SNAP: Stateful Network-Wide Abstractions for Packet Processing

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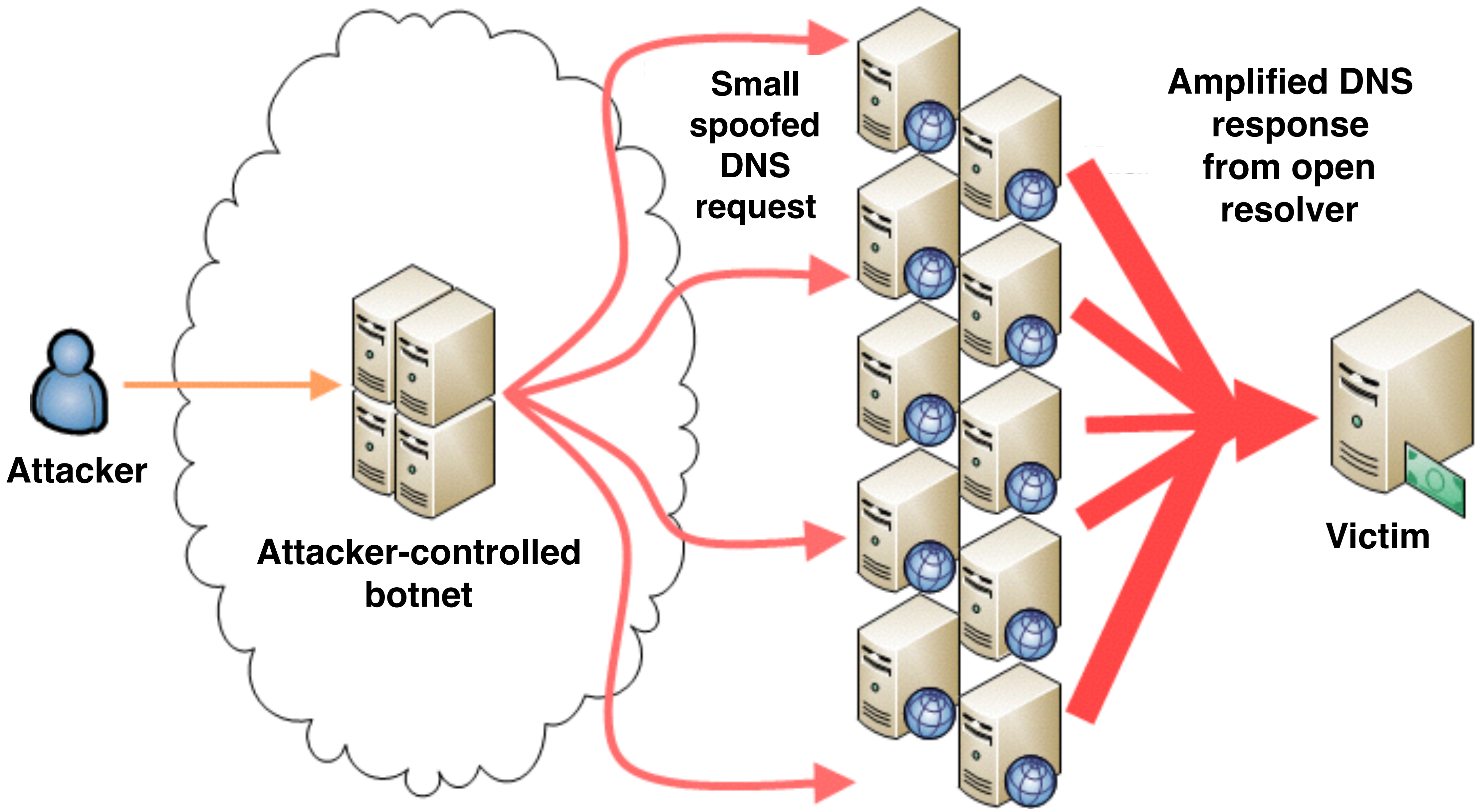
Two-tiered Programming Model

1. **Stateless** OpenFlow rules
    - process each packet independently
2. **Stateful** component
    - on top of controller
    - changes rules based on current state

Example - Detecting DNS Reflection Attacks



http://ddosandbotnets.blogspot.com

Example - Detecting DNS Reflection Attacks [1]

- For each host
  - Record DNS **requests**
  - Increment a counter for **unmatched responses**
  - Mark as **suspicious** after a threshold

[1] Bohatei: flexible and elastic DDoS defense, Fayaz et.al.

Practical Concerns

- Cannot send every packet to the controller
- Cannot have **per-packet stateful** processing
    - decide what to do with the packet based on packets seen so far!

Opportunity:
Local State on Data Plane

- Programmatic control over local state
    - P4, OpenState, POF, Open vSwitch
- Simple stateful network functions can be offloaded to programmable switches!

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  - P4,
- Simpl loaded to programmable switches!

Too low level!

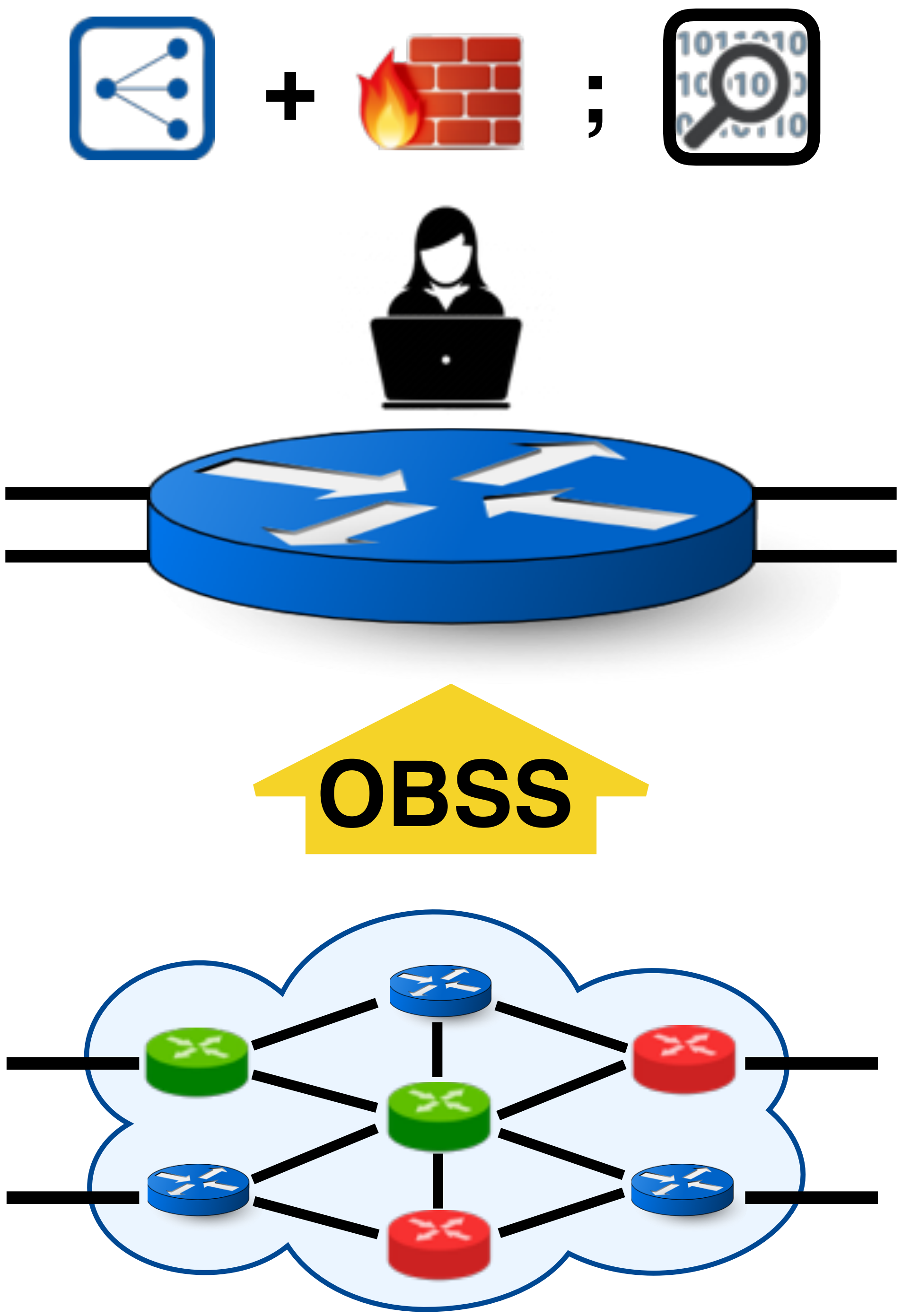
Our Goal

1. **High-level programming language**
    - one big **stateful** switch!
2. **Compiler**
    - to automatically distribute stateful programs

Our Contribution

SNAP Language and Compiler

SNAP - Language



- One Big Stateful Switch **(OBSS)**
- Composition

DNS Reflection Detection in SNAP

```
if srcip in CSNET & dstport = 53 then
   seen[srcip][dns.id] ← True
else if dstip in CSNET & srcport = 53 then
   if ~seen[dstip][dns.id] then
      unmatched[dstip]++;
      if unmatched[dstip] = threshold then
         susp[dstip] ← True
   else id
else id
```

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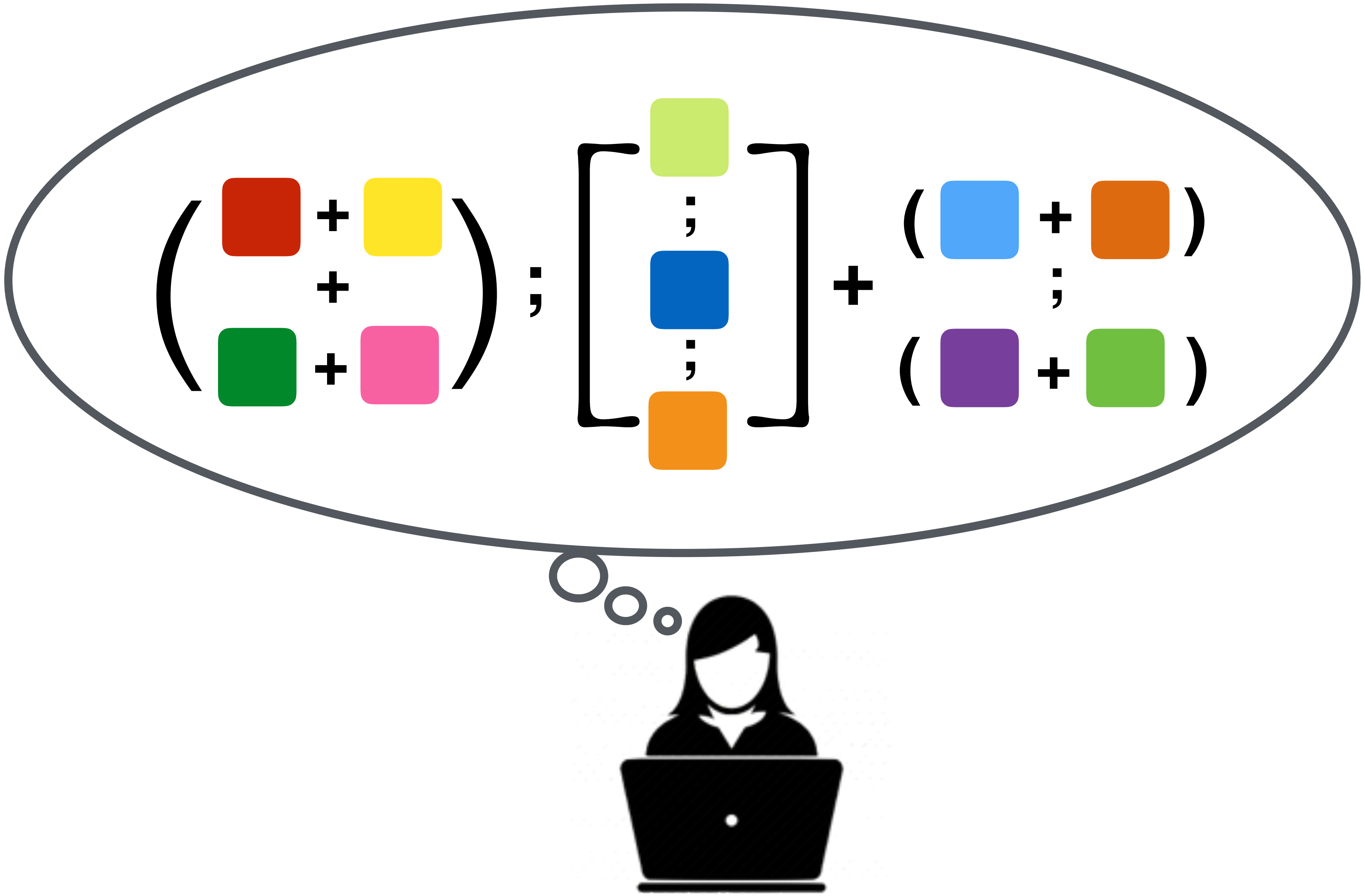
Composition



SNAP - Compiler

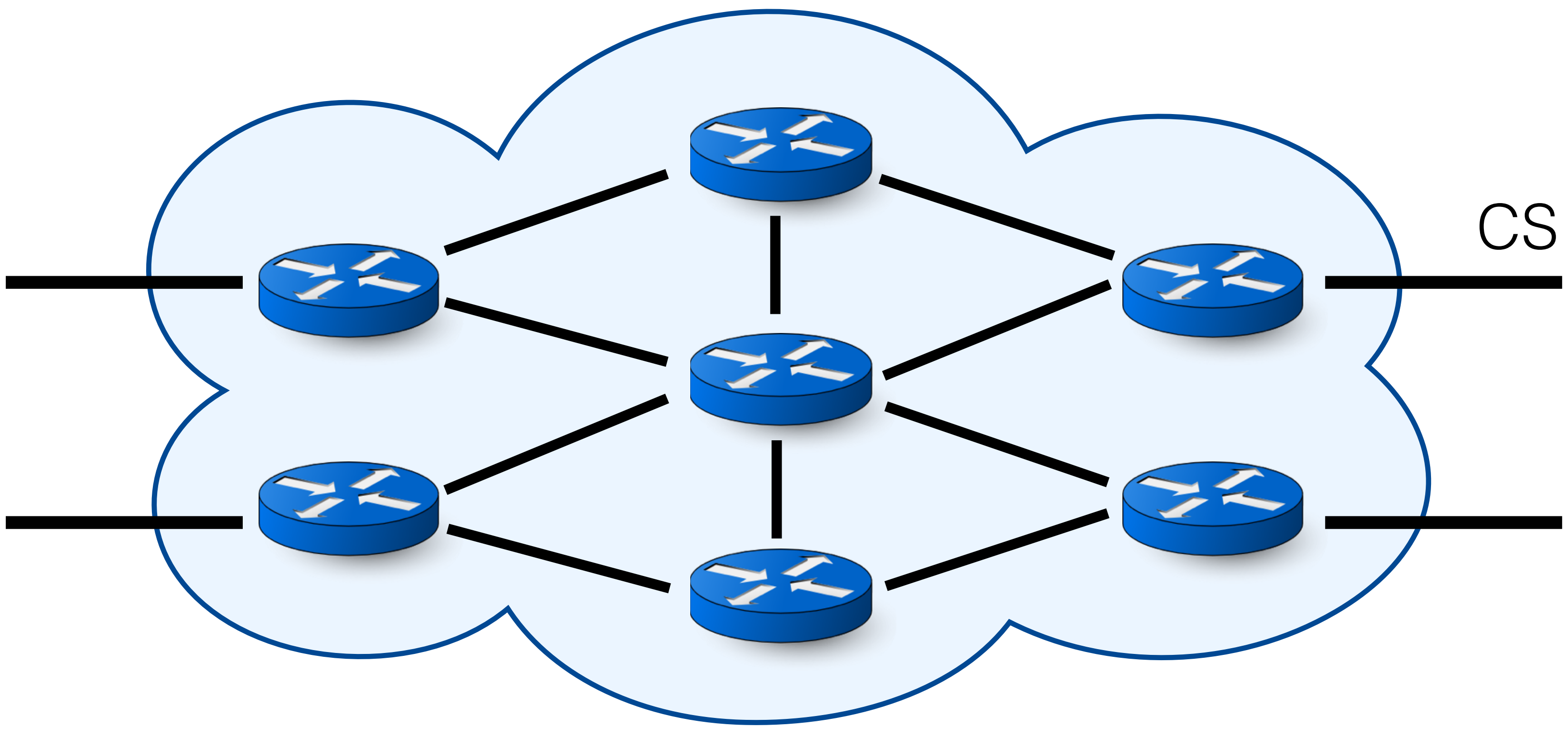
where to place state variables

how to forward packets through them

Program Analysis

- Each flow should go through switches with
    - all the state variables that it needs
    - in the correct order

Mixed-Integer Linear Program (MILP)



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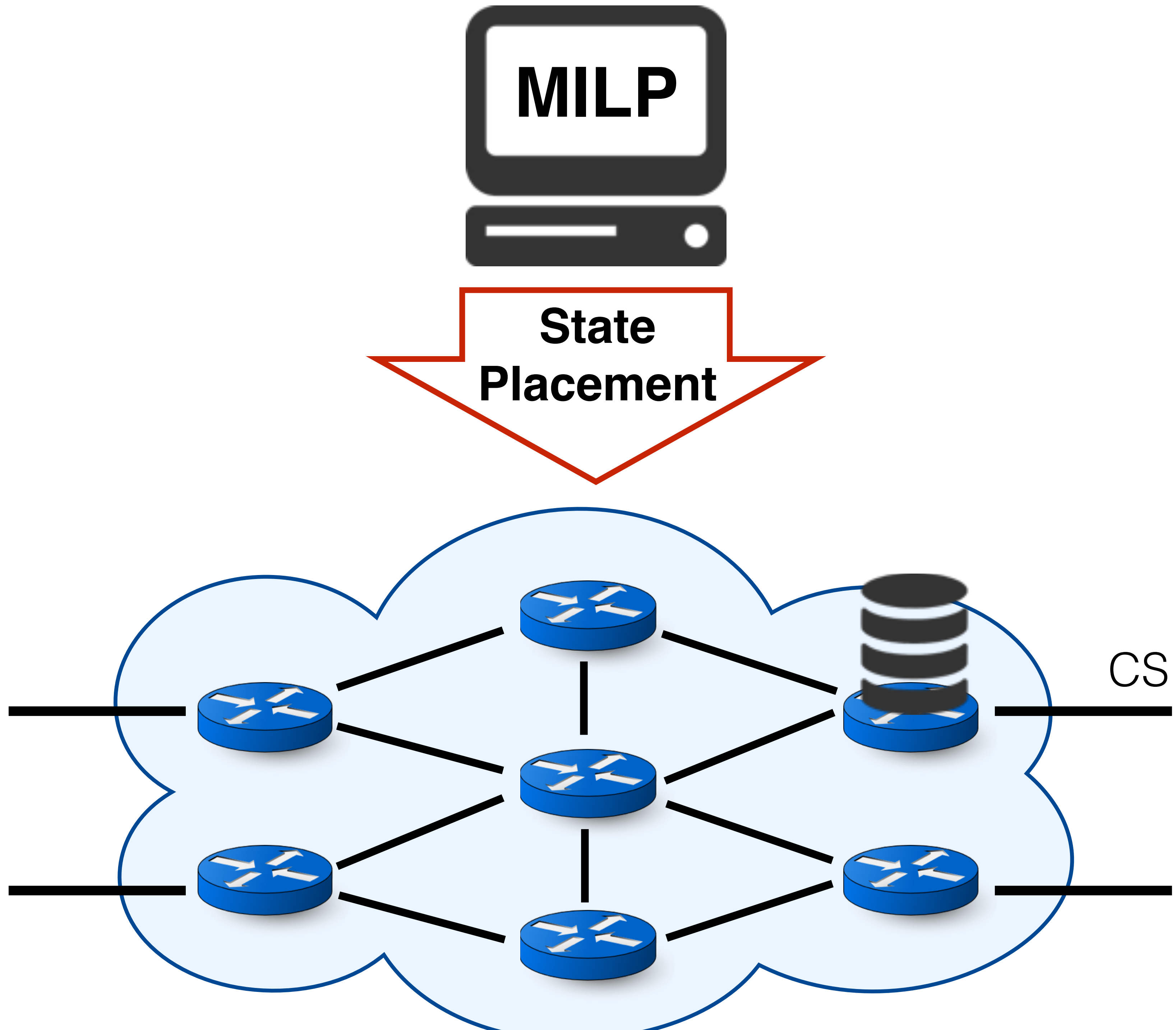

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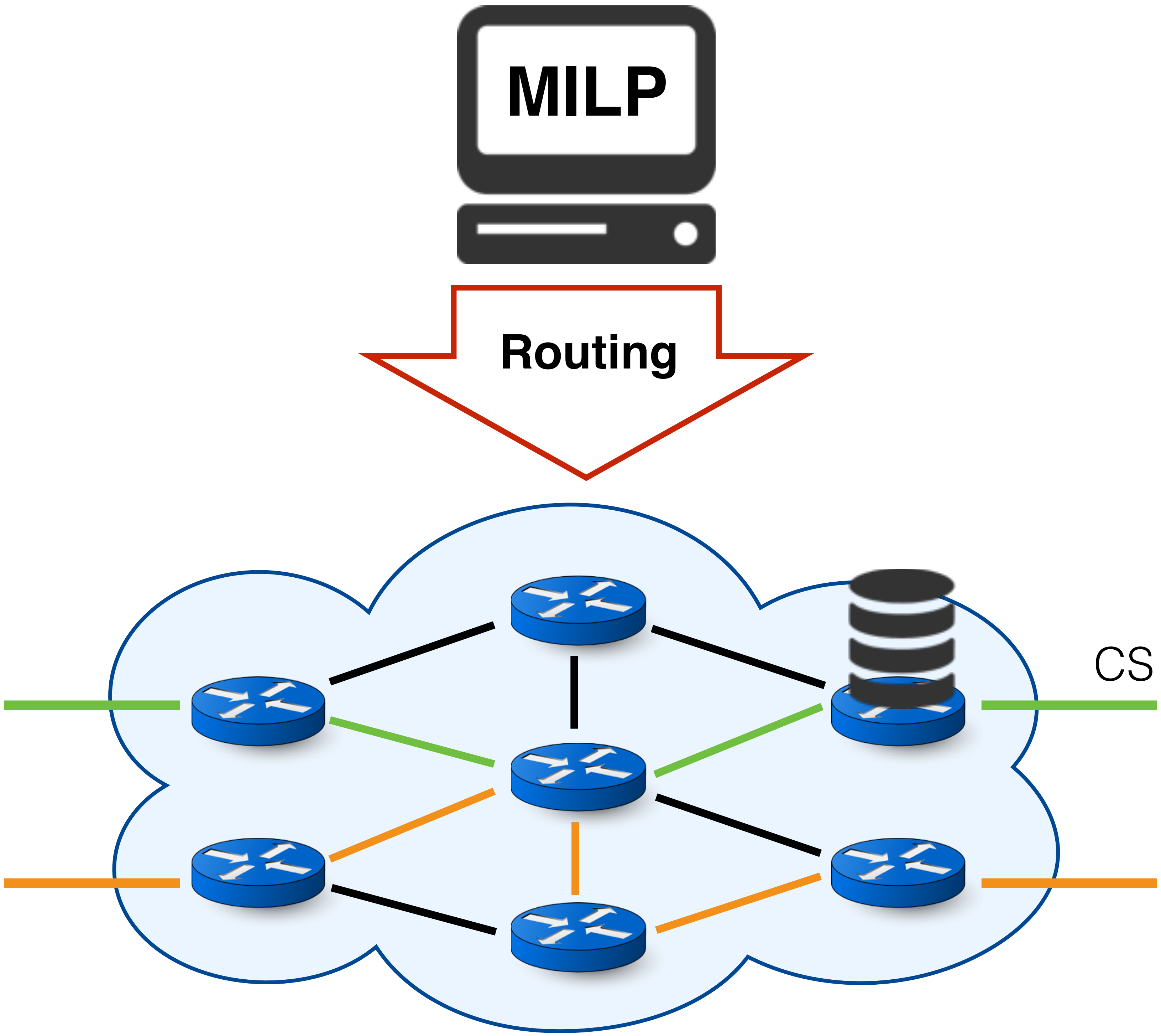
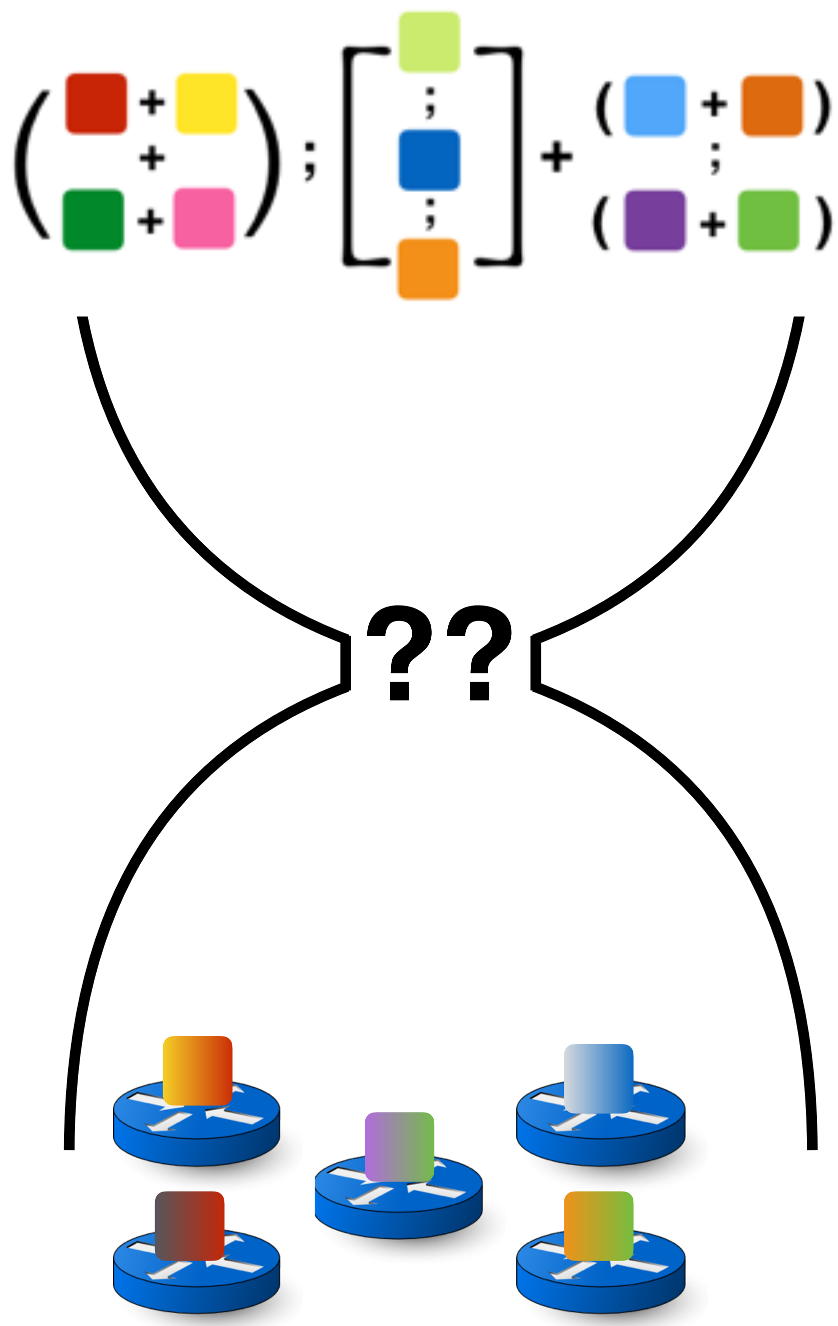


Intermediate Representation (IR)



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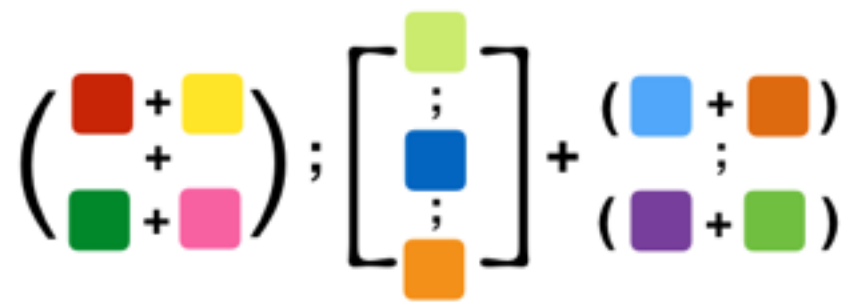
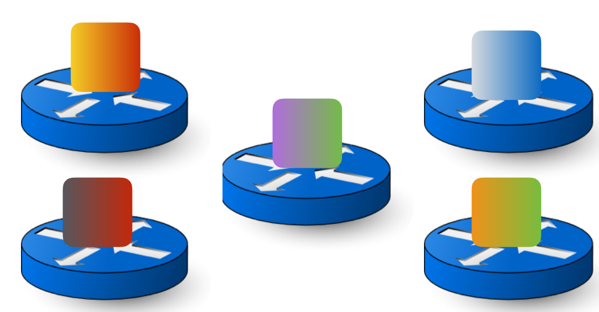


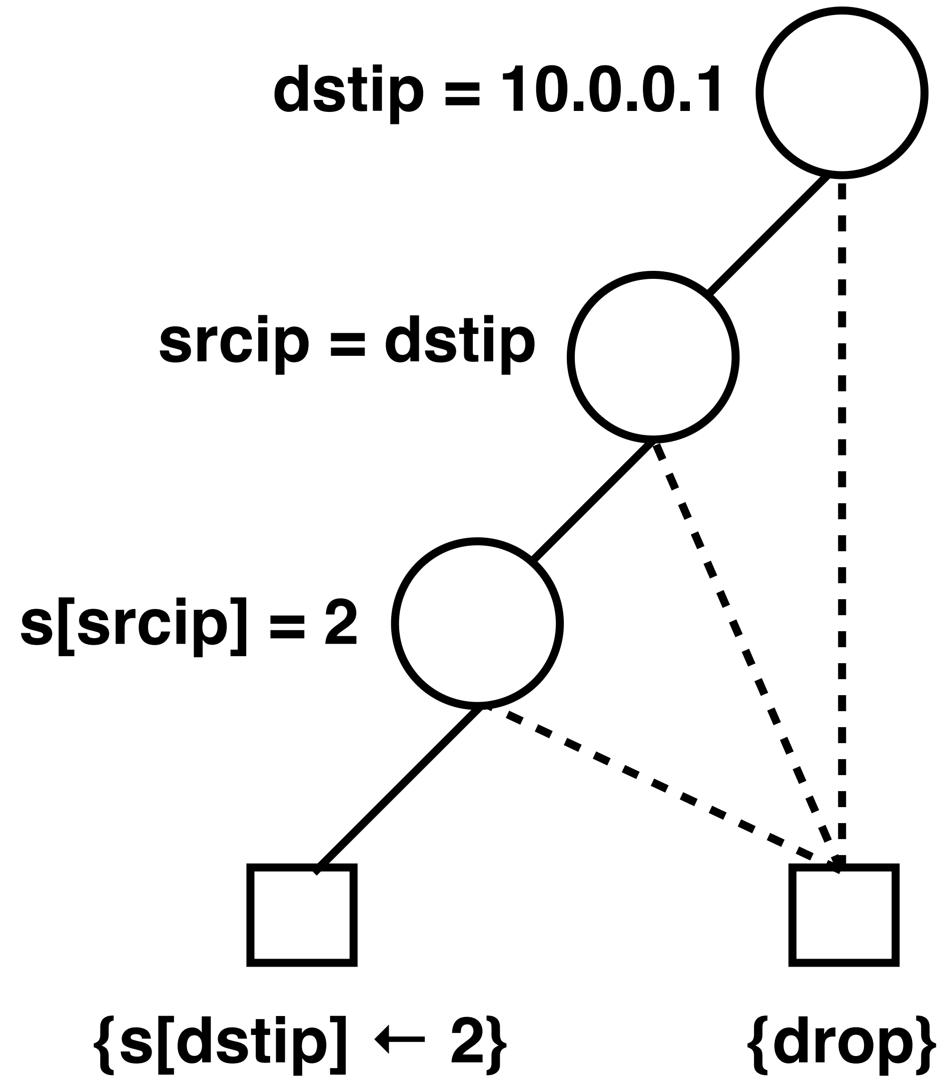
Composable and Easily Partitioned IR



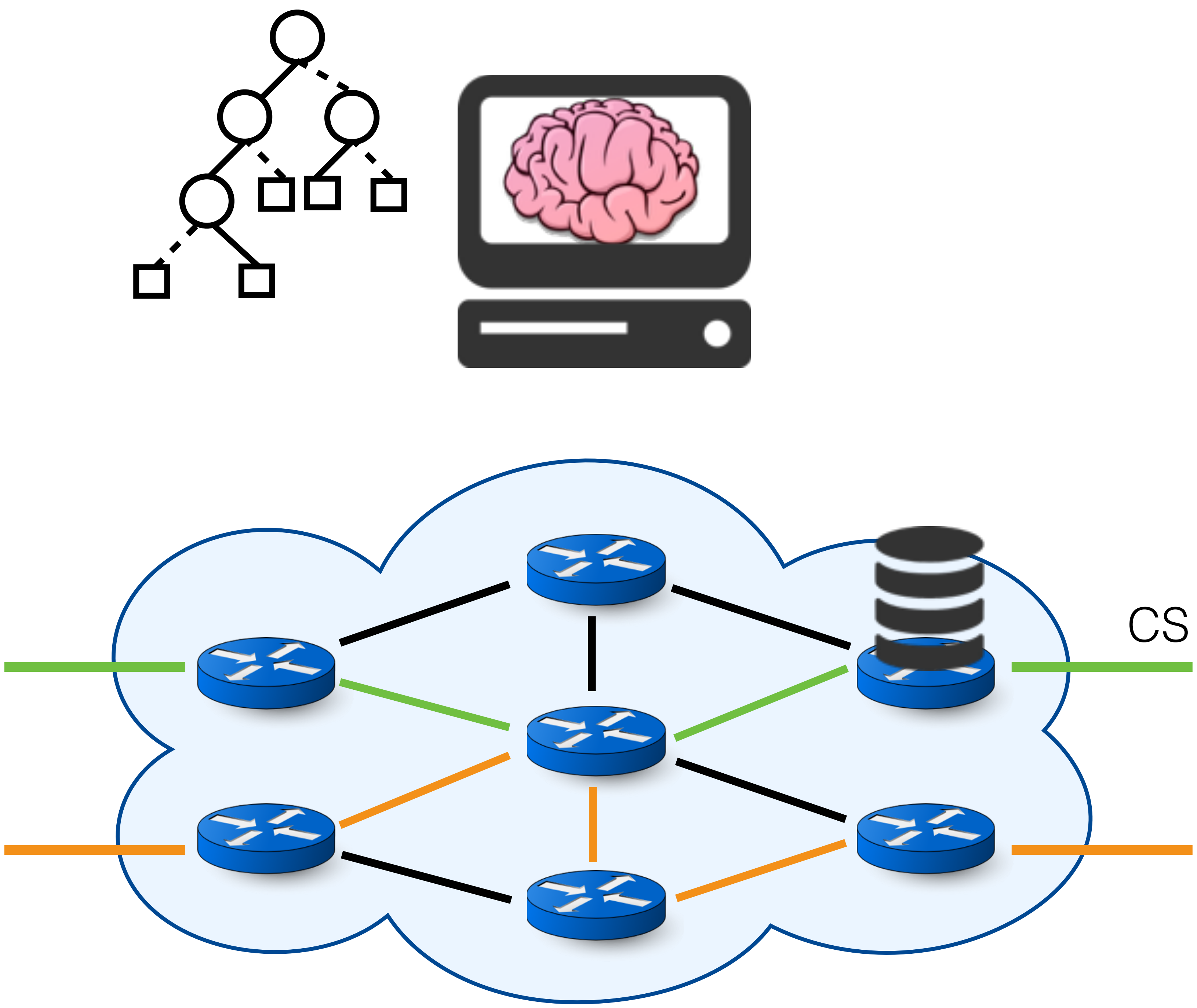
Extended Forwarding Decision Diagrams (xFDDs)

- Intermediate node:
  test on header fields and state

- Leaf: set of action sequences



Distributing the xFDD



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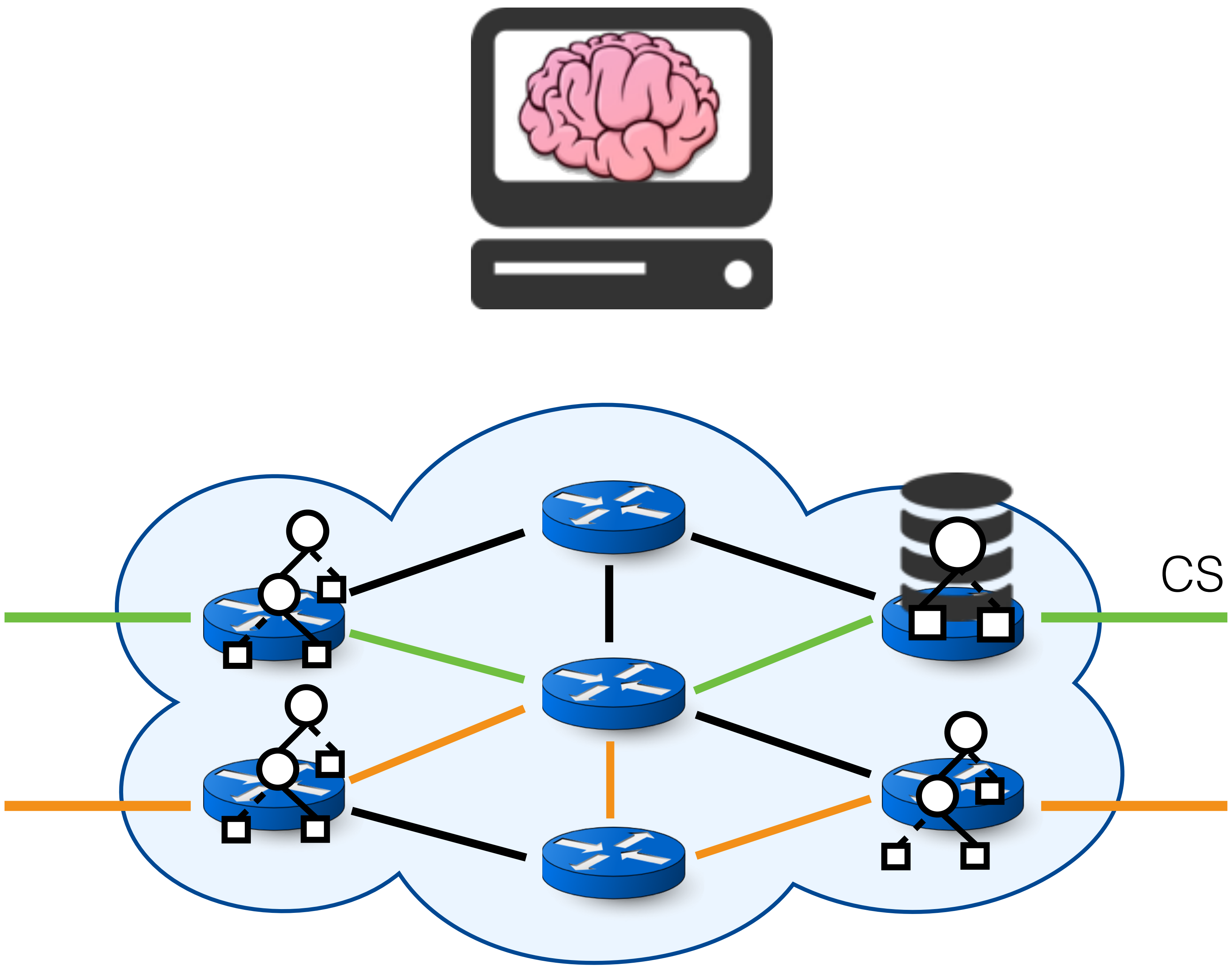
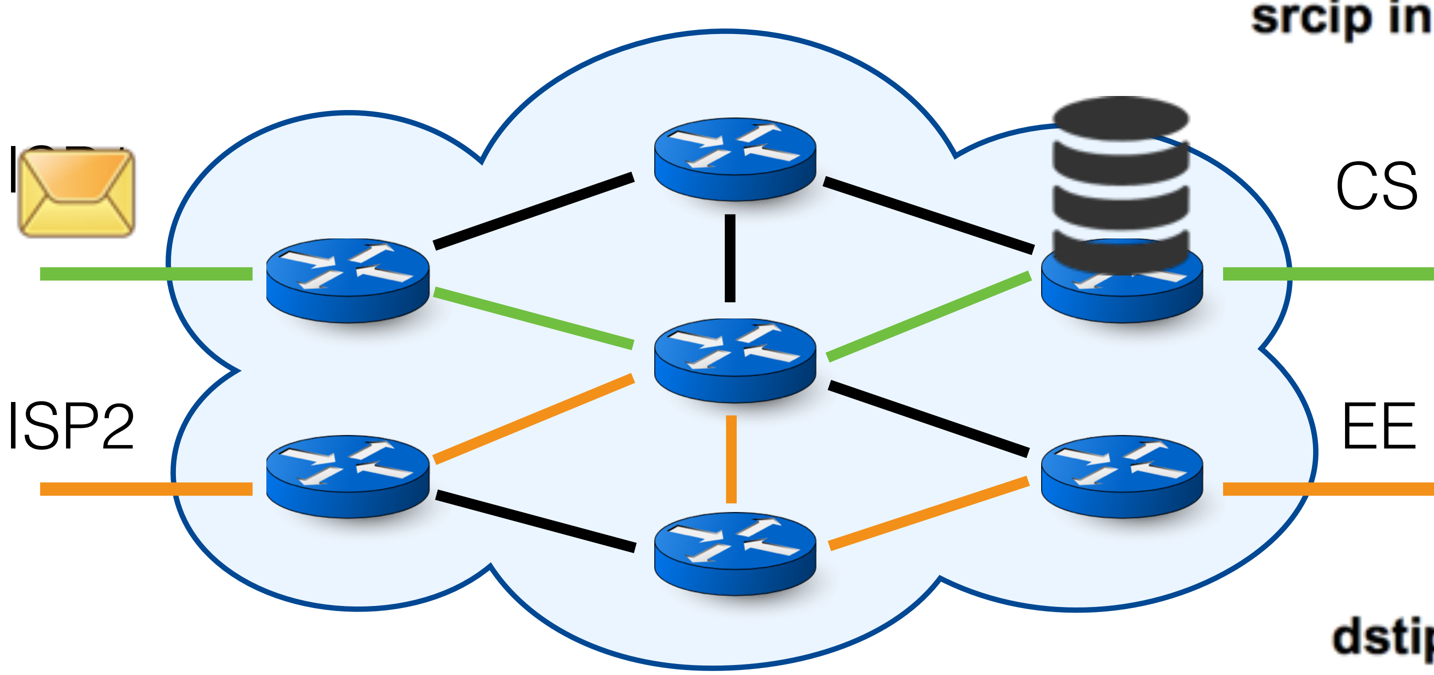
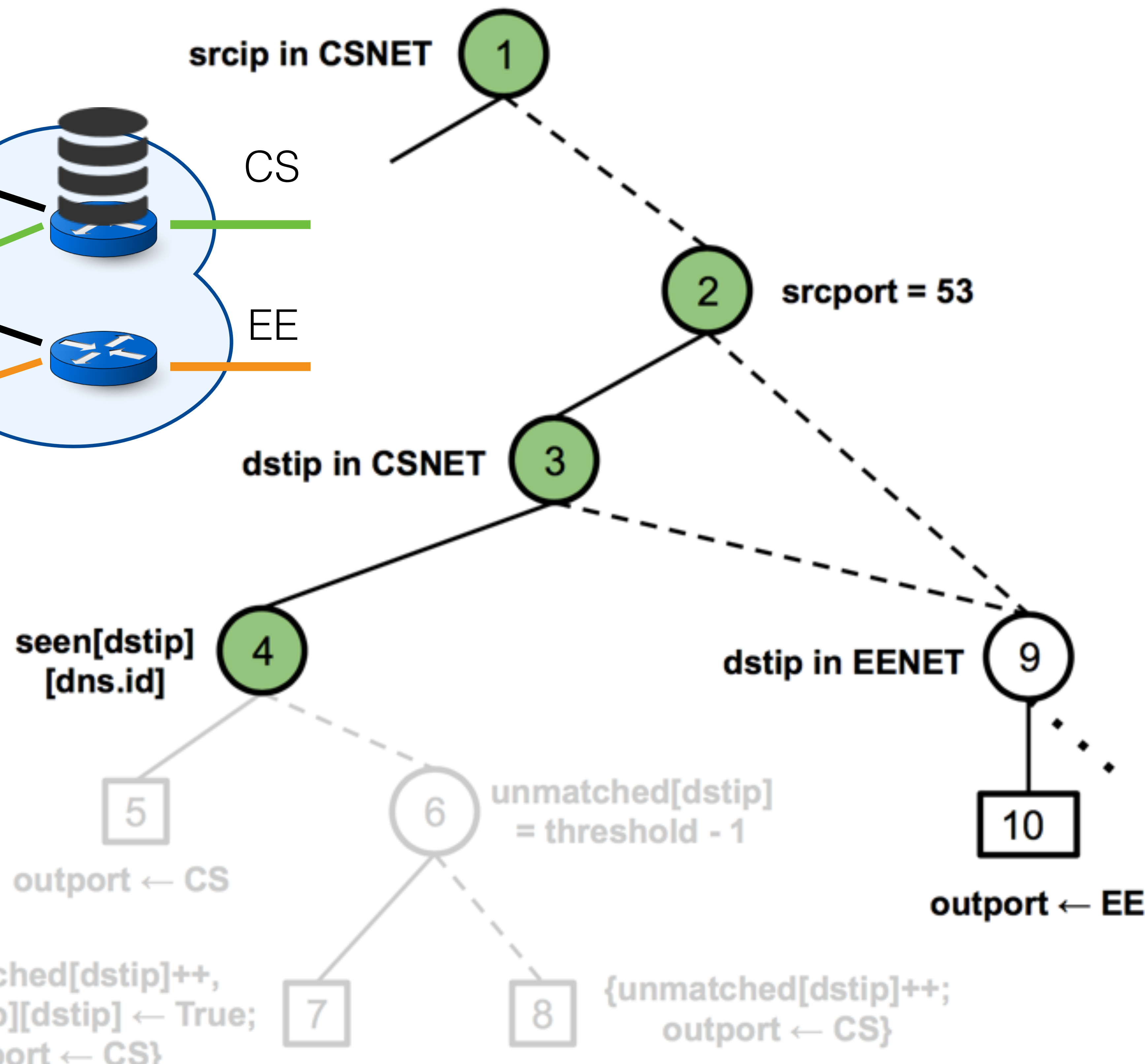


Putting It All Together





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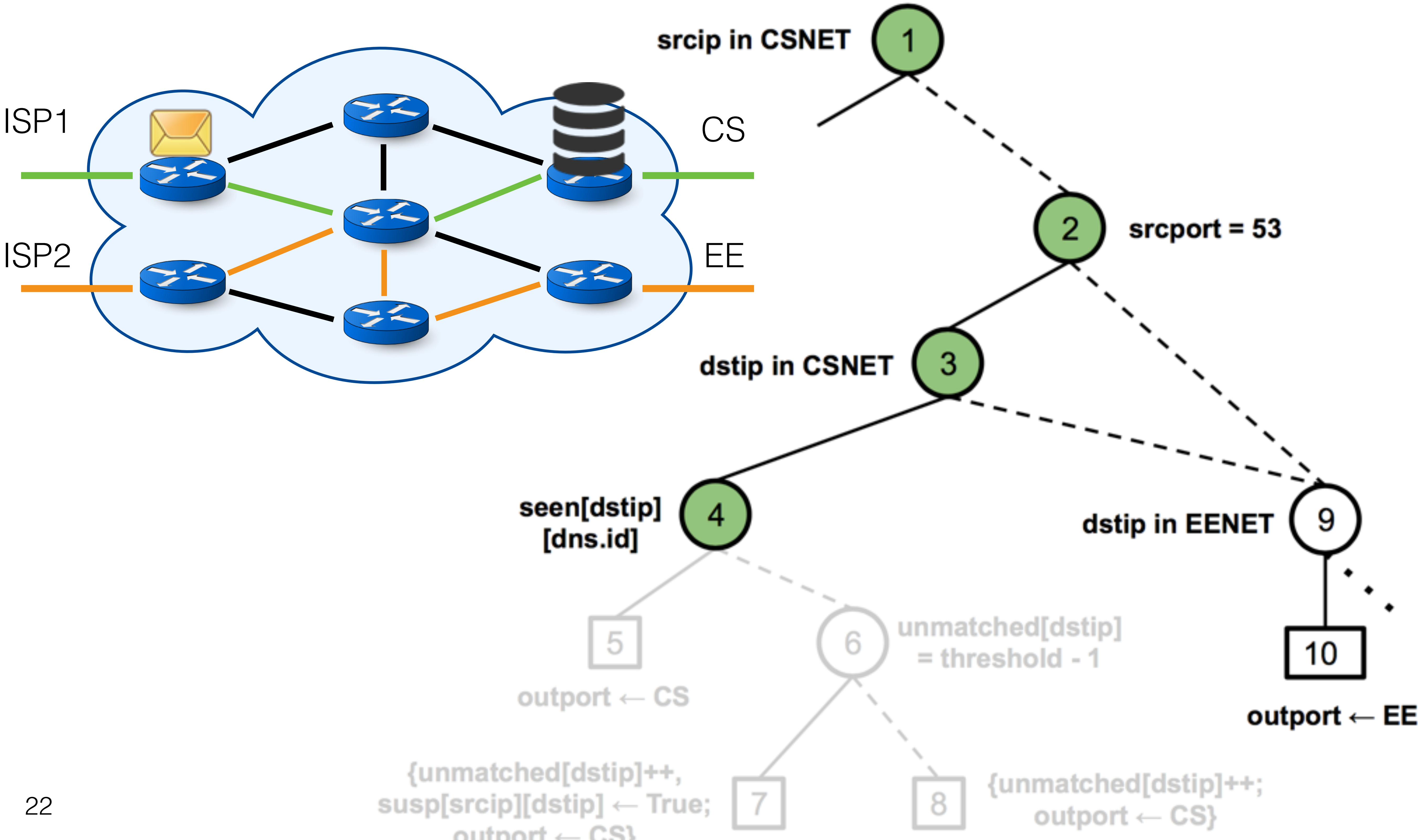

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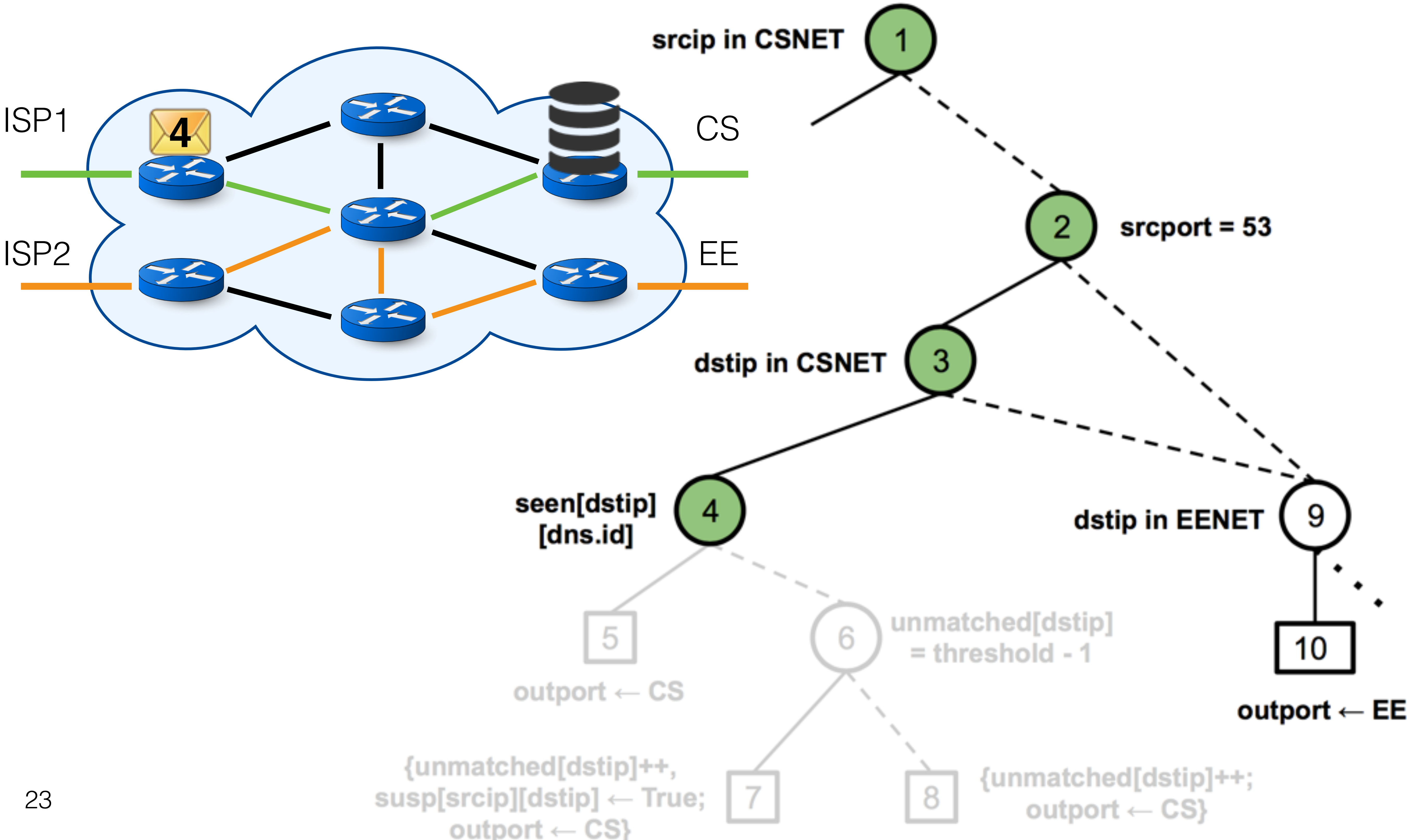

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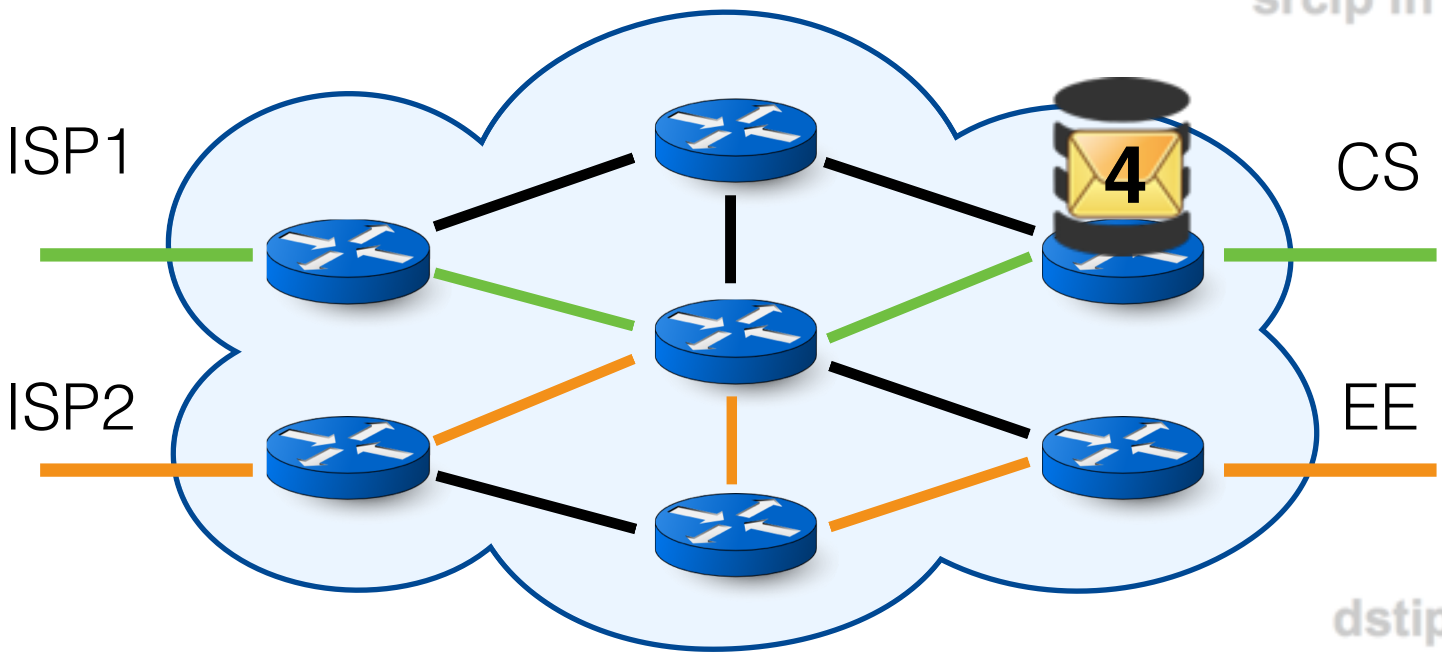

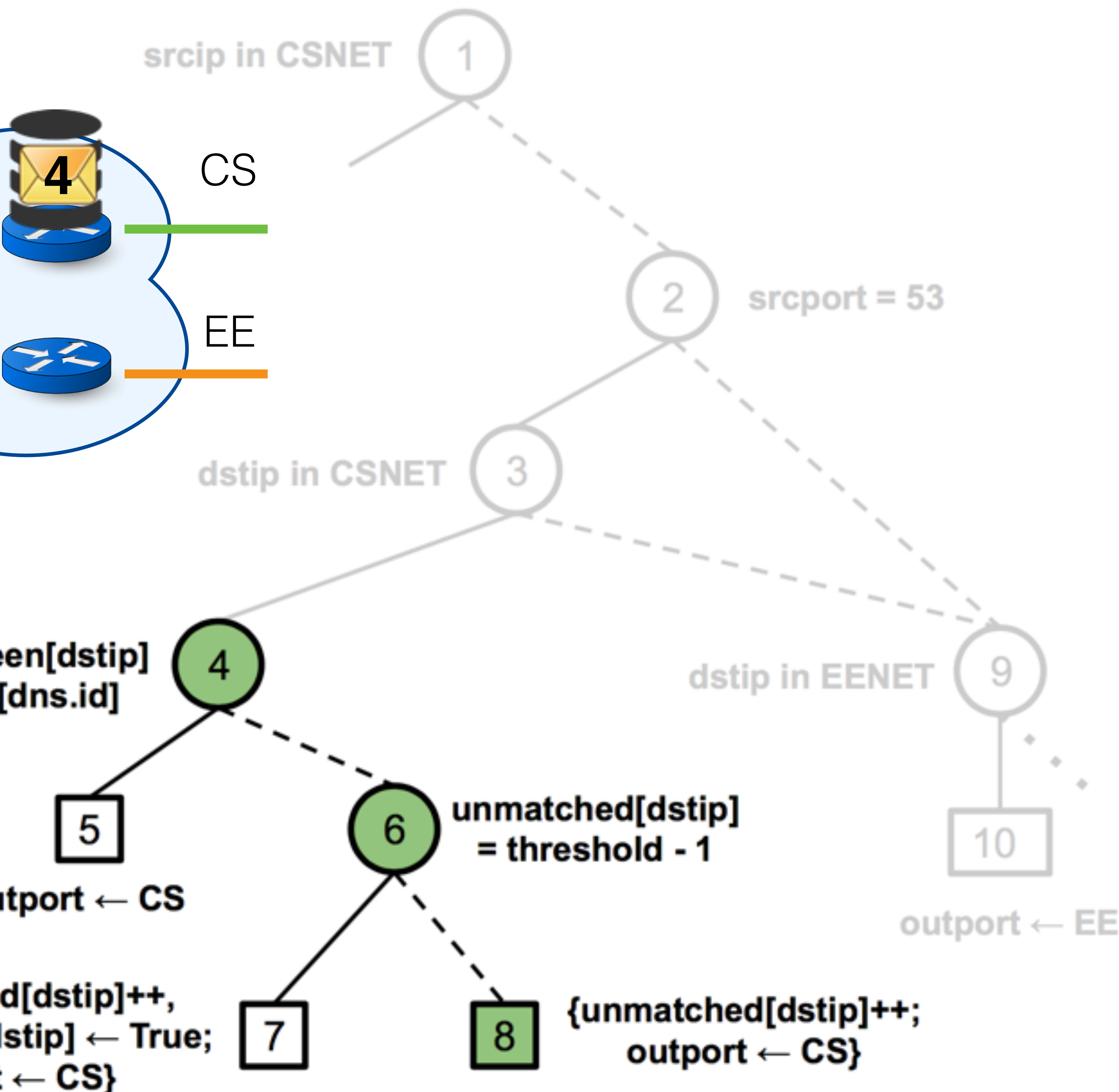

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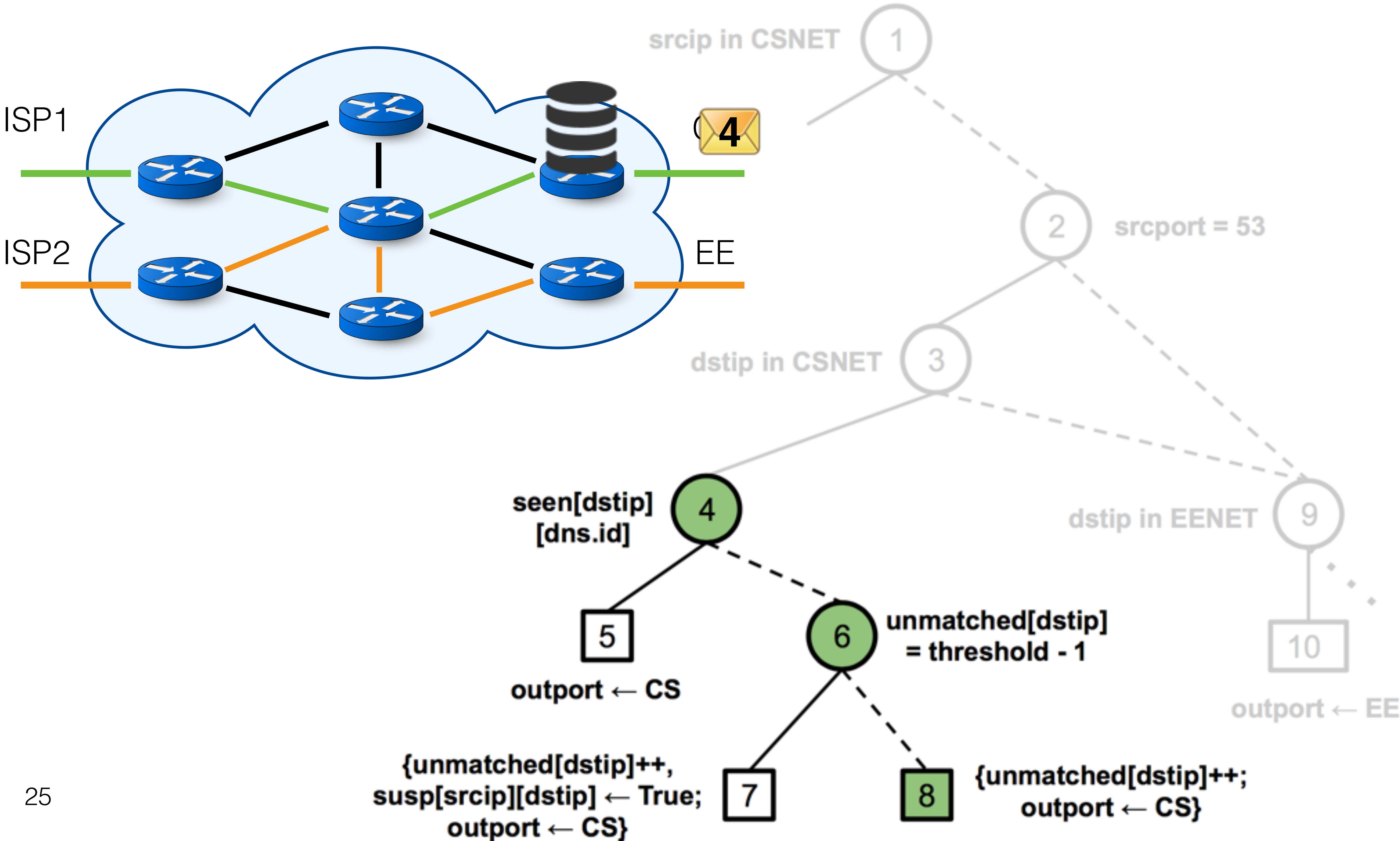
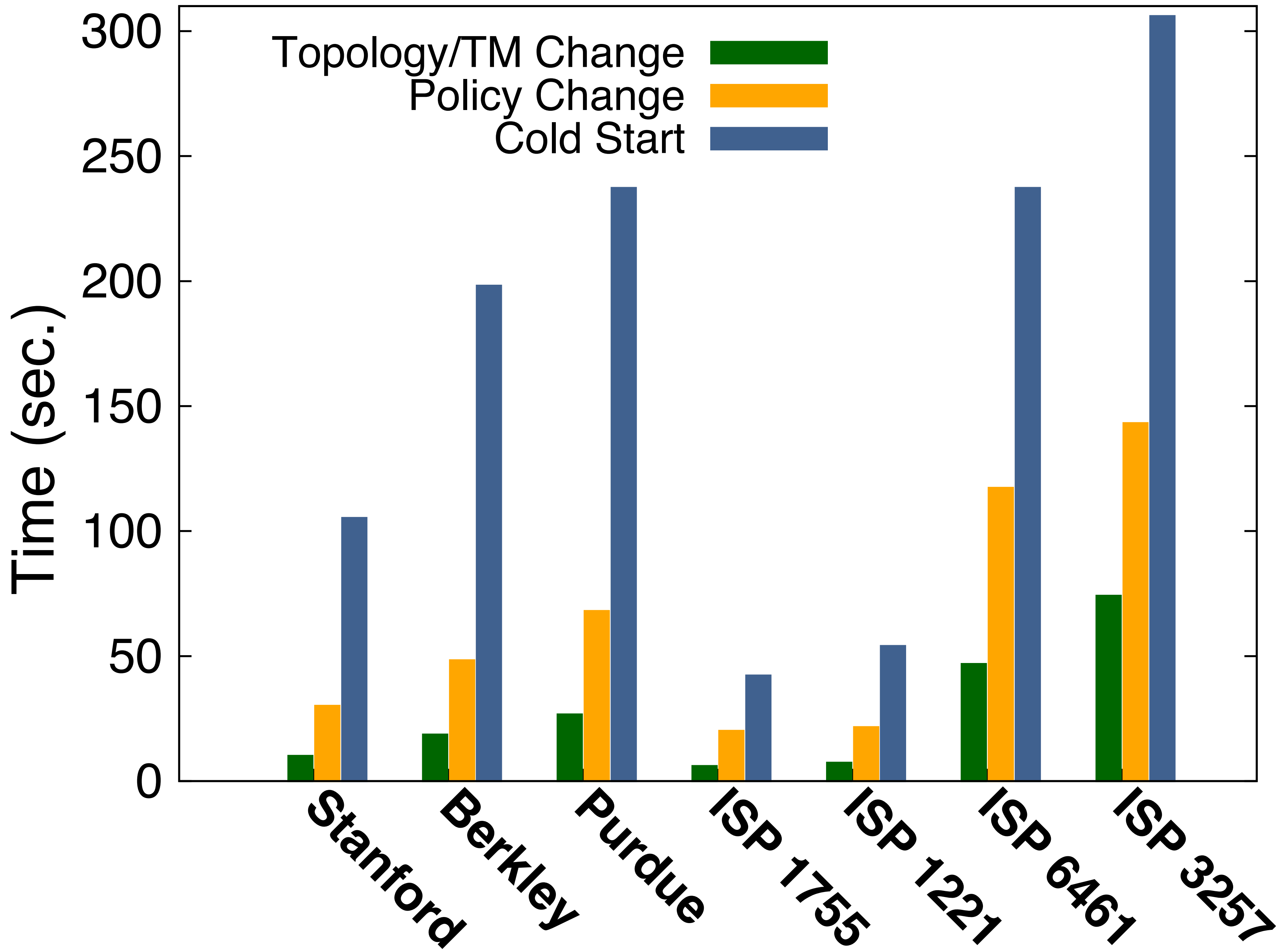


Compiler Evaluation - Benchmarks and Scenarios

- Topologies with 100s of switches and edges
  - 7 campus and ISPs
- Scenarios
  - Cold start
  - Policy change
  - Topology/TM change

Compiler Evaluation - Results



Thank You!

Questions?