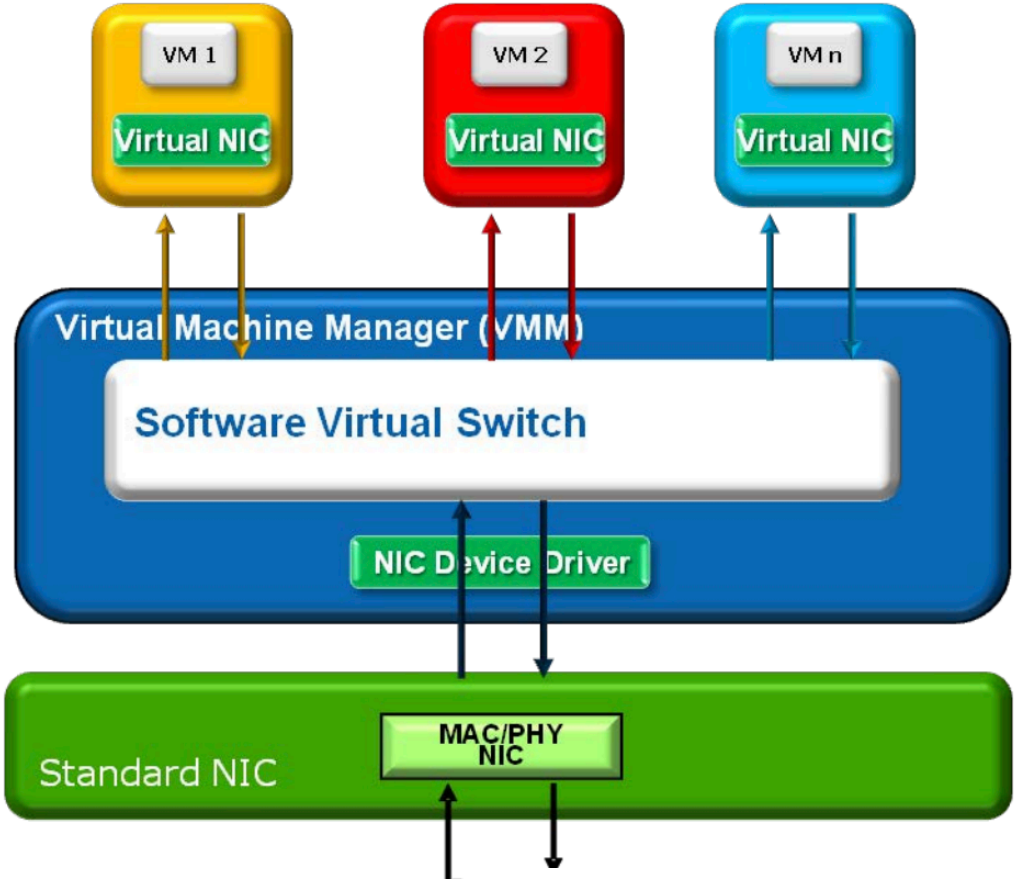
- Receive Side Scaling
  - Load balance incoming packets across different queues.
  - Hash of packet header fields mapped to queue index.
  - Can pick which queue corresponds to which index.

- Flow Director
  - Maintain explicit mapping between packet header fields and queue.
  - Other actions including dropping and incrementing counters.

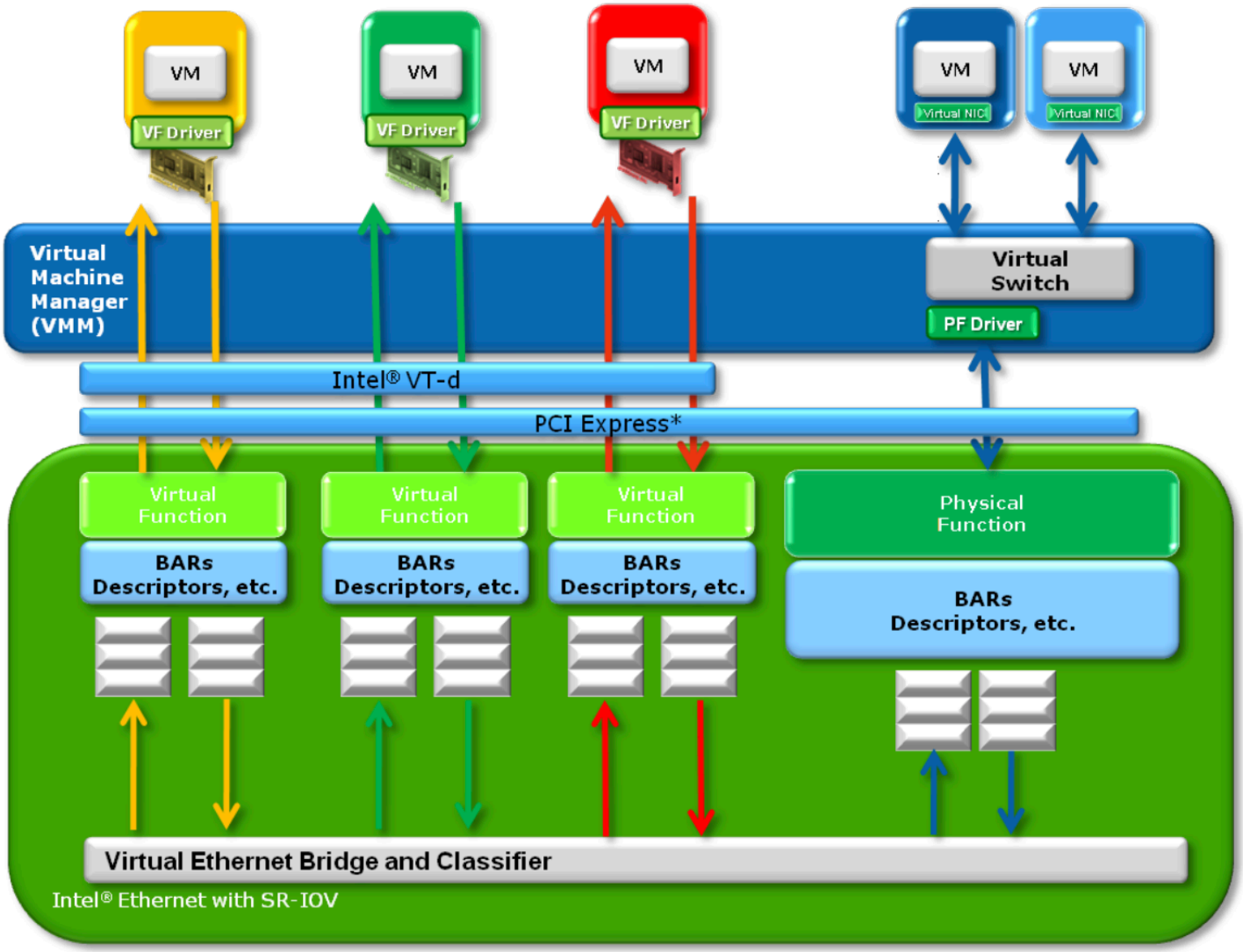
NIC Features: Virtualization



NIC Features: Virtualization

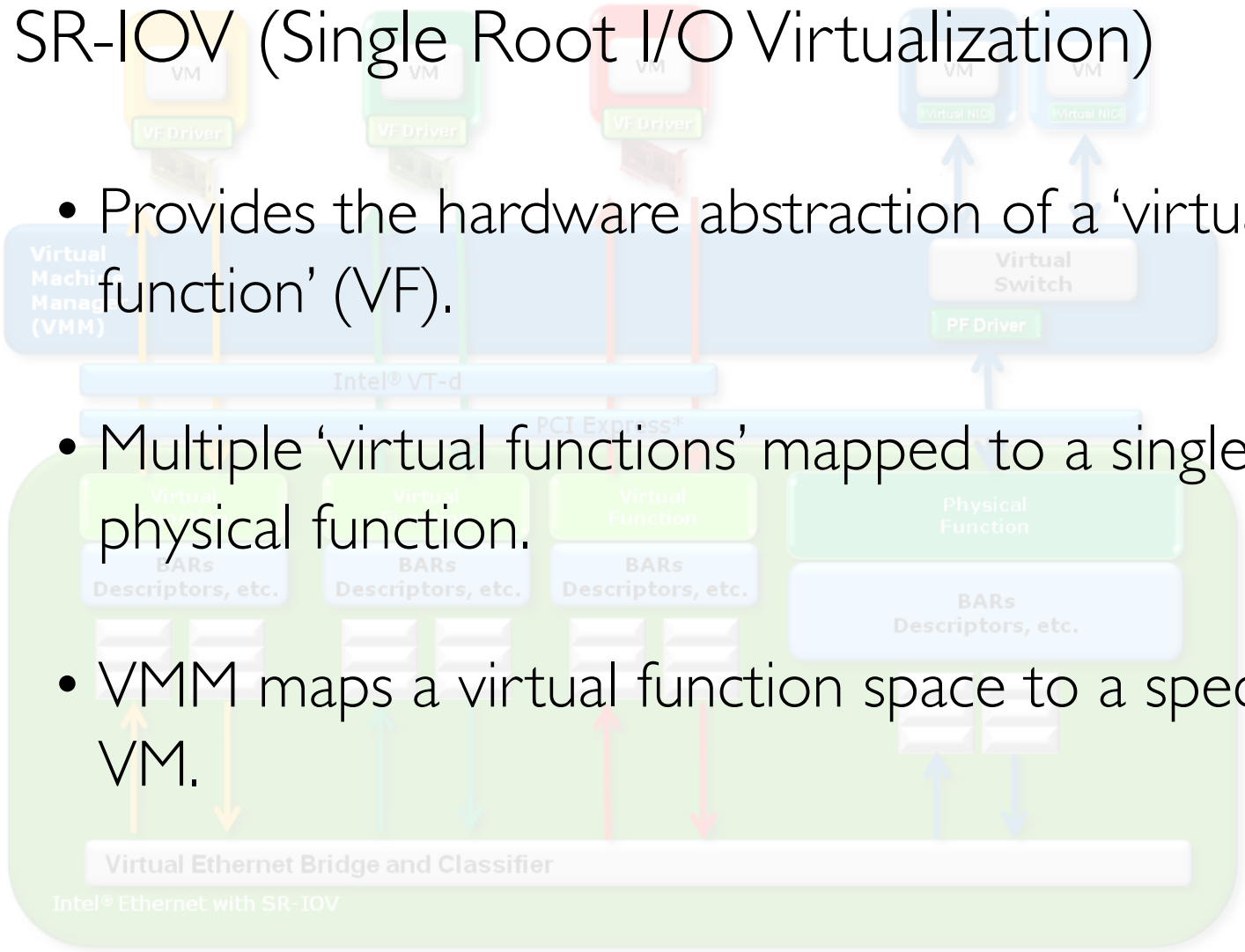


NIC Features: Virtualization



NIC Features: Virtualization

- SR-IOV (Single Root I/O Virtualization)
  - Provides the hardware abstraction of a 'virtual function' (VF).
  - Multiple 'virtual functions' mapped to a single physical function.
  - VMM maps a virtual function space to a specific VM.

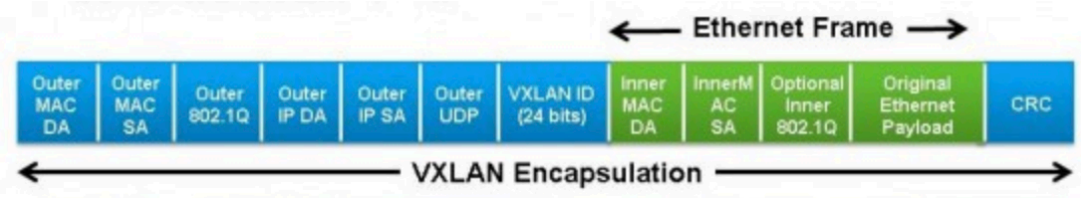


NIC Features: Virtualization

- SR-IOV (Single Root I/O Virtualization)
  - Share a single physical port across multiple VMs.
- VMDq (Virtual Machine Device Queues)
  - Sort packets across VM specific queues based on MAC address and VLAN tags.
- Round-robin across VM queues.

NIC Features: Tunneling

- Examples:
  - VXLAN:



  - NVGRE:

- Offload encapsulation/decapsulation.
- Ability to parse tunneled information.

Limitations

- Lack of flexibility and fine-grained control.
  - E.g. TSO offload can be useless without VXLAN support.
  - Even minor fixes can take years.
- Resource constraints.
  - Limited memory (packet buffers, flow table size, etc).
  - E.g. Flow Director allows only 8K flow entries.

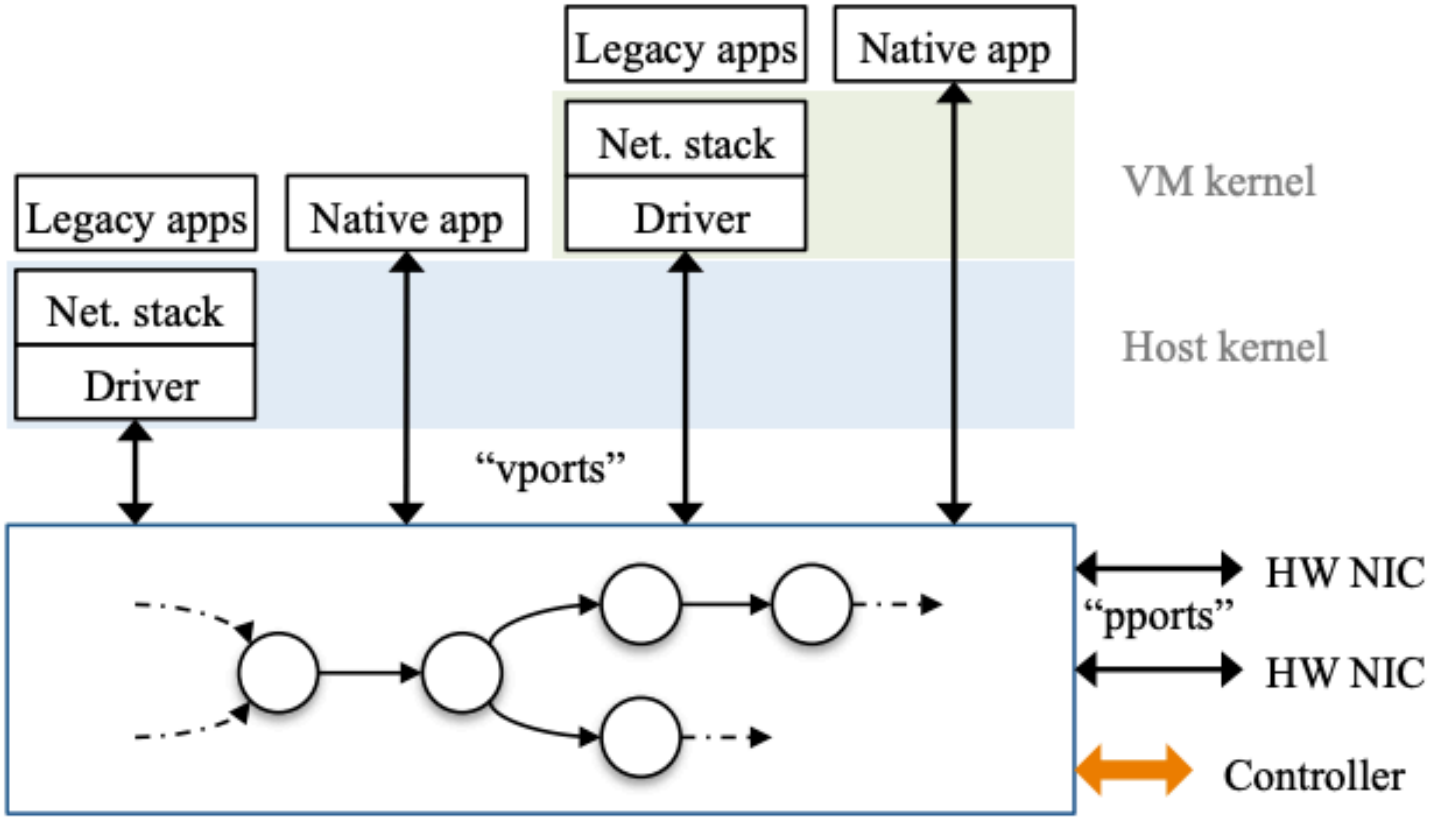
SoftNIC: A Software NIC to Augment Hardware

Sangjin Han, Keon Jang, Aurojit Panda,
Shoumik Palkar, Dongsu Han, Sylvia Ratnasamy

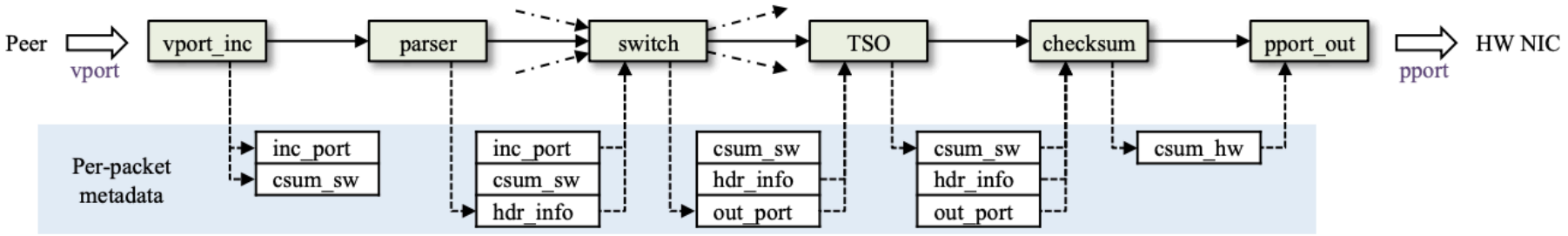
SoftNIC Design Goals

- Programmability and extensibility
- Application performance isolation
- Backwards Compatibility

Architecture

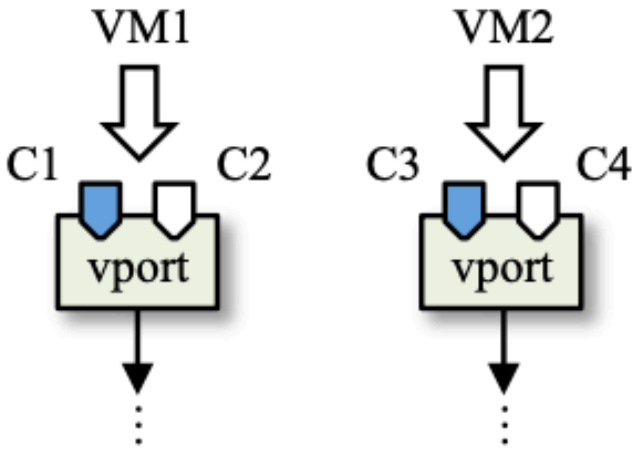


Packet Processing Example

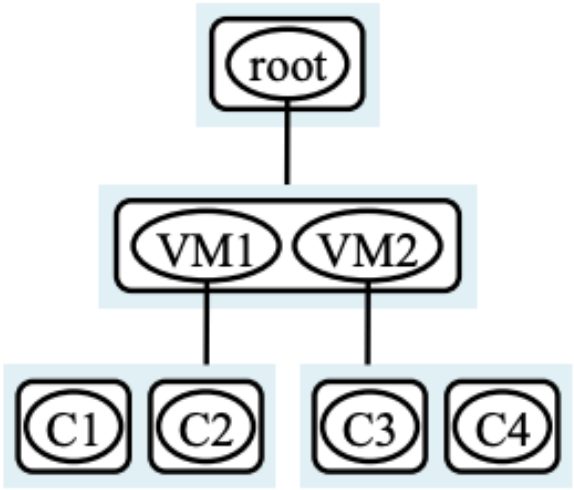


Resource Scheduling

- Allocate both processor and bandwidth resources.



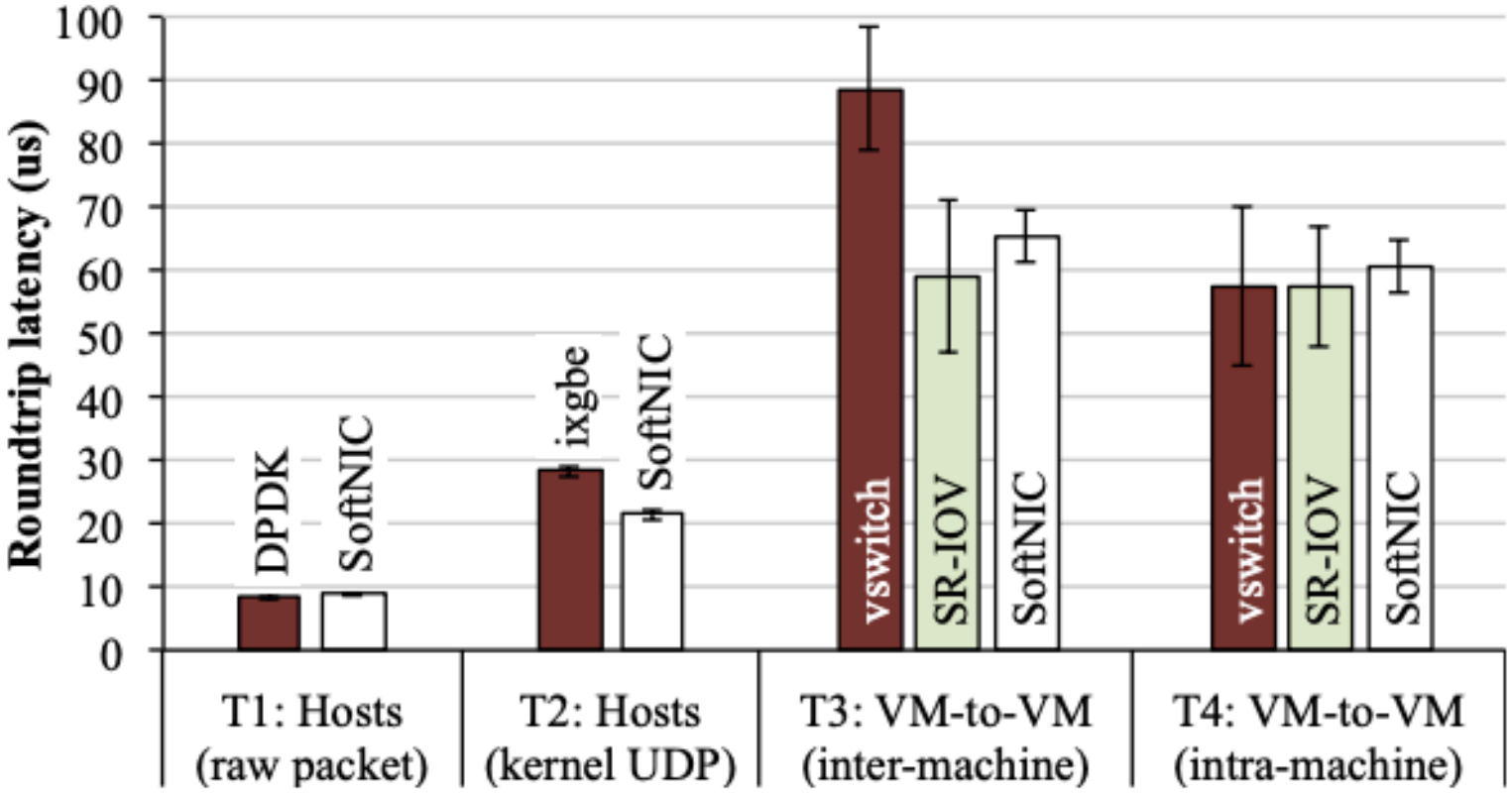
C1, C3: high priority, 1 Gbps
C2, C4: low priority, no limit
Per VM: 5 Gbps limit



Implementation

- Over DPDK.
- Dedicate a small number of cores to SoftNIC.
  - Multi-core scaling achieved by associating each SoftNIC core with different set of queues.
  - Requires peers to ensure packets from same flow go to the same queue.
- Polling to check for packets from vport and pport.
- Batching to amortize software processing overheads.

Evaluation


Roundtrip latency (us)
100
90
80
70
60
50
40
30
20
10
0
DPDK
SoftNIC
ixgbe
SoftNIC
vswitch
SR-IOV
SoftNIC
vswitch
SR-IOV
SoftNIC
T1: Hosts (raw packet)
T2: Hosts (kernel UDP)
T3: VM-to-VM (inter-machine)
T4: VM-to-VM (intra-machine)

Case Studies

- If NICS do not understand tunneling format, cannot support TSO for "inner" TCP frames.

- SoftNIC can be used to augment the TSO/LRO feature in these cases.

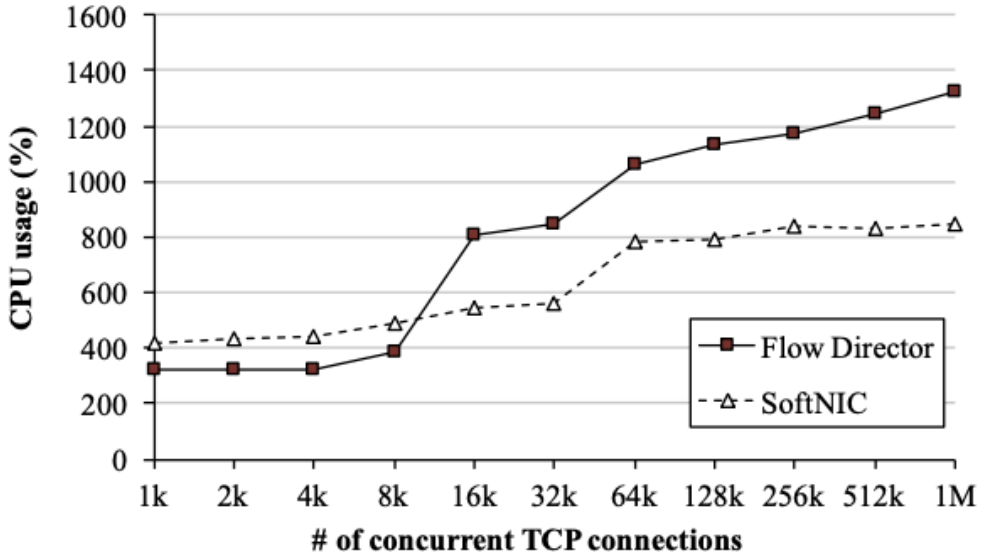
Case Studies

- NIC supports a limited number of "rate-limiters" – few hundreds.
  - There may be thousands of flows.
- SoftNIC can be used to implement a scalable rate limiter.

Case Studies

- Flow Director directs packets with specific header fields to specific queues.
  - Can only support 8K entries.

- SoftNIC can support almost unlimited flow entries using system memory.



Case Studies

- Scaling legacy applications: send packets to different cores based on hash of packet header fields.
- RSS (NIC feature) is too limiting.
- SoftNIC can be used to provide such scaling.

Your Opinions

- Pros:
  - End-to-end latency and throughput is very close to bare metal.
  - Scheduling framework to support a wide range of policies.
  - Better cache utilization and low context-switching overhead by dedicating a small number of cores.
  - Case studies to show how SoftNIC can implement a variety of NIC features.
  - Backwards-compatible.
  - Flexible

Your Opinions

- Cons:
  - What happens as network speed increases further?
  - High CPU usage due to constant polling.
  - Small latency overhead.
  - Users need to define modules and workflow.
  - Comparison with FPGA-based or SoC-based NICs?

Your Opinions

- Ideas:
  - Telemetry in SoftNIC.
  - Use SoftNIC to provide SLOs to VMs/Apps in multi-tenant datacenters.
  - More features/usecases based on hardware-software codesign.
  - Congestion control for pipeline / scheduling.
  - Explore control plane interaction.
  - Comparison with programmable hardware NIC.