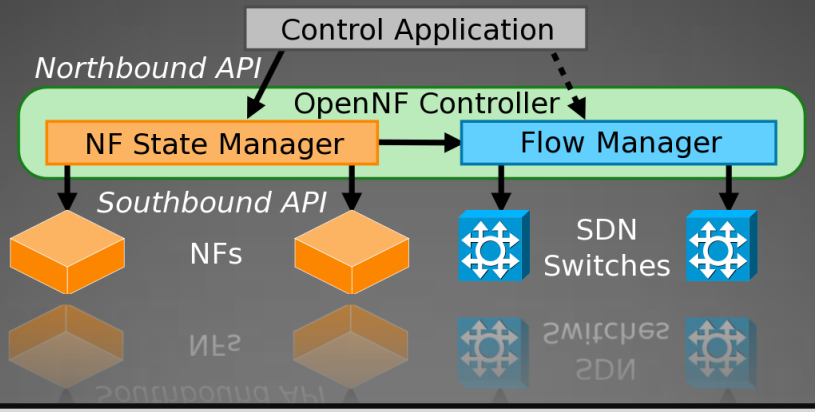

OpenNF: Enabling Innovation in Network Function Control

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Aaron Gember-Jacobson, Chaithan Prakash, Raajay Viswanathan, Robert Grandl, Junaid Khalid, Sourav Das, Aditya Akella

Network functions (NFs)

- Perform sophisticated *stateful* actions on packets/flows

WAN optimizer

Caching proxy

Intrusion detection system (IDS)

NF trends

- NFV → dynamically allocate NF instances

NF trends

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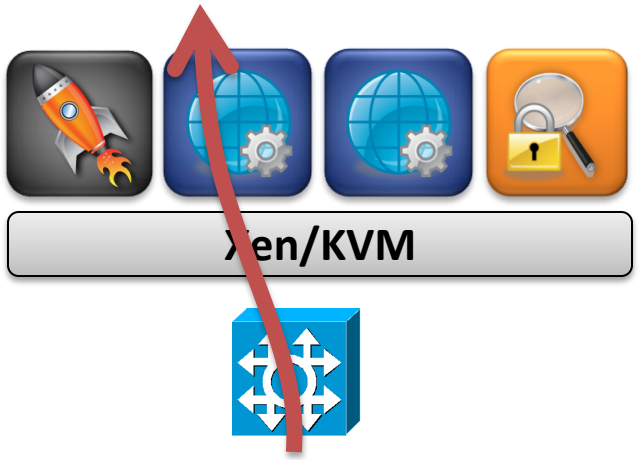
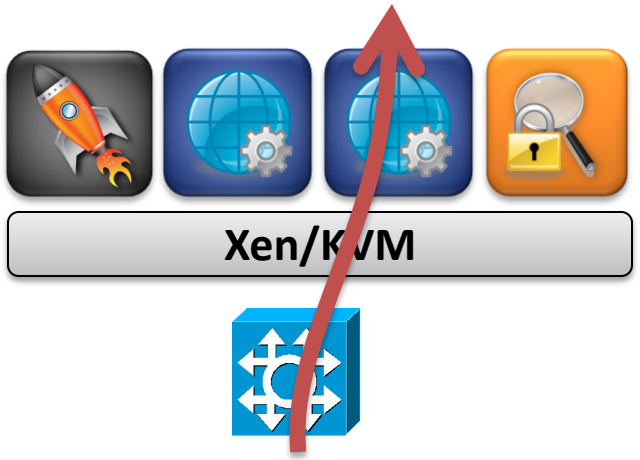
NF trends

- NFV → dynamically allocate NF instances
- SDN → dynamically reroute flows



NF trends

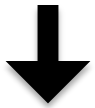
- NFV → dynamically allocate NF instances
- SDN → dynamically reroute flows



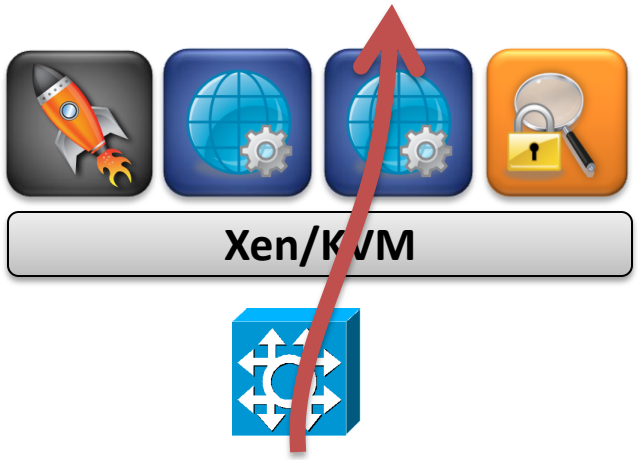
NF trends

- NFV → dynamically allocate NF instances

- SDN → dynamically reroute flows



Dynamic reallocation of packet processing



Example: elastic NF scaling

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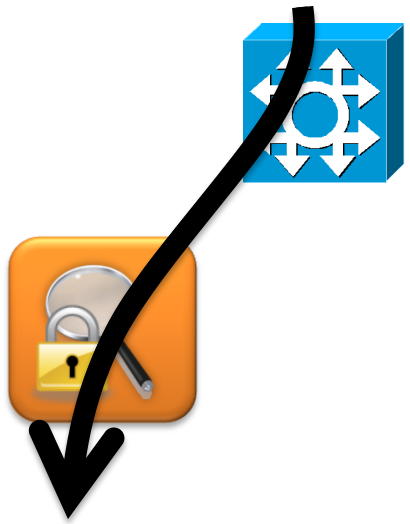
1. Satisfy performance SLAs



Example: elastic NF scaling

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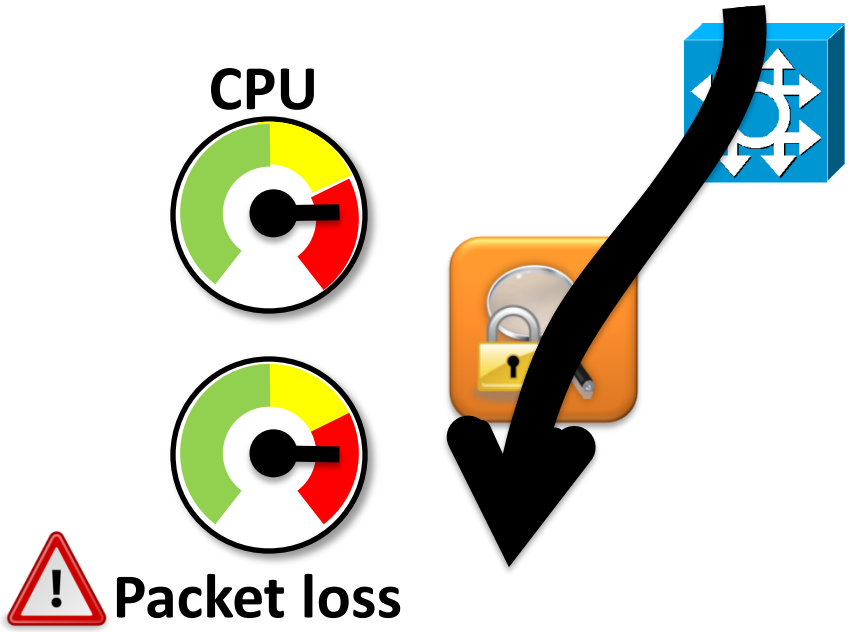

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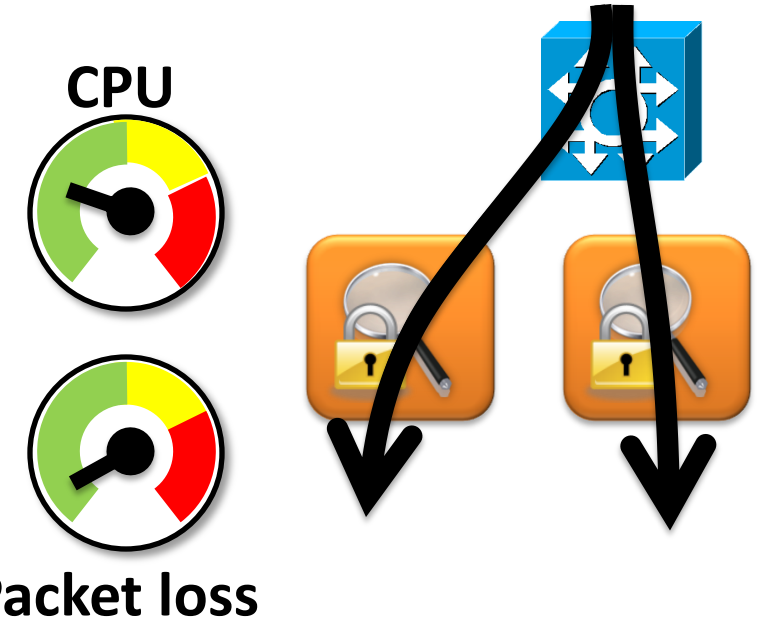
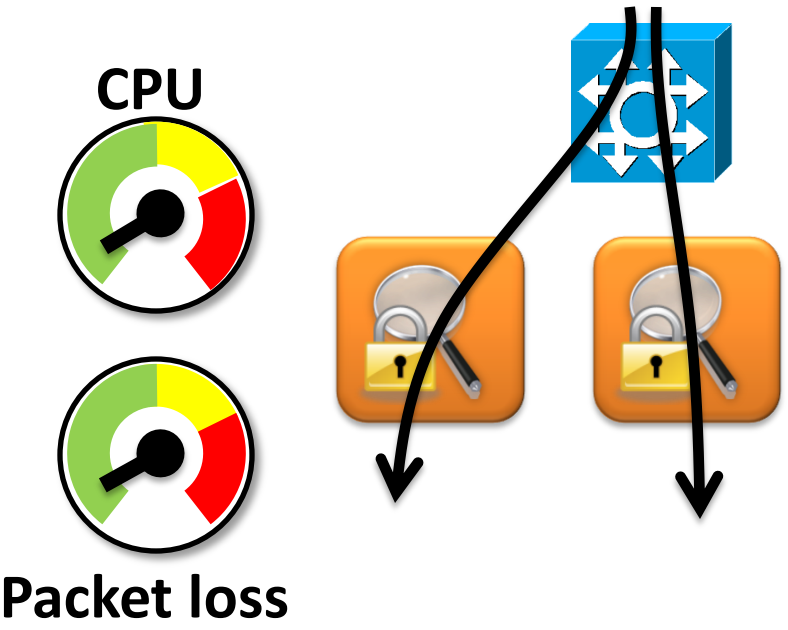


Example: elastic NF scaling

1. Satisfy performance SLAs
2. Minimize operating costs



Example: elastic NF scaling

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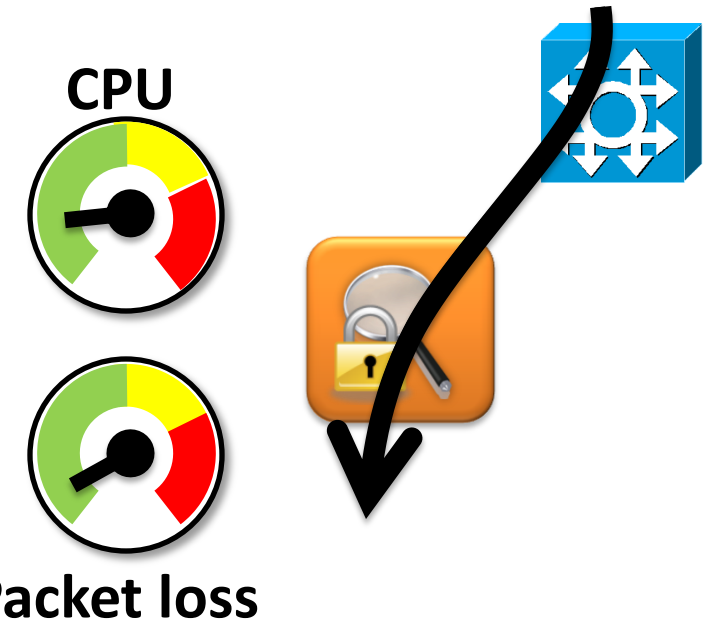
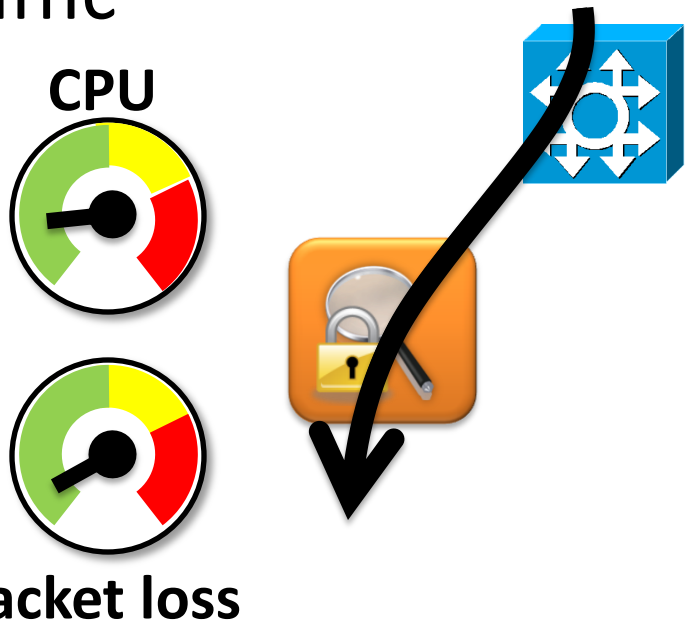


Example: elastic NF scaling

1. Satisfy performance SLAs
2. Minimize operating costs
3. Accurately monitor traffic



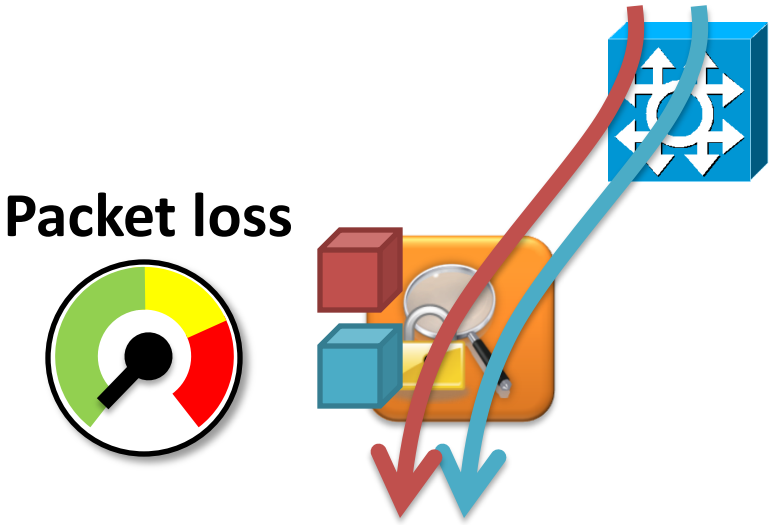
Problem: NFV+SDN is insufficient

To **simultaneously**…

1. Satisfy performance SLAs
2. Minimize operating costs
3. Accurately monitor traffic

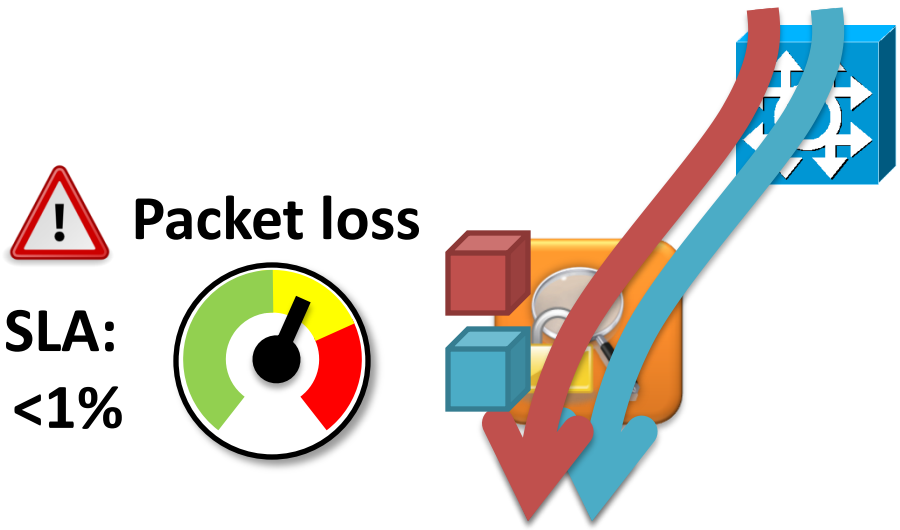
Cannot effectively implement
new services or abstractions!

Why NFV + SDN falls short



1. SLAs 2. Cost 3. Accuracy

Why NFV + SDN falls short



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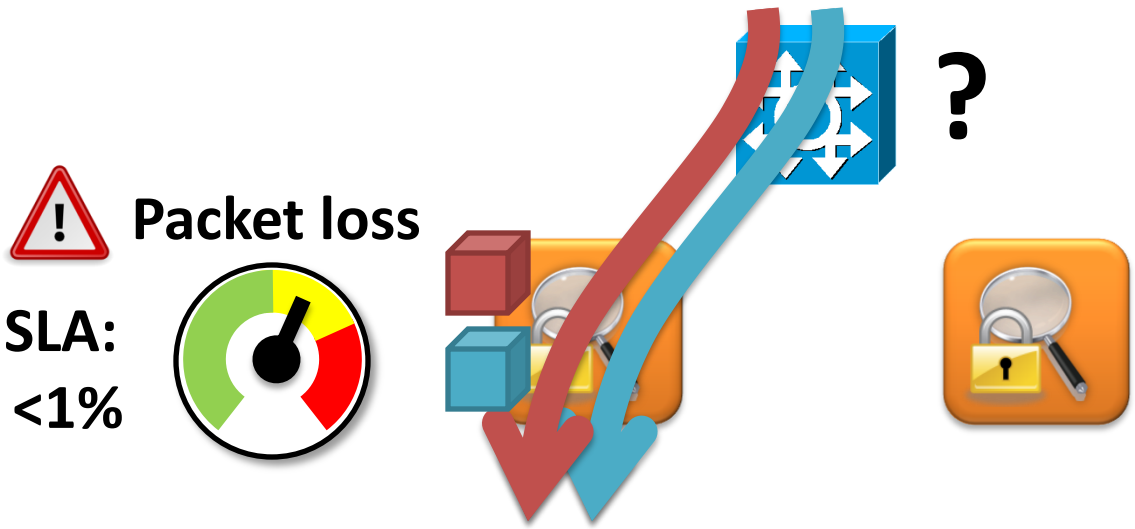

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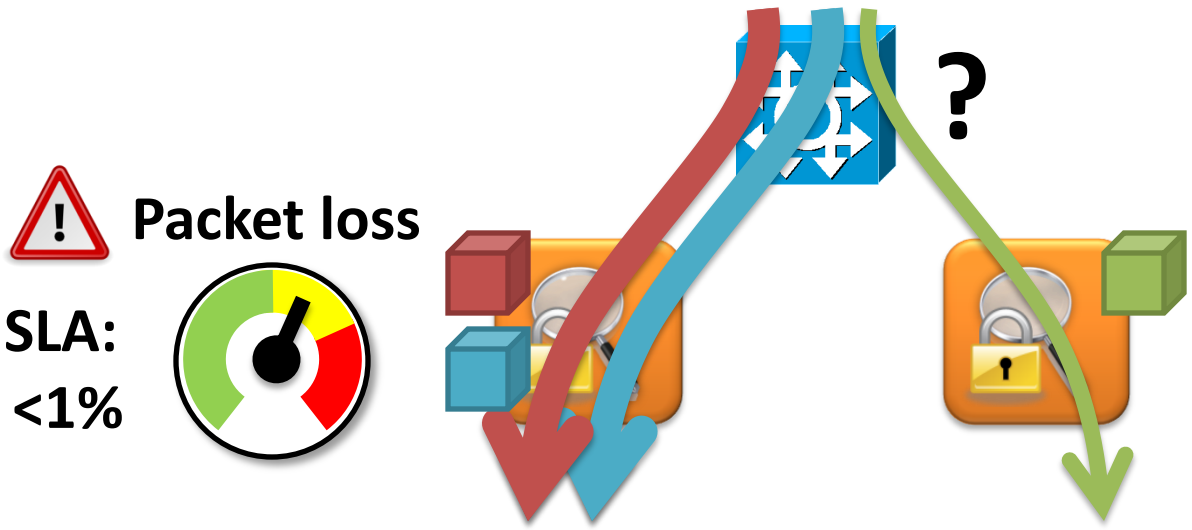
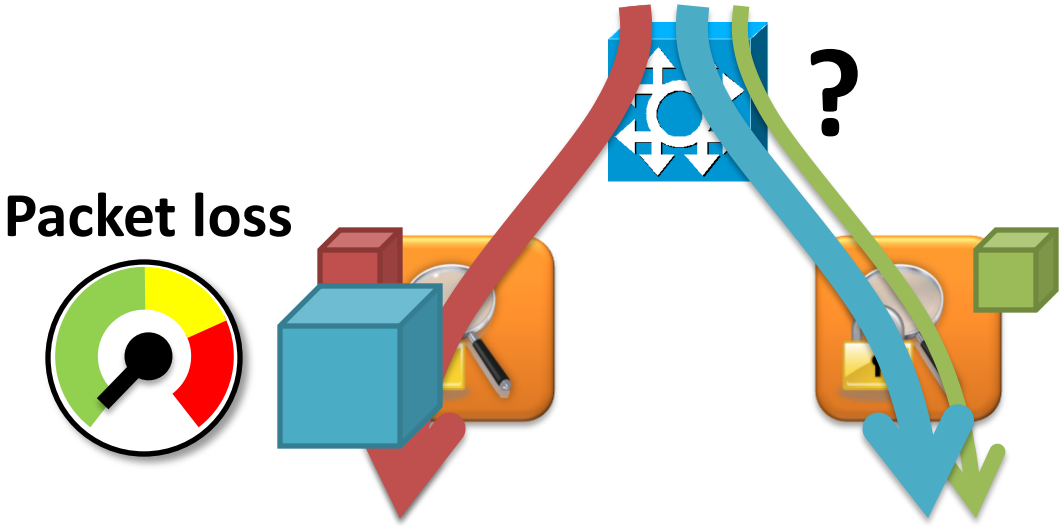


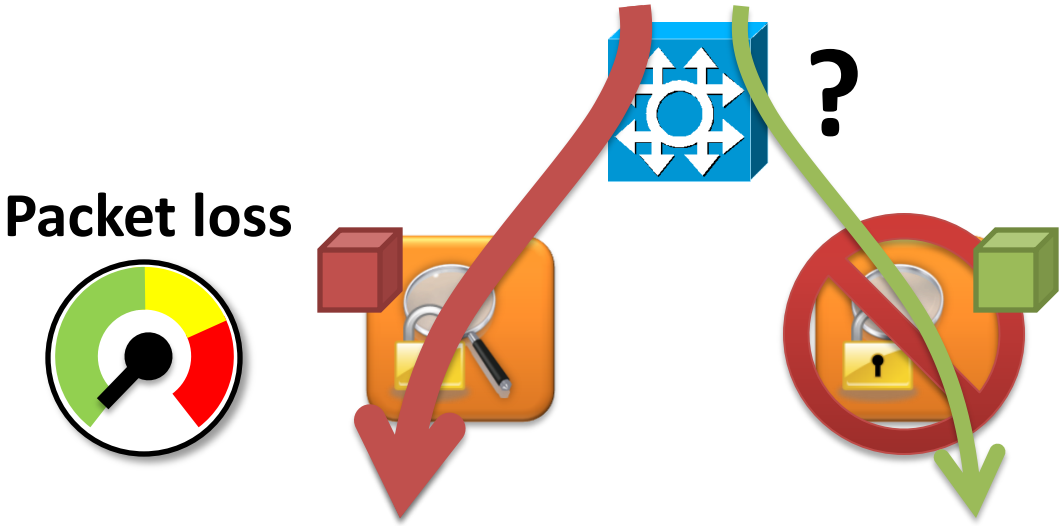
	1. SLAs	2. Cost	3. Accuracy
Reroute new flows *[Stratos - arXiv:1305.0209]*	✗	✓	?

Why NFV + SDN falls short



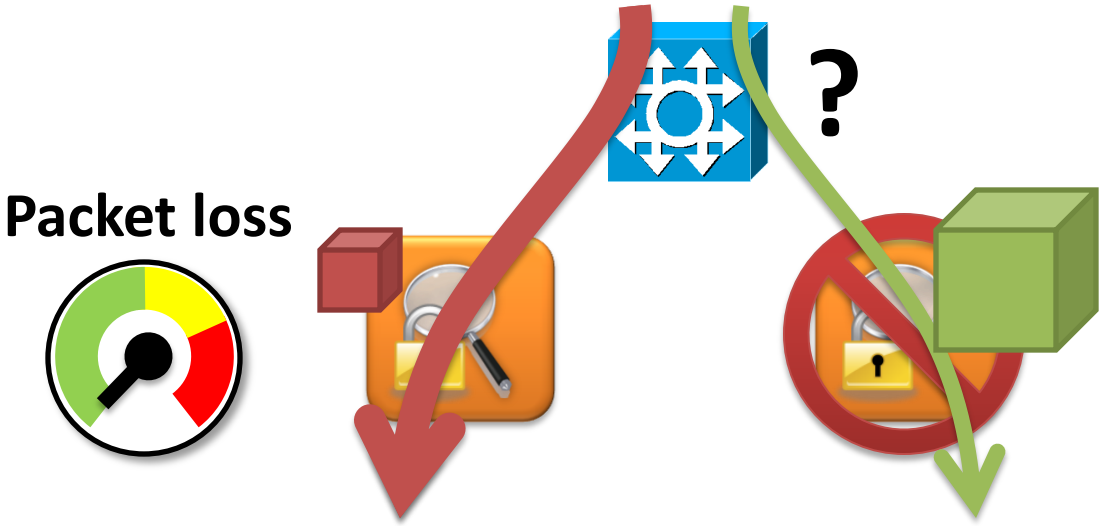
	1. SLAs	2. Cost	3. Accuracy
Reroute new flows *[Stratos - arXiv:1305.0209]*	✗	✓	?
Reroute existing flows *[SIMPLE - SIGCOMM '13]*	✓	✓	✗

Why NFV + SDN falls short



	1. SLAs	2. Cost	3. Accuracy
Reroute new flows *[Stratos - arXiv:1305.0209]*	✗	✓	?
Reroute existing flows *[SIMPLE - SIGCOMM '13]*	✓	✓	✗

Why NFV + SDN falls short



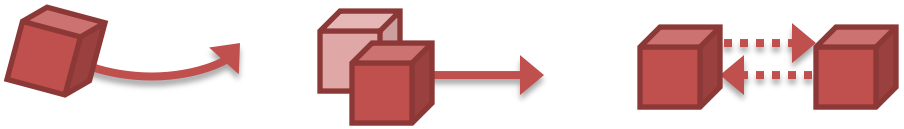
	1. SLAs	2. Cost	3. Accuracy
Reroute new flows *[Stratos - arXiv:1305.0209]*	✗	✓	?
Reroute existing flows *[SIMPLE - SIGCOMM '13]*	✓	✓	✗

Why NFV + SDN falls short

	1. SLAs	2. Cost	3. Accuracy
Reroute new flows *[Stratos - arXiv:1305.0209]*	✗	✓	?
Reroute existing flows *[SIMPLE - SIGCOMM '13]*	✓	✓	✗
Wait for flows to die *[Stratos - arXiv:1305.0209]*	✓	✗	✓

SLAs + cost + accuracy: What do we need?

- Quickly move, copy, or share internal NF state alongside updates to network forwarding state



- Guarantees: loss-free, order-preserving, …

Also applies to other scenarios

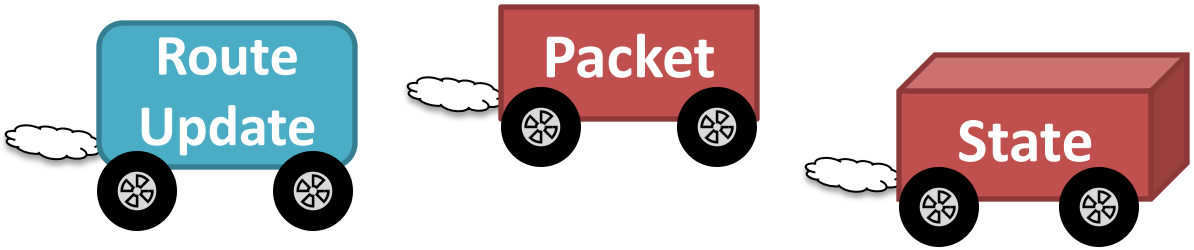
Outline

- Motivation and requirements
- Challenges
- OpenNF architecture
  - State export/import
  - State operations
  - Guarantees
- Evaluation

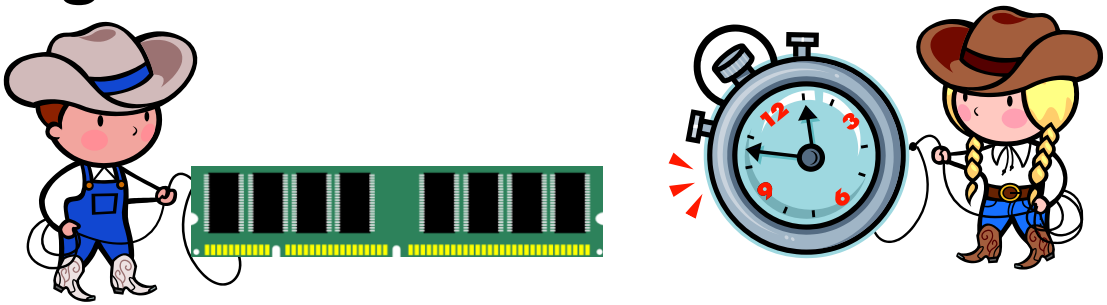
Challenges

1. Supporting many NFs with minimal changes

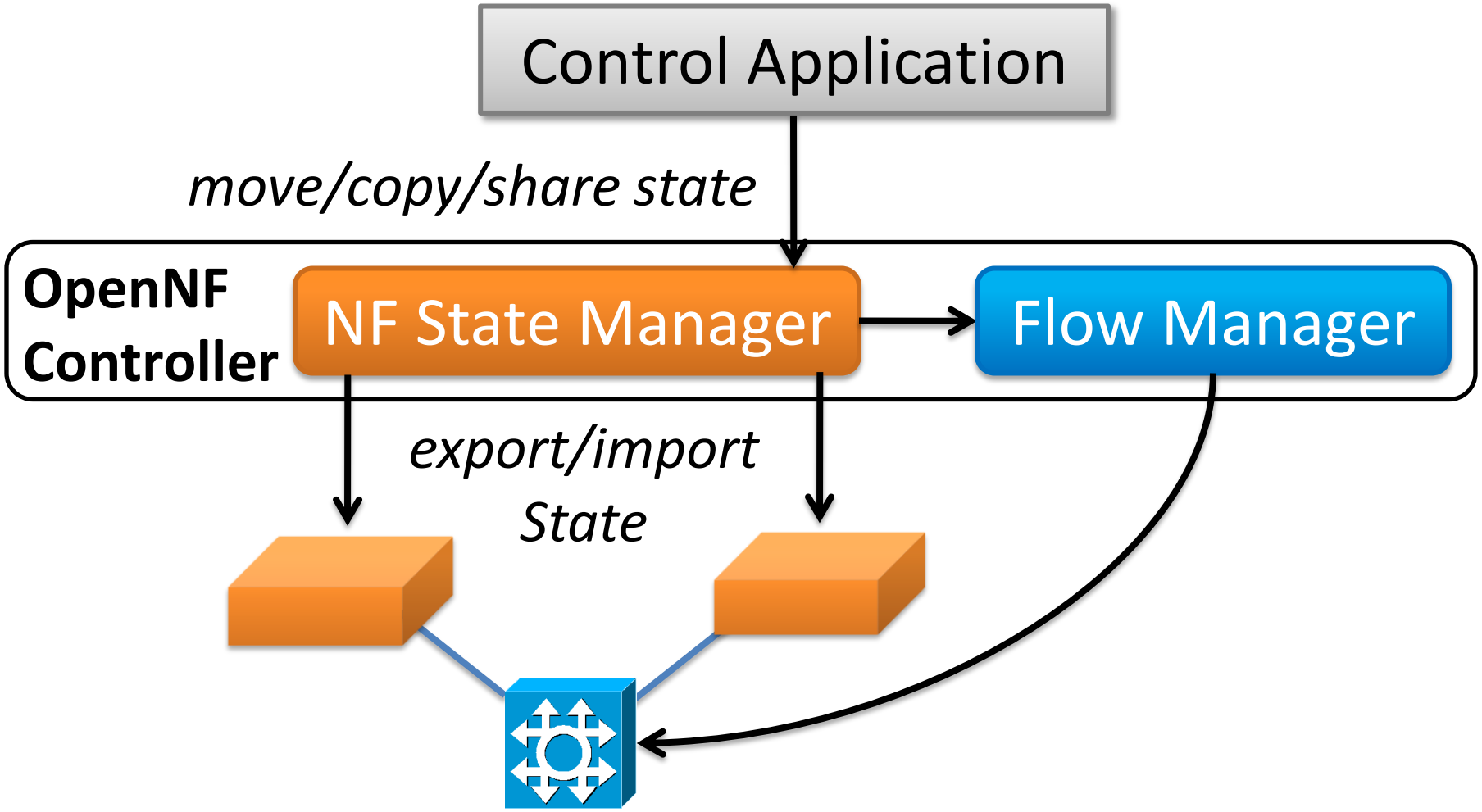
2. Dealing with race conditions



3. Bounding overhead

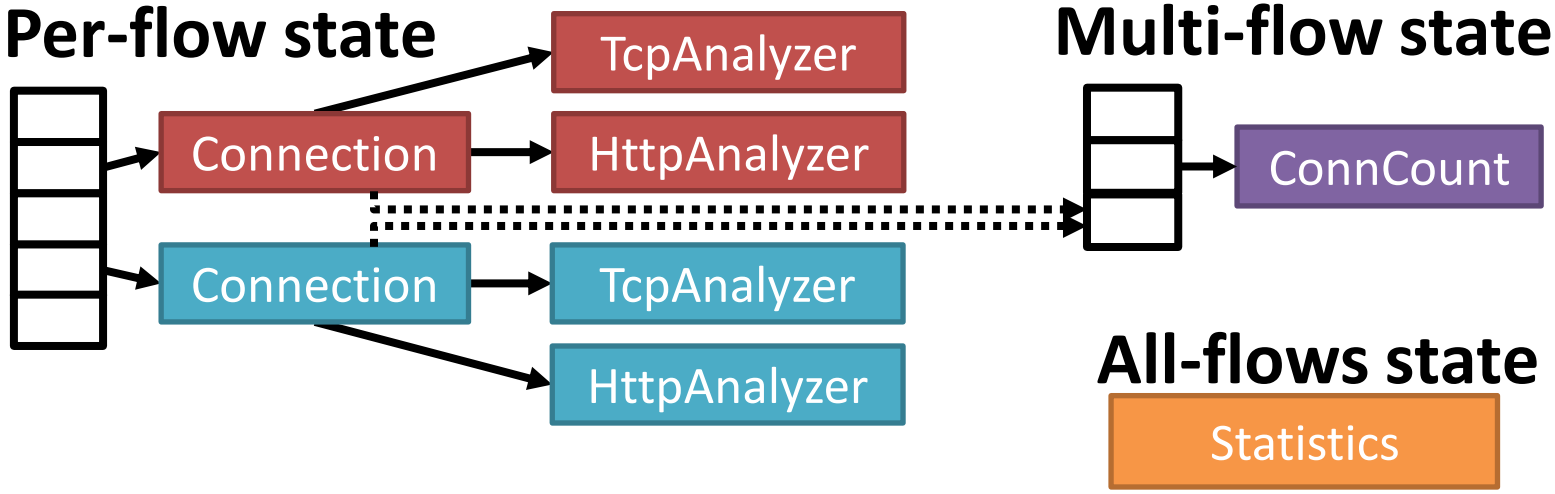


OpenNF overview



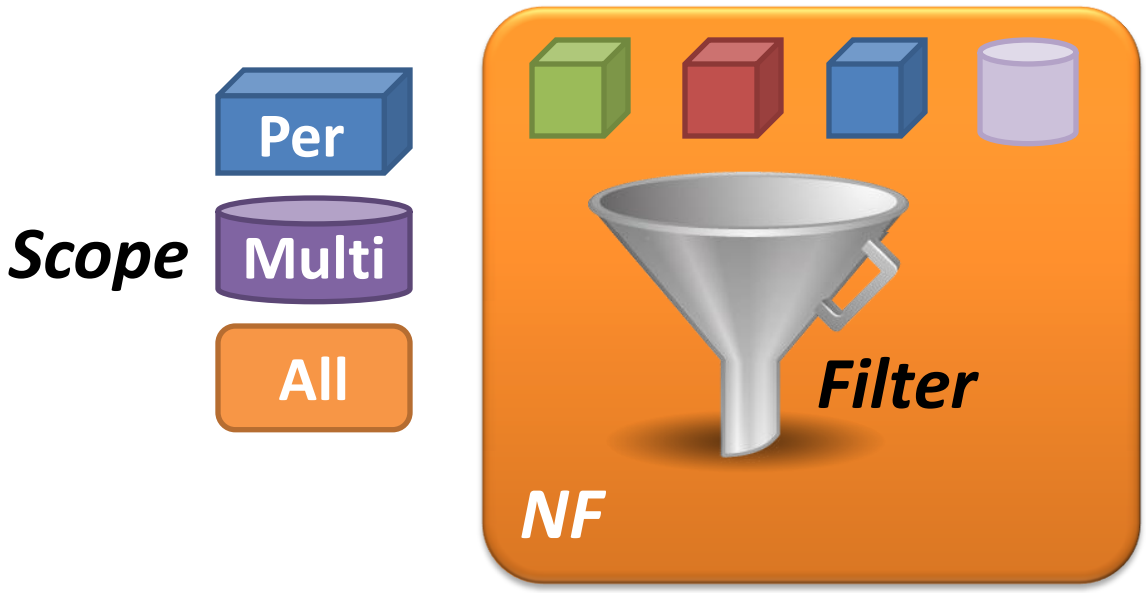
NF state taxonomy

State created or updated by an NF applies to either a **single flow** or a **collection of flows**



NF API: export/import state

- Functions: `get`, `put`, `delete`



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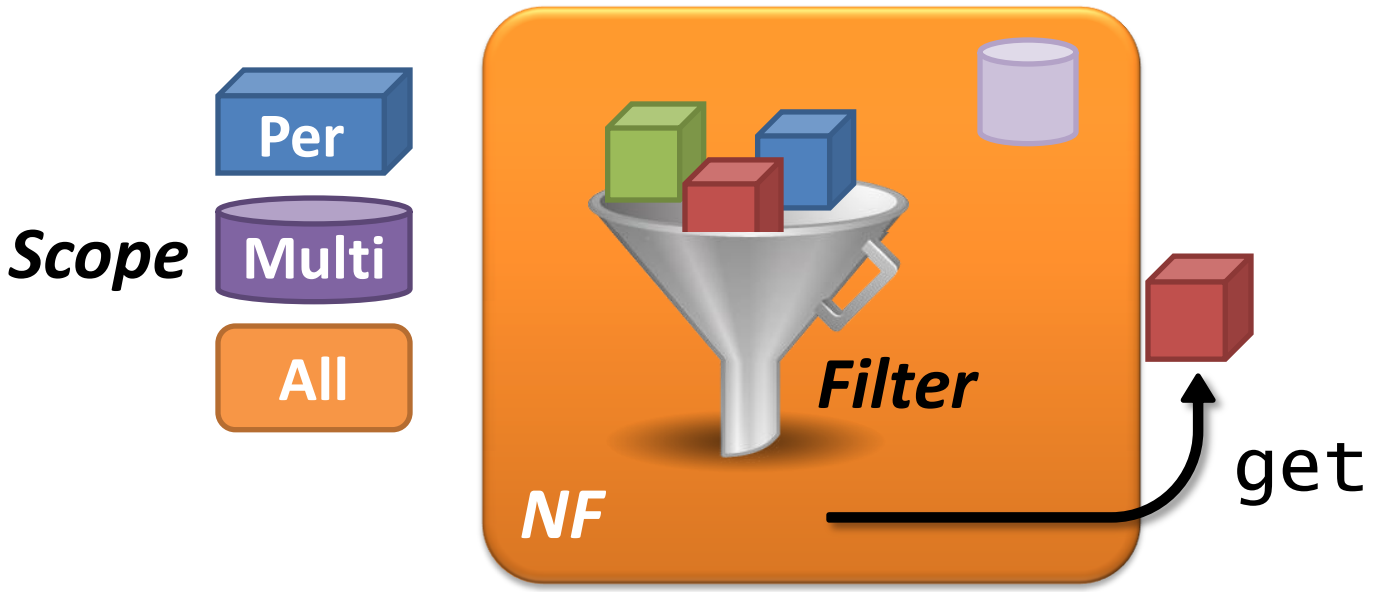

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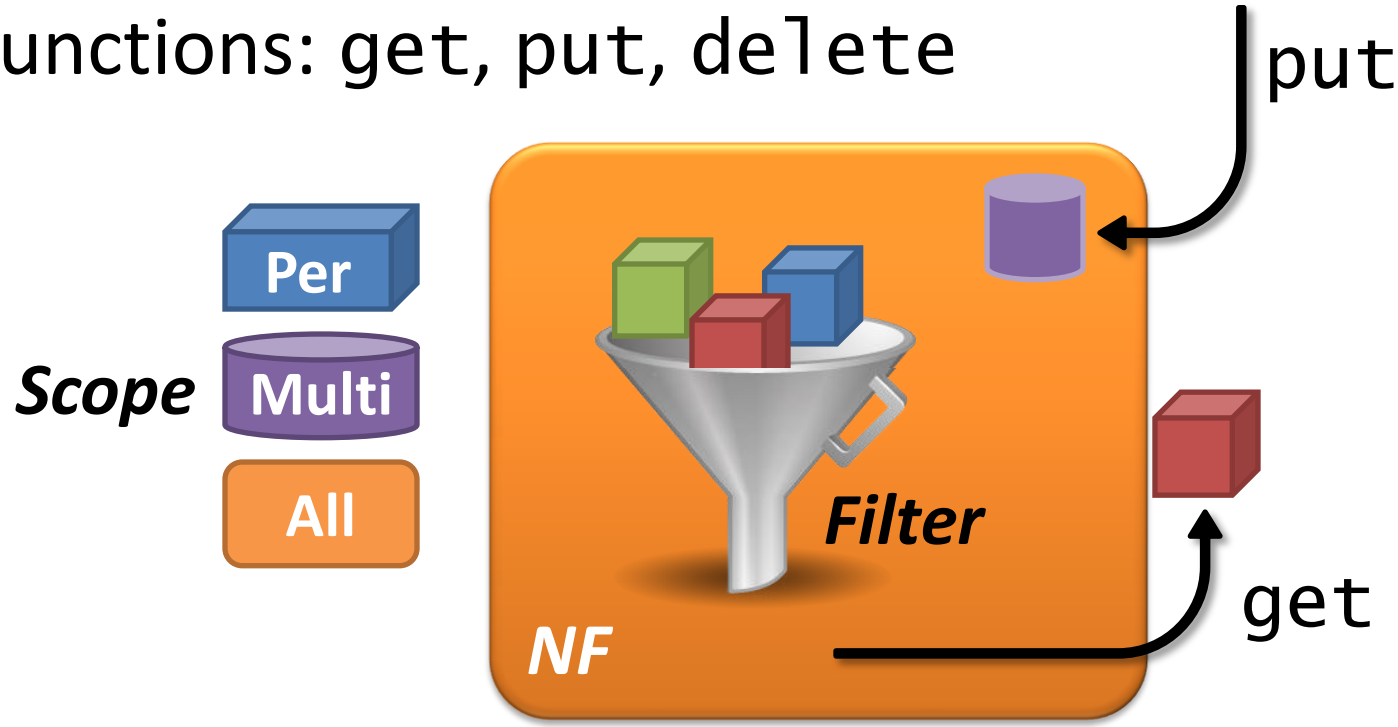

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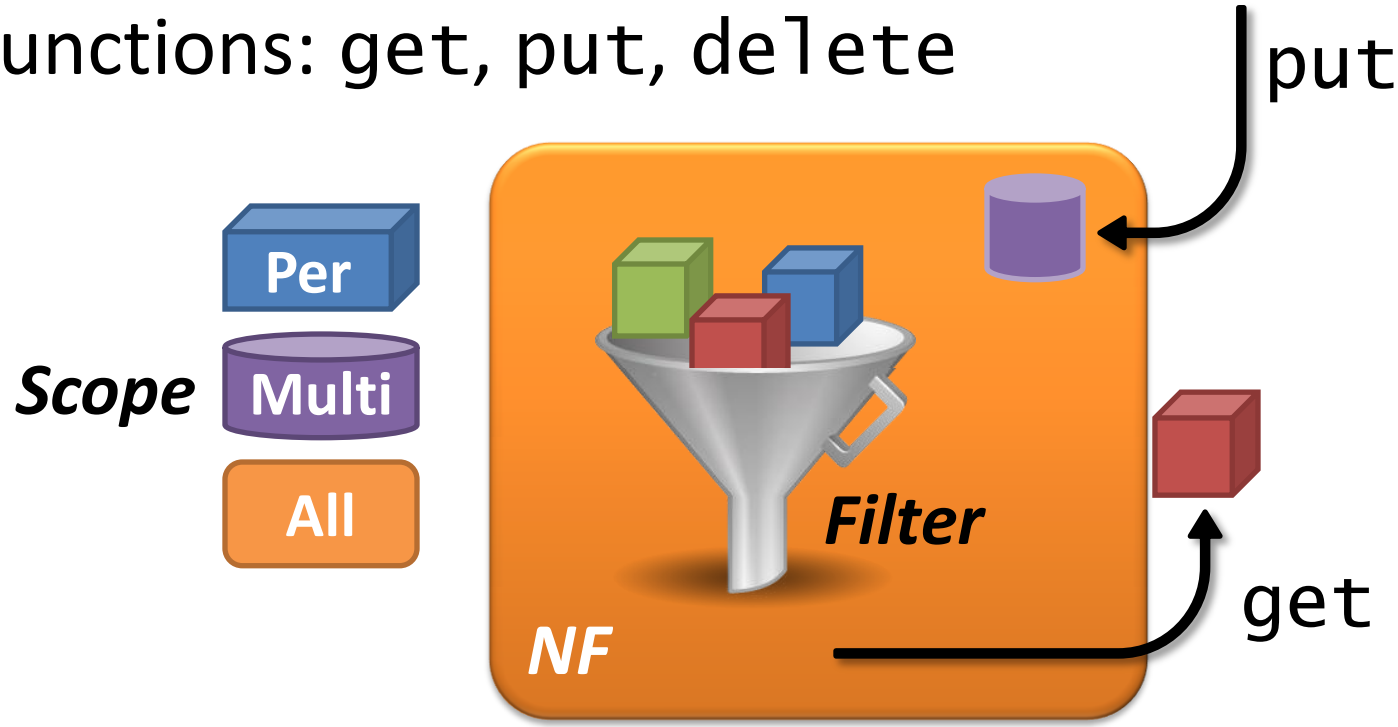
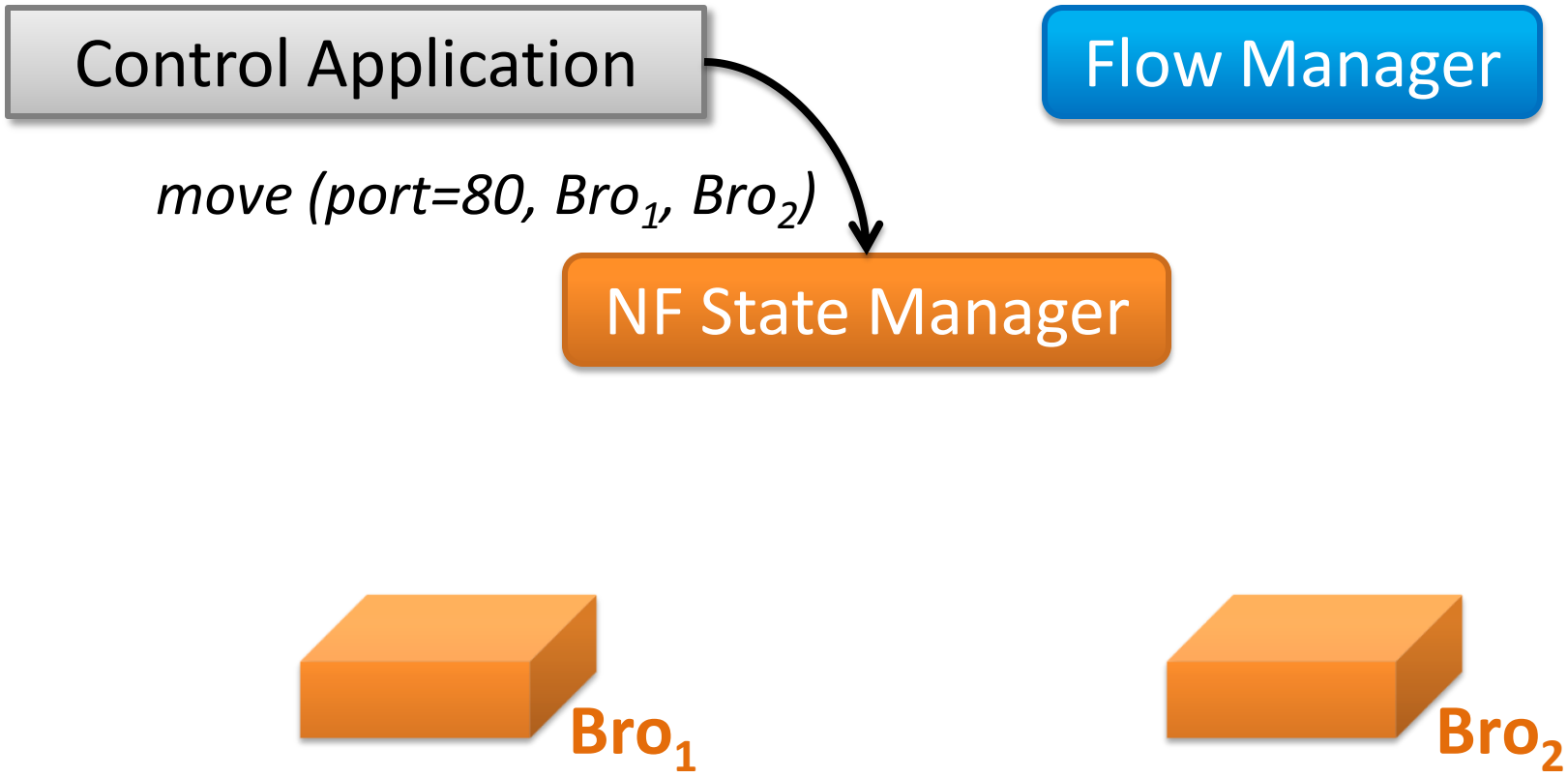


No need to expose/change internal state organization!

Control operations: move



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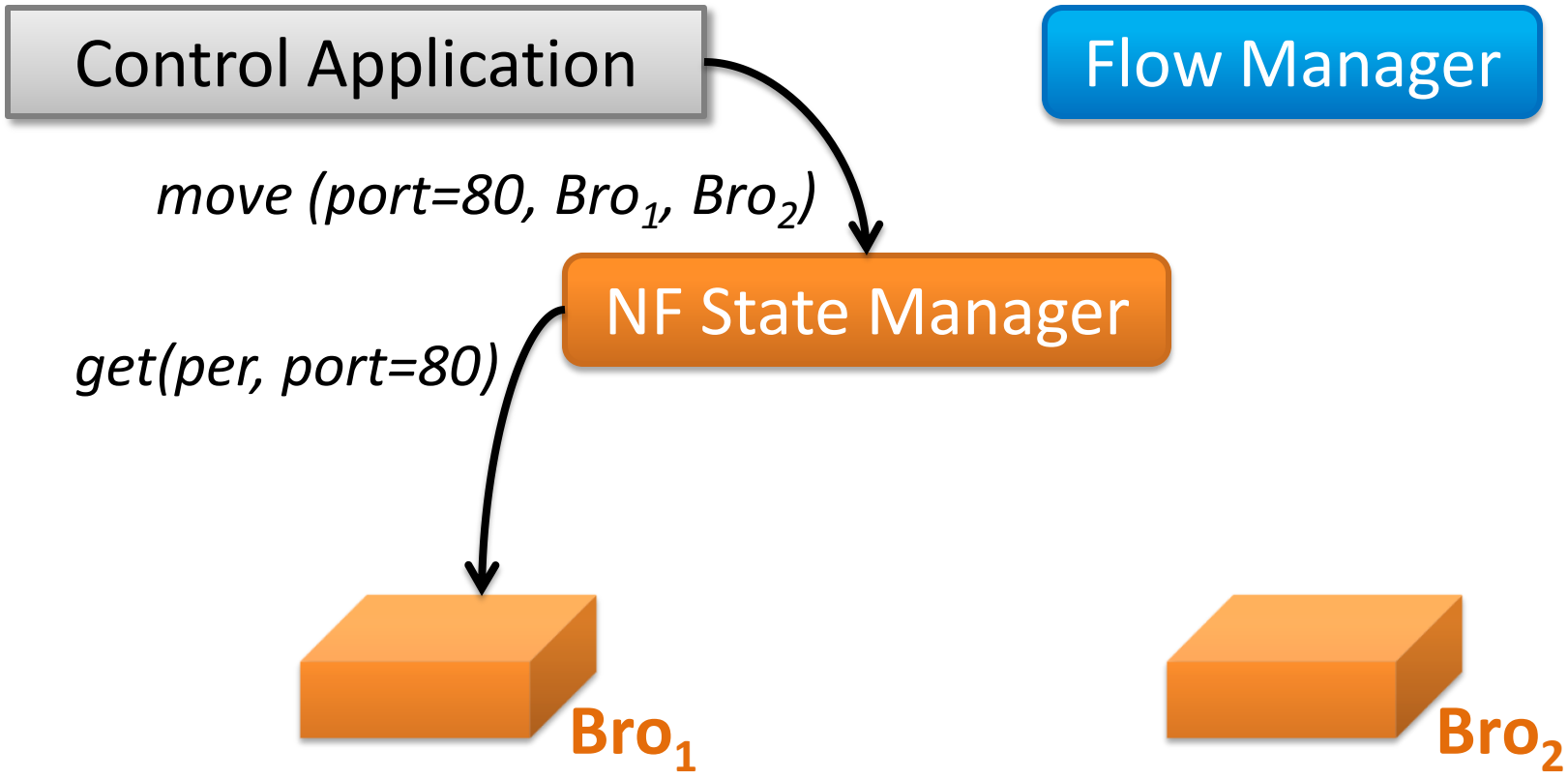

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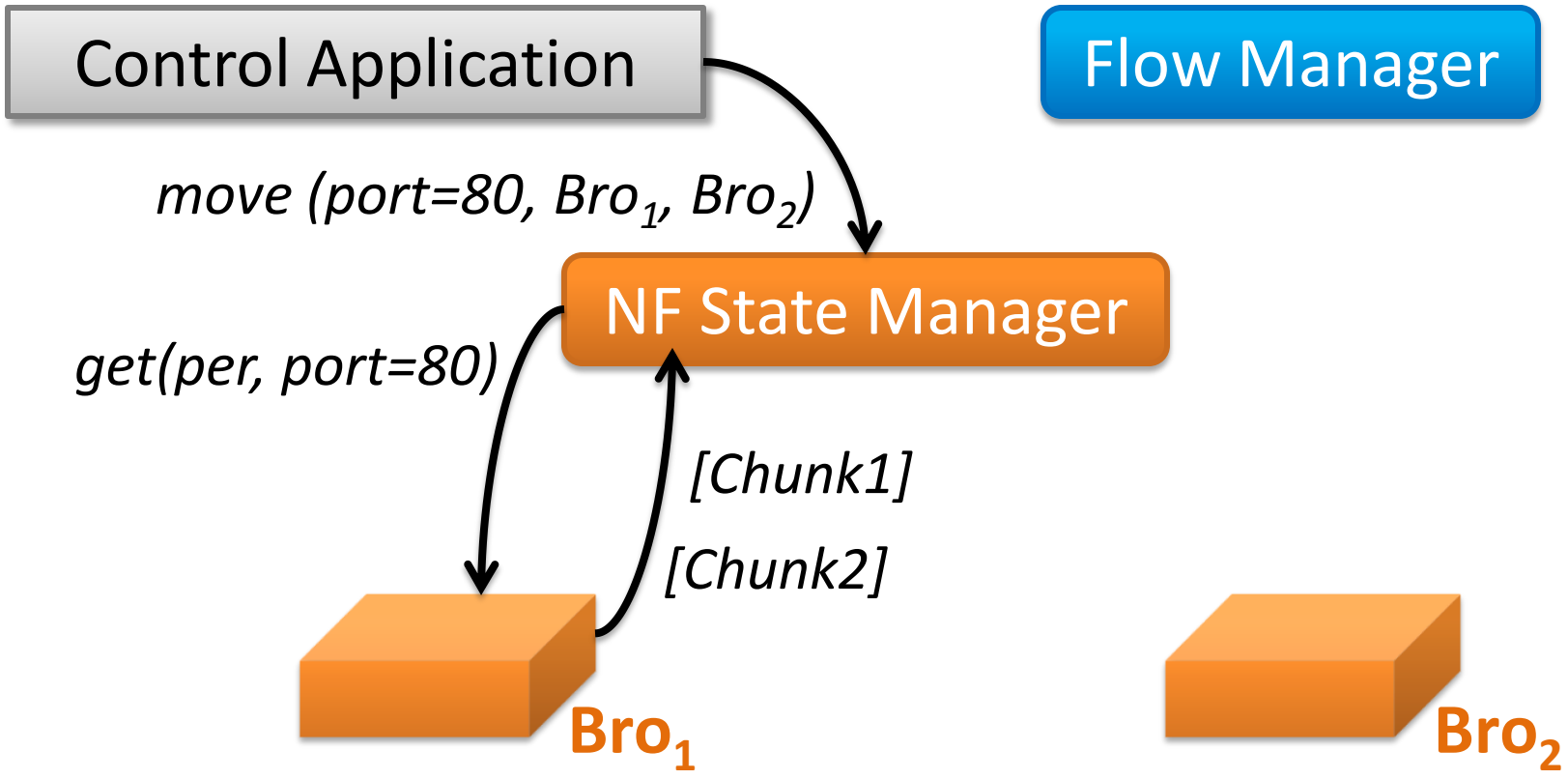

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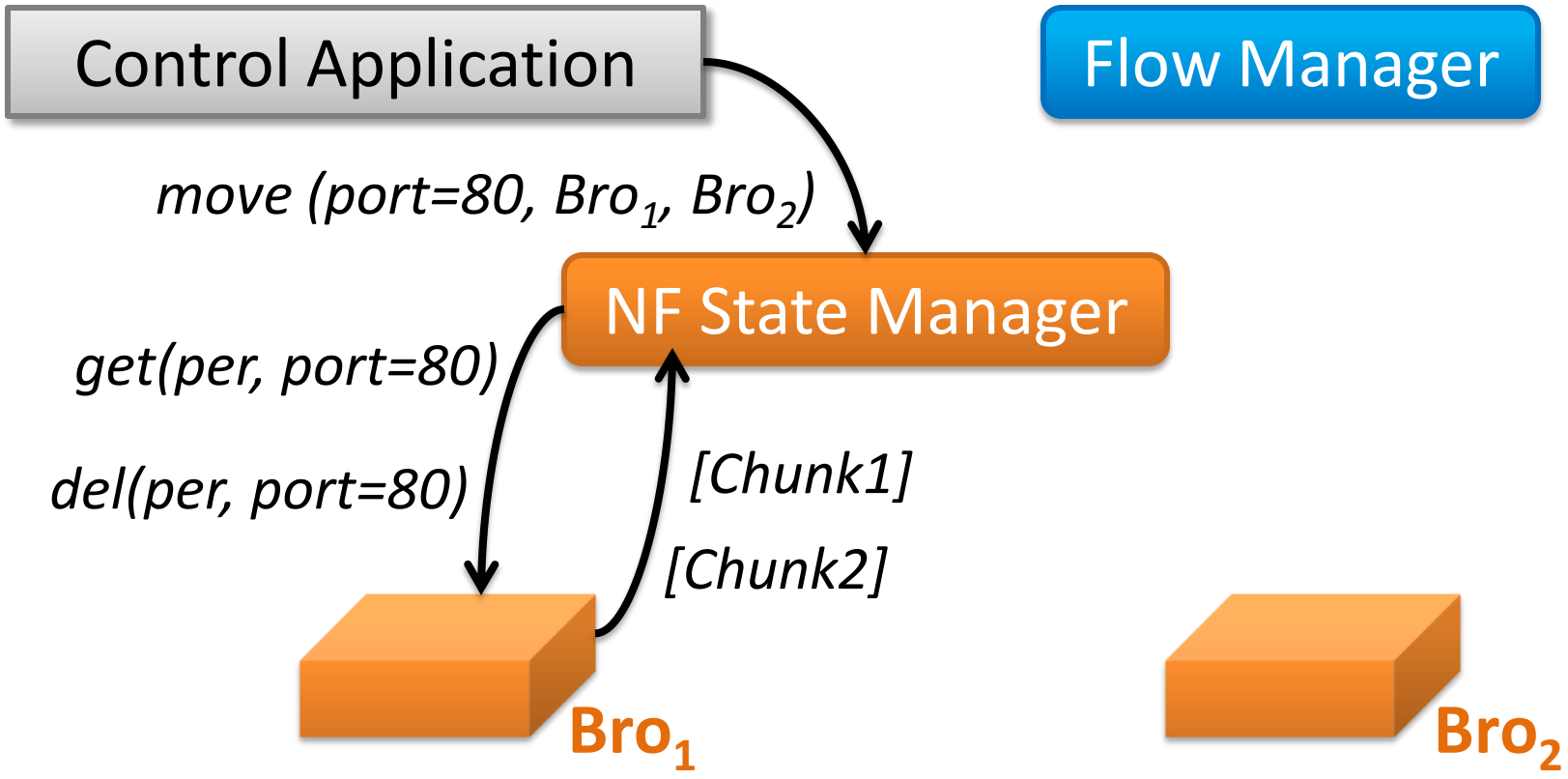

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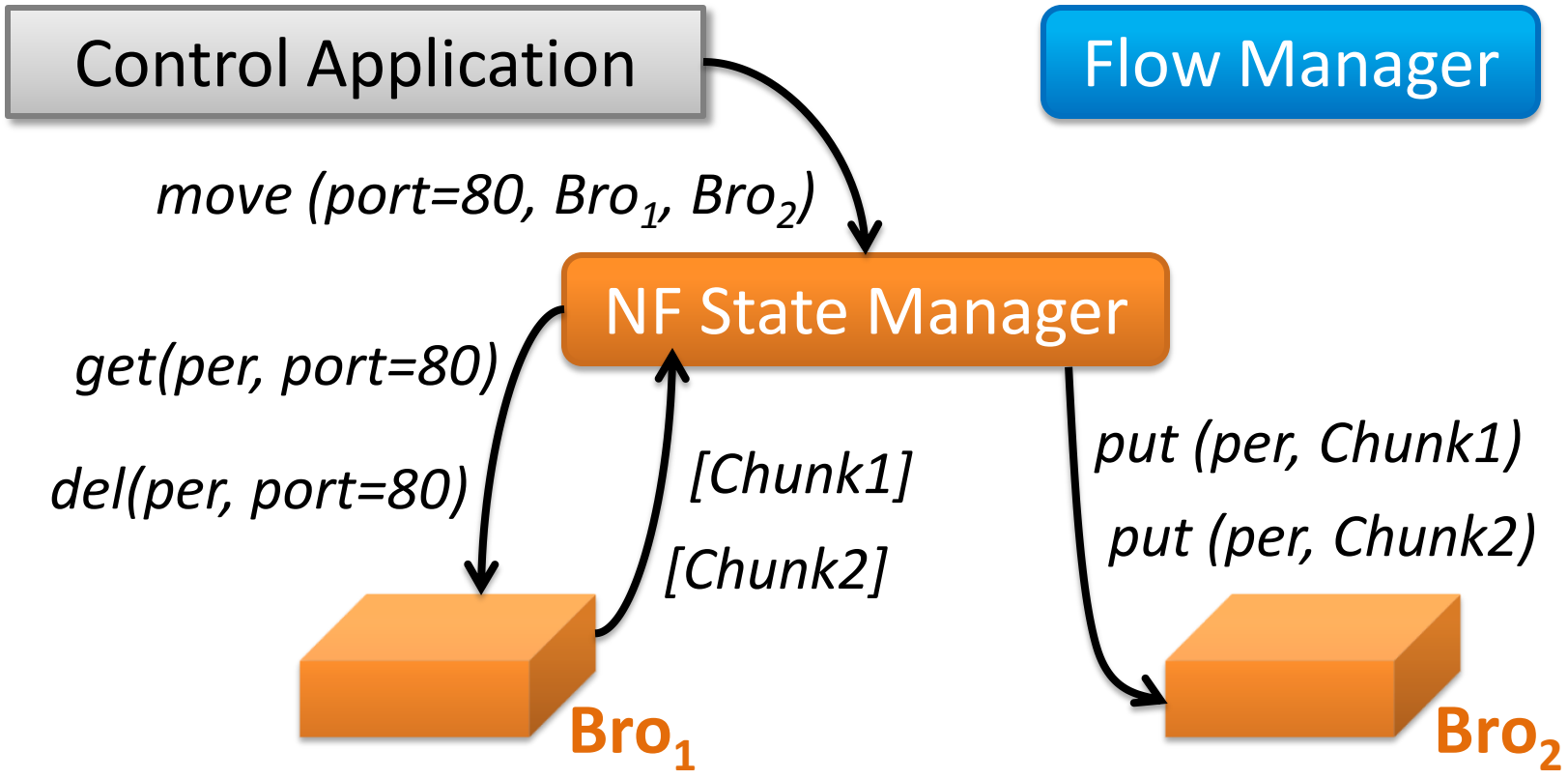

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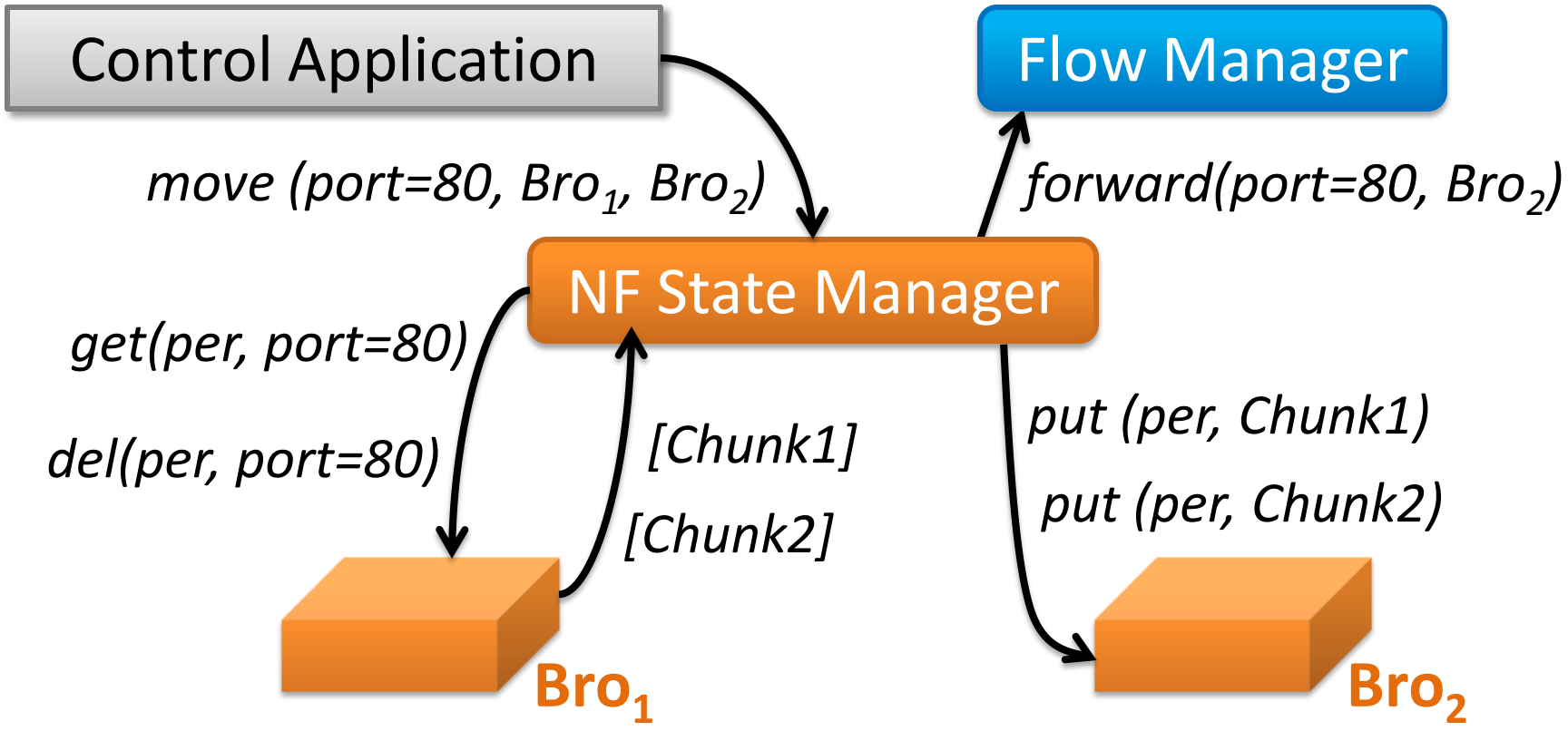

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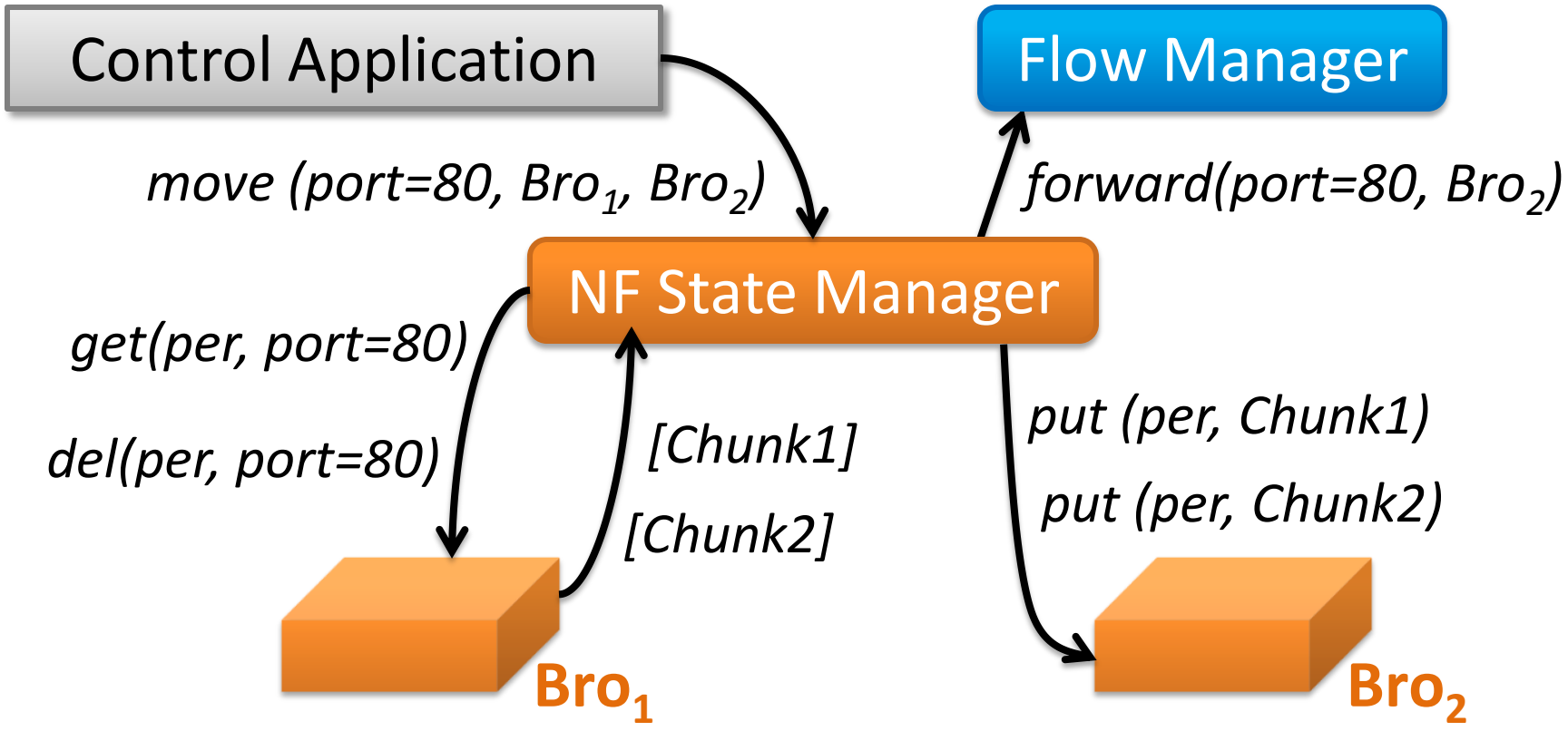
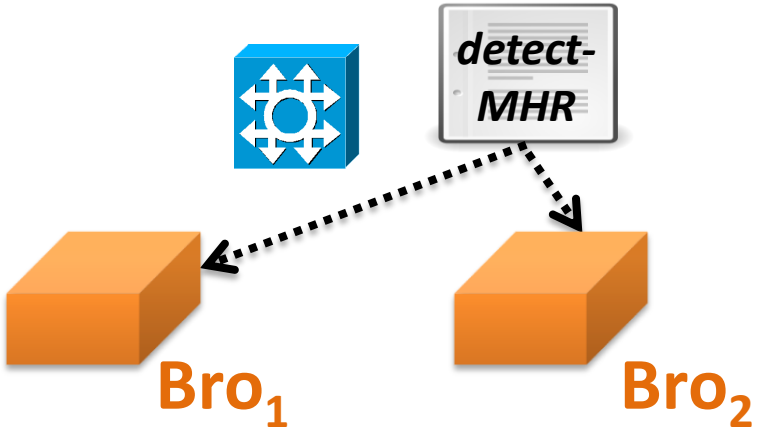


Also provide copy and share

Lost updates during move



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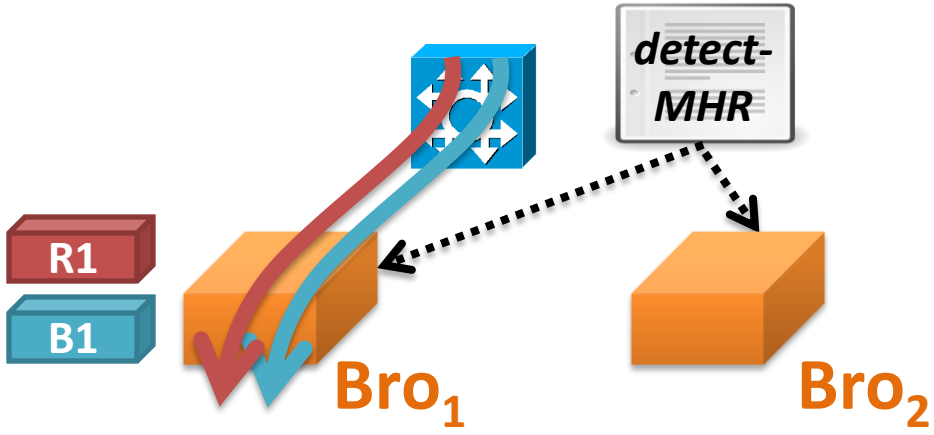
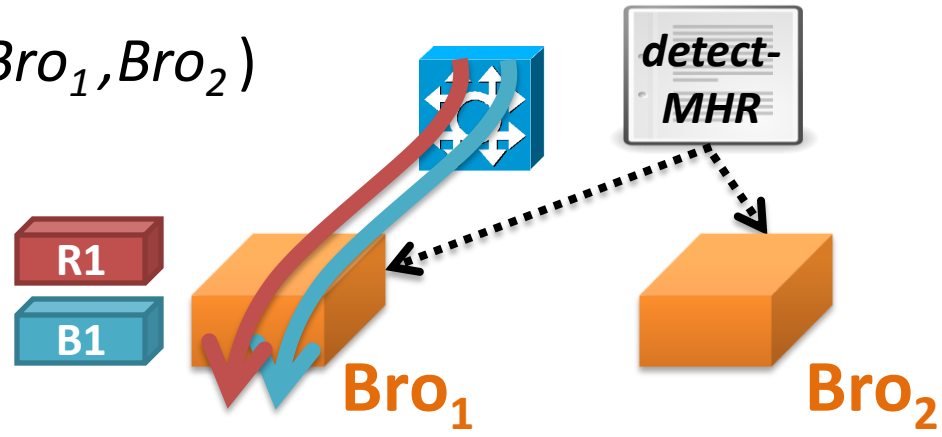


Lost updates during move

move(red,Bro$_1$,Bro$_2$)



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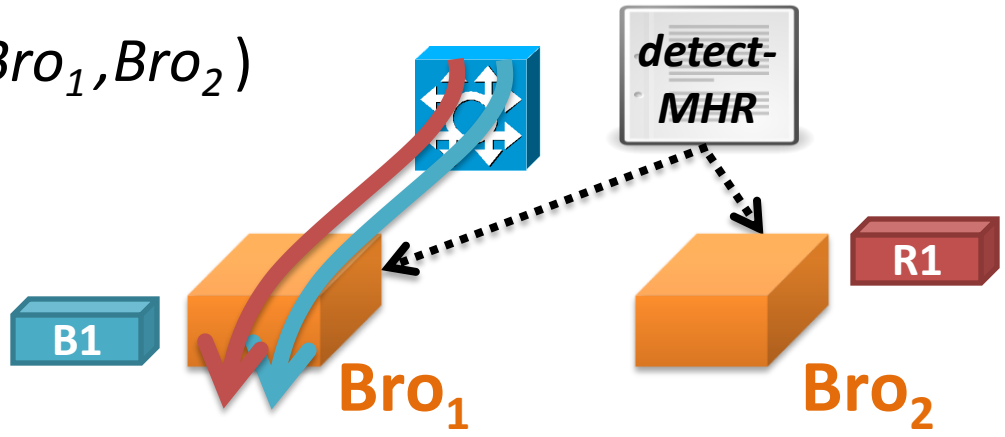

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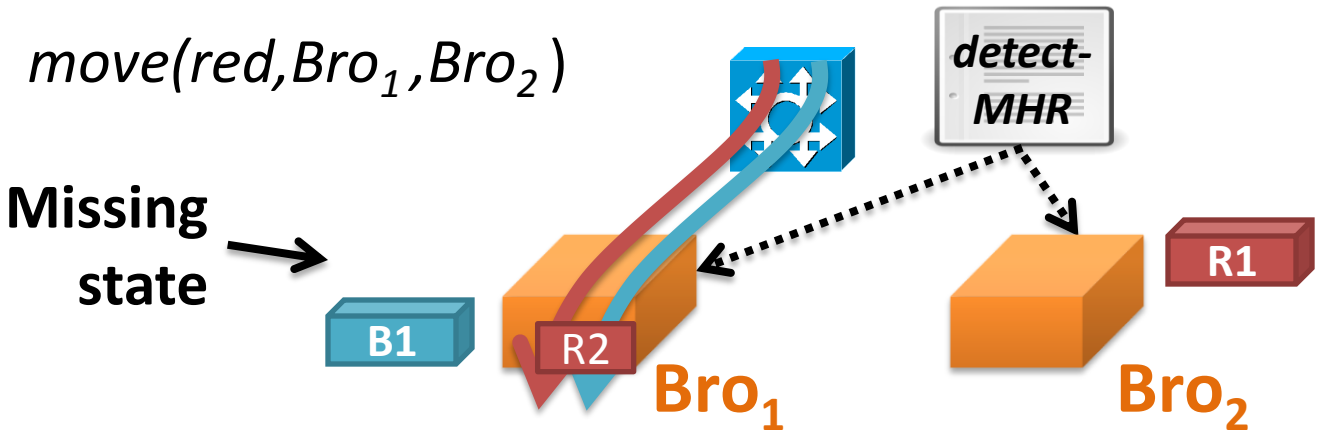

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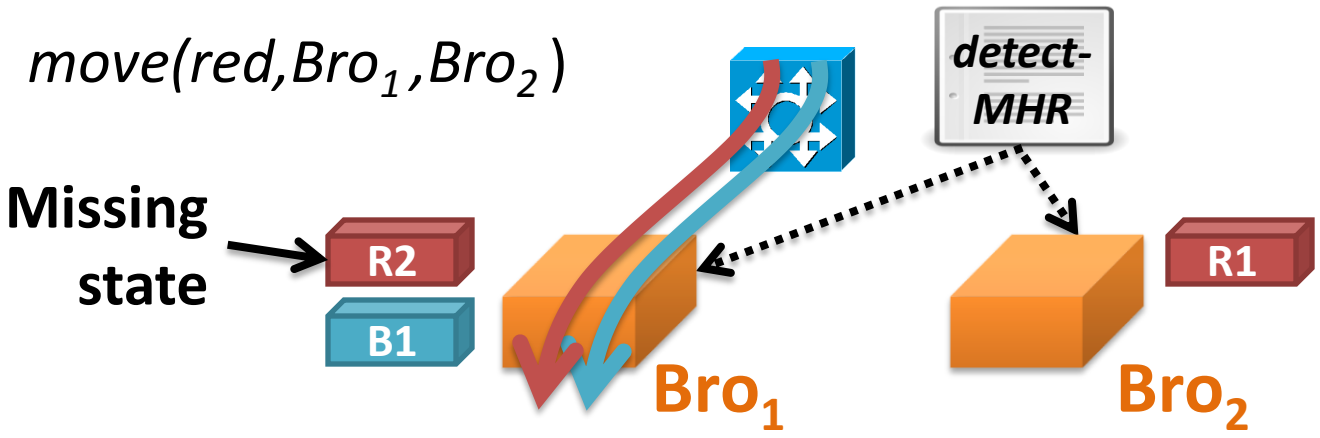

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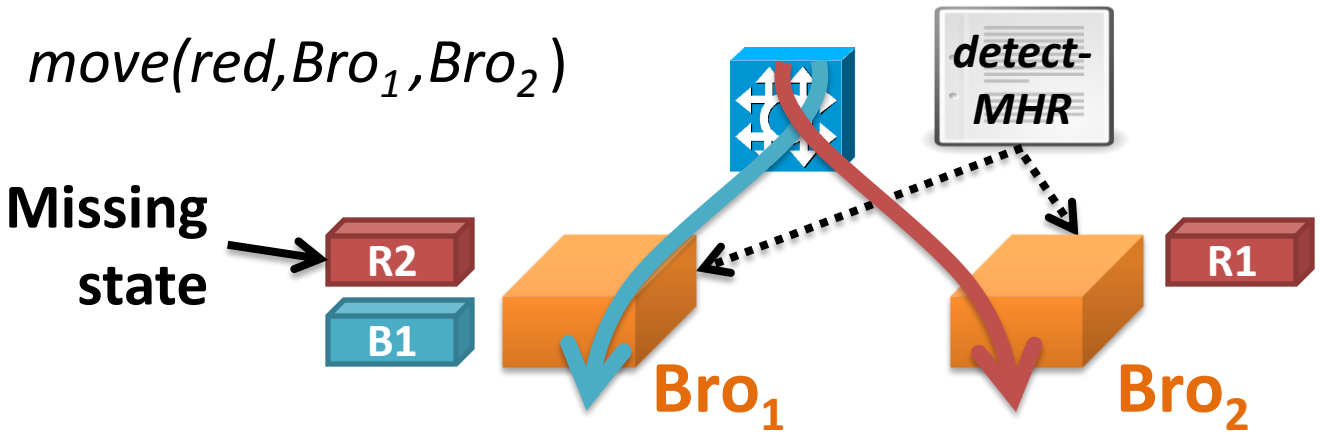

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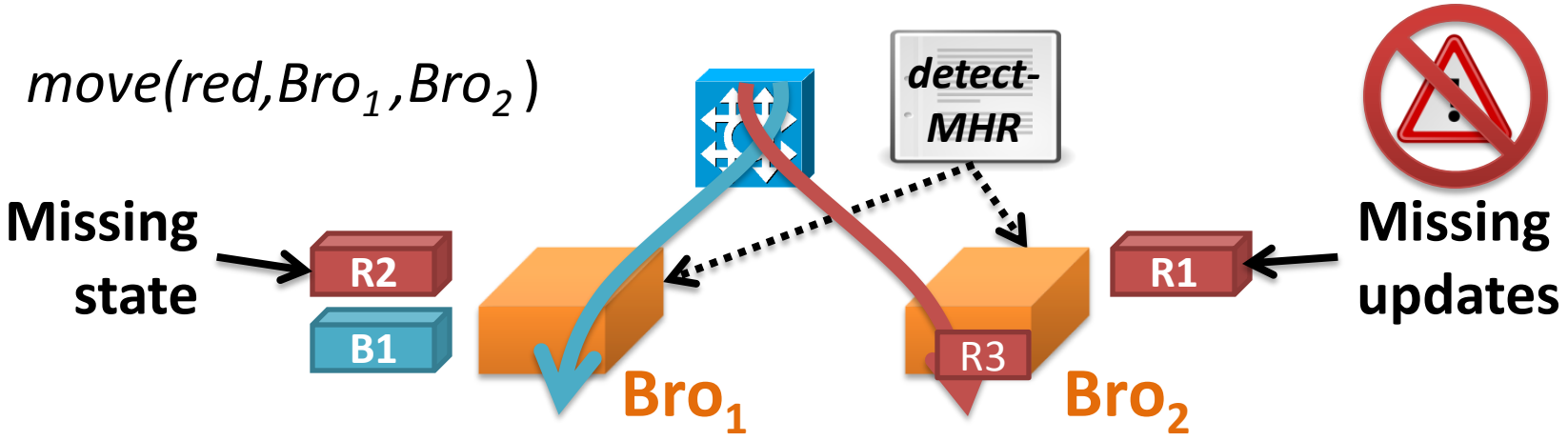

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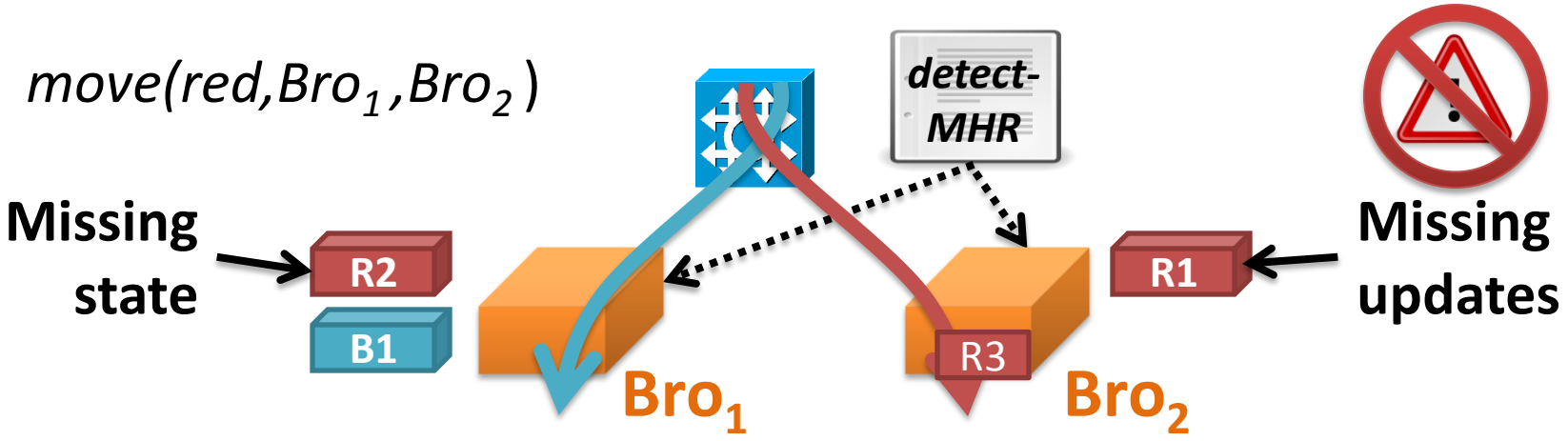
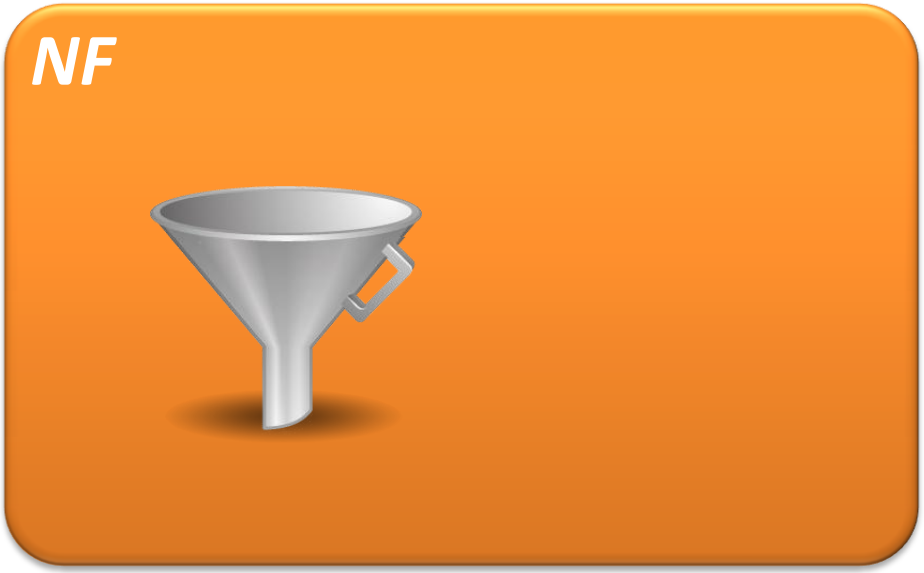


Loss-free: All state updates should be reflected in the transferred state, and all packets should be processed

✗ Split/Merge *[NSDI '13]*: pause traffic, buffer packets

– Packets in-transit when buffering starts are dropped

NF API: observe/prevent updates using events



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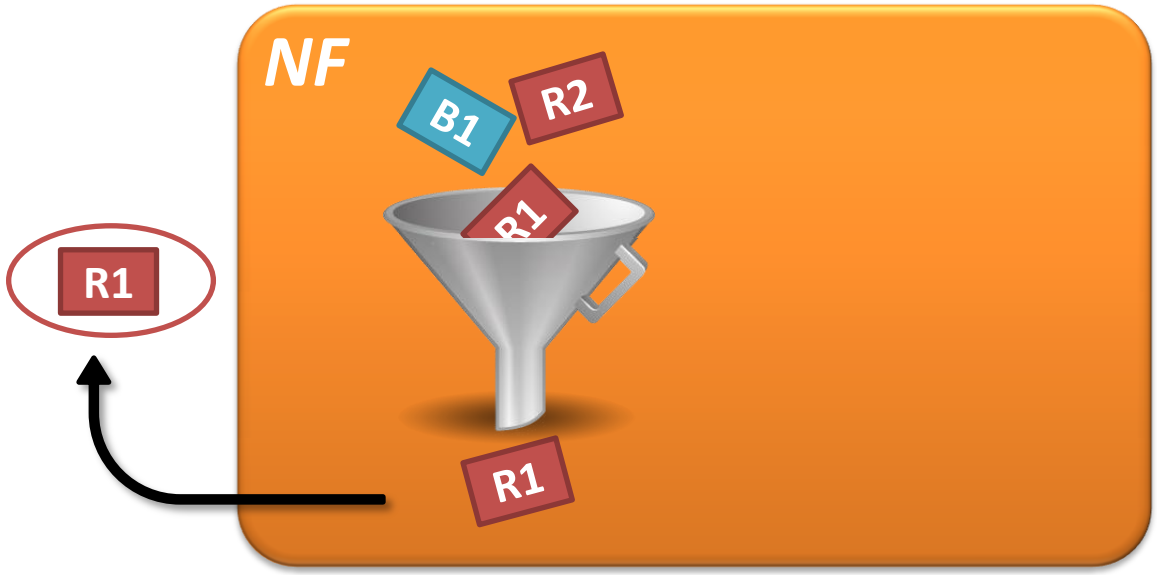

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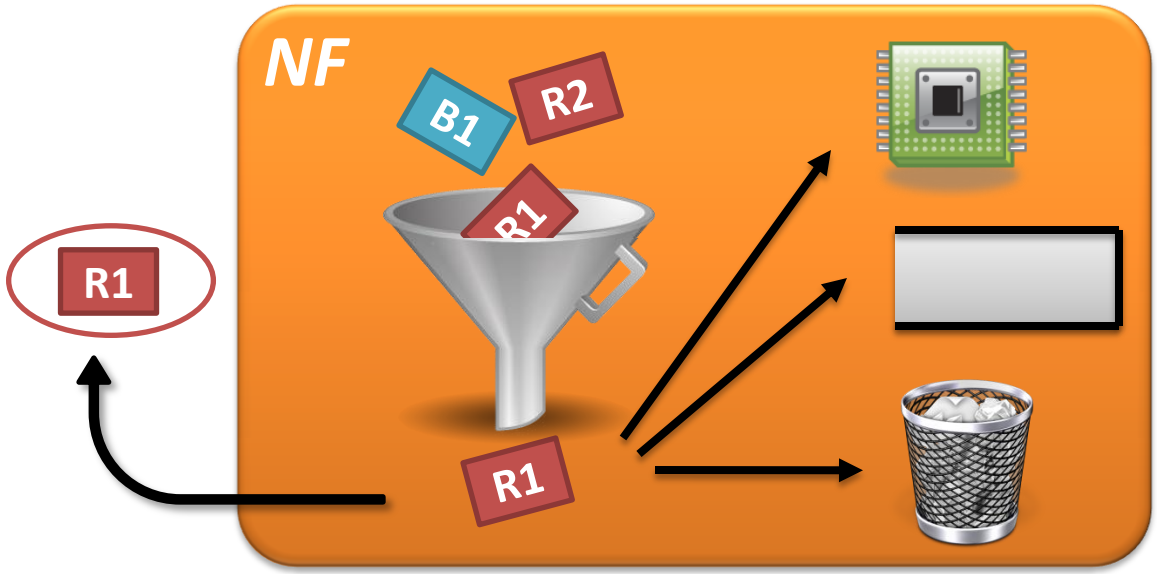

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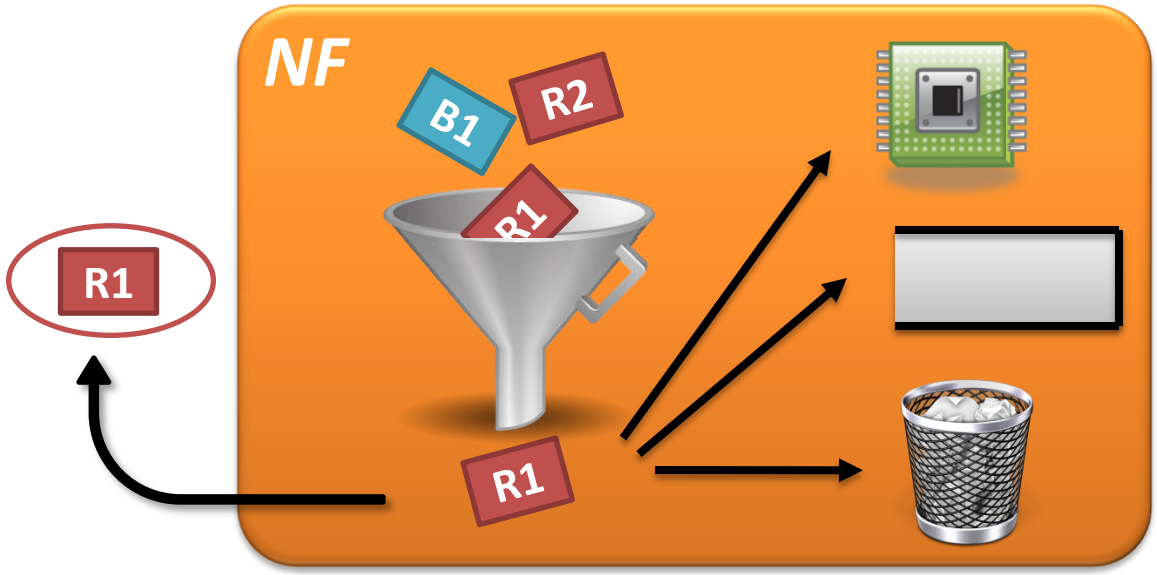
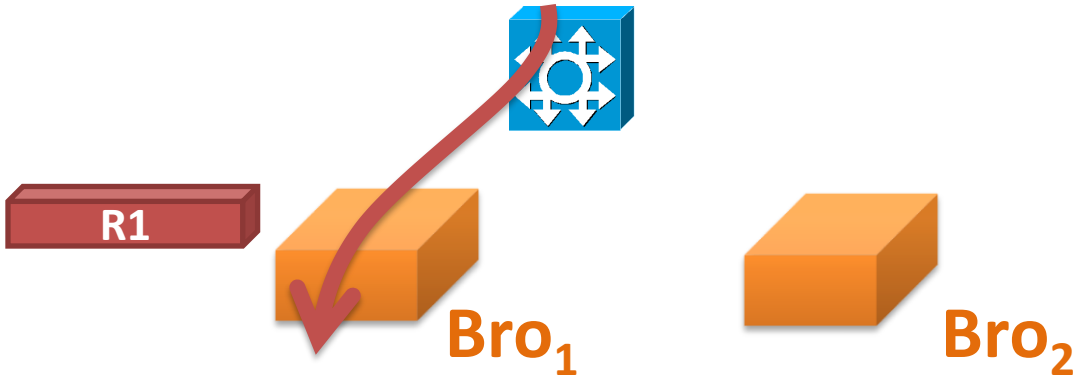


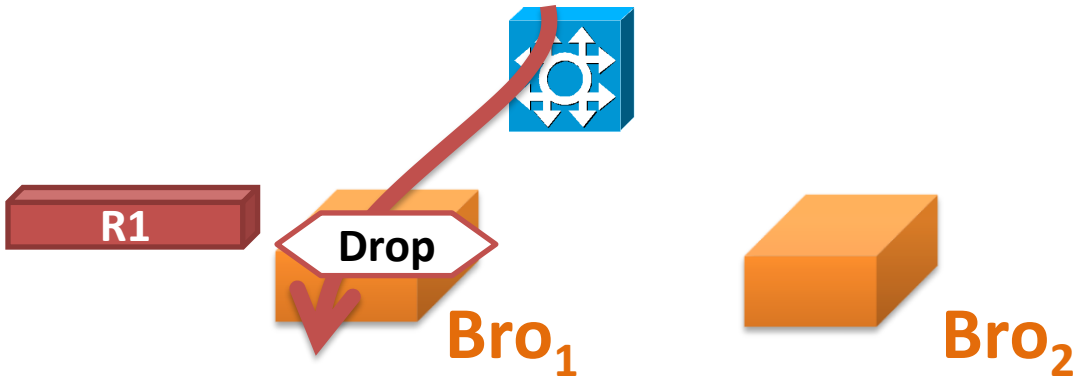
Only need to change an NF's receive packet function!

Use events for loss-free move



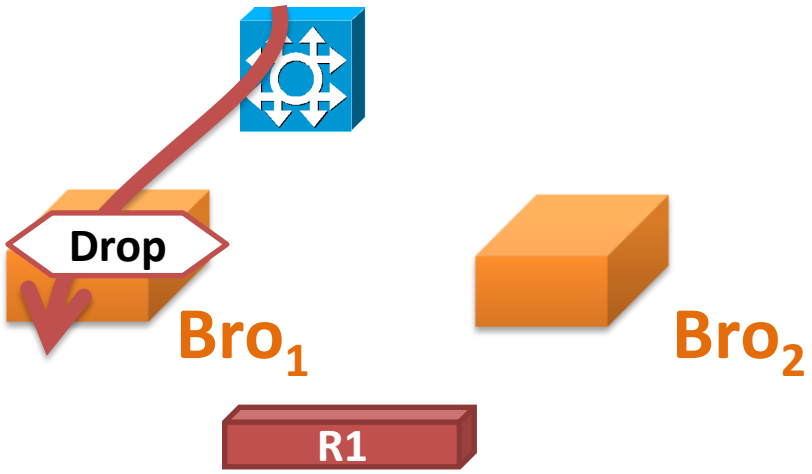
Use events for loss-free move

1. `enableEvents(red,drop)` on Bro_1



Use events for loss-free move

1. `enableEvents(red,drop)` on Bro_1
2. `get/delete` on Bro_1



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1. `enableEvents(red,drop)` on Bro_1
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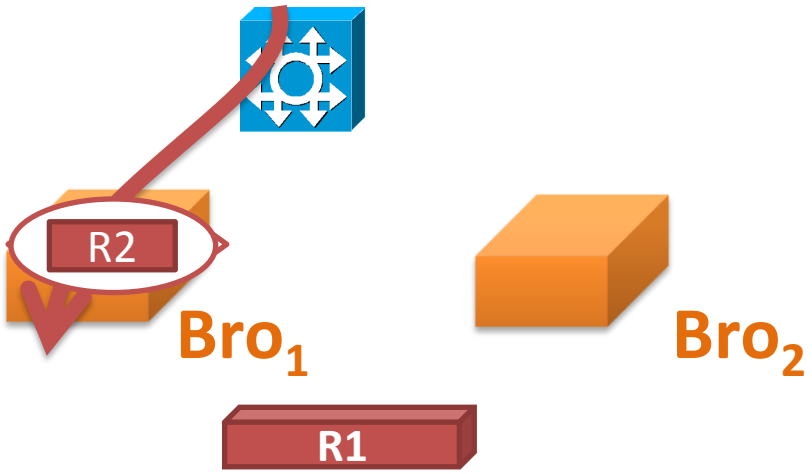
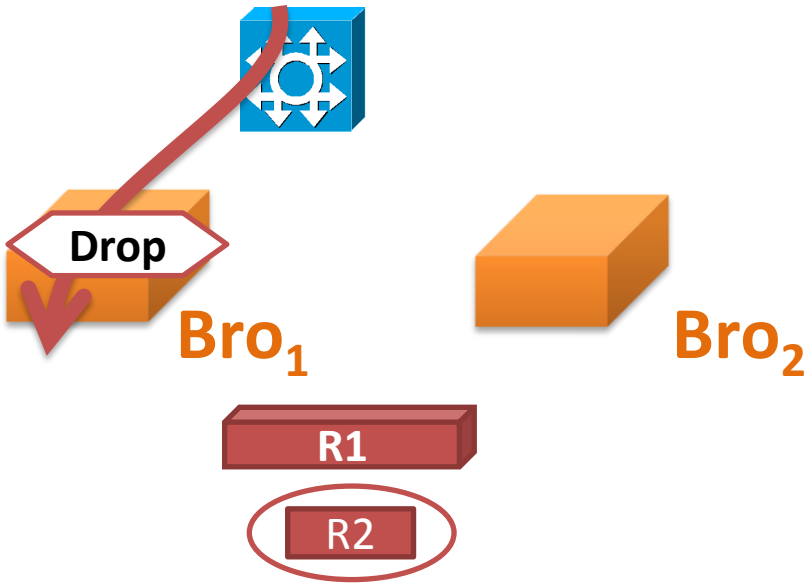


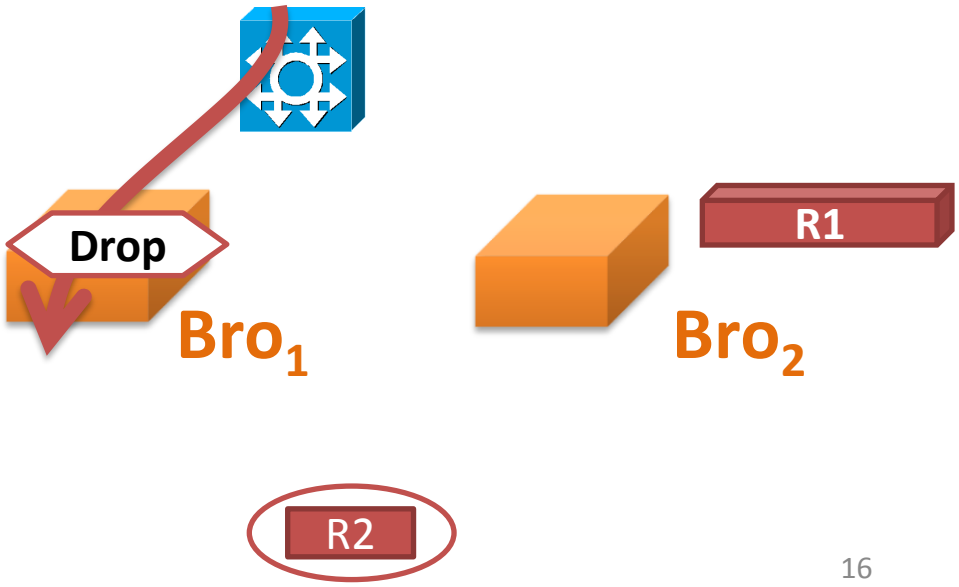
Use events for loss-free move

1. `enableEvents(red,drop)` on Bro_1
2. `get/delete` on Bro_1
3. Buffer events at controller



Use events for loss-free move

1. `enableEvents(red,drop)` on Bro_1
2. `get/delete` on Bro_1
3. Buffer events at controller
4. `put` on Bro_2



Use events for loss-free move

1. `enableEvents(red,drop)` on Bro_1
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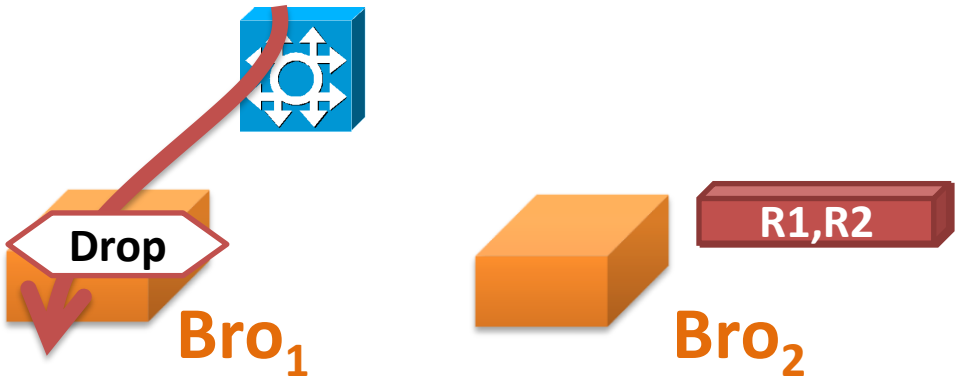
3. Buffer events at controller
4. `put` on Bro_2
5. Flush packets in events to Bro_2



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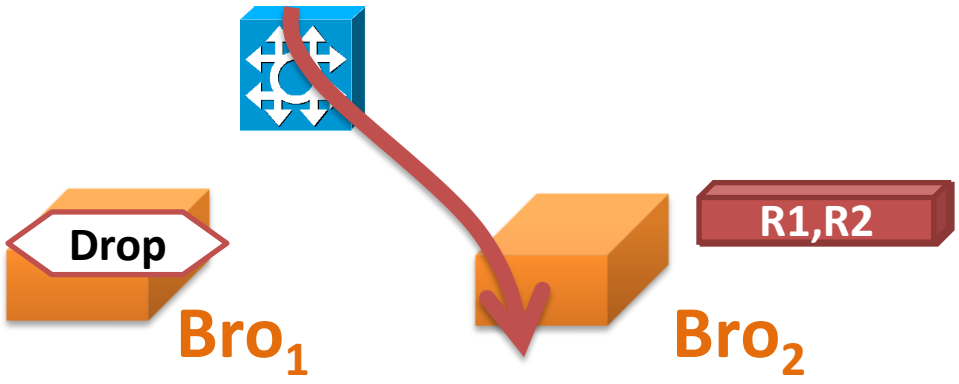
5. Flush packets in events to Bro_2
6. Update forwarding



Use events for loss-free move

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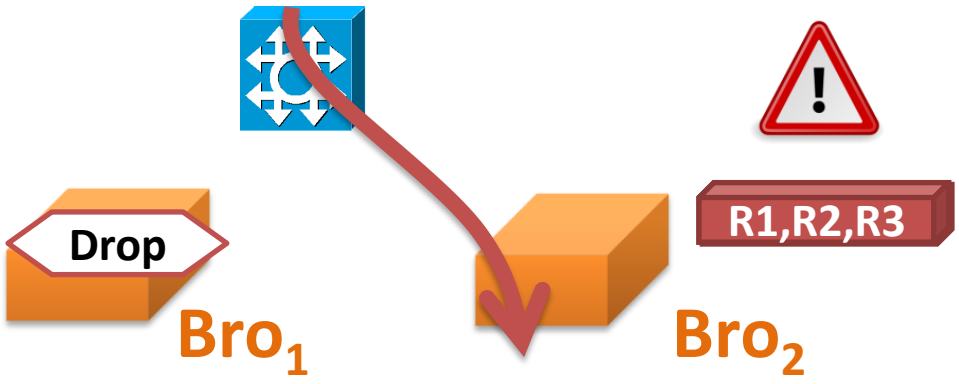
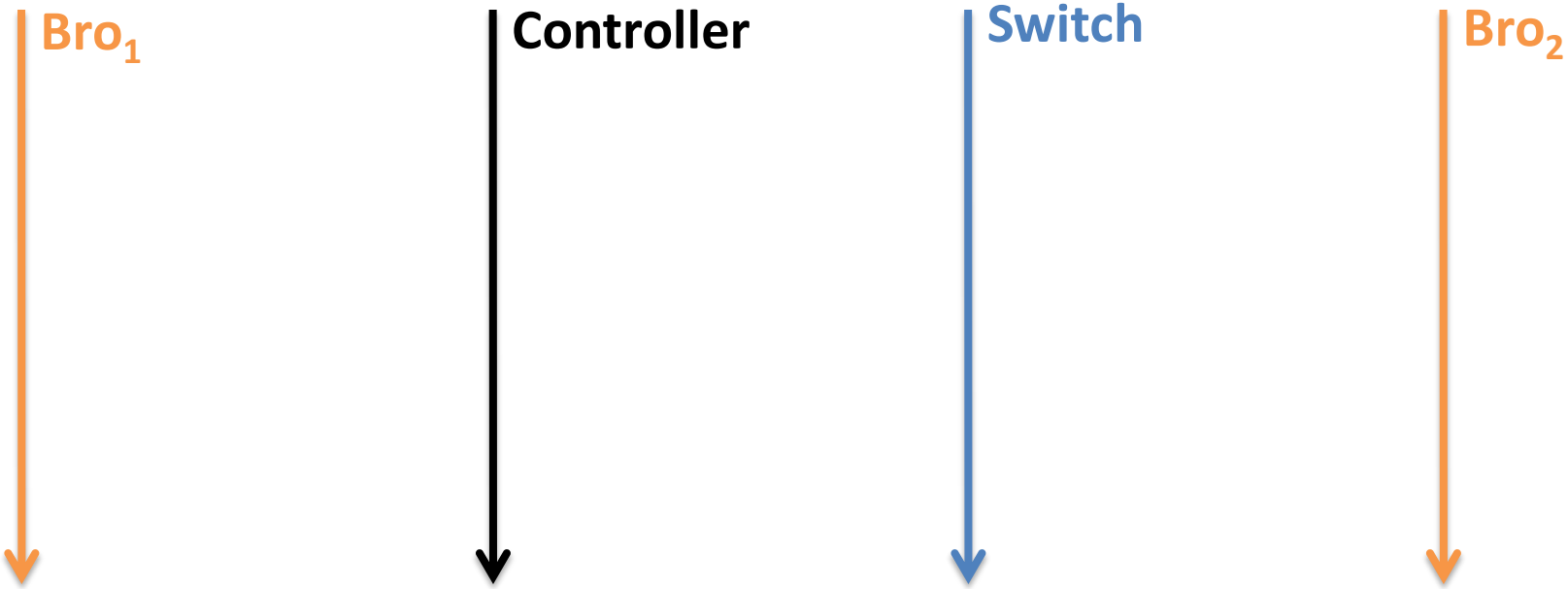
3. Buffer events at controller
4. `put` on Bro_2
5. Flush packets in events to Bro_2
6. Update forwarding



Re-ordering of packets

- False positives from Bro's `weird` script



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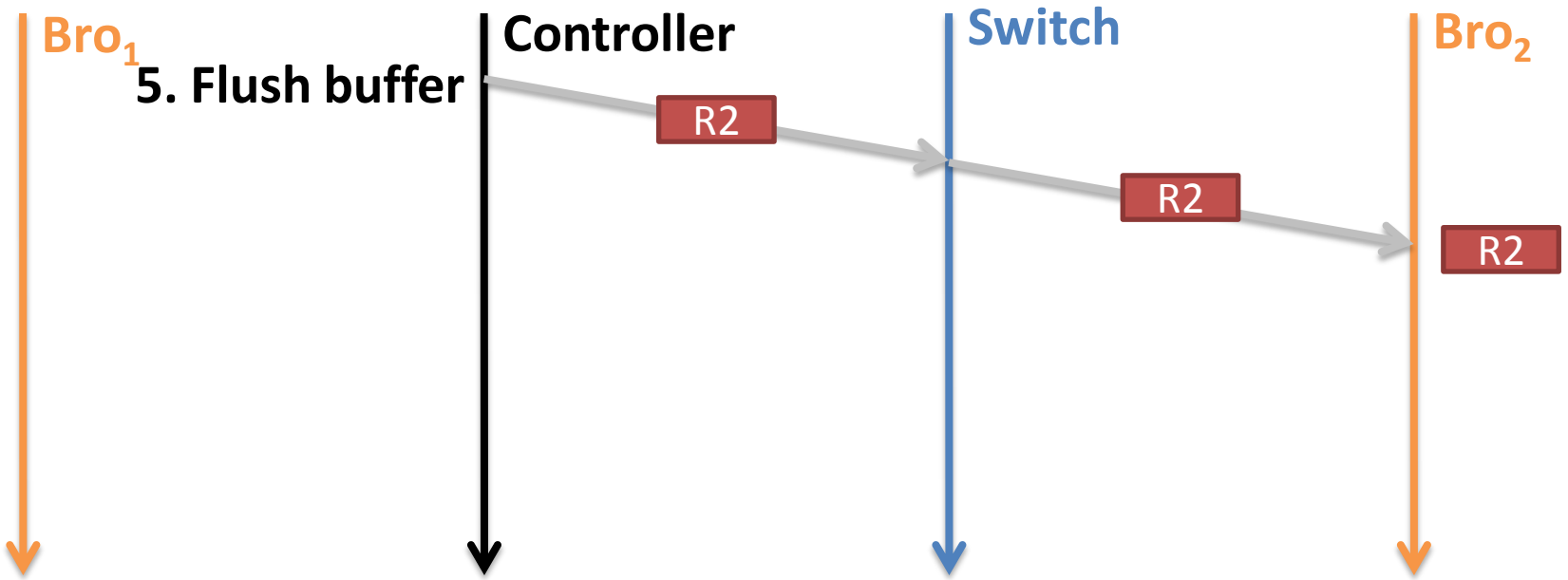

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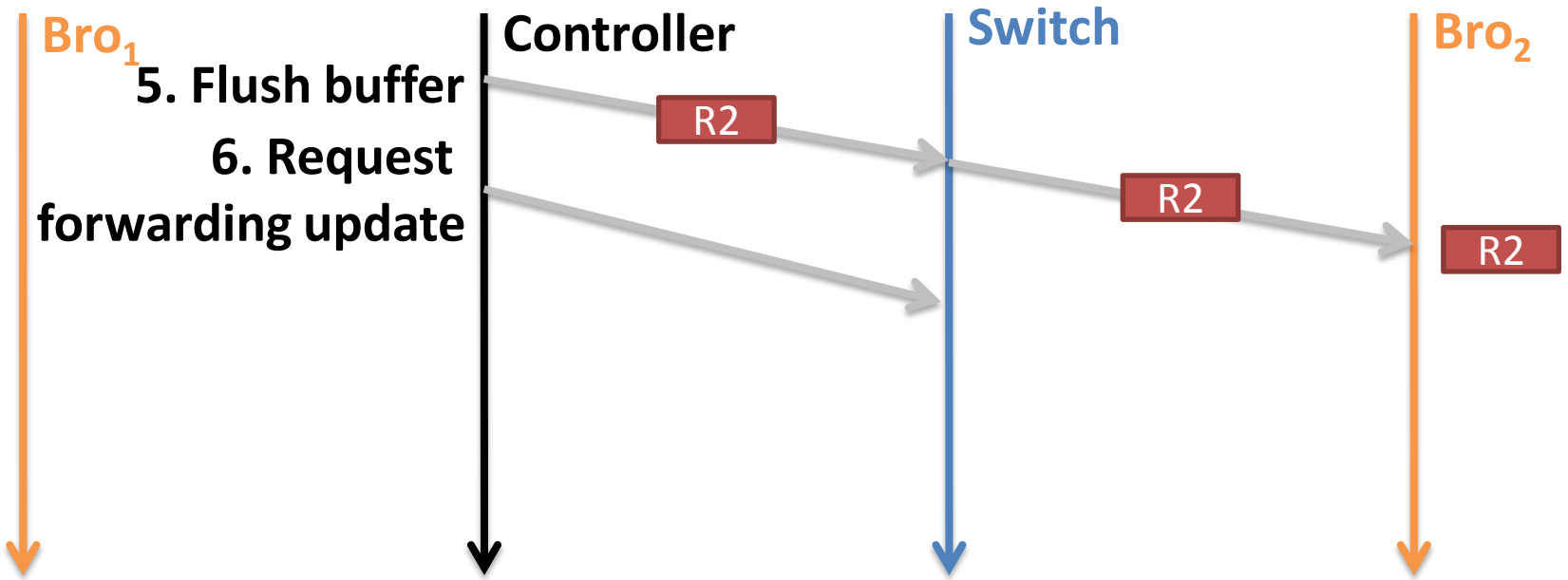

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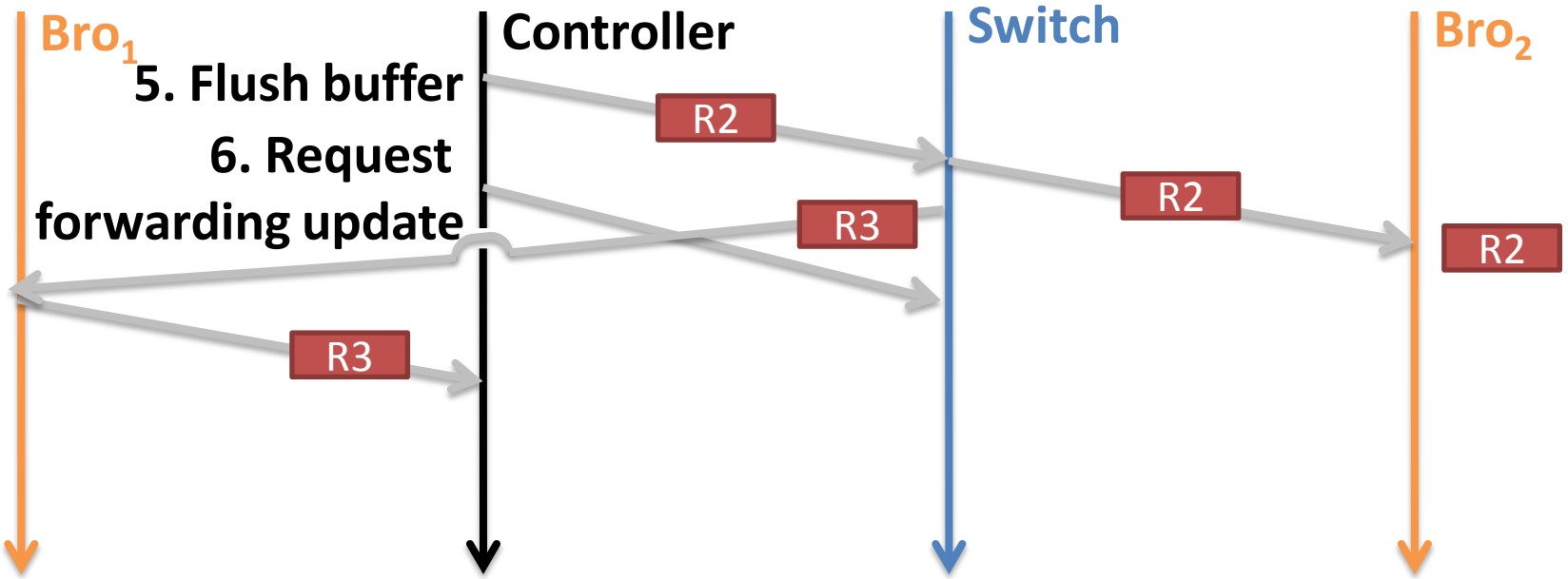

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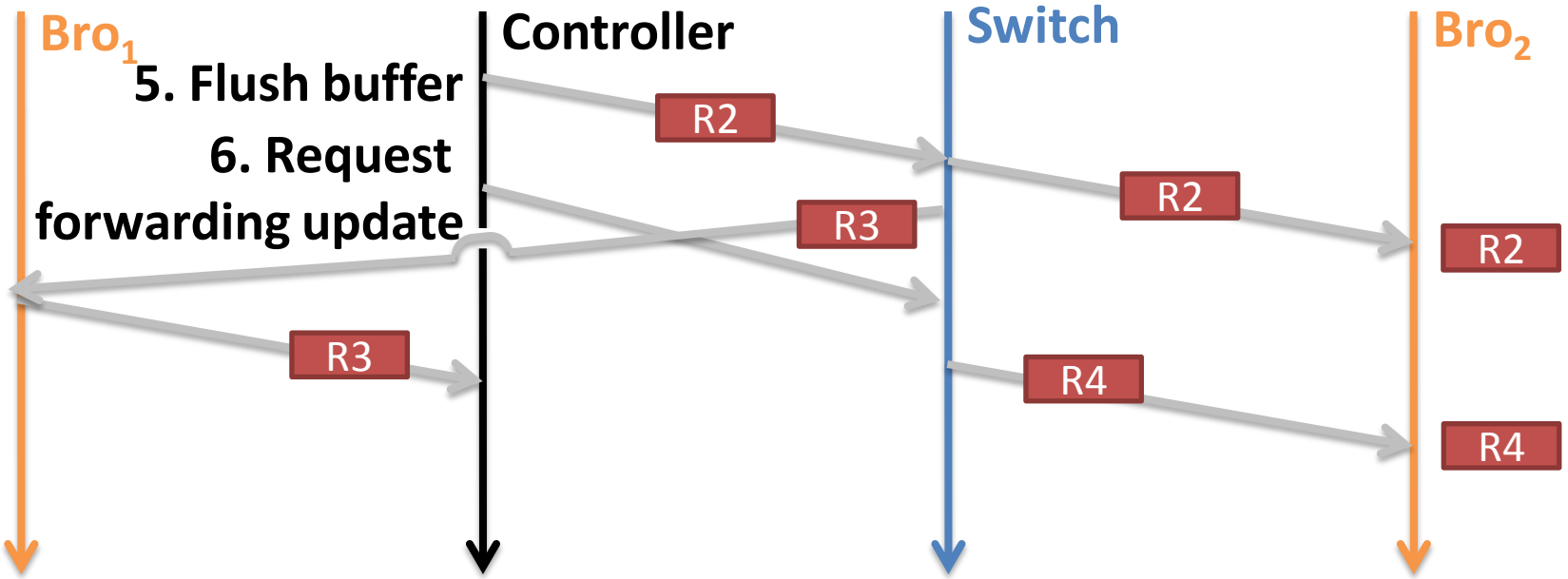

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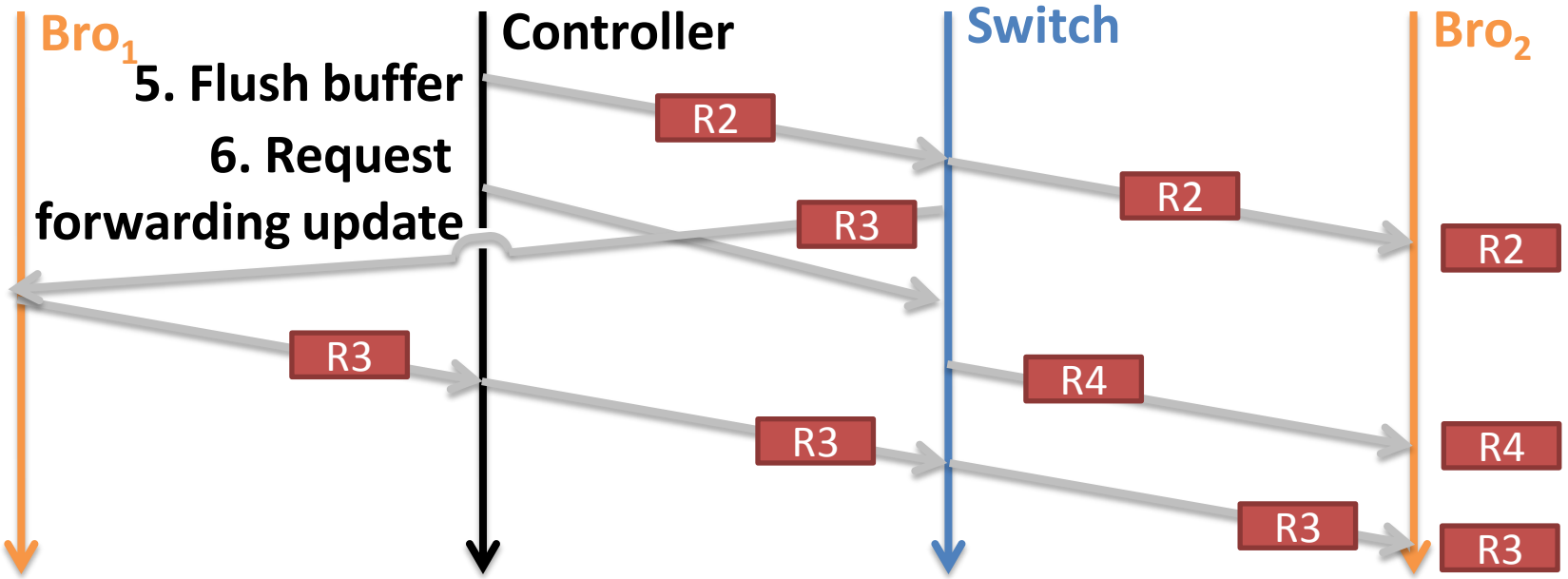

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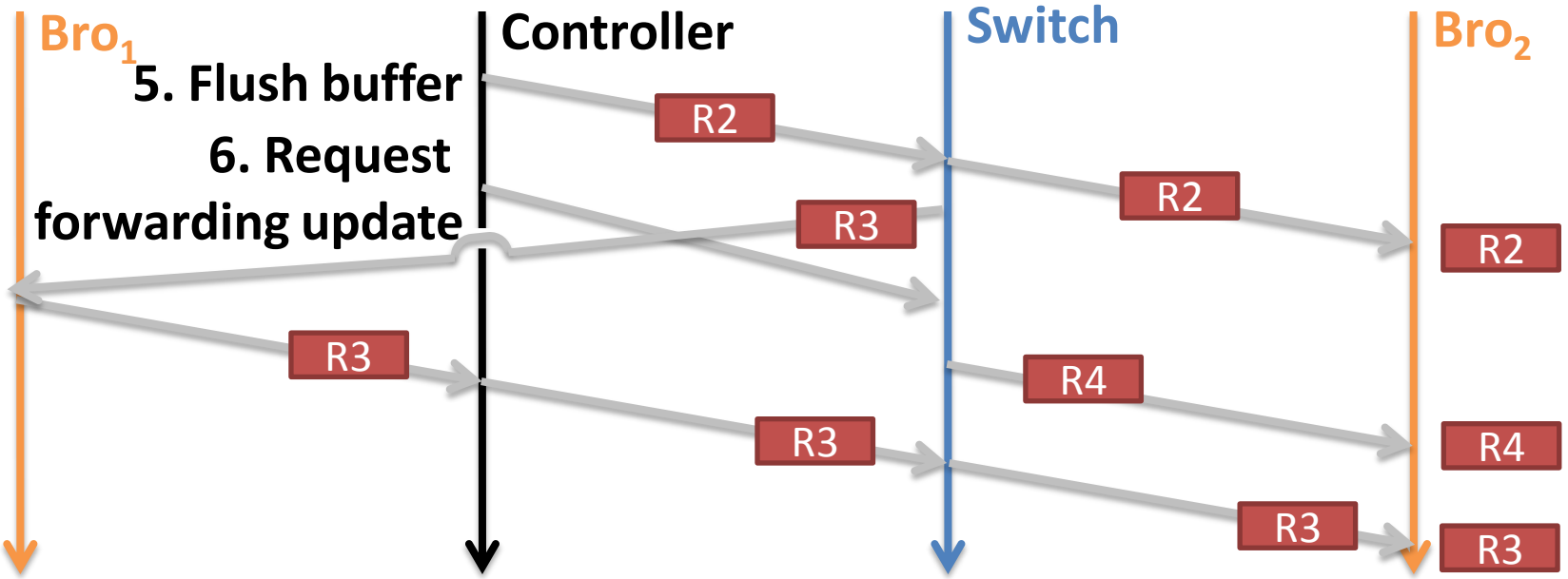


Order-preserving: All packets should be processed in the order they were forwarded by the switch

OpenNF: SLAs + cost + accuracy

1. Dealing with diversity

Export/import state based
on its association with flows

2. Dealing with race conditions

Events + Lock-step forwarding updates

Implementation

- Controller (*3.8K lines of Java*)
- Communication library (2.6K lines of C)
- Modified NFs (3-8% increase in code)

Bro IDS

iptables

Squid Cache

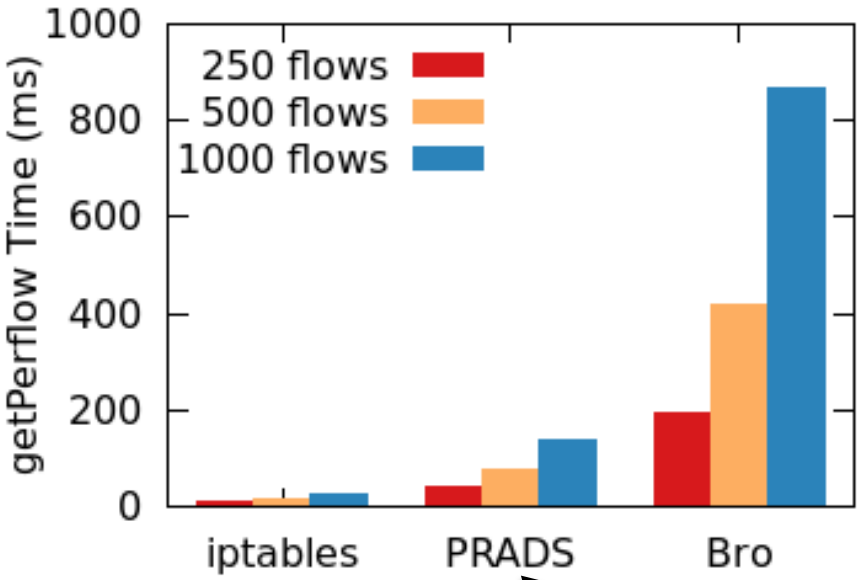
PRADS

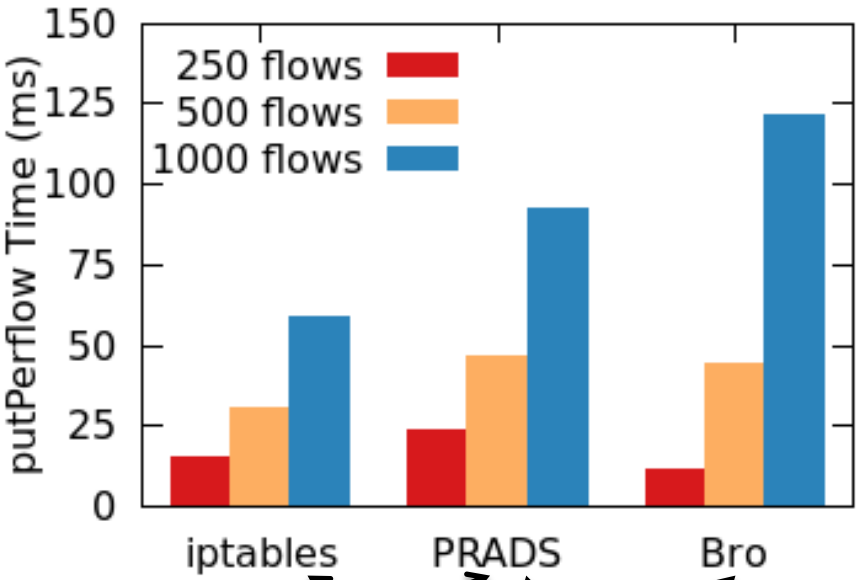
Overall benefits for elastic scaling

- Bro IDS processing 10K pkts/sec
  - *At 180 sec:* move HTTP flows (489) to new IDS
  - *At 360 sec:* move back to old IDS
- SLAs: 260ms to move (loss-free)

- Accuracy: same log entries as using one IDS
  - VM replication: incorrect log entries
- Cost: scale down after state is moved
  - Stratos: scale down delayed 25+ minutes
    [arXiv:1305.0209]

Evaluation: state export/import



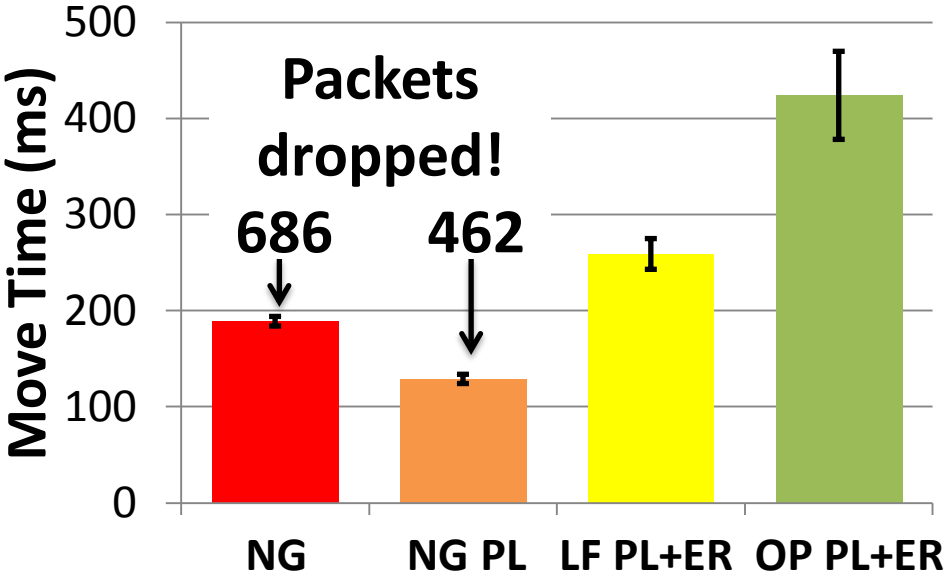


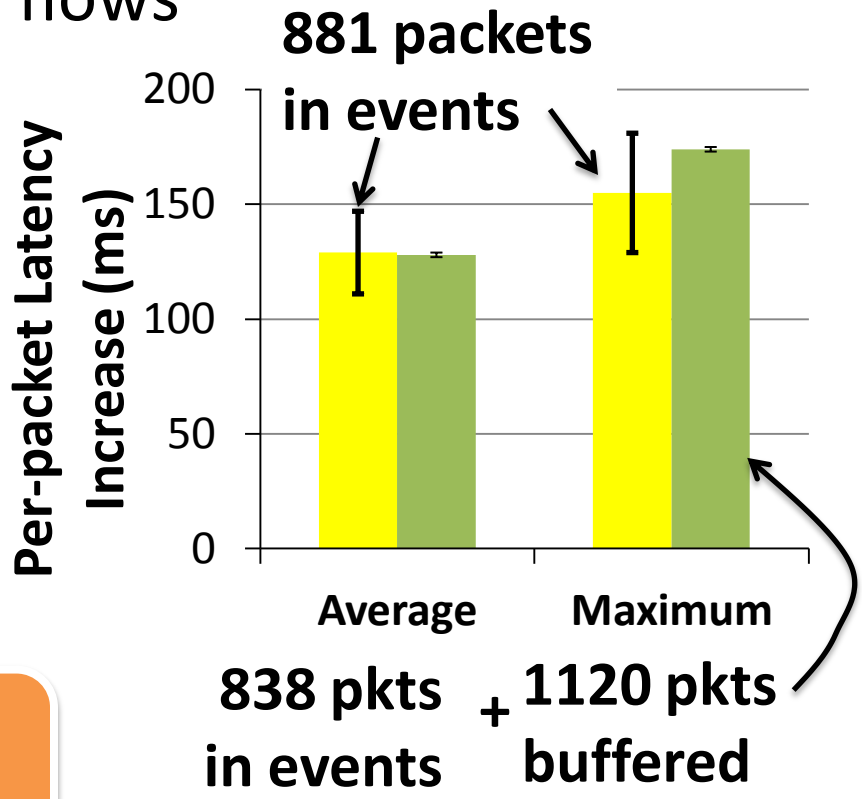
Serialization/deserialization costs dominate

Cost grows with state complexity

Evaluation: operations

- PRADS asset detector processing 5K pkts/sec
- Move per-flow state for 500 flows

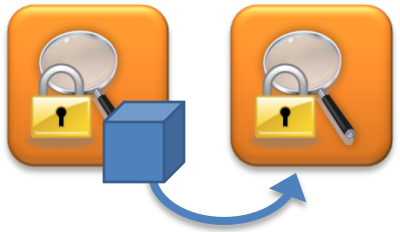




Operations are efficient, but guarantees come at a cost!

Conclusion

- Dynamic reallocation of packet processing enables new services



- Realizing SLAs + cost + accuracy requires quick, safe control of internal NF state
- OpenNF provides flexible and efficient control with few NF modifications

http://opennf.cs.wisc.edu