github.com/dyssect/dyssect

# Dyssect: Dynamic Scaling of Stateful Network Functions


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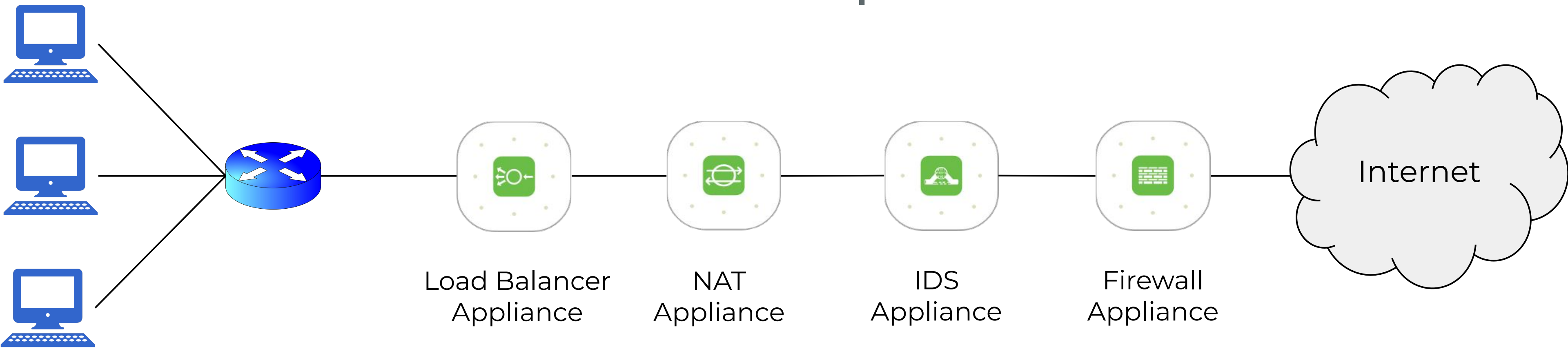
UFMT and UFMS[1] UFMS[2] UFMG[3] Uber Technologies, Inc.[4]

# Introduction

## Conventional Enterprise Network




**More** Expensive
**Less** Manageable

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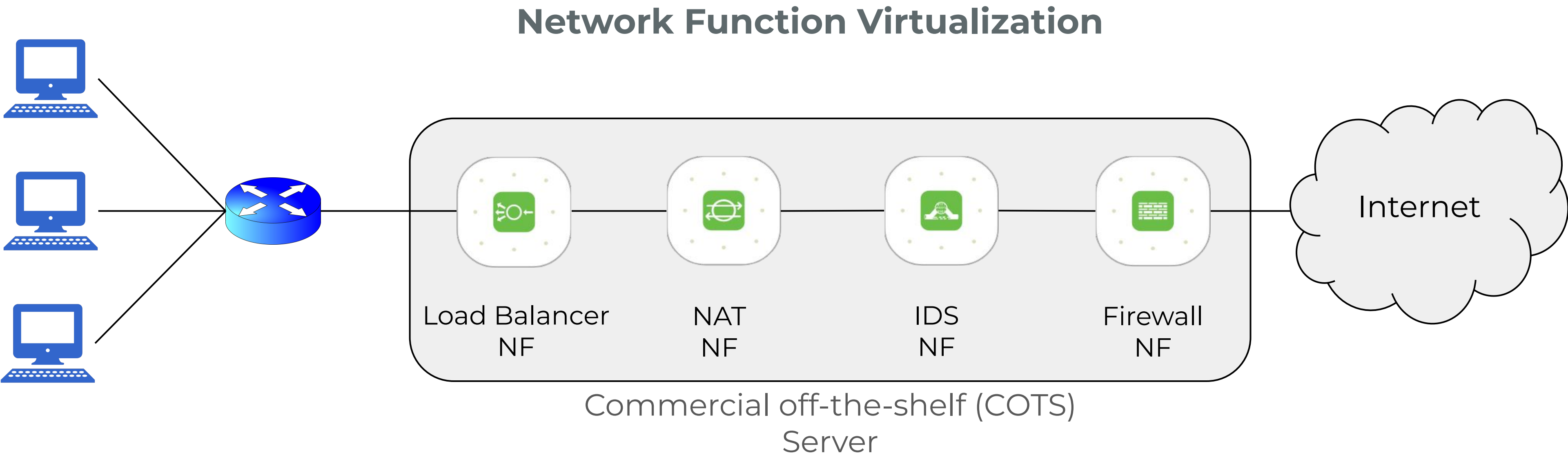


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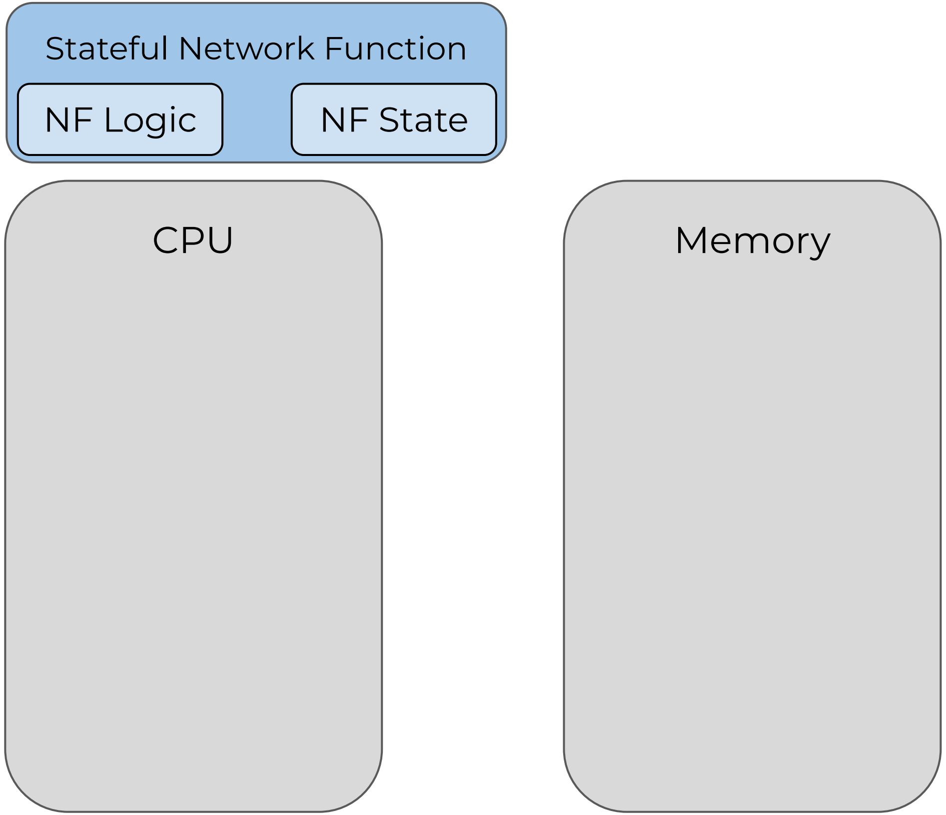


- The vast majority of network functions are *stateful* and may require state updates on a *per-packet* basis;

- Concurrent accesses:
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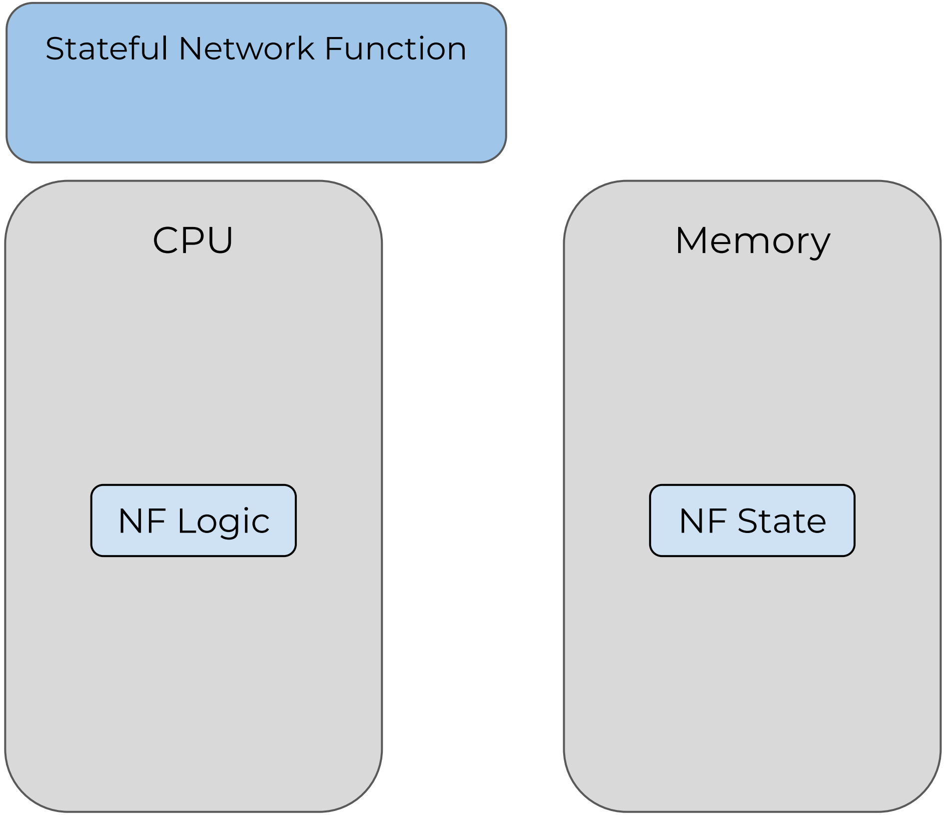


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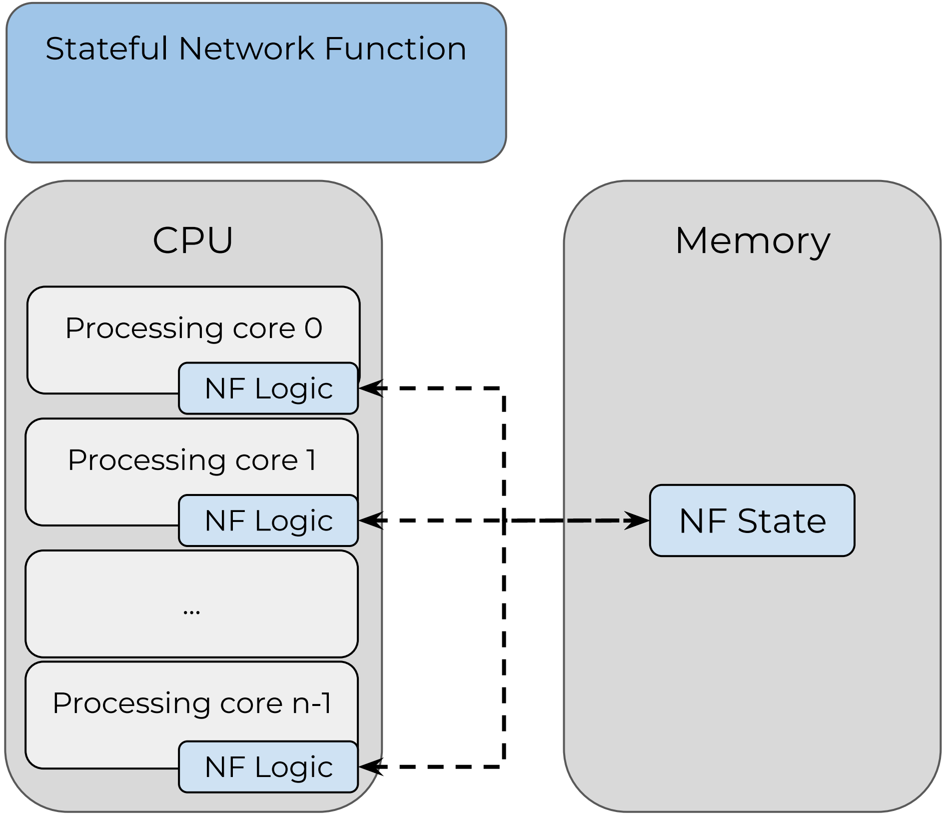


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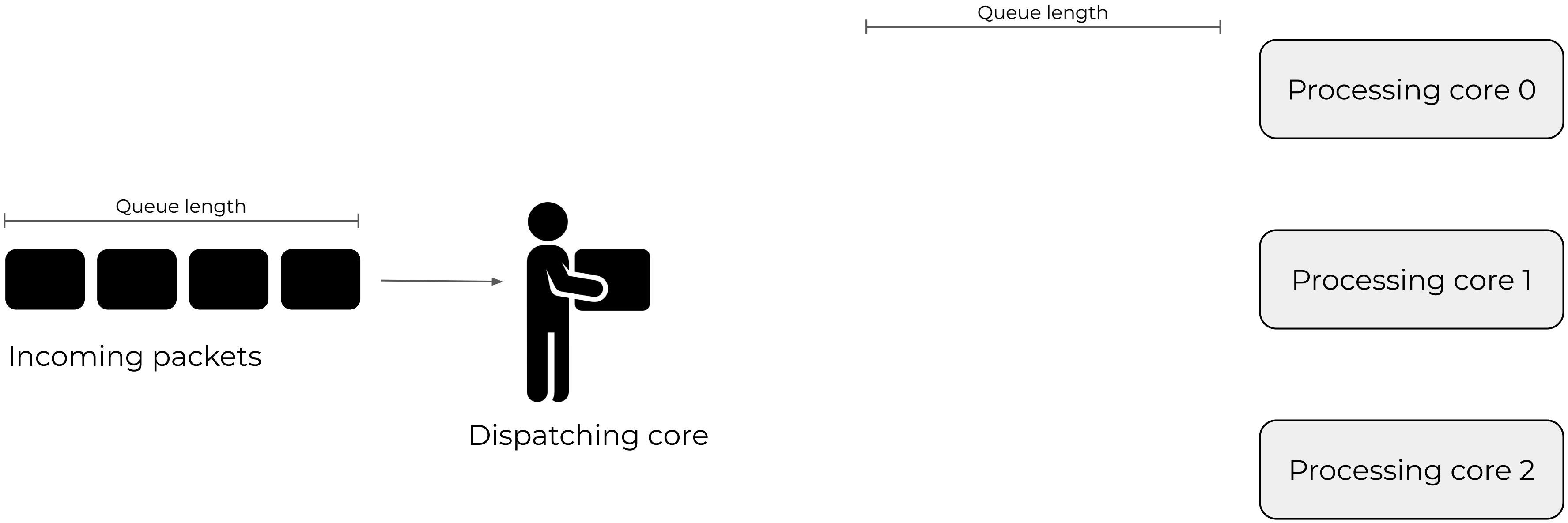

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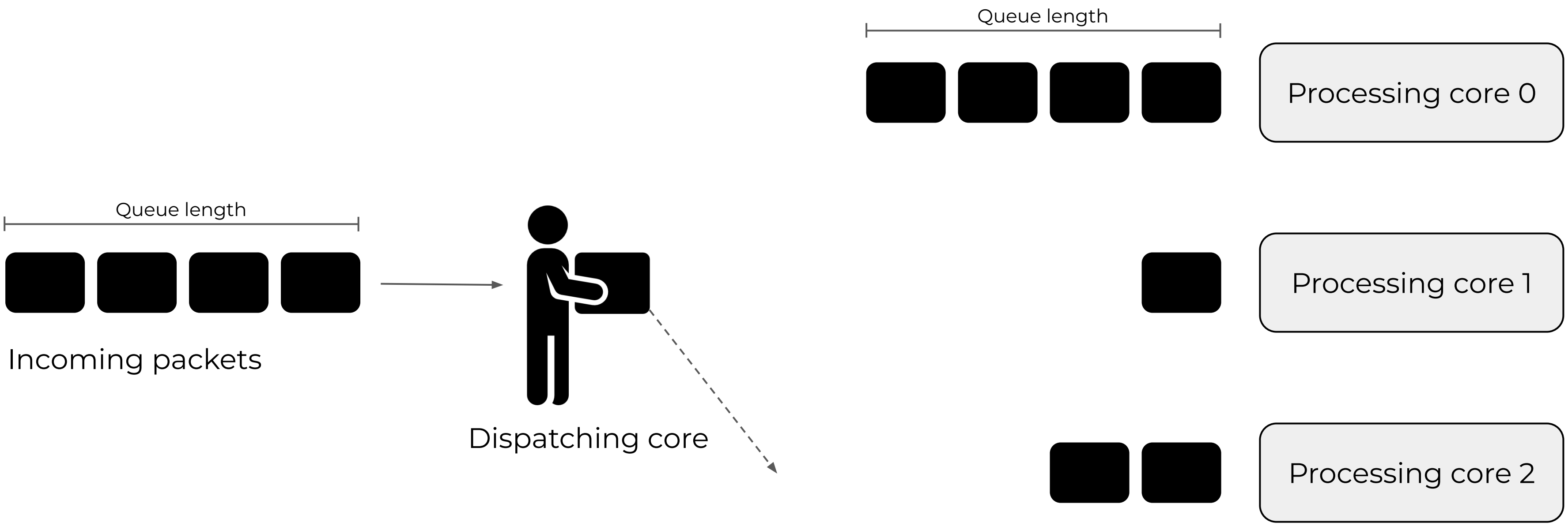

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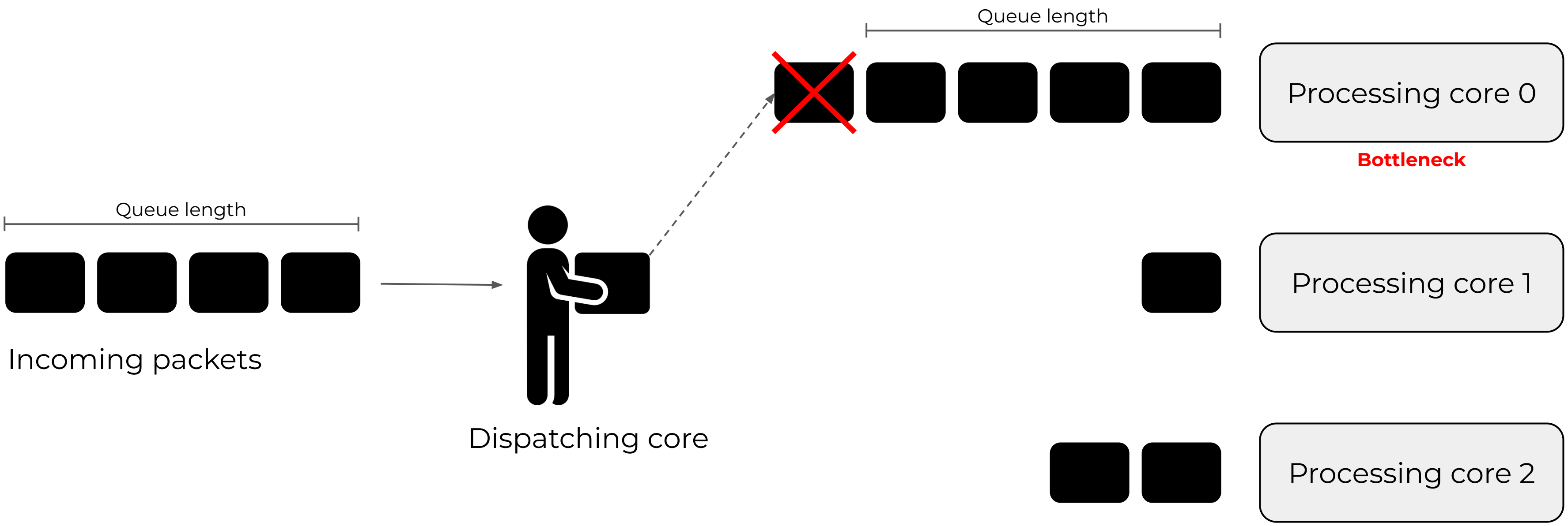

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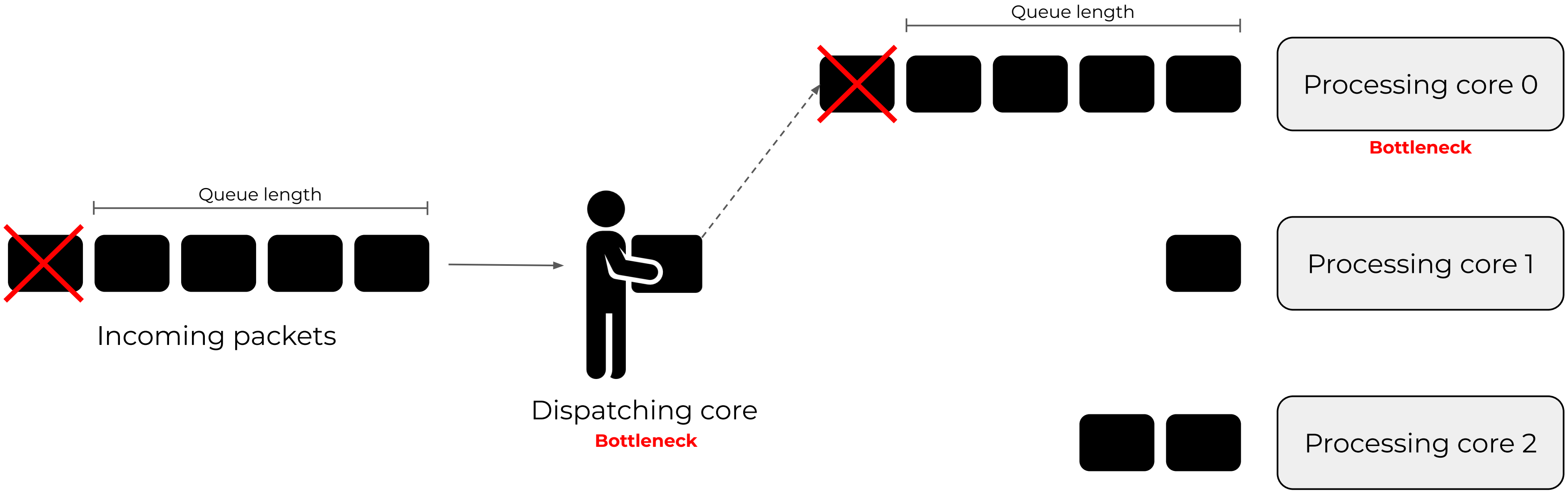

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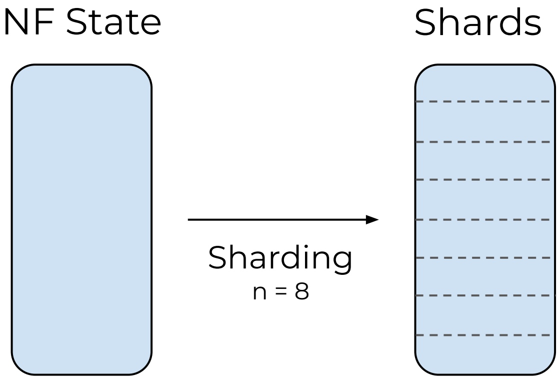


- Several research proposals use state *sharding* to avoid the use of locks;

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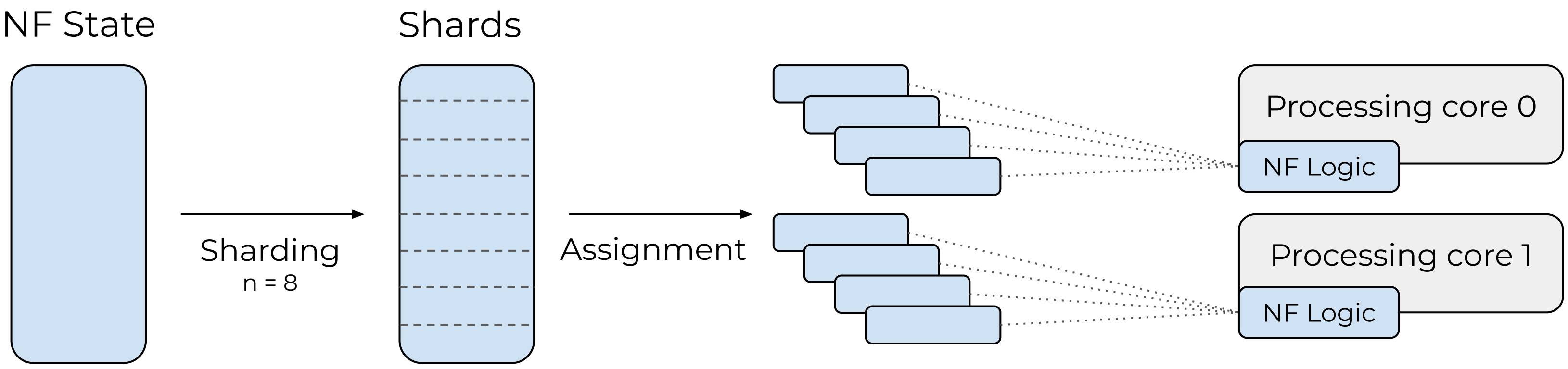


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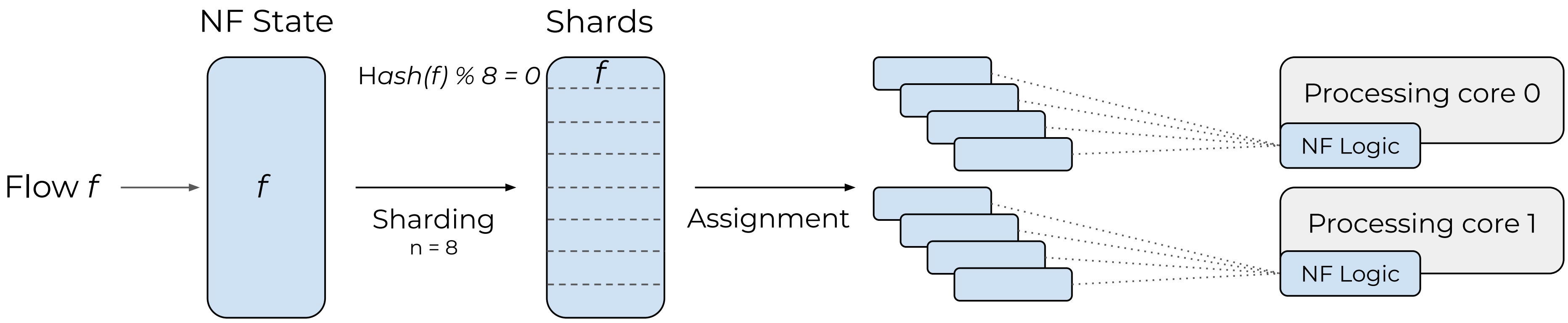


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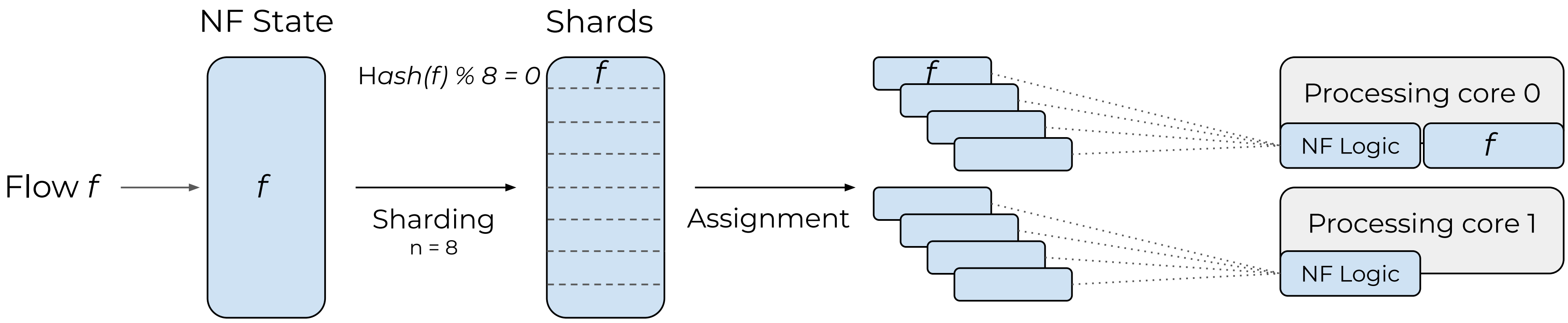


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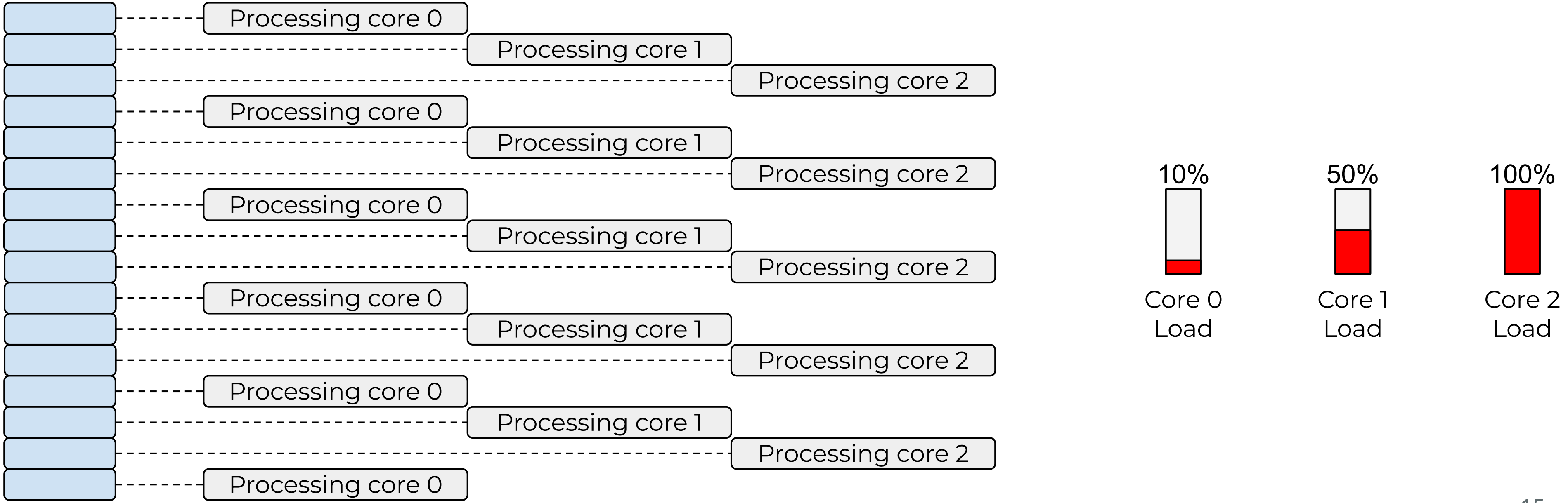

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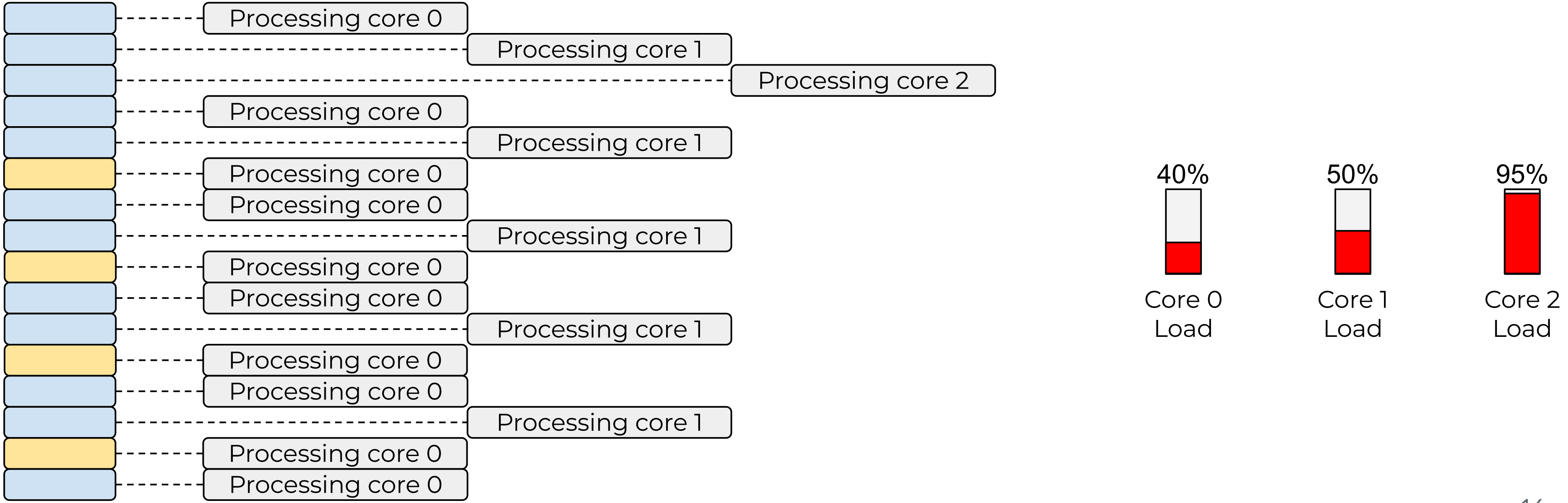

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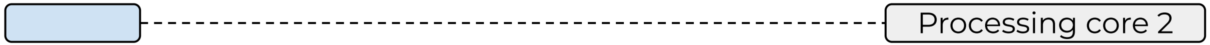
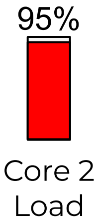
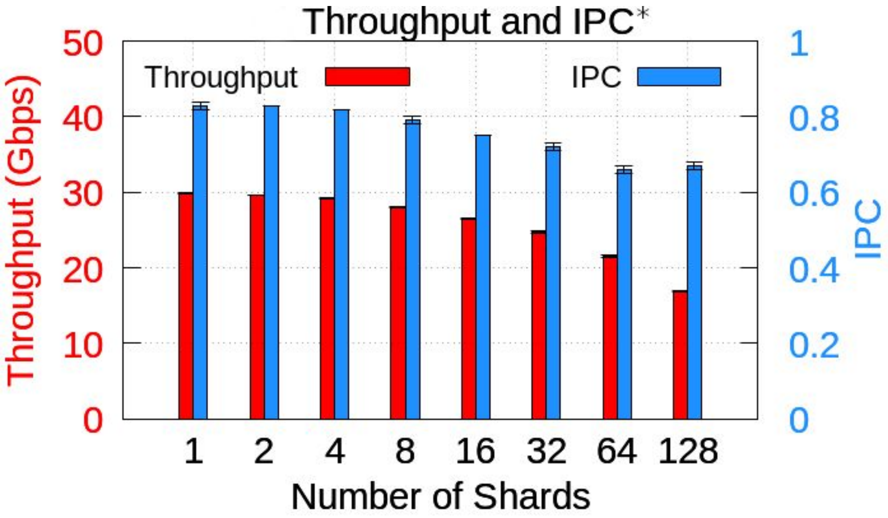


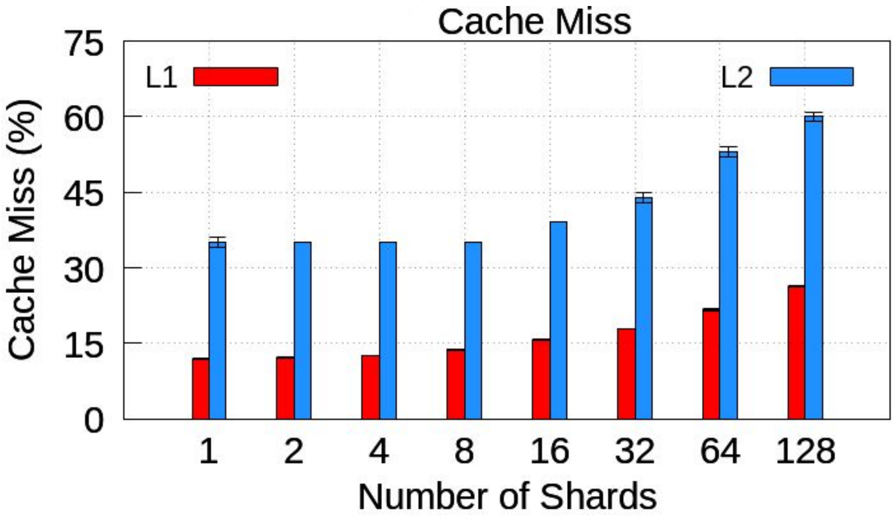




- One shard might have multiple large-volume flows;
- Systems cannot allocate more cores to handle the load, as the shard is assigned to a single core.

# Introduction

- We evaluate the performance impact of the number of shards in CPU metrics:
  - The throughput drops up to 43.3% comparing 1 *vs.* 128 shards;




*IPC = Instructions per Cycle

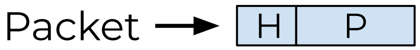
# Contributions

Dyssect:

- steers packets to cores;
- moves shards between cores;
- disaggregates of state from network functions;
- avoids frequent shard transfers;
- uses optimization models.

# Dyssect

***State Management***



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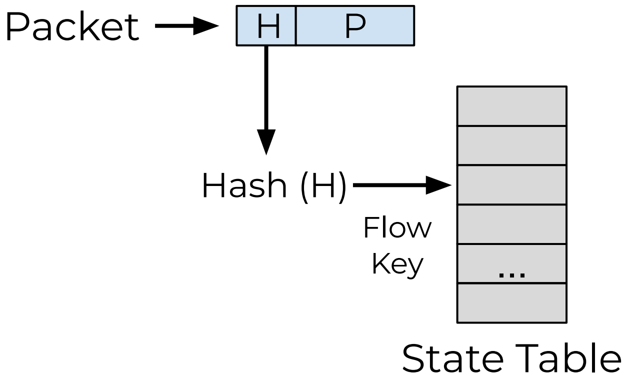

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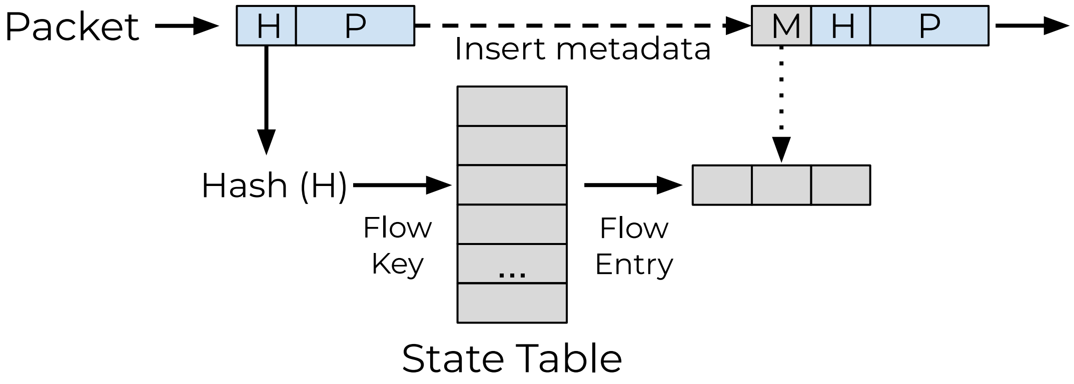

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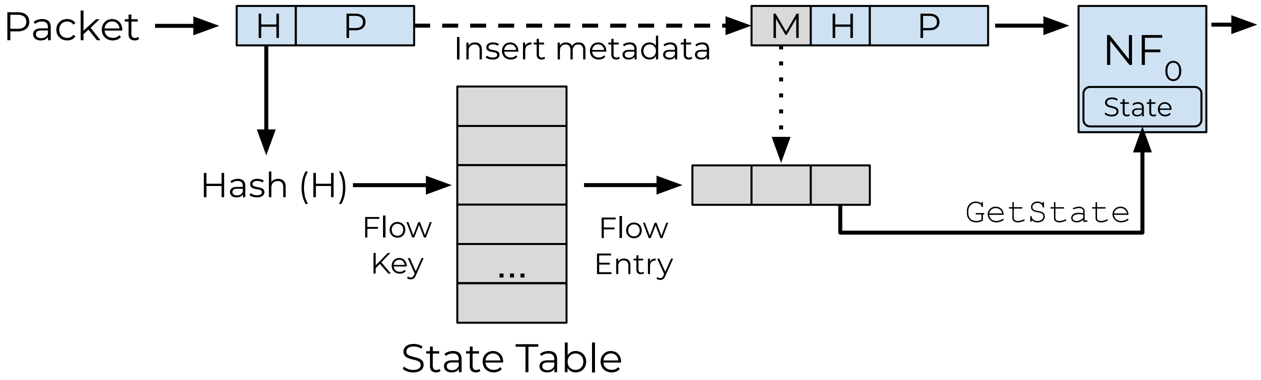

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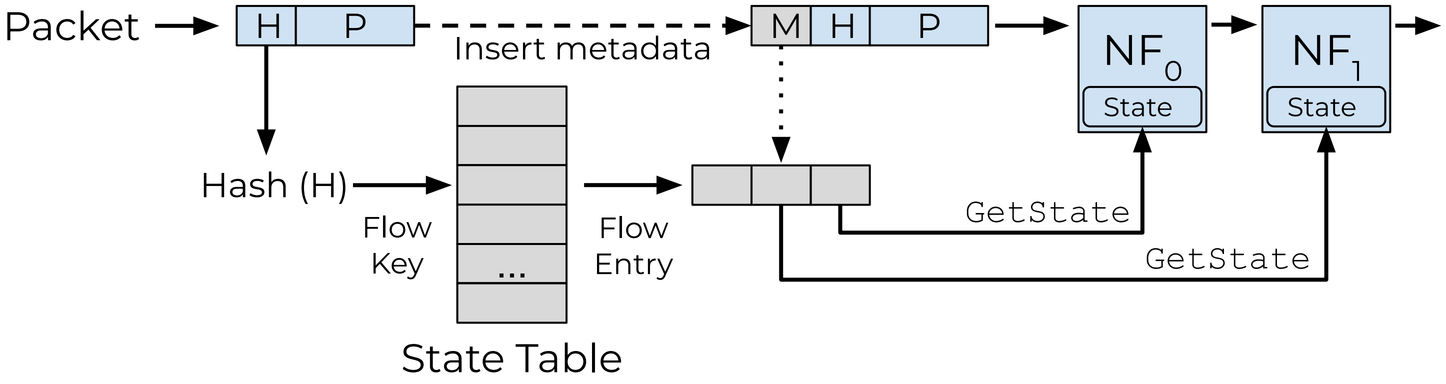

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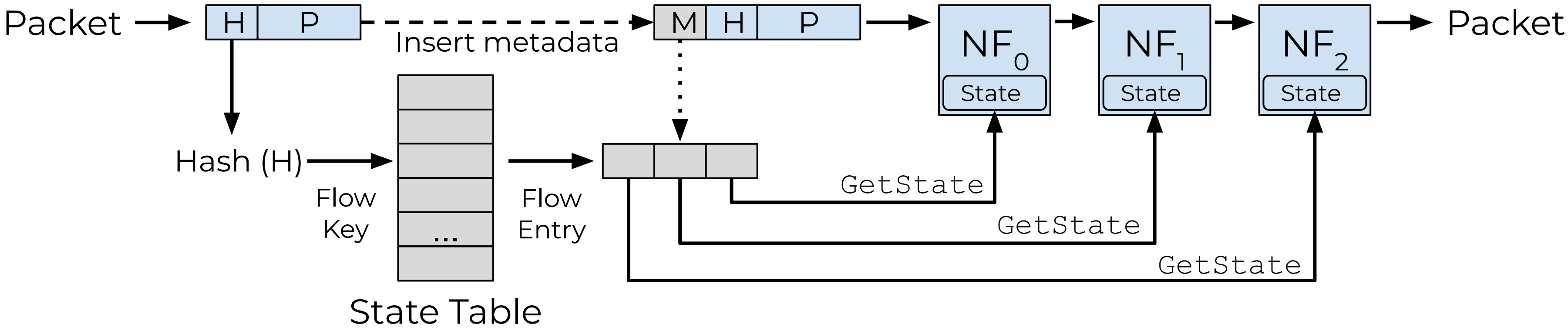
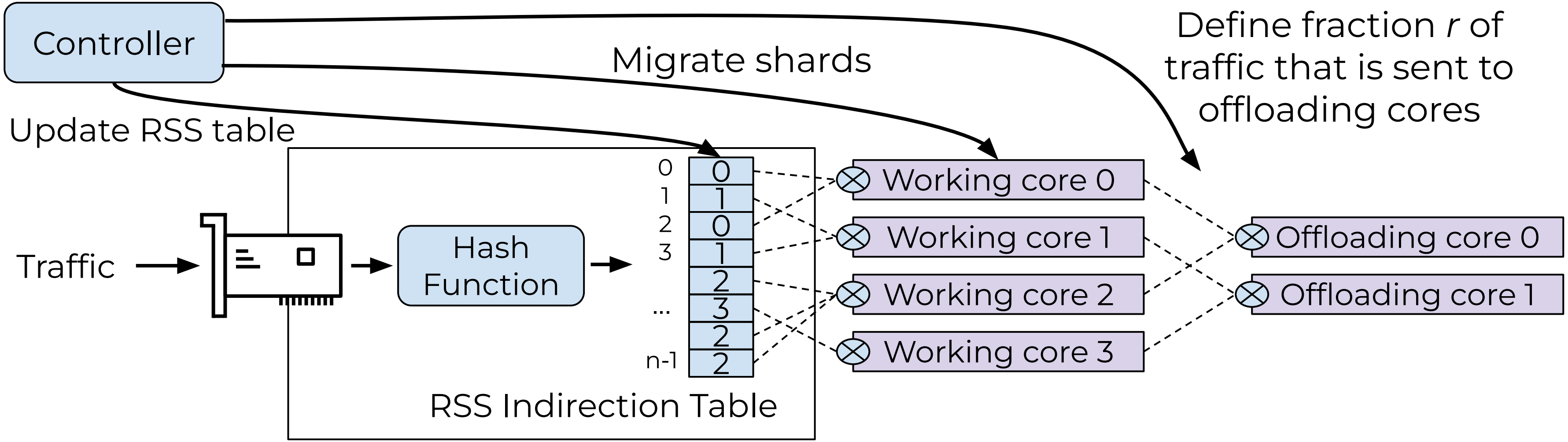


# Dyssect

## *Flow Assignment*

- Controller updates RSS table, migrates shards, and defines a subset of flows in a shard to forward to an offloading core;
- Dyssect splits cores into working or offloading cores.



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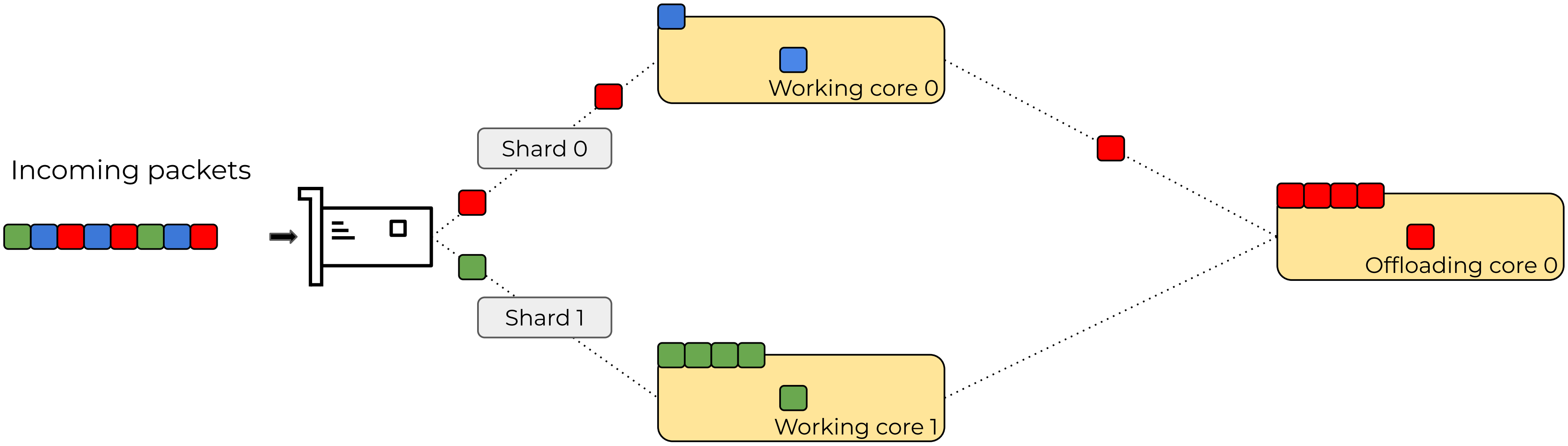
## *Flow Assignment*

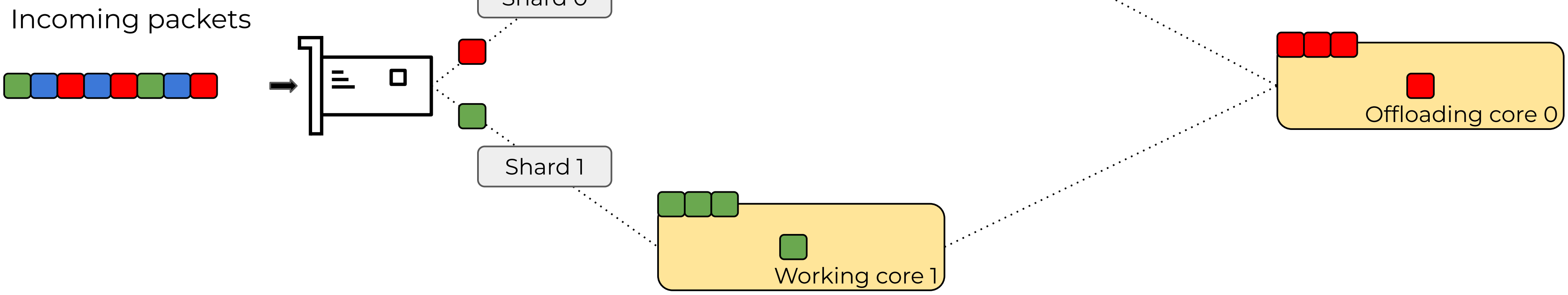
**Time $T_1$**



# Dyssect

## *Flow Assignment*

**Time $T_2$**



# Dyssect

## *Correctness Analysis*

- **Deadlock freedom**
  - Controller can disable packet processing;
  - Working cores enqueue packet into queues;
  - Offloading cores never blocks during scaling operations.
  - **If there exists an incoming packet *p*, at a certain moment, *p* turns into an outgoing packet.**
- **Packet ordering**
  - Controller can reassign shards, offloading cores, or change offload ratio;
  - Auxiliary queues are swapped by the Controller;
  - *Scaling algorithms;*
  - **For any pair of packets from the same flow, the first packet of the pair is always processed first.**

*Check the formal proofs in our paper.*

# Dyssect

## *Flow Assignment Optimization*

Optimization models:

- Long-timescale optimization:
    - minimizes the number of active working and offloading cores.

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Optimization models:

- Long-timescale optimization:
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- Short-timescale optimization:
  - minimizes the number of shard migrations and offloading core reassociations.
- *Constraints*:
  - SLO, core utilization,  shard ratio, working and offloading cores relationship.

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# Evaluation

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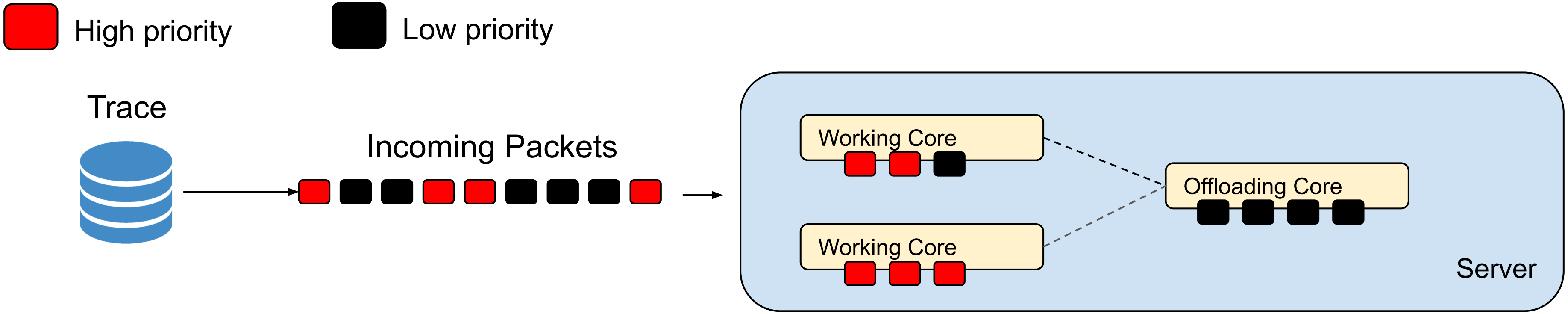
- Use Case I: traffic class prioritization;
- Use Case II: alternate optimization targets;
- Use Case III: SmartNIC offloading.

# Evaluation

***Use Case I***

- Real trace;
- High and low priority flows;
- Scaling traffic to simulate throughputs from ~2.5 to ~22 Gbps;
- Network functions: NAT and IDS.



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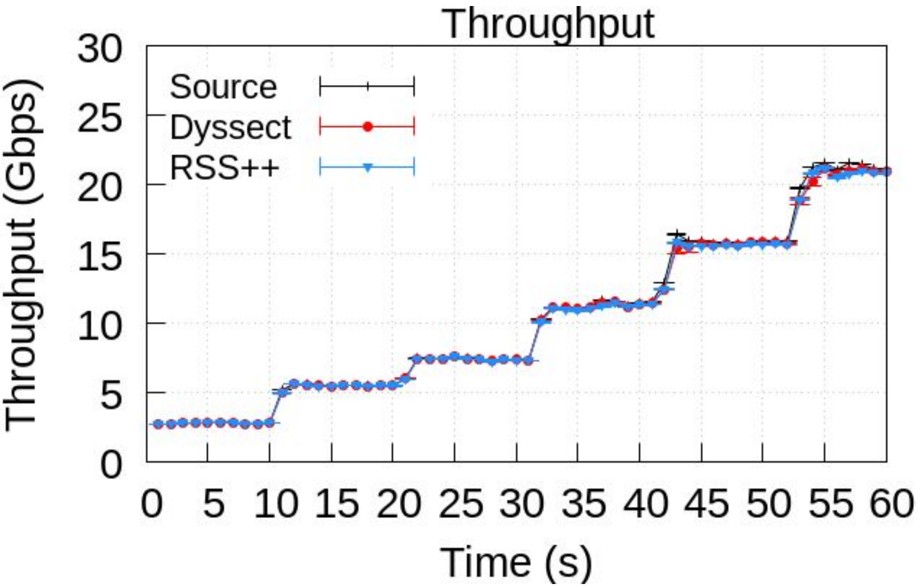
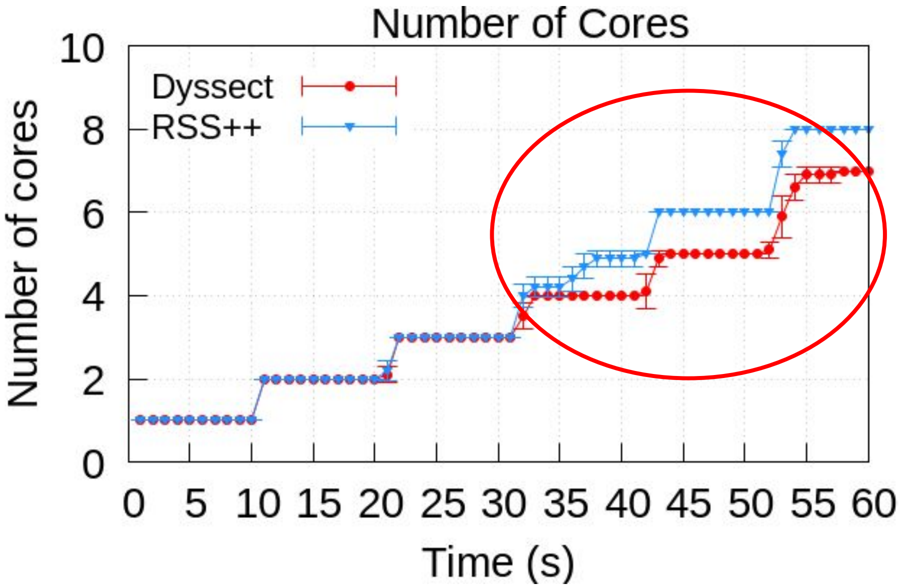
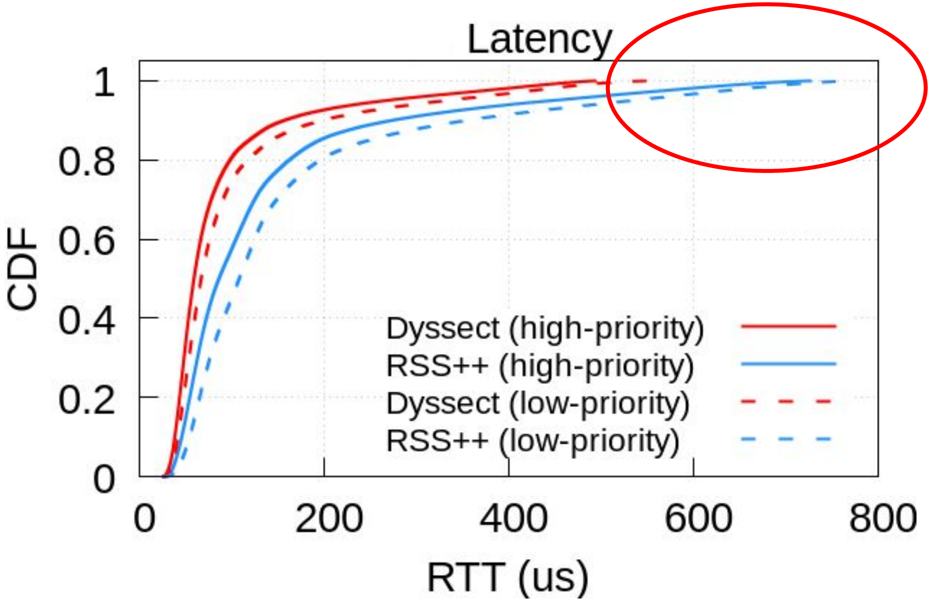
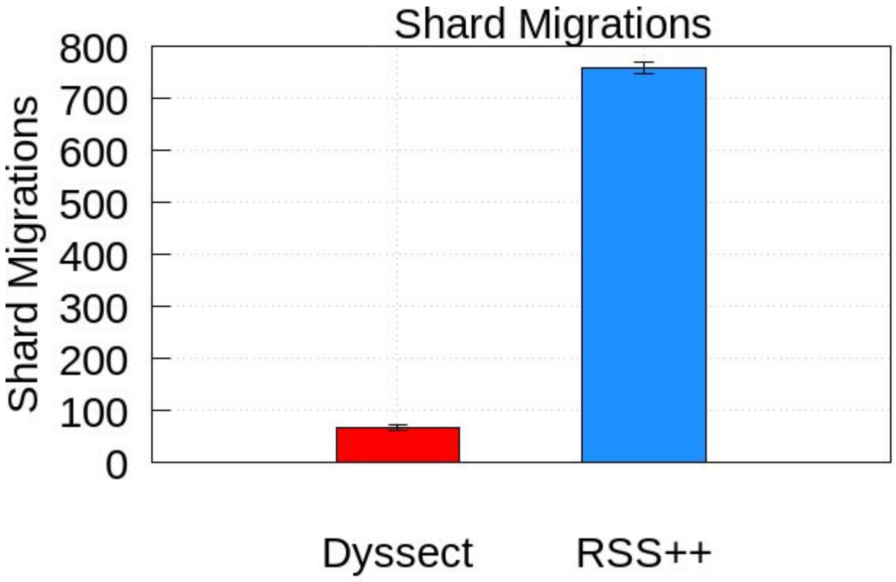


# Evaluation

*Use Case I*



# Evaluation

***Use Case II***

- We explore Dyssect using a different optimization model:
  - Load balance optimization model (below);
- This model minimizes the quadratic difference between a target value T and the utilization of working and offloading cores.

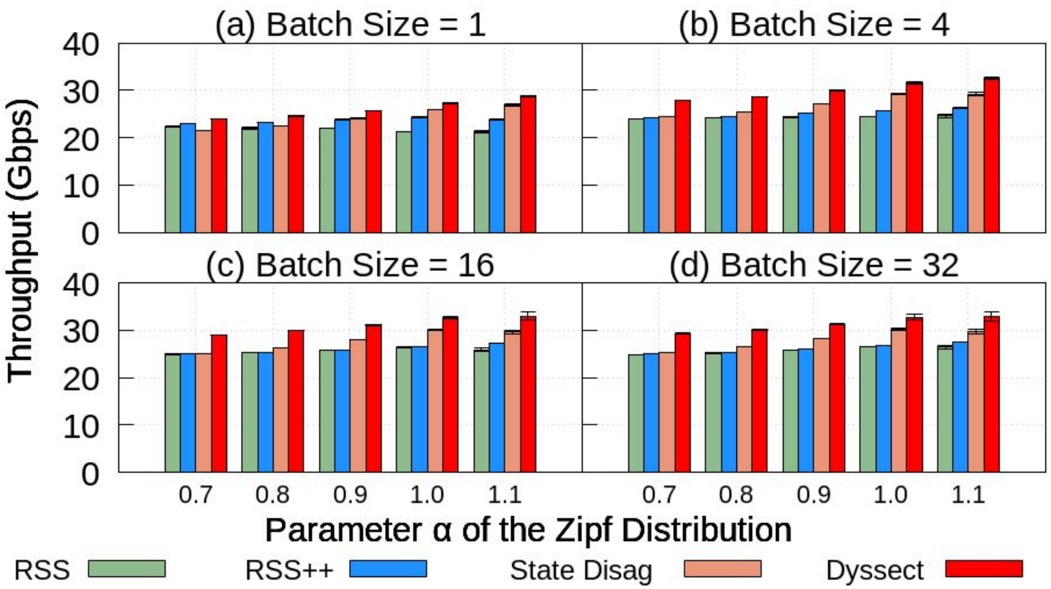
$$\text{minimize} \quad \sum_{c \in C} (u_c^{\mathrm{w}} - T)^2 + \sum_{k \in C} (u_k^{\mathrm{o}} - T)^2 + \alpha(\text{Eq. } 16), \tag{21}$$

$$\text{subject to Equations } 2 - 11 \text{ and Equations } 19 - 20$$

*Check the equation definitions in our paper.*

# Evaluation

***Use Case II***

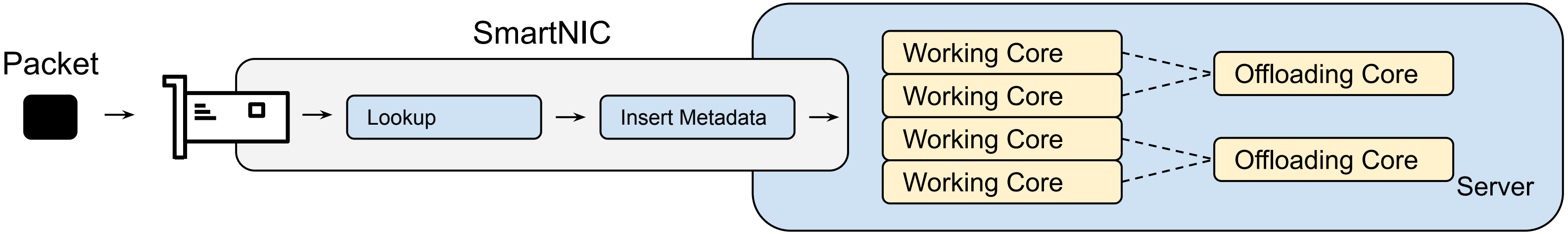



- Synthetic trace (Zipf distribution);
- Load balance optimization model;
- Network functions: NAT and IDS.

# Evaluation

***Use Case III***

- We offload the lookup function to a SmartNIC;
- SmartNIC performs the lookup and inserts the address into the packet metadata;
- Working cores skip the lookup if the metadata already contains an address.



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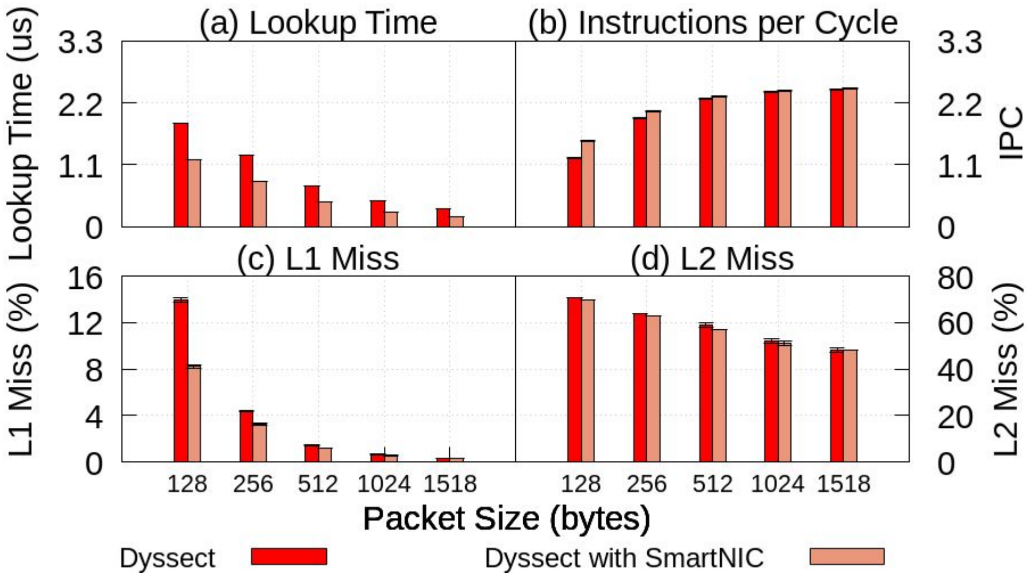
***Use Case III***




- We use Netronome NFP-4000 2x40 Gbps;
- Synthetic trace (Zipf distribution with $\alpha$ = 1.1);
- Measurements of a single core.

# Conclusion

- Sharding impacts on the performance of stateful network functions;
- Dyssect disaggregates states from network functions;
- Dyssect employs optimization models;
- Dyssect increases throughput up to 19% and reduces tail latency up to 32% when compared with other load-balancing proposals.

*https://github.com/dyssect/dyssect*

# Thank you!

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