Implementing Software Virtual Routers on Multi-core PCs using Click

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Background

- Traditionally, high performance networking devices:
  - -Built as custom hardware
  - -Made of various specialized “CPUs”
  - -Specialized multi-cores

- Software routers
  - - Familiar programming environment
  - - Easily extensible
  - - Cheap
  - - Generic packet processing capability
  - - Run on (slow ?) commodity hardware ?

Background

- But recent advances in commodity HW architectures

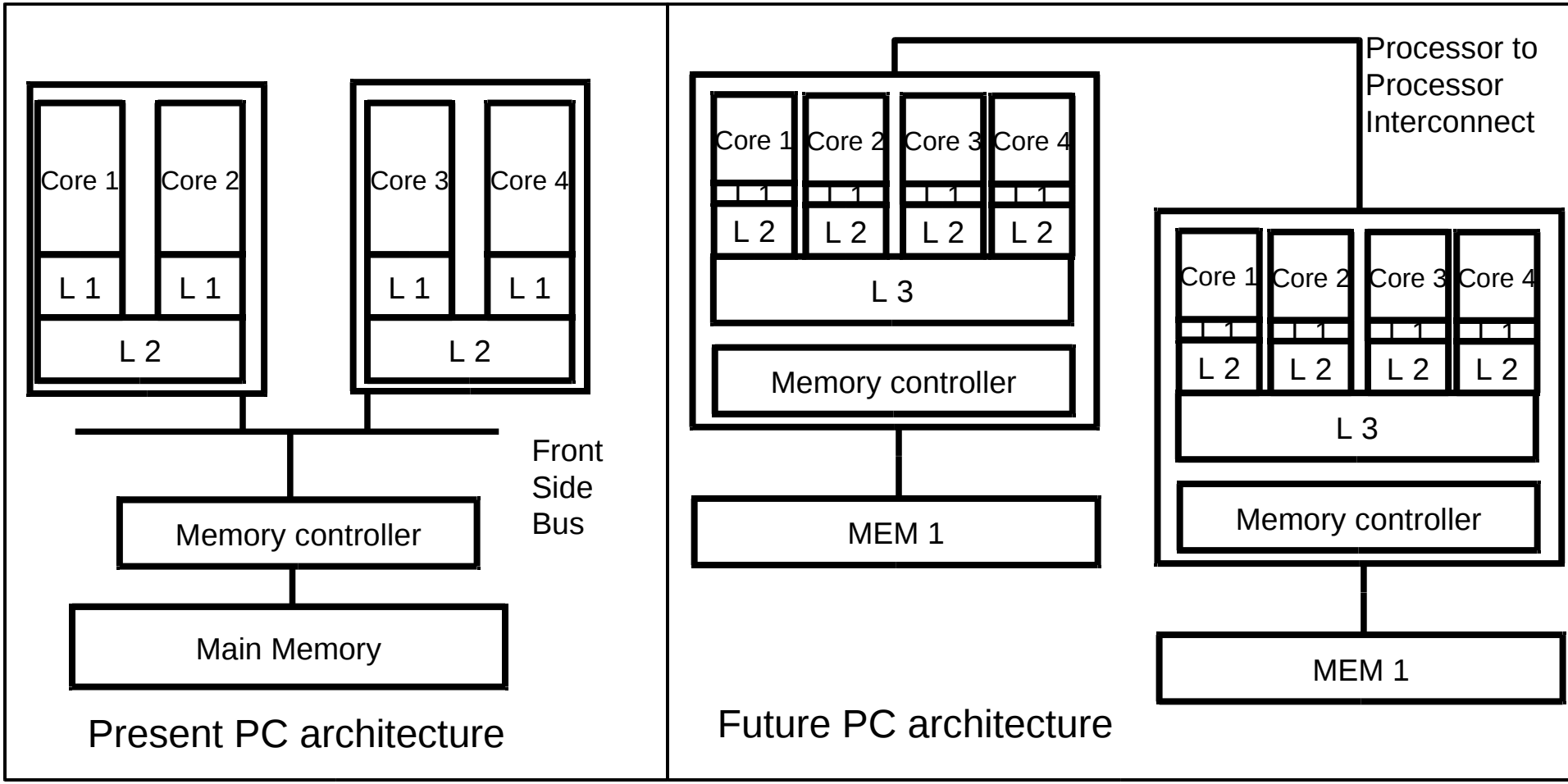
  - Multi-core (With very high clock frequency)

  - Buses (usual bottlenecks) are disappearing

- What about implementing virtual routers with all those available CPU cycles ?

Background

CPU Cache hierarchies



- Memory closer to the CPU: fast and small
- Memory Further from the CPU: slow and big
- Huge memory latency difference between L1 and Main memory (up to a factor 100)

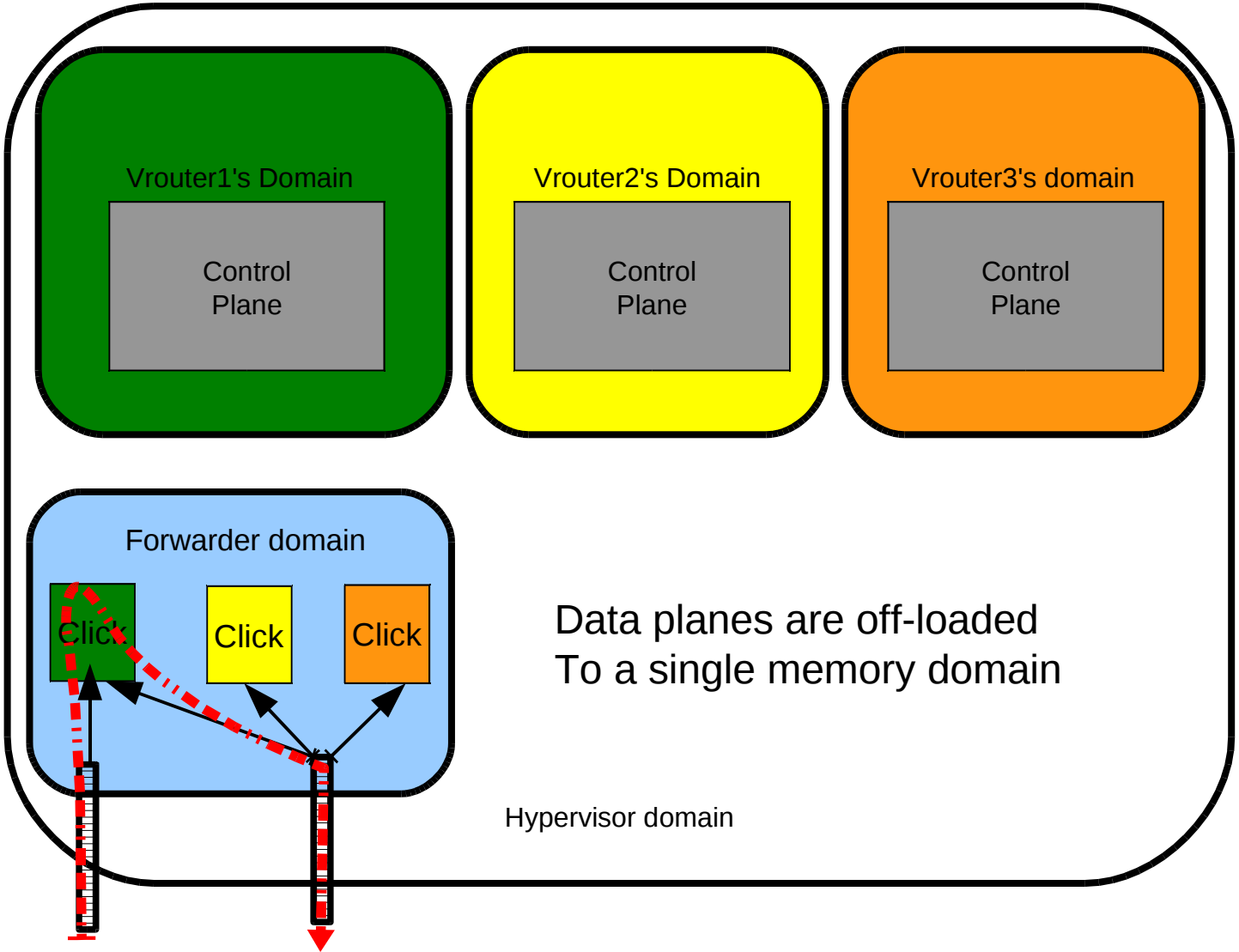
Background

Some numbers :

Setup	Performances	Bottleneck
User Mode Linux IPv4 performances (64 bytes)	About 59 Kpps	Context switch Kernel space – user space
Xen – Guest Domain IPv4 performances (64 bytes)	About 150 Kpps	Context switch Hypervisor space – user space
Xen – Priviledged Domain IPv4 performances (64 bytes)	About 800 Kpps	Single core cycles limitation
Linux - kernel IPv4 performances (64 bytes)	About 800 Kpps	Single core cycles limitation
6 running cores Raw performances (64 bytes)	About 7.2 Mpps	Memory latency
6 running cores IPv4 performances (64 bytes)	About 4.4 Mpps	Memory latency

Software Virtual Routers : Data plane

Aim : To avoid memory domain switch per packet



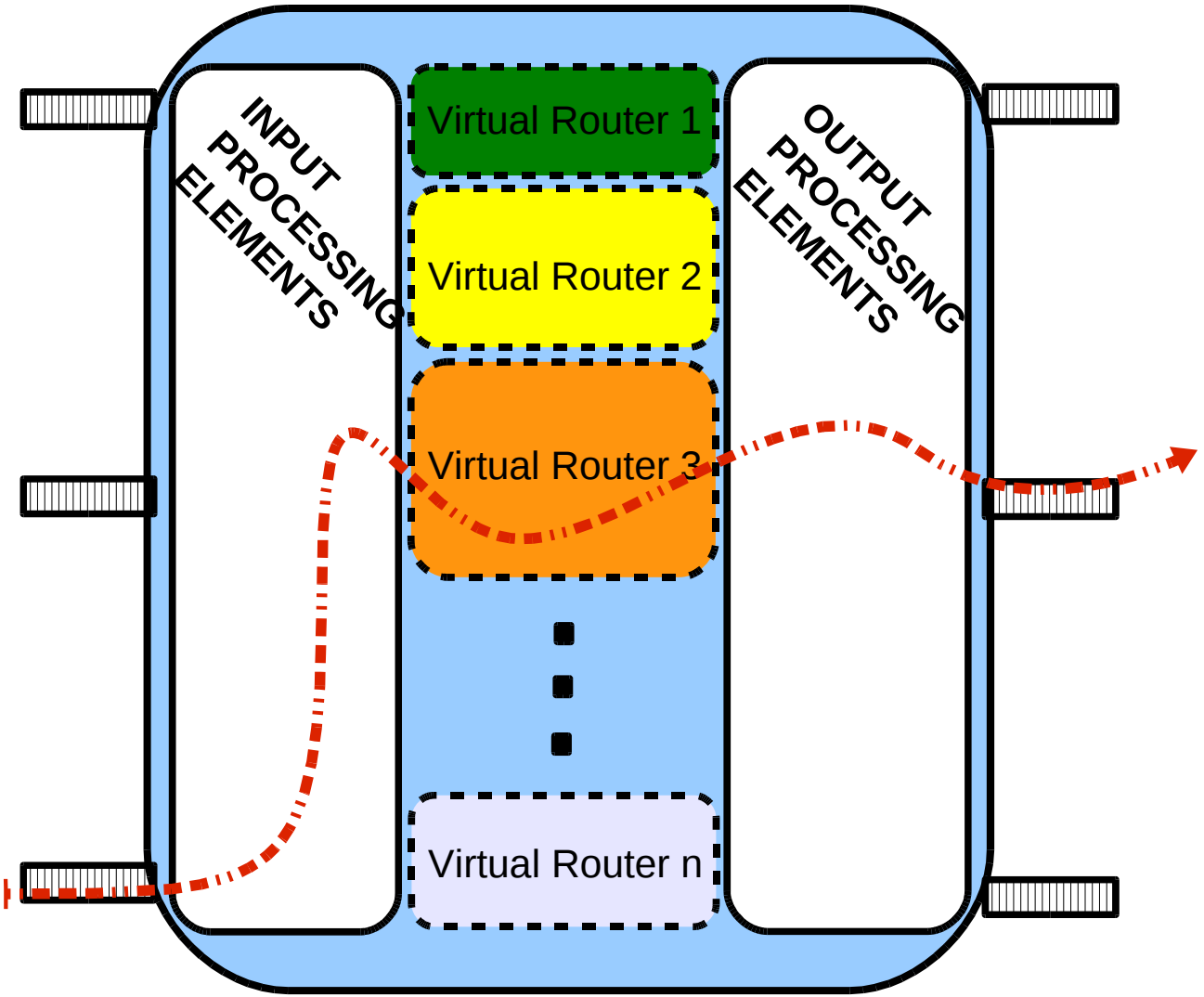
Legend

Single Memory Segment

Physical NIC

Packets

Forwarder Domain Architecture : overview



Legend

Single memory space

Static part of the Forwarding engine

Dynamic part of the Forwarding engine

Packets

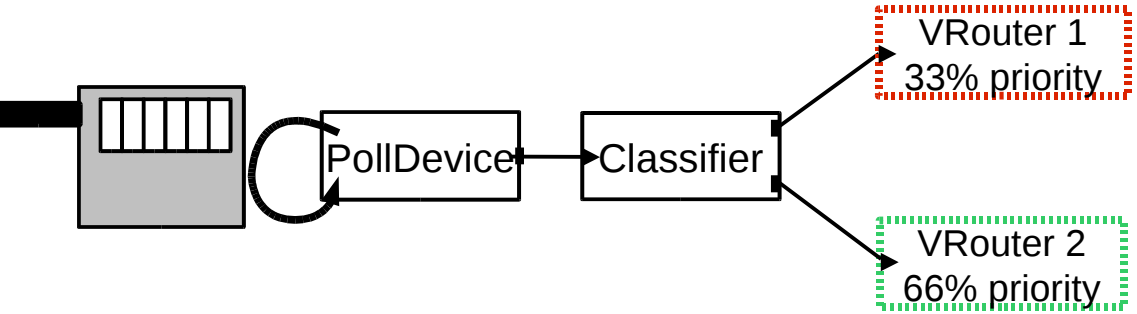
Physical NIC

Forwarder Domain Architecture: input processing

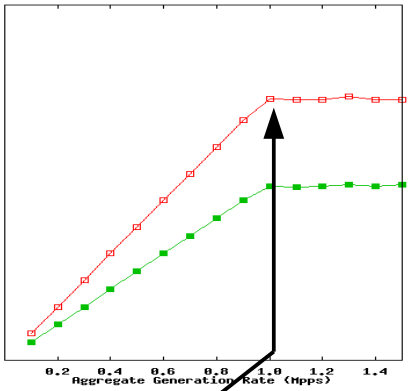
Shared hardware queues

+ scales well with the number of supported virtual routers

- requires software classification: subject to unfairness



Broadcast ethernet
Trafic is replicated
on all vrouters



Bottleneck

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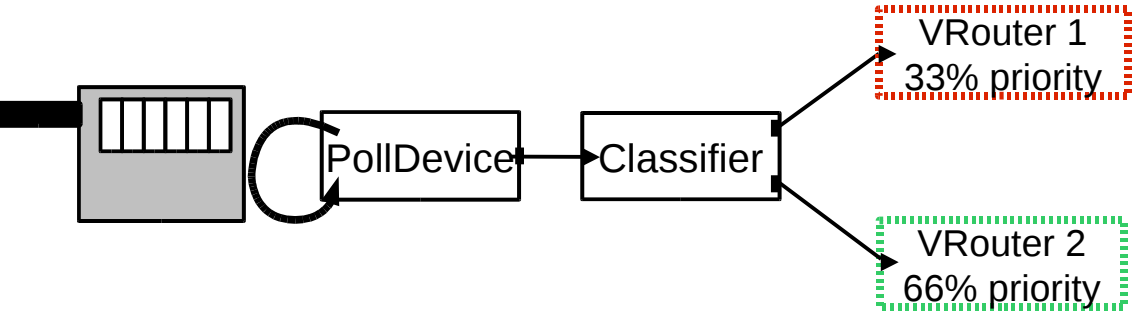
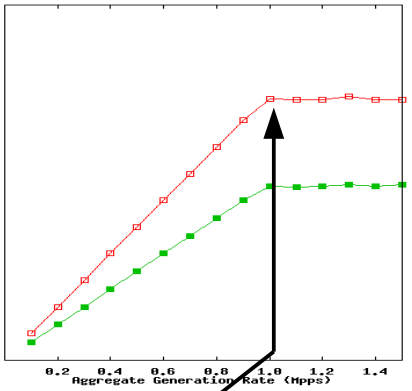


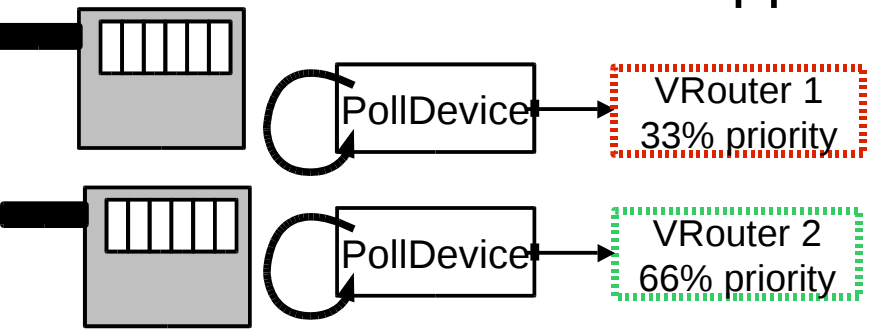


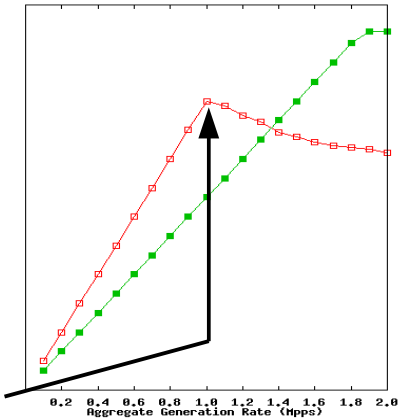
Bottleneck

Dedicated hardware queues

+ Can drop packets before they hit memory: achieve fairness

- Limited number of supported virtual routers

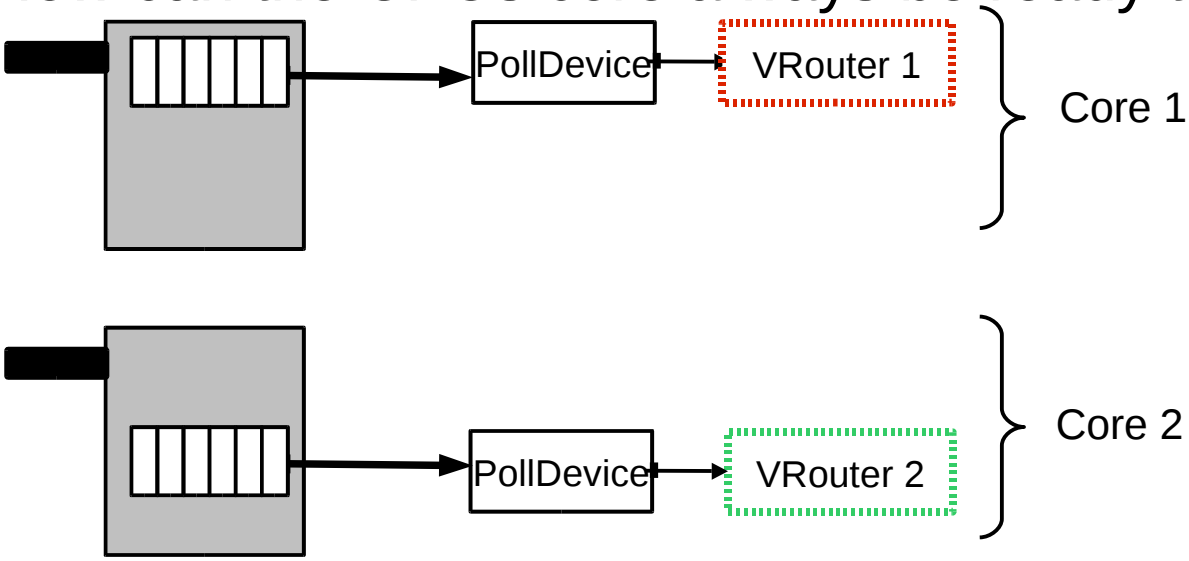




Bottleneck

Forwarder Domain Architecture: input processing

How can the CPUs core always be ready to poll everywhere ?



Forwarder Domain Architecture: input processing

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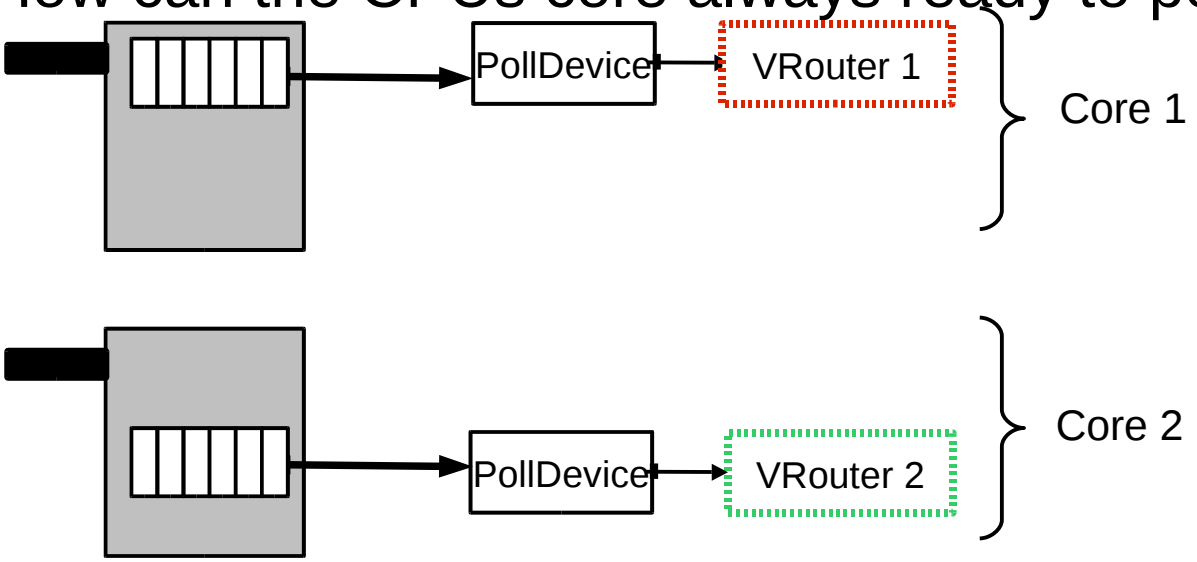
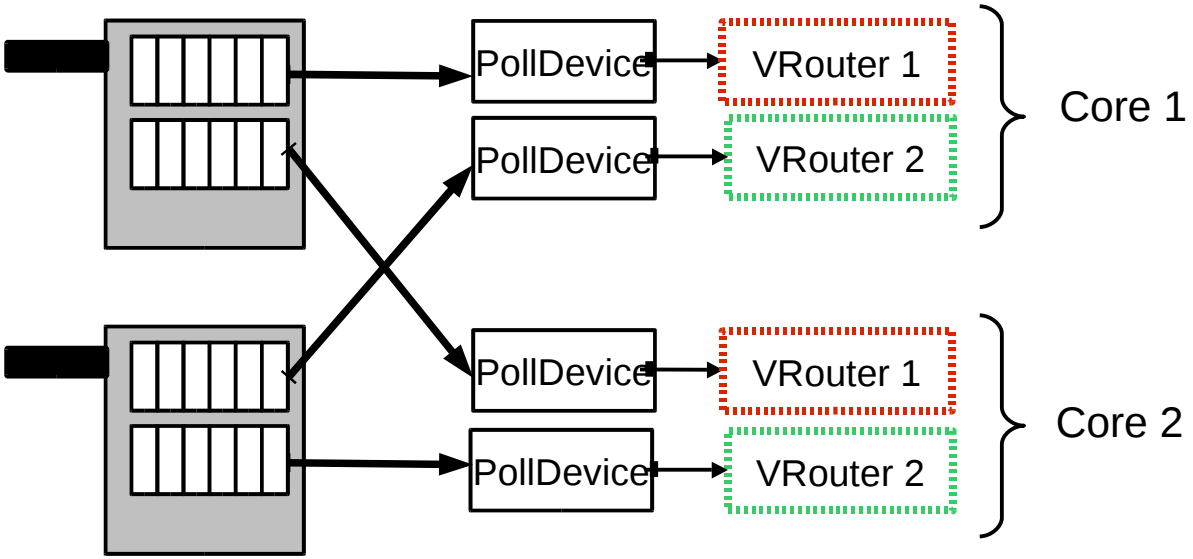


By exploiting NICs with multiple hardware queues :

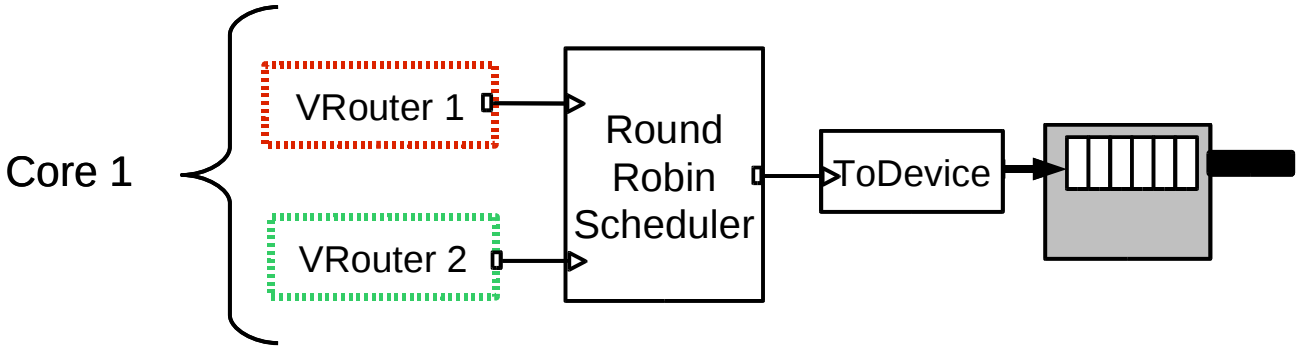


Forwarder Domain Architecture: output processing

A Single ToDevice per hardware queue

+ Avoid costly cache misses

- Limited to a single core



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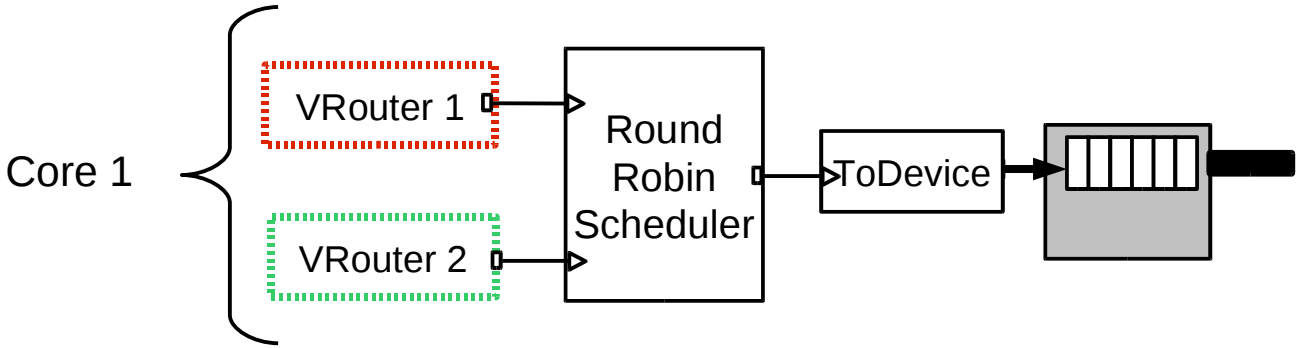
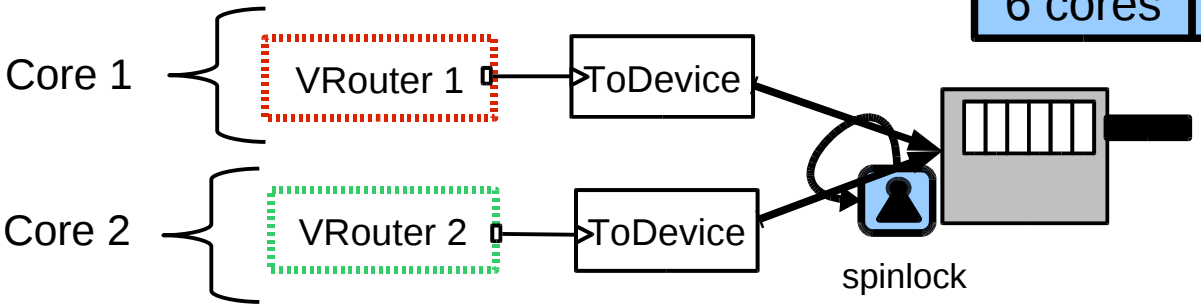


Several ToDevice per hardware queue

+ Can exploits all the cores cycles

- Spinlock can trigger cache misses

	Spinlock Perf loss
2 cores	-15%
4 cores	-33%
6 cores	-45%

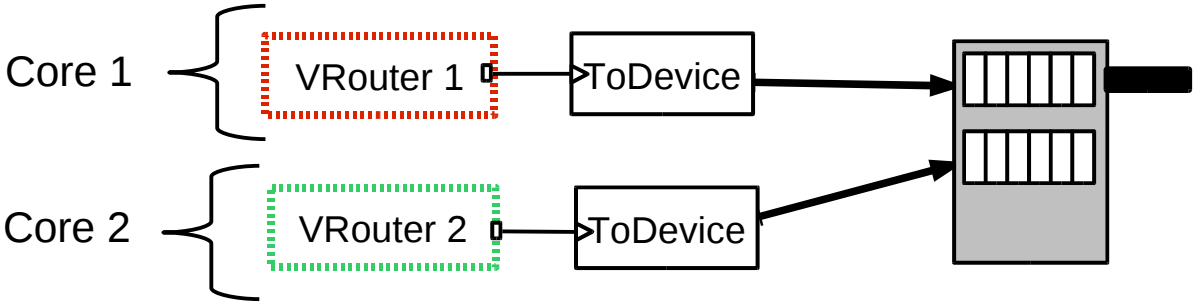


Forwarder Domain Architecture: output processing

Exploiting several hardware queues

+ Can exploit all the cores cycles

- Limited number of supported vrouters.



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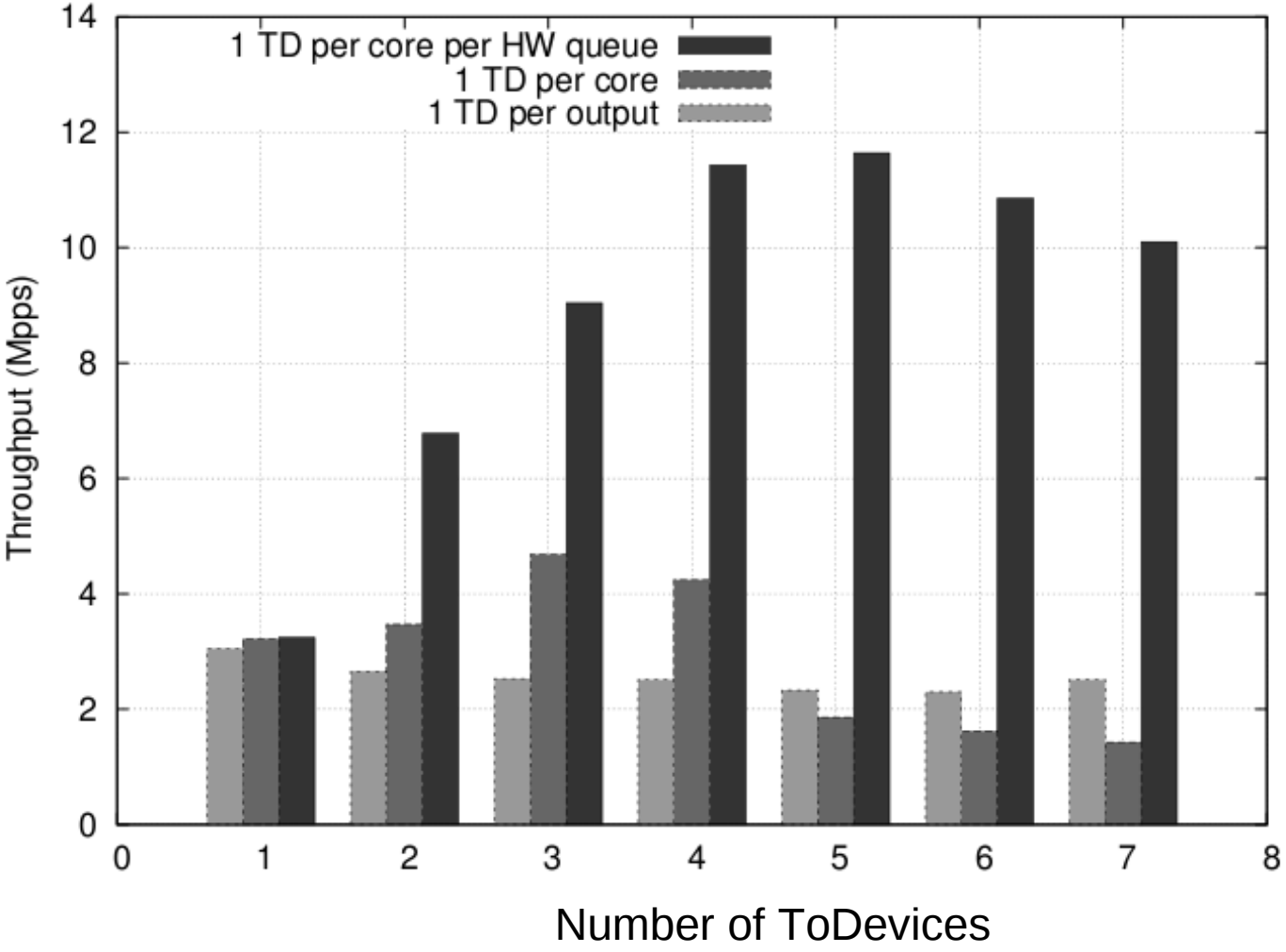

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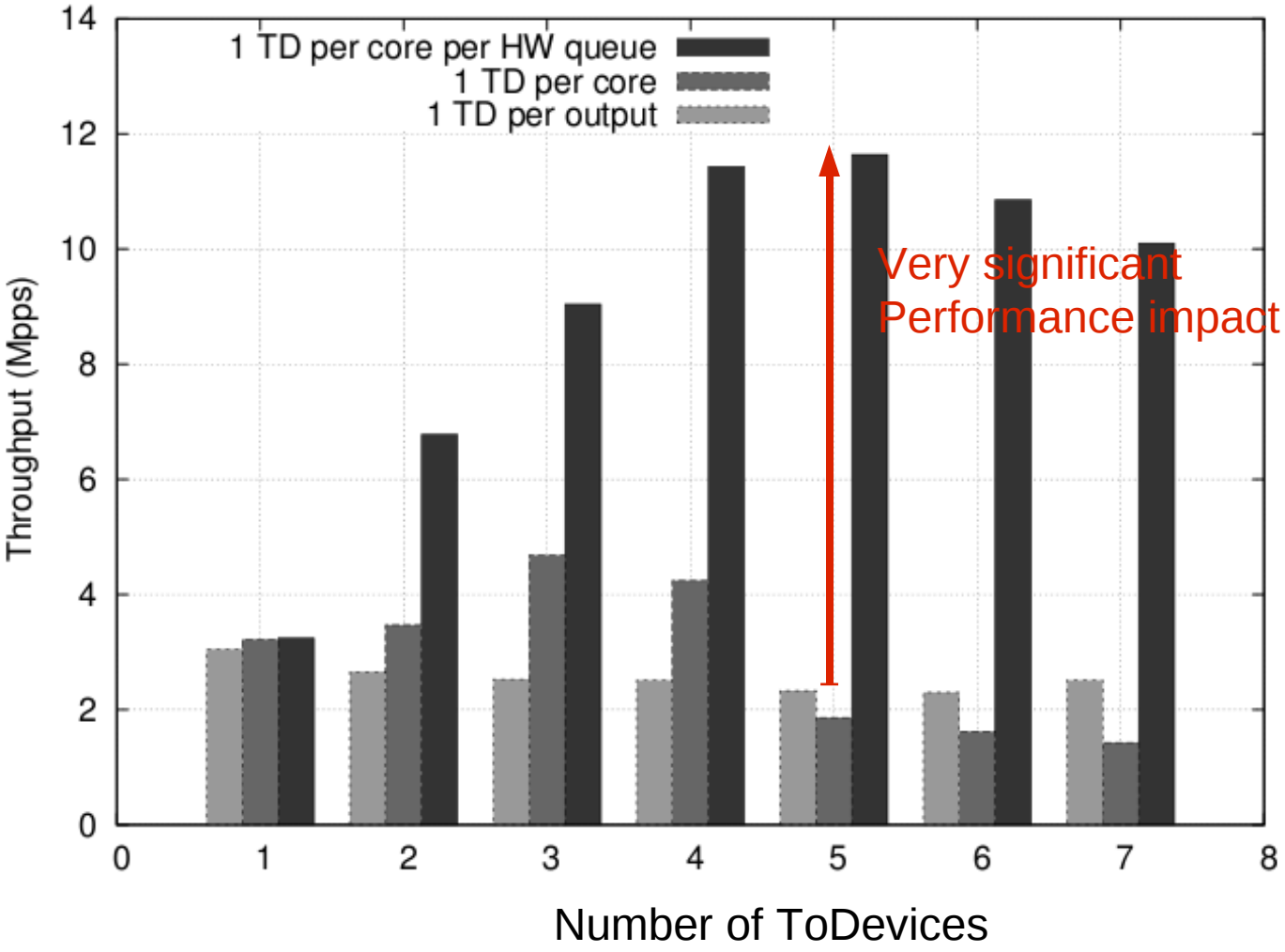

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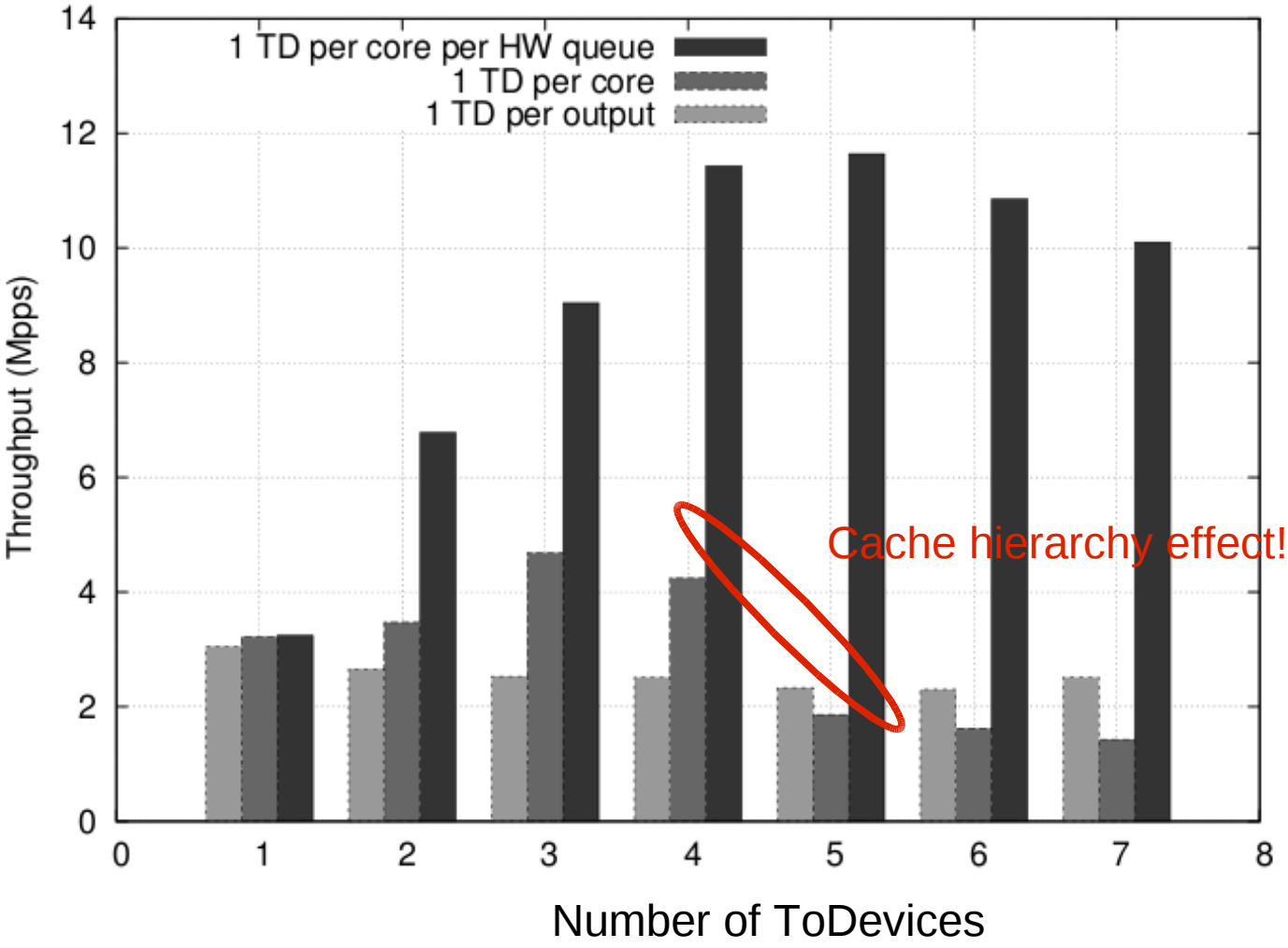
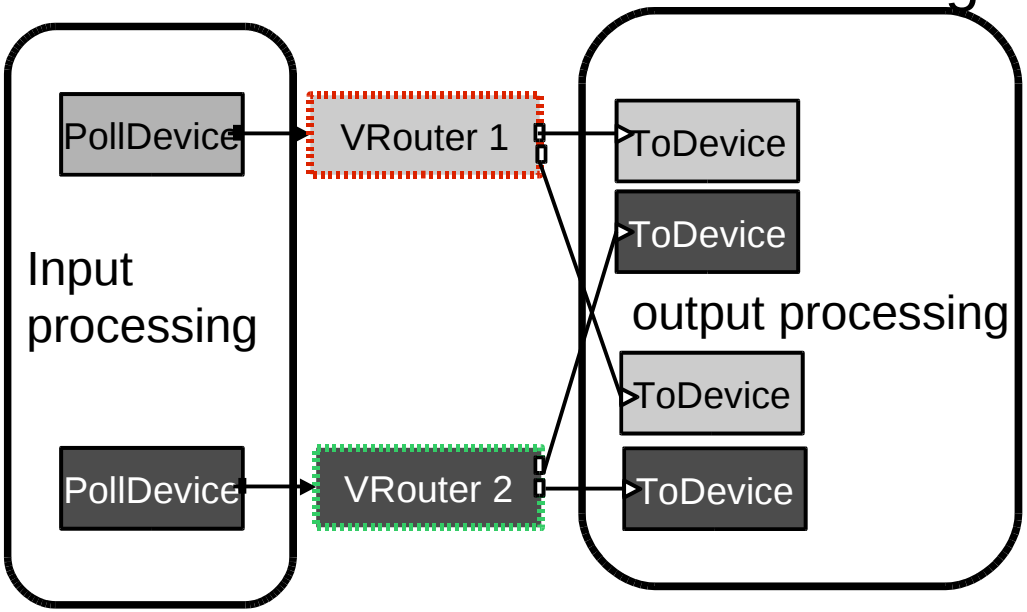
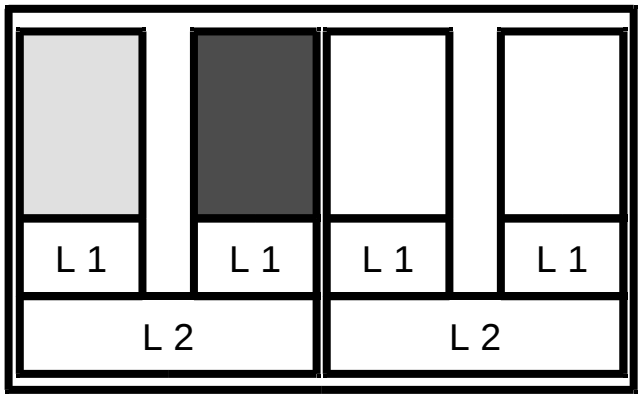


Forwarder Domain Architecture: switching

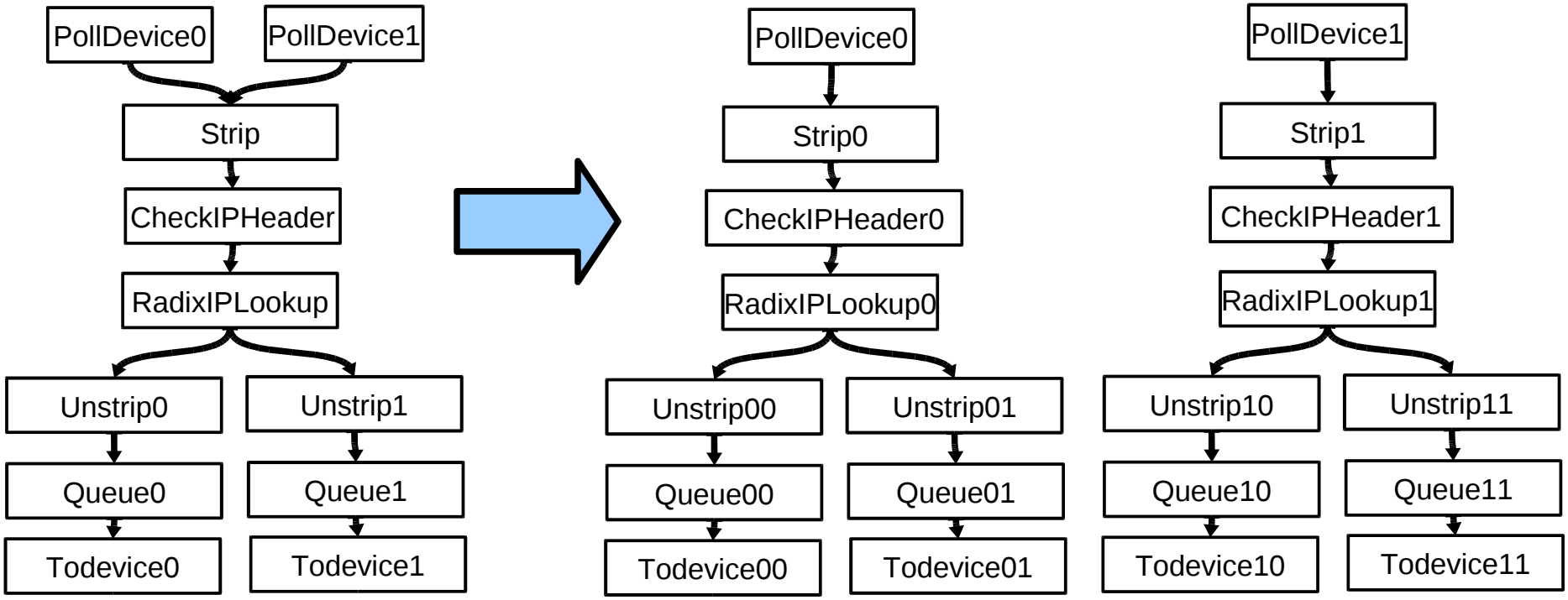
- We don't know
  - On which outgoing interface a packet will be switched.
- But we want
  - To always keep packets on the same cache hierarchy.
- Solution
  - Software Tree based scheduling.





Forwarder Domain Architecture: switching

- Software Tree based scheduling requires elements replication



Forwarder Domain Architecture: switching

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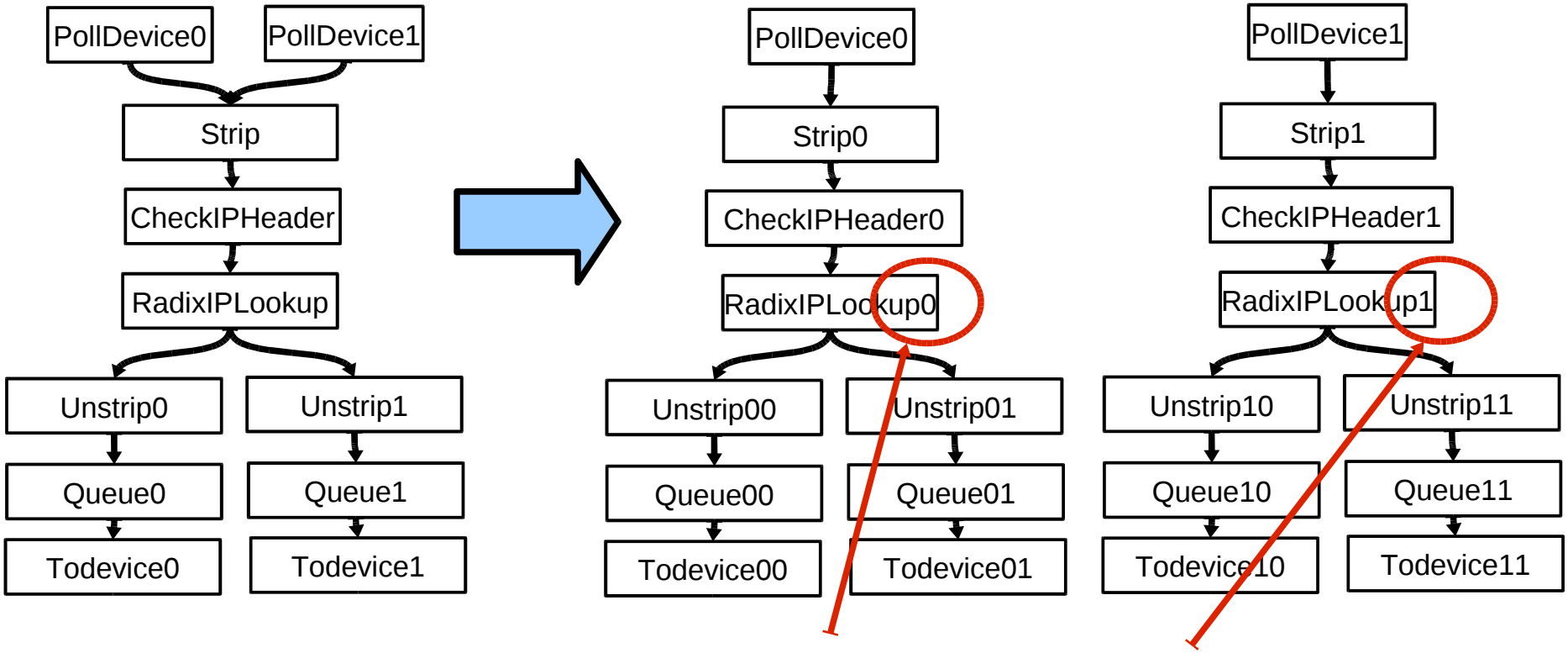
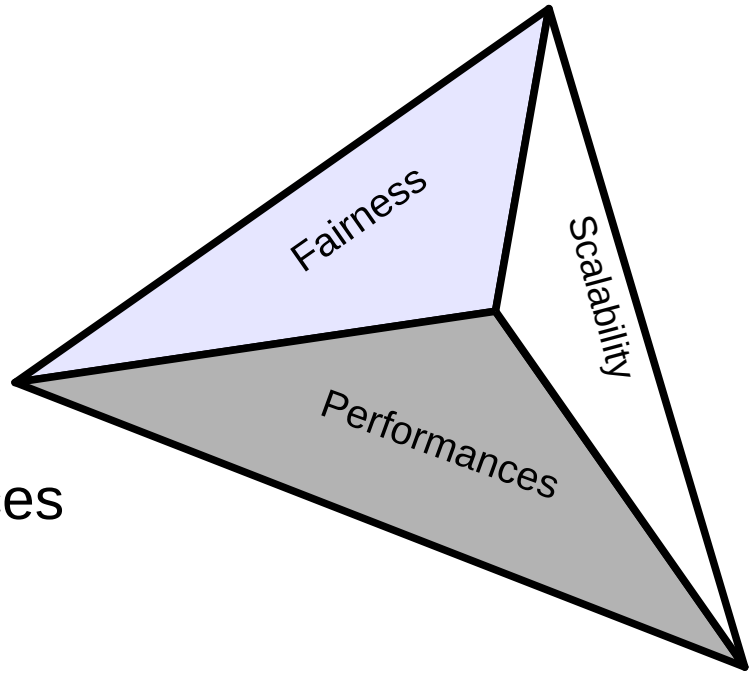


And element data replication too!

Forwarder Domain Architecture: Summary

Building a shared forwarding path for vrouters is a trade-off
Between the desired:



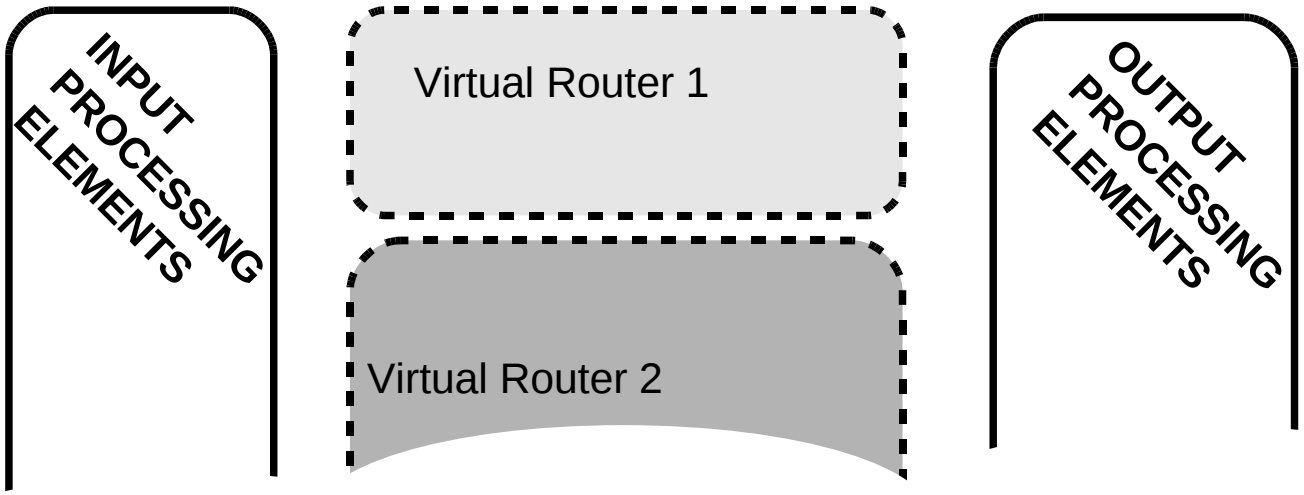
- Desired Scalability depends on
  - Level of fairness and performances

- Fairness is obtained by:
  - Assigning tickets wisely to the Click scheduler

- Performances is obtained by :
  - Distributing the computation among CPU cores to maximize the number of available CPU cycles
  - Keeping packets as deep as possible inside the cache hierarchy to minimize memory latency

Forwarder Domain Architecture : Merging

So far we talked about input processing, output processing and switching.



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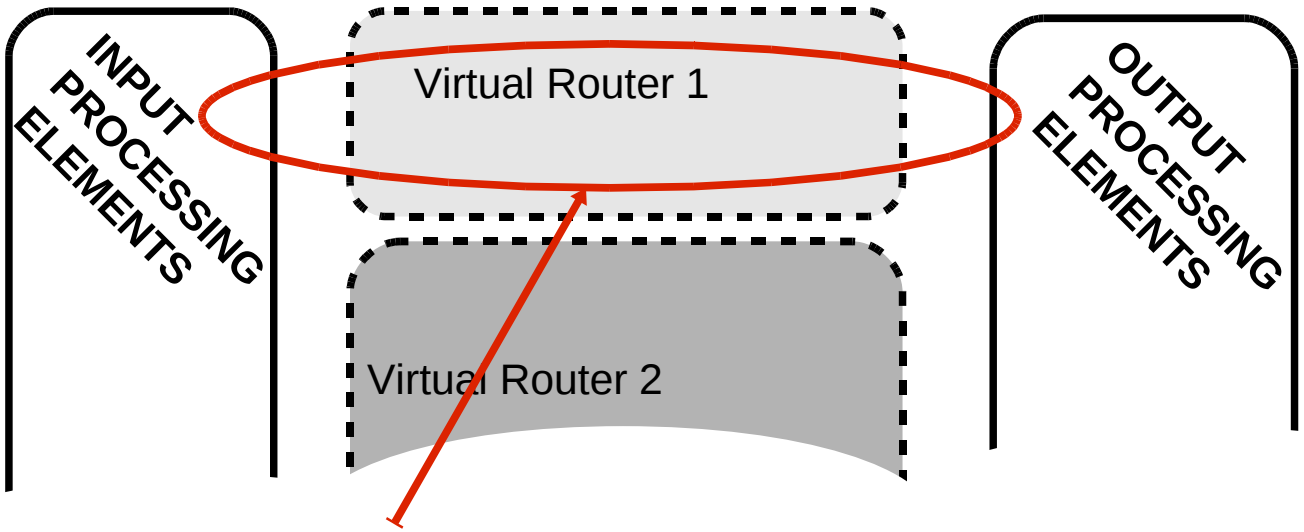
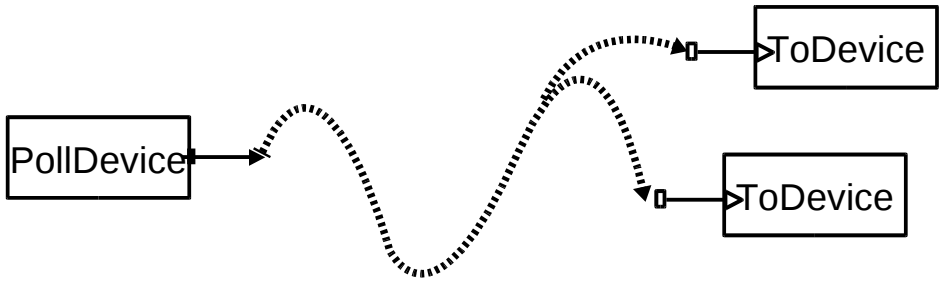


But what about the syntactic glue between Input/ouput processing elements
And the vrouters ?

Goal : From Virtual Routers Click configuration designers perpective, the forwarder Domain architecture stays opaque.

Forwarder Domain Architecture : Merging

Vrouters click configurations are the same as routers config
Anything between Poll/From-Device and ToDevice



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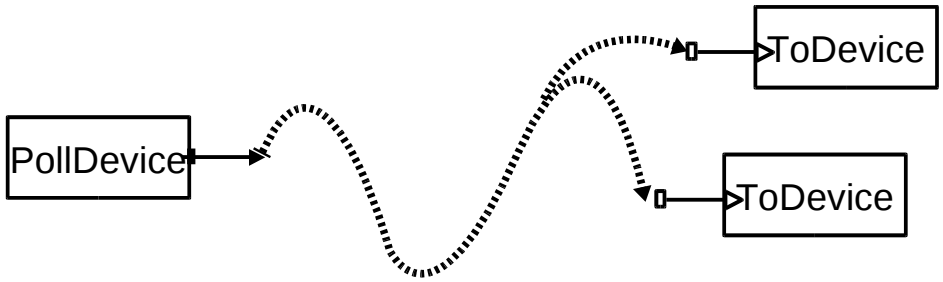
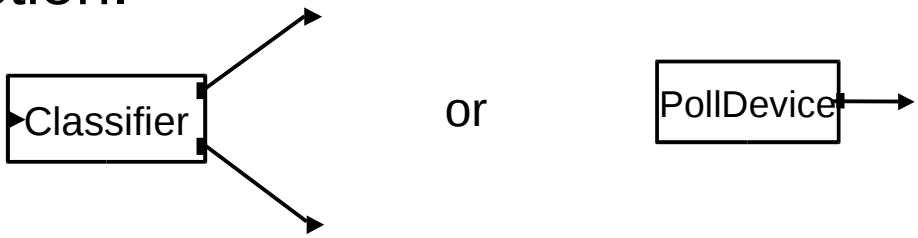


Input processing elements are all ending by a “push” connection.



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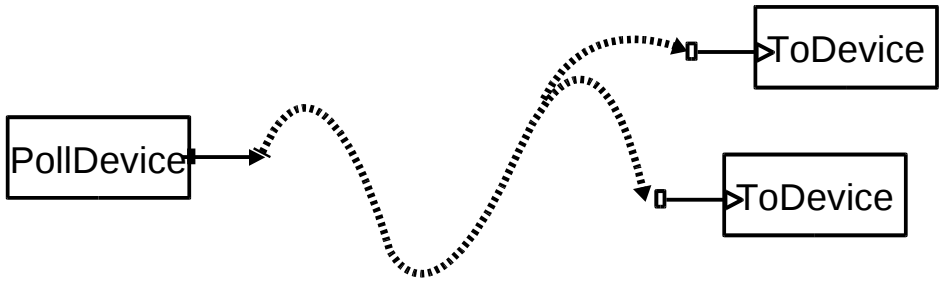

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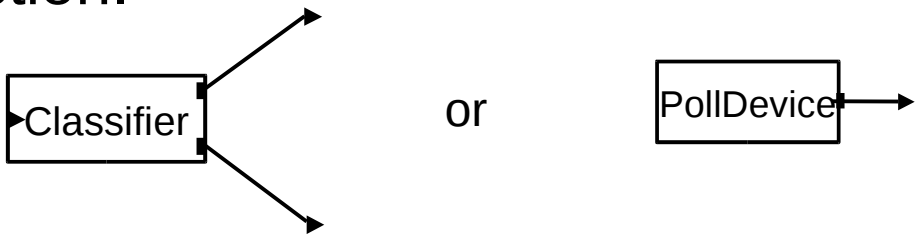
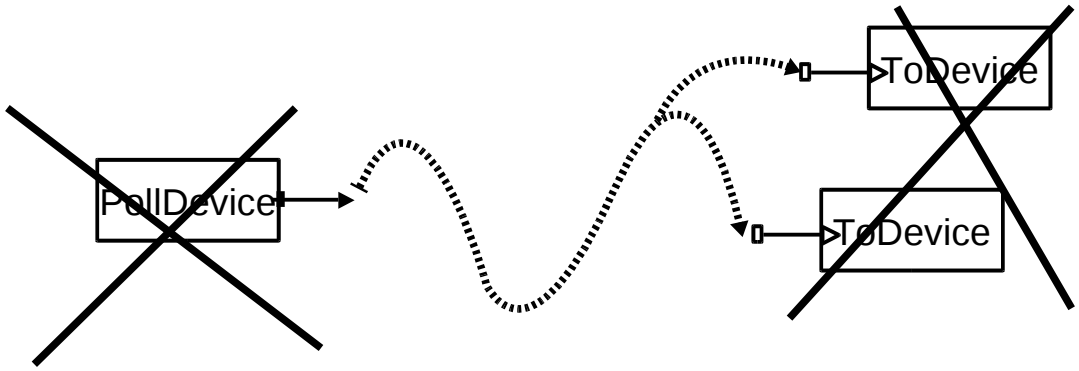


Output processing elements are all starting by a “pull” connexion.

Forwarder Domain Architecture : Merging

1. Suppress PollDevice/Todevice from the config



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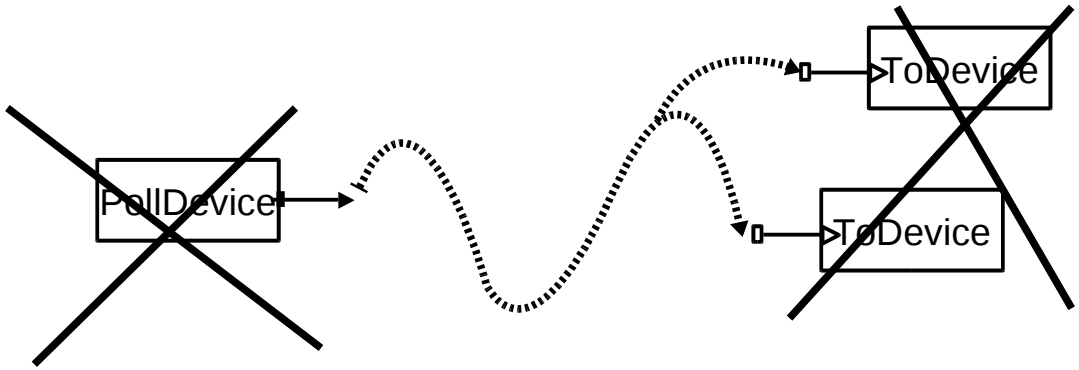
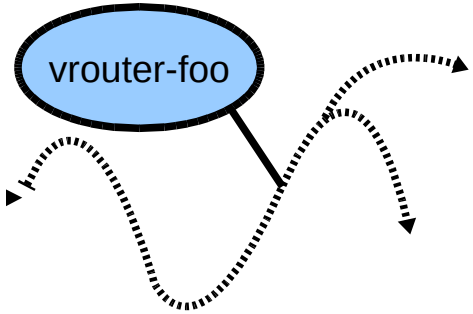


2. Prefix all the elements names with the Vrouter ID.



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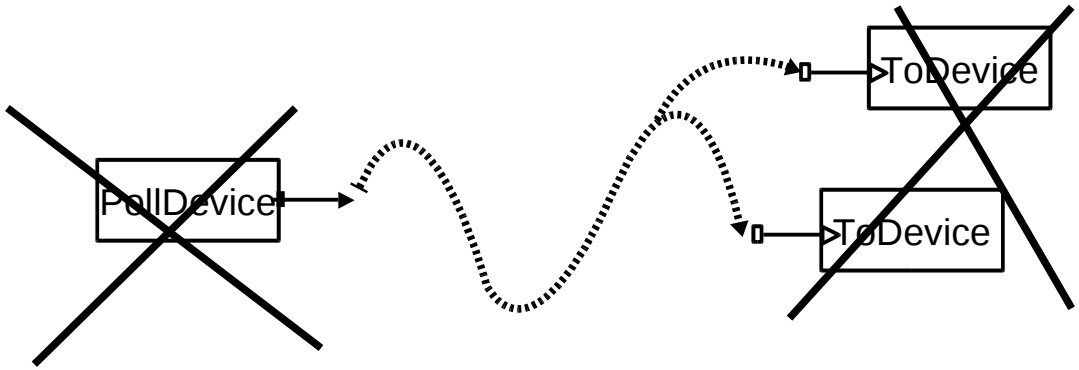

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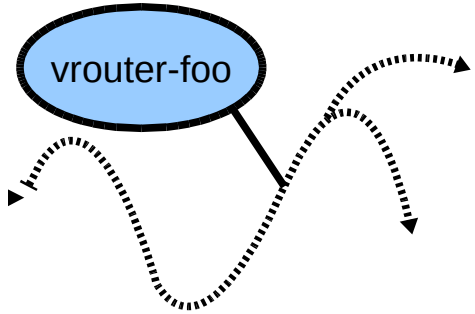
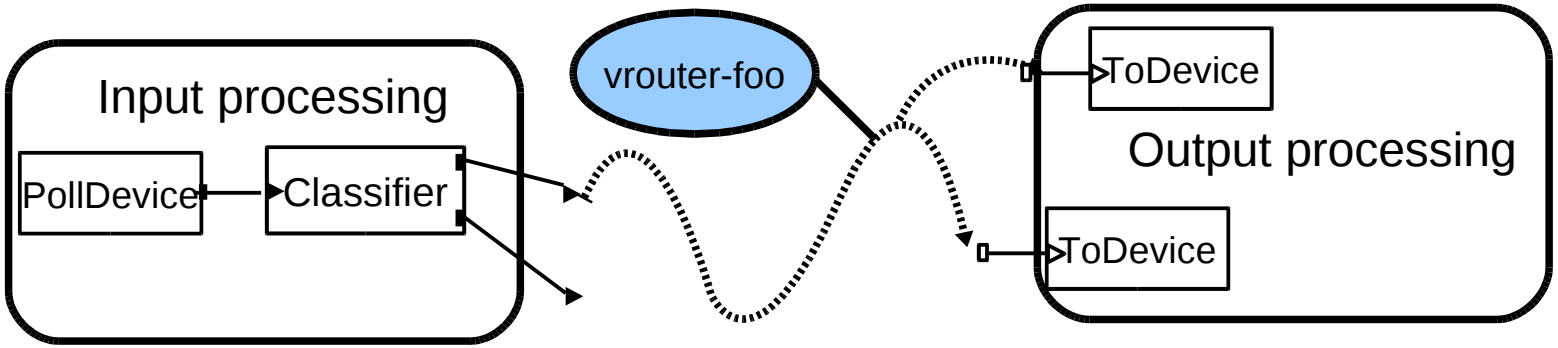


3. Find free slots and plug the config in the forwarder domain



Forwarder Domain Architecture : Merging

All the vrouter handlers are stored under the assigned prefix directory within the click-fs.

```
Ex: /click/vrouter-foo/counter/count
    /click/vrouter-foo/counter/reset
    /click/vrouter-foo/counter/bit_rate
```

This directory is then exported to the virtual router address space

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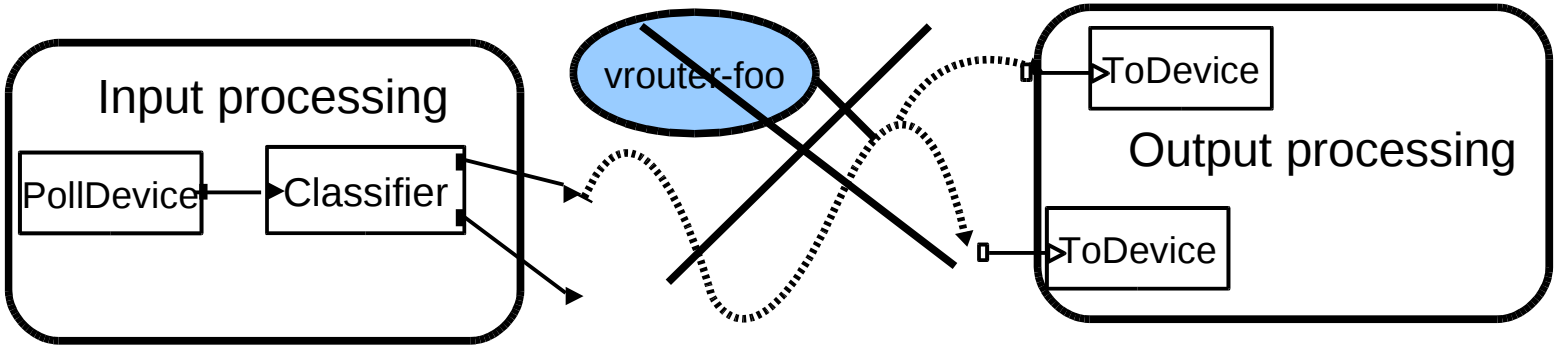
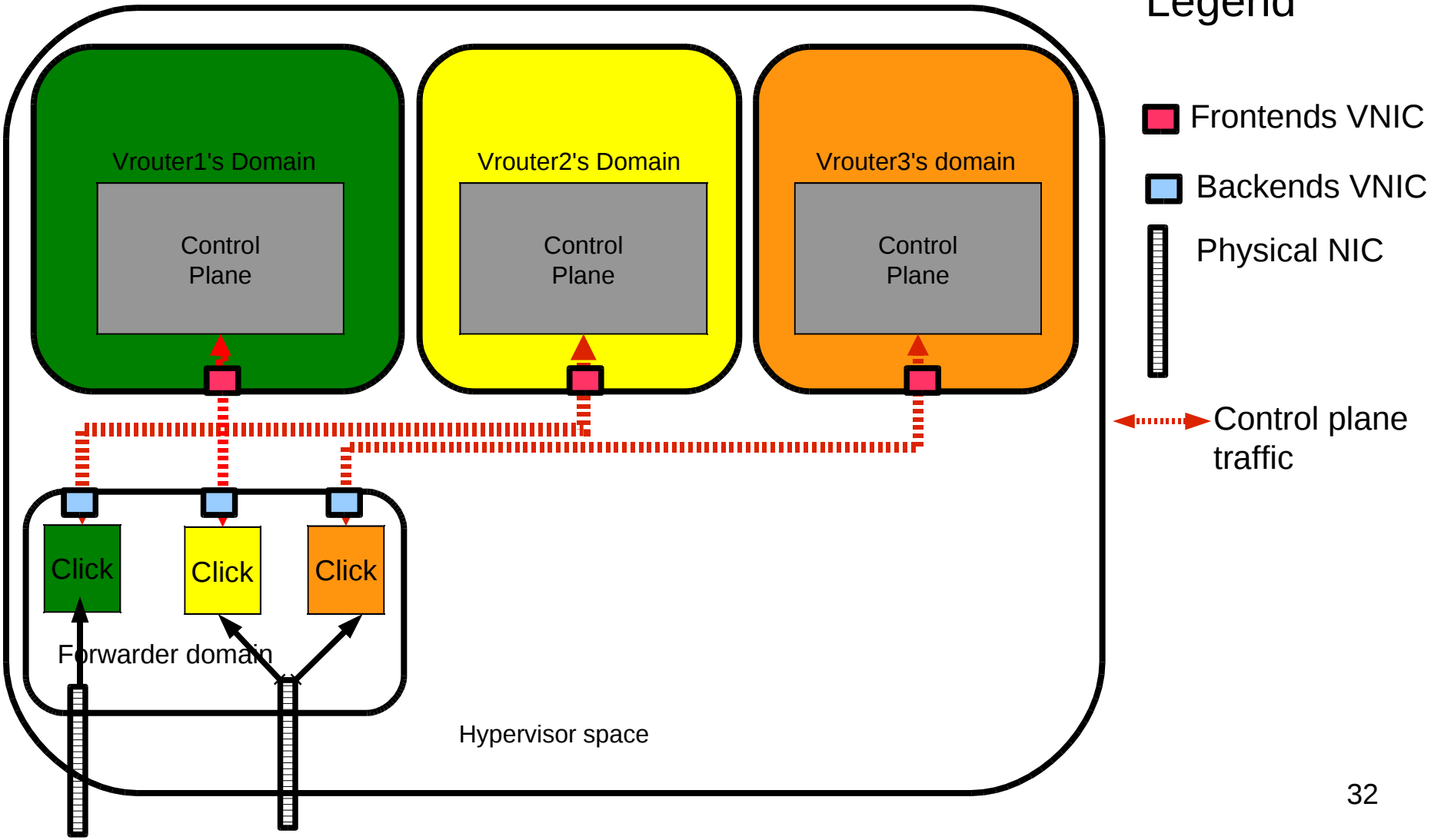
To delete/update the vrouter config, all the elements prefixed with the vrouter-id are deleted from the Click config



Software Virtual Routers : Control plane connection

How is the control plane trafic sent/received to/from vrouters ?



Forwarder Domain Architecture : Control plane

For the trafic coming from the vrouter control plane

- A mapping file that associates backends with the physical NICs help us to build the Click plumbing.

For the trafic going to the vrouter control plane

- Vrouter's use the equivalent of the “ToHost” element to indicate a interest in receiving trafic

Forwarder Domain Architecture : Future work

- Platform software packaging.

- Vrouter management.

- Automatic ressource allocation and scheduling of concurrents vrouters

- performances requirements to physical ressources mapping.