PacketScope: Monitoring the Packet Lifecycle Within a Switch

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Outline

1. Peeking Inside the Switch
2. Packet Lifecycle Query Language
3. Efficient Query Compilation
4. PacketScope Prototype

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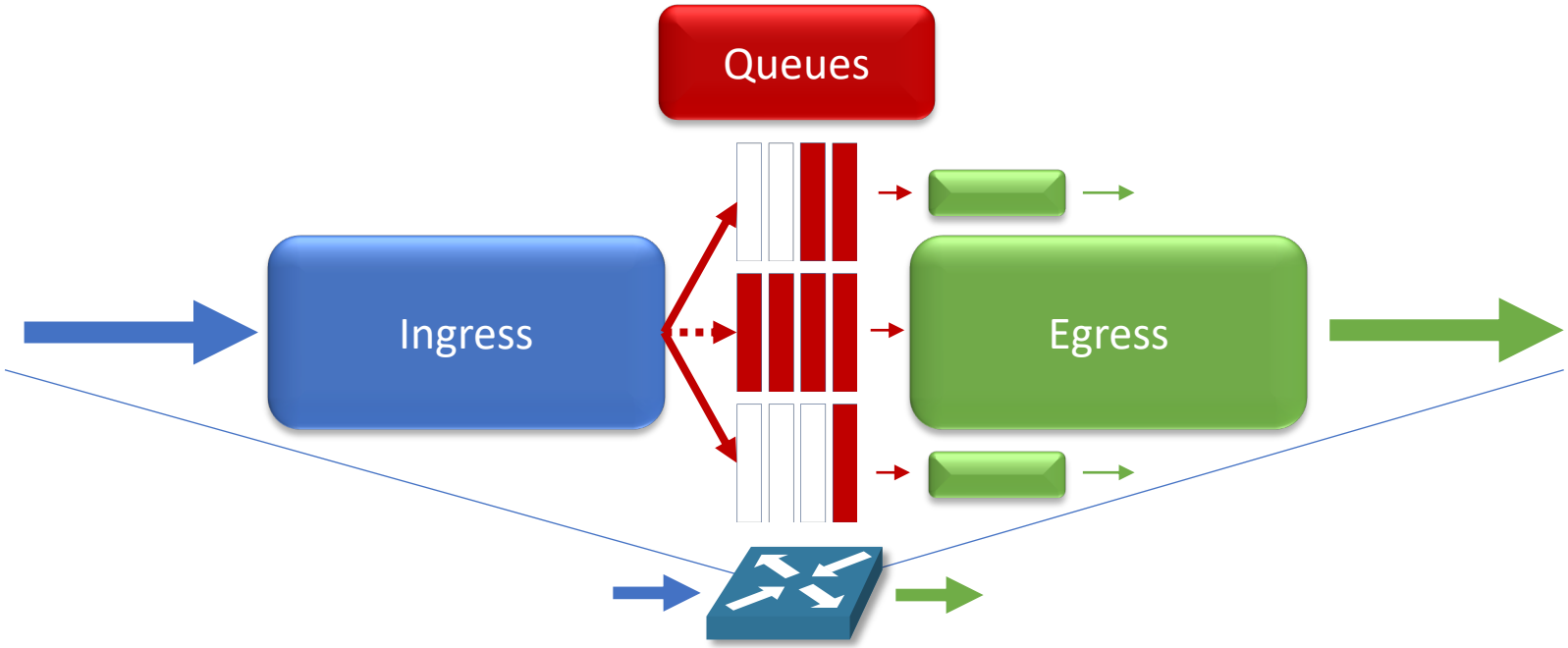
What Happens Inside a (Programmable) Switch?

- Packets are modified in the switch
  - Multiple pipelines
- Access Control List (ACL) drops
- Queues cause delays and loss



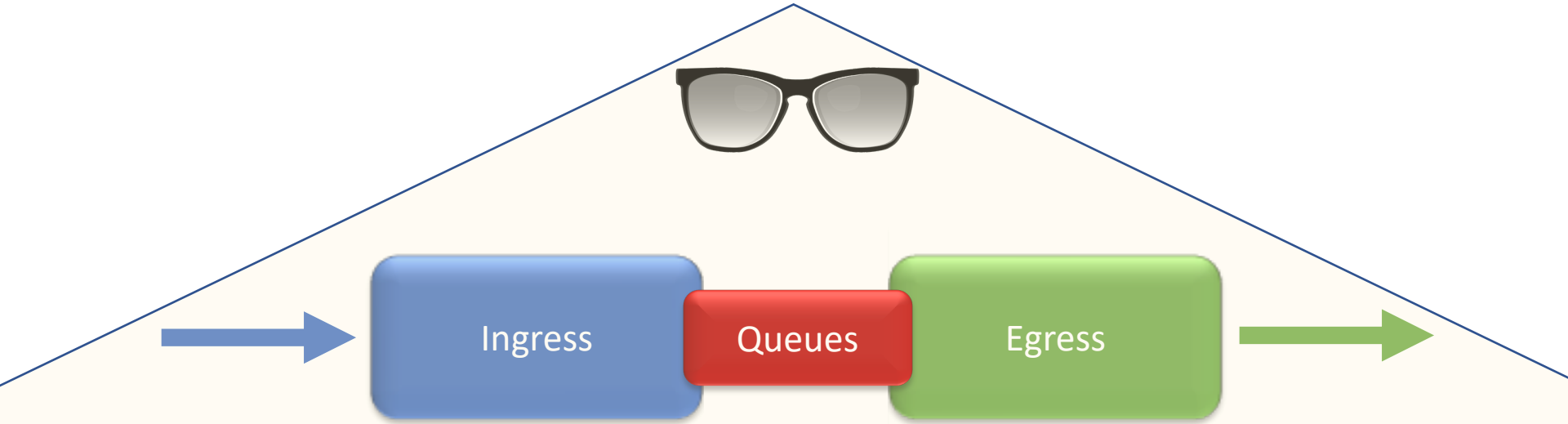
Prior Systems Don't Peek Inside

- Switch monitoring is important
- Want to adapt dataflow monitoring systems
  - map, filter, reduce operators on incoming tuples
- Prior systems only captured packets as they arrived at a switch[1,3]
  - Or only provide queuing delay info[2]

[1] Sonata (SIGCOMM '18), [2] Marple (SIGCOMM '17), [3] Gigascope (SIGMOD '03)

Introducing PacketScope

- Monitoring the packet lifecycle
  - Packet modifications
  - ACL drops
  - Queuing delays/loss



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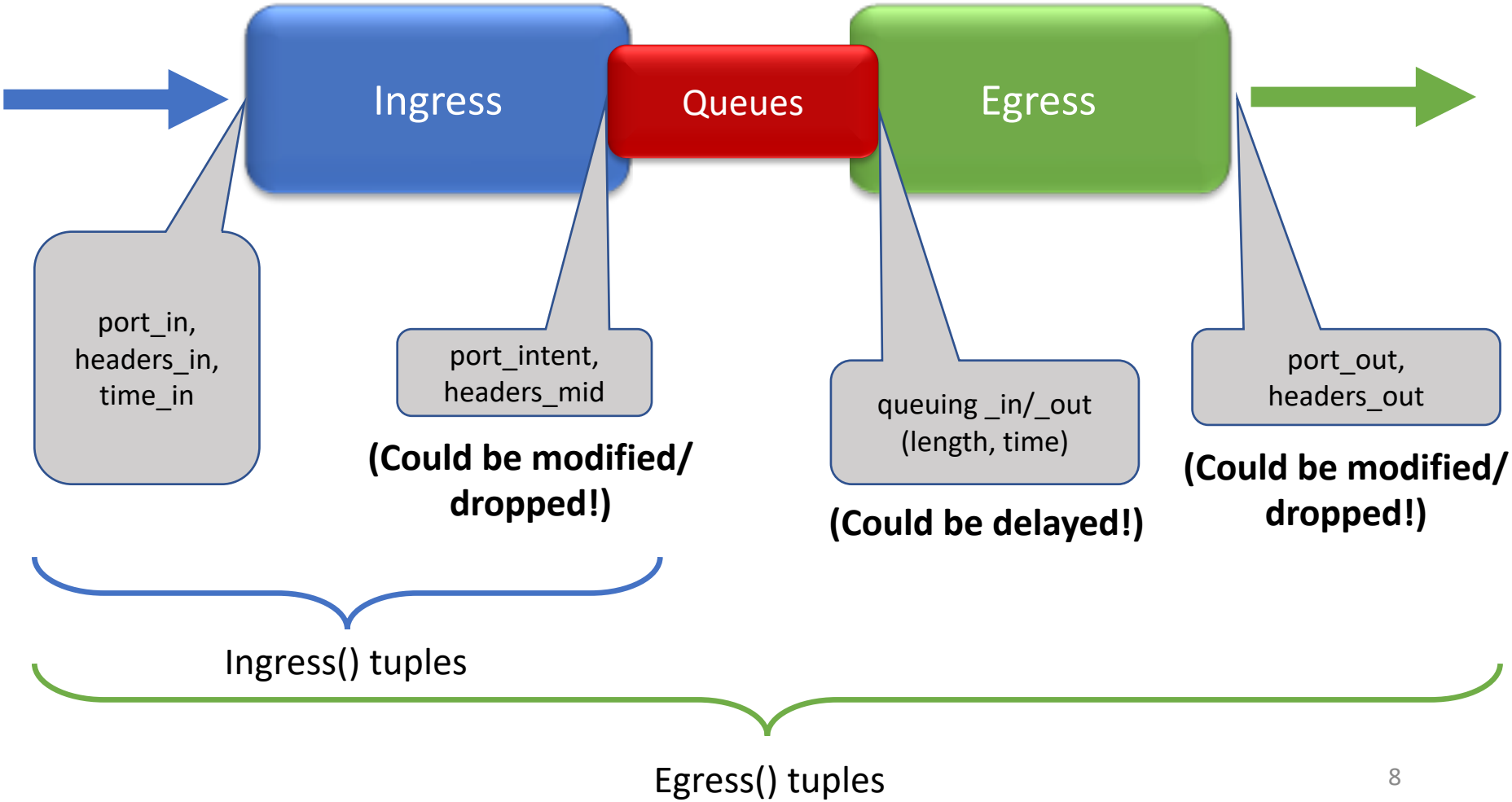
The Life of a Packet



Example Query

- Count un-dropped SSH packets that traverse a NAT

```
1 undropped_SSH_NAT = egress()
2
3
4
```

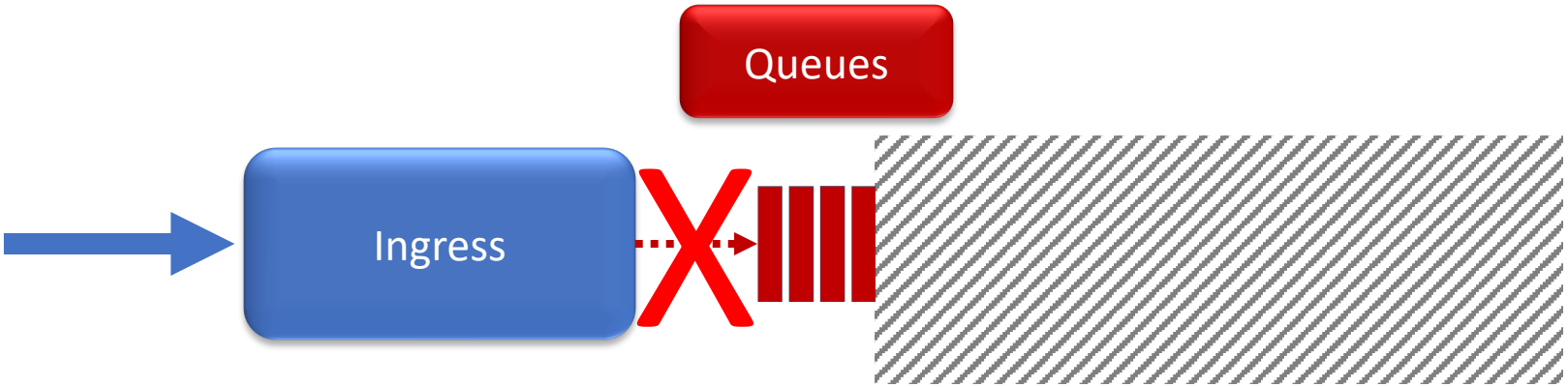
Not Lost

SSH Packets

Crossing a NAT

Not Dropped

How To Track Queuing Loss?



- Loss happens outside ingress/egress processing
  - We can't insert processing to capture packet
- Cannot execute query on individual packet tuples
  - But over time, we can track aggregate counts by keeping state
- *.lost*(*groupby_fields*, *epoch_ms*) operator
  - count packets grouped by *groupby_fields* every *epoch_ms*
    - Arrival time determines epoch placement

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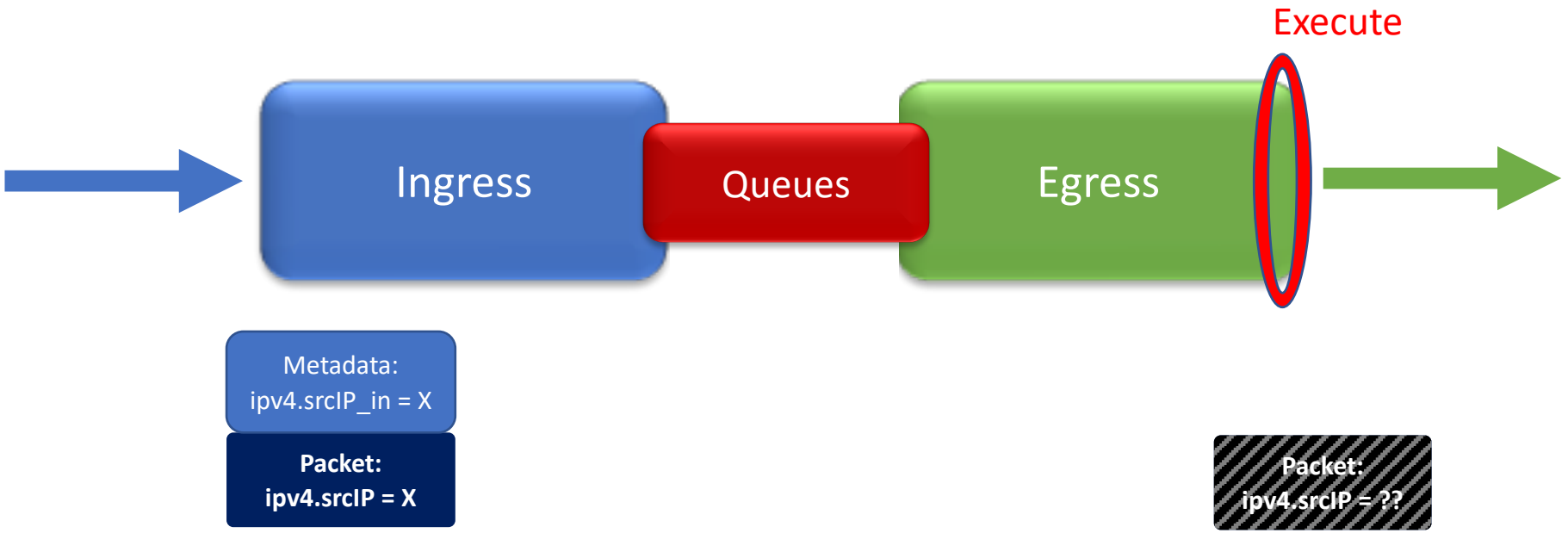
Compilation: "**Tag Little**, Compute Early"

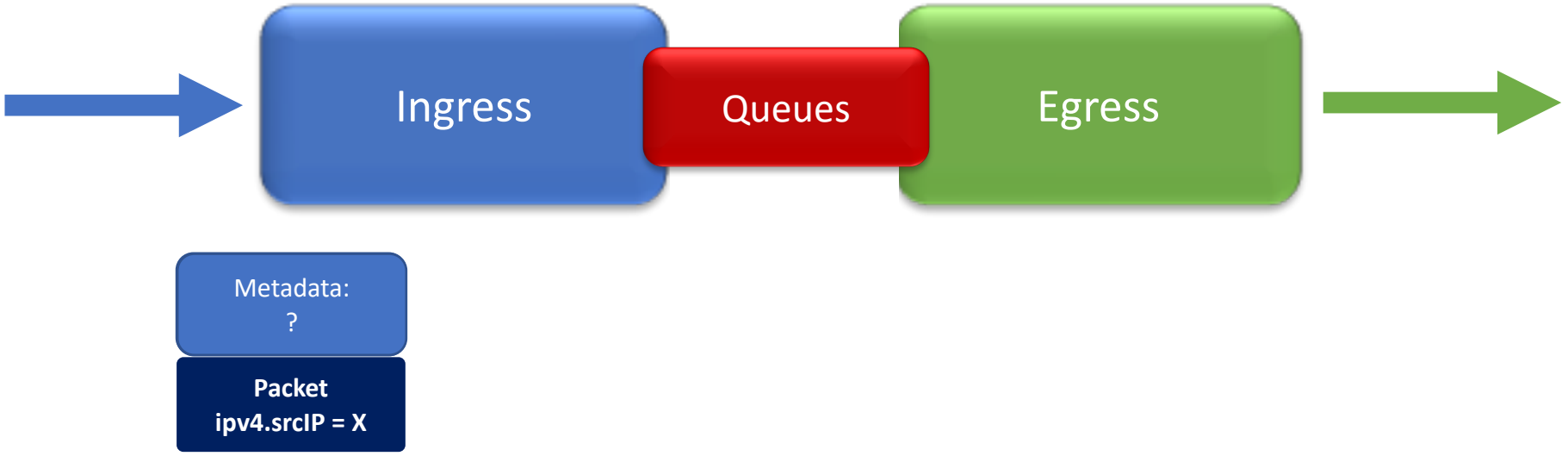


E.g. Queries across ports?

.filter(ipv4.srcIP_in != ipv4.srcIP_out)

A: Tag packet with metadata

Compilation:“Tag Little, **Compute Early**”

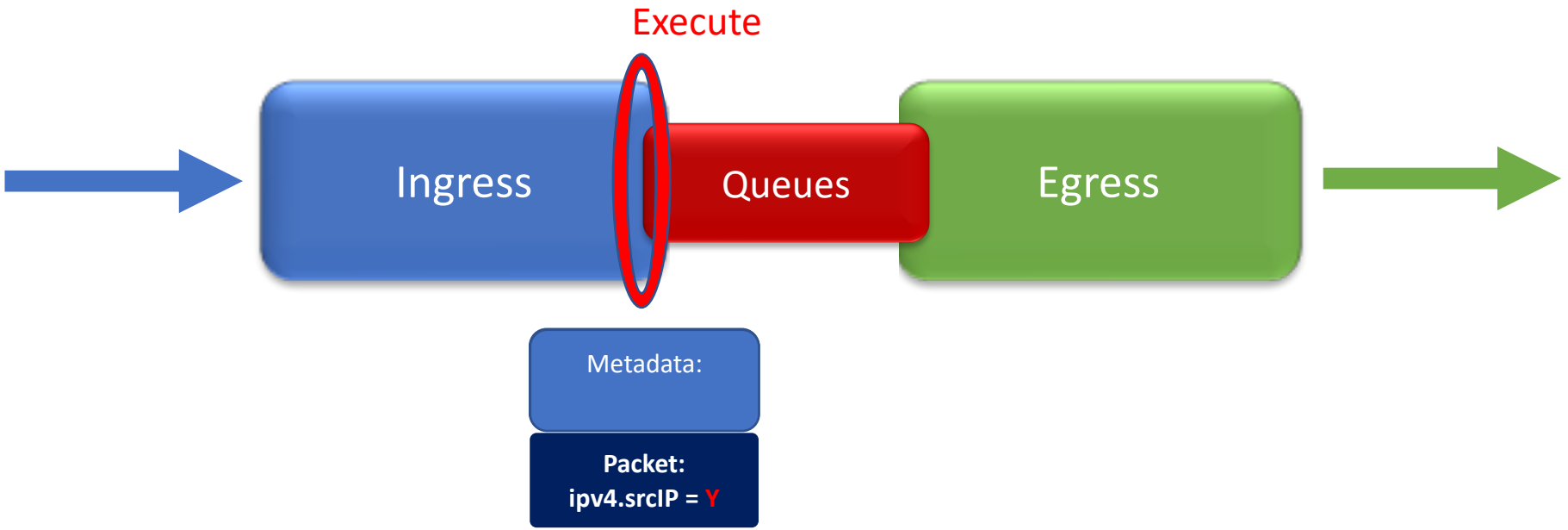


Where to place computation?

.filter(ipv4.srcIP_in != ipv4.srcIP_**mid**)…

A: As early as possible!

Compilation:“Tag Little, **Compute Early**”



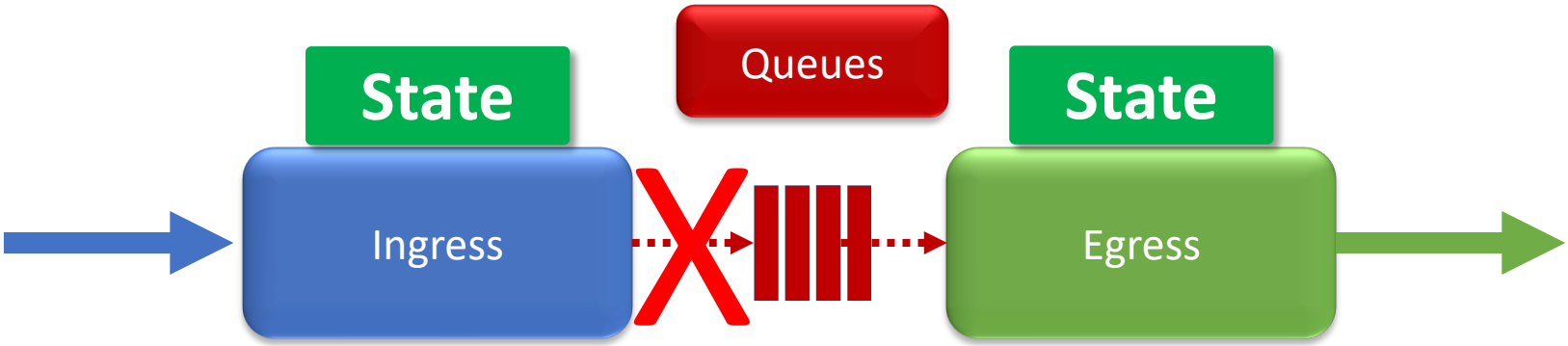
Where to place computation?

.filter(ipv4.srcIP_in != ipv4.srcIP_**mid**)…

A: As early as possible!

- Metadata can be reused for future processing.

How To Compile Lost Operator?



- *.lost([ipv4.srcIP], 10ms)*

- Compile as a *join* of two queries:
  - Count by *ipv4.srcIP* on ingress
  - Count by *ipv4.srcIP* on egress
- Report difference every *10ms of* packet arrival times

- Gory details in paper

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PacketScope Prototype

- We built a prototype[1] in Python and P4 with:
  - Support for packet modifications, queuing delays
  - Tag little, compute early compilation
- We also built a queuing loss query prototype
  - Uses the BMv2 software model
- More details and future work in paper

[1] As an extension to Sonata (SIGCOMM ‘18)

Conclusion

- PacketScope is a network telemetry system
  - Using a dataflow programming model (map, filter, reduce)
  - That supports queries on the full packet lifecycle:
    - Packet modifications
    - ACL drops
    - Queuing delays/loss
  - And compiles efficiently to programmable switches