Where is the Debugger for my Software-Defined Network?

[ndb]

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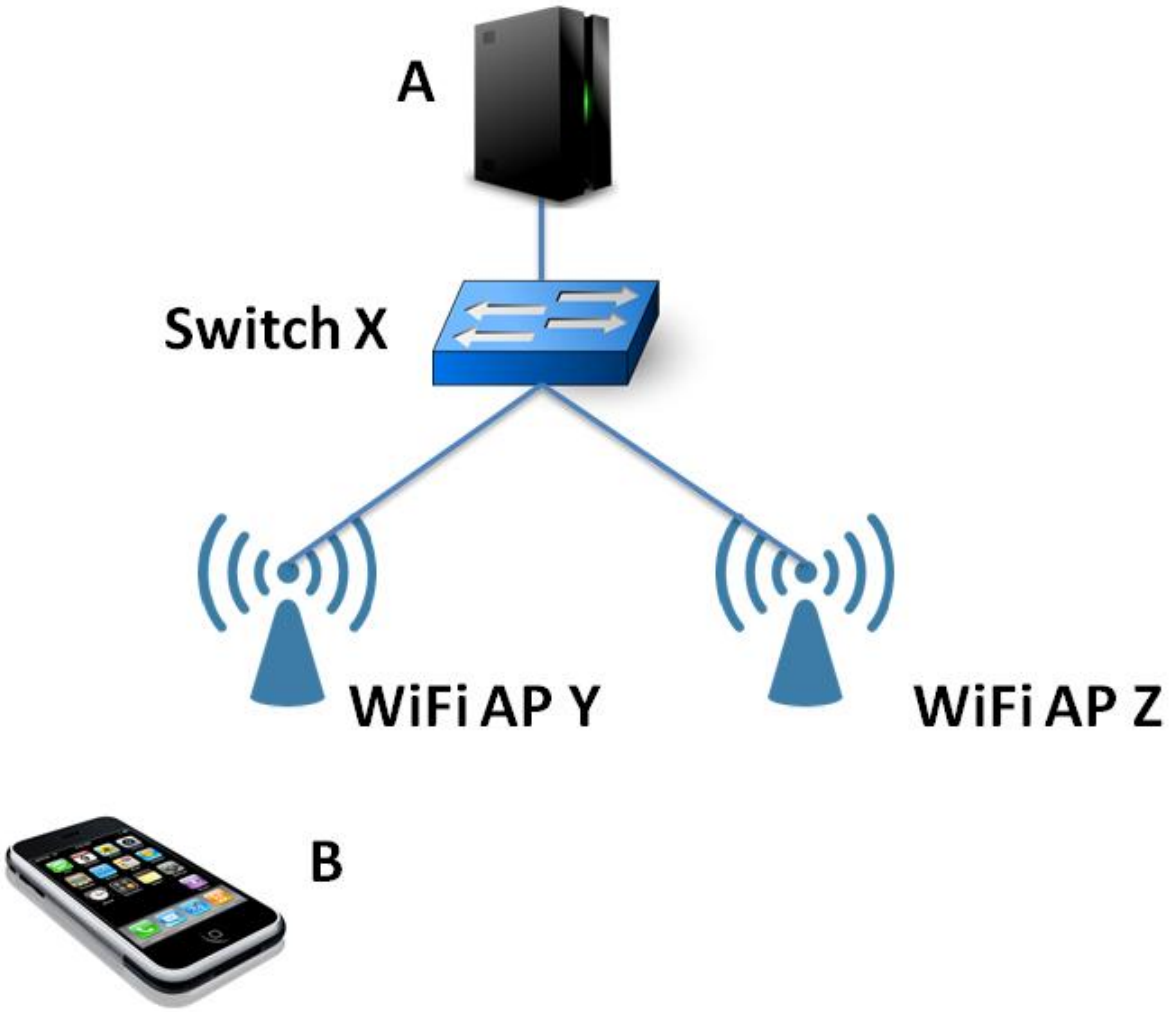
Bug story: incomplete handover



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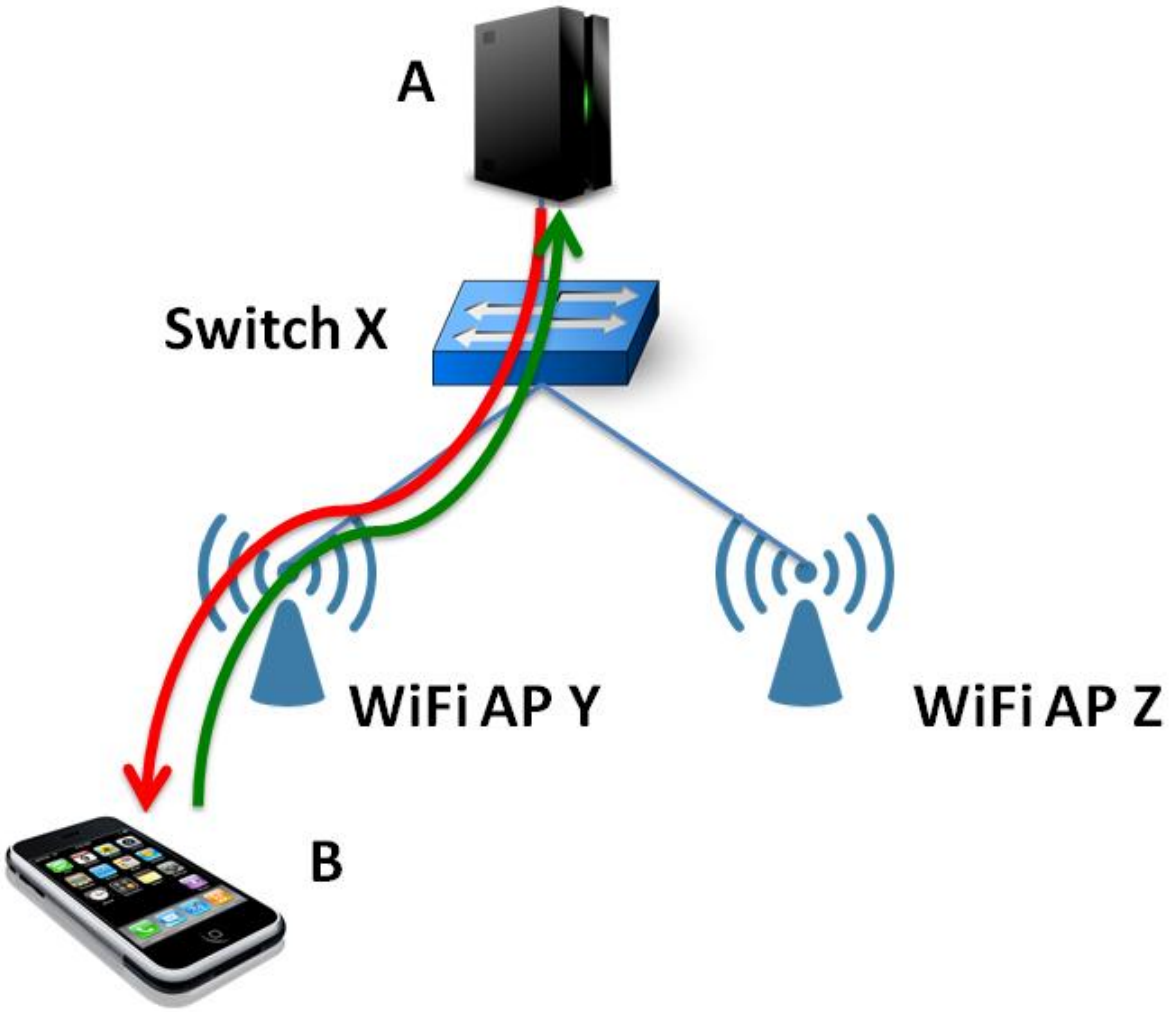

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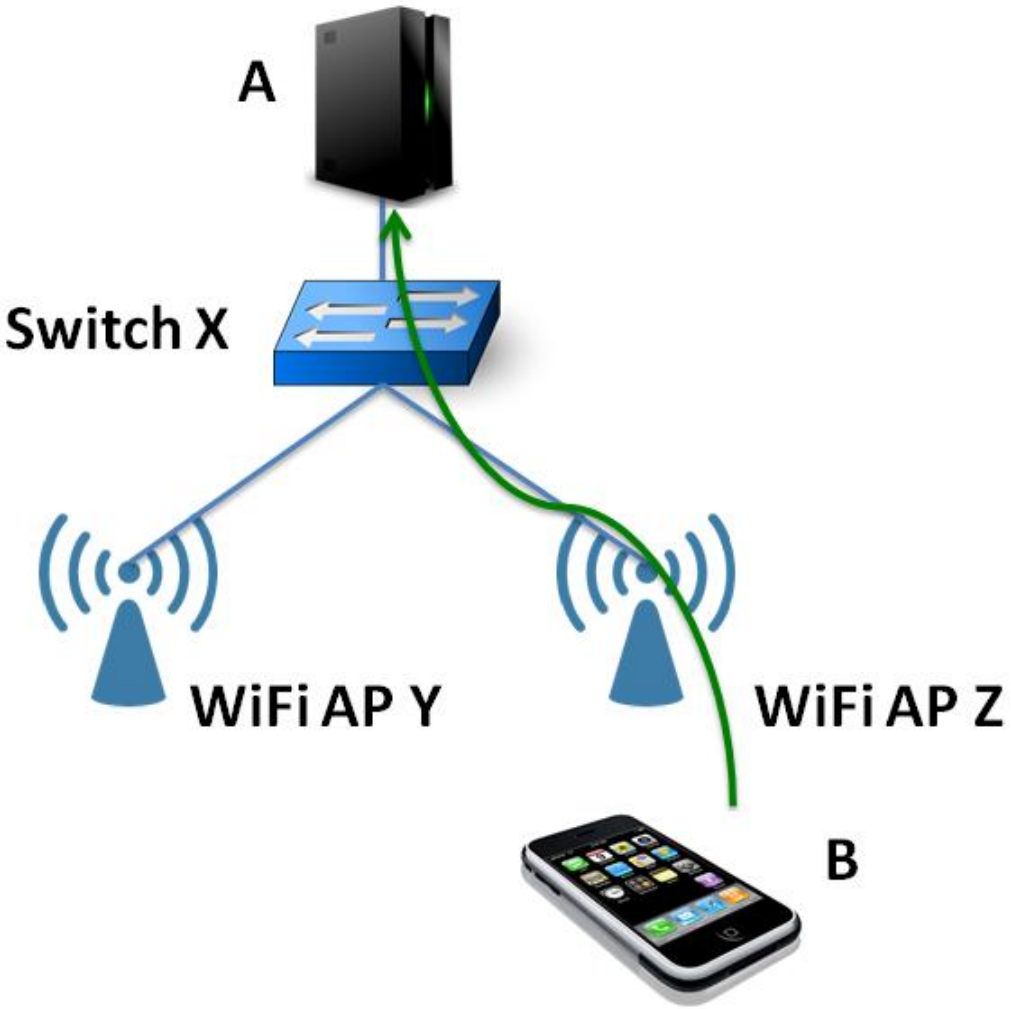

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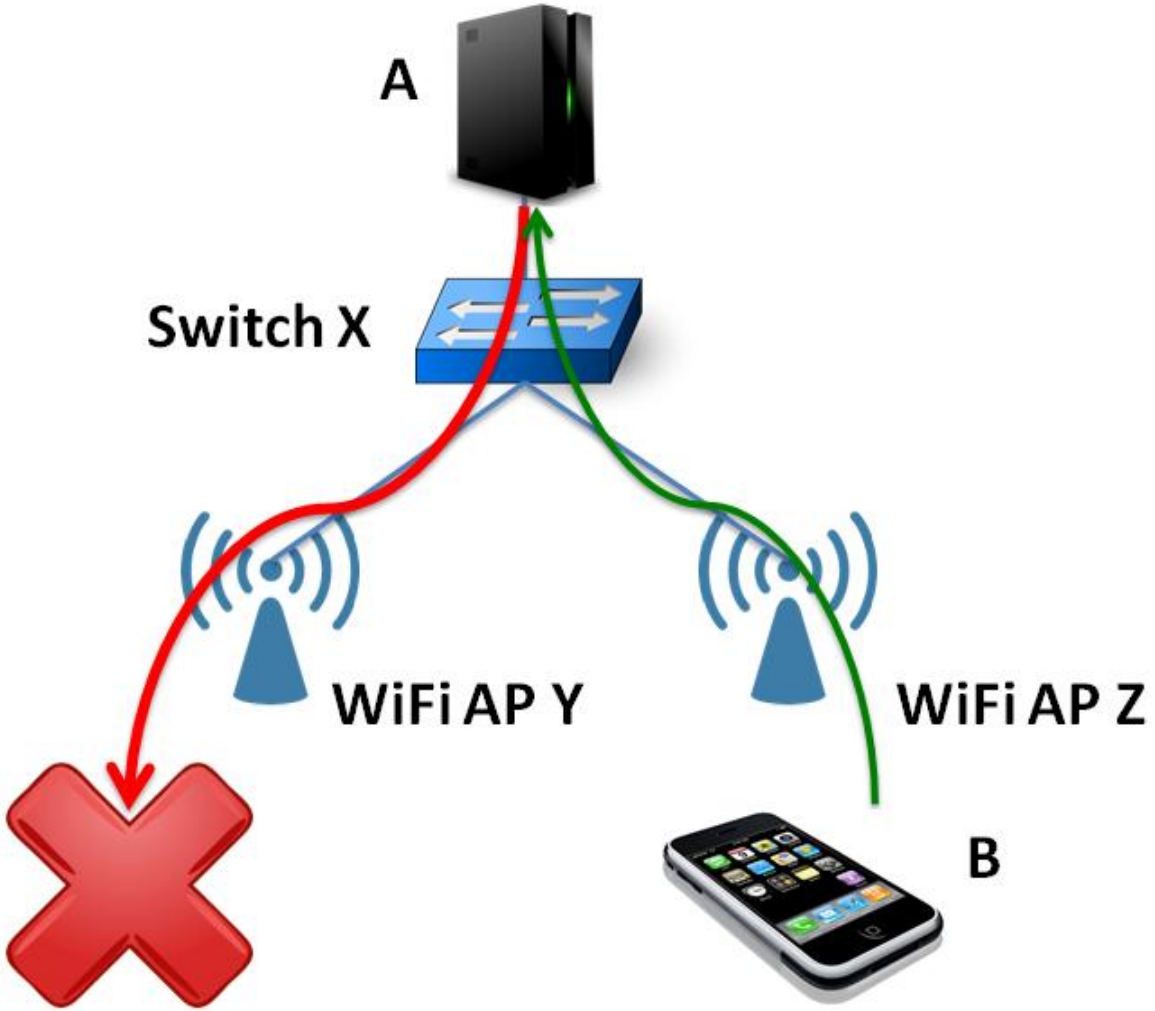


Debugging SDNs

- Bugs can be anywhere in the SDN stack
  - Hardware, control plane logic, race conditions
- Switch state might change rapidly
- Bugs might show up rarely

How can we exploit the SDN architecture
to systematically track down
the root cause of bugs?

ndb: Network Debugger

Goal

- Capture and reconstruct the sequence of events leading to the errant behavior

Allow users to define a Network Breakpoint

- A (header, switch) filter to identify the errant behavior

Produce a Packet Backtrace

- Path taken by the packet
- State of the flow table at each switch

Debugging software programs

```
Function A():
    i = …; j = …;
    u = B(i, j)
```

```
Function B(x, y):
    k = …;
    v = C(x, k)
```

```
Function C(x, y):
    …
    w = abort()
```

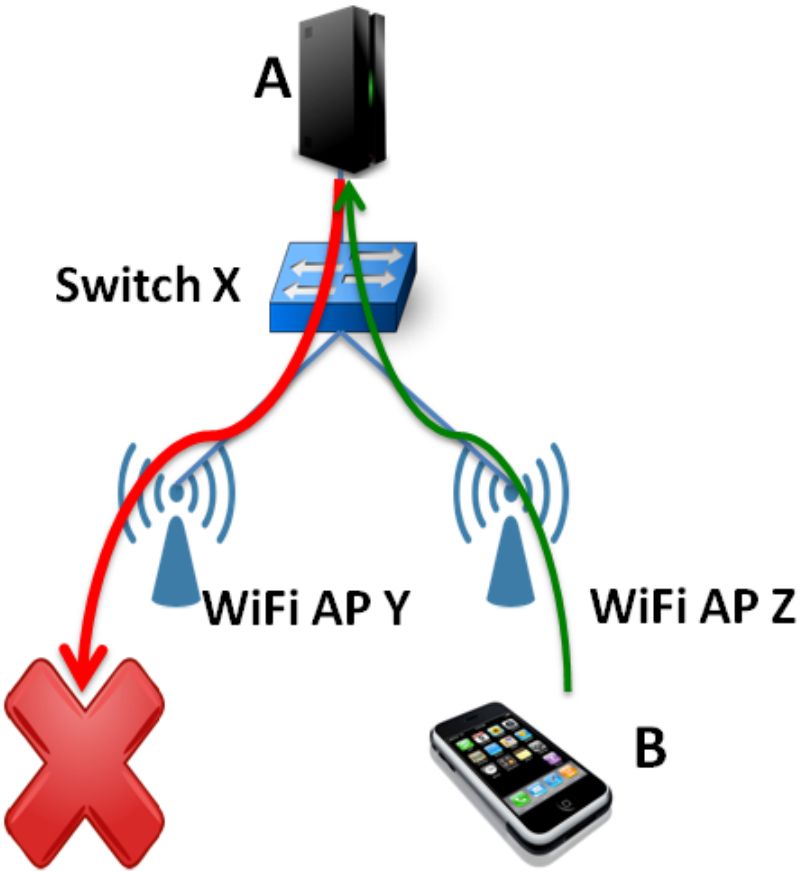
Breakpoint

"line 25, `w = abort()`"

Backtrace

File "A", line 10, **Function A()**
File "B", line 43, **Function B()**
File "C", line 21, **Function C()**

Debugging networks

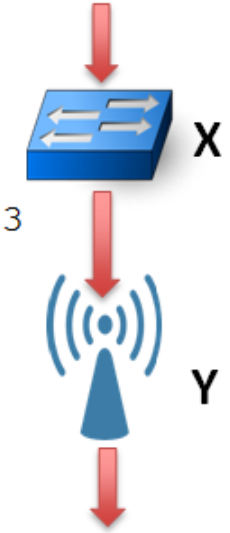


Breakpoint

"ICMP packets A->B,
arriving at X,
but not Z"

Backtrace

```
Switch X: {
  inport: p0,
  outports: [p1]
  mods: [...]
  matched flow: 23 [...]
  matched table version: 3
}
Switch Y: {
  inport p1,
  outports: [p3]
  mods: ...
  ...
}
```



Using `ndb` to debug common issues

Reachability

- Symptom: A is not able to talk to B
- Breakpoint: *"Packet A->B, not reaching B"*

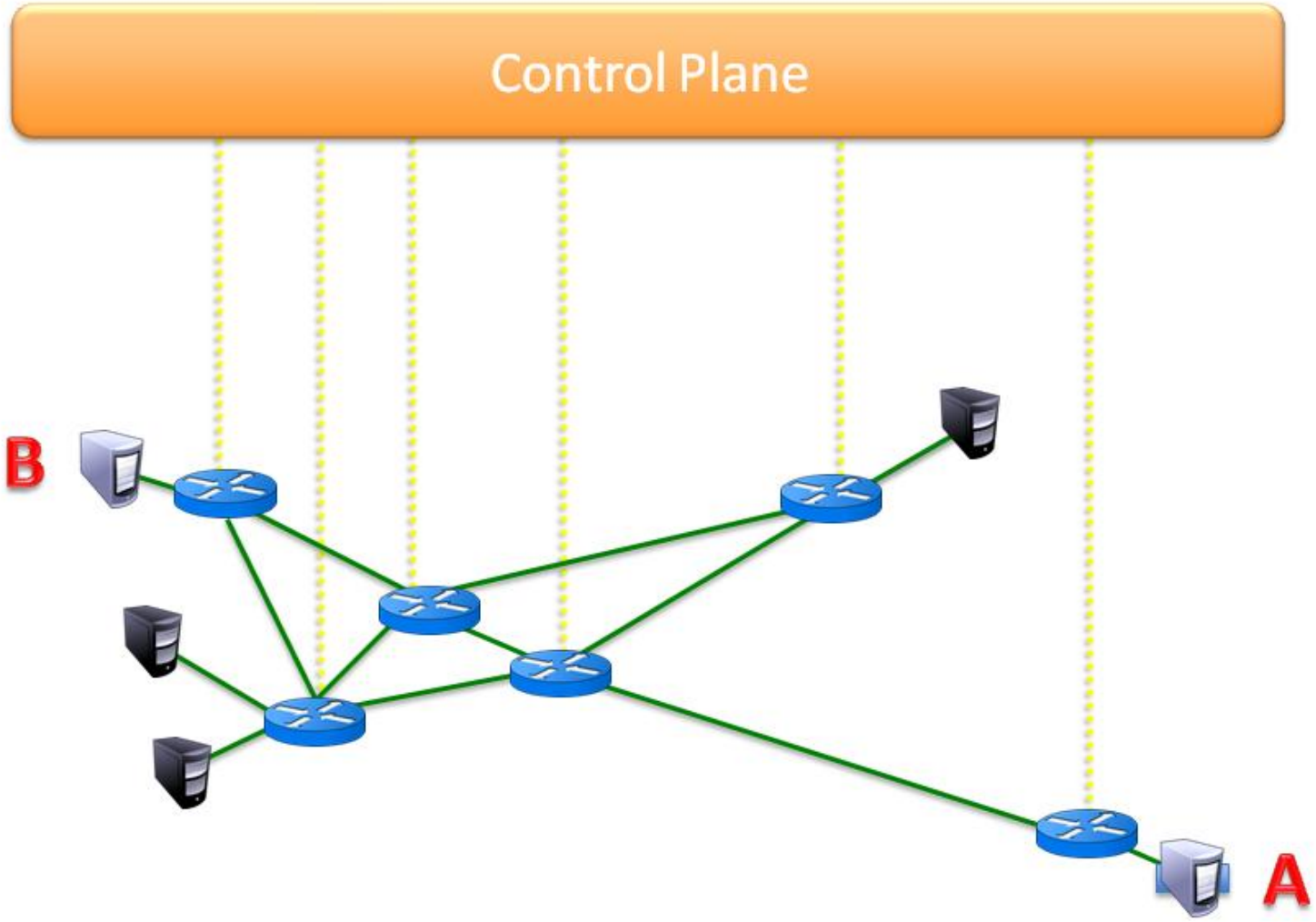
Isolation

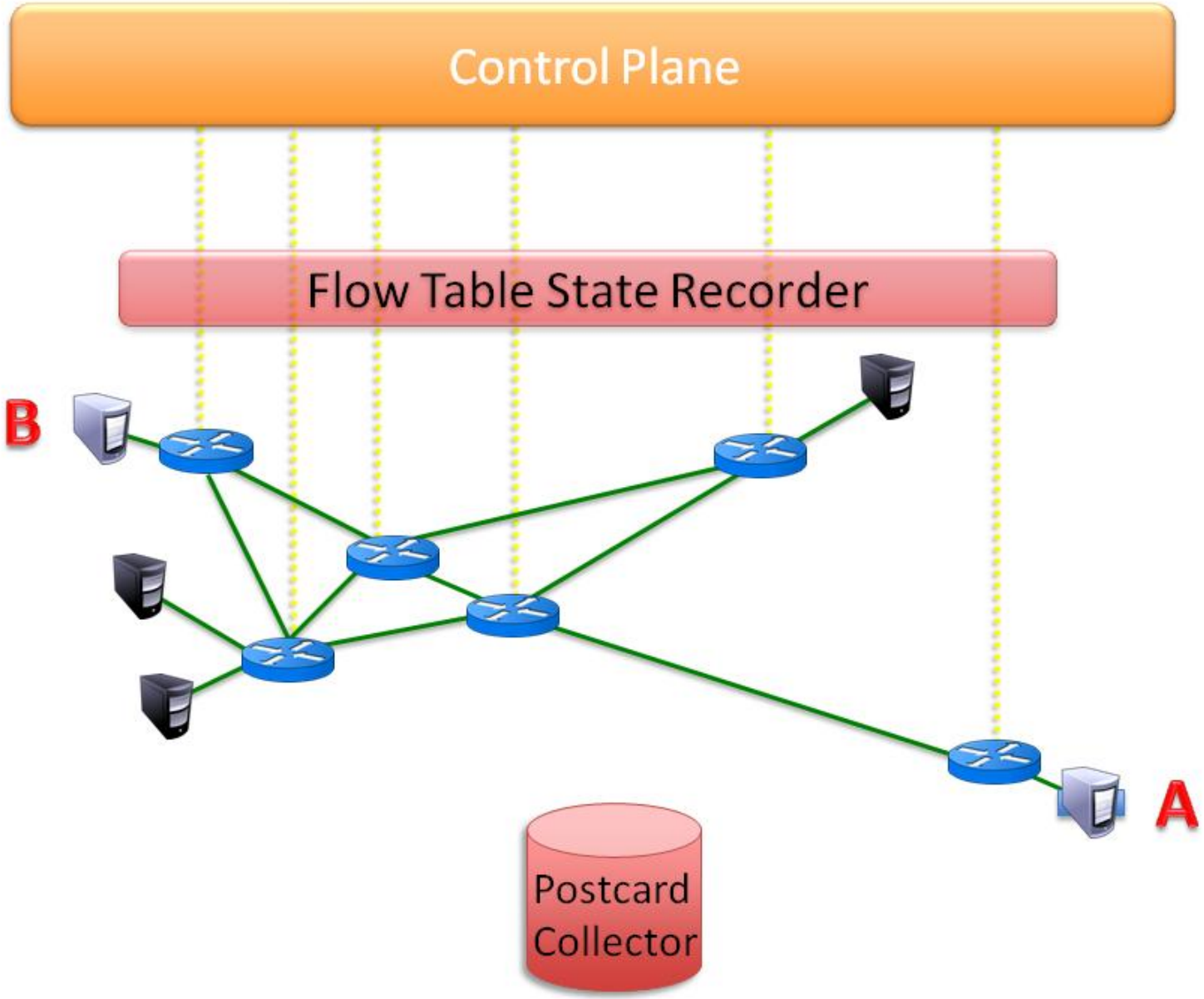
- Symptom: A is talking to B, but it shouldn't
- Breakpoint: *"Packet A->B, reaching B"*

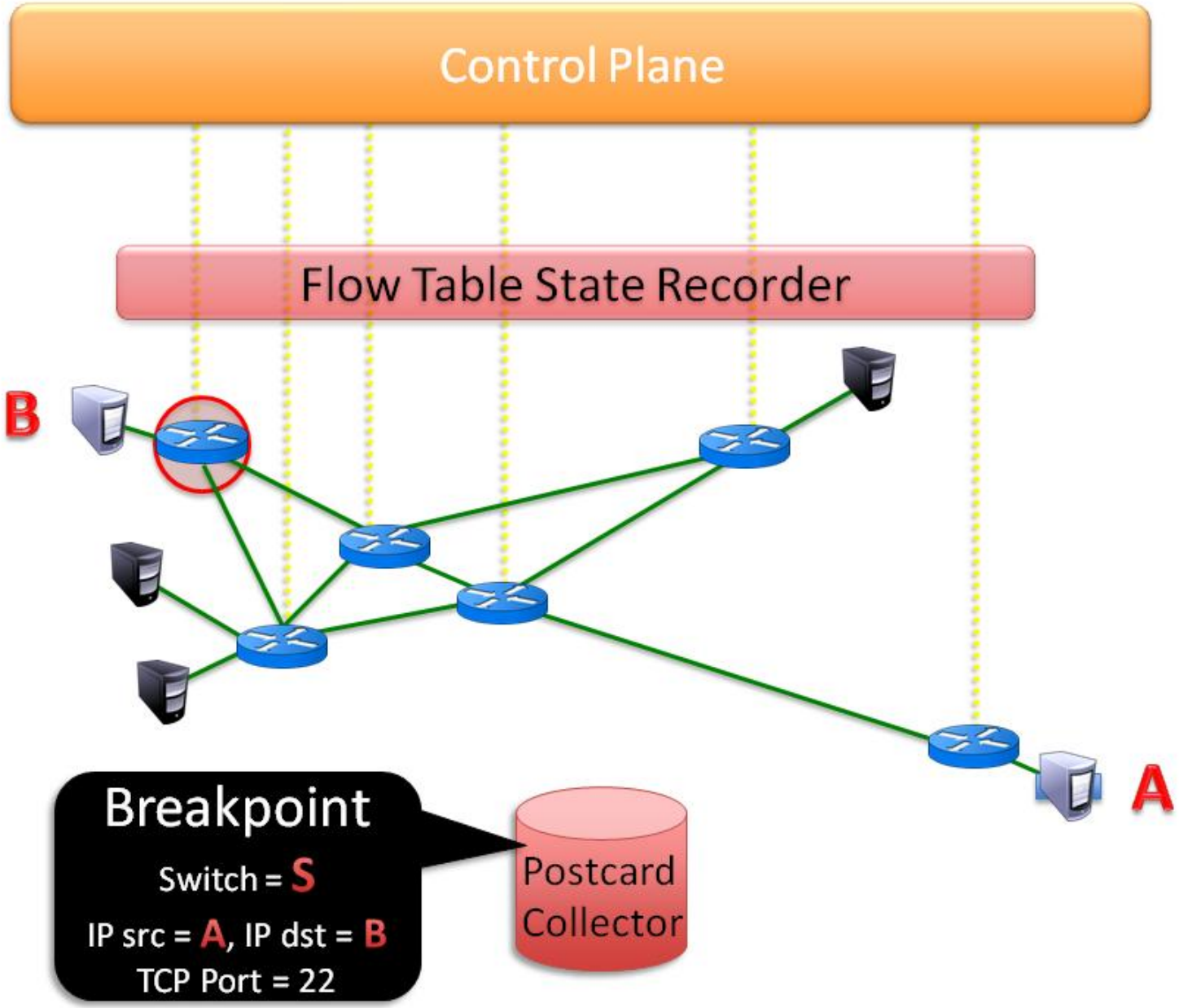
Race conditions

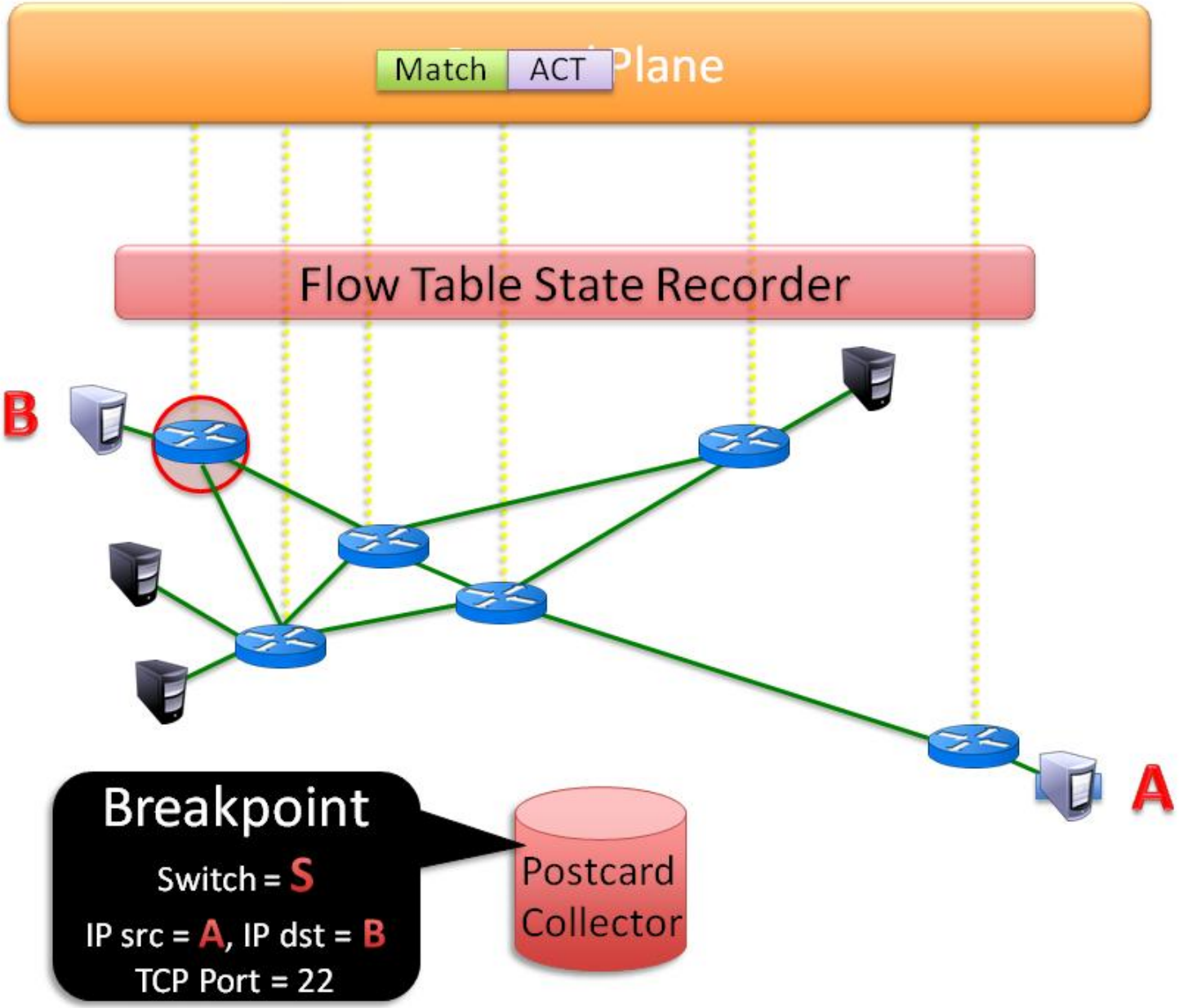
- Symptom: Flow entries not reaching on time
- Breakpoint: *"Packet-in at switch S, port P"*

So, how does `ndb` work?


Control Plane
B
A


Control Plane
Flow Table State Recorder
B
A
Postcard
Collector


Control Plane
Flow Table State Recorder
B
A
Breakpoint
Switch = S
IP src = A, IP dst = B
TCP Port = 22
Postcard Collector


Match
ACT
Plane
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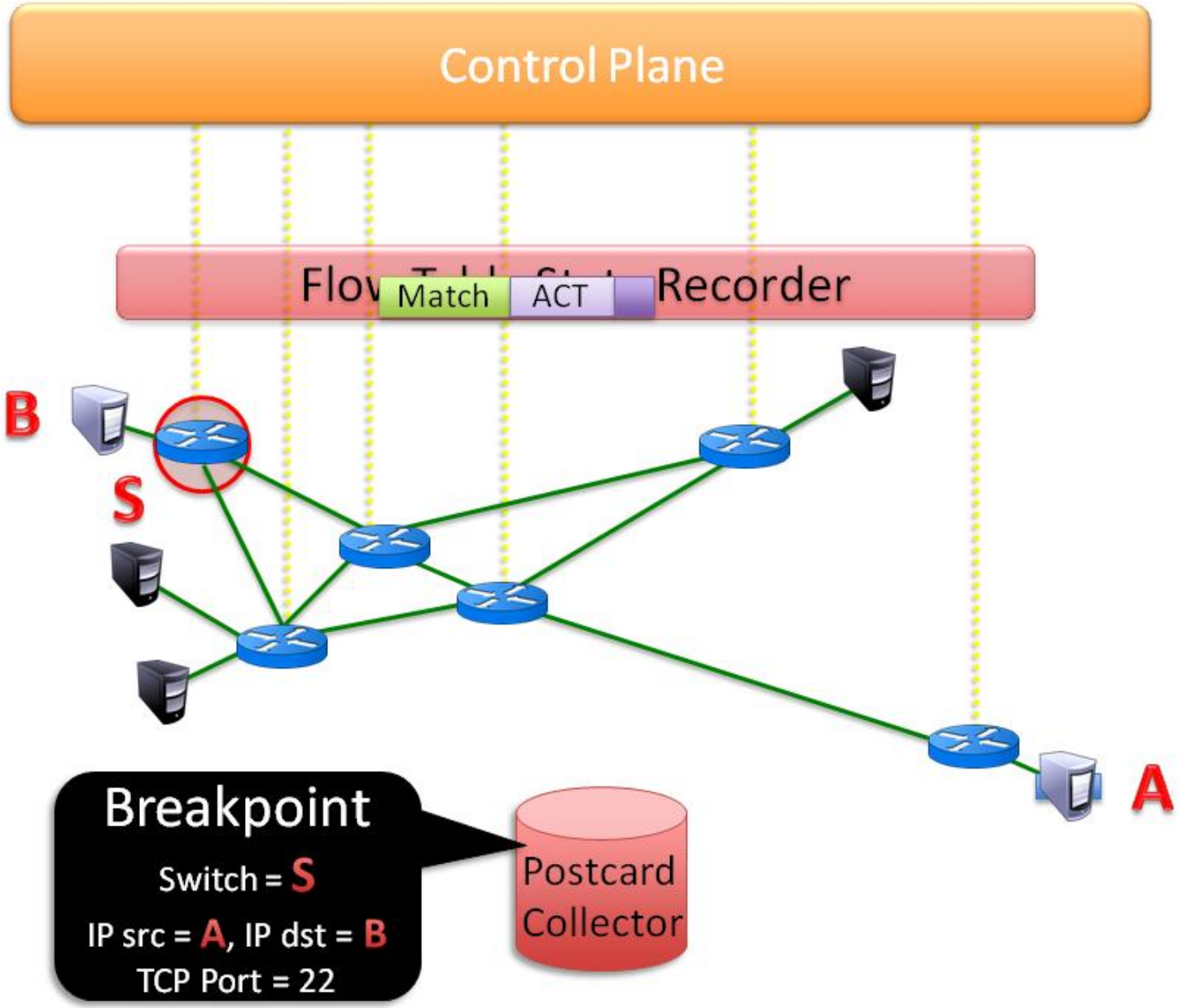
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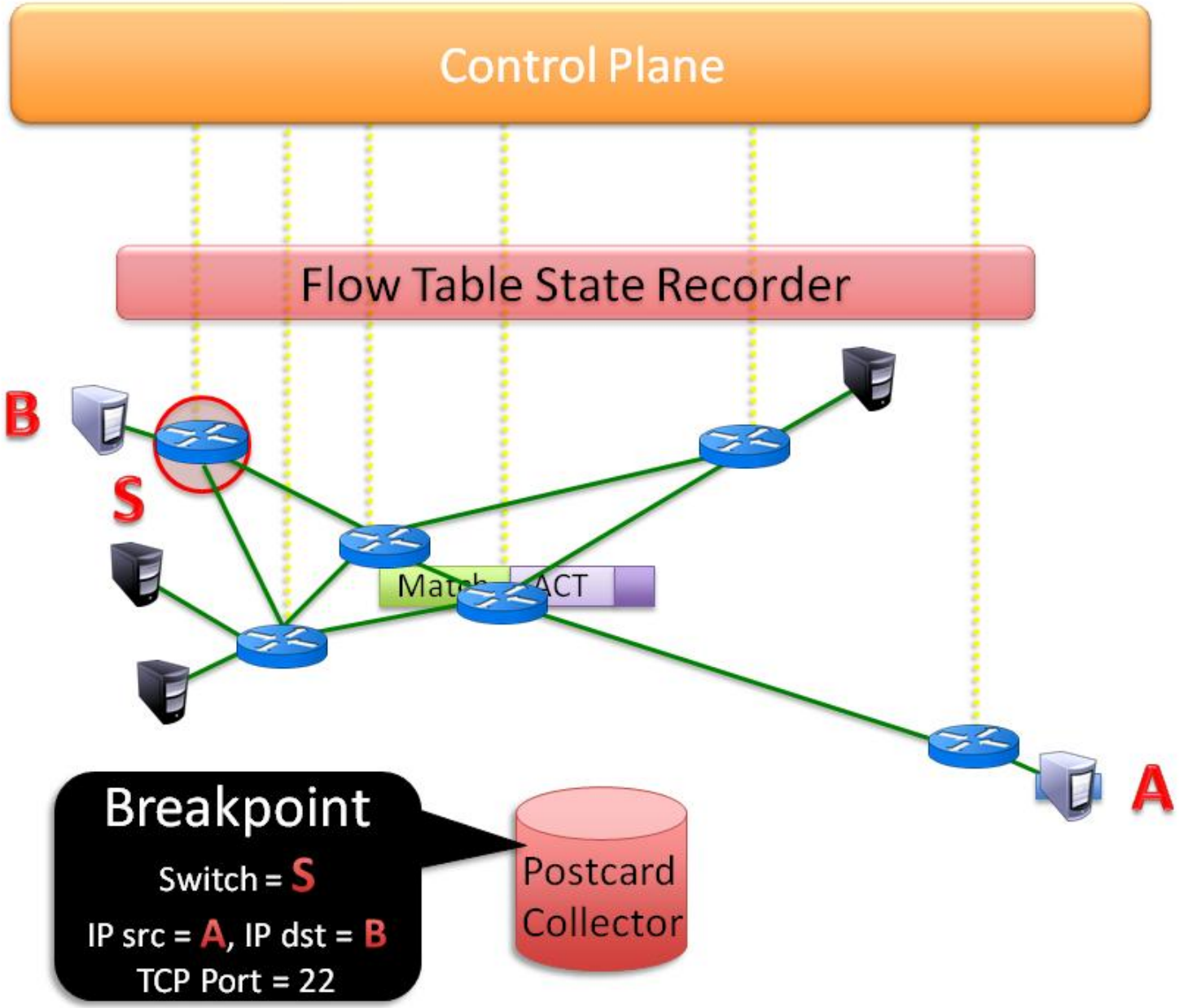
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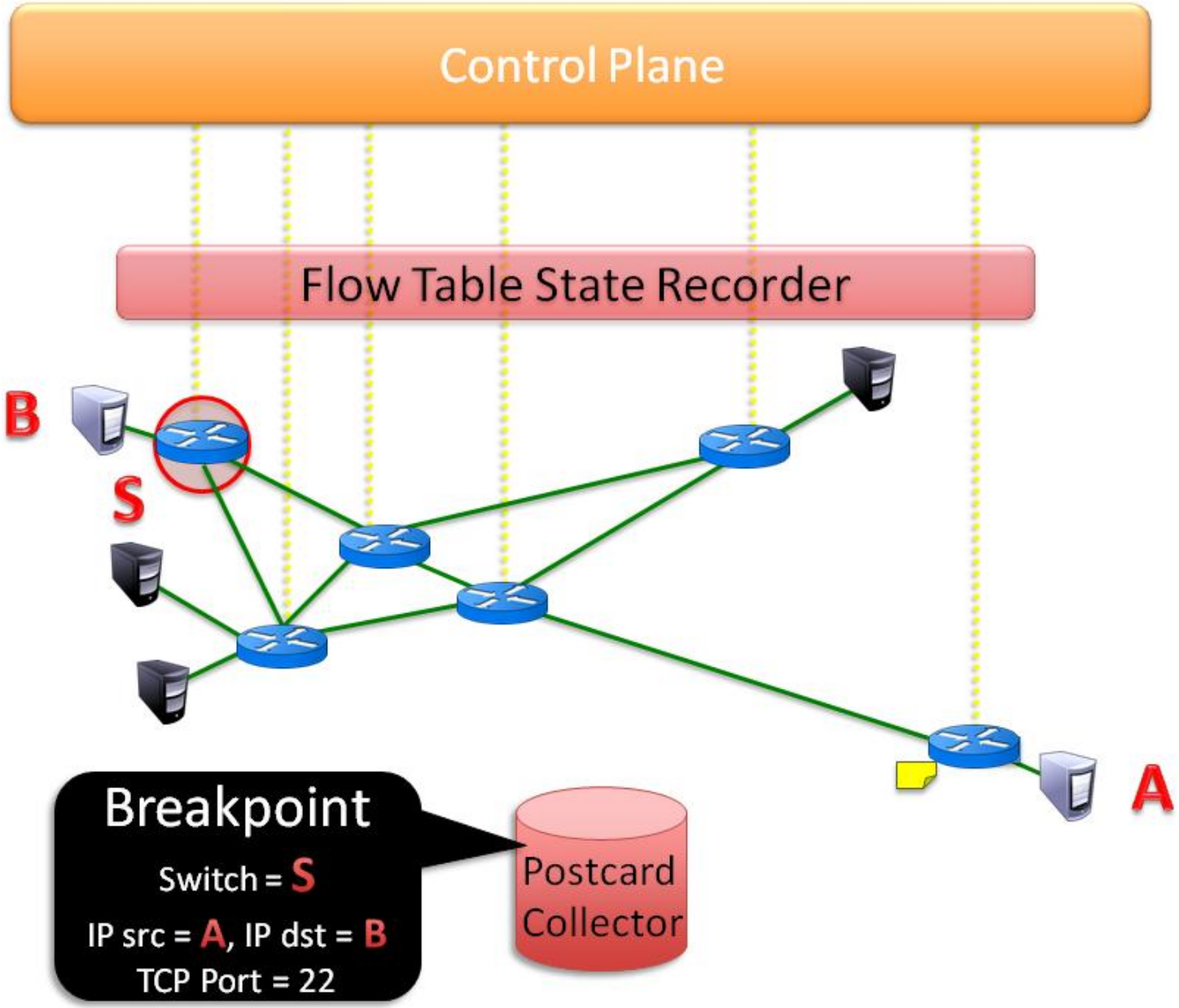
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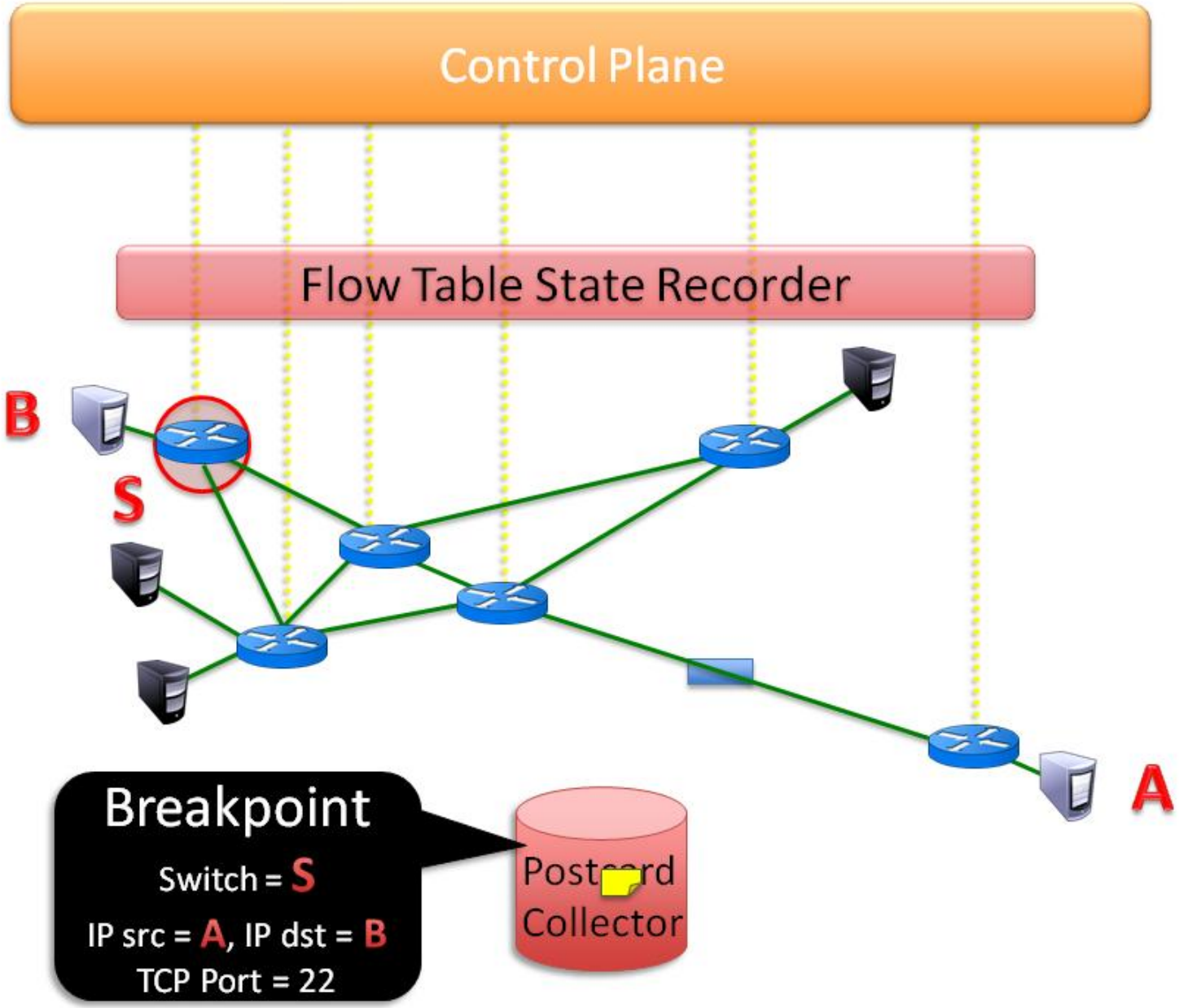
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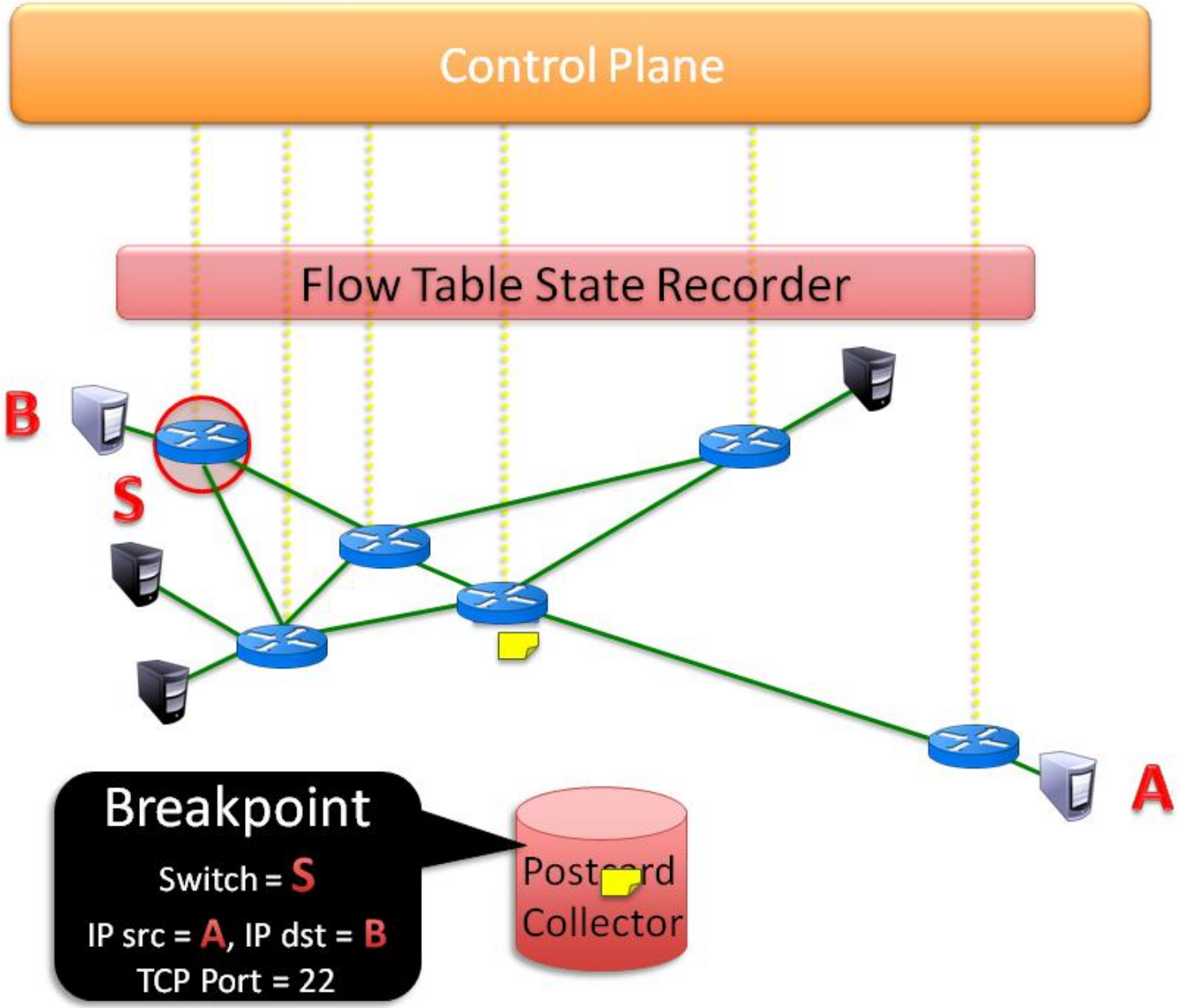
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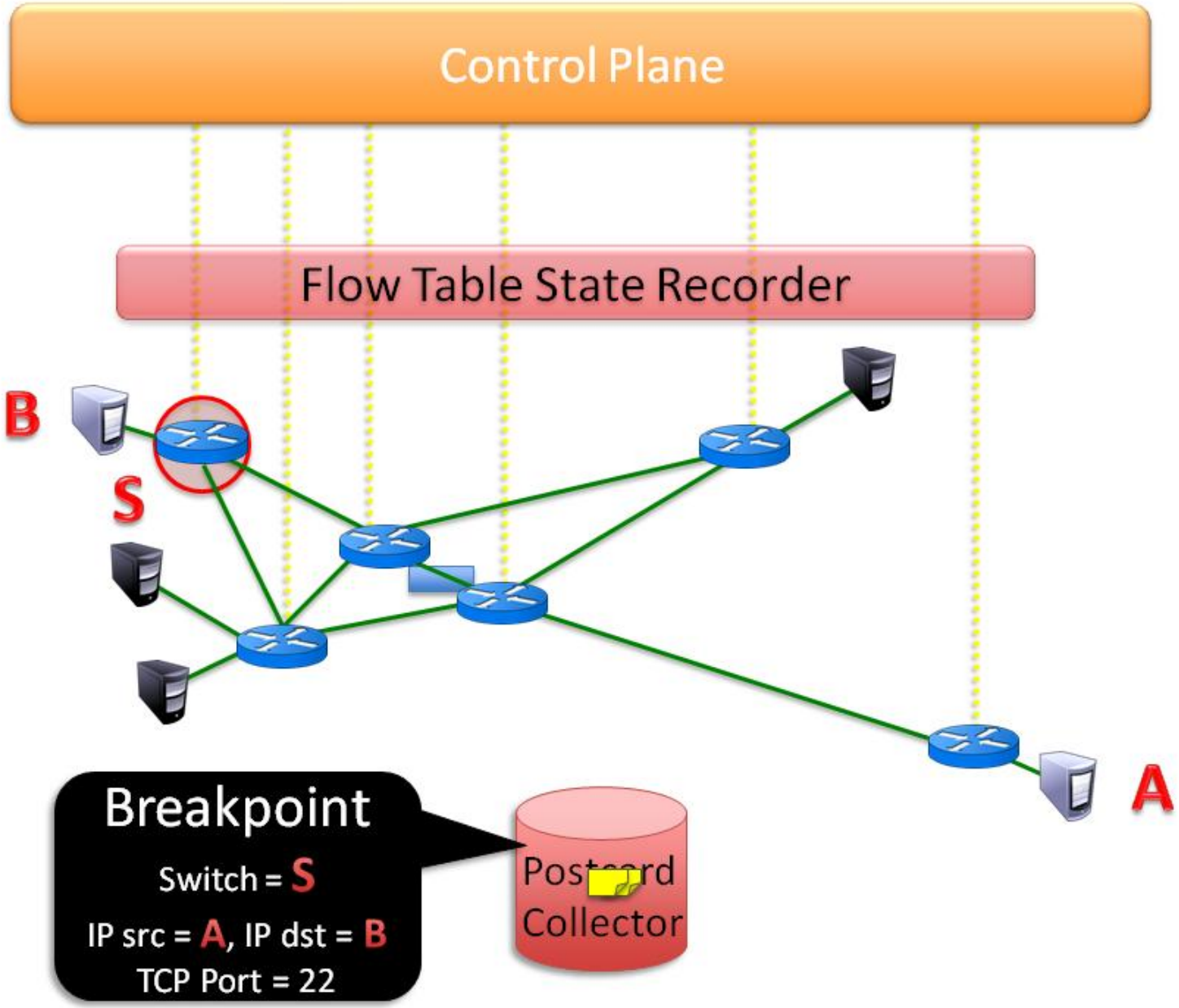
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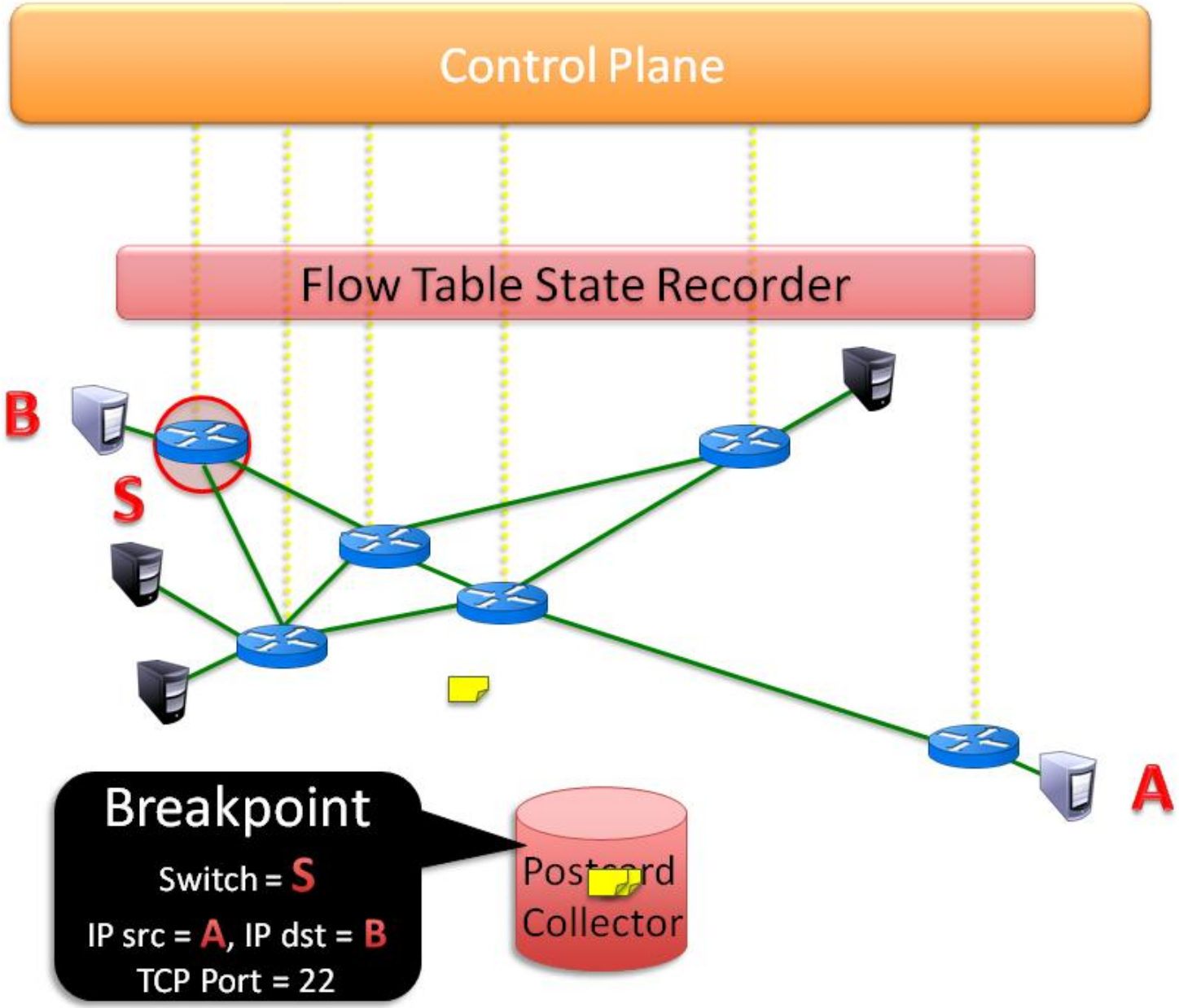
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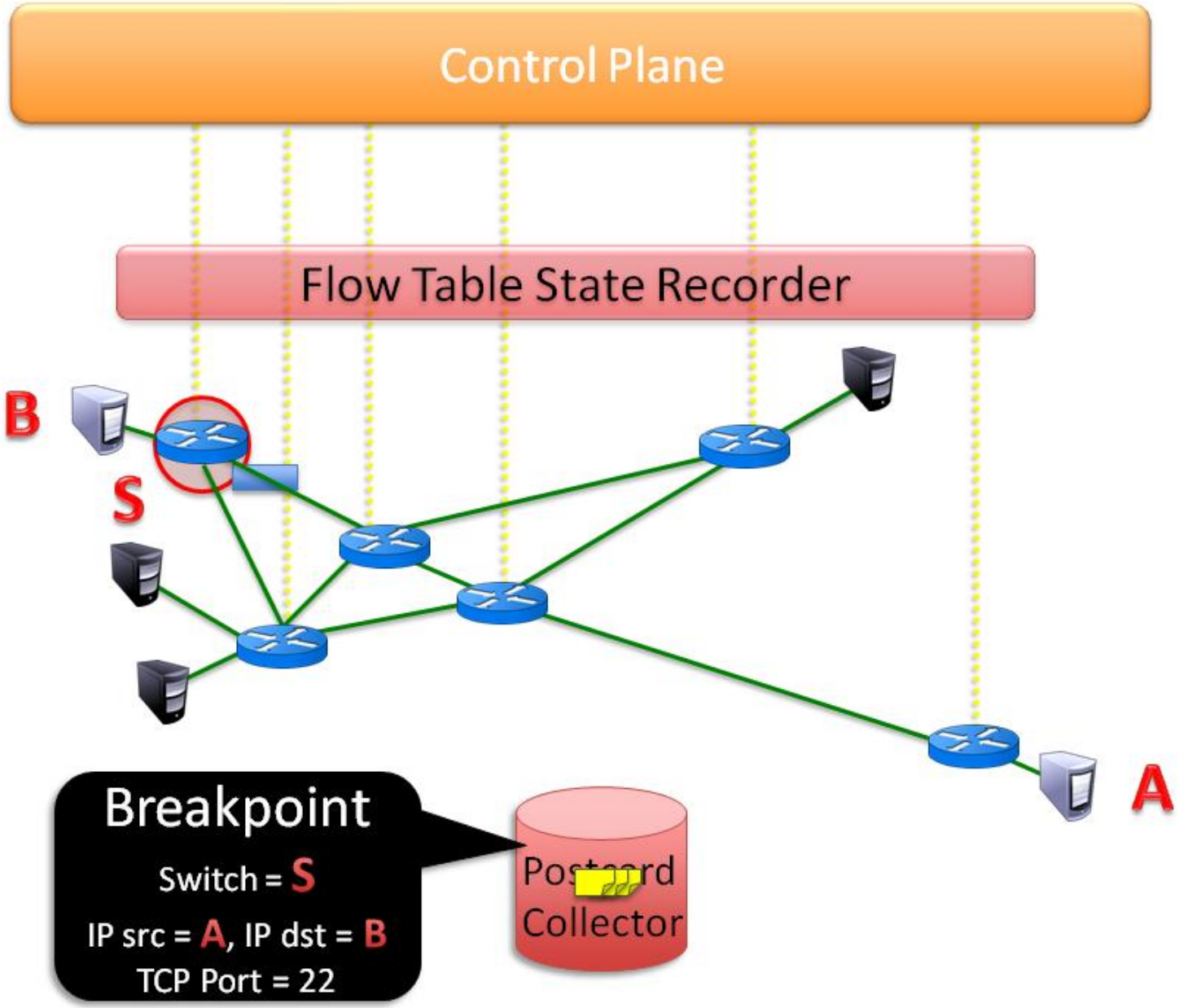
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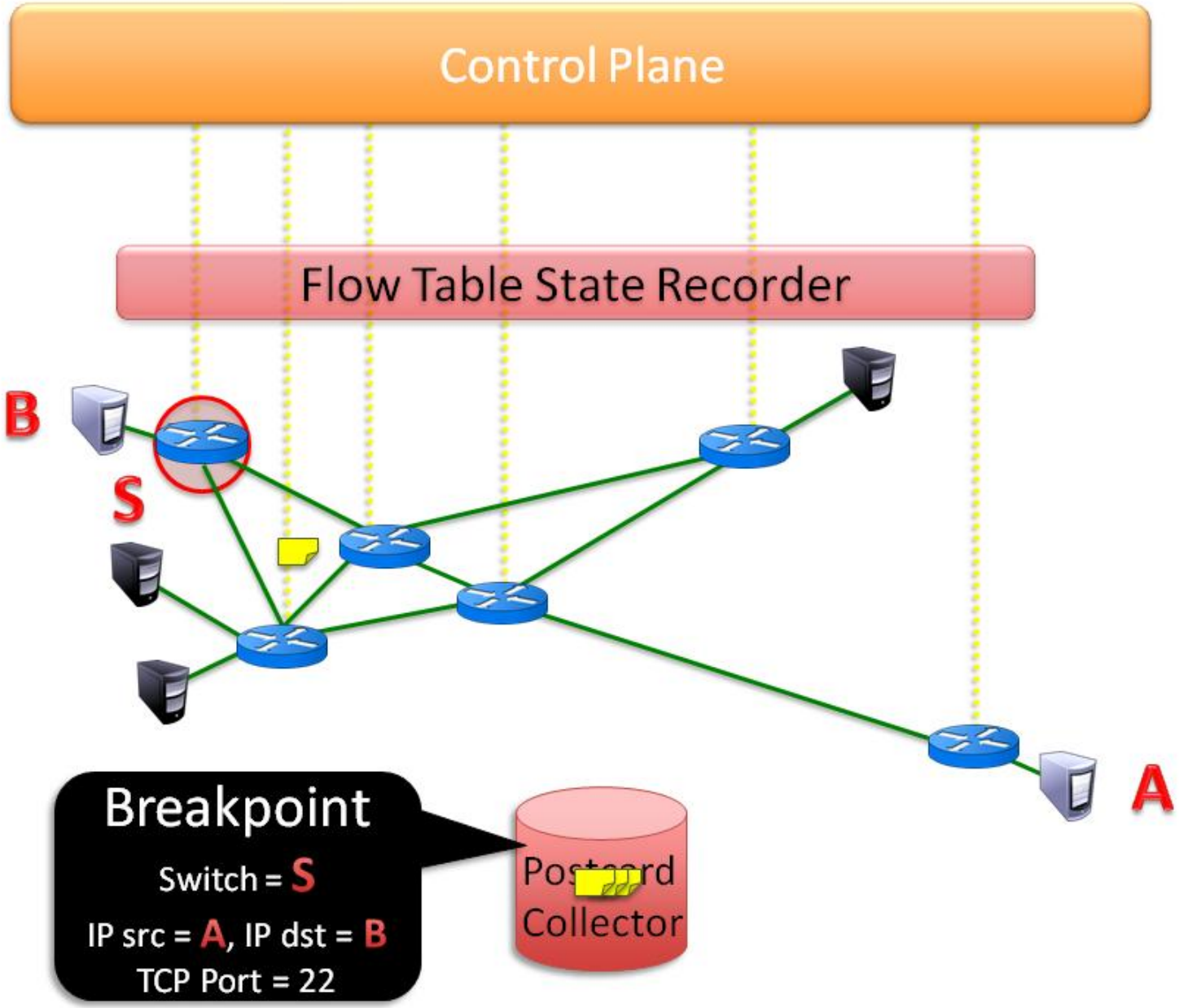
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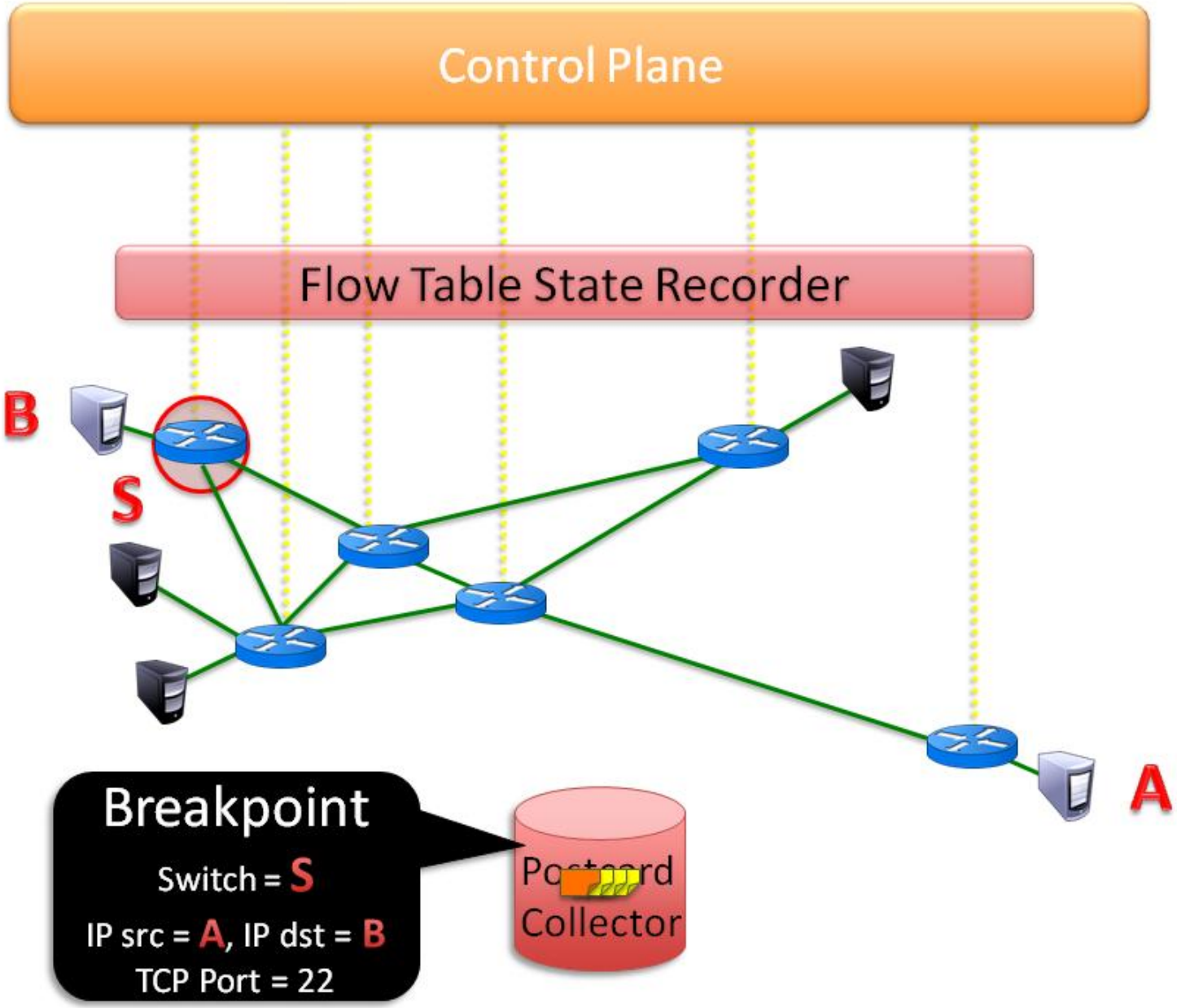
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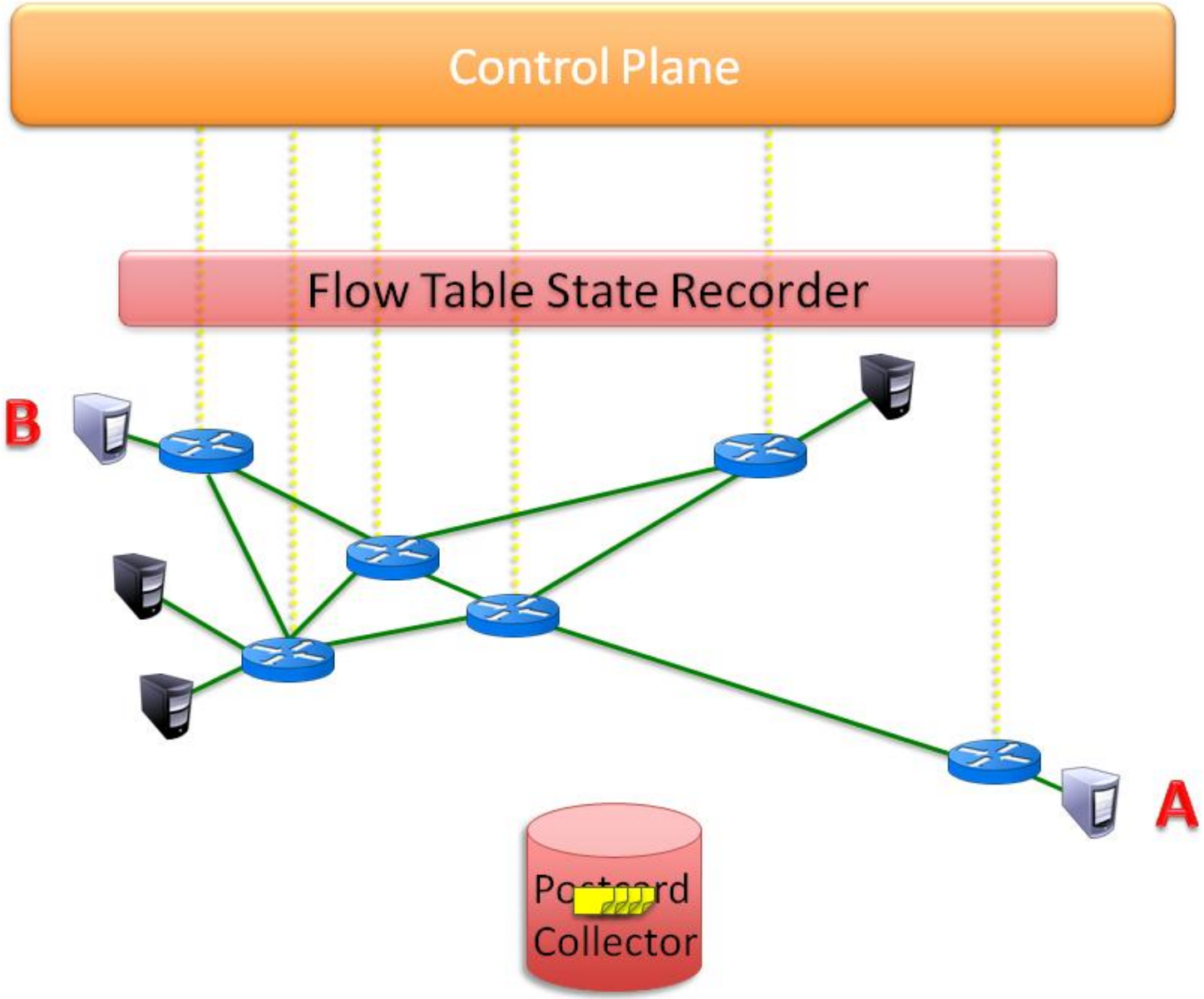
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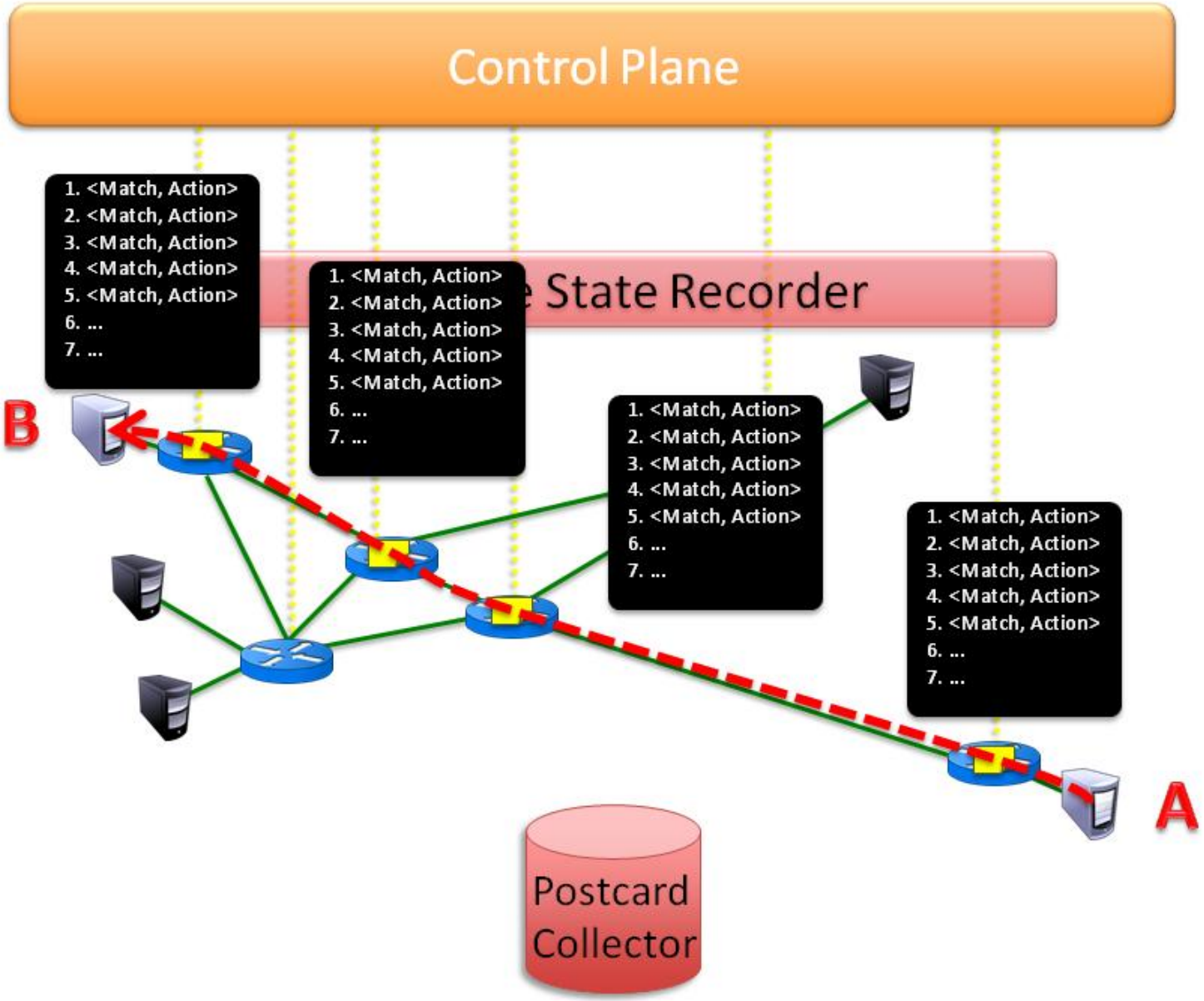
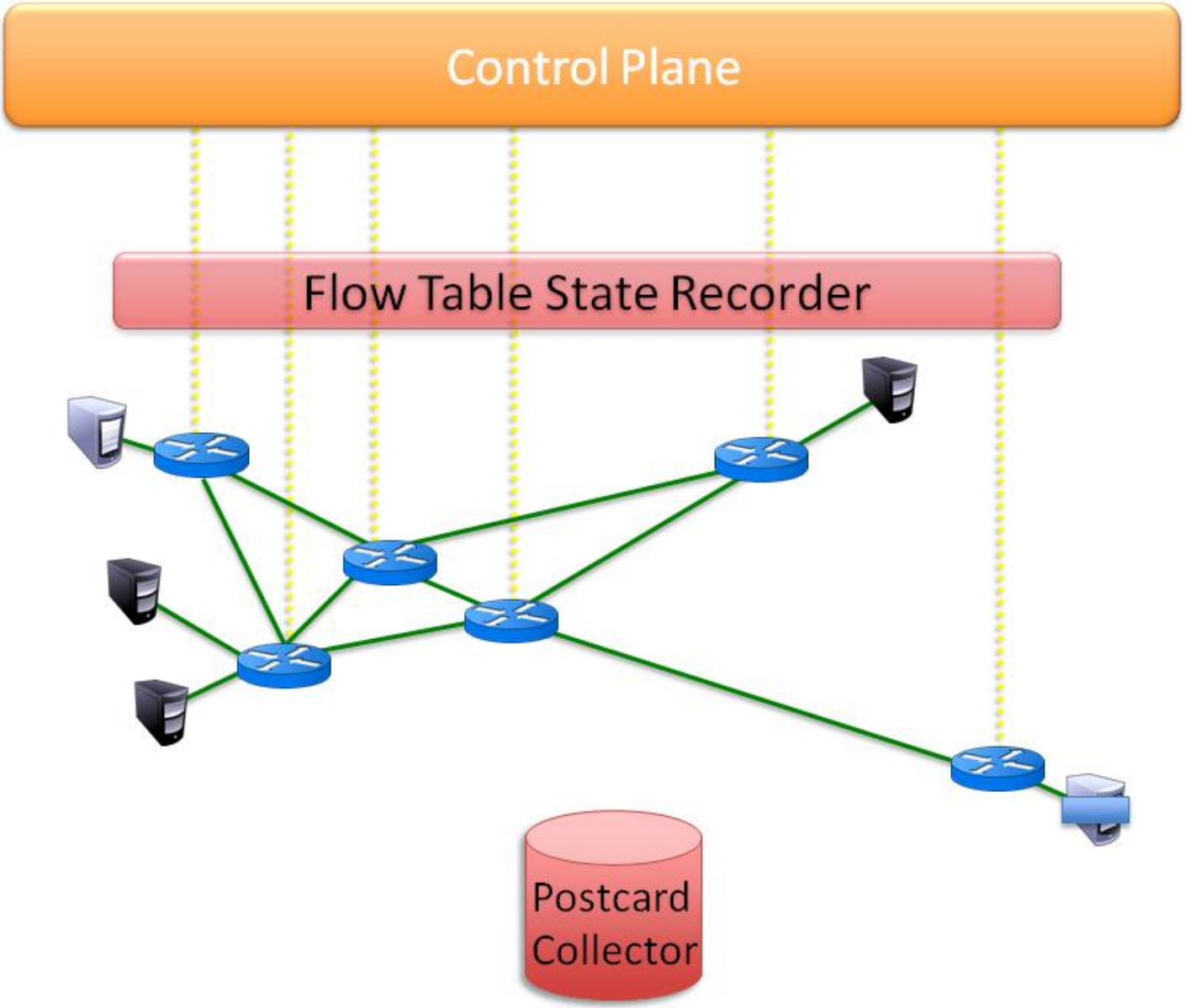
Collector


Control Plane
State Recorder
1. <Match, Action>
2. <Match, Action>
3. <Match, Action>
4. <Match, Action>
5. <Match, Action>
6. ...
7. ...
1. <Match, Action>
2. <Match, Action>
3. <Match, Action>
4. <Match, Action>
5. <Match, Action>
6. ...
7. ...
1. <Match, Action>
2. <Match, Action>
3. <Match, Action>
4. <Match, Action>
5. <Match, Action>
6. ...
7. ...
1. <Match, Action>
2. <Match, Action>
3. <Match, Action>
4. <Match, Action>
5. <Match, Action>
6. ...
7. ...
B
A
Postcard Collector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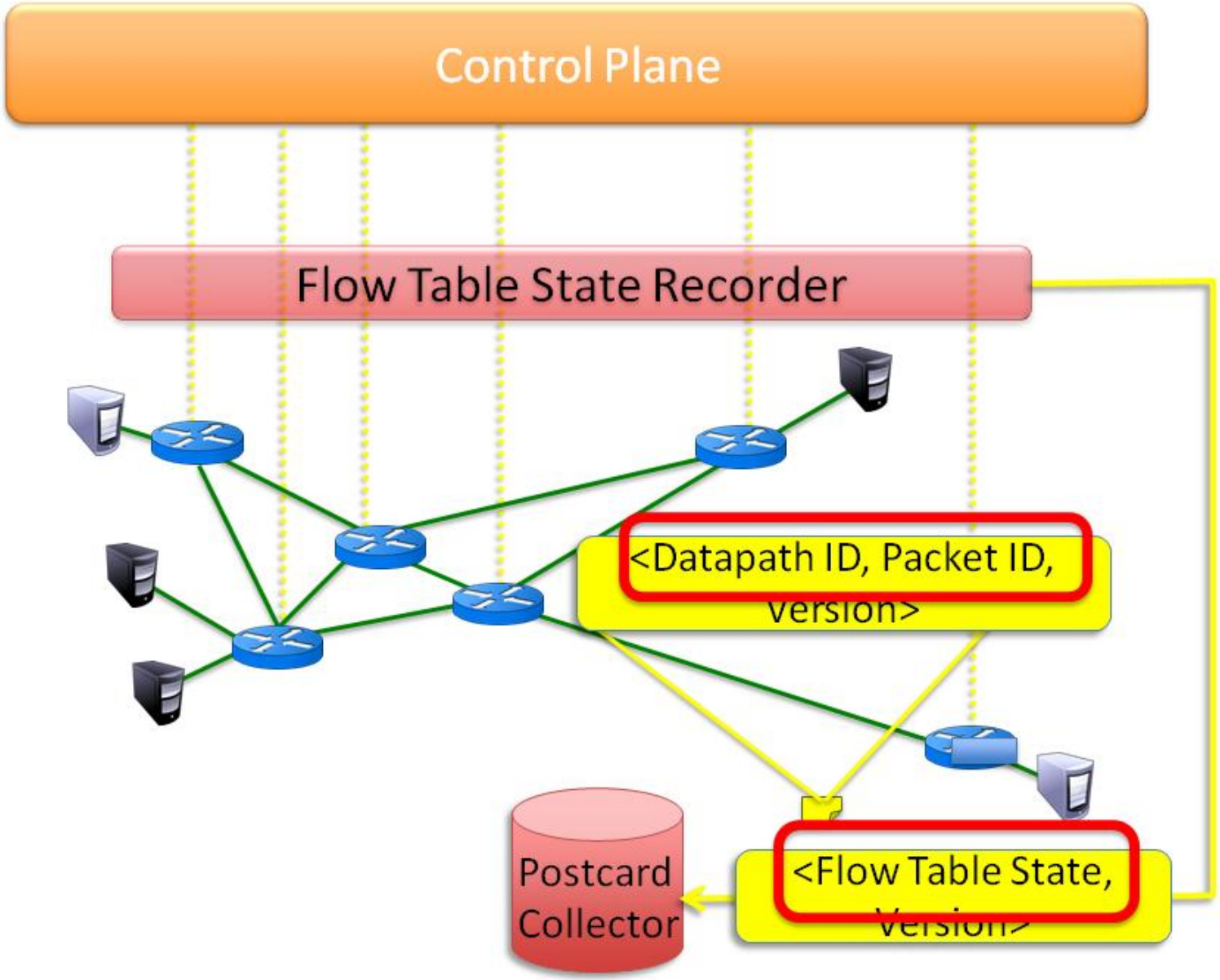
Control Plane
Flow Table State Recorder
<Datapath ID, Packet ID,
Version>
Postcard
Collector
<Flow Table State,
Version>

Who benefits

Network developers

- Programmers debugging control programs

Network operators

- Find policy errors
- Send error report to switch vendor
- Send error report to control program vendor

Performance and scalability

Control channel

- Negligible overhead
- No postcards
- Extra flow-mods

Postcards in the datapath

- Single collector server for the entire Stanford backbone
- Selective postcard generation to reduce overhead
- Parallelize postcard collection

Status

First working prototype of `ndb`

- Works without change to switches or controller

Code undergoing heavy churn

- Will be made available once stable

Summary

- `ndb`: Network Breakpoint + Packet Backtrace
- Systematically track down root cause of bugs
- Practical and deployable today