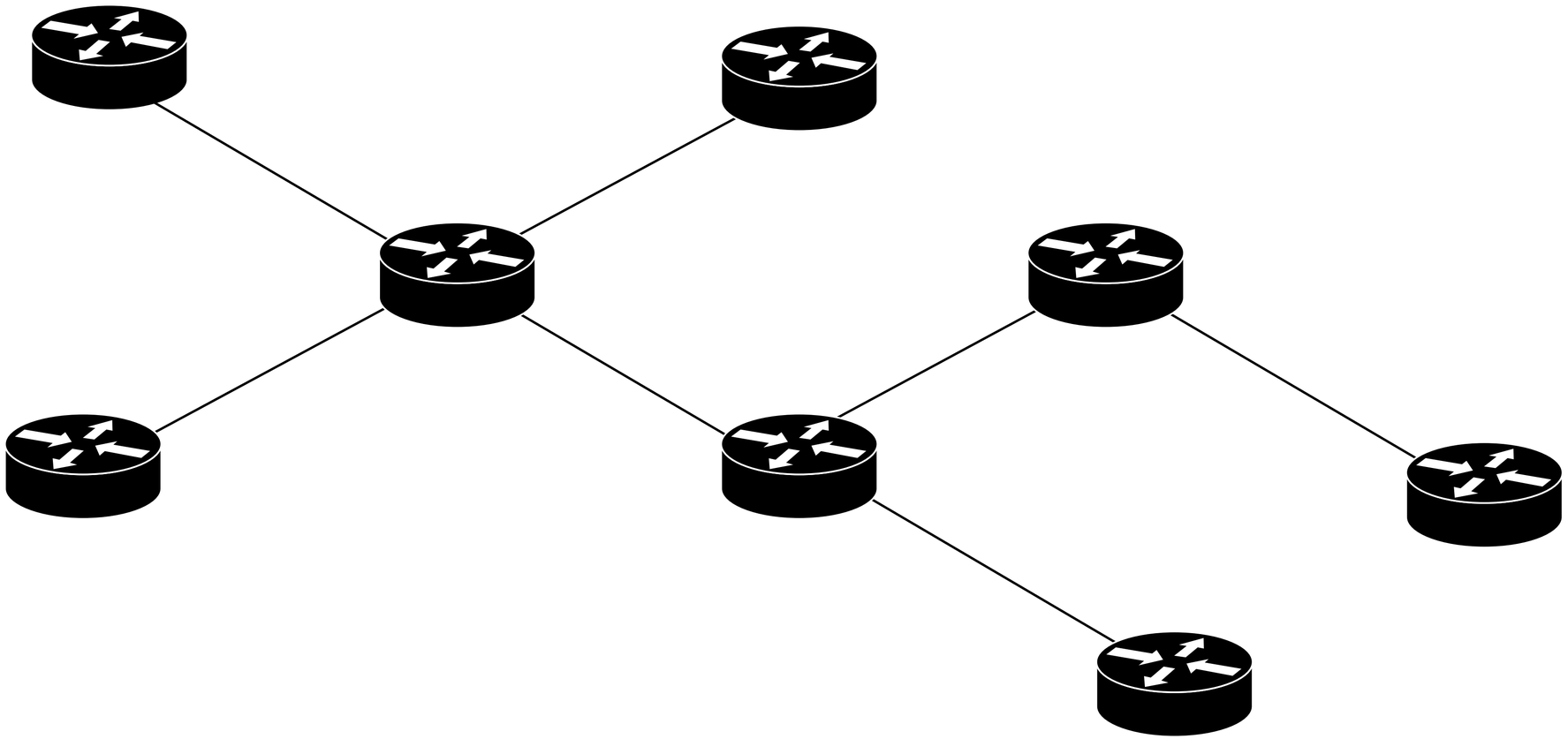
A Case for Spraying Packets in Software Middleboxes

Hugo Sadok, Miguel Elias M. Campista, Luís Henrique M. K. Costa

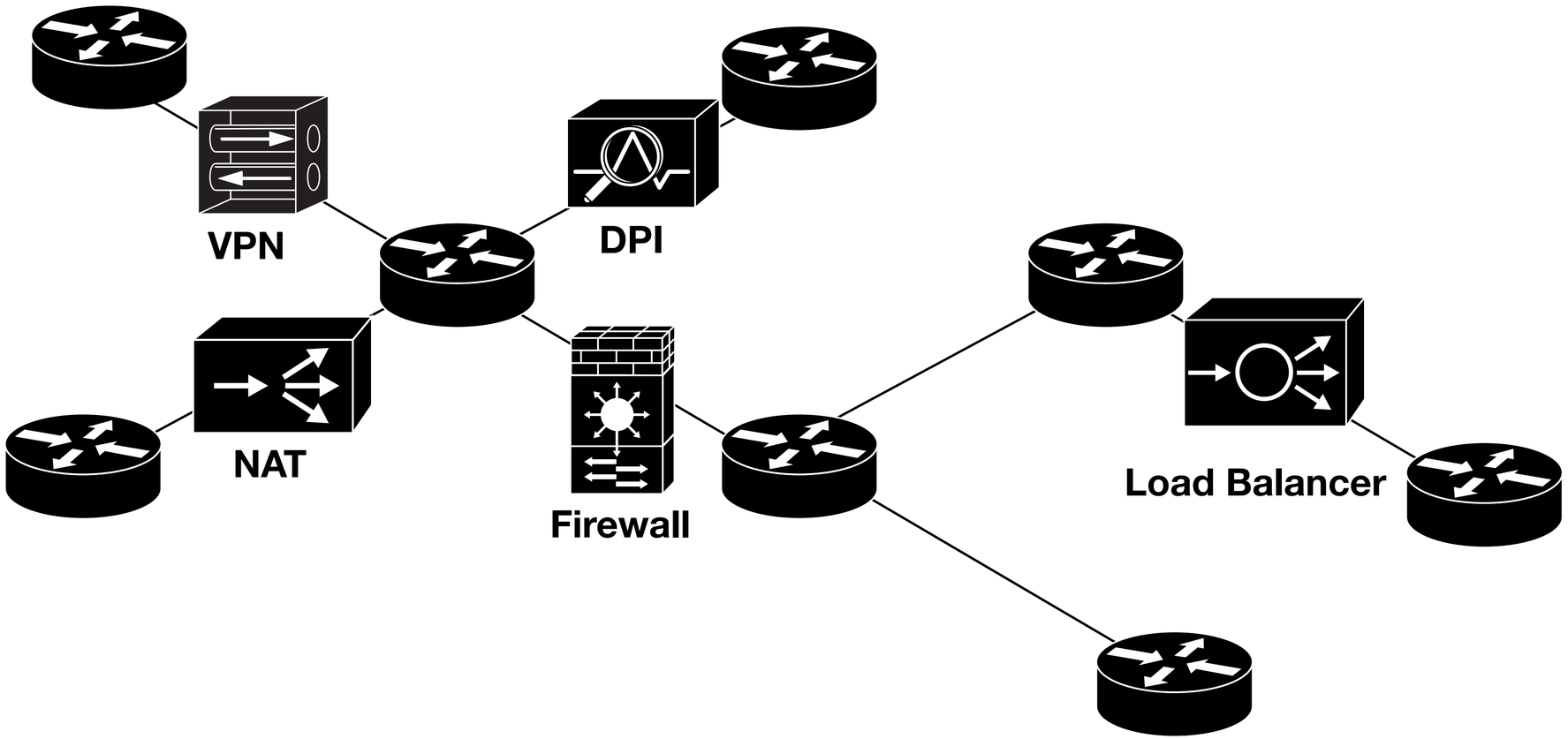
Programa de Engenharia Elétrica — PEE/COPPE/UFRJ
Universidade Federal do Rio de Janeiro

GTA / UFRJ
Grupo de Teleinformática e Automação

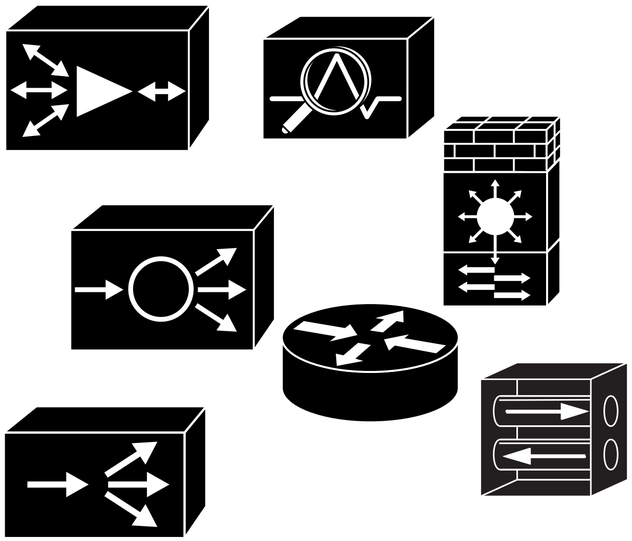
Middleboxes



Middleboxes

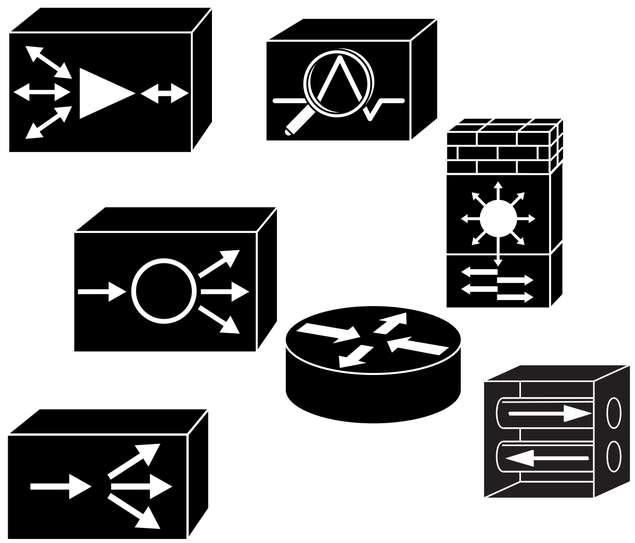


Software Middleboxes

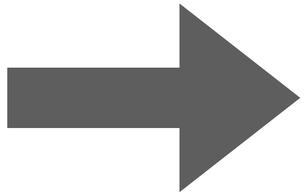


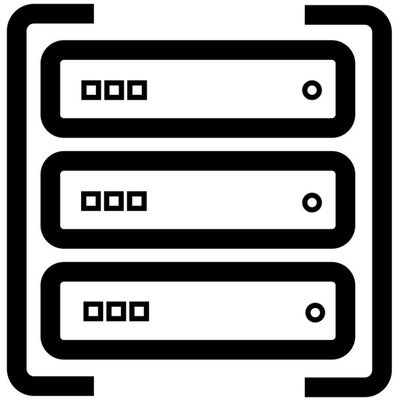
Purpose-built hardware

Software Middleboxes



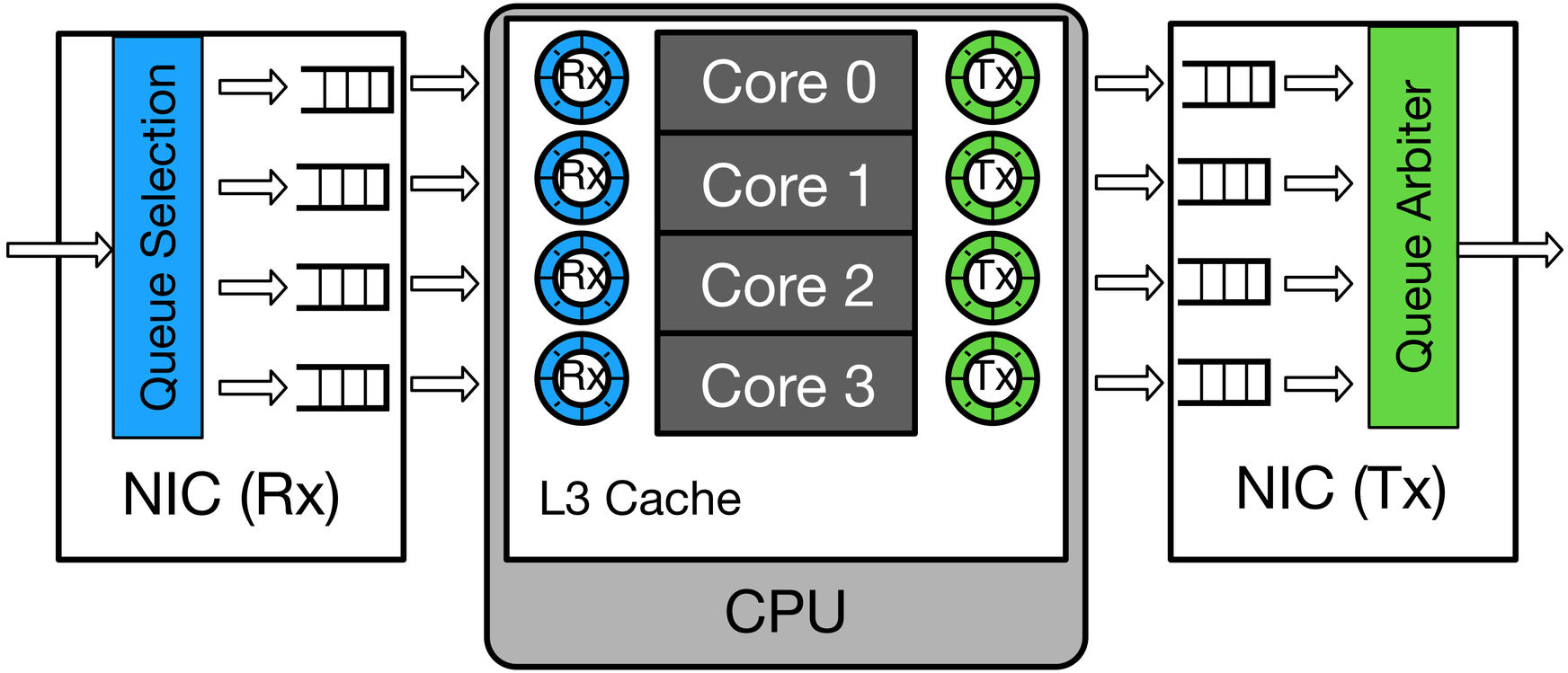
Purpose-built hardware



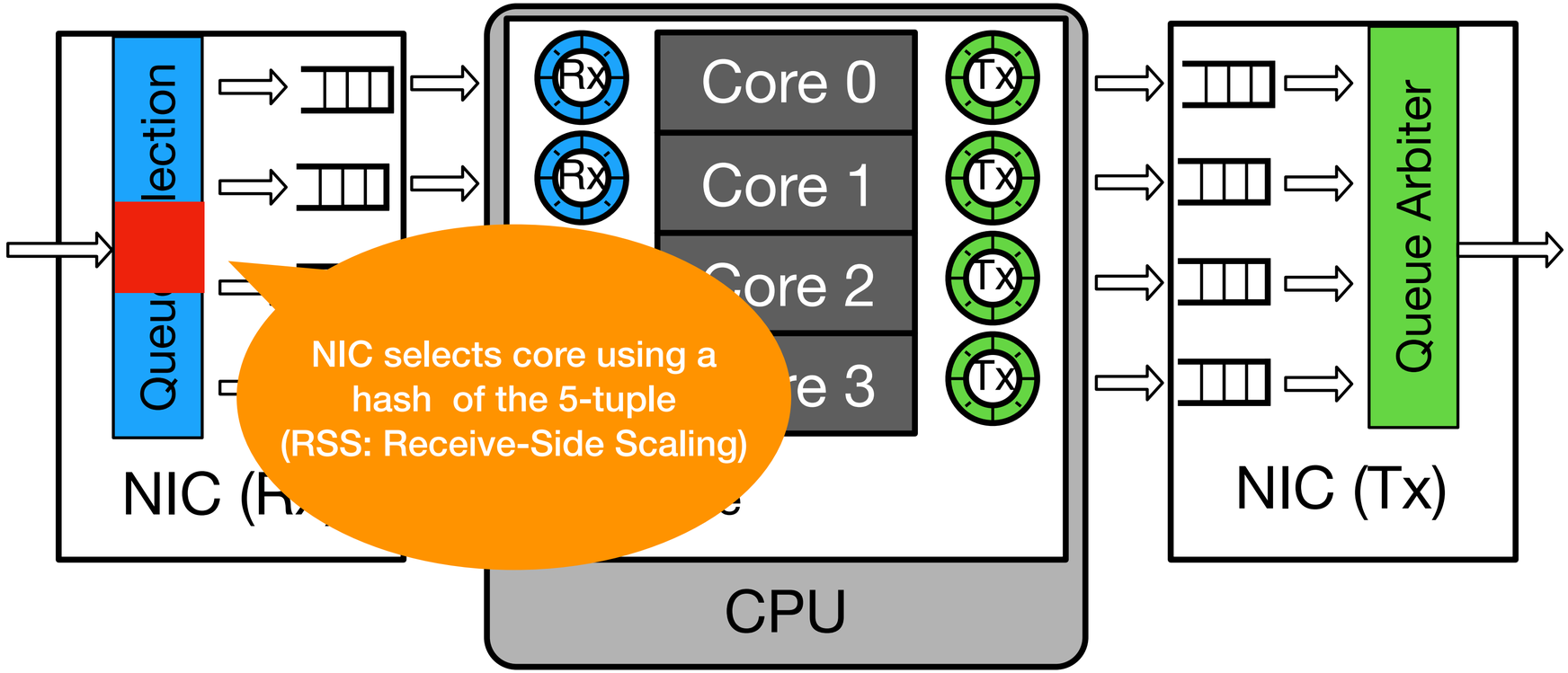


Commodity servers

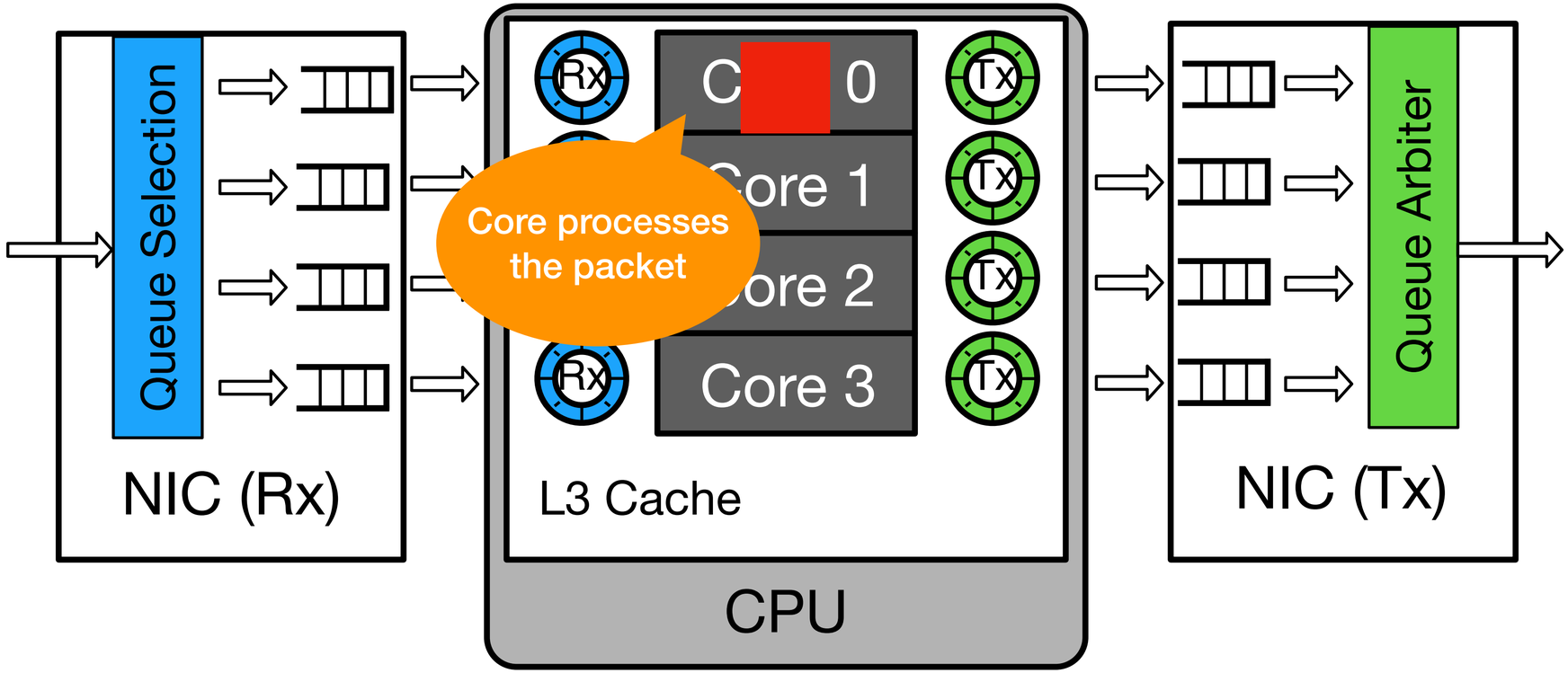
Software Middlebox Architecture



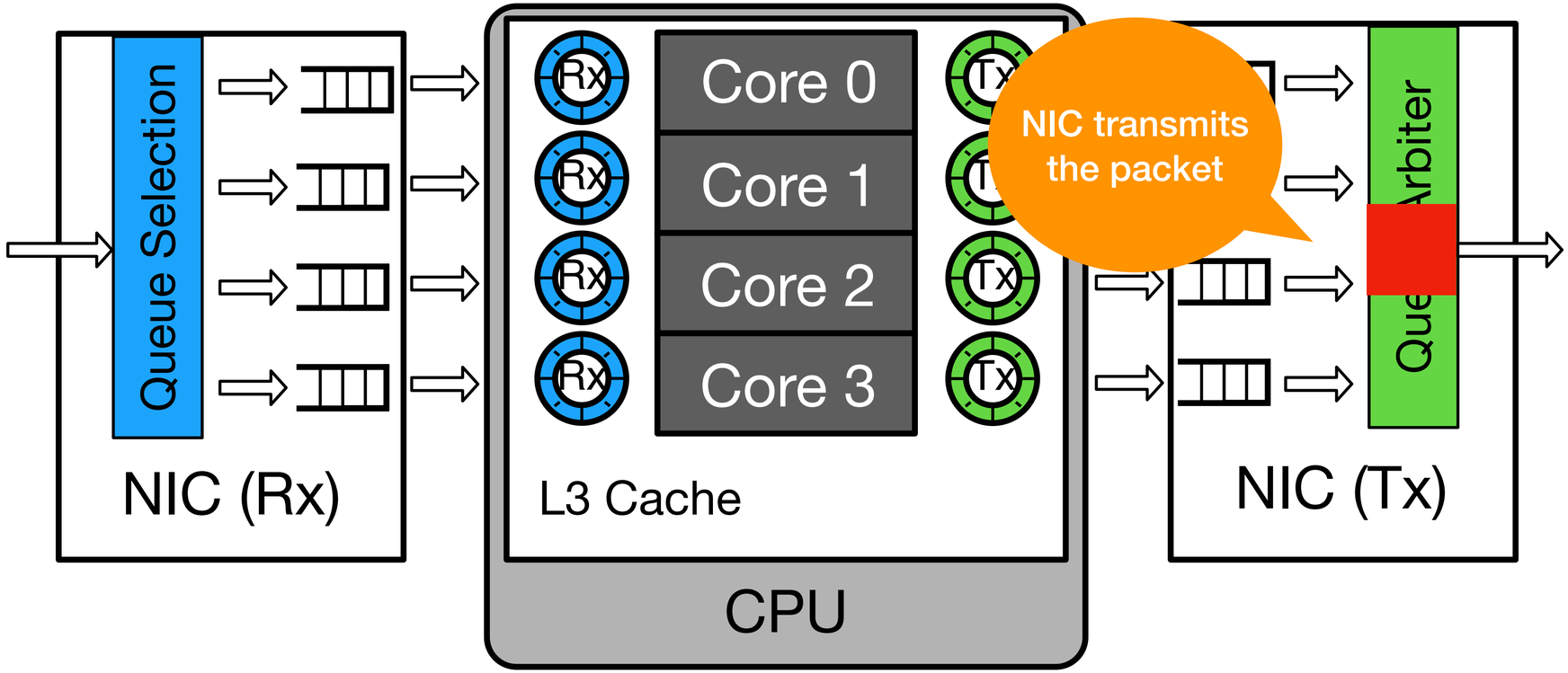
Software Middlebox Architecture



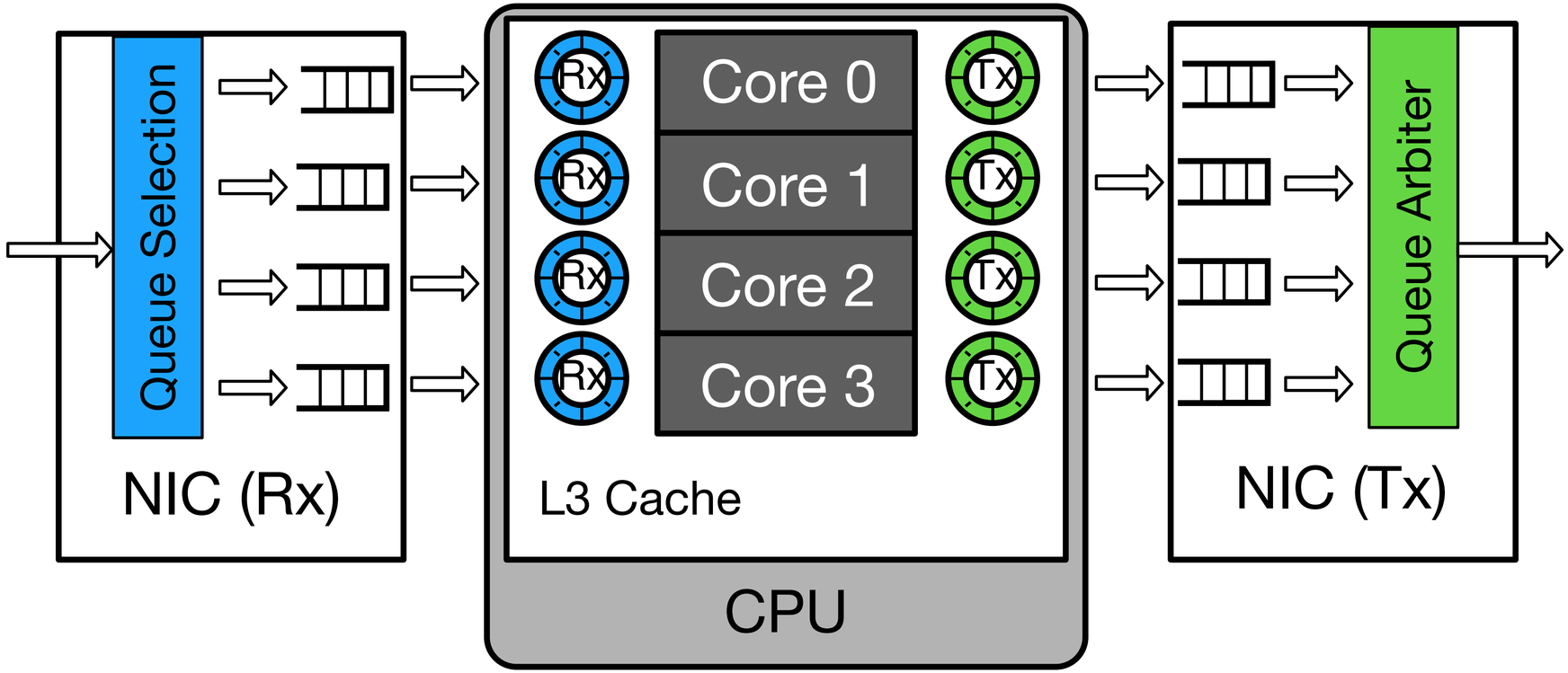
Software Middlebox Architecture



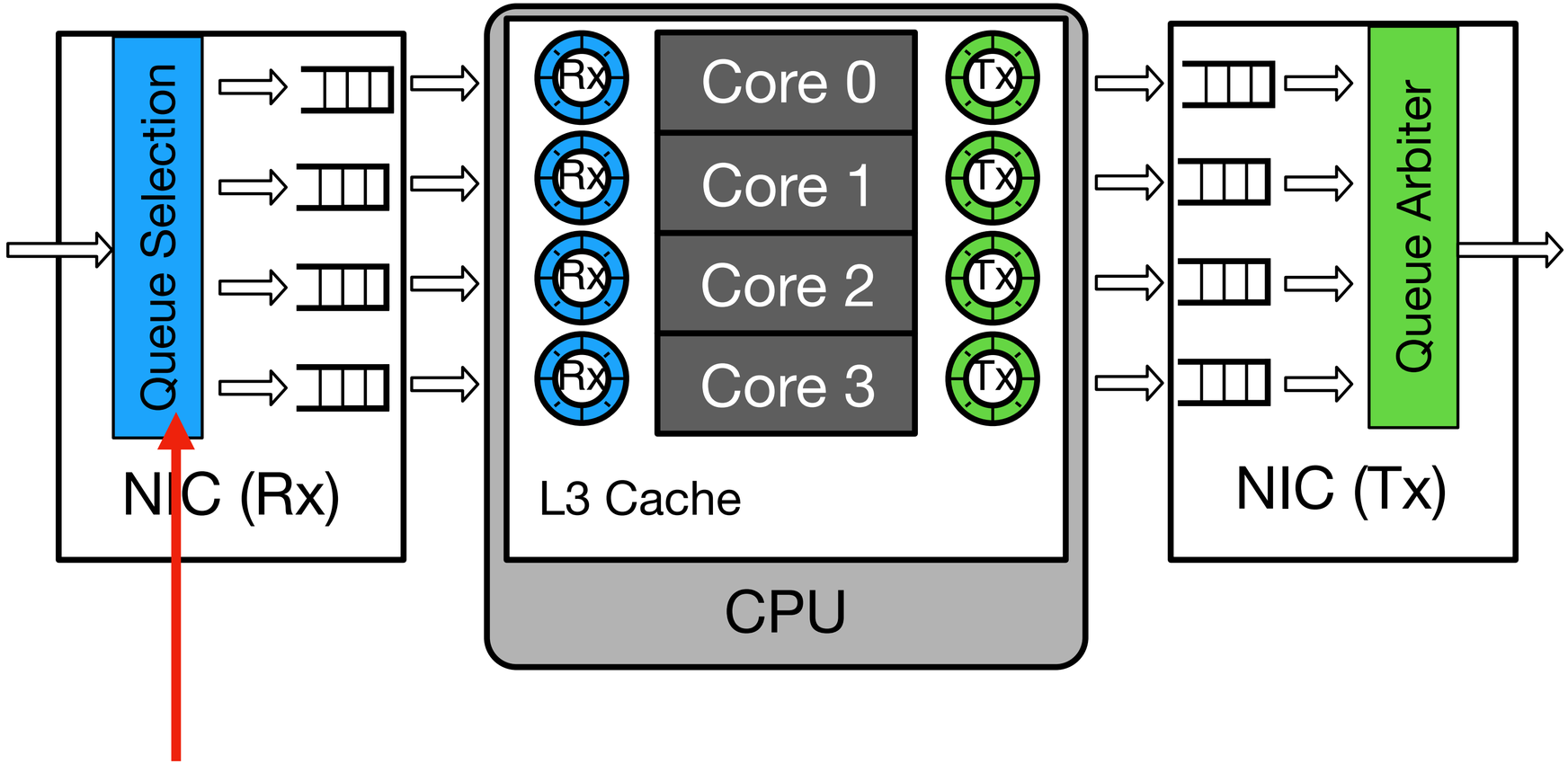
Software Middlebox Architecture



Software Middlebox Architecture

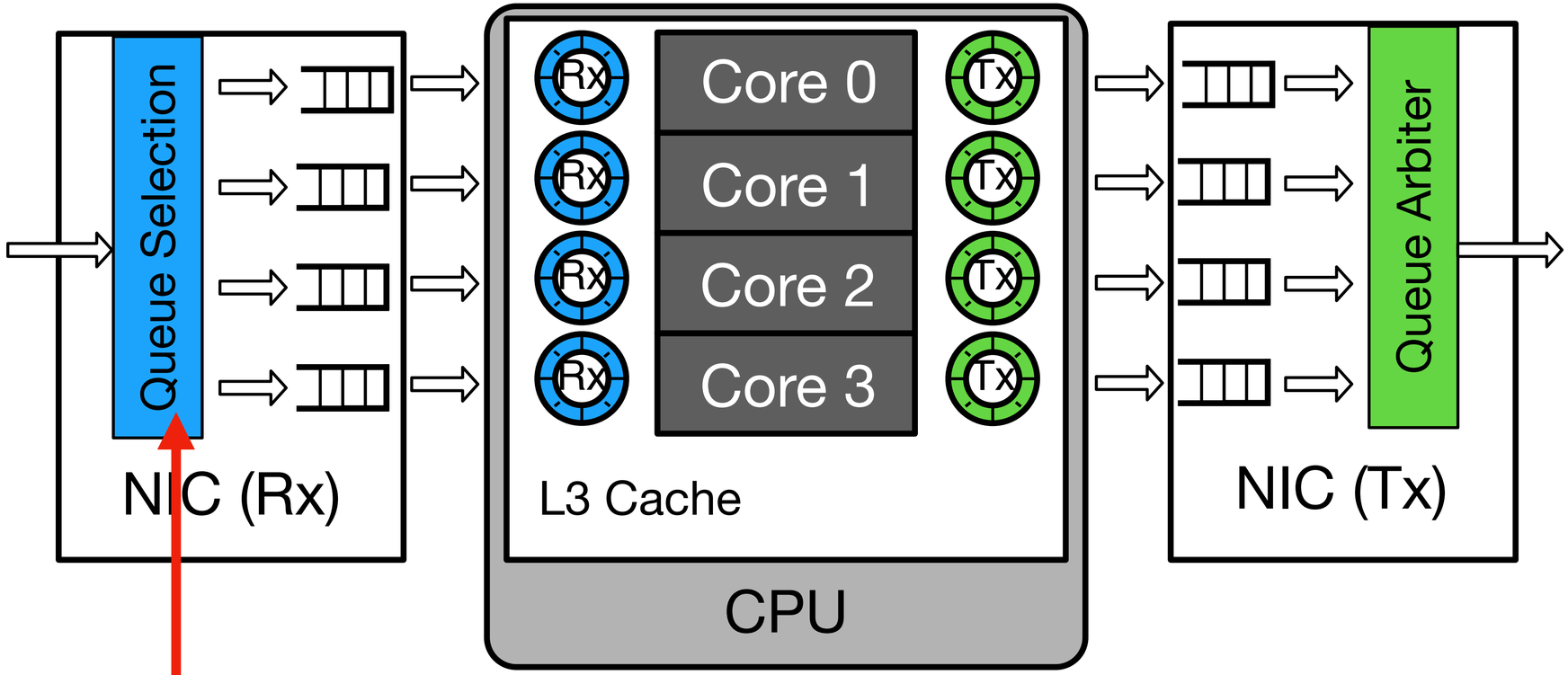


Software Middlebox Architecture



Why hash flows to cores?

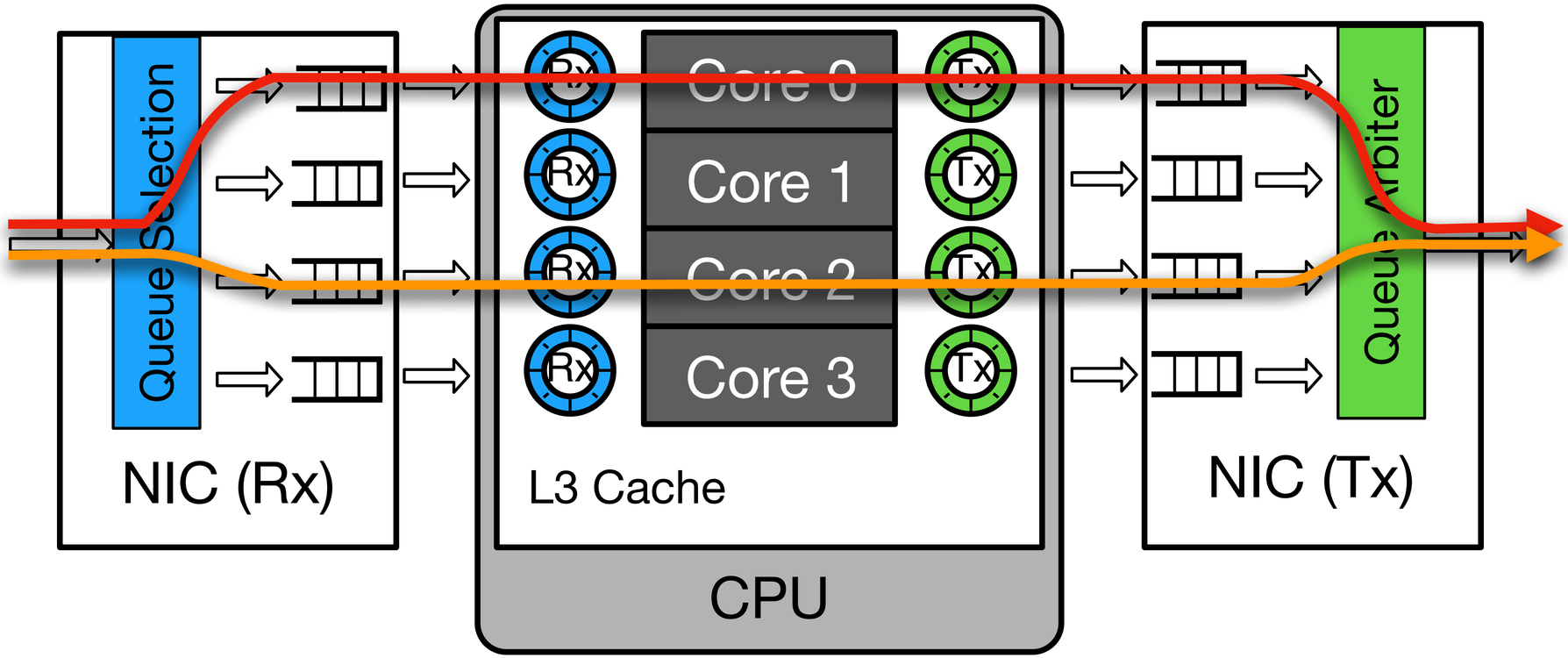
Software Middlebox Architecture



Why hash flows to cores?

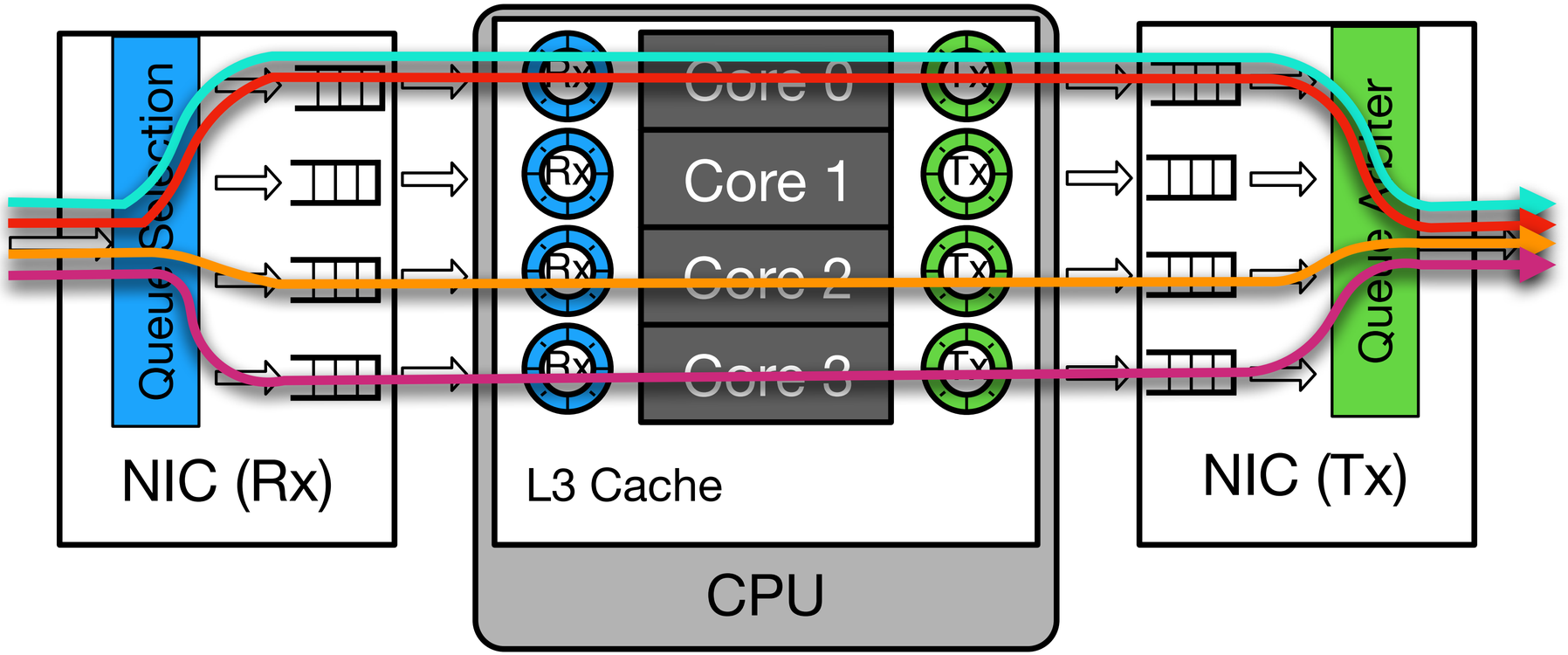
1. Avoids packet reordering
2. Facilitates flow state handling

Problems with Hashing Flows to Cores



Inefficiency

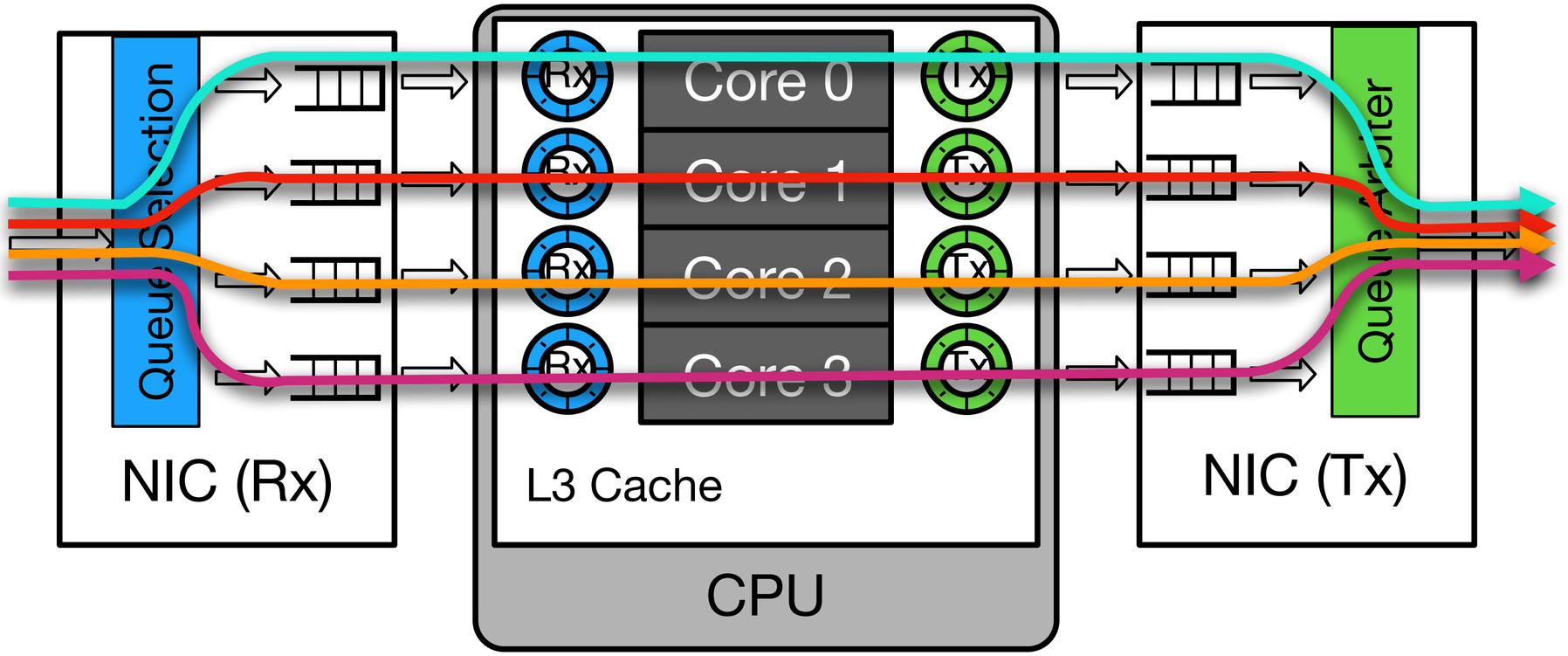
Problems with Hashing Flows to Cores



Inefficiency

Unfairness

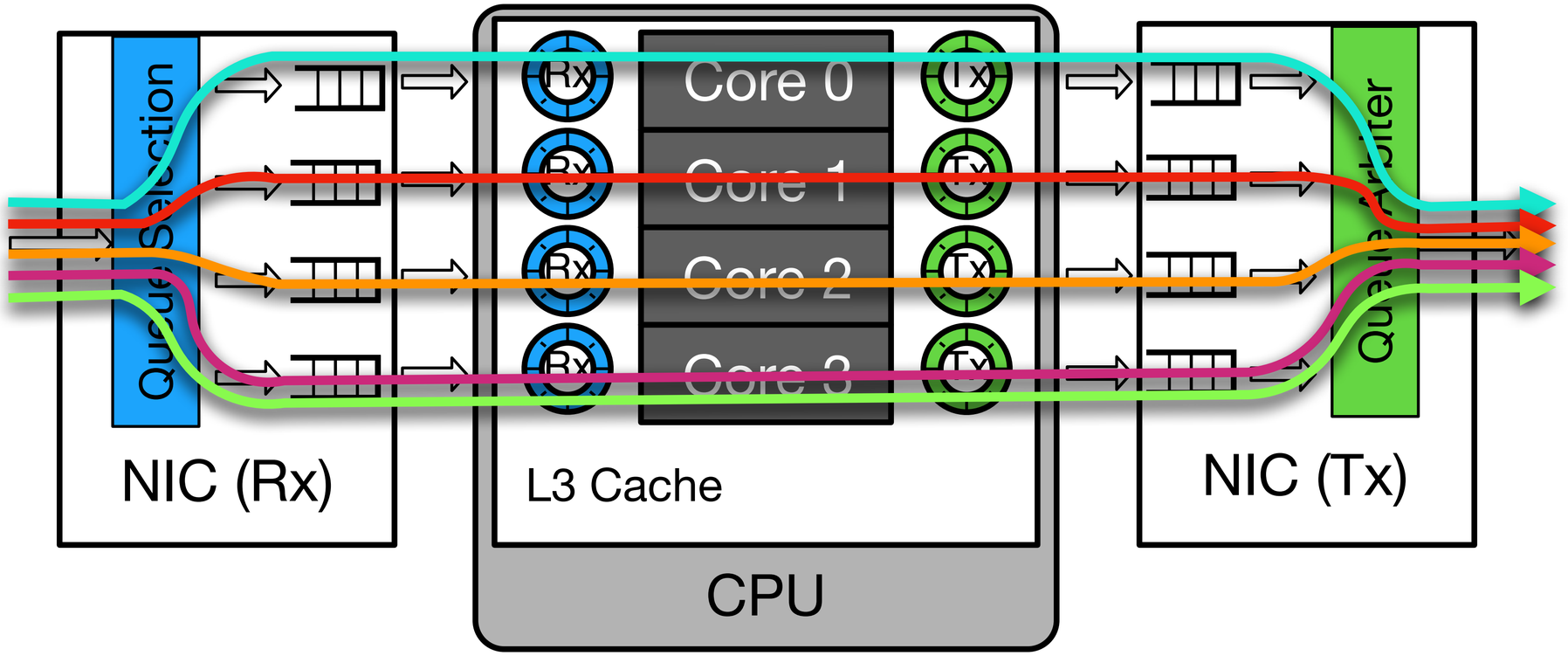
Problems with Hashing Flows to Cores



Inefficiency

Unfairness

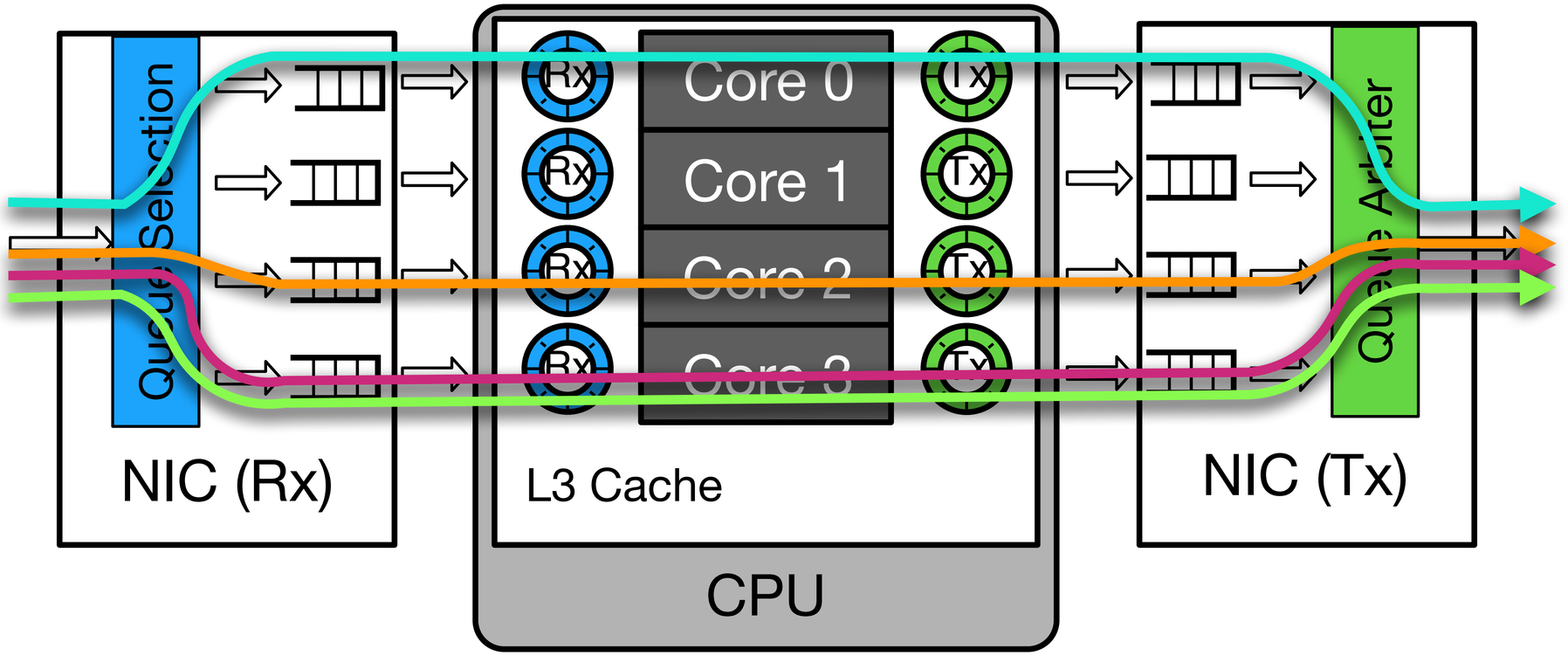
Problems with Hashing Flows to Cores



Inefficiency

Unfairness

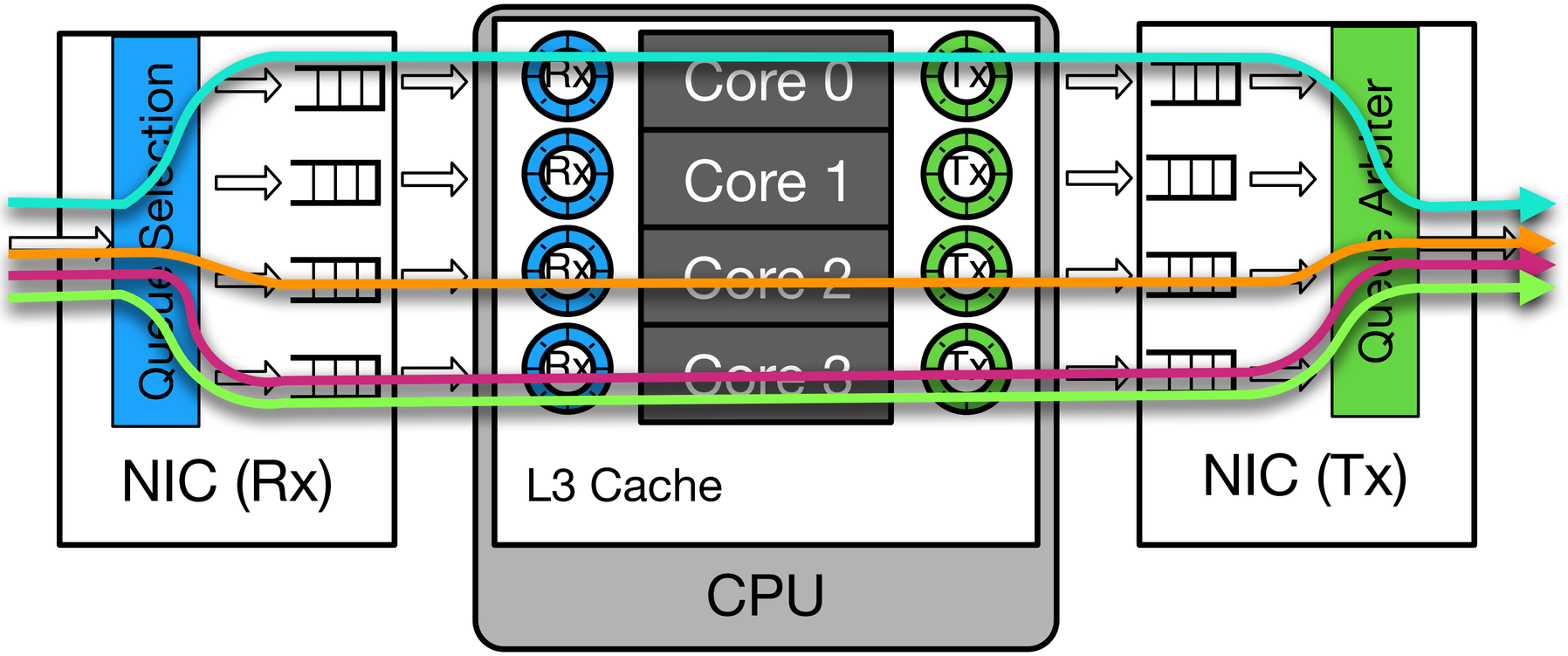
Problems with Hashing Flows to Cores



Inefficiency

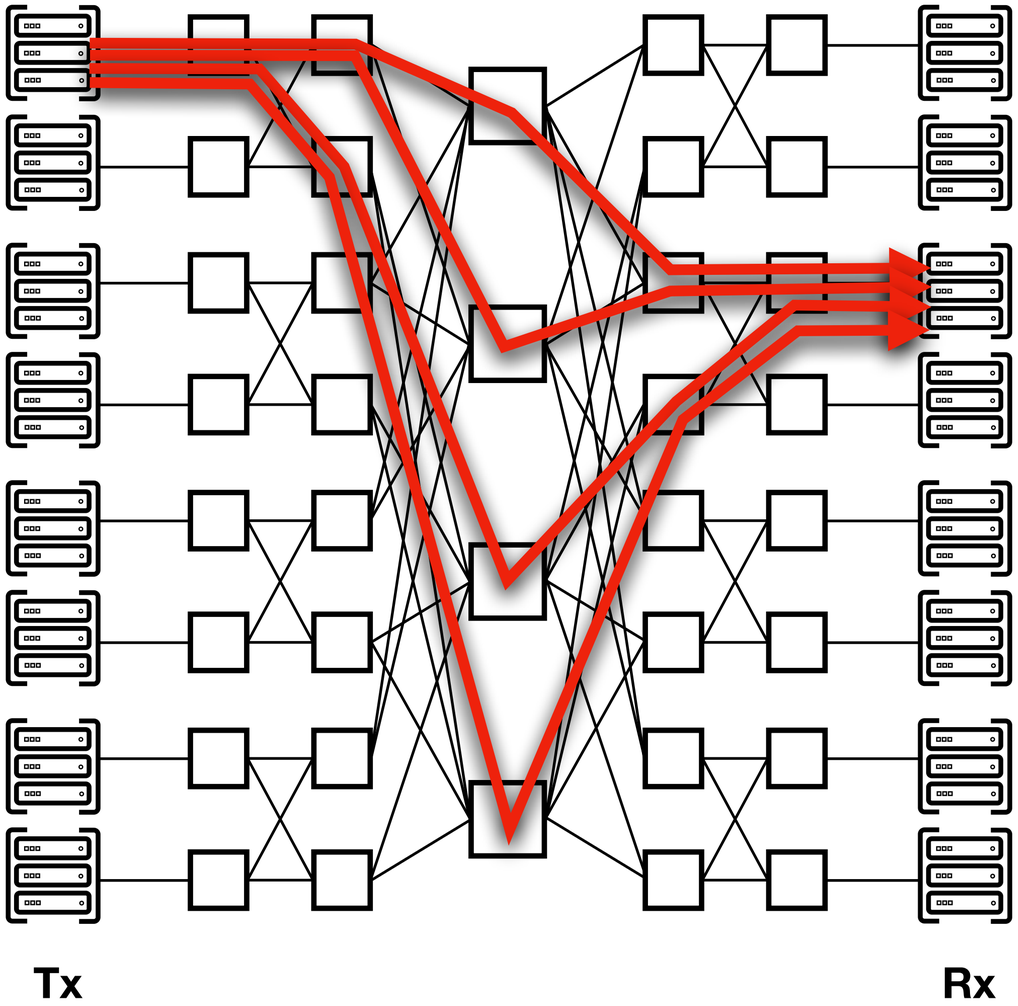
Unfairness

Problems with Hashing Flows to Cores



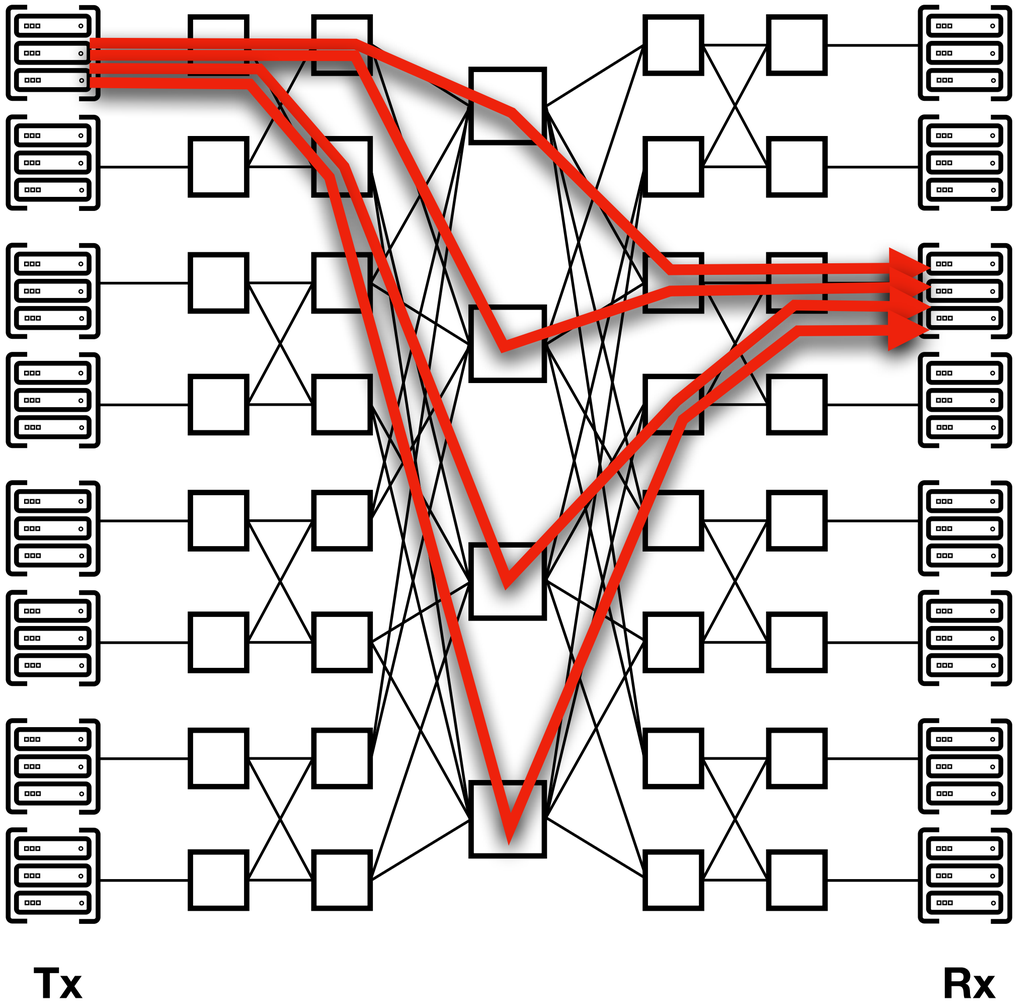
No matter how you do it, mapping flows to cores is inefficient and unfair

Analogous Problem in Datacenters



- Multiple paths
- Low and similar latencies

Analogous Problem in Datacenters



- Multiple paths
- Low and similar latencies

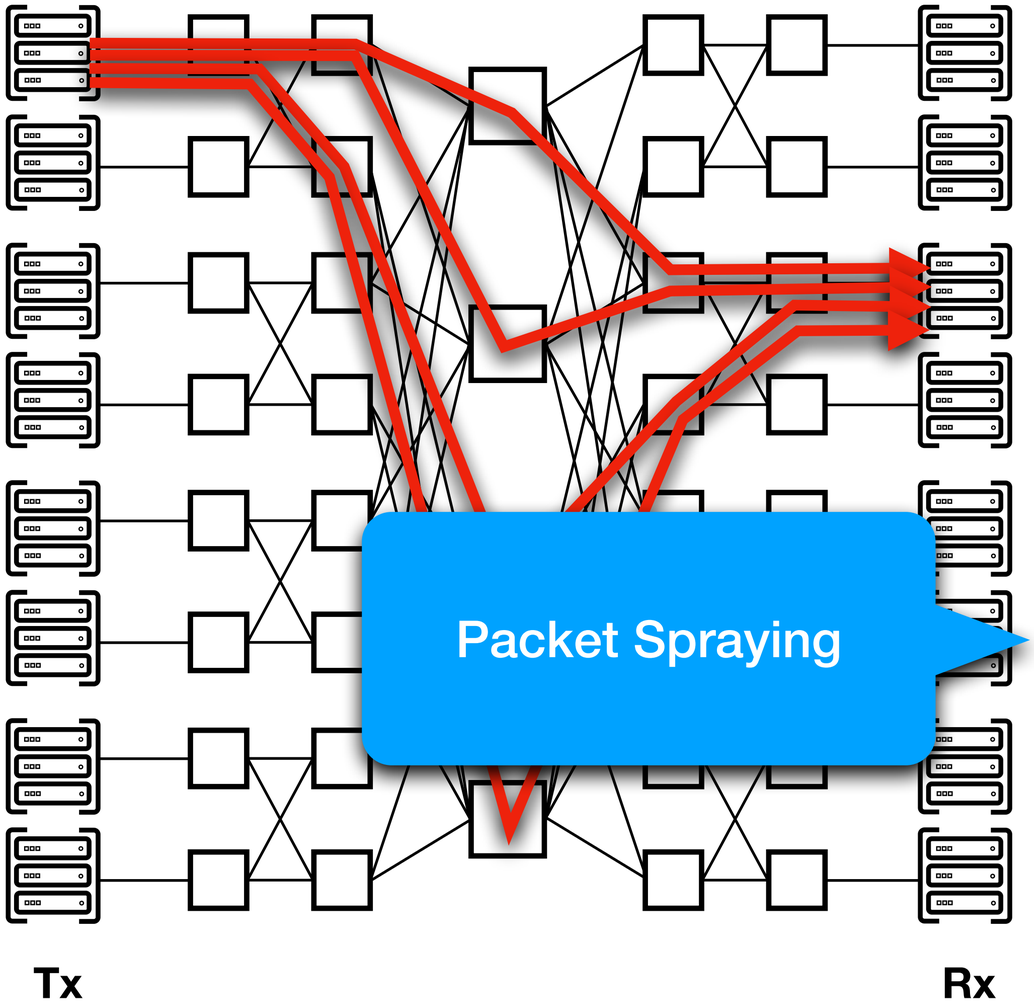
RPS [INFOCOM ’13]

pFabric [SIGCOMM ’13]

NDP [SIGCOMM ’17]

Hermes [SIGCOMM ’17]

Analogous Problem in Datacenters



- Multiple paths
- Low and similar latencies

RPS [INFOCOM ’13]

pFabric [SIGCOMM ’13]

NDP [SIGCOMM ’17]

Hermes [SIGCOMM ’17]

Can software middleboxes also benefit from load balancing packets at a finer granularity?

Can software middleboxes also benefit from load balancing packets at a finer granularity?

Sprayer

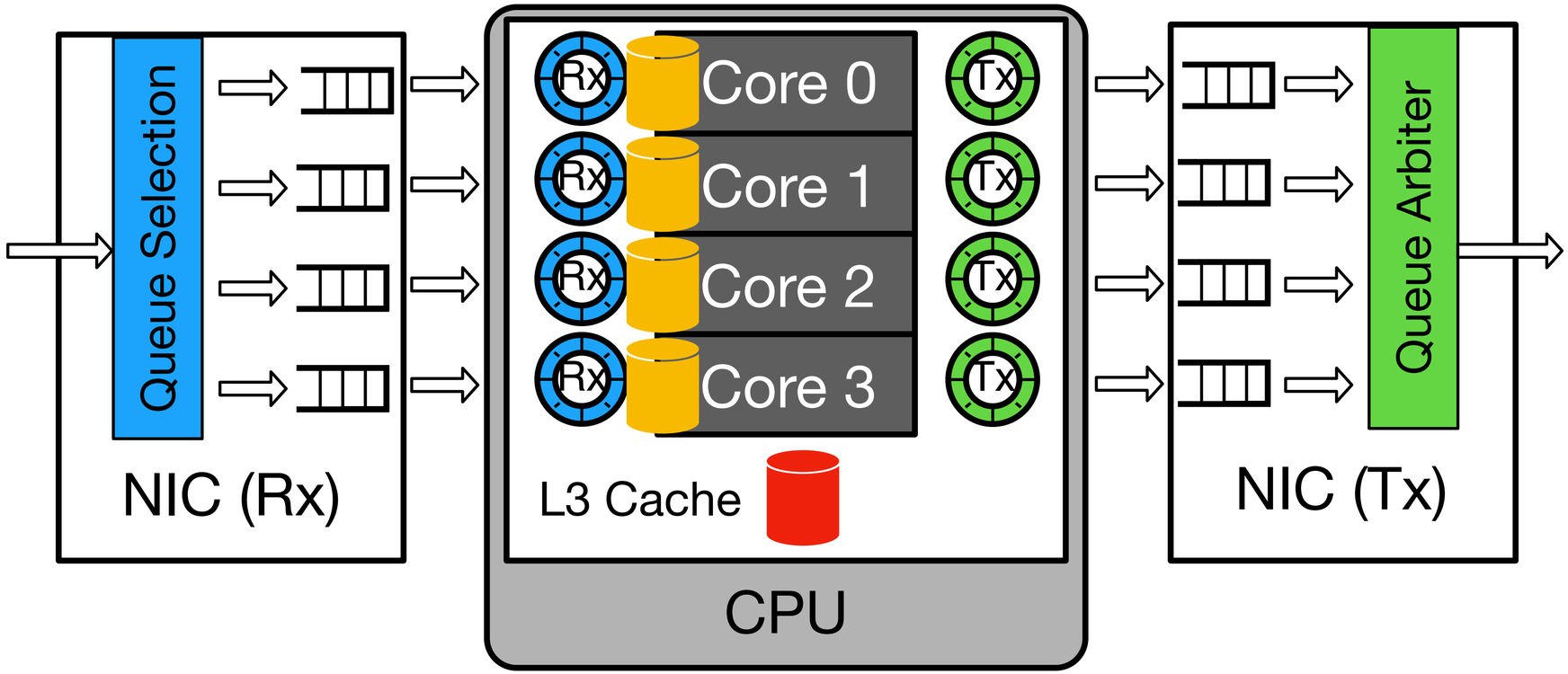
Can software middleboxes also benefit from load balancing packets at a finer granularity?

Sprayer

1. Efficiently handle flow state
2. Spray packets using existing NICs

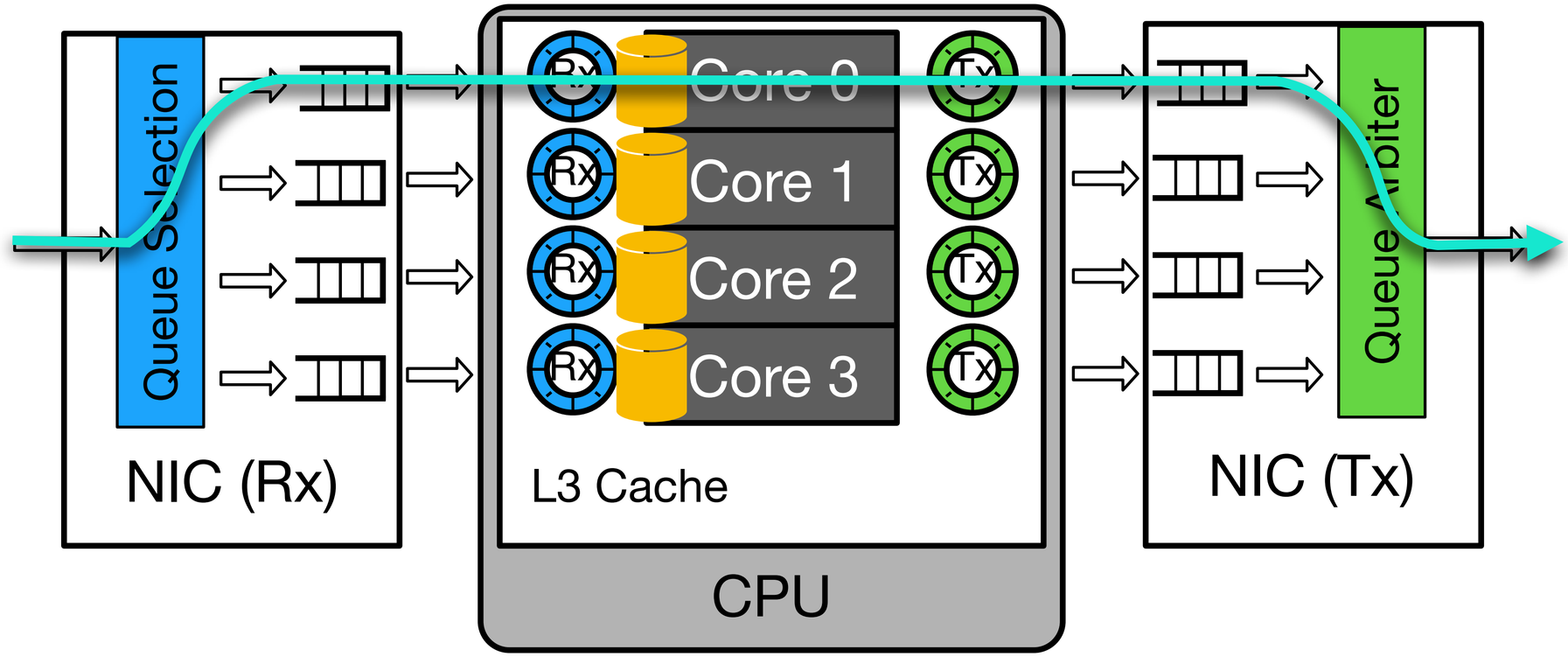
How to efficiently handle flow state?

How to efficiently handle flow state?



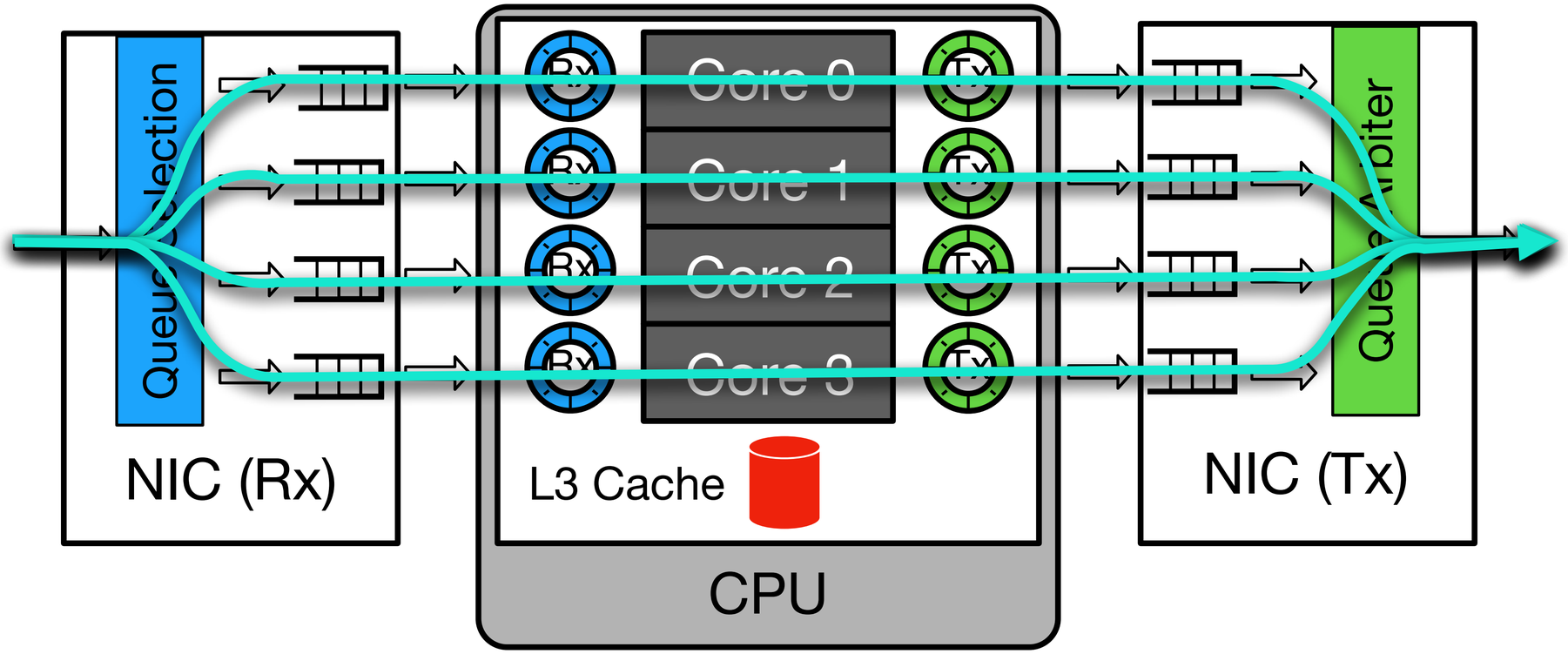
NFs have two types of state: local and global

How to efficiently handle flow state?



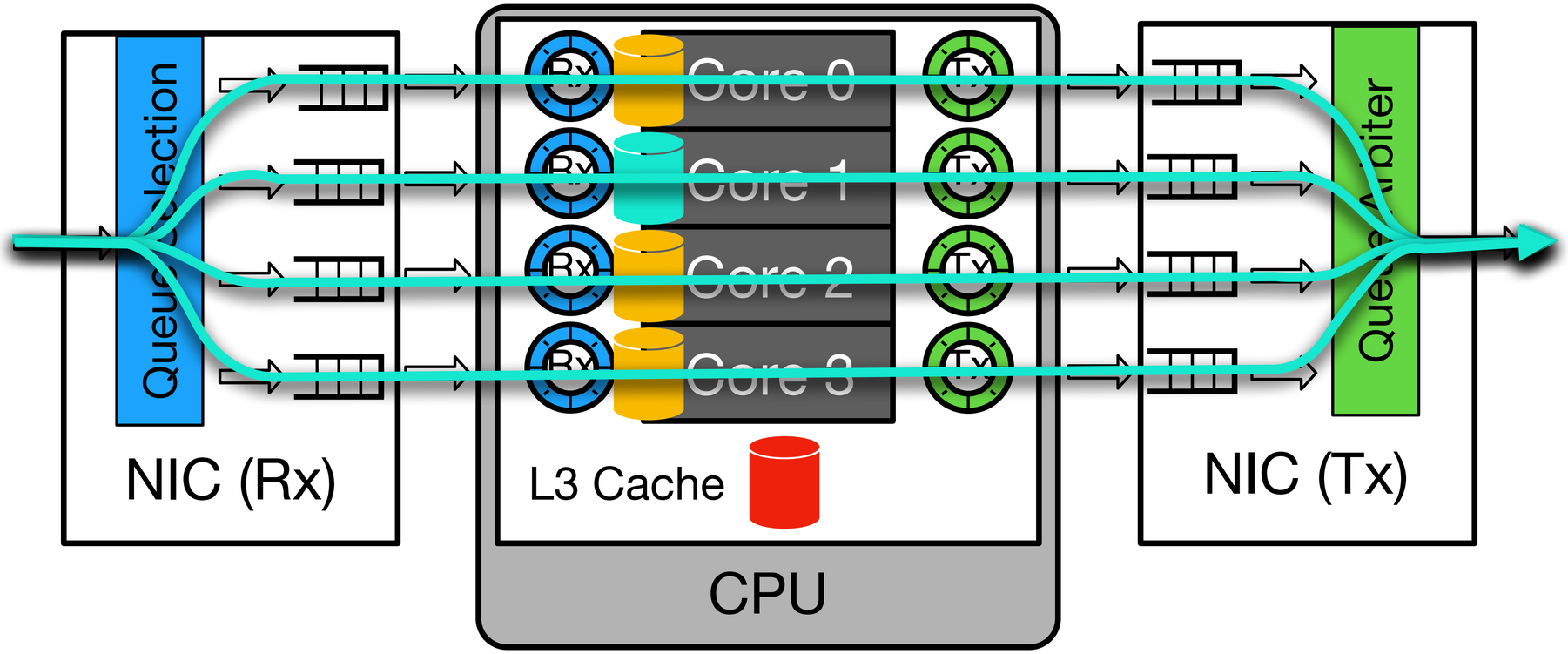
When all packets from the same flow go to the same core, flow state is partitionable

How to efficiently handle flow state?



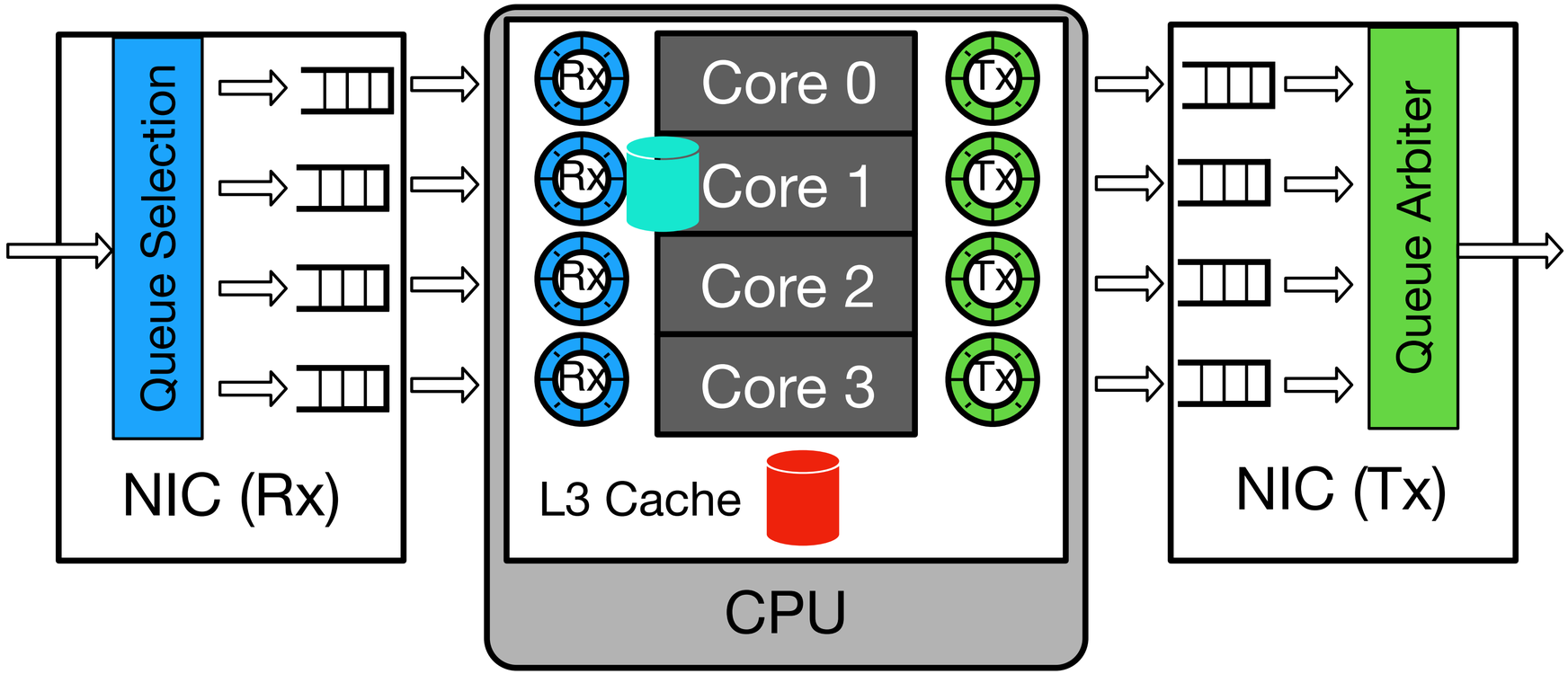
If we spray packets and let every core update the state for a given flow, we lose this property…

How to efficiently handle flow state?



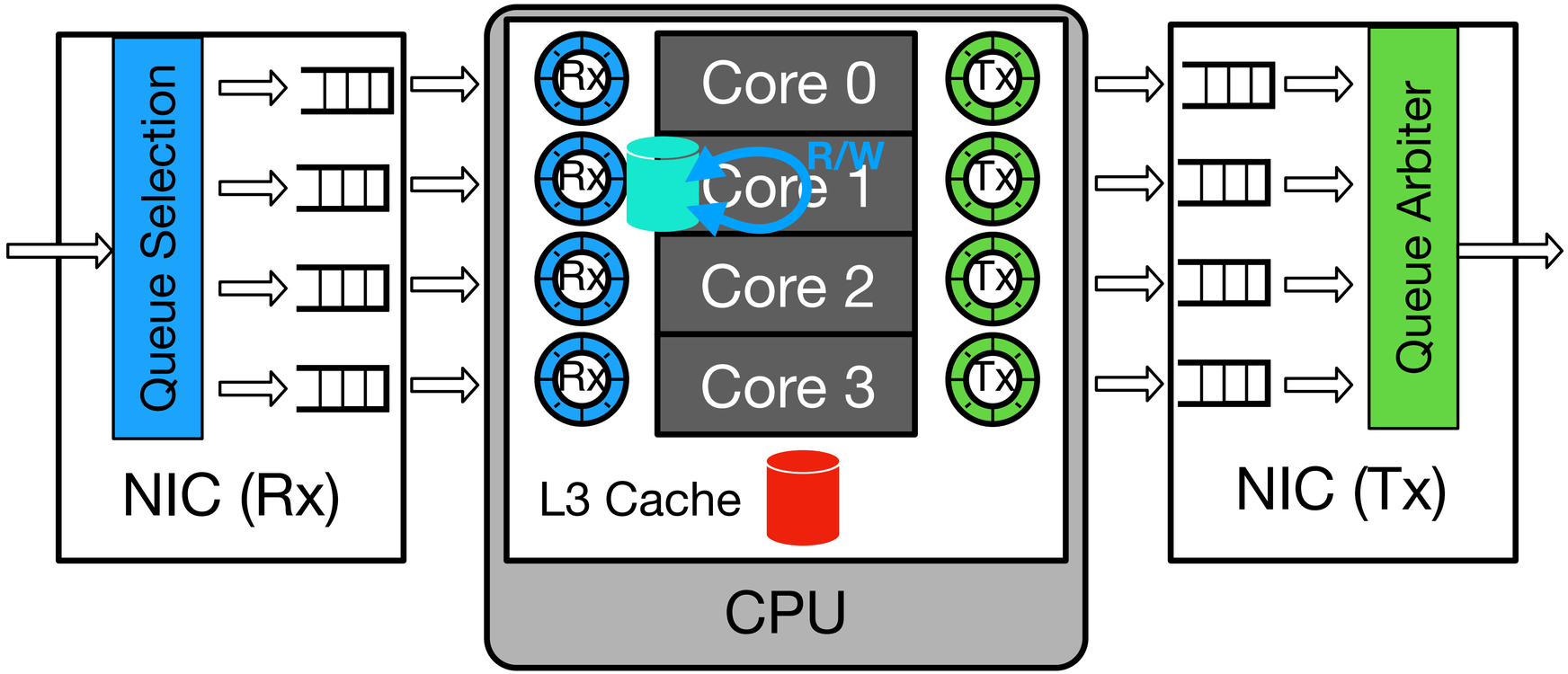
However, we get similar benefits if we provide writing partition

How to efficiently handle flow state?



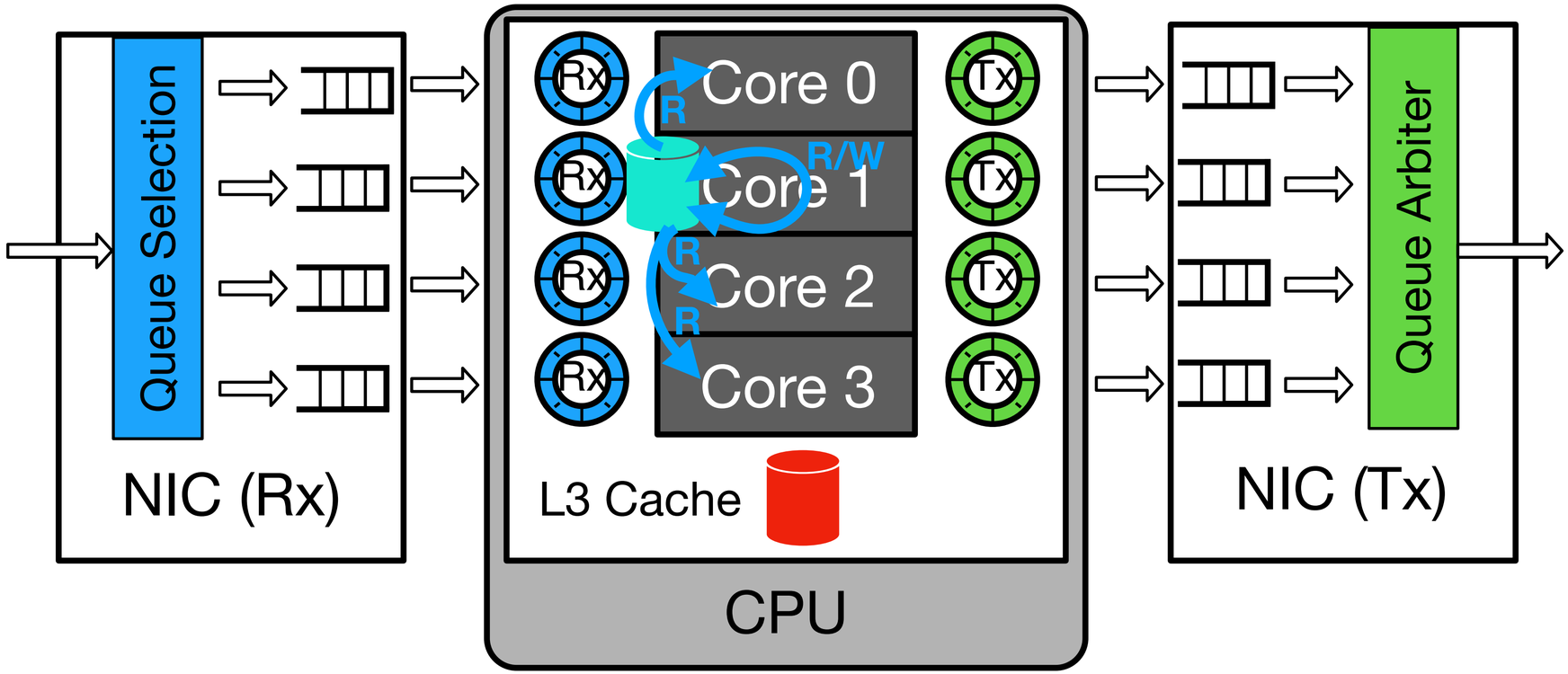
However, we get similar benefits if we provide writing partition

How to efficiently handle flow state?



However, we get similar benefits if we provide writing partition

How to efficiently handle flow state?



However, we get similar benefits if we provide writing partition

How to achieve writing partition?

How to achieve writing partition?

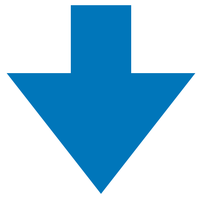
Many NFs only need to change flow state when TCP connections start or finish

***e.g.*, NAT, firewall, load balancer, traffic monitor**

How to achieve writing partition?

Many NFs only need to change flow state when TCP connections start or finish

***e.g.*, NAT, firewall, load balancer, traffic monitor**



Ensure that packets at the beginning or end of the same TCP connection go to the same core

Sprayer

1. Efficiently handle flow state ✓
2. Spray packets using existing NICs

How to spray packets using existing NICs?

How to spray packets using existing NICs?

Two ways to direct packets to cores

How to spray packets using existing NICs?

Two ways to direct packets to cores

RSS: use hash of the 5-tuple

How to spray packets using existing NICs?

Two ways to direct packets to cores

RSS: use hash of the 5-tuple

Flow Director: match arbitrary header field

How to spray packets using existing NICs?

Two ways to direct packets to cores

RSS: use hash of the 5-tuple

Flow Director: match arbitrary header field

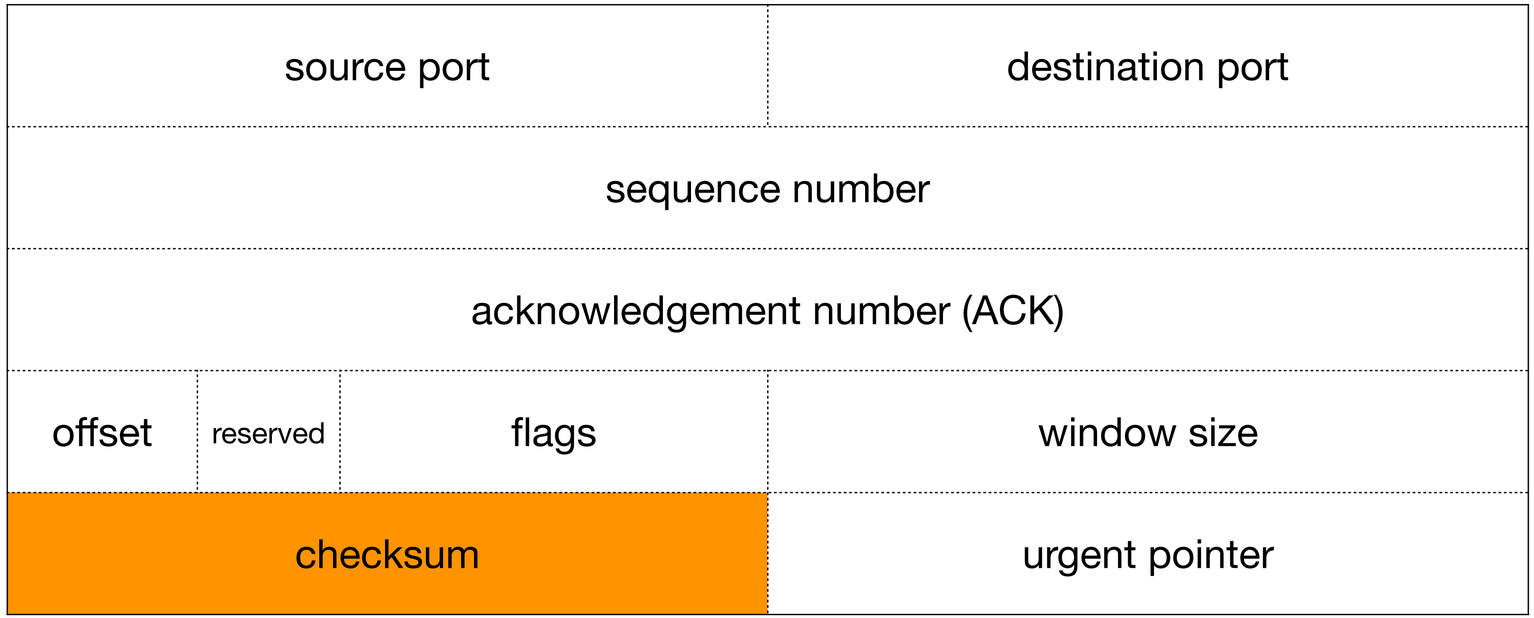
How to spray packets using existing NICs?

TCP Header

<table>
<tr><td colspan="3">source port</td><td>destination port</td></tr>
<tr><td colspan="4">sequence number</td></tr>
<tr><td colspan="4">acknowledgement number (ACK)</td></tr>
<tr><td>offset</td><td>reserved</td><td>flags</td><td>window size</td></tr>
<tr><td colspan="3">checksum</td><td>urgent pointer</td></tr>
</table>

How to spray packets using existing NICs?

TCP Header



Sprayer

1. Efficiently handle flow state ✓
2. Spray packets using existing NICs ✓

Preliminary Evaluation

Preliminary Evaluation

- Will packet reordering have a significant impact on TCP?

Preliminary Evaluation

- Will packet reordering have a significant impact on TCP?
- How much improvement do we get from Sprayer?

Preliminary Evaluation

Throughput

Latency

Fairness

Preliminary Evaluation

Throughput

Latency

Fairness

- Consistent throughput, regardless of the number of concurrent flows

Preliminary Evaluation

Throughput

Latency

Fairness

- Consistent throughput, regardless of the number of concurrent flows
- Significant improvement for small number of flows

Preliminary Evaluation

Throughput

- Consistent throughput, regardless of the number of concurrent flows
- Significant improvement for small number of flows
- Packet reordering is not enough to significantly harm TCP

Latency

Fairness

Preliminary Evaluation

Throughput

- Consistent throughput, regardless of the number of concurrent flows
- Significant improvement for small number of flows
- Packet reordering is not enough to significantly harm TCP

Latency

- Sprayer processes packets from the same flow in parallel, reducing the latency

Fairness

Preliminary Evaluation

Throughput

- Consistent throughput, regardless of the number of concurrent flows
- Significant improvement for small number of flows
- Packet reordering is not enough to significantly harm TCP

Latency

- Sprayer processes packets from the same flow in parallel, reducing the latency

Fairness

- Sprayer achieves nearly perfect fairness

Preliminary Evaluation

Throughput

- Consistent throughput, regardless of the number of concurrent flows
- Significant improvement for small number of flows
- Packet reordering is not enough to significantly harm TCP

Latency

- Sprayer processes packets from the same flow in parallel, reducing the latency

Fairness

- Sprayer achieves nearly perfect fairness
- RSS suffers from hash collisions

Takeaways

Takeaways

- Matching flows to cores causes inefficiency and unfairness

Takeaways

- Matching flows to cores causes inefficiency and unfairness
- We need to load balance packets at a finer granularity

Takeaways

- Matching flows to cores causes inefficiency and unfairness
- We need to load balance packets at a finer granularity
- Sprayer takes the first step by:
  - Ensuring that flow states are handled efficiently
  - Working with commodity NICs

Open Questions

Open Questions

- What about other types of NFs?

Open Questions

- What about other types of NFs?
- Can Sprayer benefit from programmable NICs?

Open Questions

- What about other types of NFs?
- Can Sprayer benefit from programmable NICs?
- What about other transport protocols?