OpenNF: Enabling Innovation in Network Function Control

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Network functions (NFs)

- Perform sophisticated *stateful* actions on packets/flows

WAN optimizer

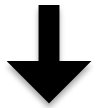
Caching proxy

Intrusion detection system (IDS)

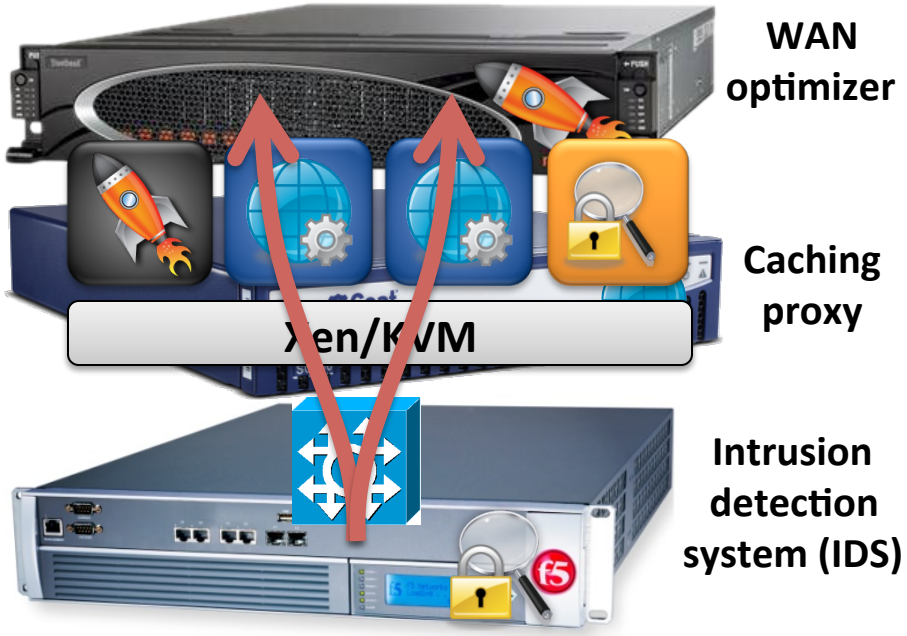
NF trends

- NFV → dynamically allocate NF instances

- SDN → dynamically reroute flows

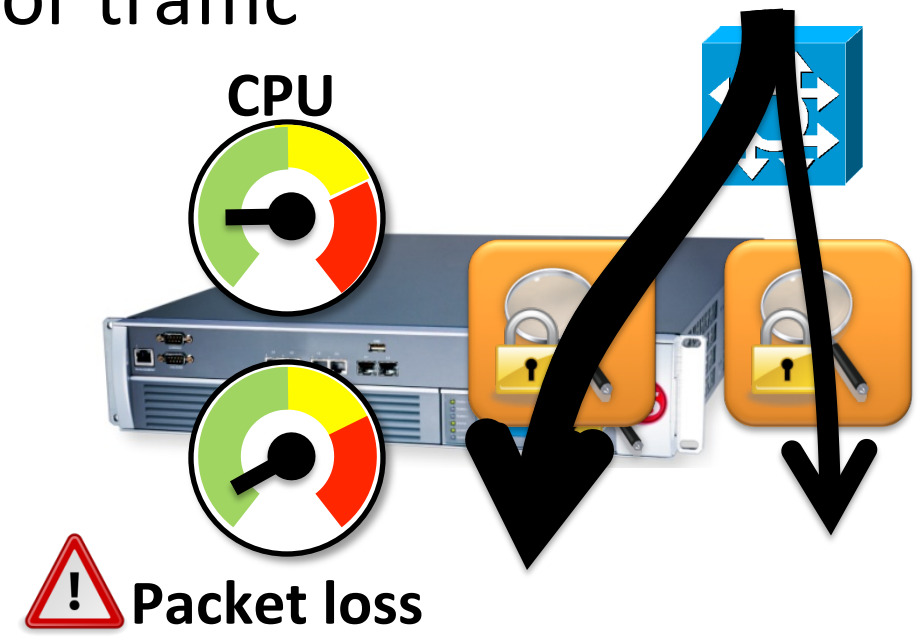


Dynamic reallocation of packet processing



Example: elastic NF scaling

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



Problem: Network Insufficient

To **simultaneously**…

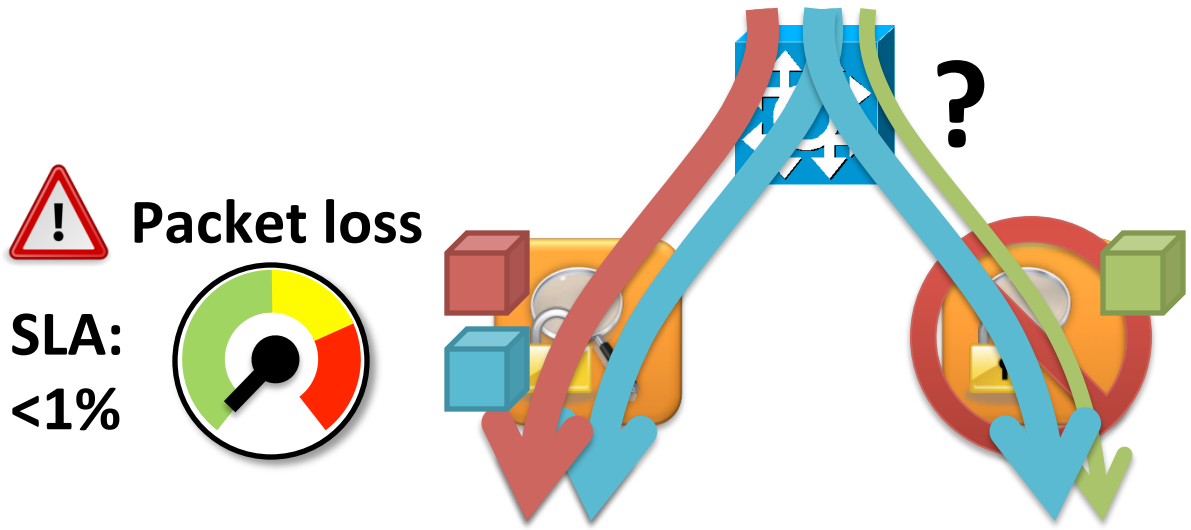
1. Satisfy performance SLAs
2. Minimize operating costs
3. Accurately monitor traffic

CPU

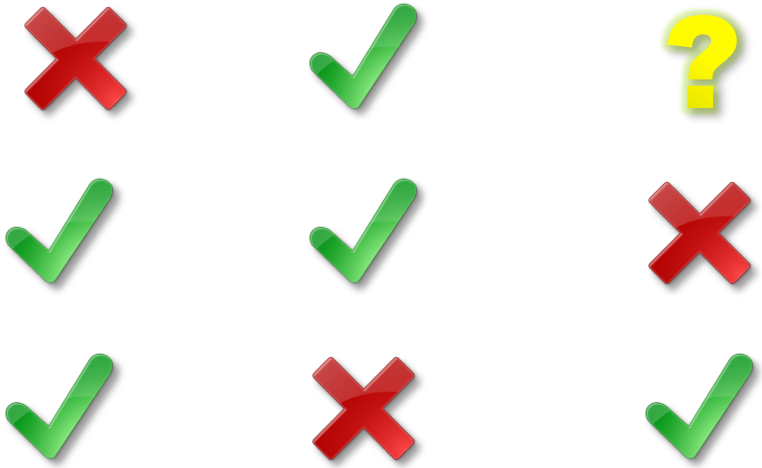
Packet loss

Cannot effectively implement
new services or abstractions!

Why NFV + SDN falls short

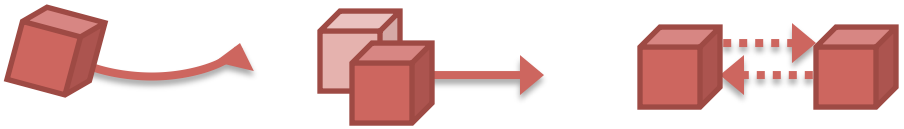


1. SLAs 2. Cost 3. Accuracy



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

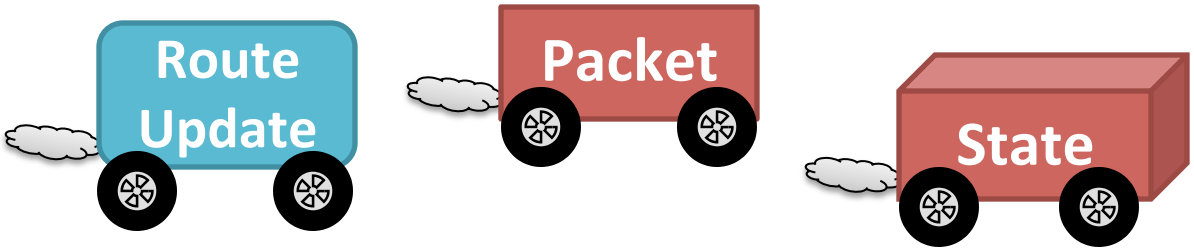
Outline

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

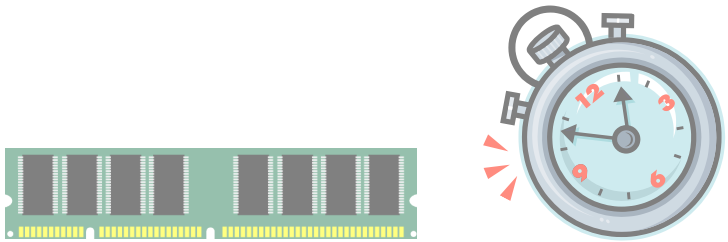
Challenges

1. Supporting many NFs with minimal changes

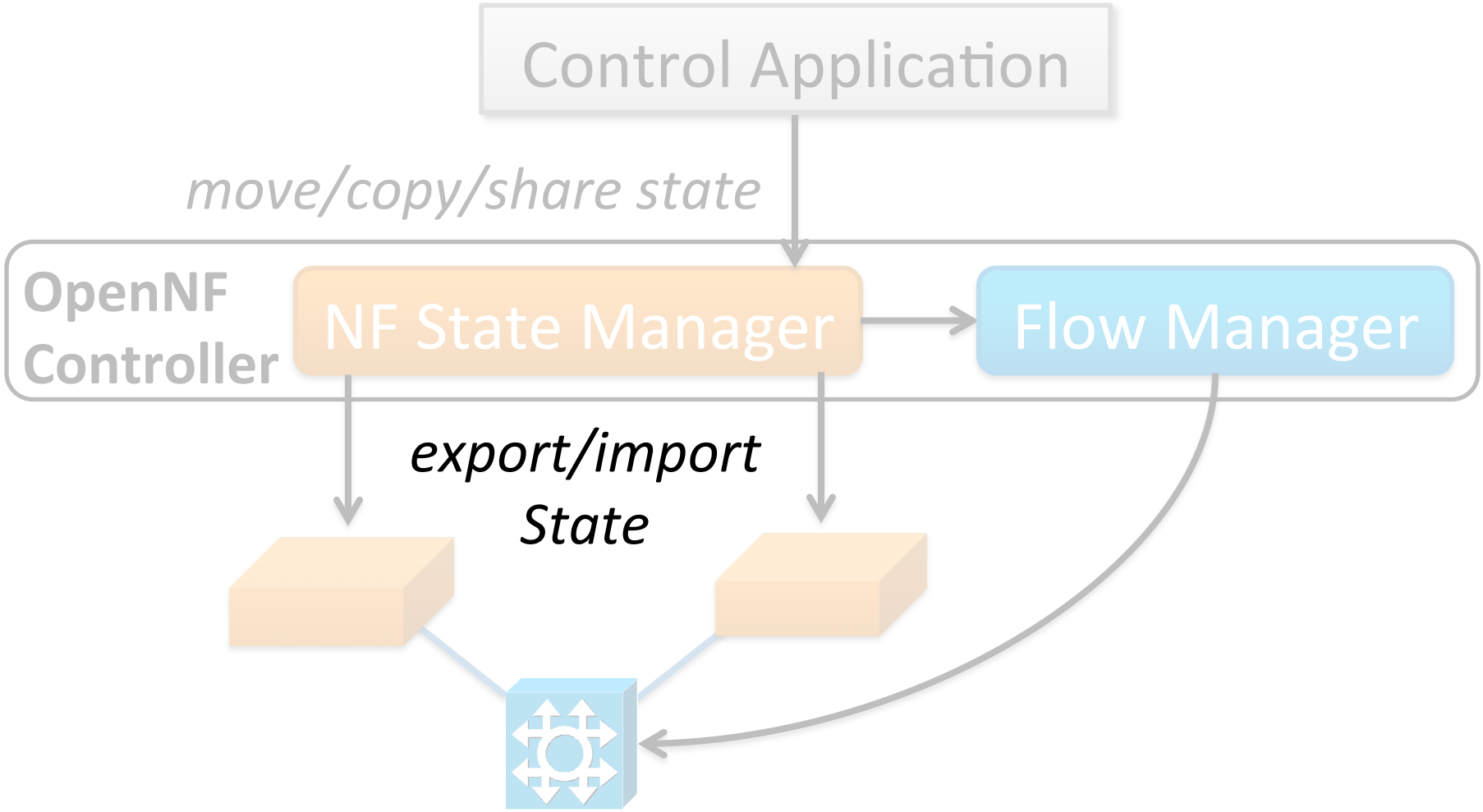
2. Dealing with race conditions



3. Bounding overhead

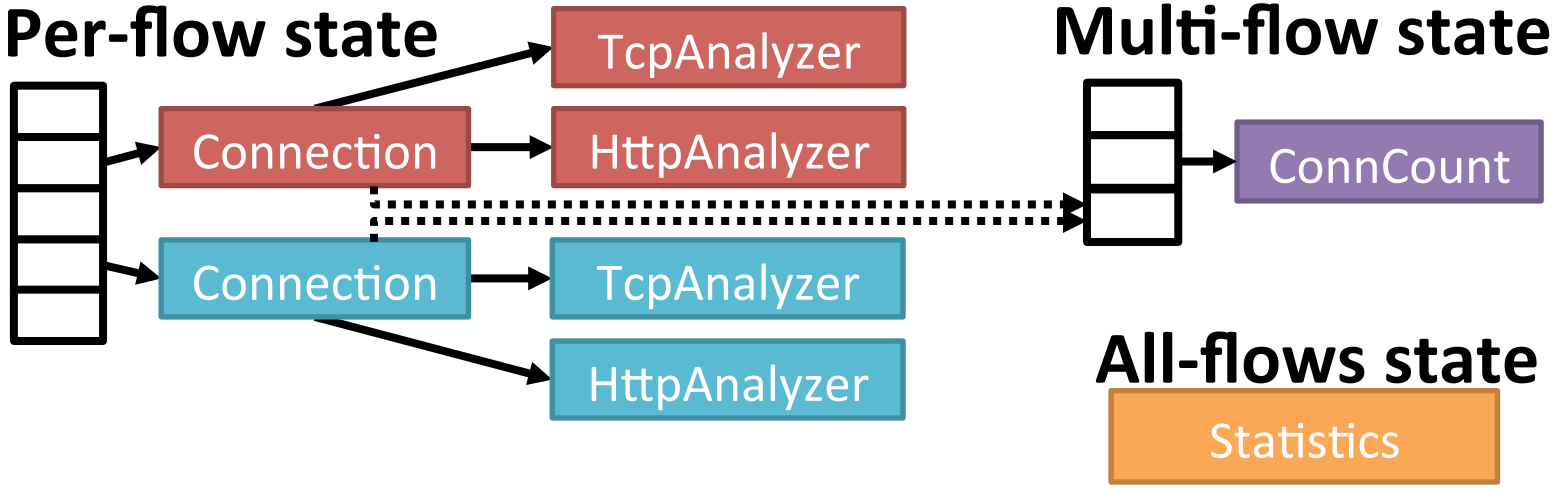


OpenNF overview



NF state taxonomy

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

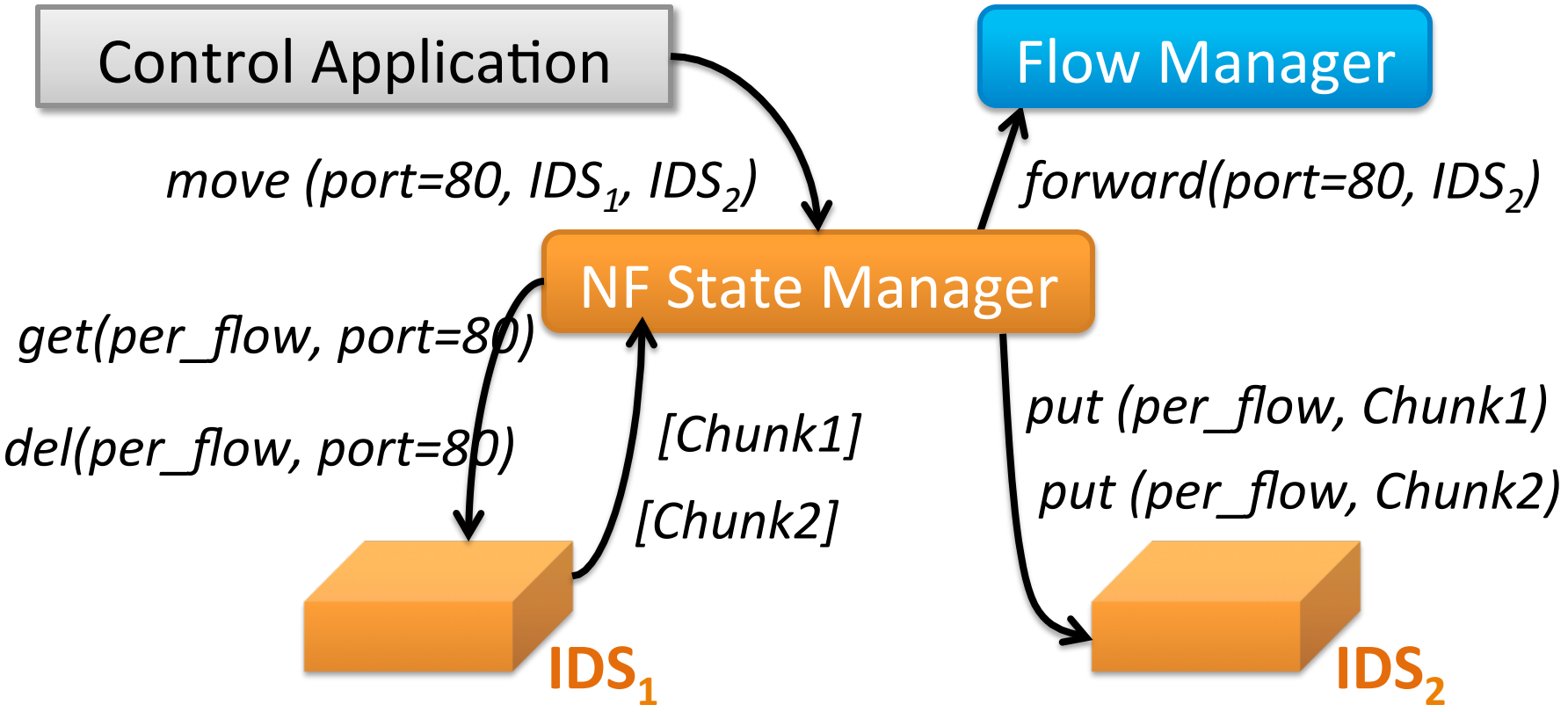


NF API: export/import state

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

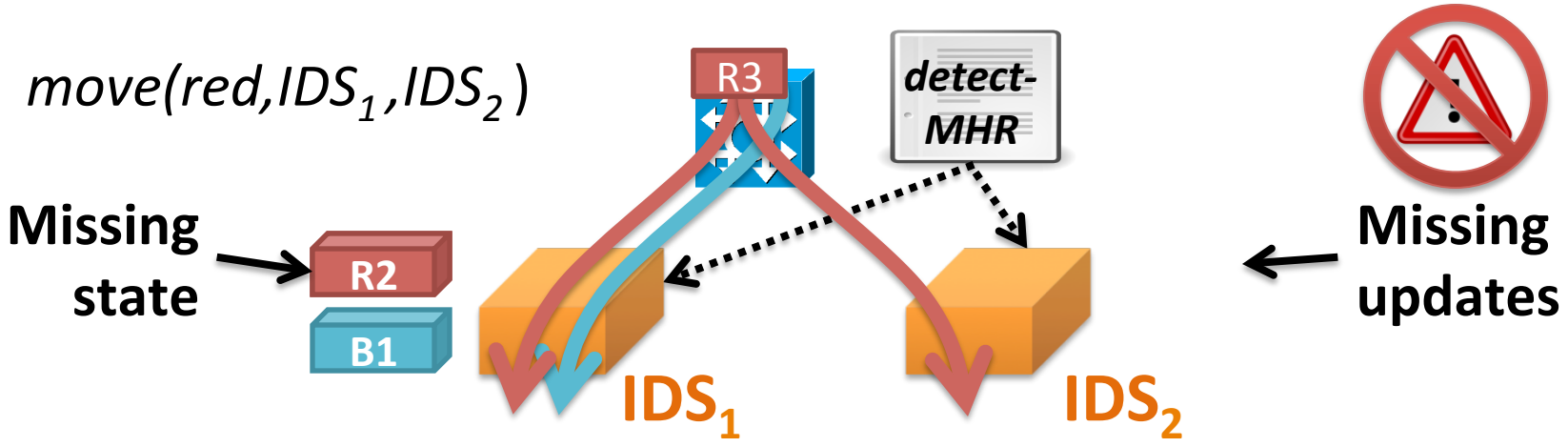
No need to expose/change internal state organization!

Control operations: move



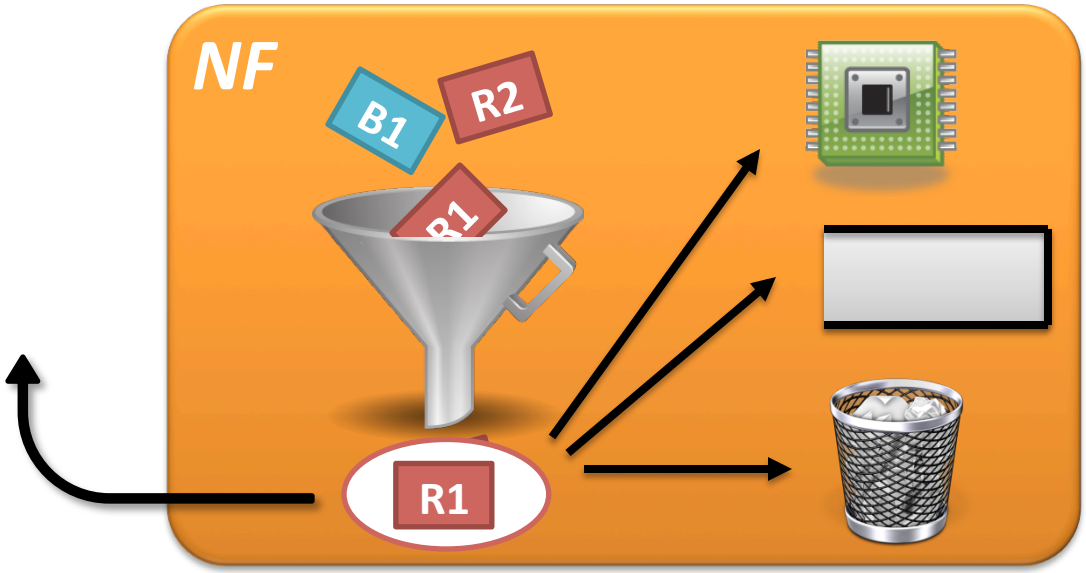
Also provide copy and share

Lost updates during move



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

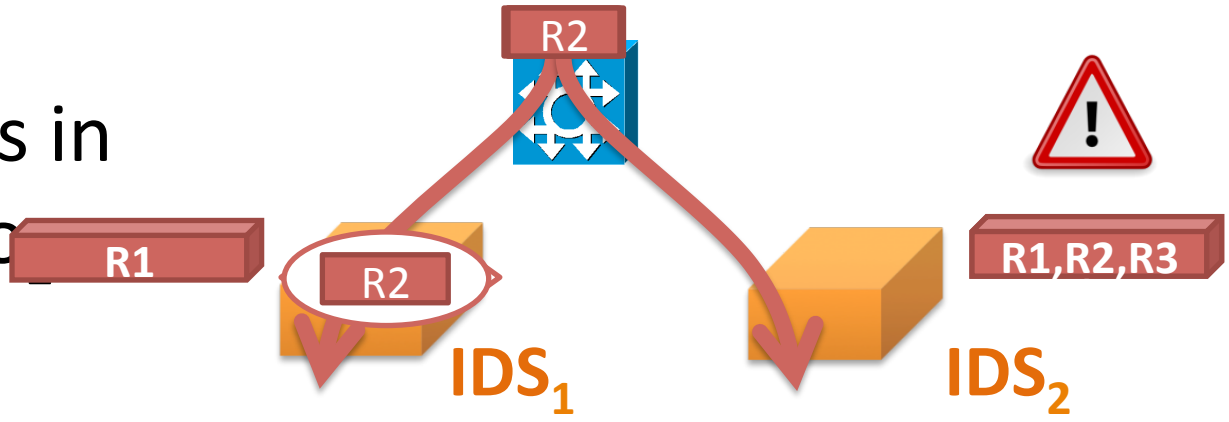
NF API: observe/prevent updates using events



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

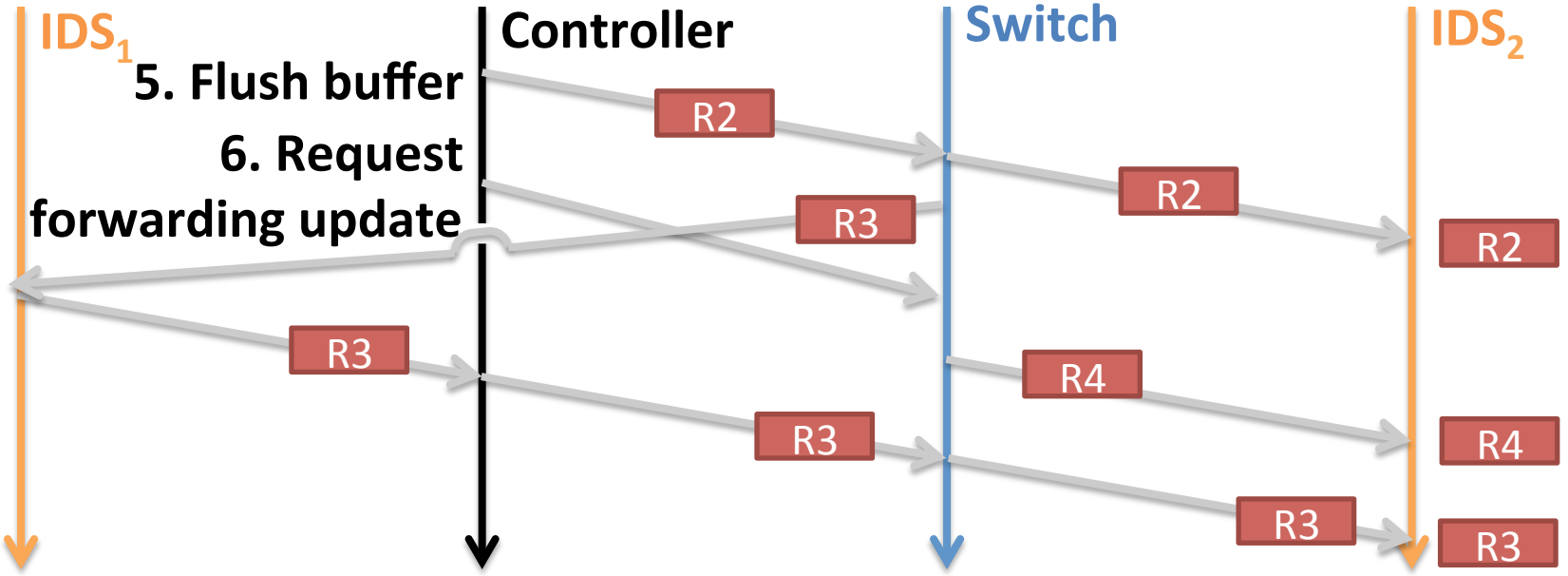
Use events for loss-free move

1. `enableEvents(red,drop)` on IDS_1
2. `get/delete` on IDS_1
3. Buffer events at controller
4. `put` on IDS_2
5. Flush packets in events to Bro
6. Update forwarding



Re-ordering of packets

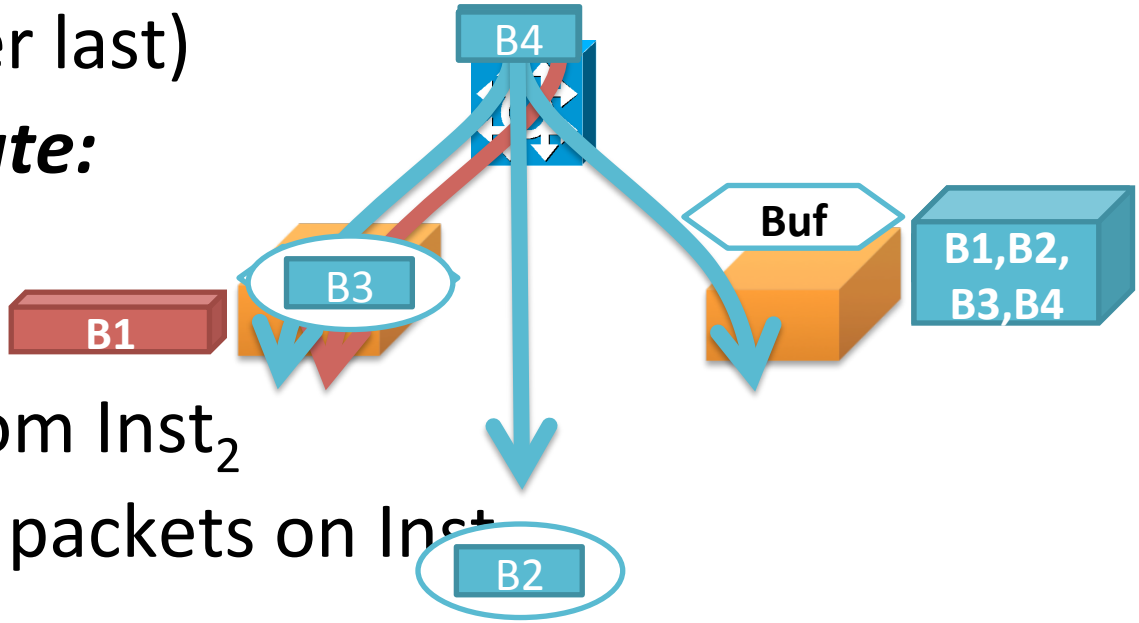
- False positives from IDS's `weird` script



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

Order-preserving move

- Flush packets in events to $Inst_2$
- `enableEvents(blue,buffer)` on $Inst_2$
- ***Forwarding update:*** send to $Inst_1$ & controller
- Wait for packet from switch (remember last)
- ***Forwarding update:*** send to $Inst_2$
- Wait for event for last packet from $Inst_2$
- Release buffer of packets on Inst



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

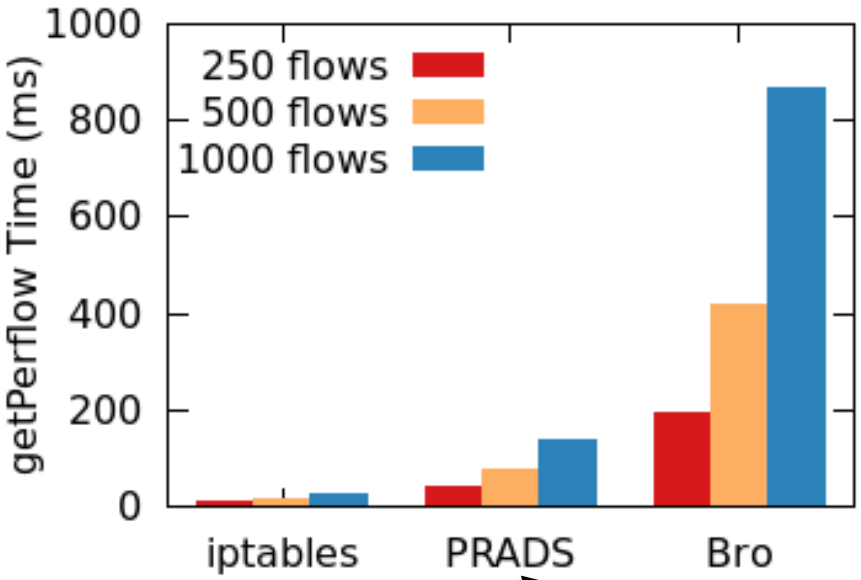
PRADS

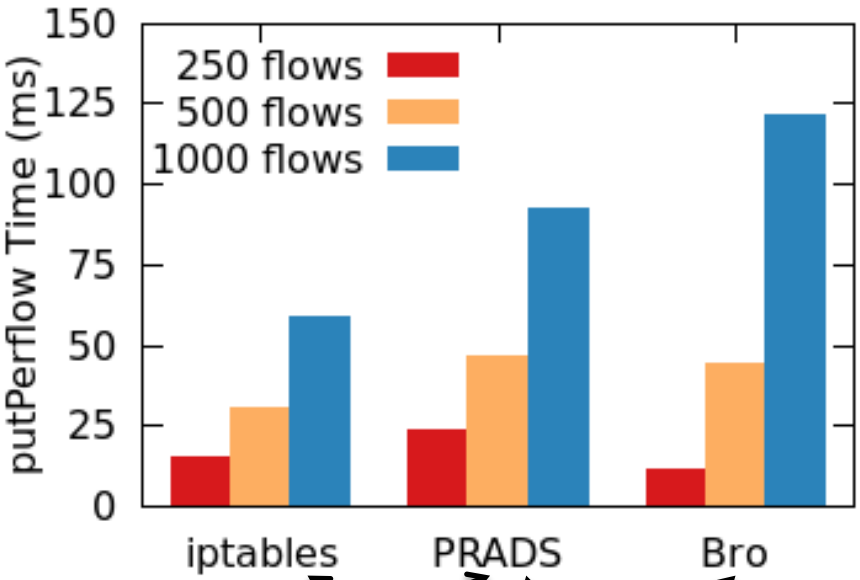
Overall benefits for elastic scaling

- 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



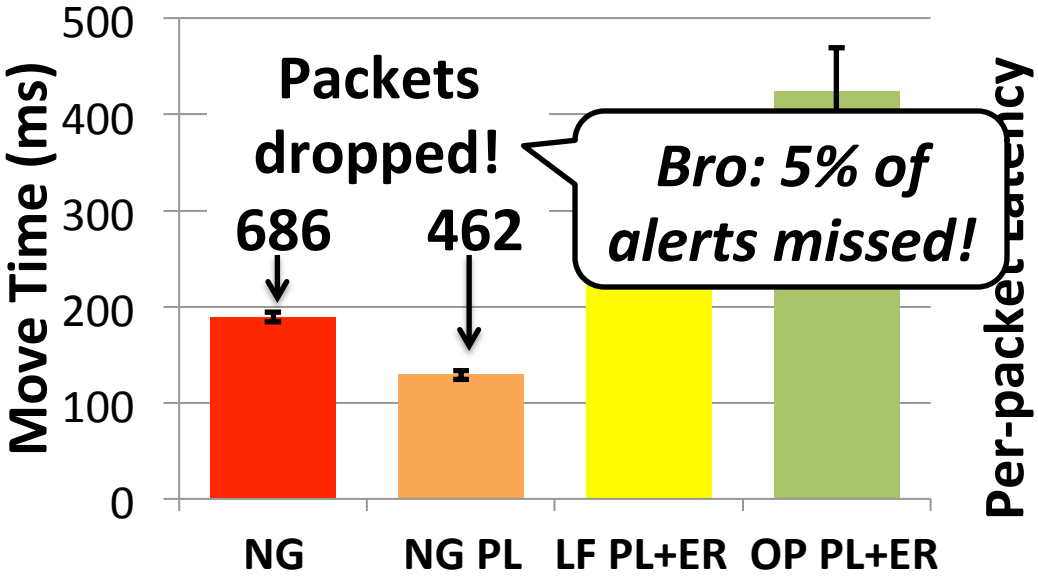


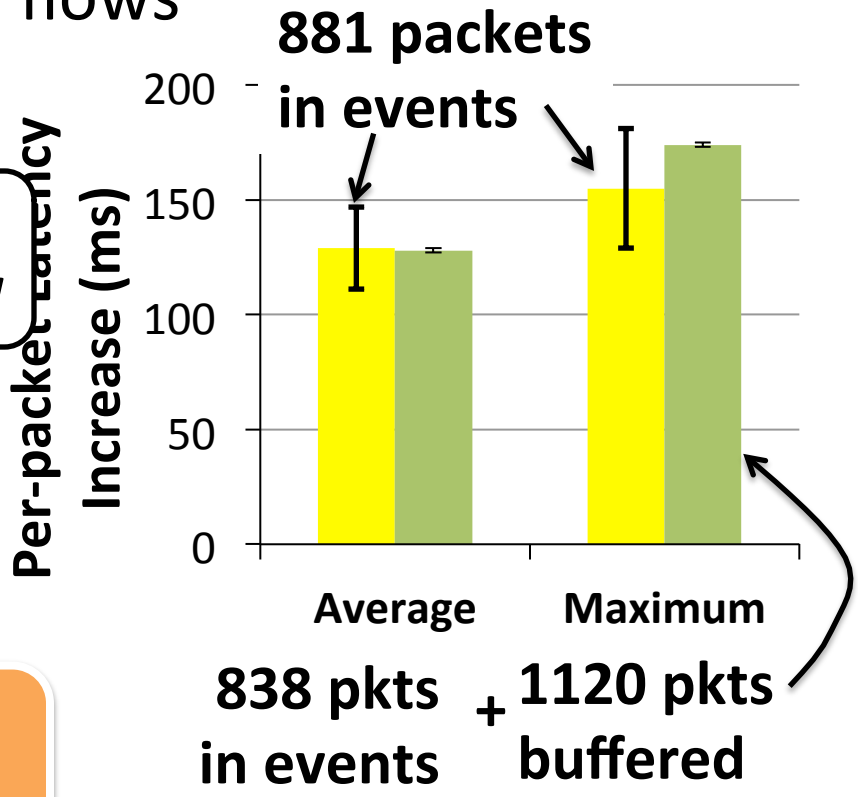
Serialization/deserialization costs dominate

Cost grows with state complexity

Evaluation: operations

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

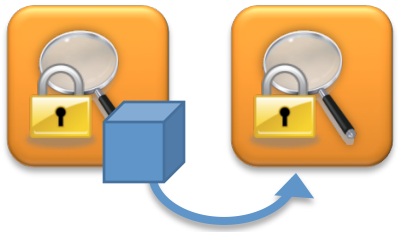




Operations are efficient, but guarantees come at a cost!

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

Thank you!

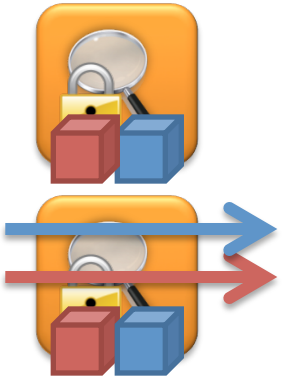
Q&A

Backup

- Related work
- Copy and share
- Order-preserving move
- Bounding overhead
- Example control application
- Evaluation: controller scalability
- Evaluation: importance of guarantees
- Evaluation: benefits of granular control

Existing approaches

- Virtual machine replication
  - Unneeded state → incorrect actions
  - Cannot combine → limited reallocation



- Split/Merge *[NSDI'13]*
  - State allocations and accesses occur via library
  - Addresses a specific problem → limited suitability
  - Packets may be dropped or re-ordered → wrong NF behavior

Copy and share operations

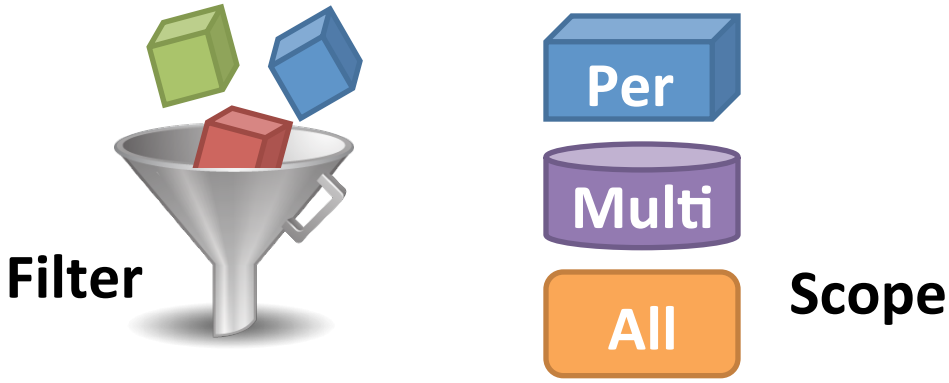
- Used when multiple instances need some state
- Copy – no or eventual consistency
  - Once, periodically, based on events, etc.
- Share – strong or strict consistency
  - Events are raised for all packets
  - Events are released one at a time
  - State is copied before releasing the next event

Copy (multi-flow): 111ms
Share (strong): 13ms/packet

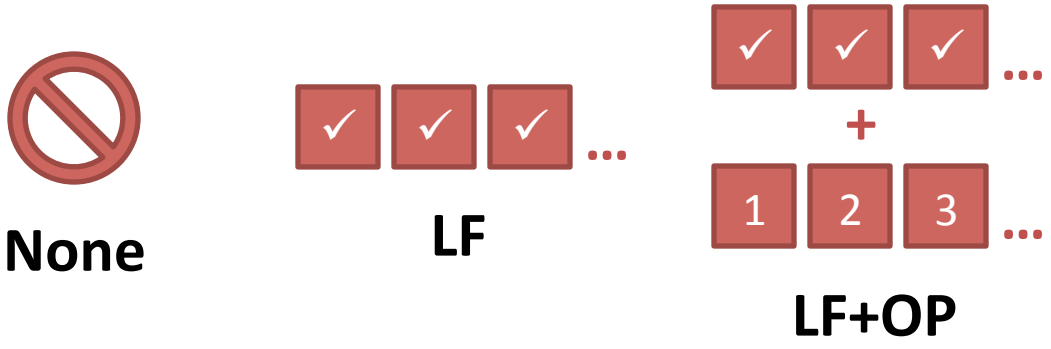
Bounding overhead

Applications decide (based on NF & objectives):

1. Granularity of operations

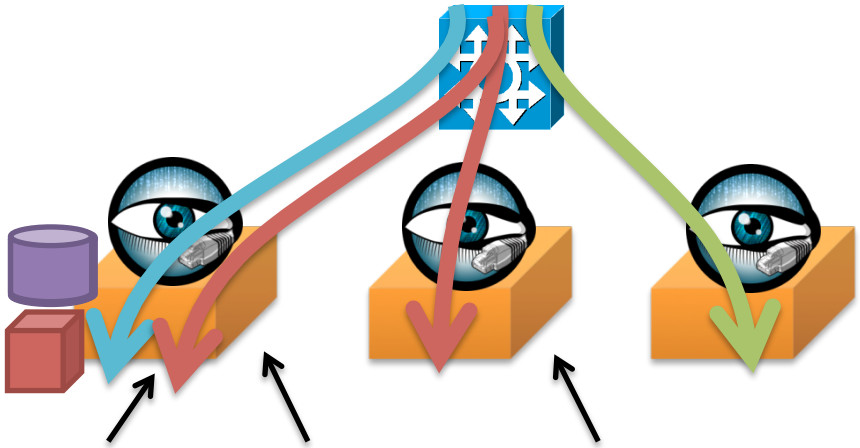


2. Guarantees desired



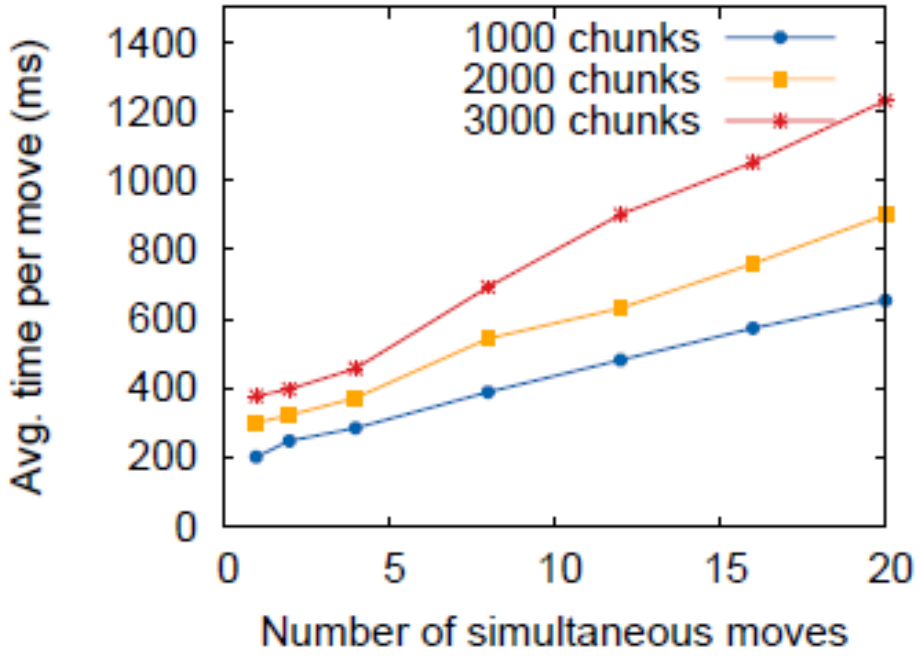
Example app: elastic NF scaling

scan.bro
vulnerable.bro
weird.bro



```
movePrefix(prefix,oldInst,newInst):
  copy(oldInst,newInst,{nw_src:prefix},multi)
  move(oldInst,newInst,{nw_src:prefix},per,LF+OP)
  while (true):
    sleep(60)
    copy(oldInst,newInst,{nw_src:prefix},multi)
    copy(newInst,oldInst,{nw_src:prefix},multi)
```

Evaluation: controller scalability



Improve scalability with P2P state transfers

Evaluation: importance of guarantees

- Bro_1 processing malicious trace @ 1K pkts/sec
- After 14K packets: move active flows to Bro_2

Alert	Baseline	NF	LF	LF+OP
Incorrect file type	26	25	24	26
MHR Match	31	28	27	31
MD5	116	111	106	116
Total	173	164	157	173

Evaluation: benefits of granular control

- HTTP requests from 2 clients (40 unique URLs)
- Initially: both go to $Squid_1$
- 20s later: reassign $Client_1$ to $Squid_2$

	Ignore	**Copy-client**	**Copy-all**
Hits @ $Squid_1$	117	117	117
Hits @ $Squid_2$	Crash!	39	50
State transferred	0 MB	4 MB	54 MB