Paving the Way for NFV: Simplifying Middlebox Modifications with StateAlyzr

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Middleboxes

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Perform sophisticated operations on network traffic

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Firewall

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Intrusion detection system (IDS)

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Caching proxy

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Intrusion detection system (IDS)

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Maintain state about connections and hosts

Network Function Virtualization (NFV)

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NFV enables ***elastic scaling*** and ***high availability***

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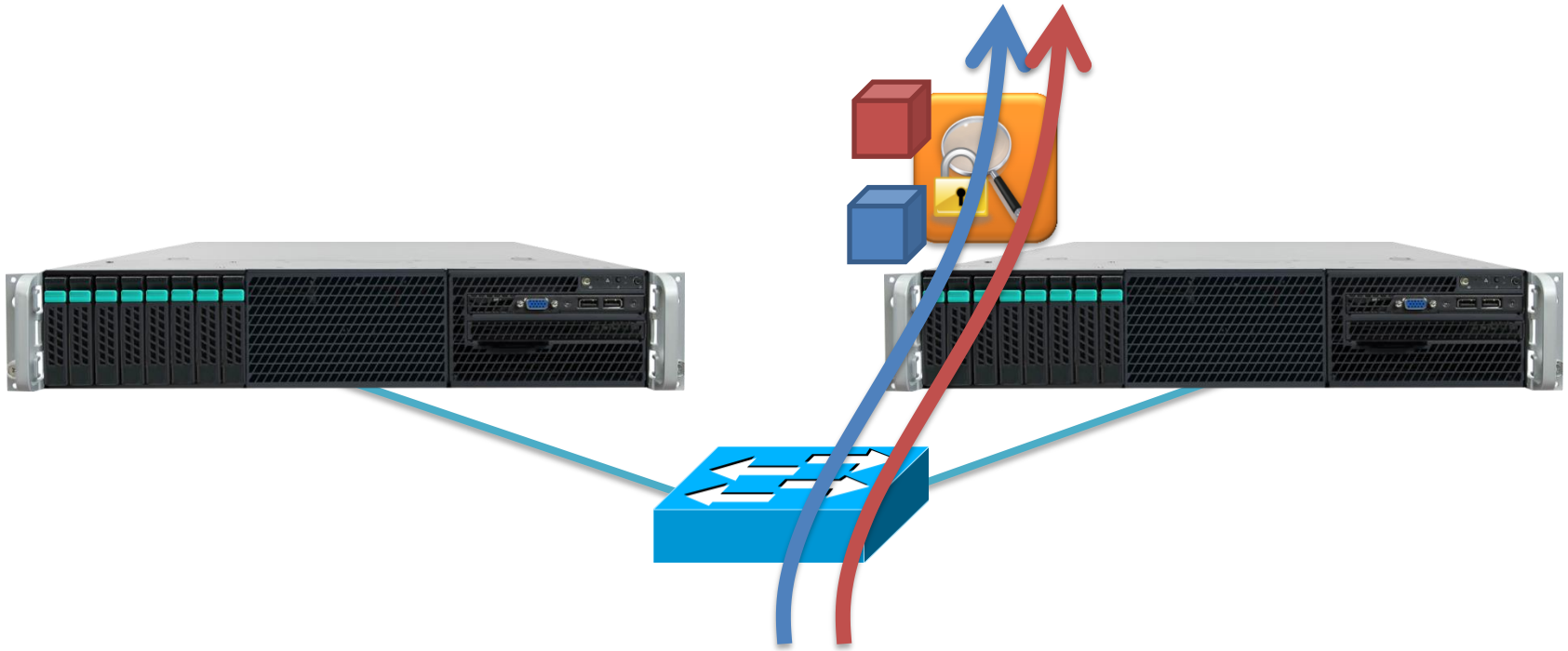

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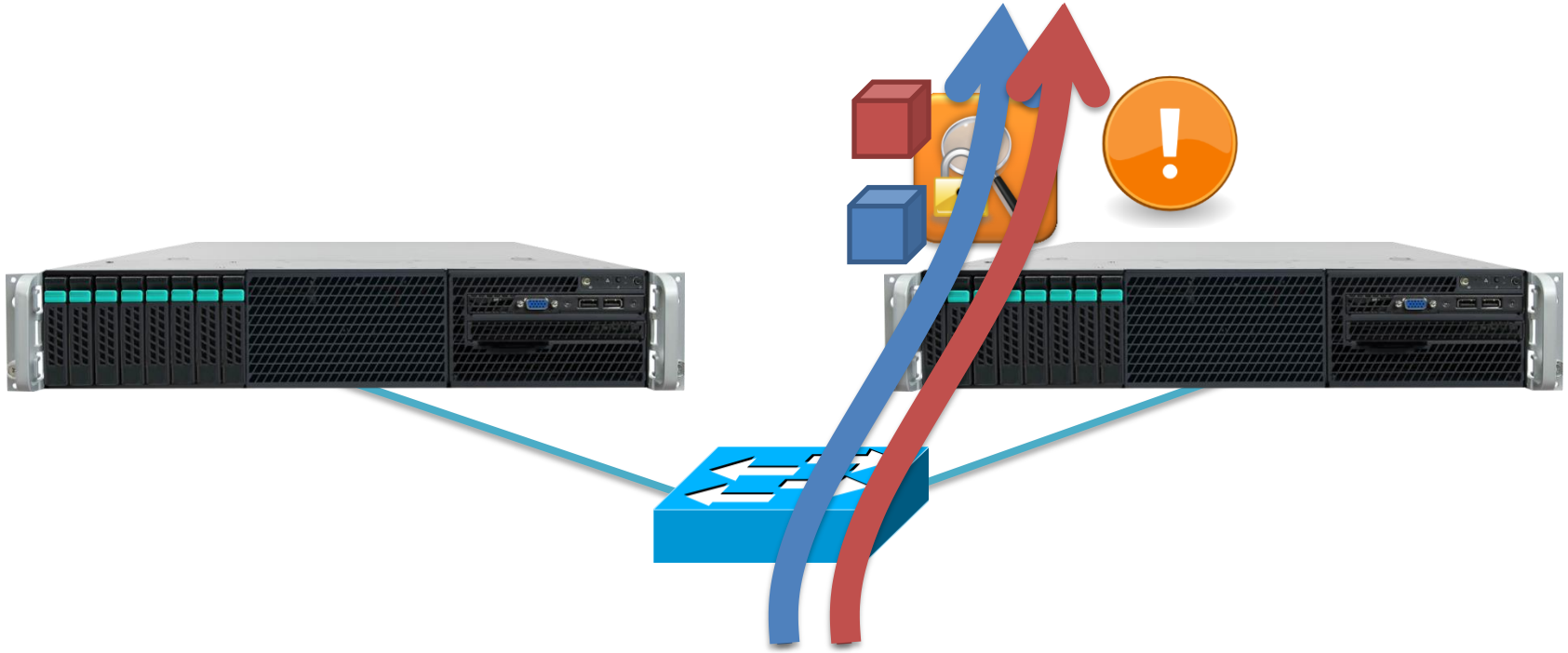

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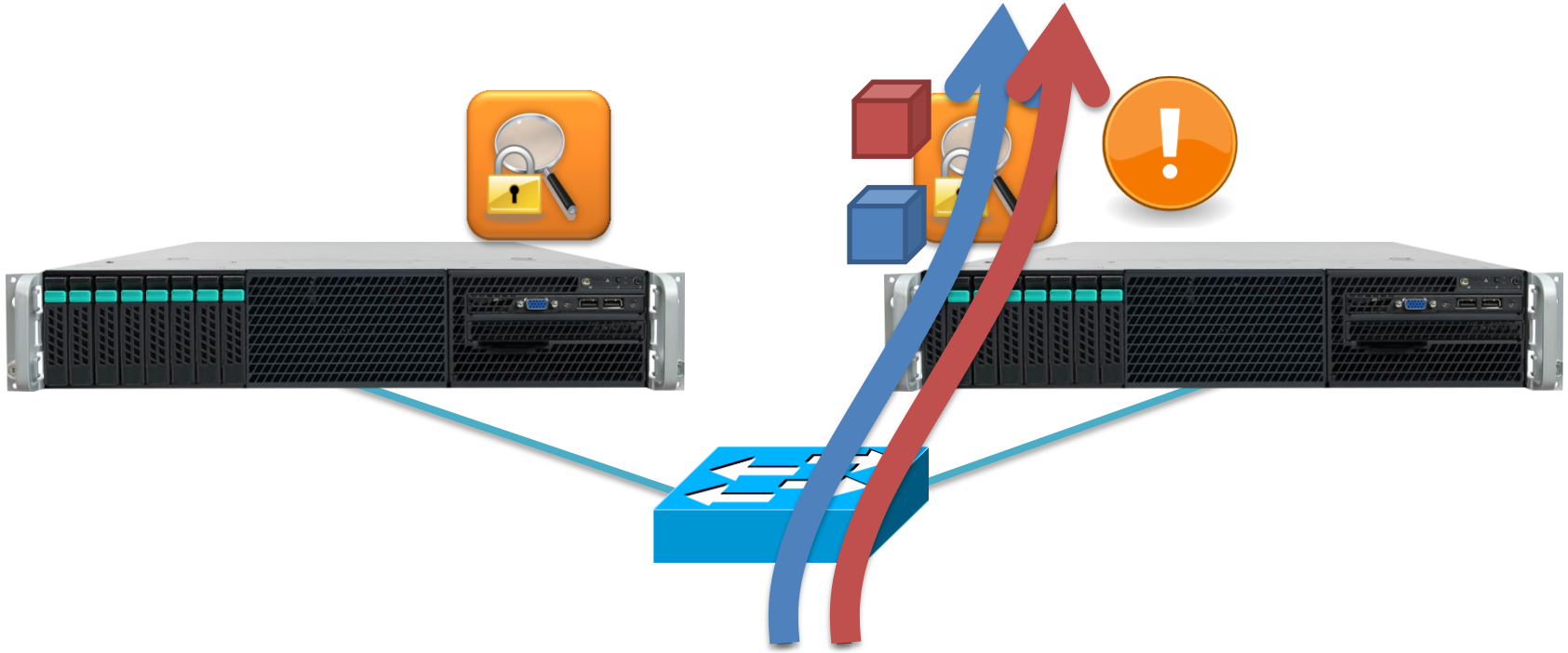

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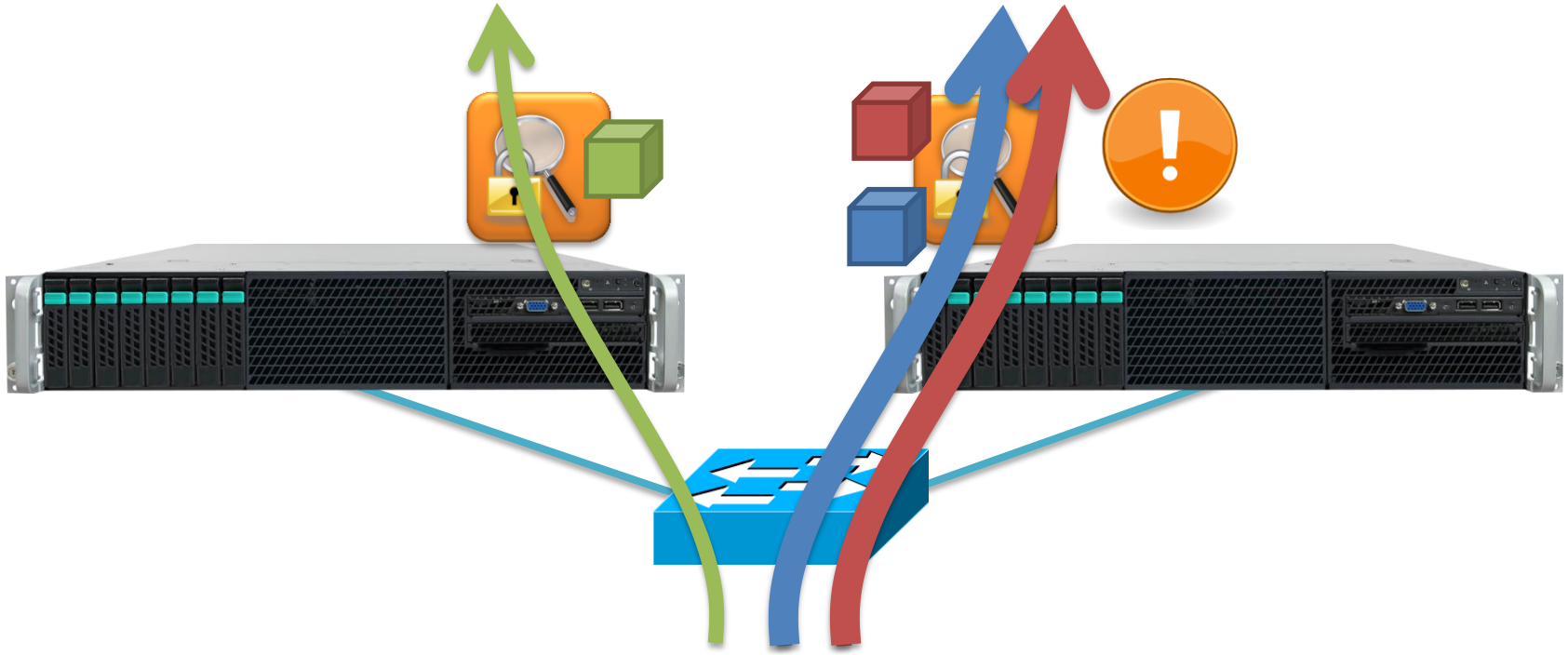

Reroute new connections

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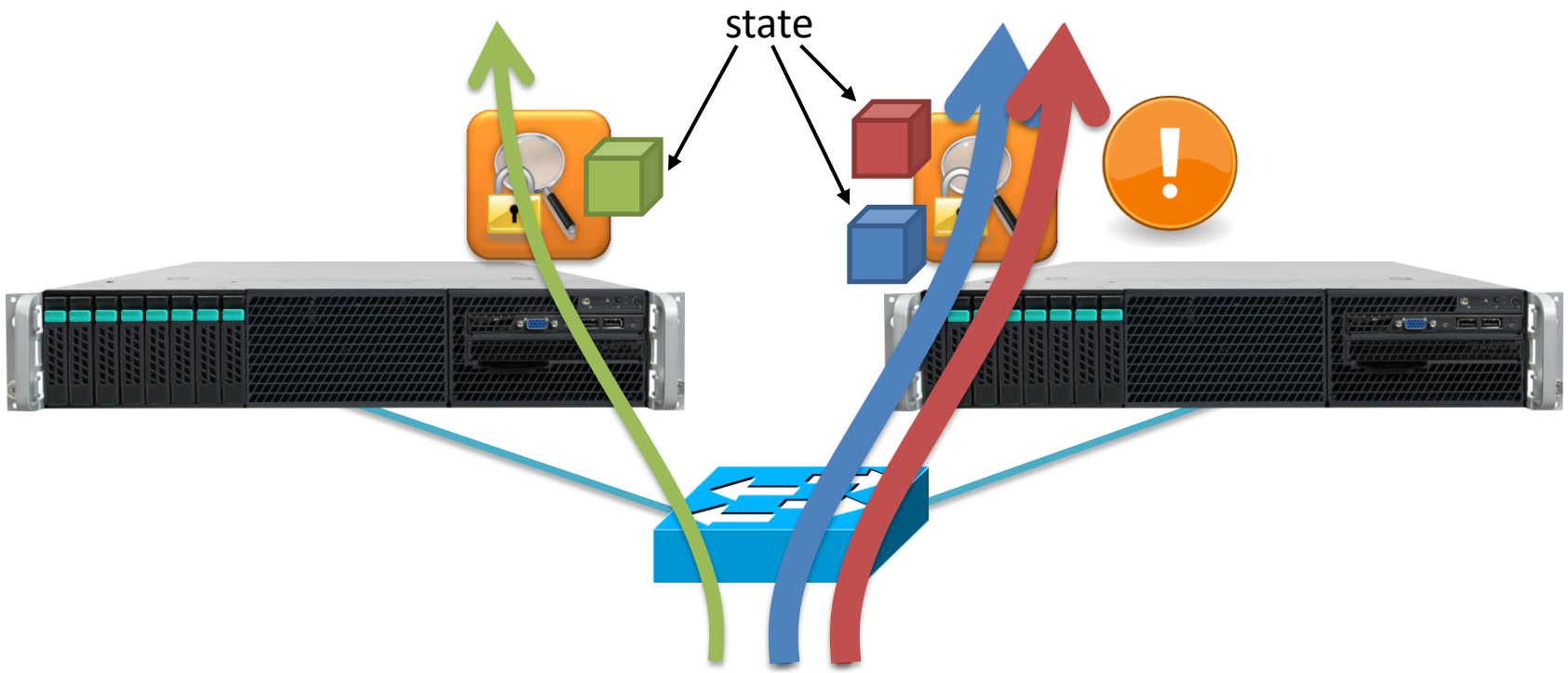

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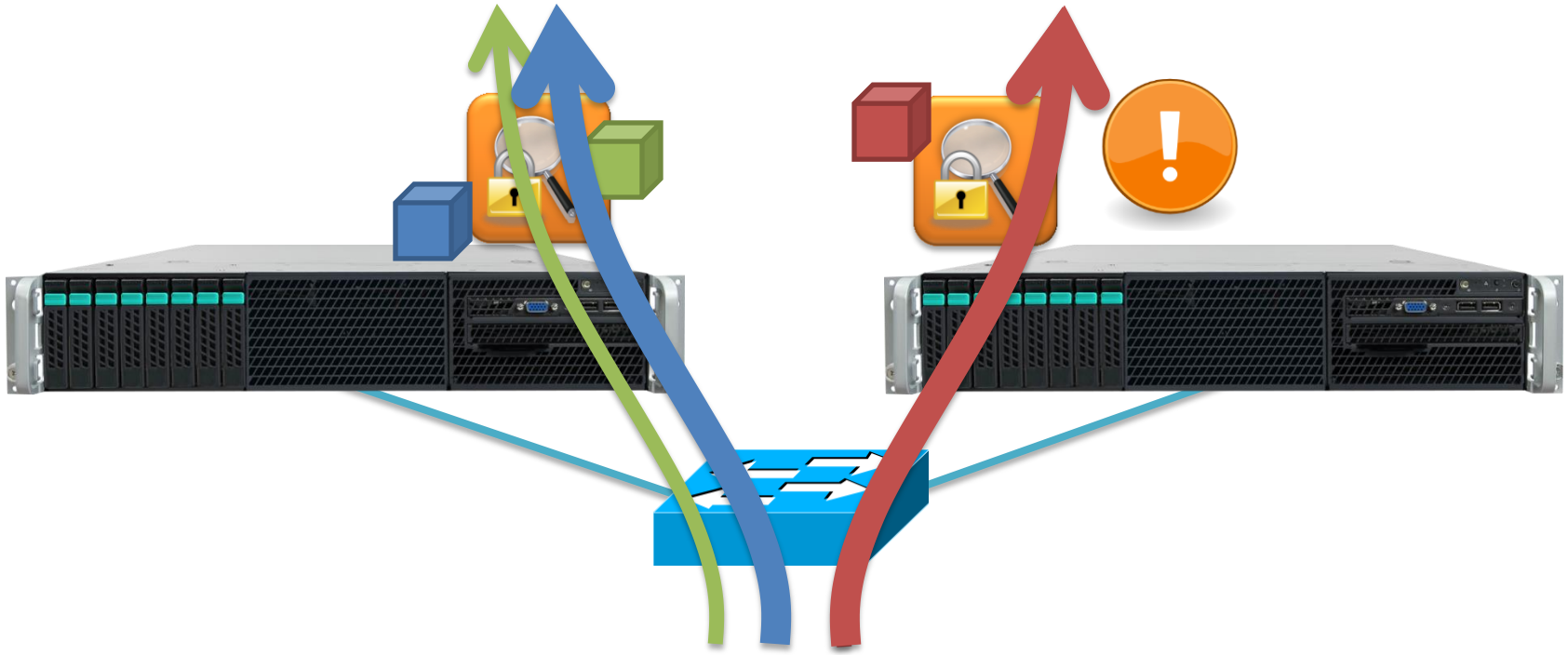

Reroute ~~new~~ existing connections

State taxonomy

State created or updated by a middlebox applies to either a **single connection** or a **set of connections**

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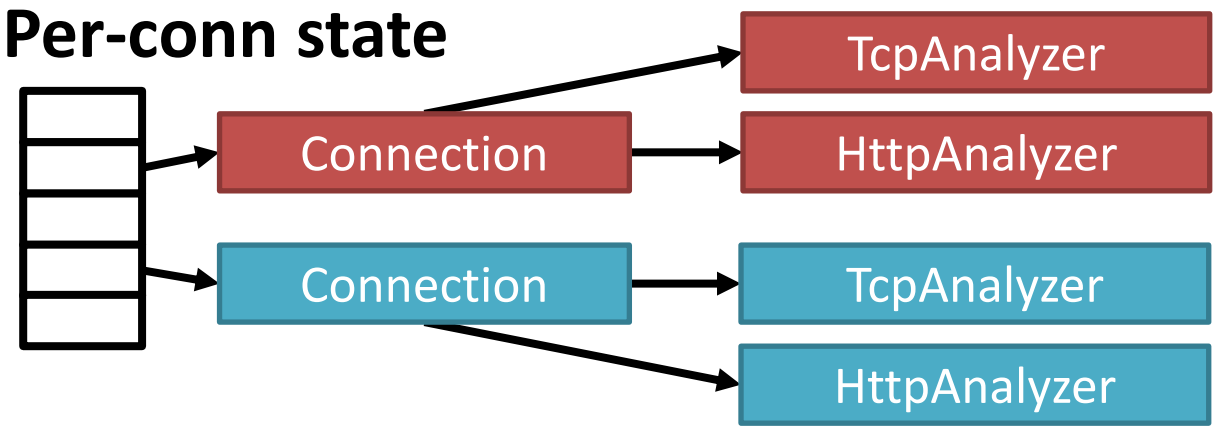

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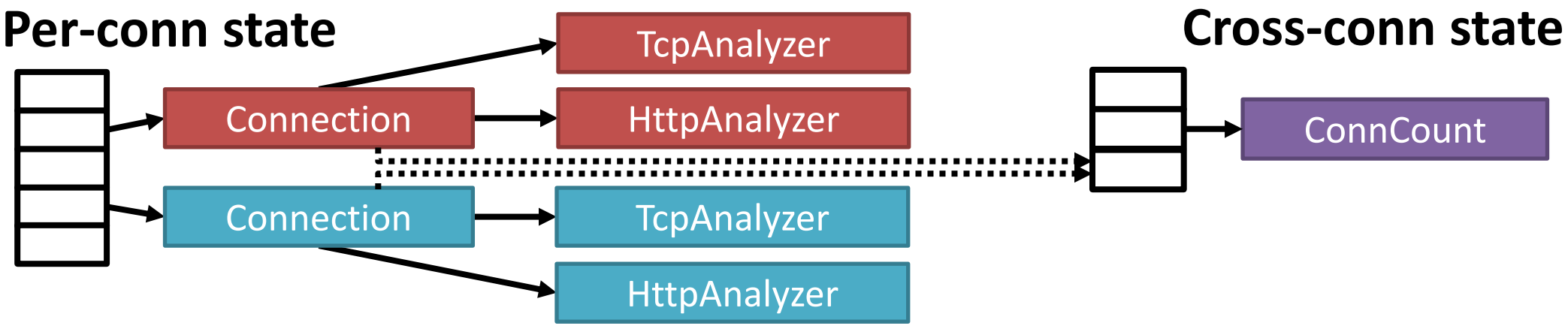

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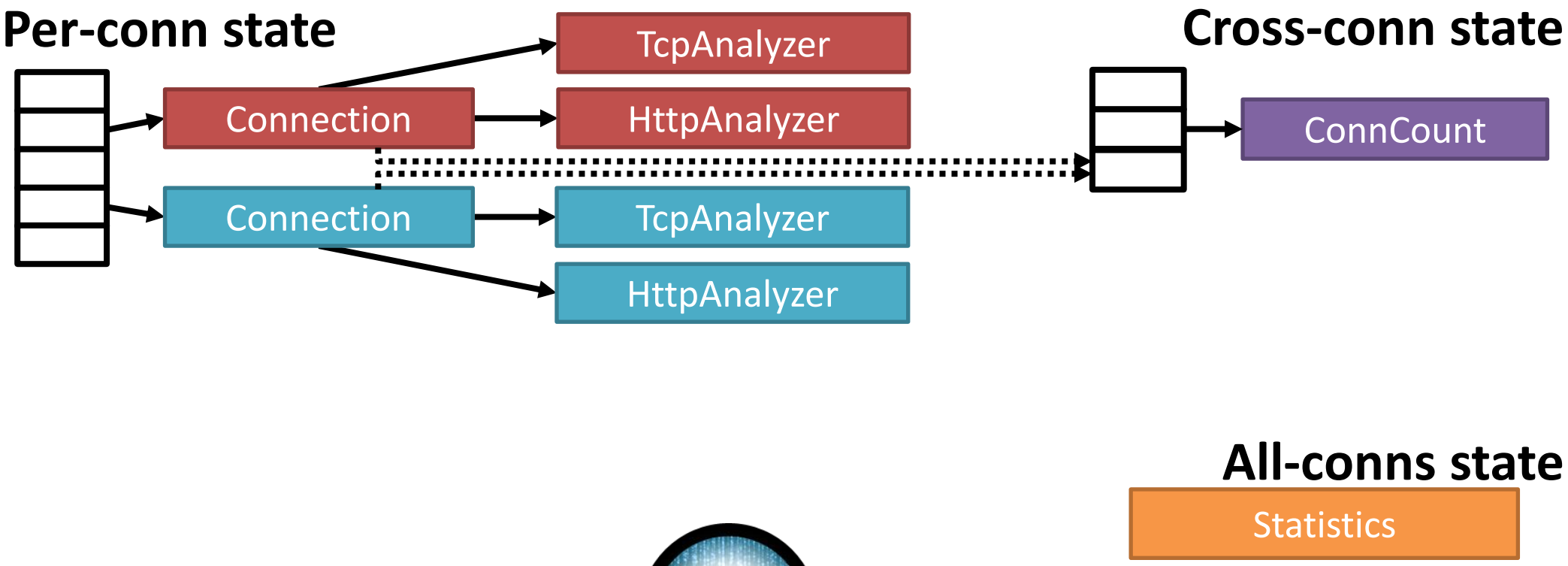

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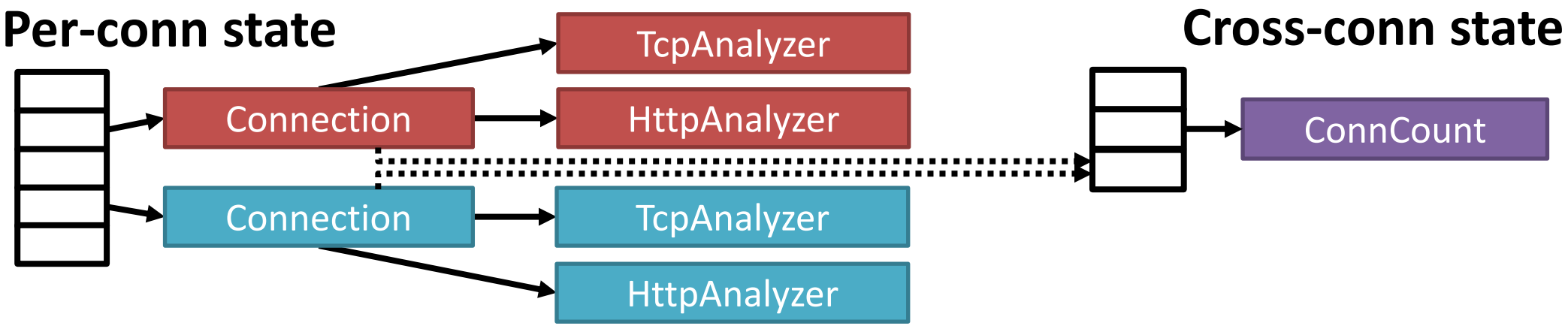

Input state

Config + Sig

All-conns state

Statistics

NFV state management -> middlebox modification

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Frameworks for transferring, or sharing live middlebox state

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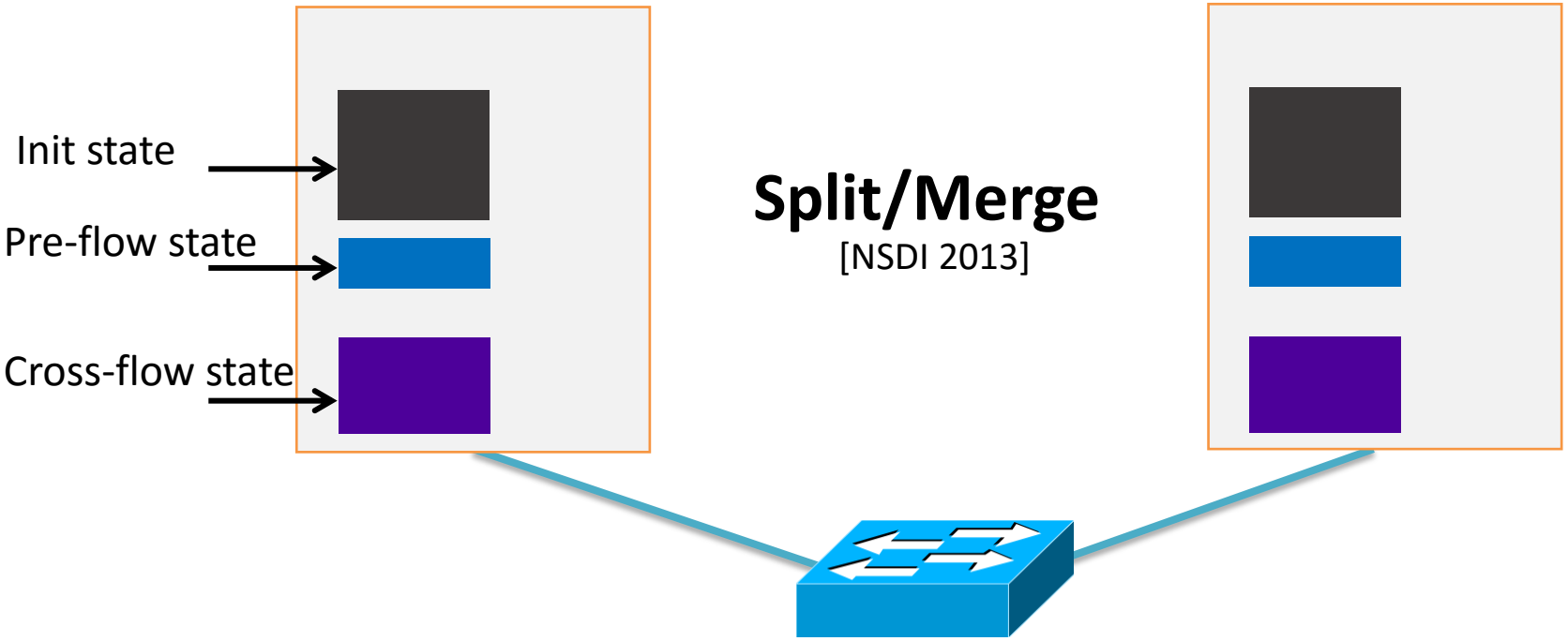

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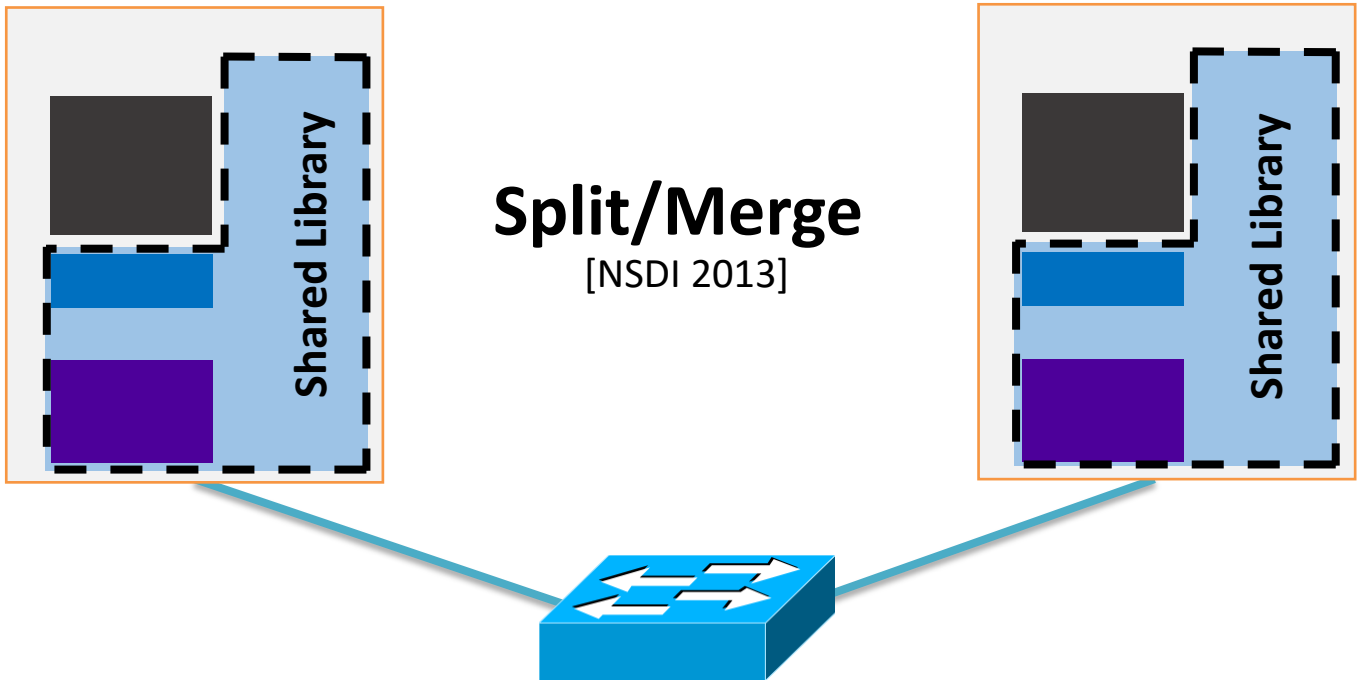

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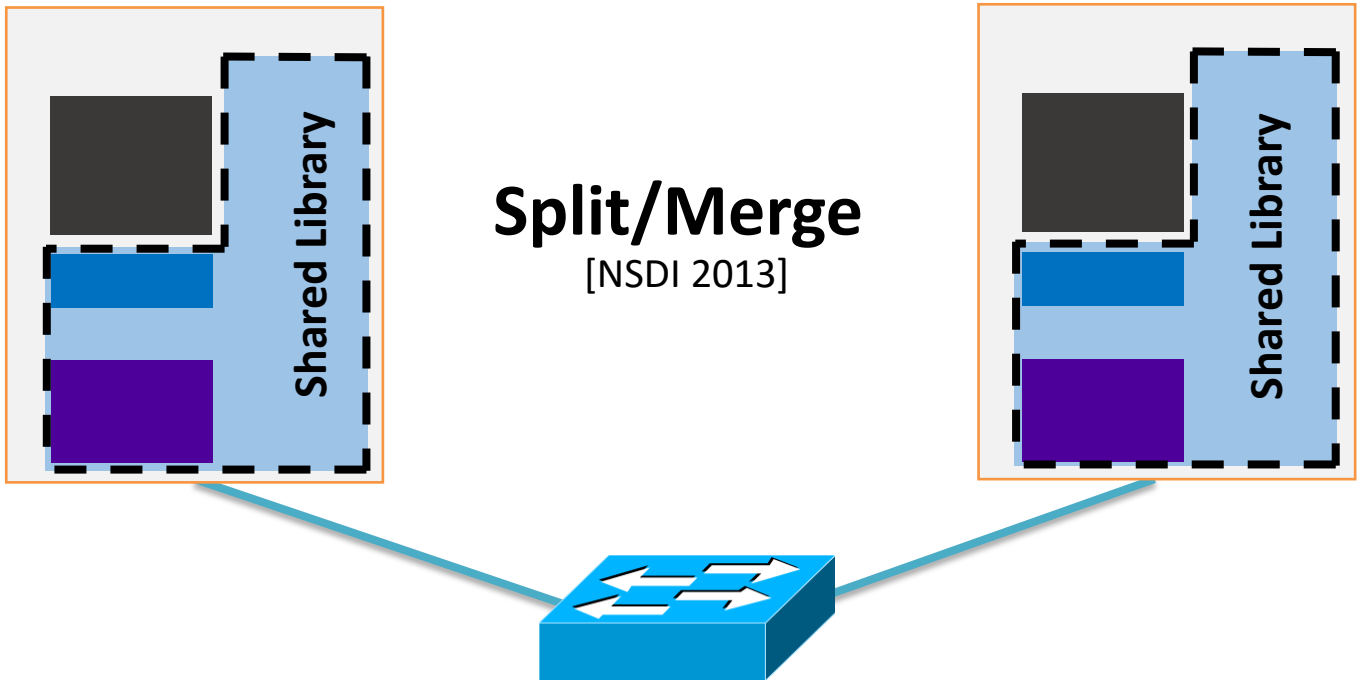

Required modifications:

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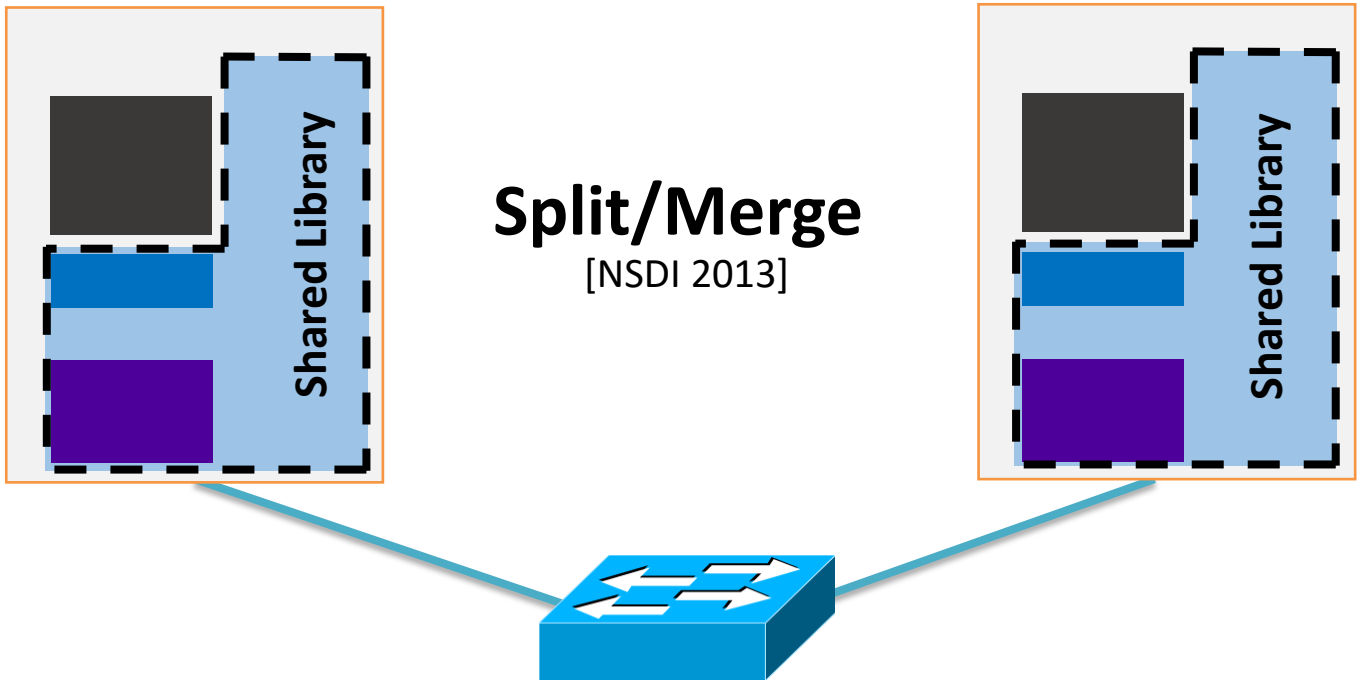

Required modifications:

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Framework	State Allocation	State Access	Serialization	Merge State
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Stateless NF [HotMiddlebox 2015]	✓	✓		

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Middleboxes are **complex**

MB	LOC (C/C++)	Classes/ Structs	Level of pointers	Number of Procedures
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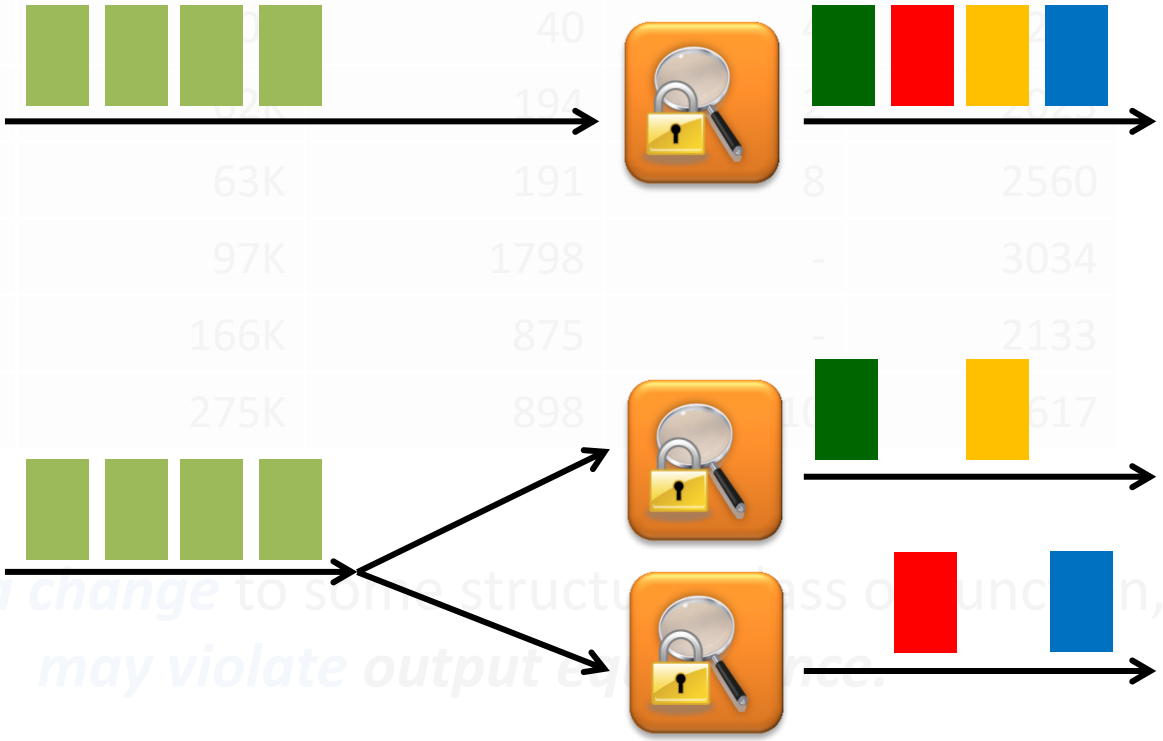

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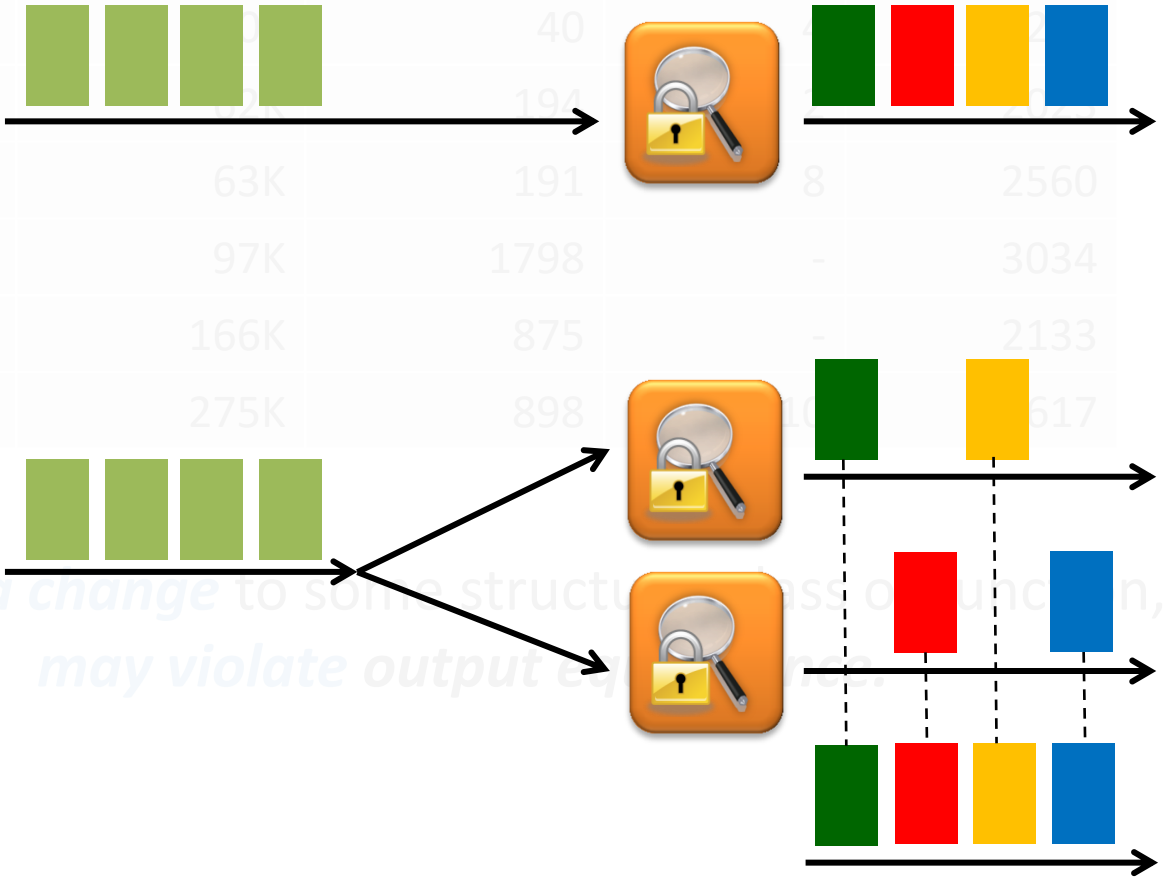

StateAlyzr: program analysis to the rescue

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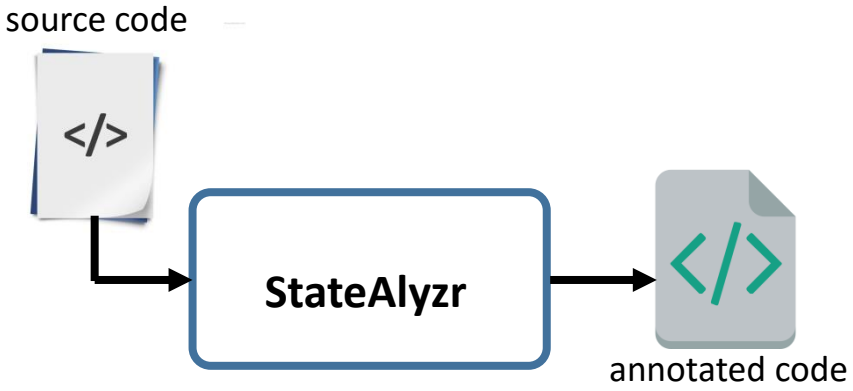

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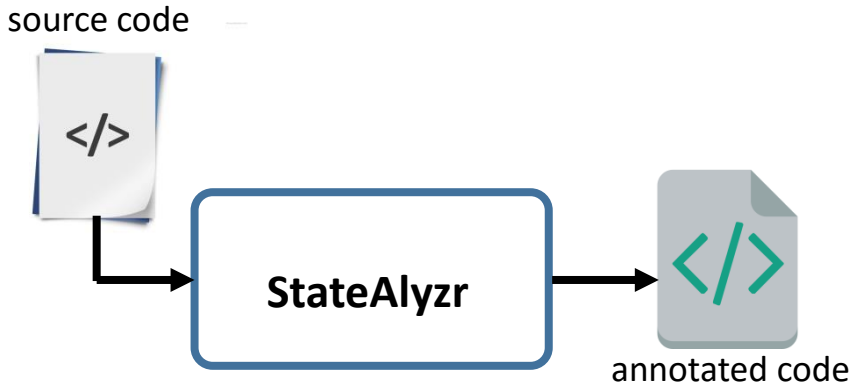

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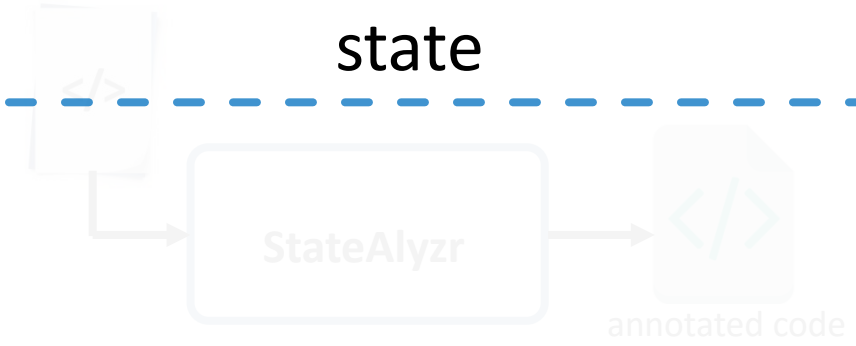

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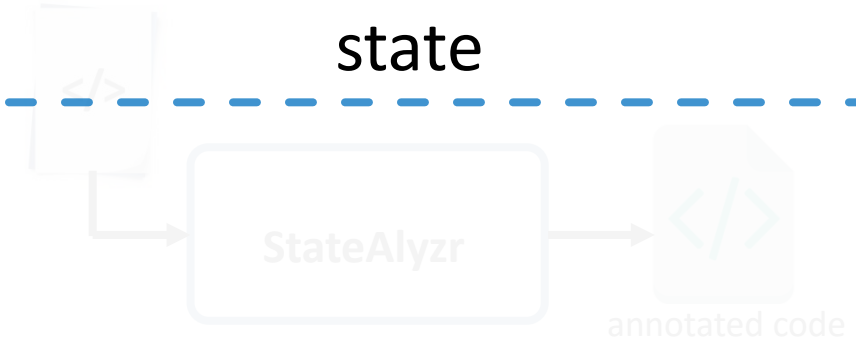

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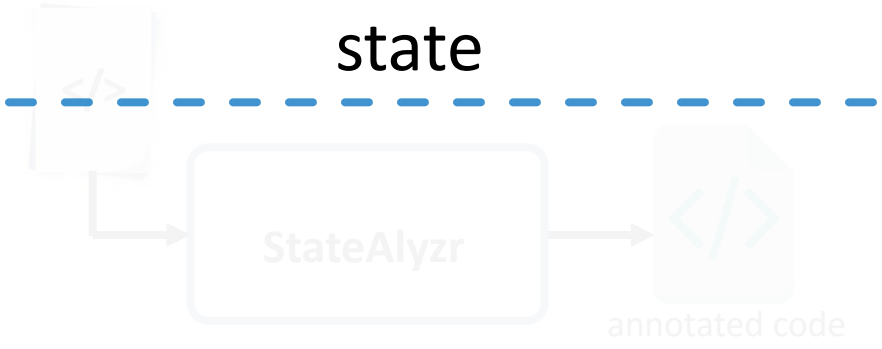

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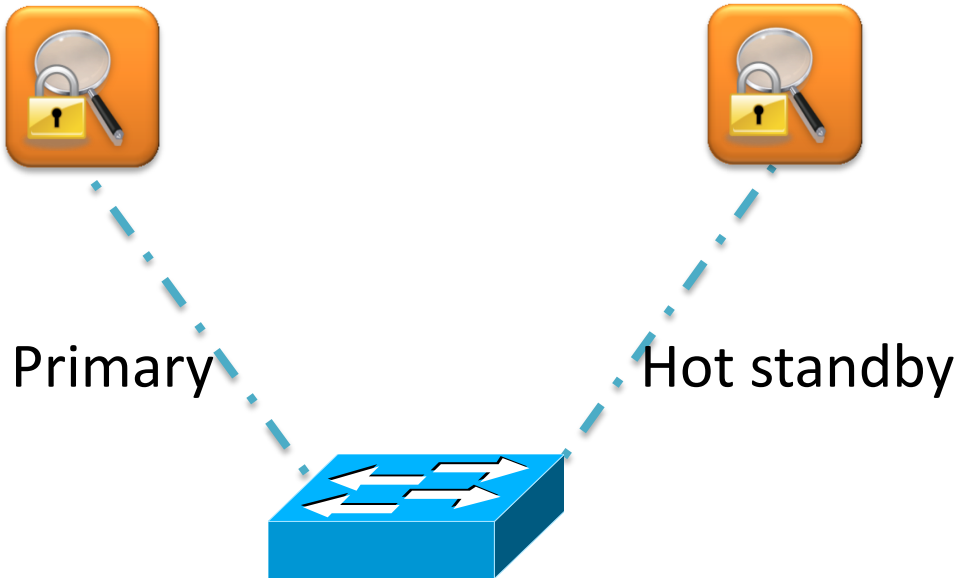

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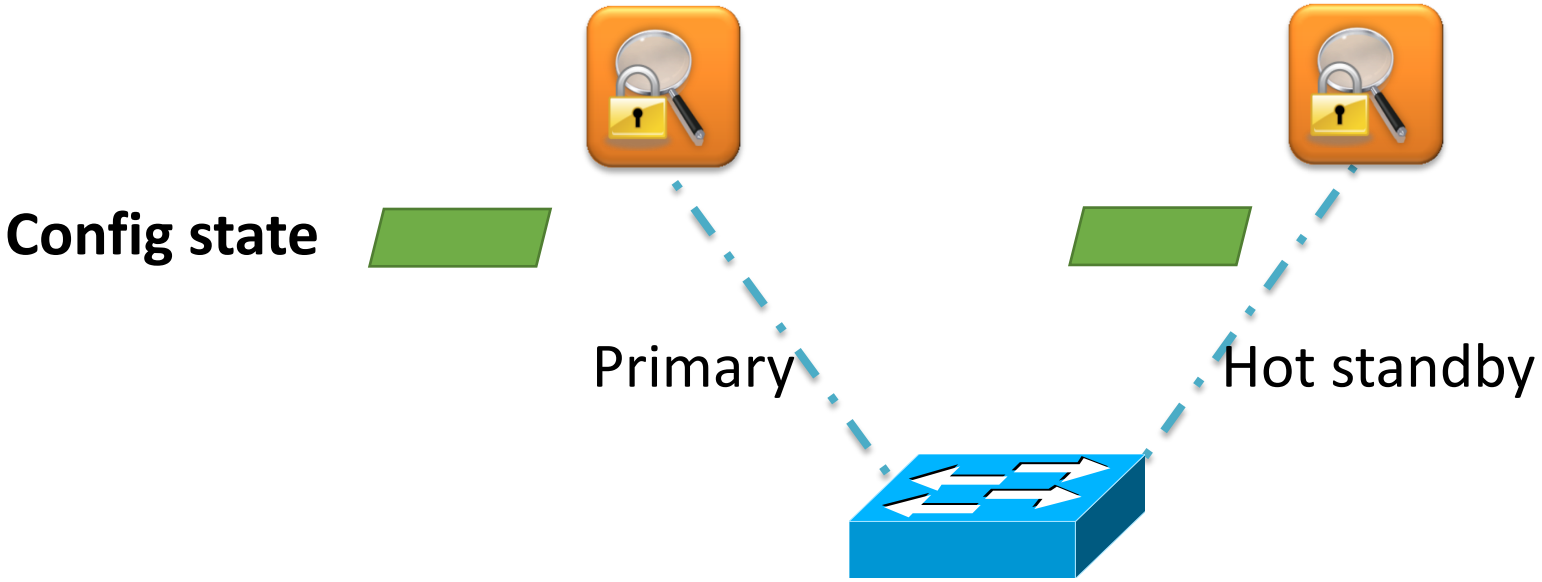

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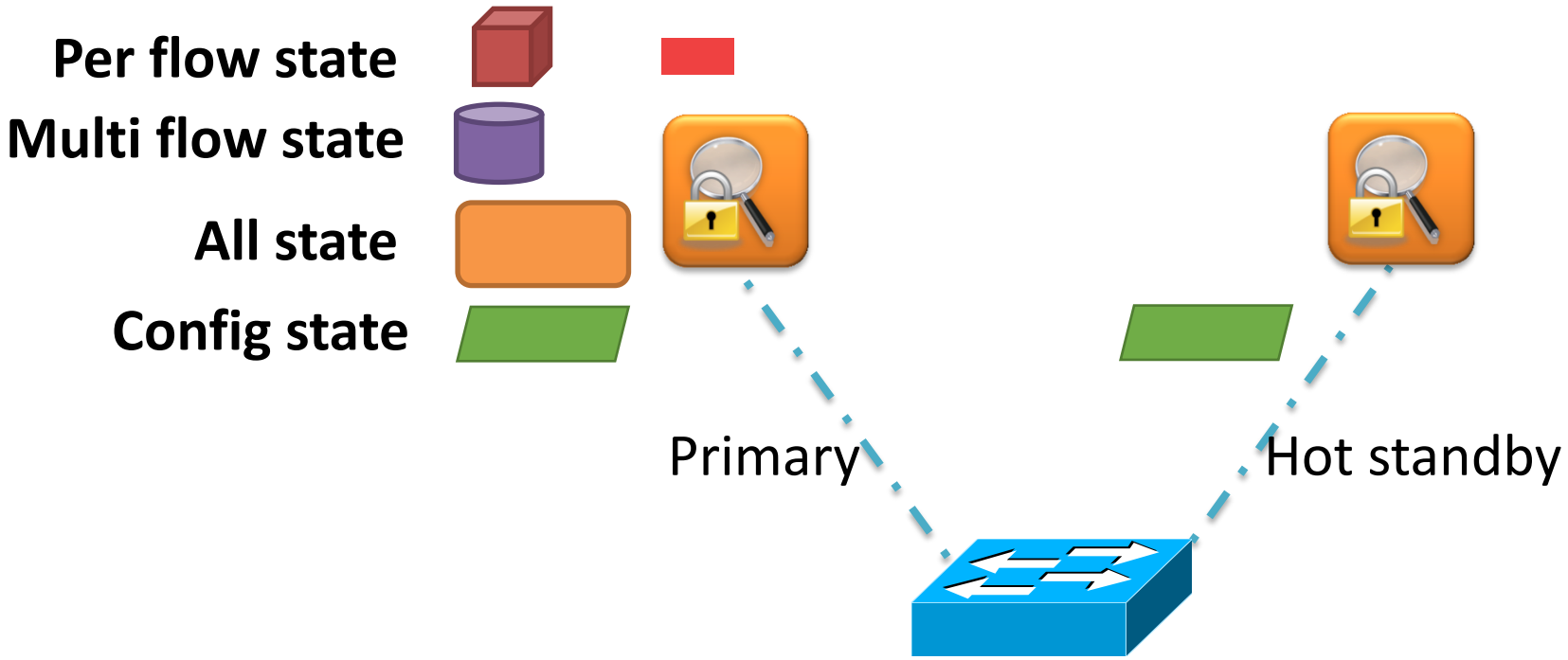

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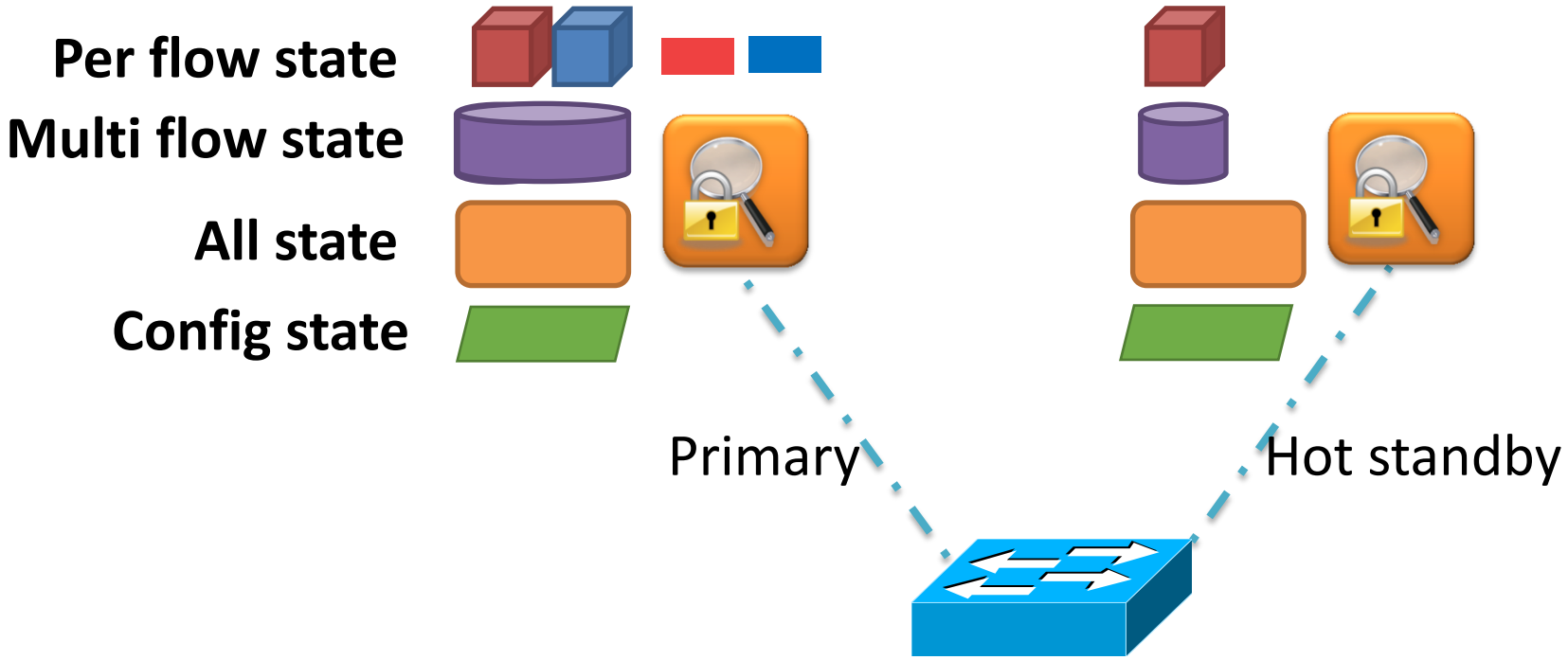

The ***primary*** sends a copy of the ***updated*** state to the ***hot standby*** after each packet

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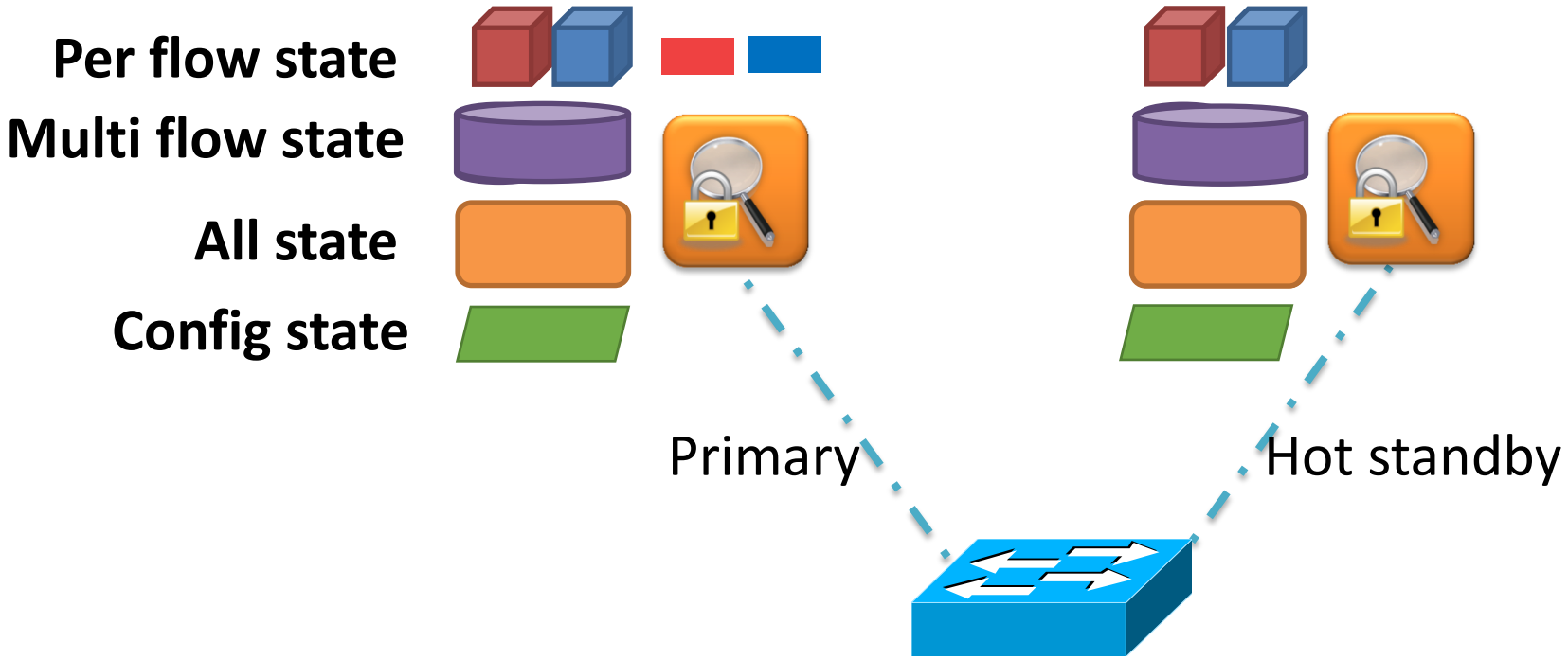

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StateAlyzr

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All
State

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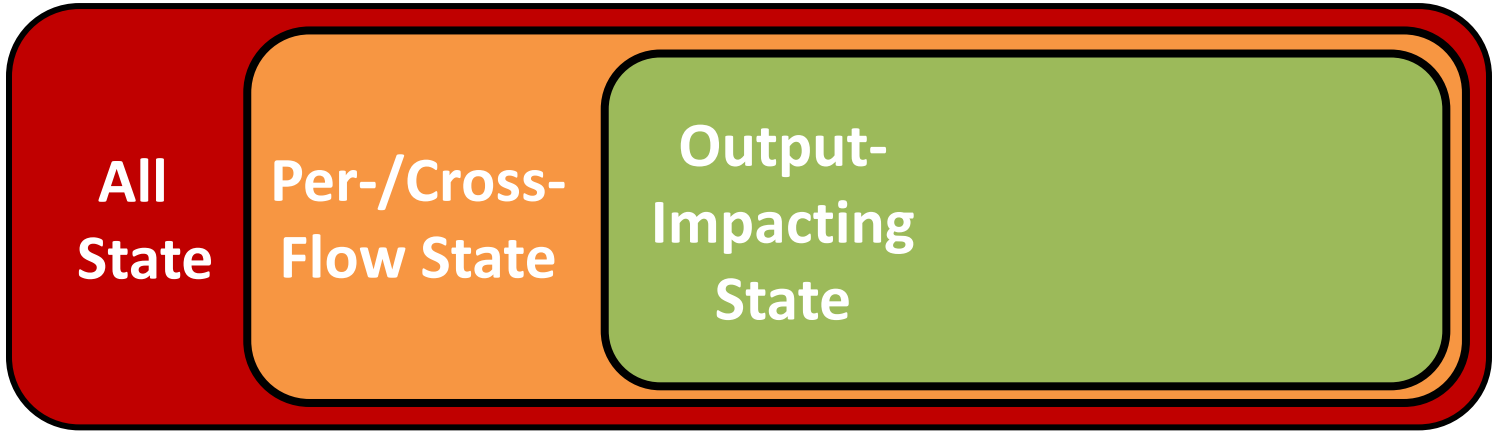

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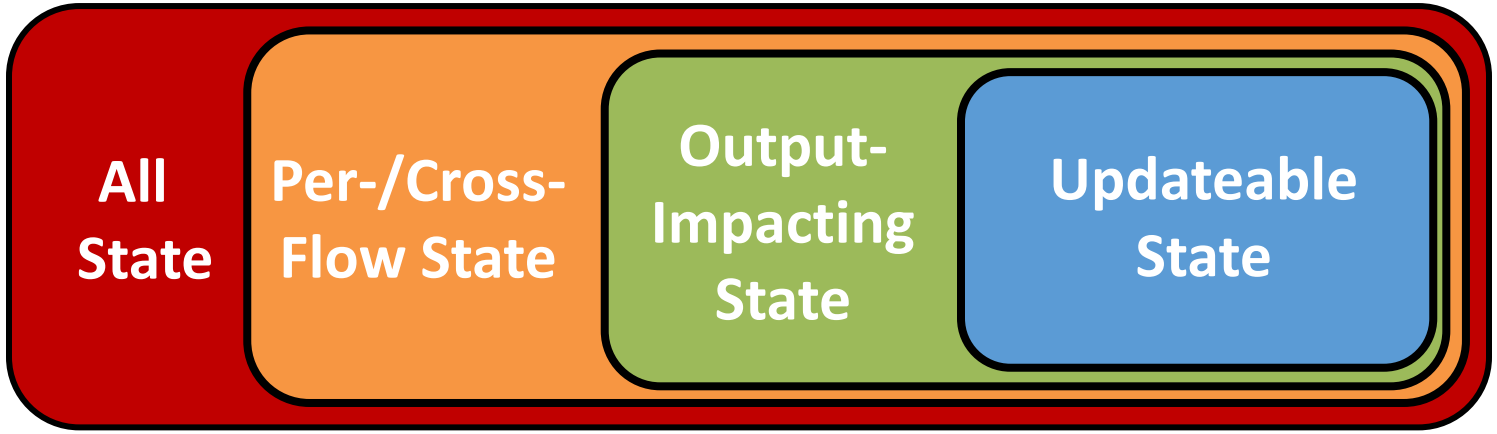
All State
Per-/Cross-Flow State
Output-Impacting State
Updateable State

Logical structure of middlebox code

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Main

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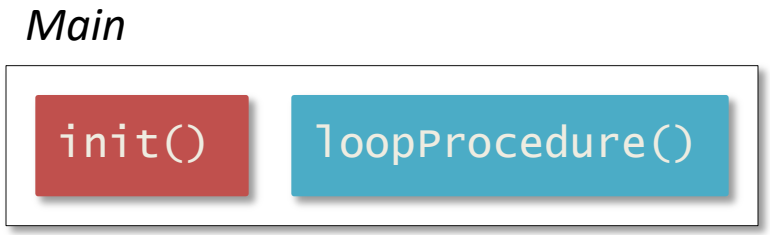

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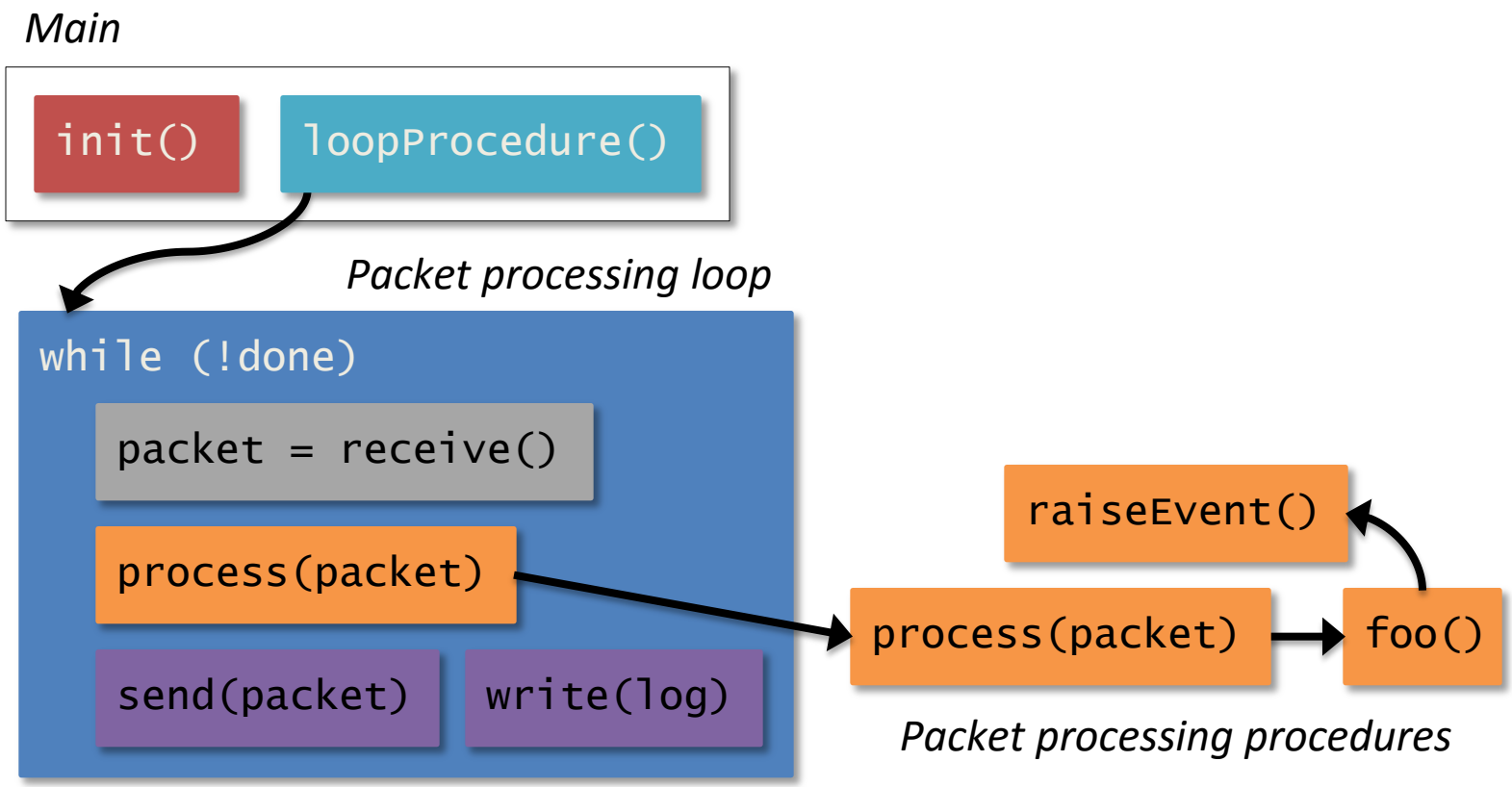

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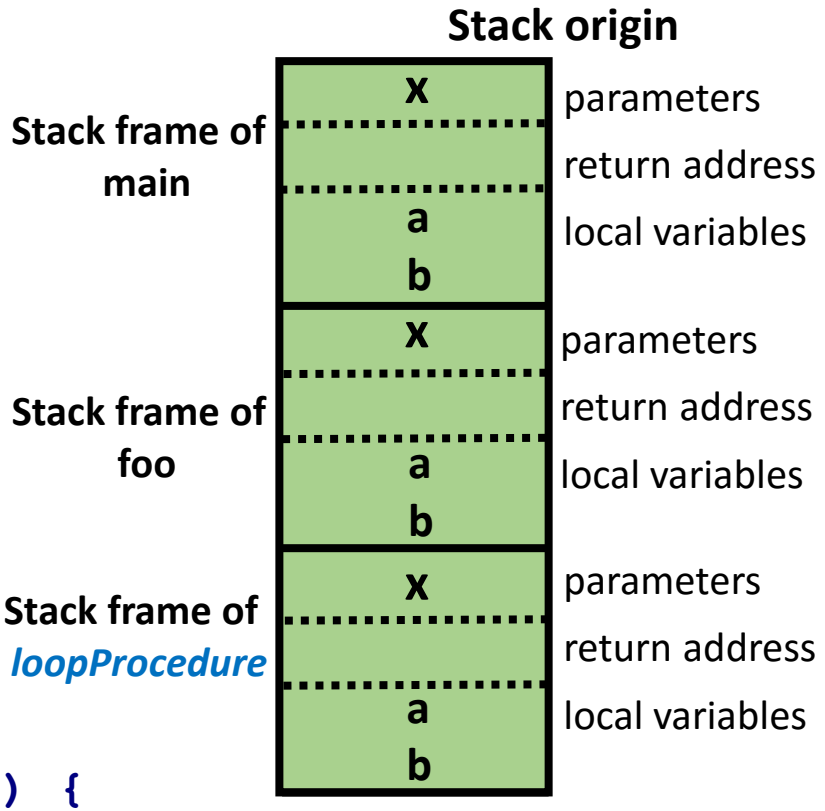


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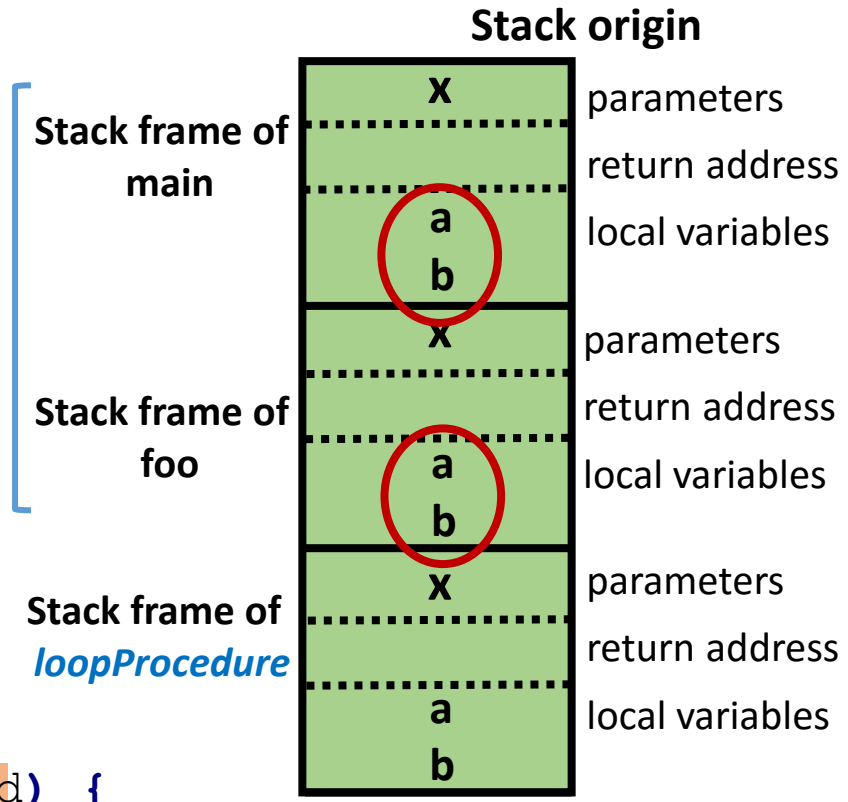


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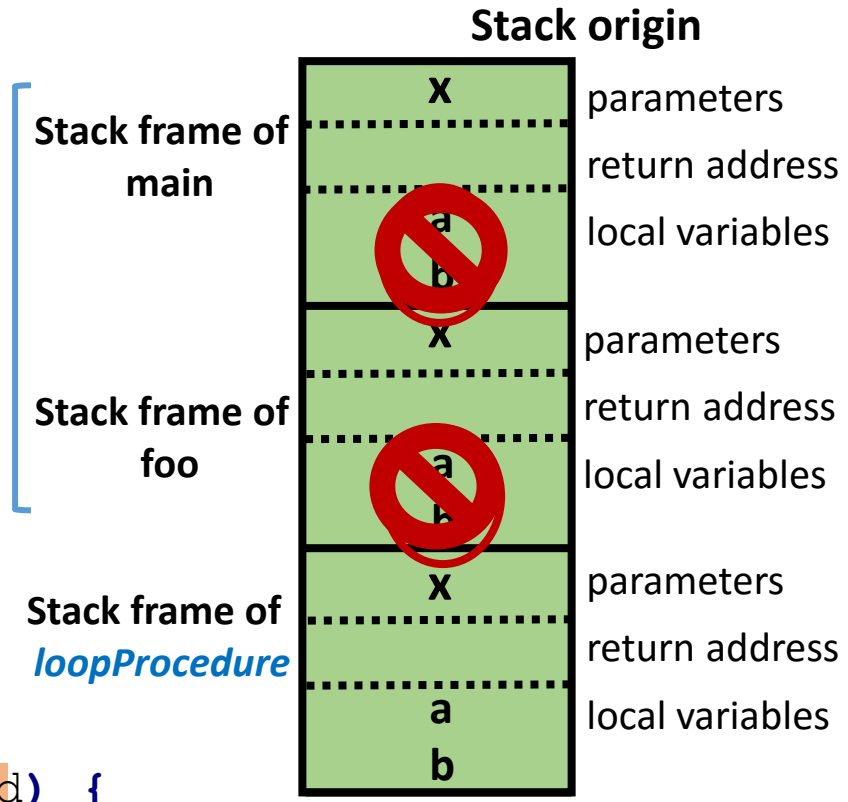
int loopProcedure(int *threshold) {
 int count = 0;
 while(1) {
  struct pcap_pkthdr pcapHdr;
  char *pkt = pcap_next(extPcap, &pcapHdr);
  .
  .
```

1. Per-/cross-flow state identification

Variables corresponding to per-/cross-flow state must be ***persistent***

Persistent state can be stored in

1. Global variables
2. Static variables
3. Local variables declared in loop proc.
4. Formal Params of loop proc.




```
int loopProcedure(int *threshold) {
 int count = 0;
 while(1) {
  struct pcap_pkthdr pcapHdr;
  char *pkt = pcap_next(extPcap, &pcapHdr);
  .
  .
```

1. Per-/cross-flow state identification

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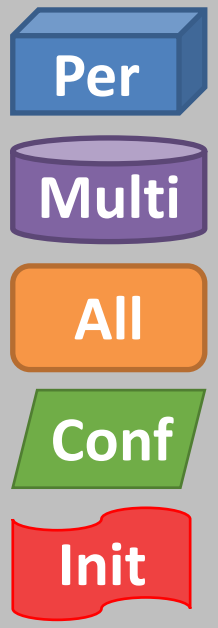

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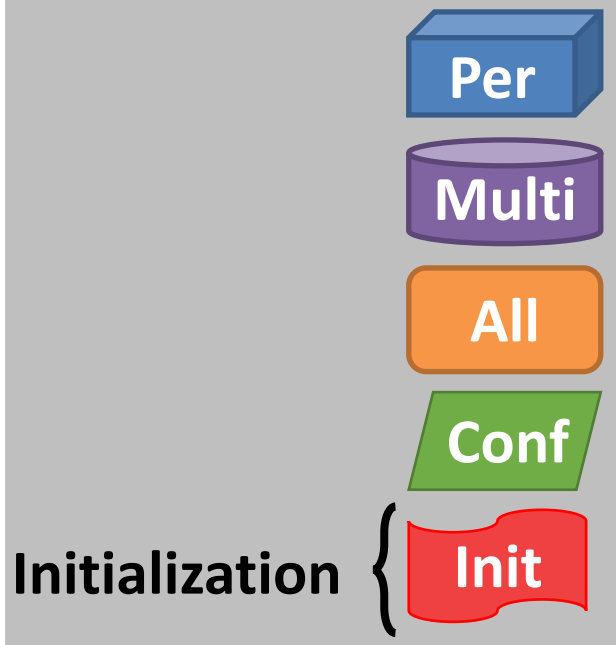
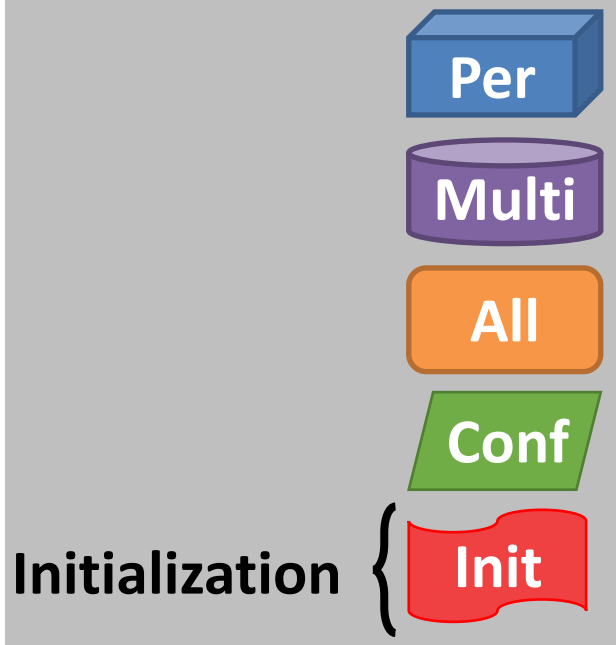


1. Per-/cross-flow state identification

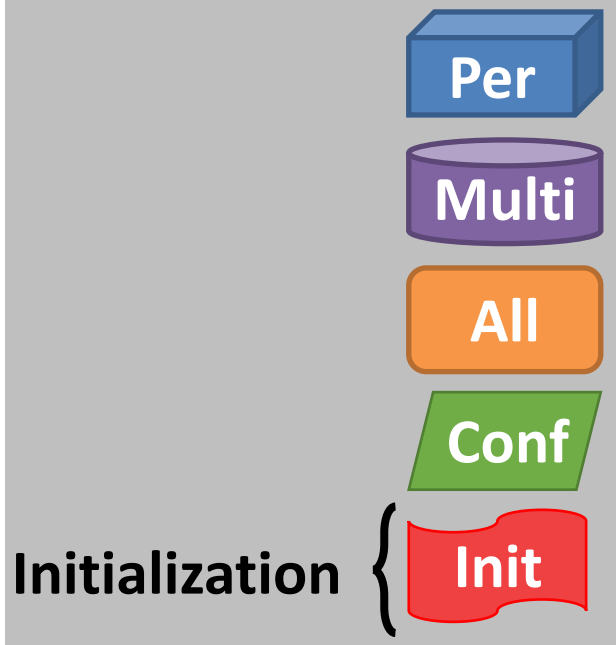
Improve precision by considering variables which are ***used*** in ***packet processing code***



How to identify packet processing code?

1. Per-/cross-flow state identification

Improve precision by considering variables which are ***used*** in ***packet processing code***



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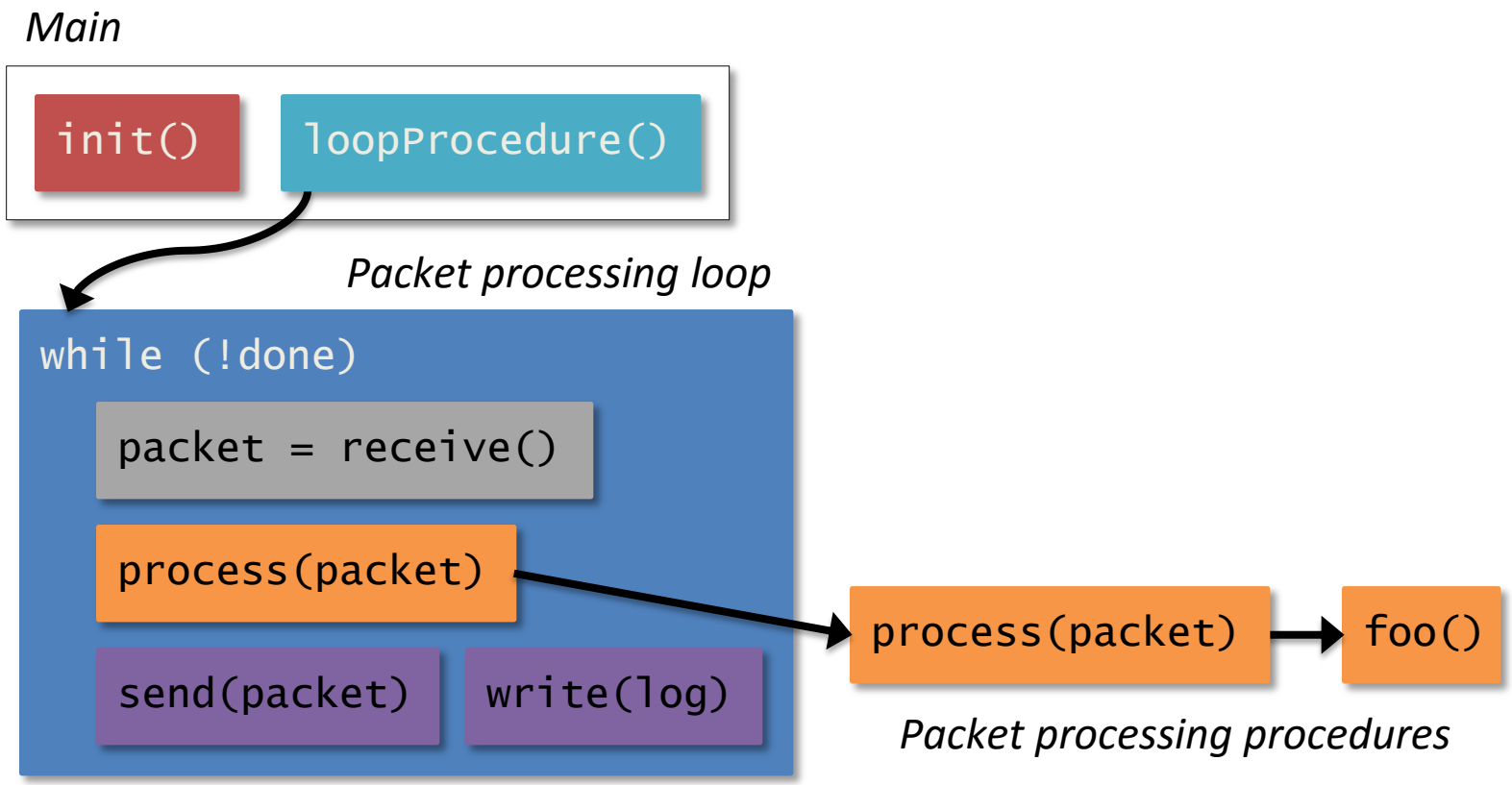

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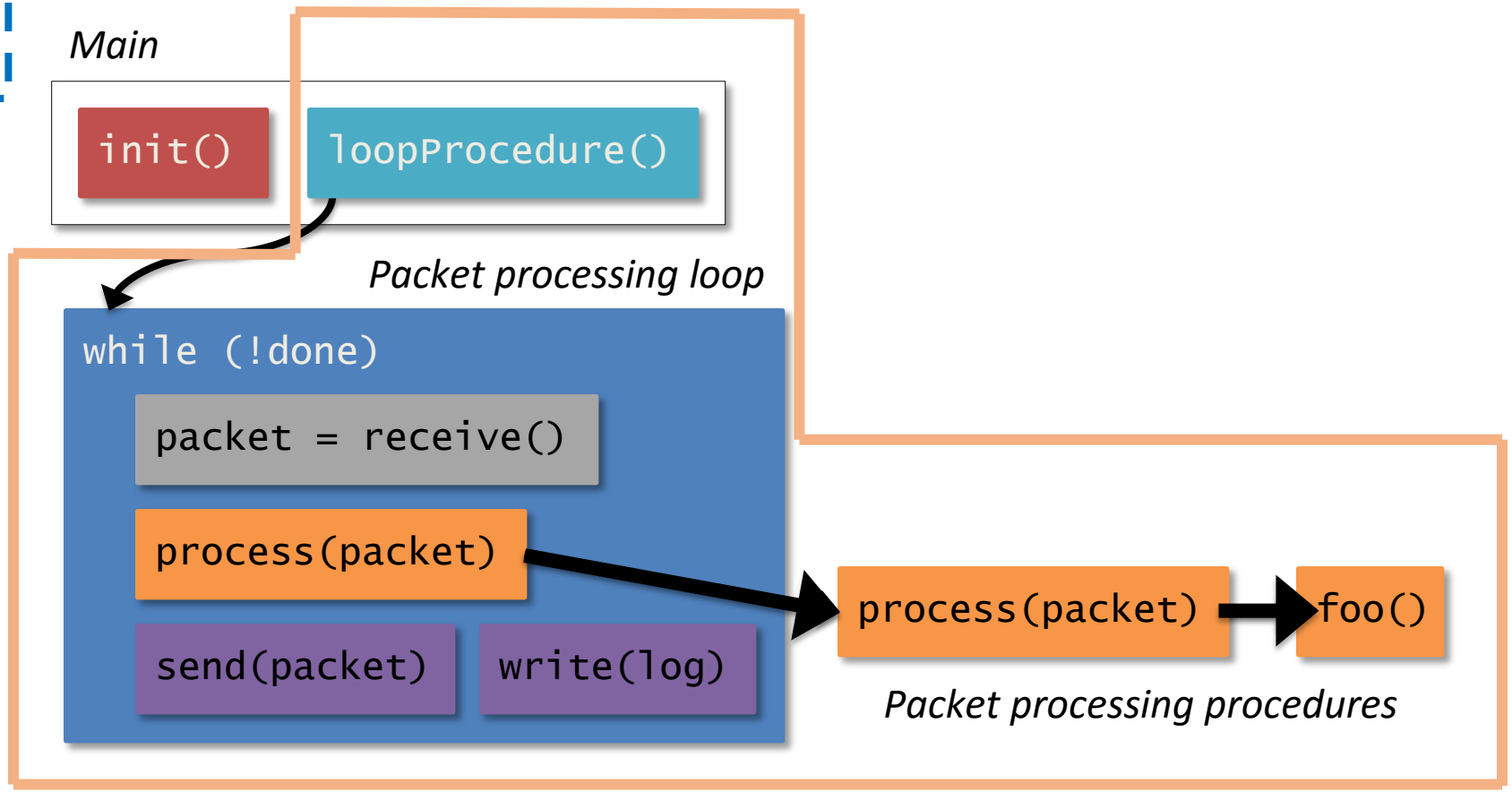

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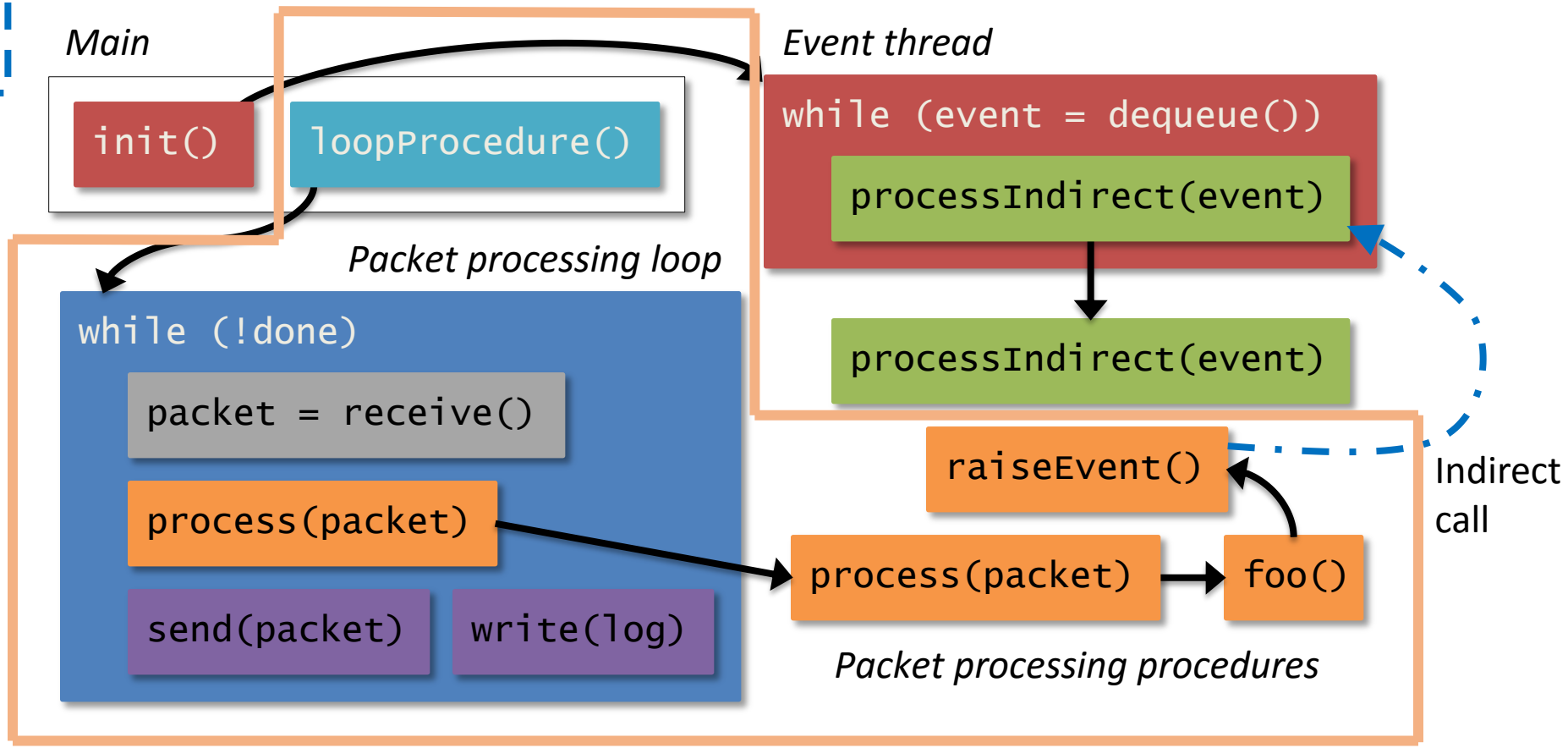

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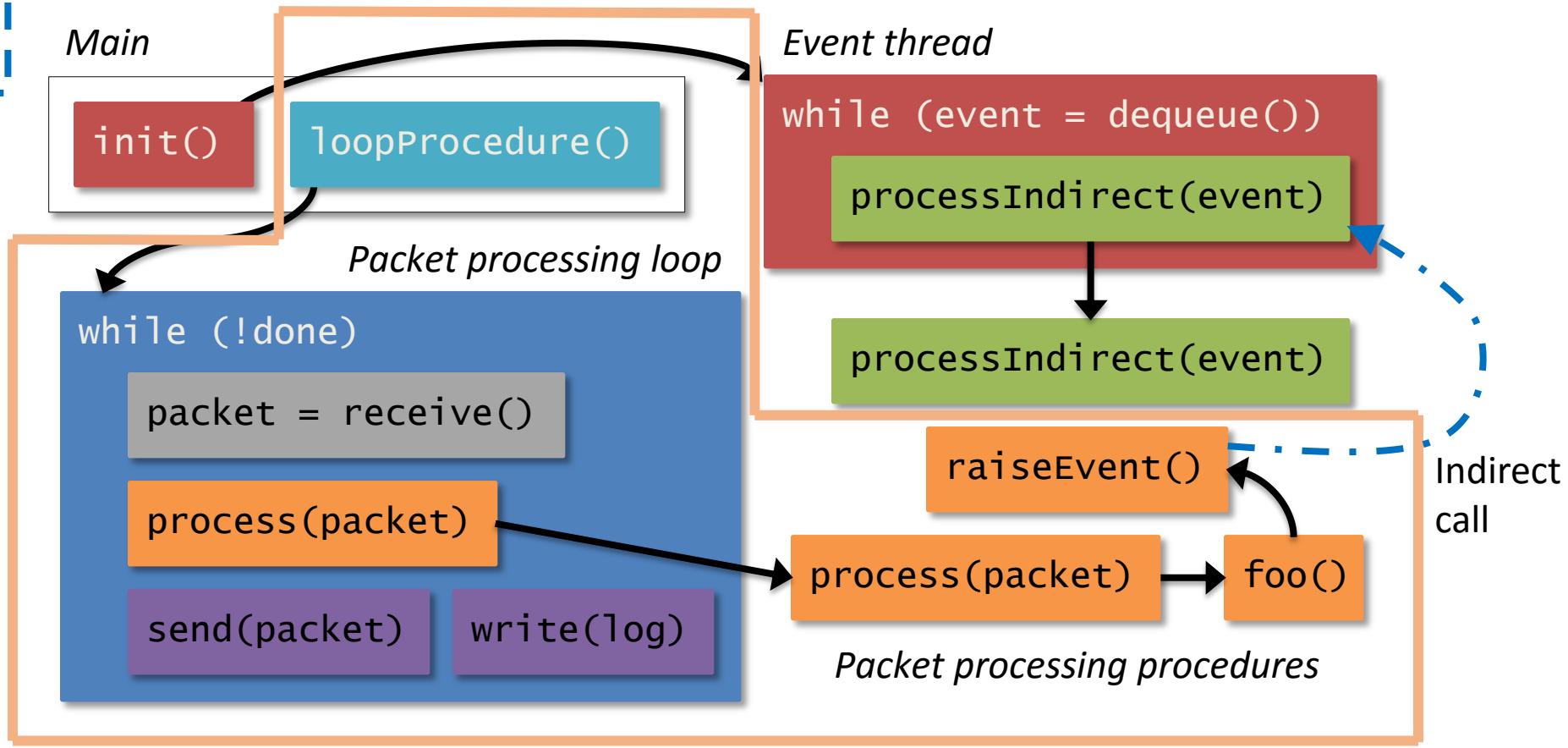
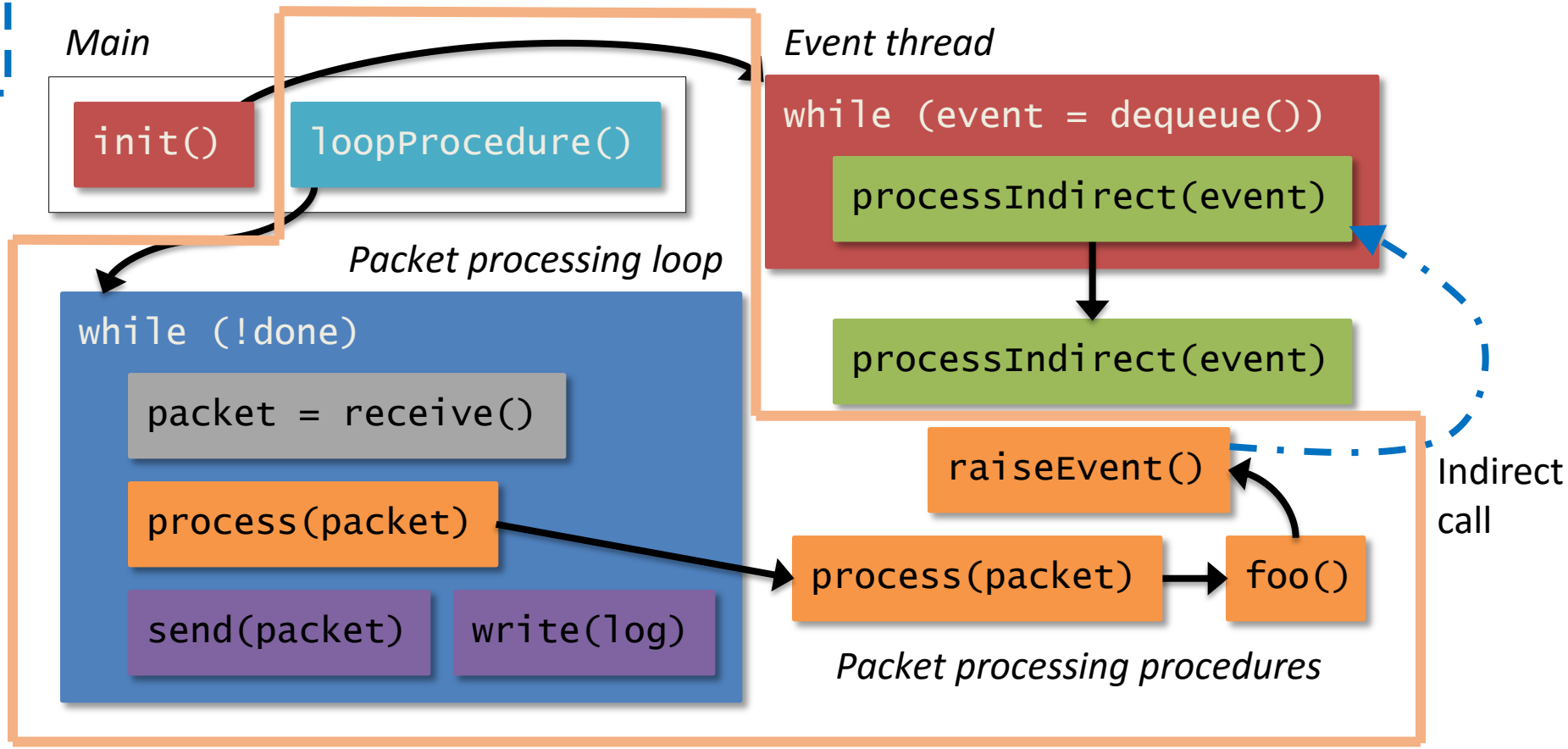



```
struct pktHdr *pkt = recv(extPcap);
src_ip = pkt->ip_src_addr;
packet_count ++;
index = src_ip + offset
```

1. Per-/cross-flow state identification

How to identify packet processing code?

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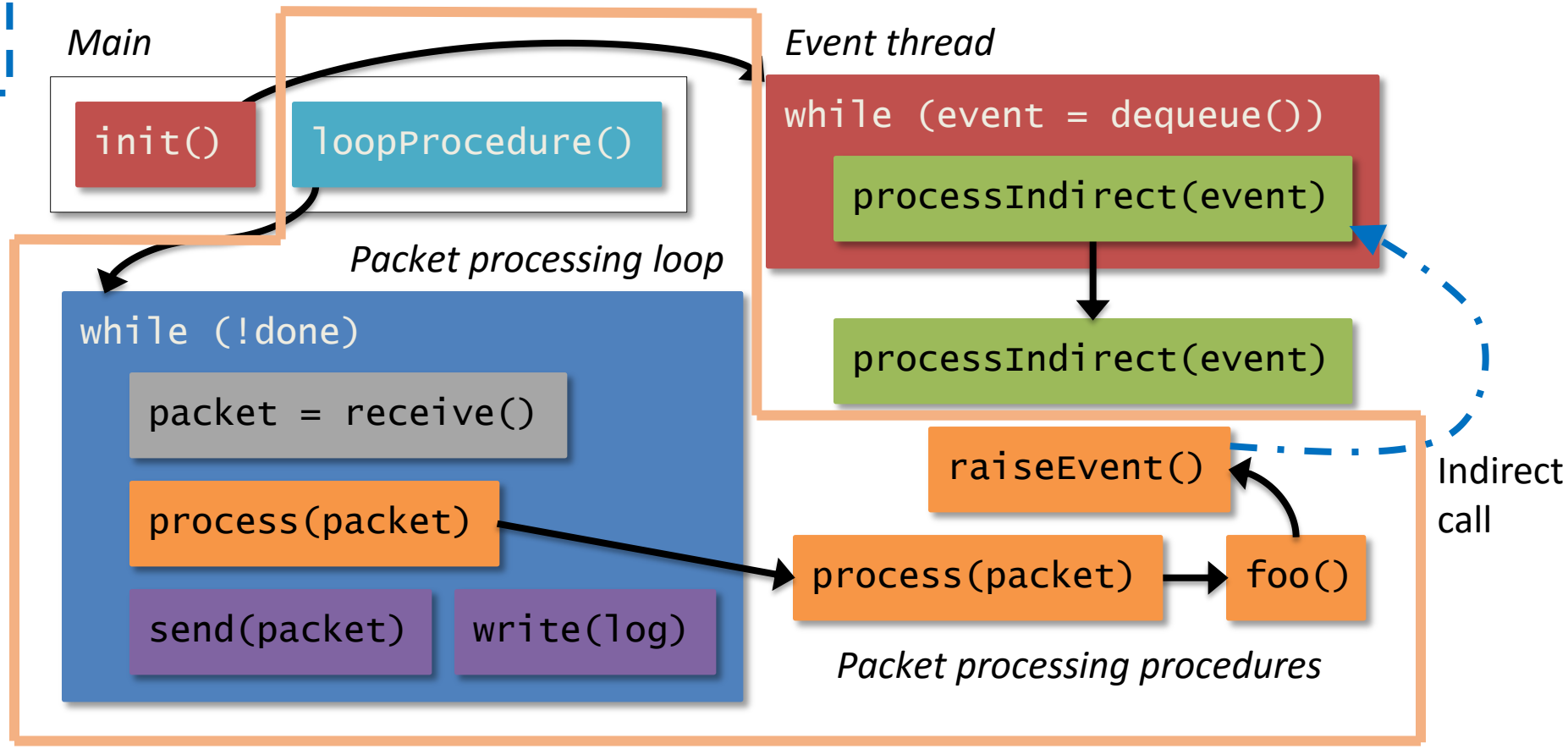
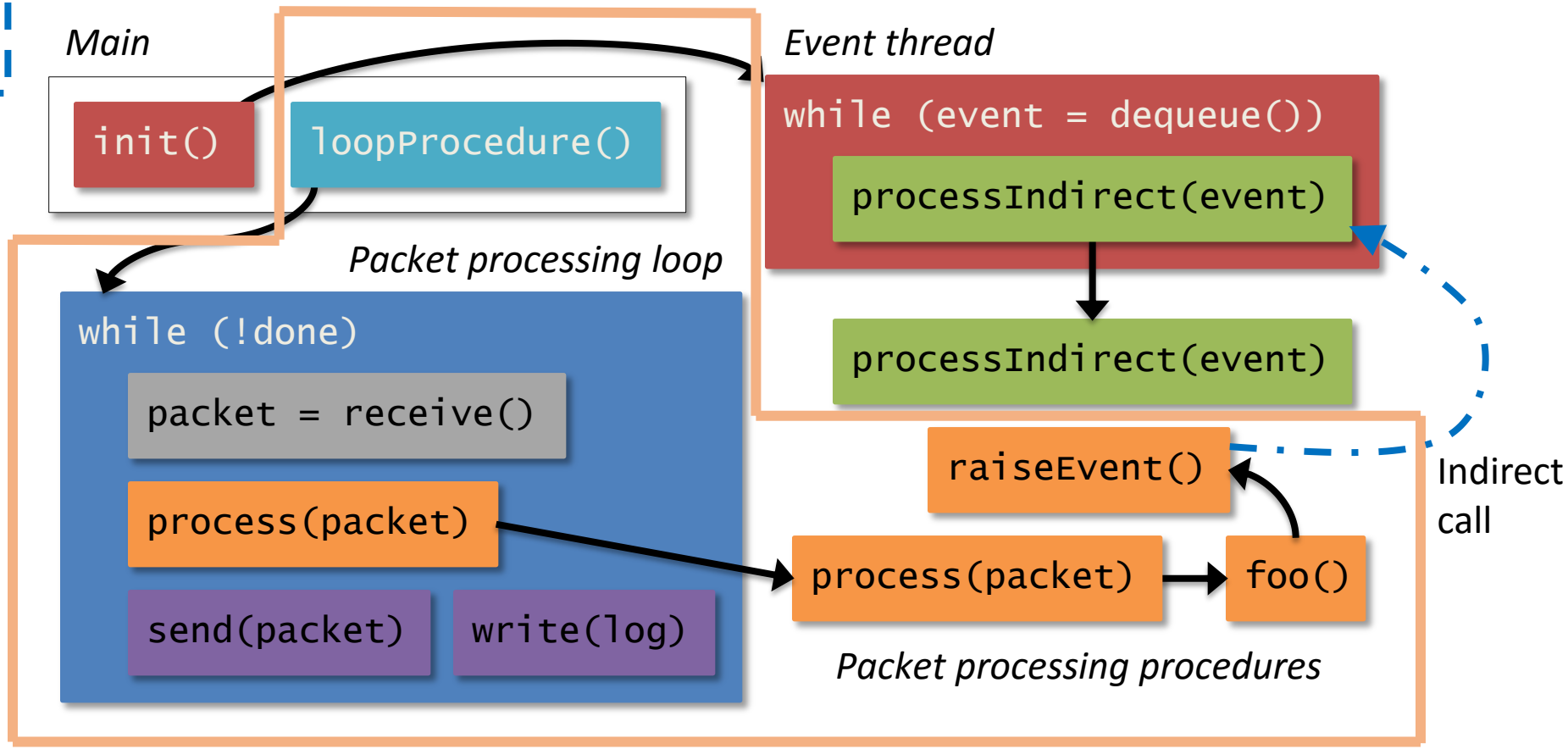



```
struct pktHdr *pkt = recv(extPcap);
src_ip = pkt->ip_src_addr;
packet_count ++;
index = src_ip + offset
```

1. Per-/cross-flow state identification

How to identify packet processing code?



Computes a ***forward slice*** from packet recv function. Any procedure appearing ***in the slice*** is considered as ***packet processing procedure***.

2. Identify updateable state

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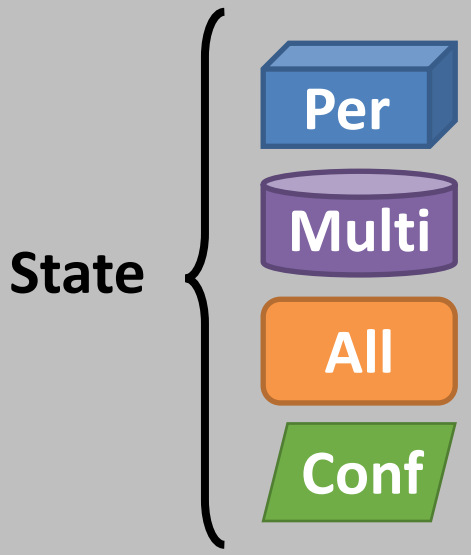
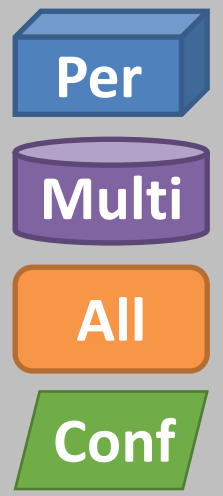


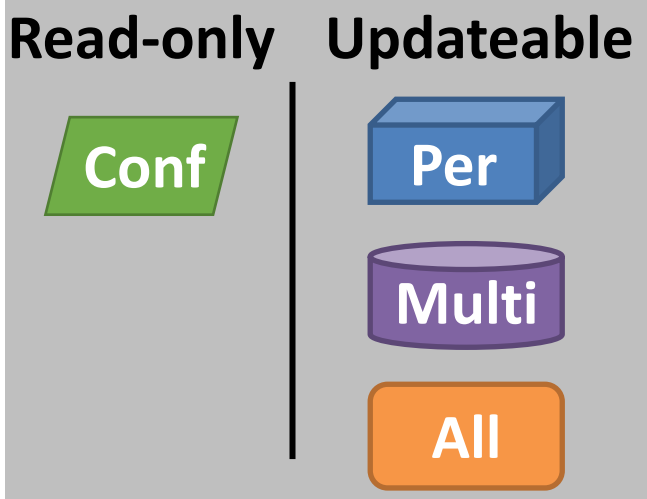
2. Identify updateable state



Read-only | Updateable

2. Identify updateable state

Whether the state is updated while processing the packet ?



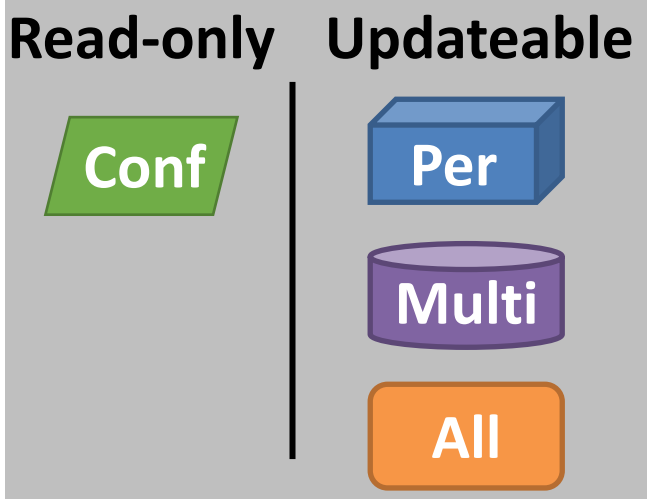
2. Identify updateable state

Whether the state is updated while processing the packet ?

- Strawman approach
  - Identify top-level variable on the left-hand-side(LHS) of assignment statement

per-/cross-flow var

```
in_port = pkt.src_port;
```



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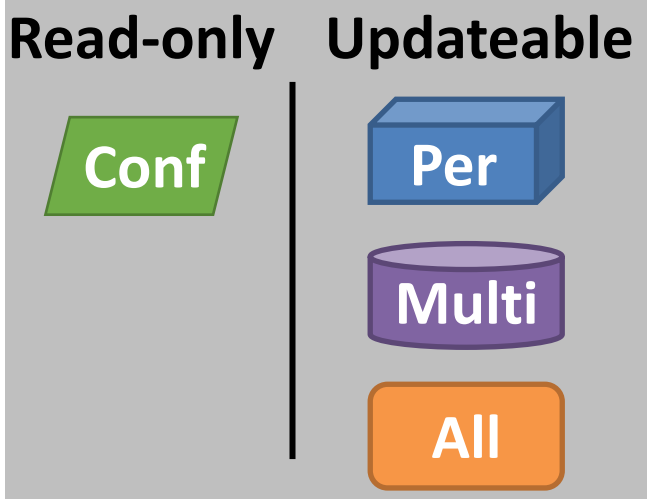
Falls short due to *aliasing*



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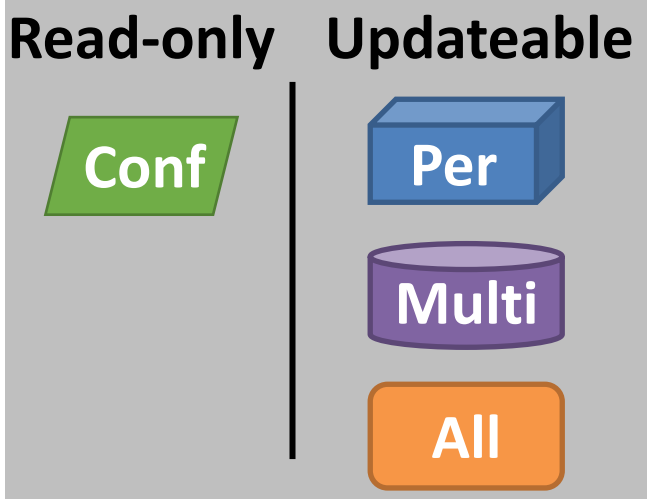
Whether the state is updated while processing the packet ?

- Strawman approach
  - Identify top-level variable on the left-hand-side(LHS) of assignment statement

per-/cross-flow var

```
int *index = &tail;
*index = (*index + 1)%100;
```

Falls short due to *aliasing*



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Whether the state is updated while processing the packet ?

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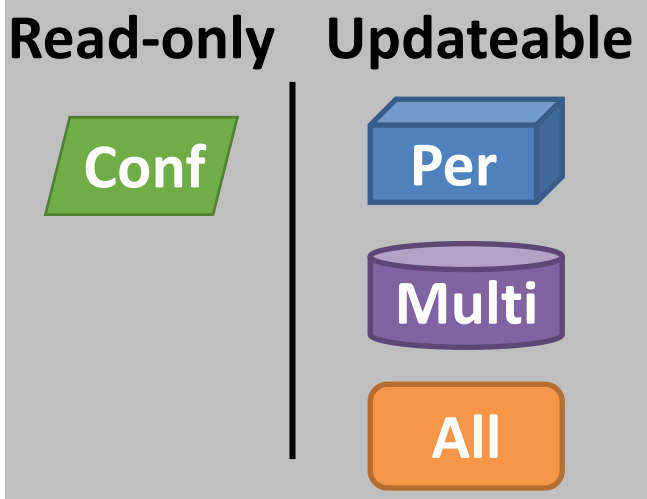
StateAlyzr employs flow-, context-, and field-insensitive ***pointer analysis*** to identify updateable variables



3. Identify states' flowspace dimensions

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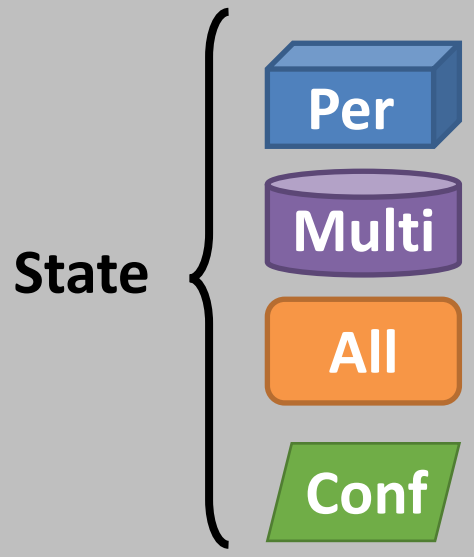

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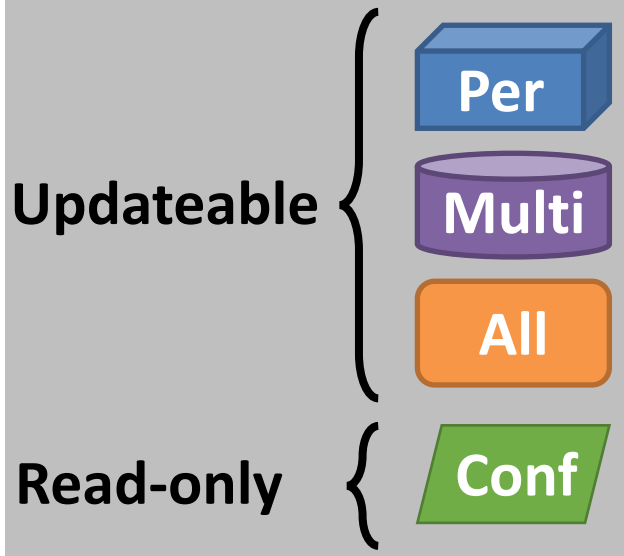
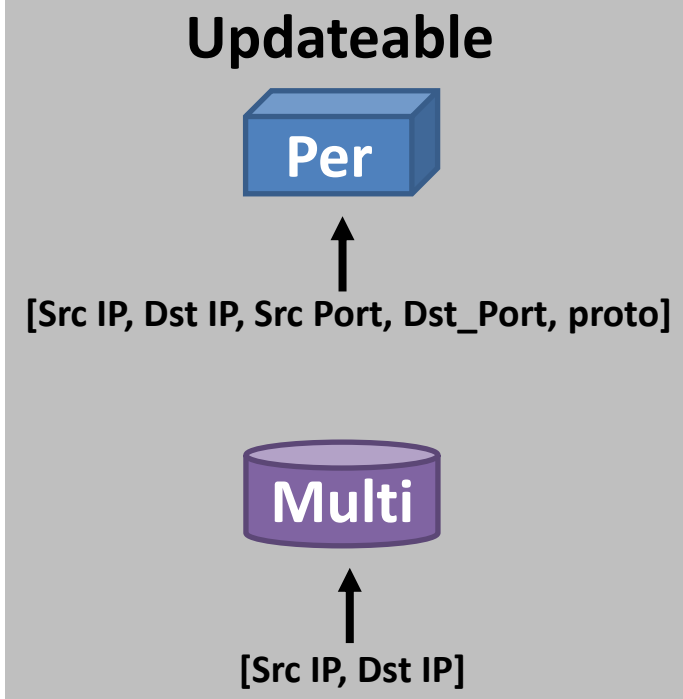


3. Identify states' flowspace dimensions

Identify a set of ***packet header*** *fields* that delineate the subset of traffic that relates to the state



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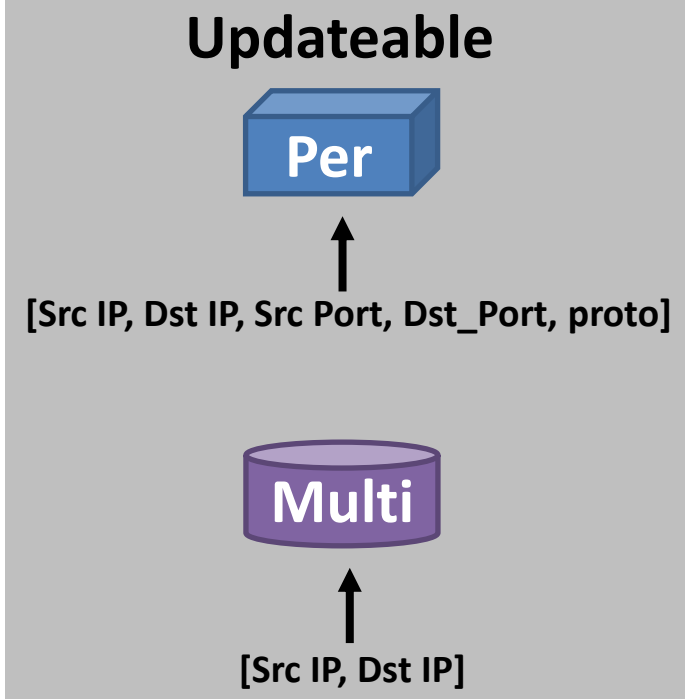
Common access patterns



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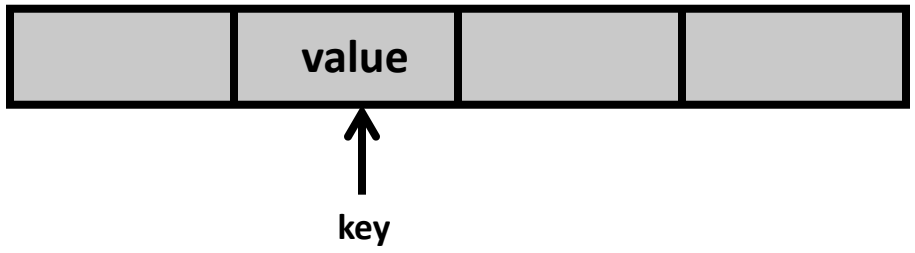
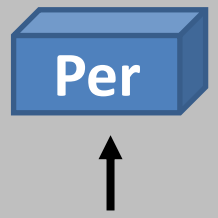
Hashtable

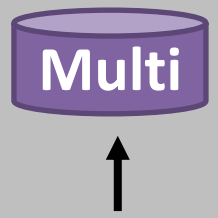


Common access patterns

Updateable



[Src IP, Dst IP, Src Port, Dst_Port, proto]



[Src IP, Dst IP]

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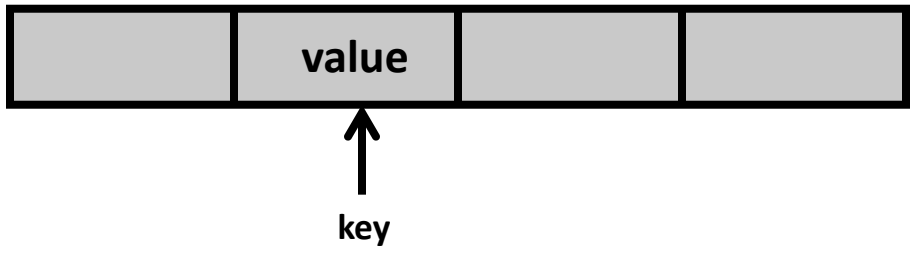
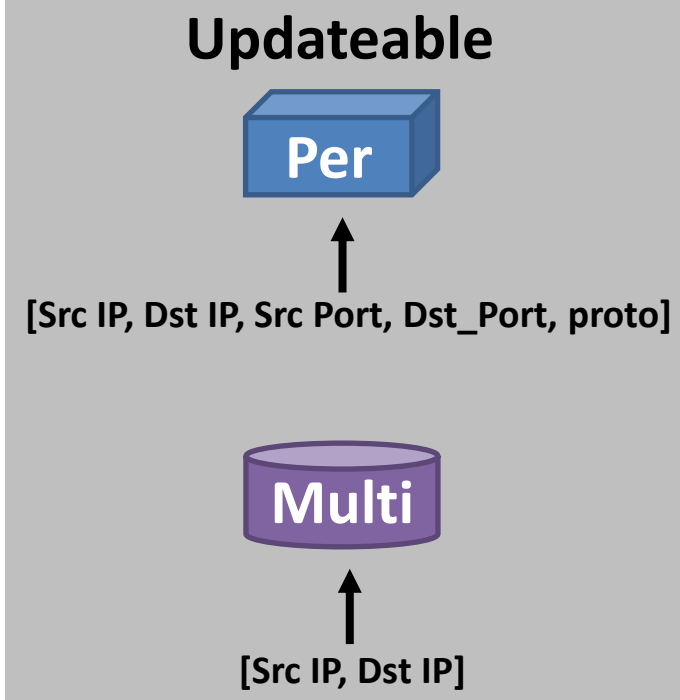


Common access patterns

1. Square brackets

```
entry = table[index];
```



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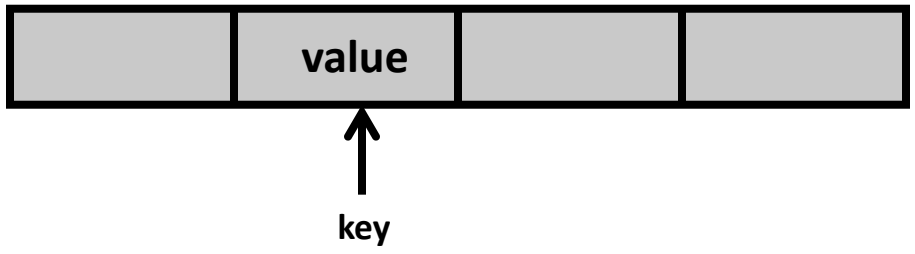

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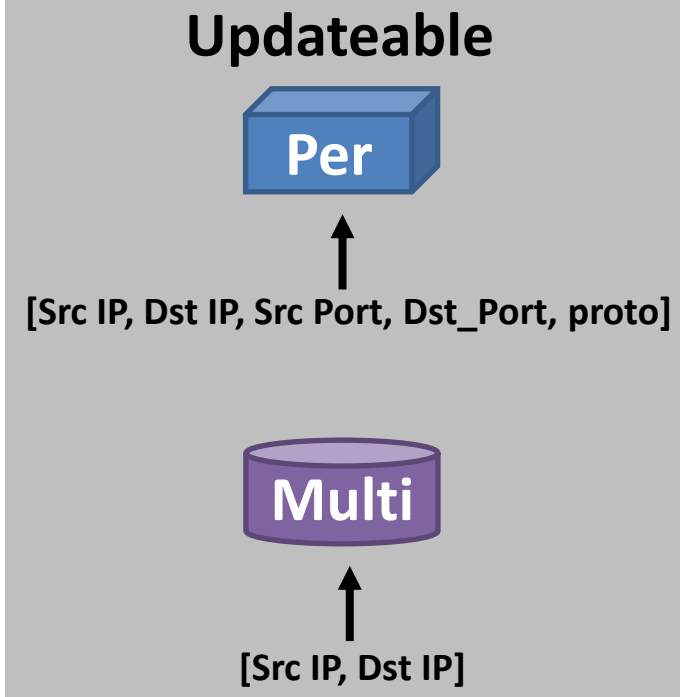

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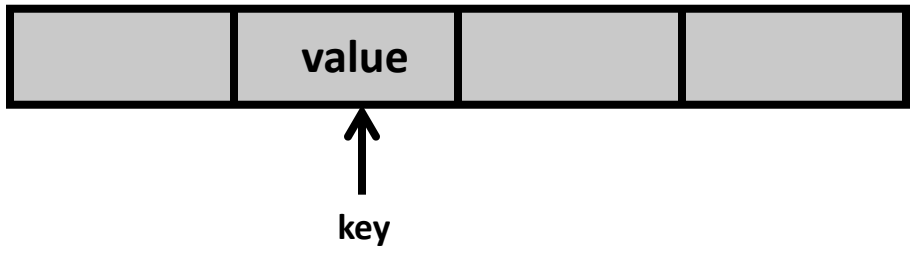
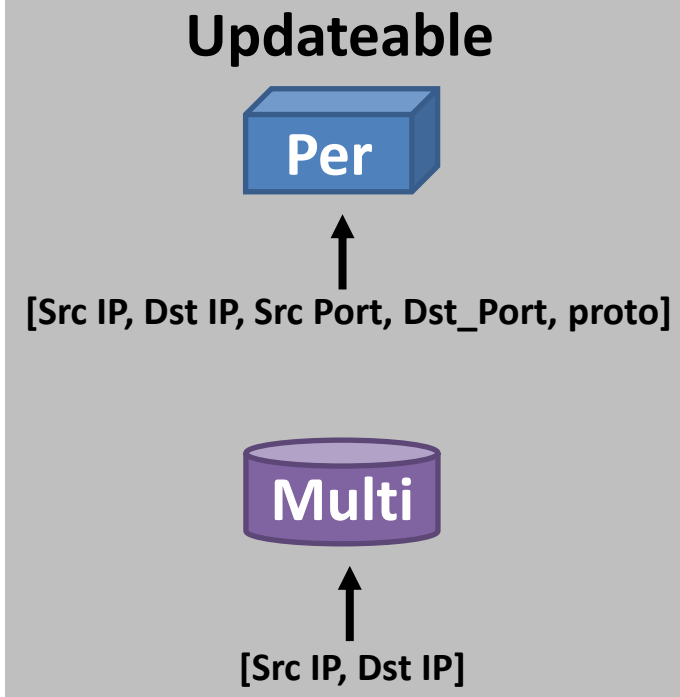


Common access patterns

1. Square brackets
2. Pointer arithmetic

```
entry = head + offset;
```



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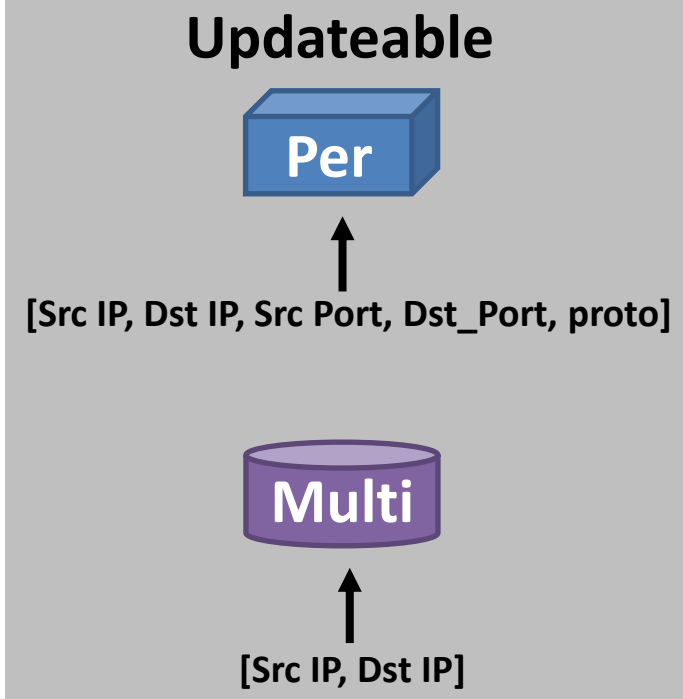
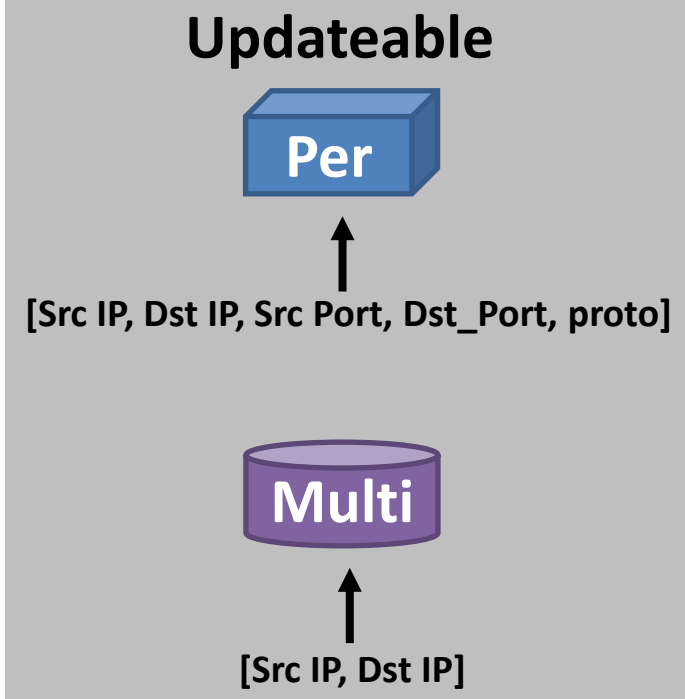


3. Identify states' flowspace dimensions

Identify a set of ***packet header*** *fields* that delineate the subset of traffic that relates to the state

Common access patterns

1. Square brackets
2. Pointer arithmetic
3. Iteration



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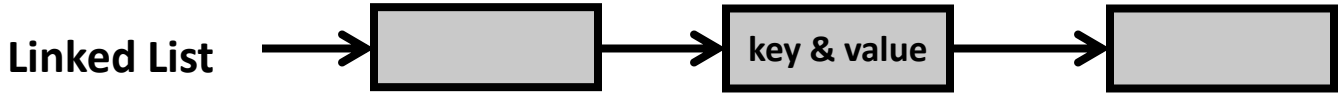
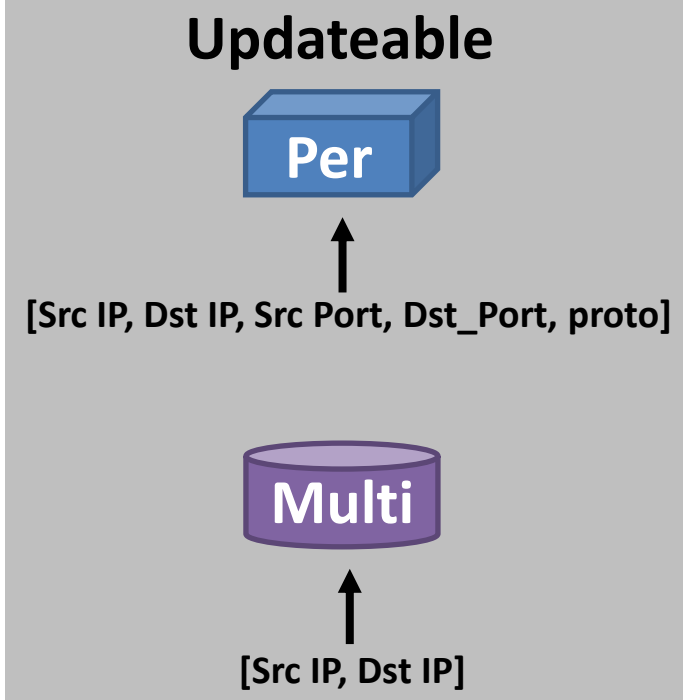


Common access patterns

1. Square brackets
2. Pointer arithmetic
3. Iteration

```
struct host *lookup(uint ip) {
 struct host *curr = hosts;
 while (curr != NULL) {
  if (curr->ip == ip)
   return curr;
  curr = curr->next;
 }
}
```



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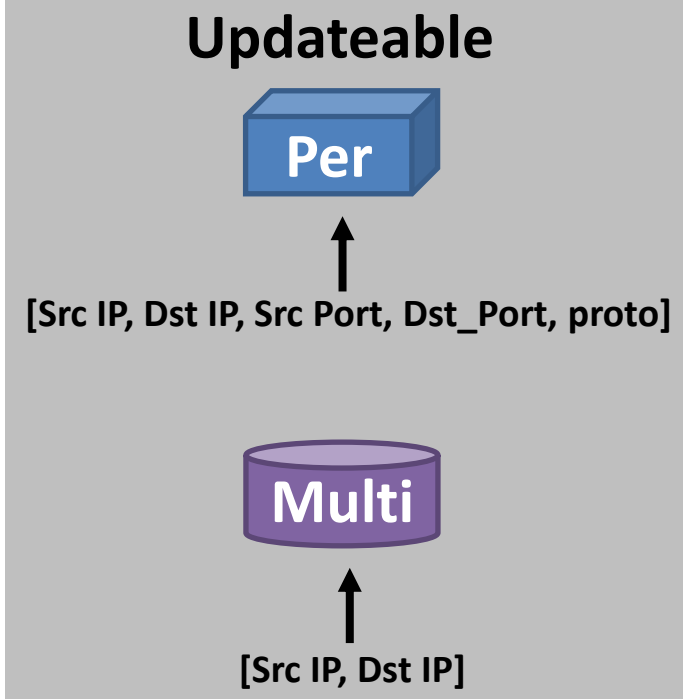



```
entry = host_map[index]
```

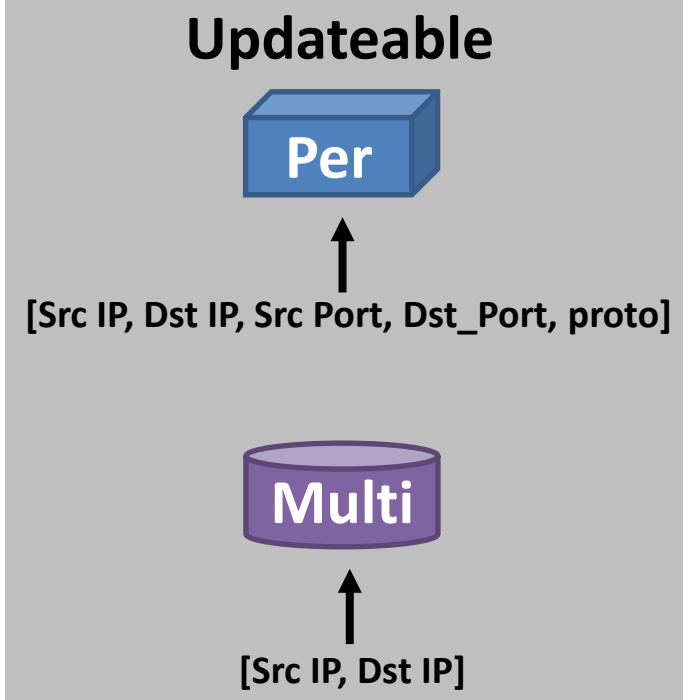
3. Identify states' flowspace dimensions

Identify a set of ***packet header*** *fields* that delineate the subset of traffic that relates to the state

Program ***chopping*** to determine relevant ***header fields***

```
struct pktHdr *pkt = recv(extPcap);
```

```
entry = host_map[index]
```

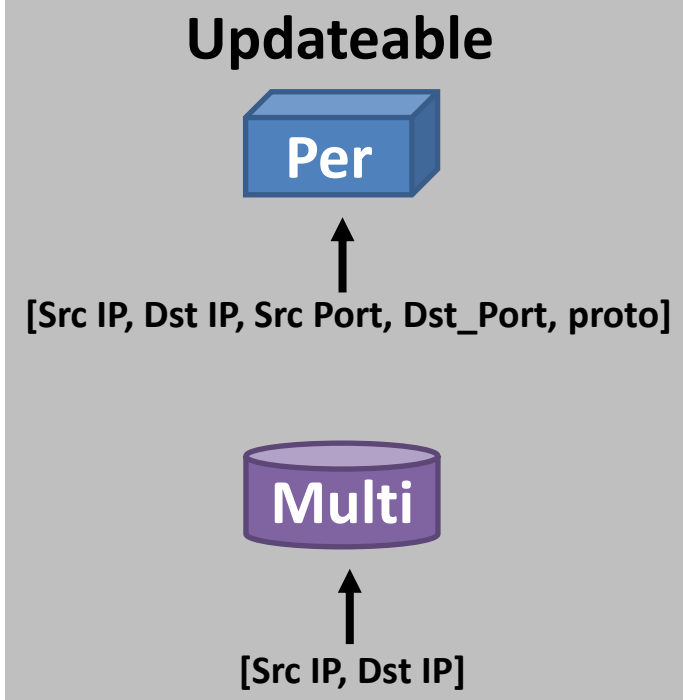


3. Identify states' flowspace dimensions

Identify a set of ***packet header*** *fields* that delineate the subset of traffic that relates to the state

Program ***chopping*** to determine relevant ***header fields***

```
struct pktHdr *pkt = recv(extPcap);
src_ip = pkt->ip_src_addr;
packet_count ++;
index = src_ip + offset
entry = host_map[index]
```



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```
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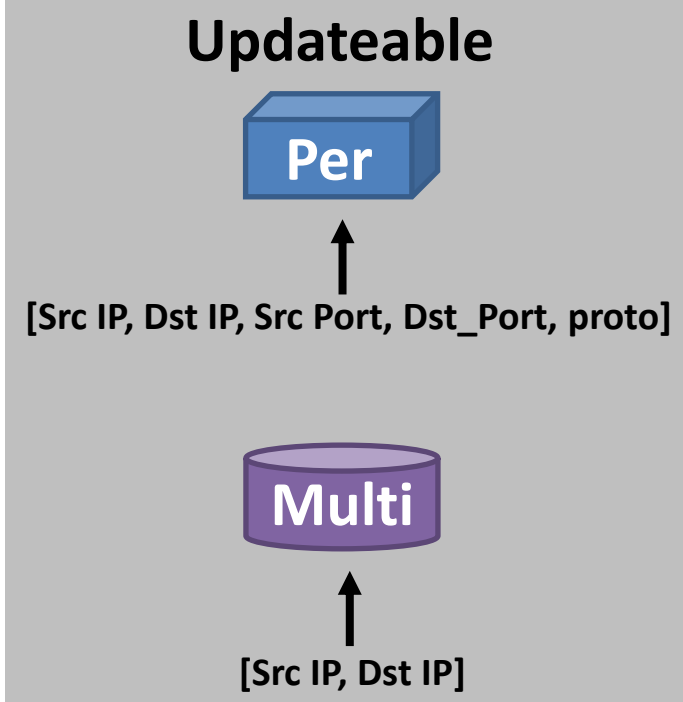
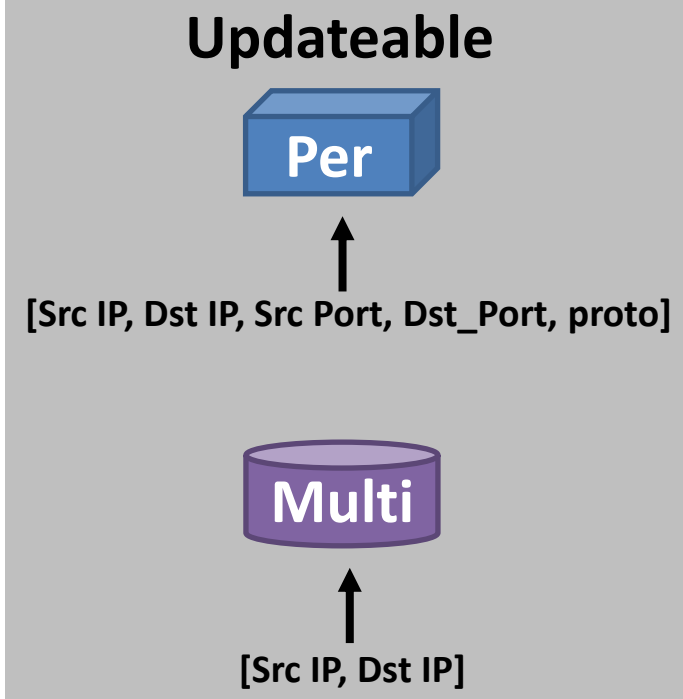
src_ip = pkt->ip_src_addr;
packet_count ++;
index = src_ip + offset
entry = host_map[index]
```



3. Identify states' flowspace dimensions

Identify a set of ***packet header*** *fields* that delineate the subset of traffic that relates to the state

Program ***chopping*** to determine relevant ***header fields***

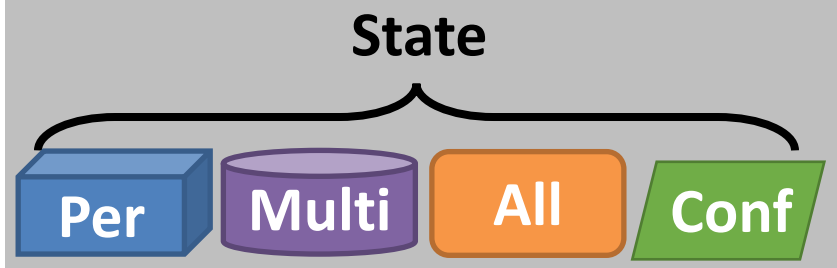


StateAlyzr steps

StateAlyzr steps

1. **Identify Per-/Cross-flow state**

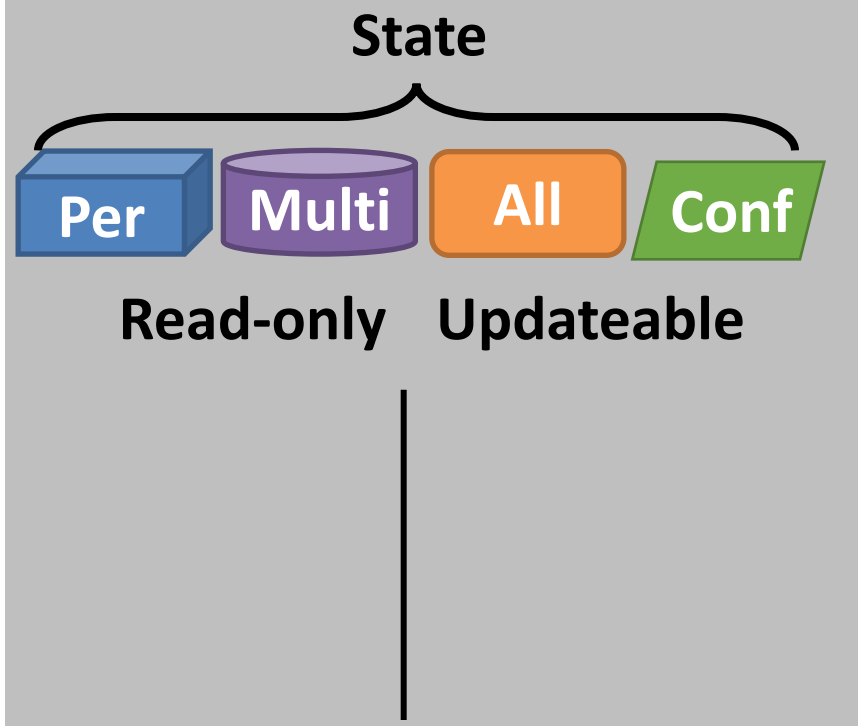
StateAlyzr steps



1. Identify Per-/Cross-flow state

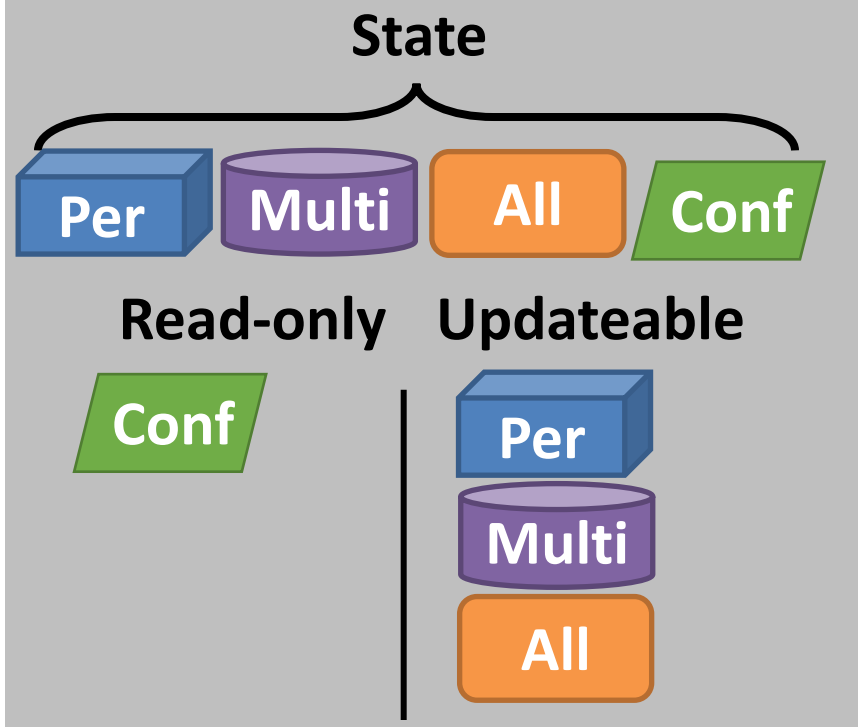
StateAlyzr steps

1. Identify Per-/Cross-flow state
2. Identify Updateable State



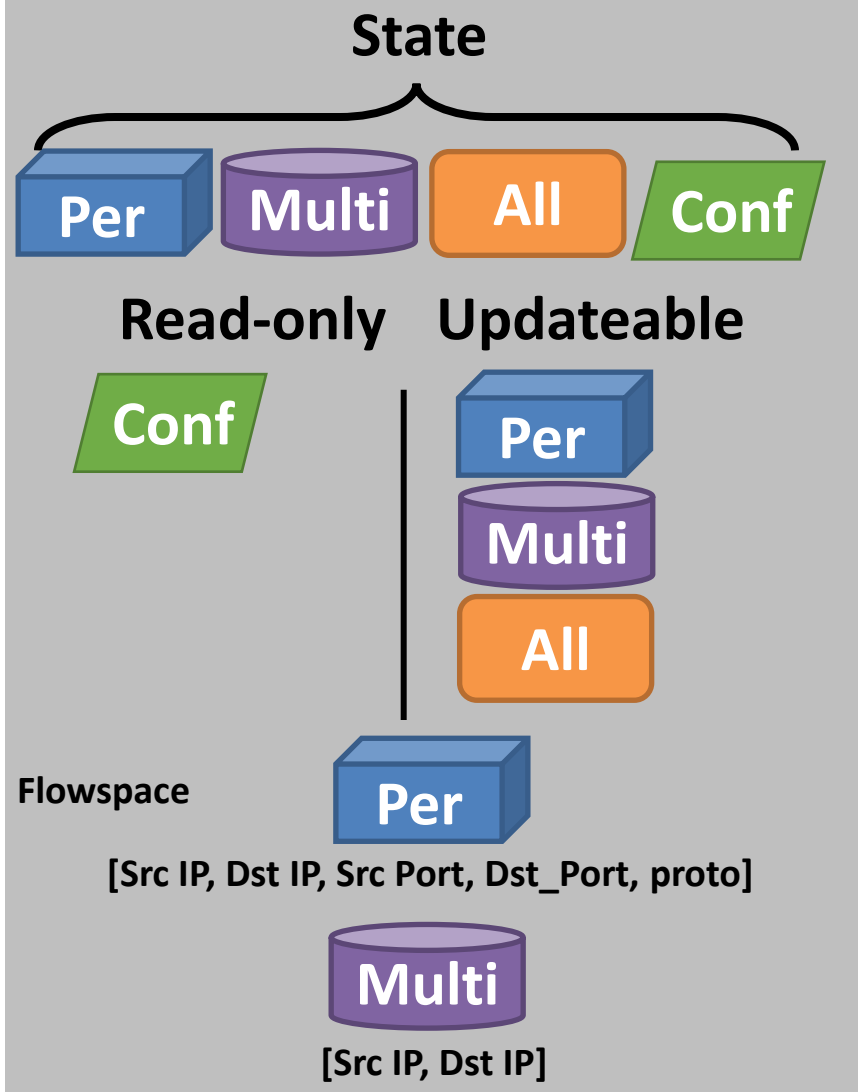
StateAlyzr steps

1. Identify Per-/Cross-flow state
2. Identify Updateable State



StateAlyzr steps

1. Identify Per-/Cross-flow state
2. Identify Updateable State
3. Identify States' Flowspace Dimensions



StateAlyzr steps

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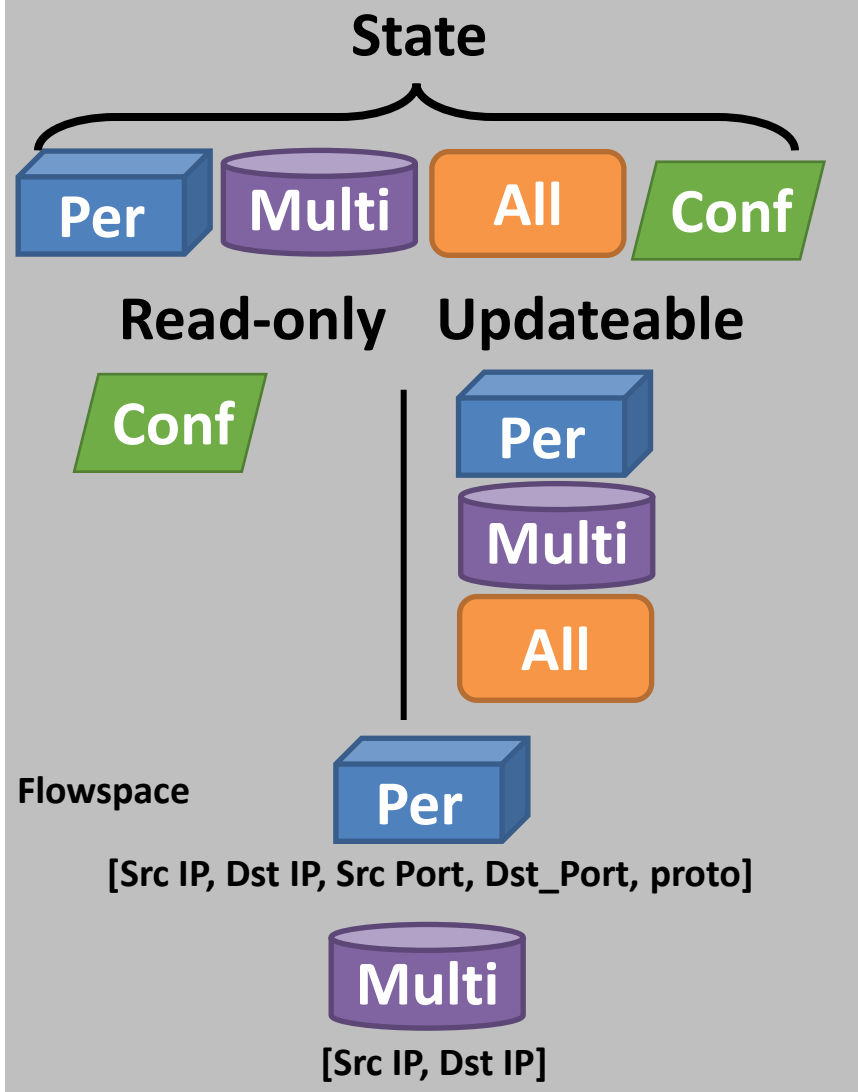
2. Identify Updateable State
3. Identify States' Flowspace Dimensions
4. Output Impacting State



StateAlyzr steps

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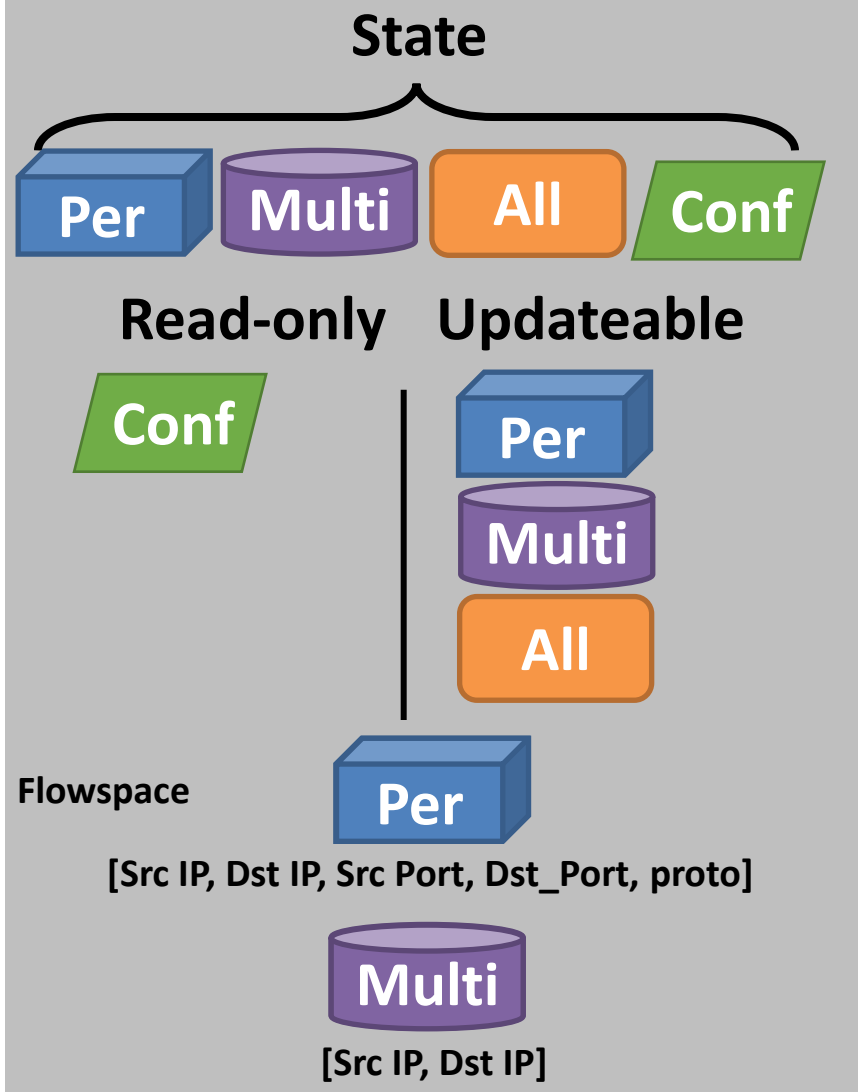

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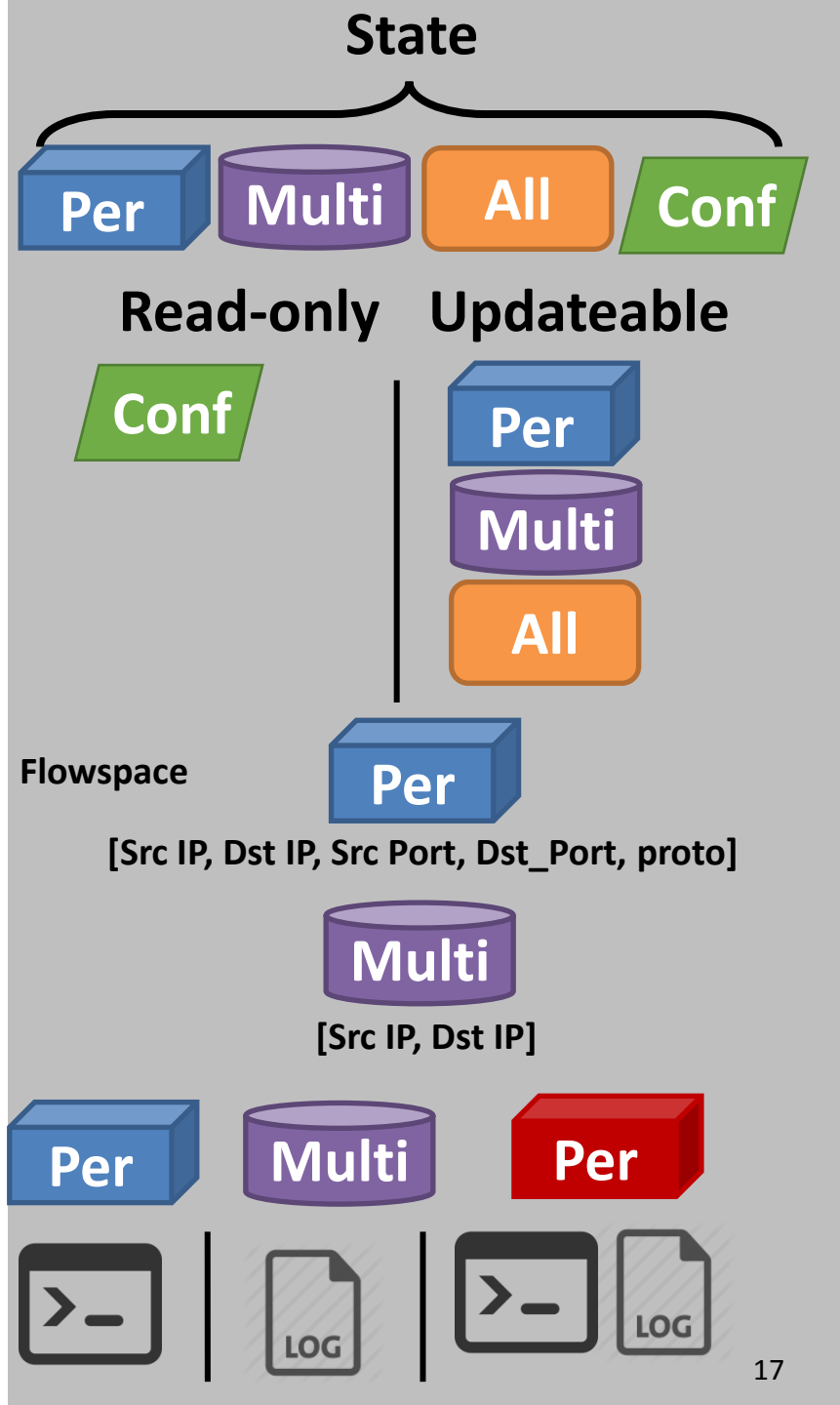

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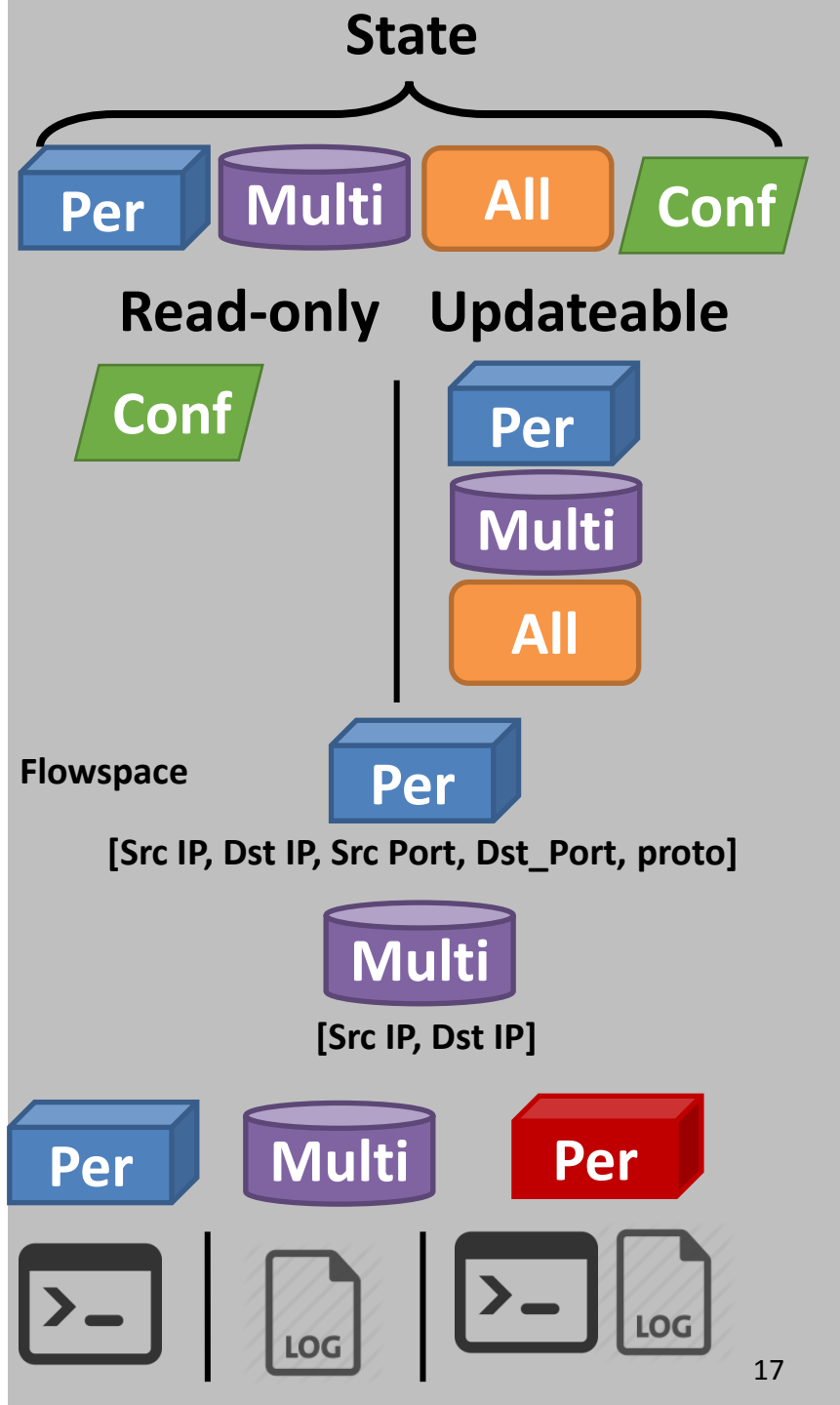

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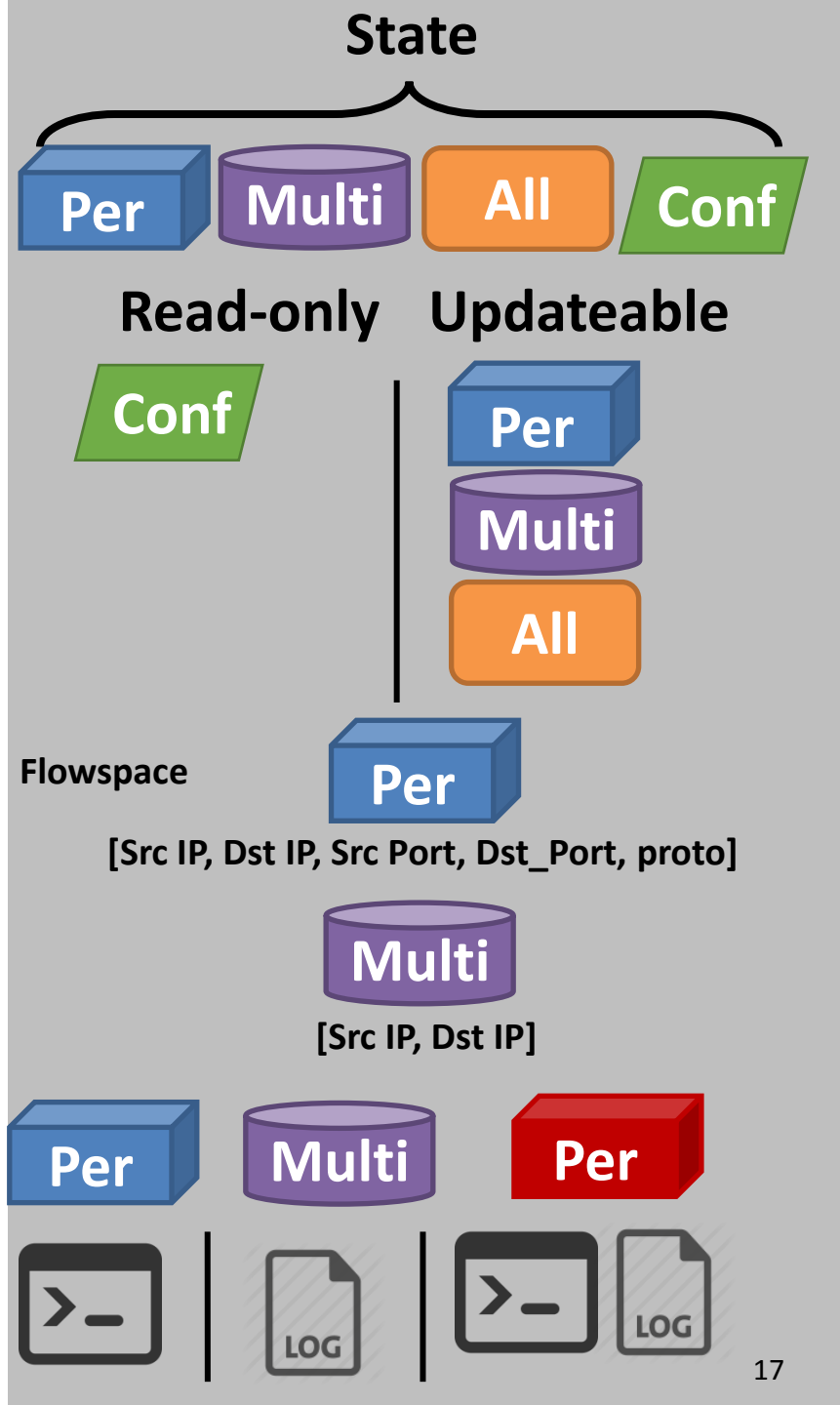
5. **Tracking Run-time Update**
   - Insert statements to do run time monitoring to track whether a variable is updated



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Evaluation

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- Precision

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- Precision
- Performance benefits at run time

Evaluation: effectiveness

	Step 0		Step 1	Step 2
MB	**All variables**	**Persistent variables**	**per-/cross-flow variables**	**Updateable variables**
PRADS	1529	61	29	10
Snort IDS	18393	507	333	148
HAproxy	7876	272	176	115
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StateAlyzr offers useful ***improvements*** in ***precision***

Theoretically ***proved*** the ***soundness*** of our algorithms

Highly available PRADS

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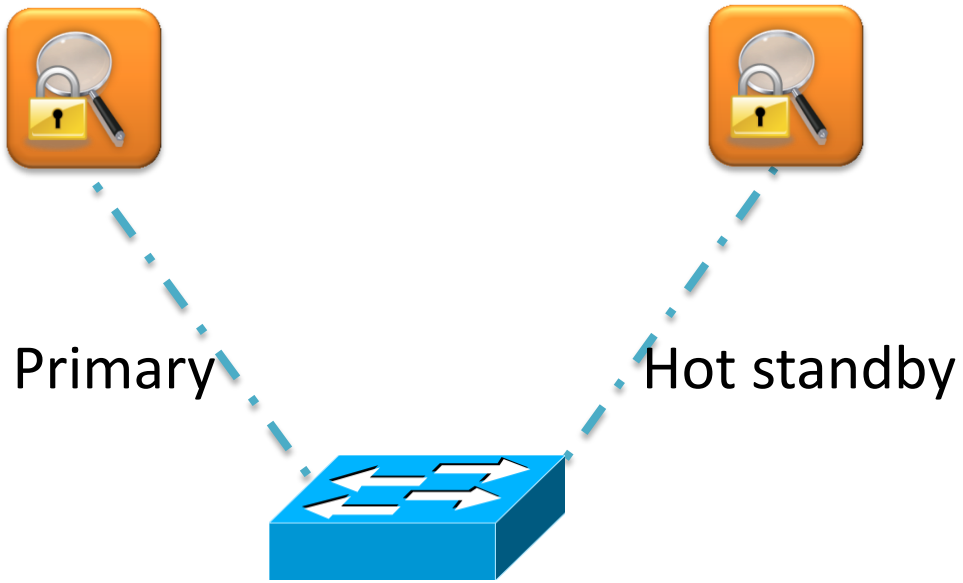

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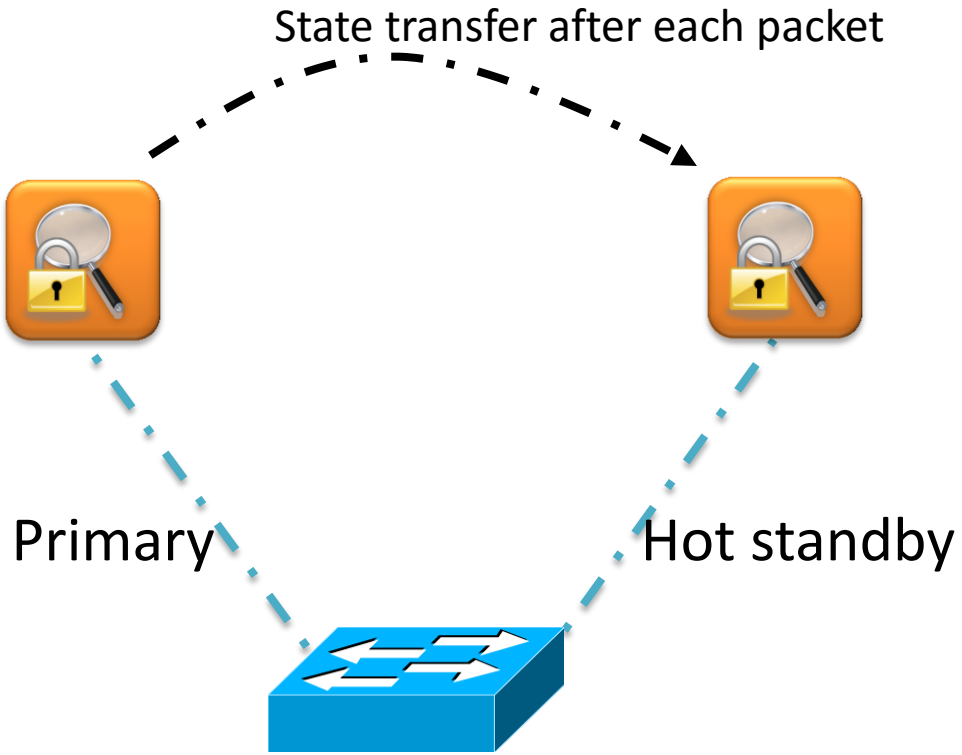

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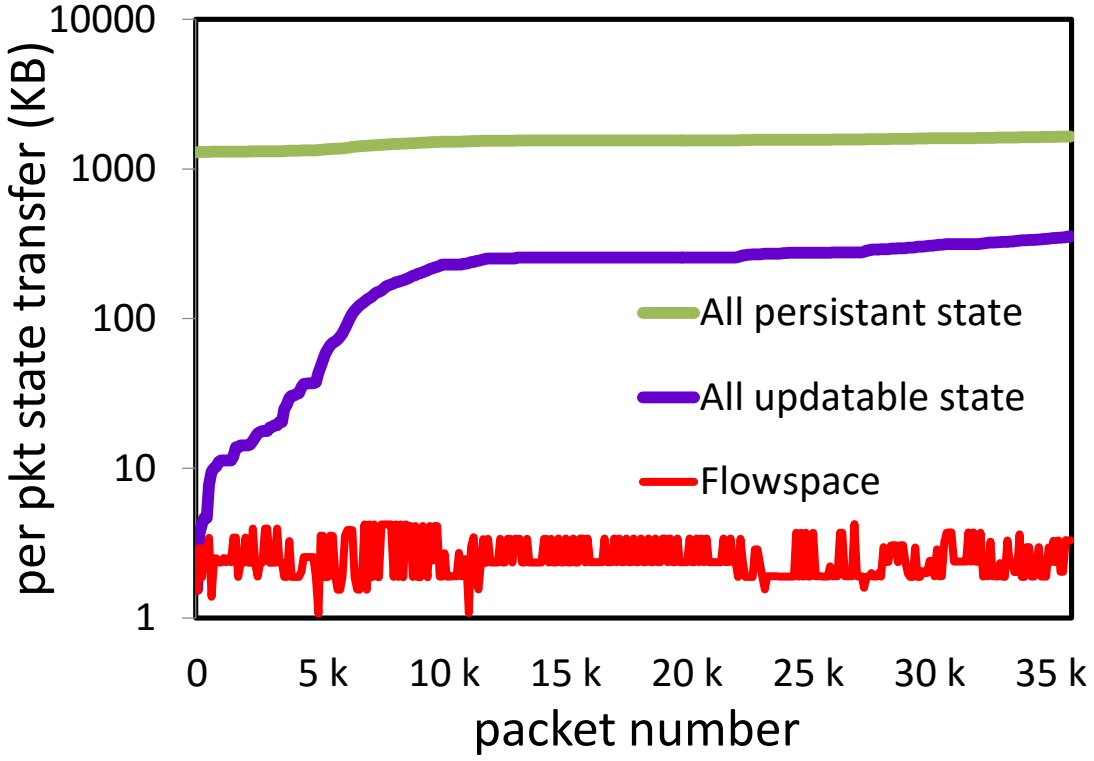

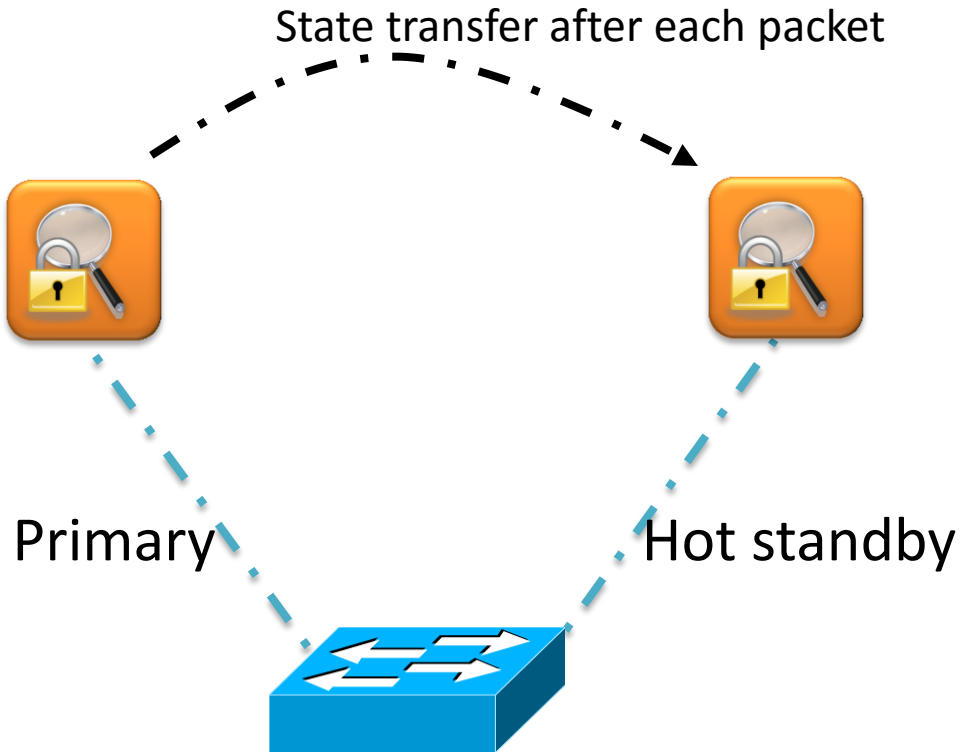

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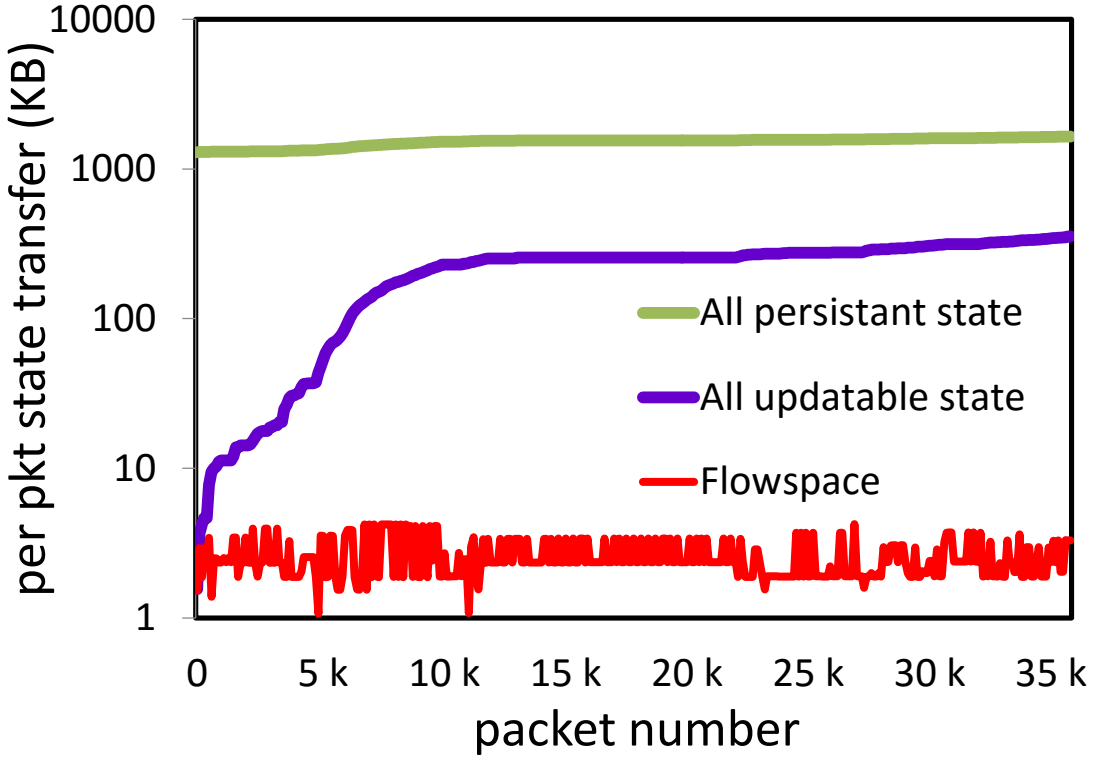

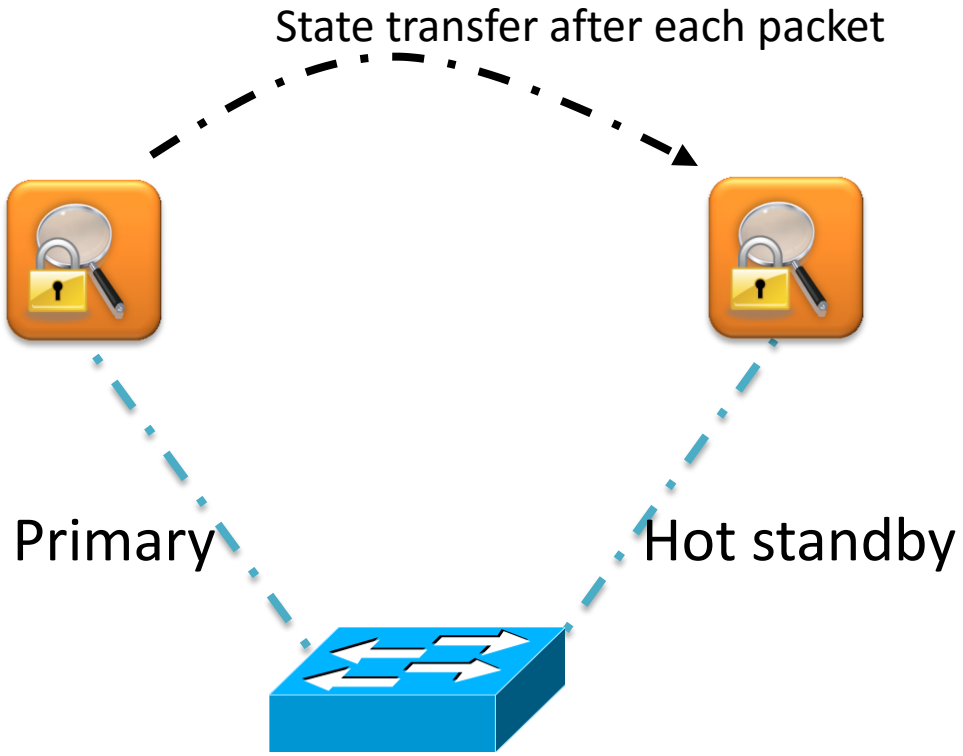

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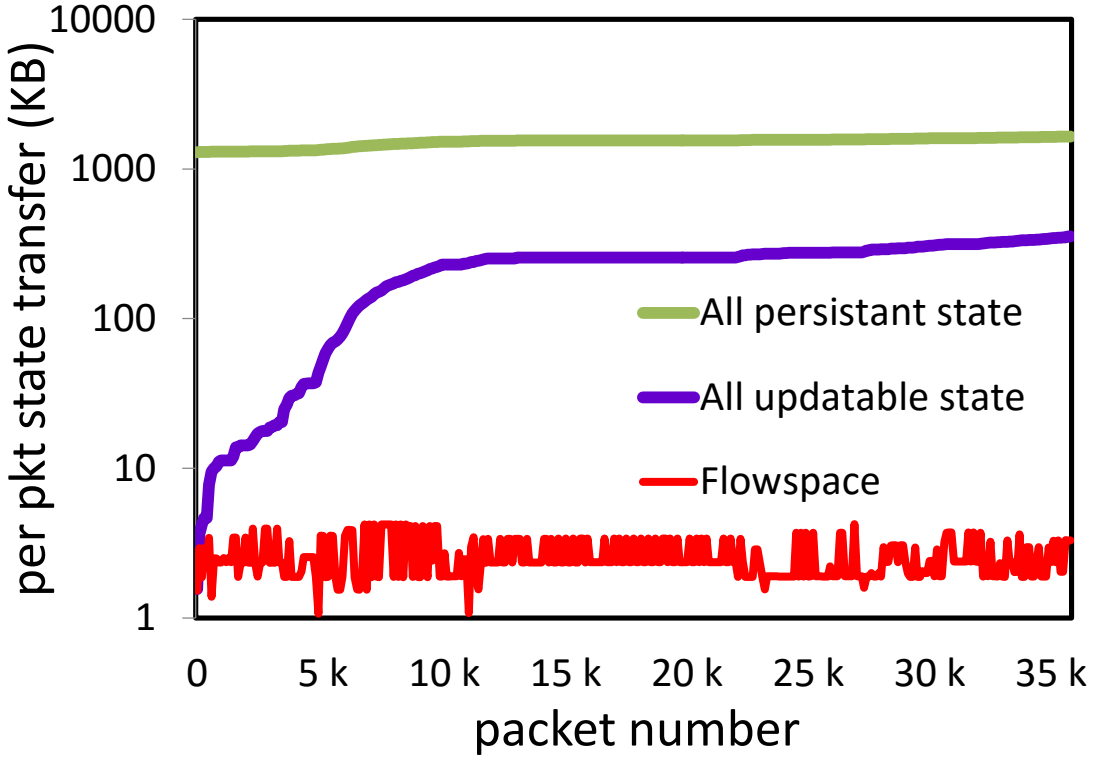

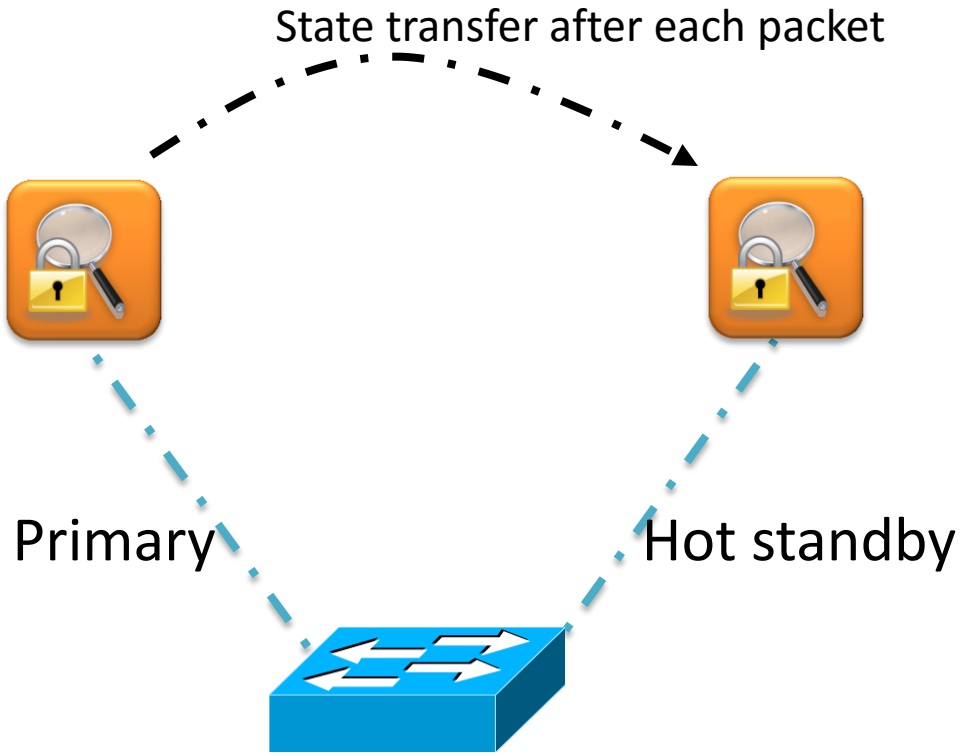

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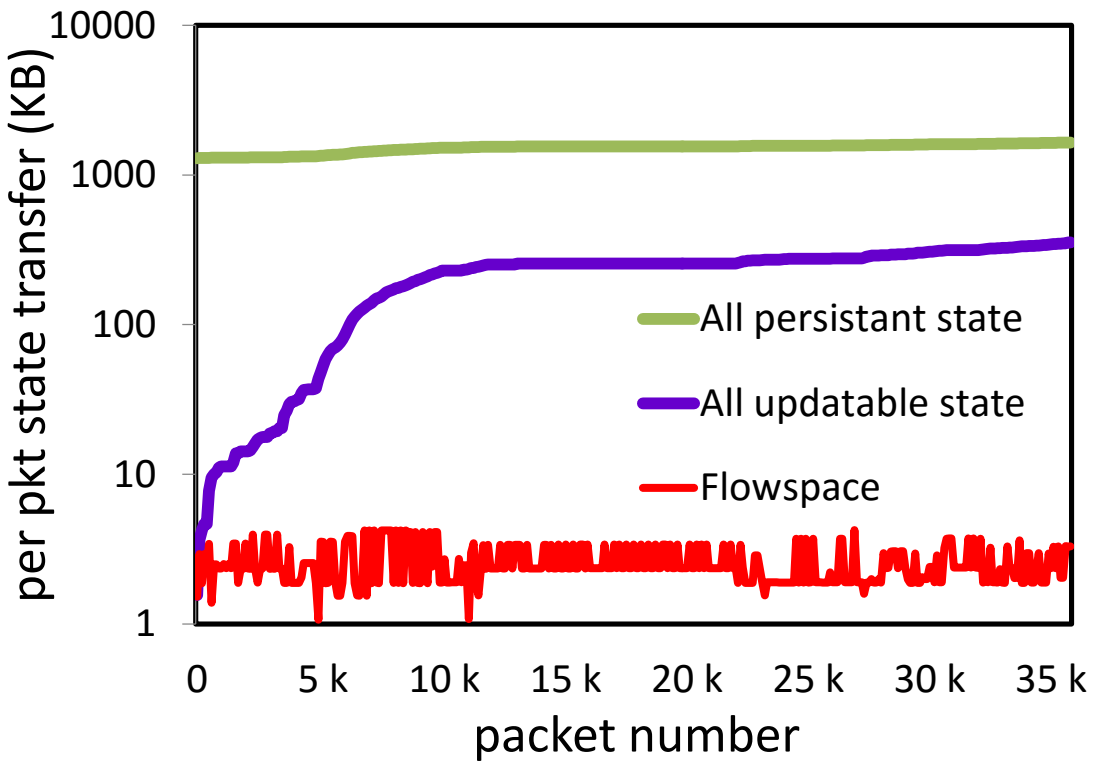

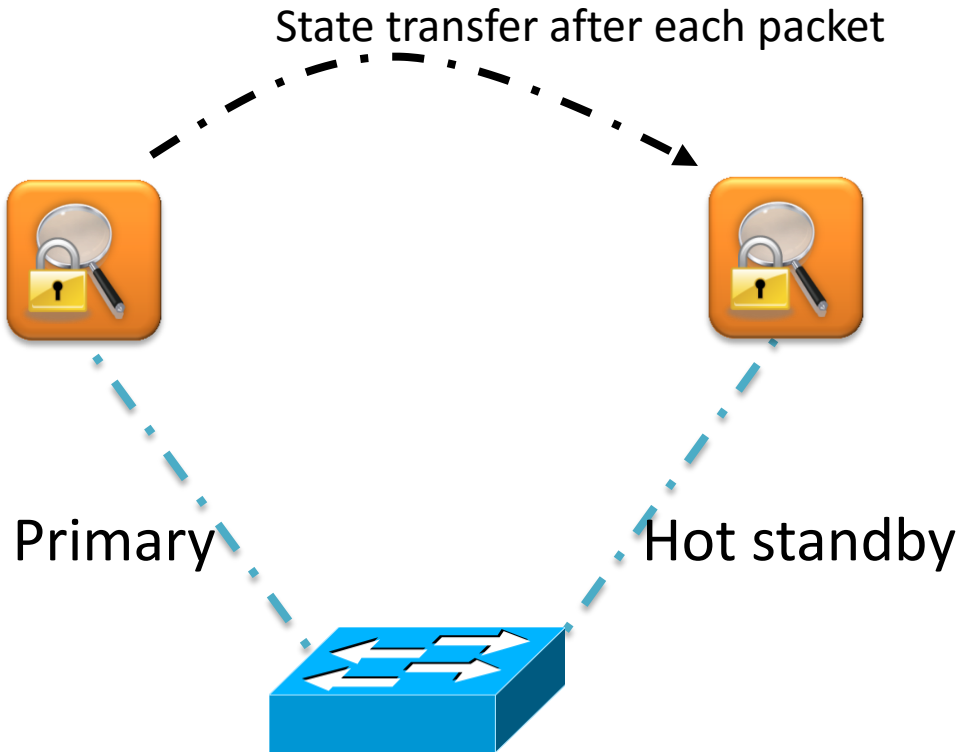

Reduction in the state transfer by *305x*

Highly available PRADS

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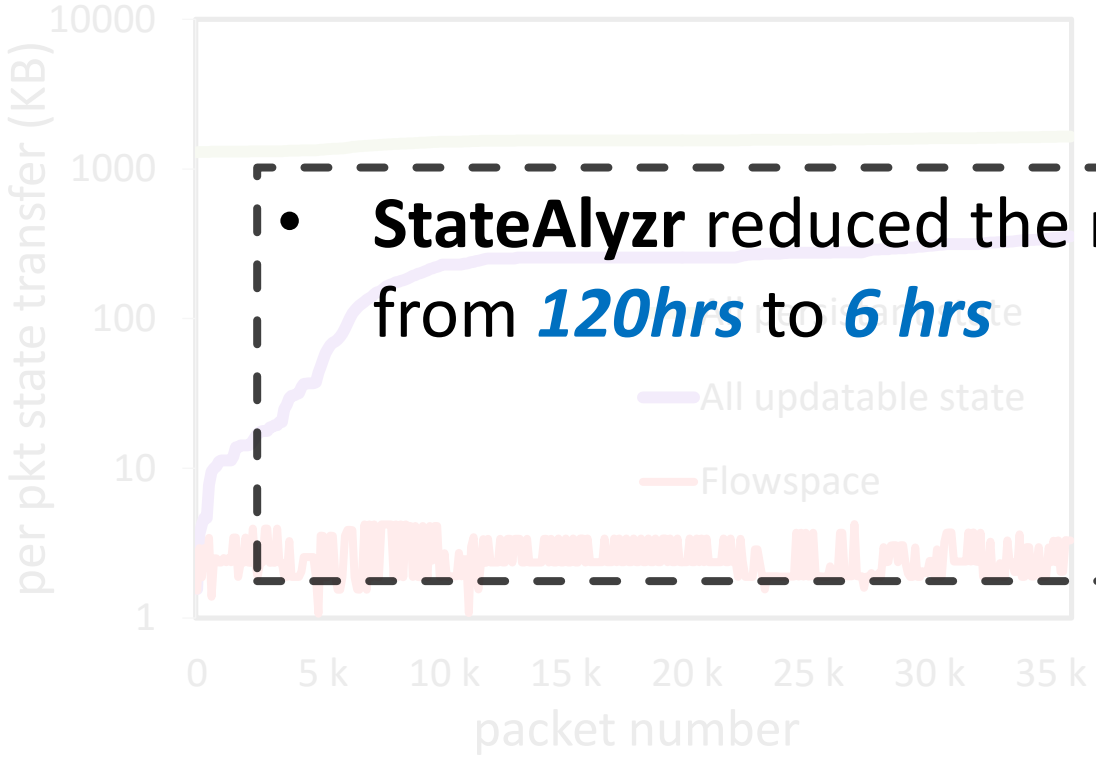

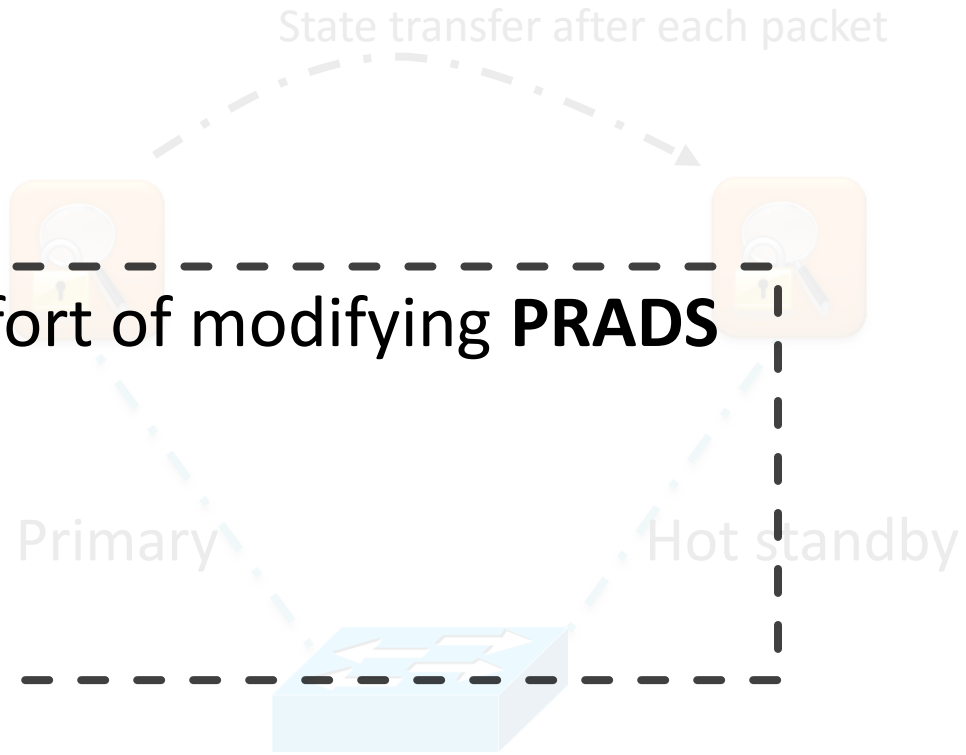

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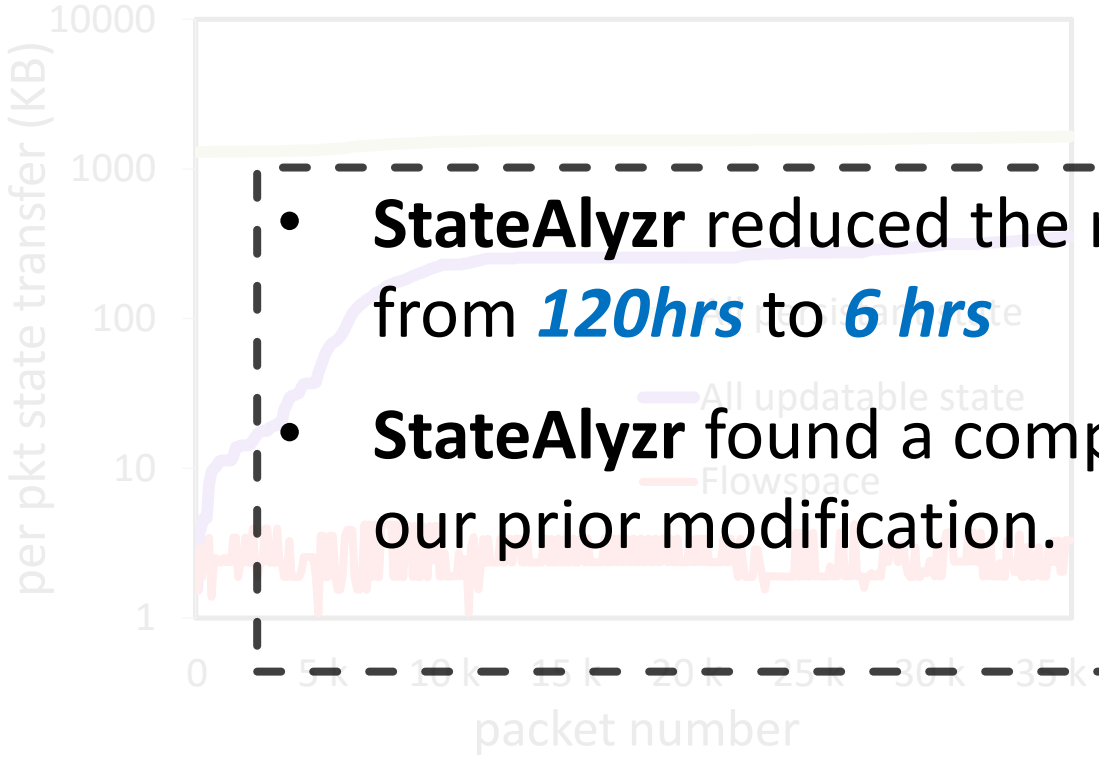

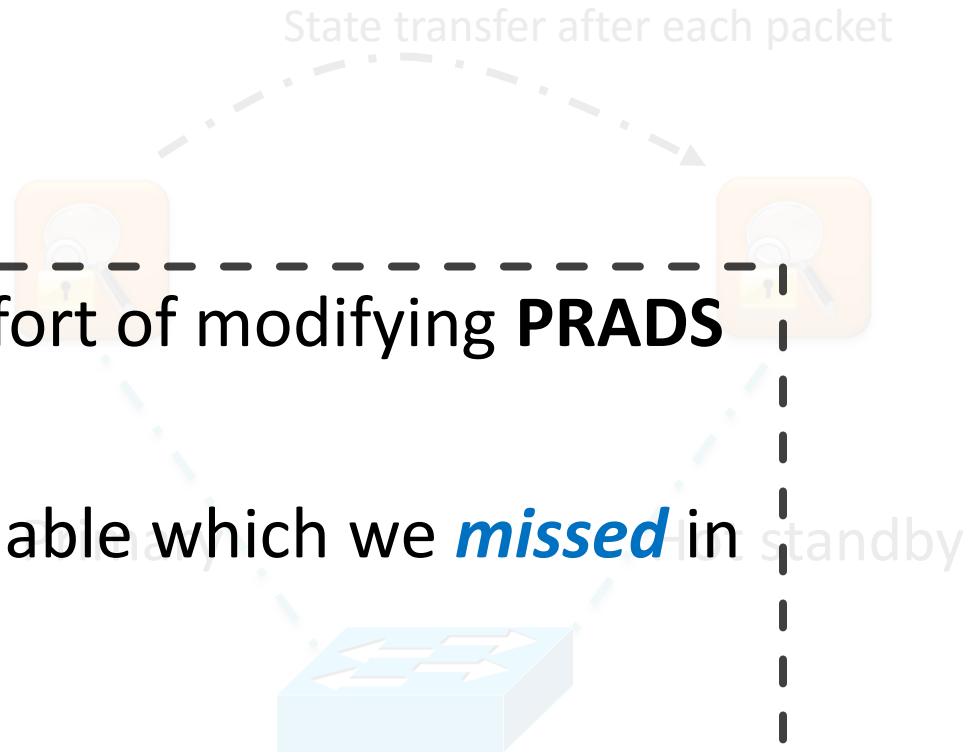

- **StateAlyzr** reduced the manual effort of modifying **PRADS** from ***120hrs*** to ***6 hrs***
- **StateAlyzr** found a compound variable which we ***missed*** in our prior modification.

Reduction in the state transfer by *305x*

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- Ultimate goal is to fully automate the process