

Pushing the Boundaries with bdrmapIT: Mapping Router Ownership at Internet Scale

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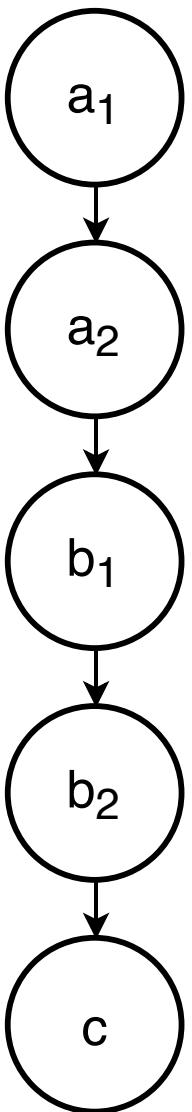
Jonathan M. Smith (University of Pennsylvania)

Problem: Interpreting Traceroute

Src:

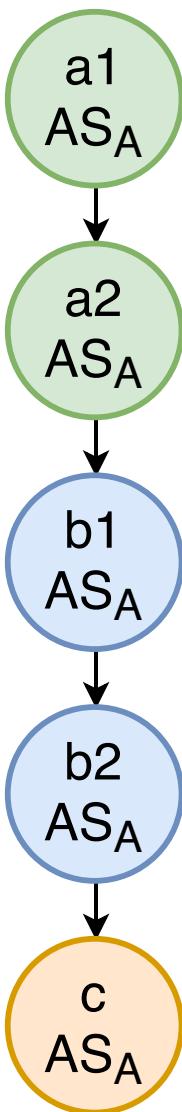
a_0

Dest: d



Problem: Interpreting Traceroute

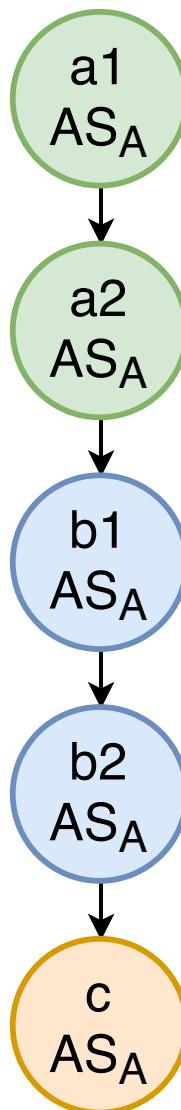
Src: a_0
Dest: d



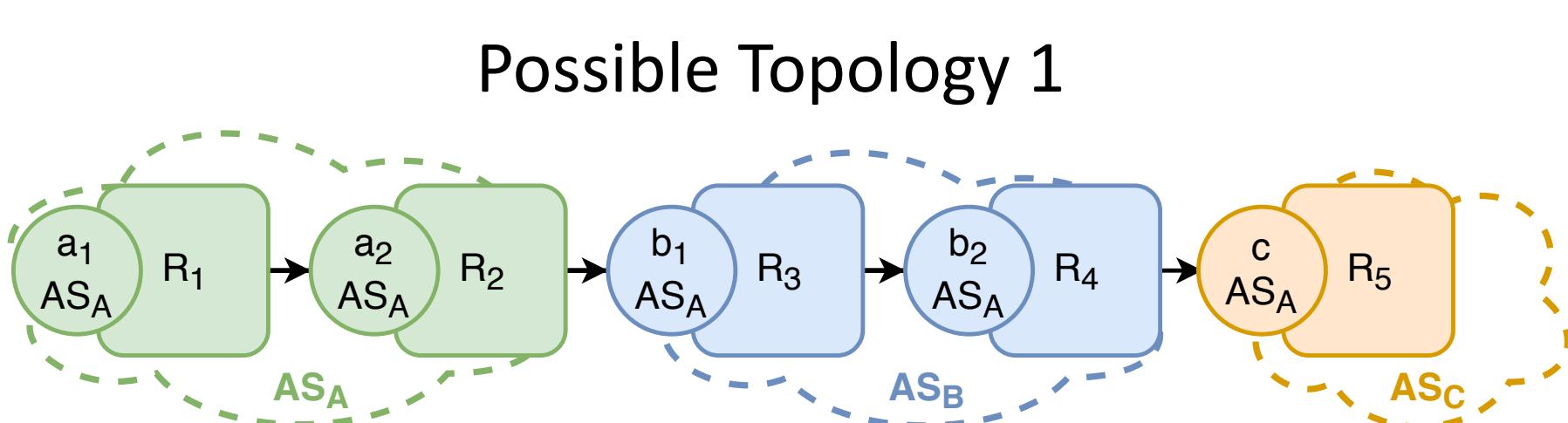
Problem: Interpreting Traceroute

Src: a_0

Dest: d



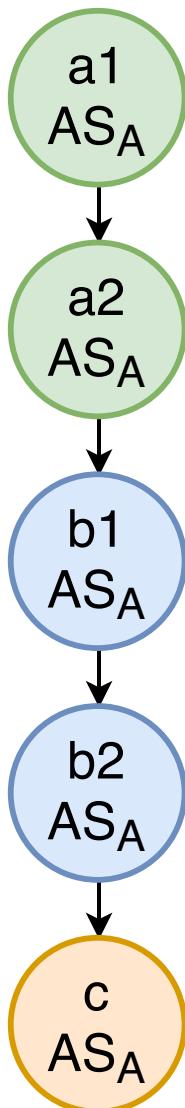
Possible Topology 1



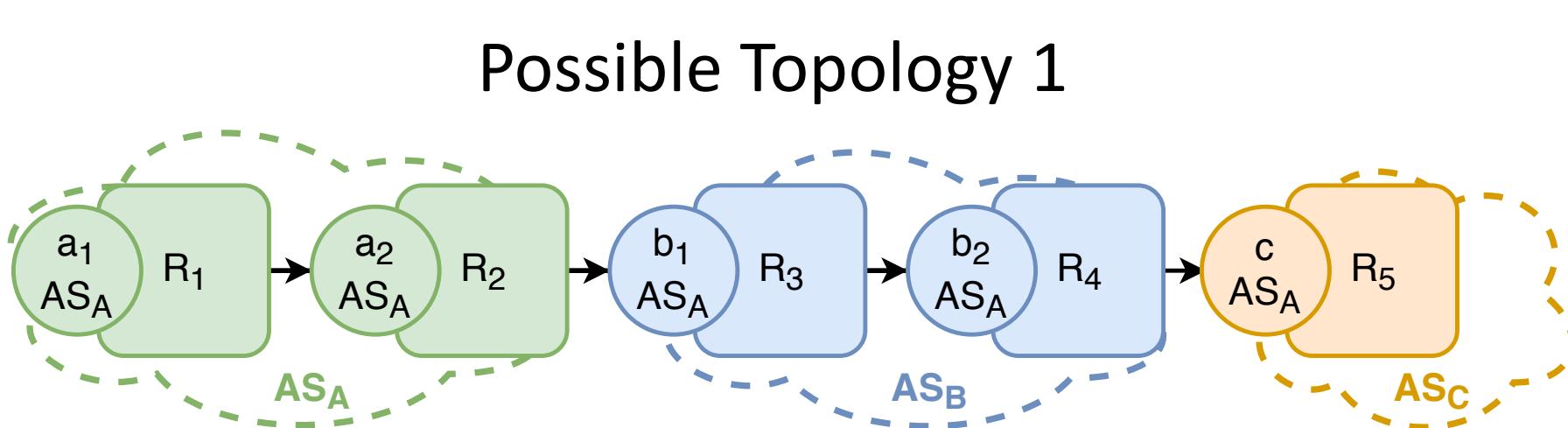
Problem: Interpreting Traceroute

Src: a_0

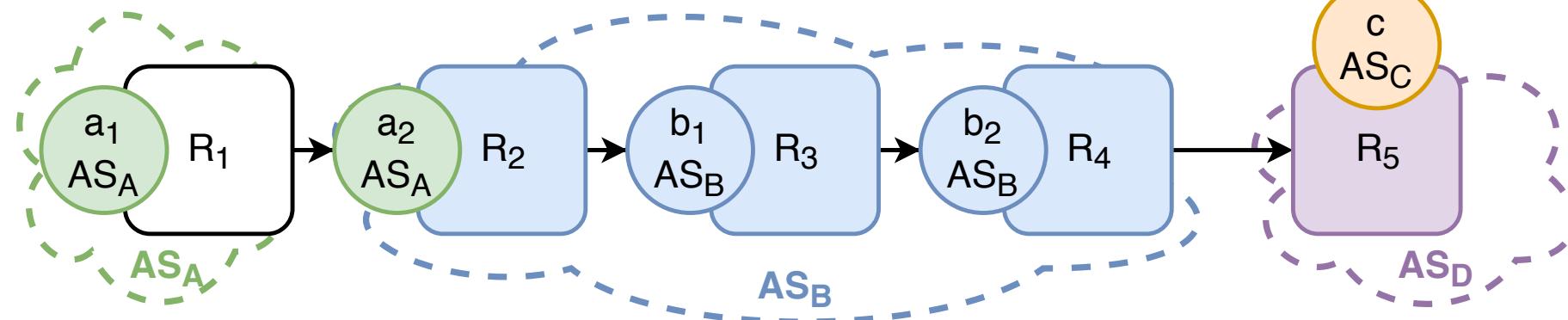
Dest: d



Possible Topology 1



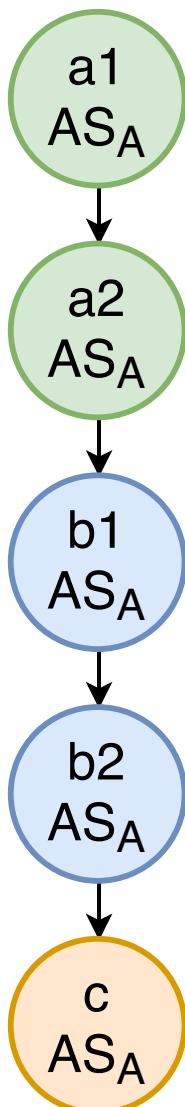
Possible Topology 2



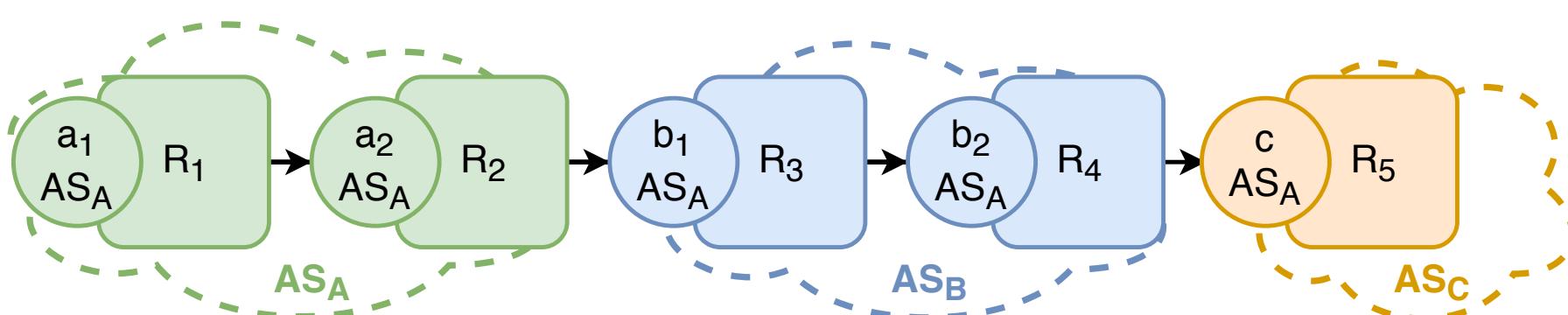
Problem: Traceroute is a Mess

Src: a_0

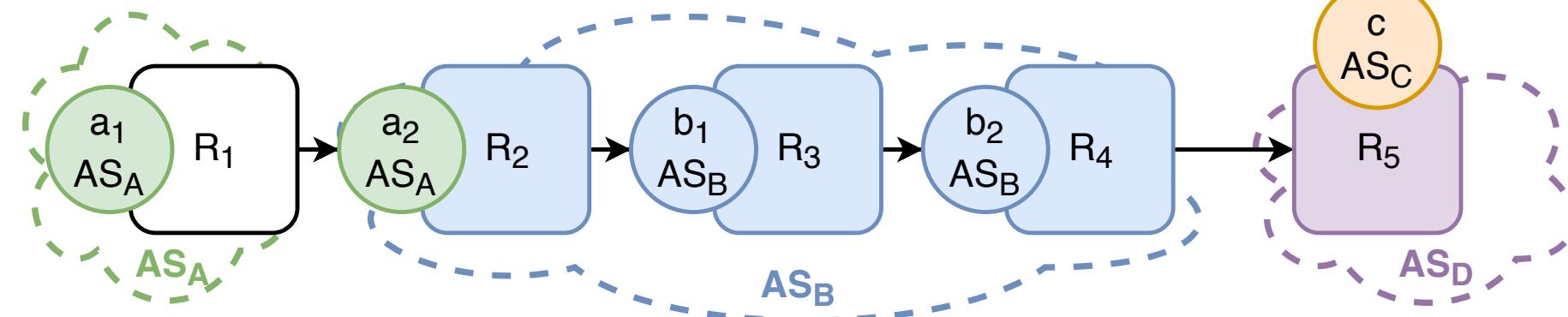
Dest: d



Possible Topology 1



Possible Topology 2



Goal

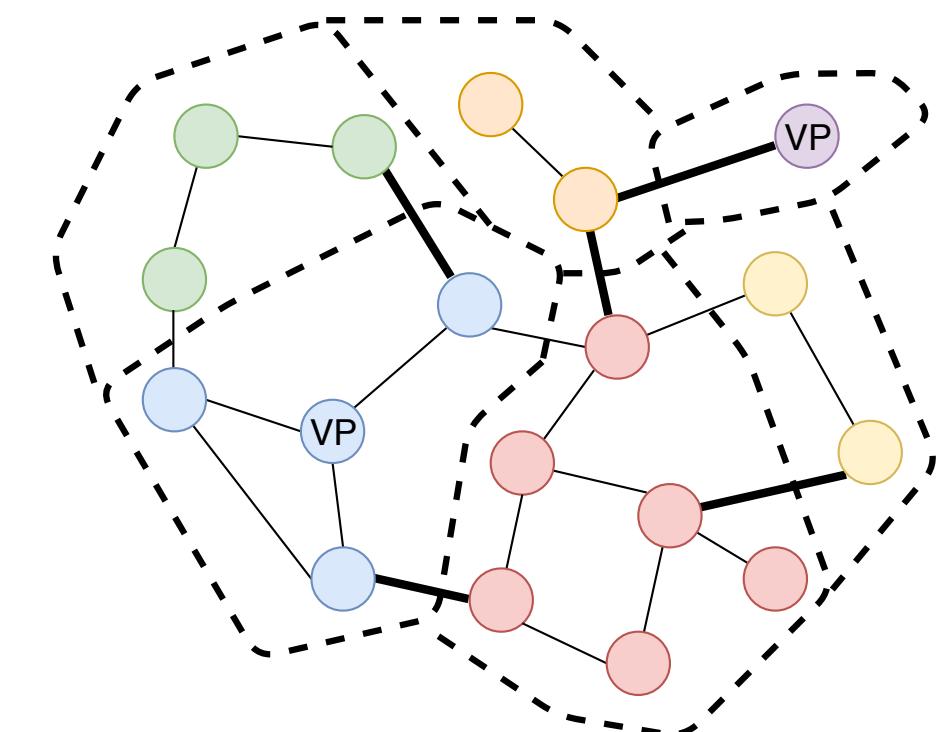
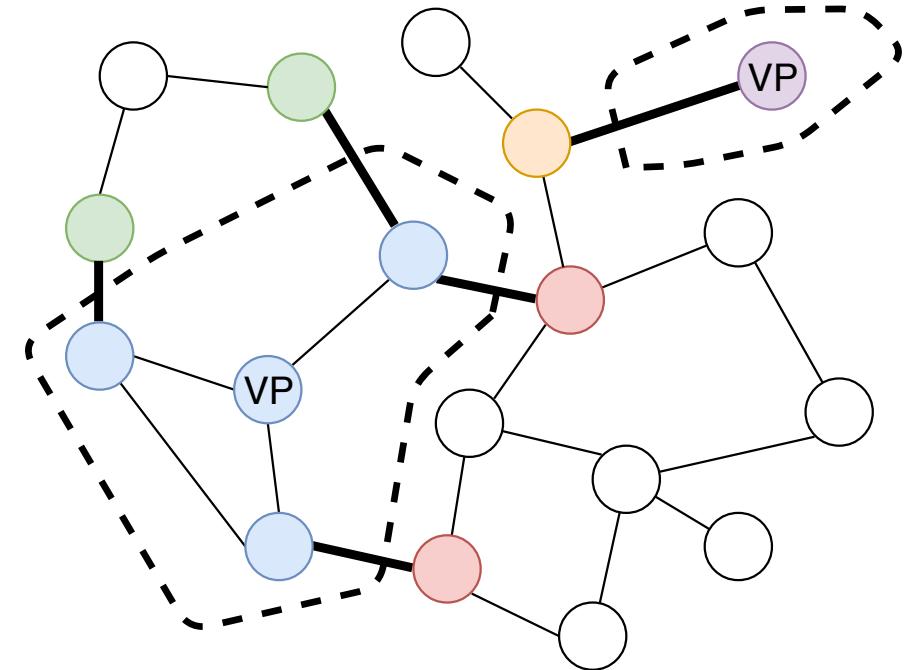
- Accurate maps of the topology discovered by traceroute
 - Determine router operators
 - Identify interdomain links

Motivation

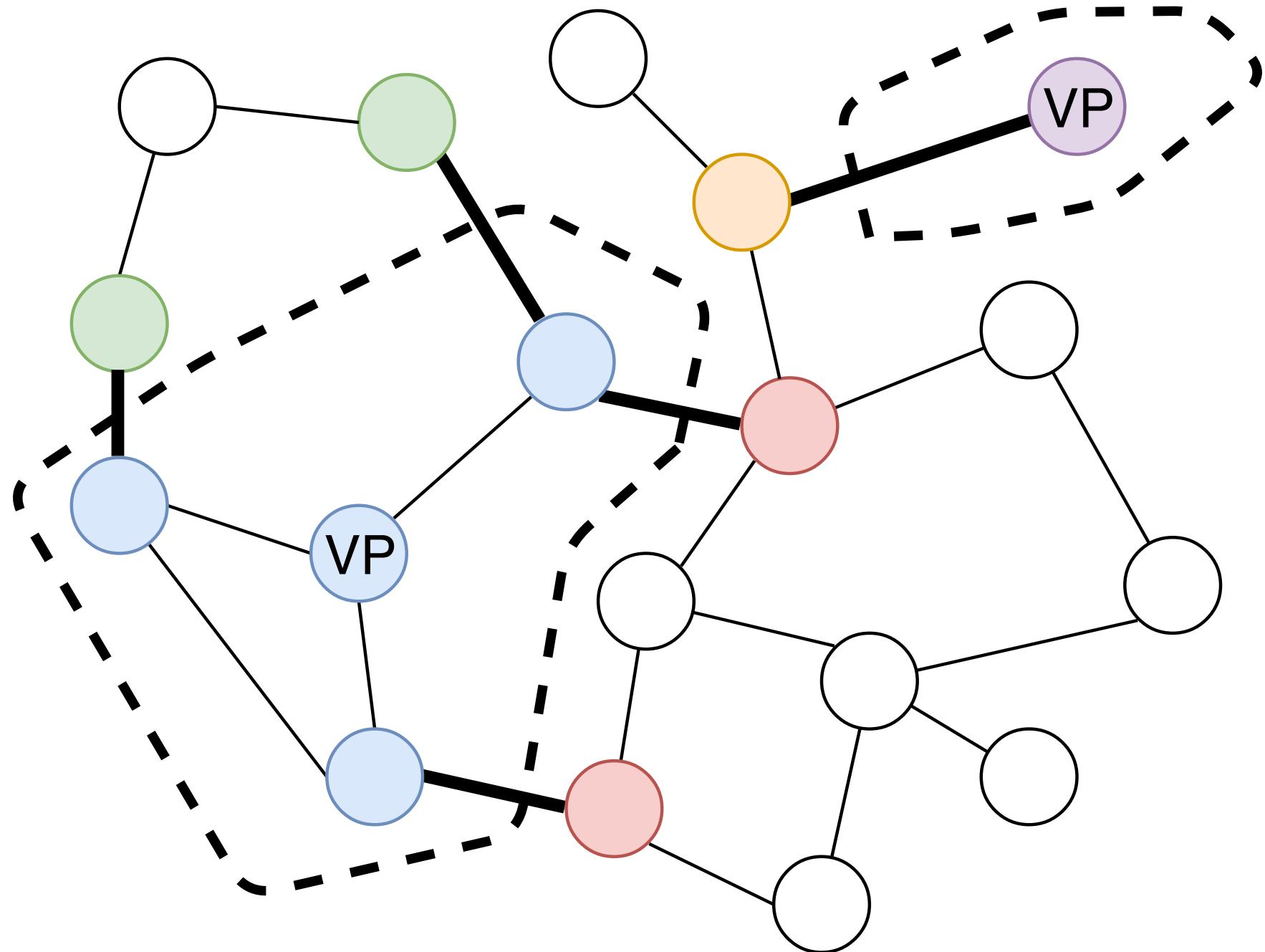
- Resiliency assessment
 - Estimate the number of links between networks
- Internet evolution
 - Is it flattening or retaining the hierarchy
- Internal topology
 - Need to know the borders first
- Fundamental problem for IP-level topology analysis

Previous Work

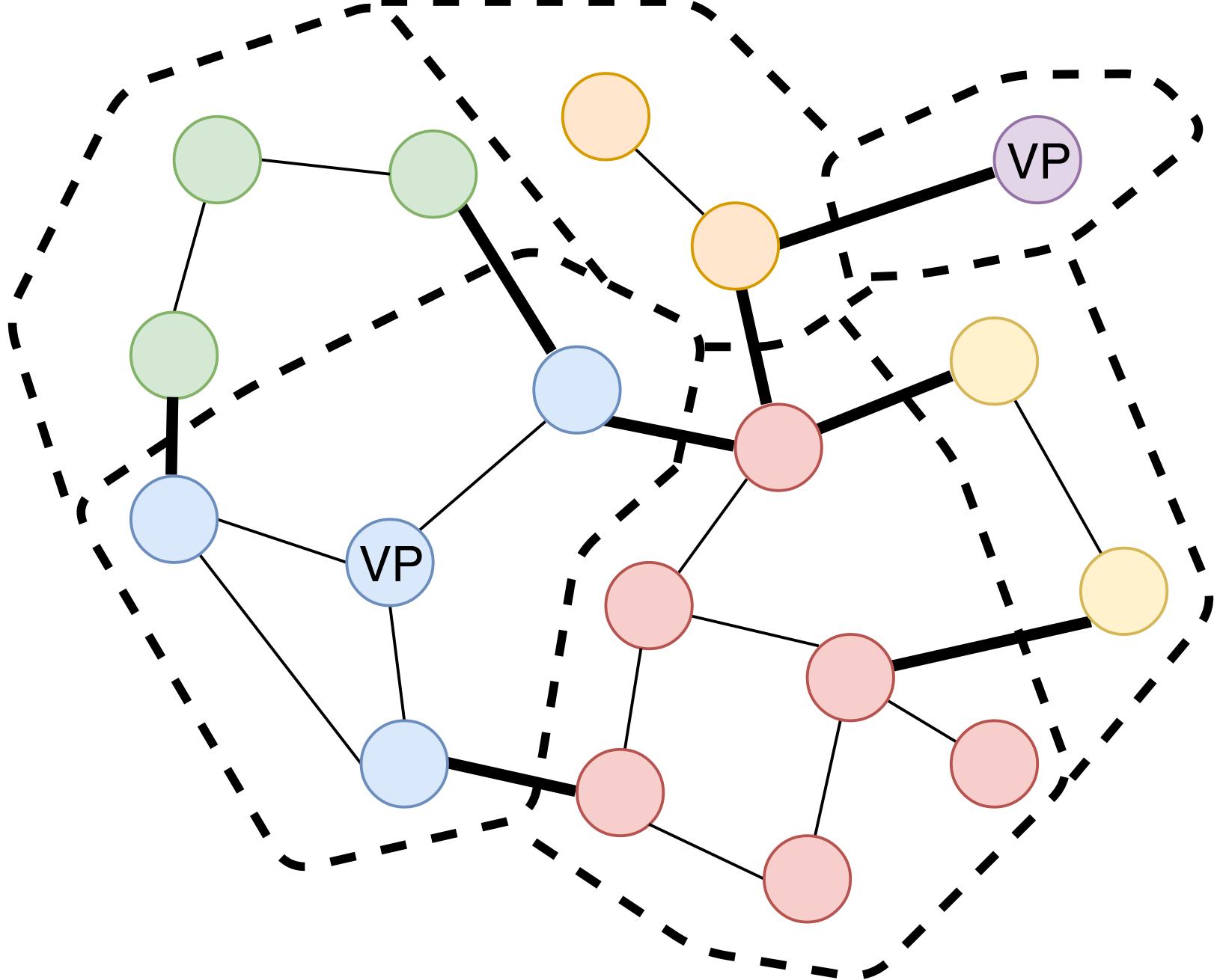
- **bdrmap** [Luckie et al. IMC '16]
 - Highly accurate
 - Limited to the border of the traceroute vantage point network
- **MAP-IT** [Marder et al. IMC '16]
 - Identifies inter-AS links at Internet-scale
 - Precise, but lower recall
- Goal is to synthesize them



Measuring Interdomain Congestion

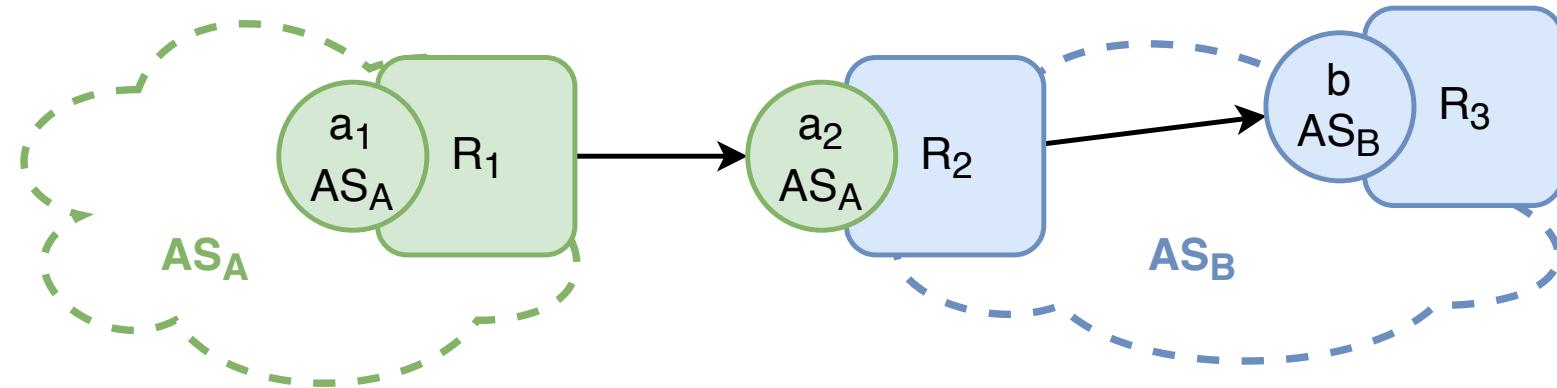


Measuring Interdomain Congestion



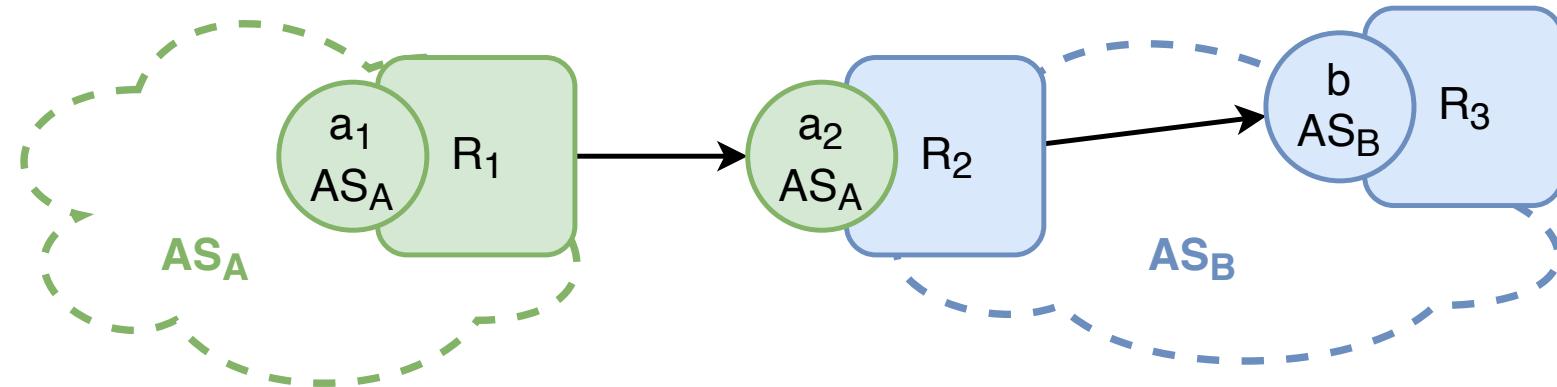
Challenges: Neighboring Address Space

- Link addresses come from *one AS*



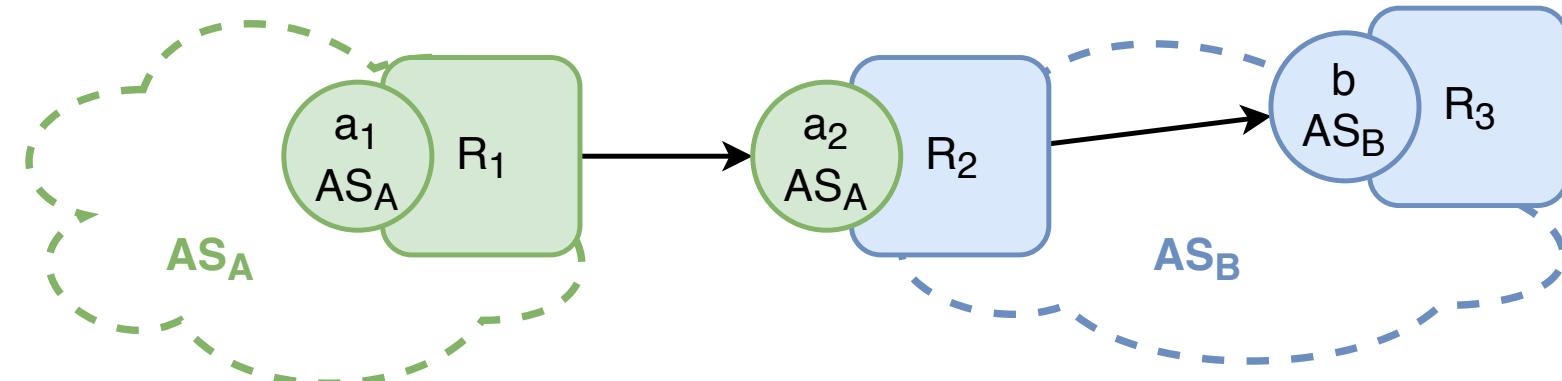
Challenges: Neighboring Address Space

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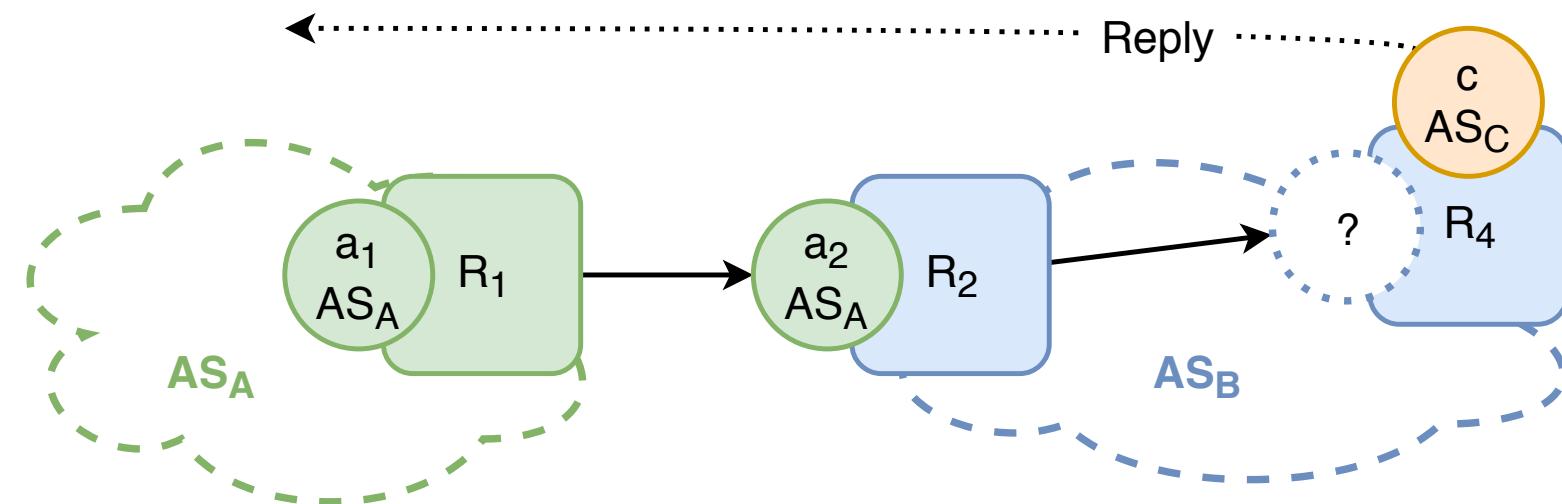


Challenges: Neighboring Address Space

- Link addresses come from *one AS*

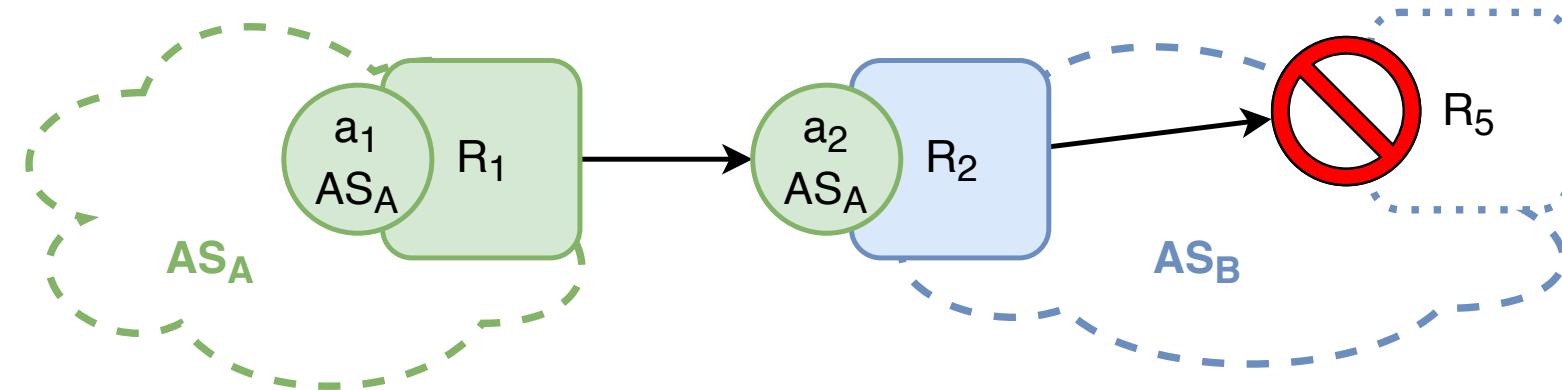


- Off path addresses



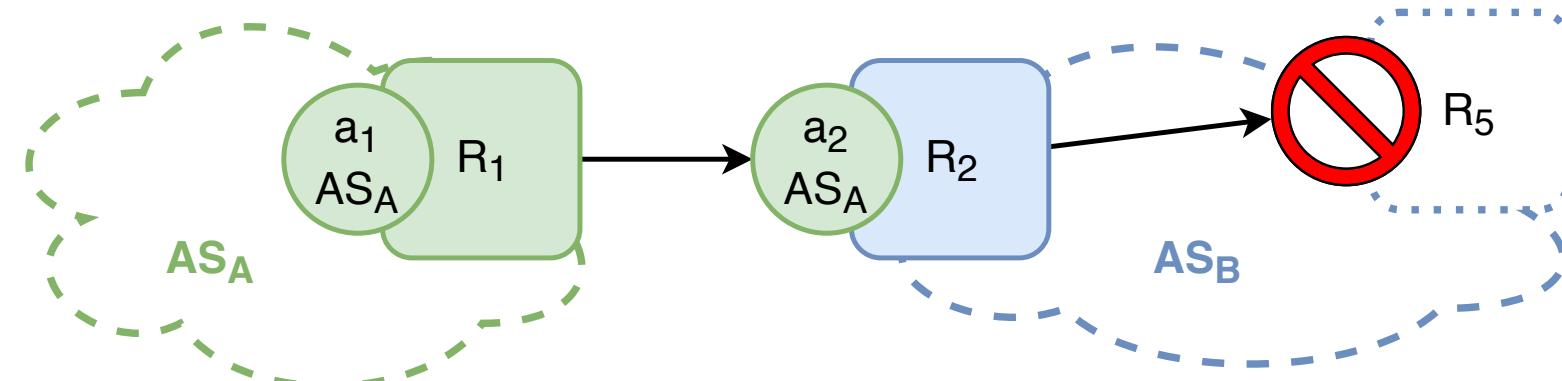
Challenges: Unresponsive Routers

- Prevent responses *past* their border

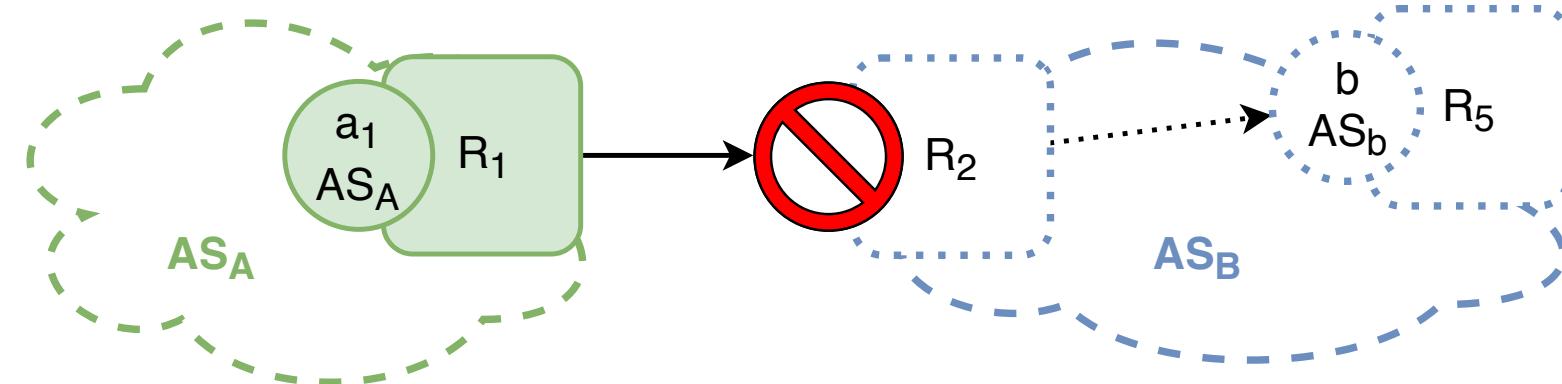


Challenges: Unresponsive Routers

- Prevent responses *past* their border

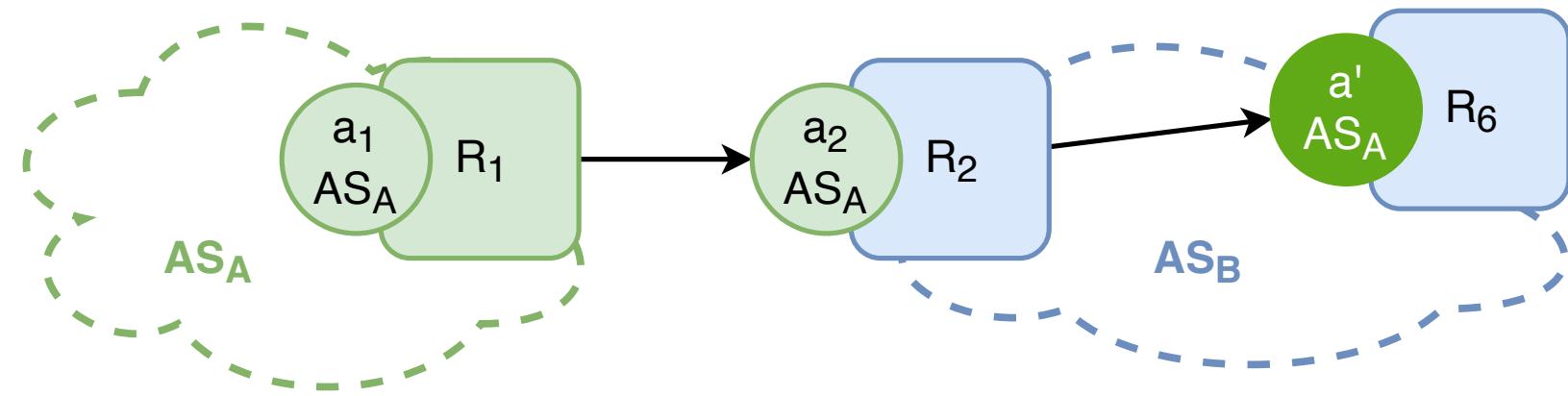


- Prevent responses *at* their border



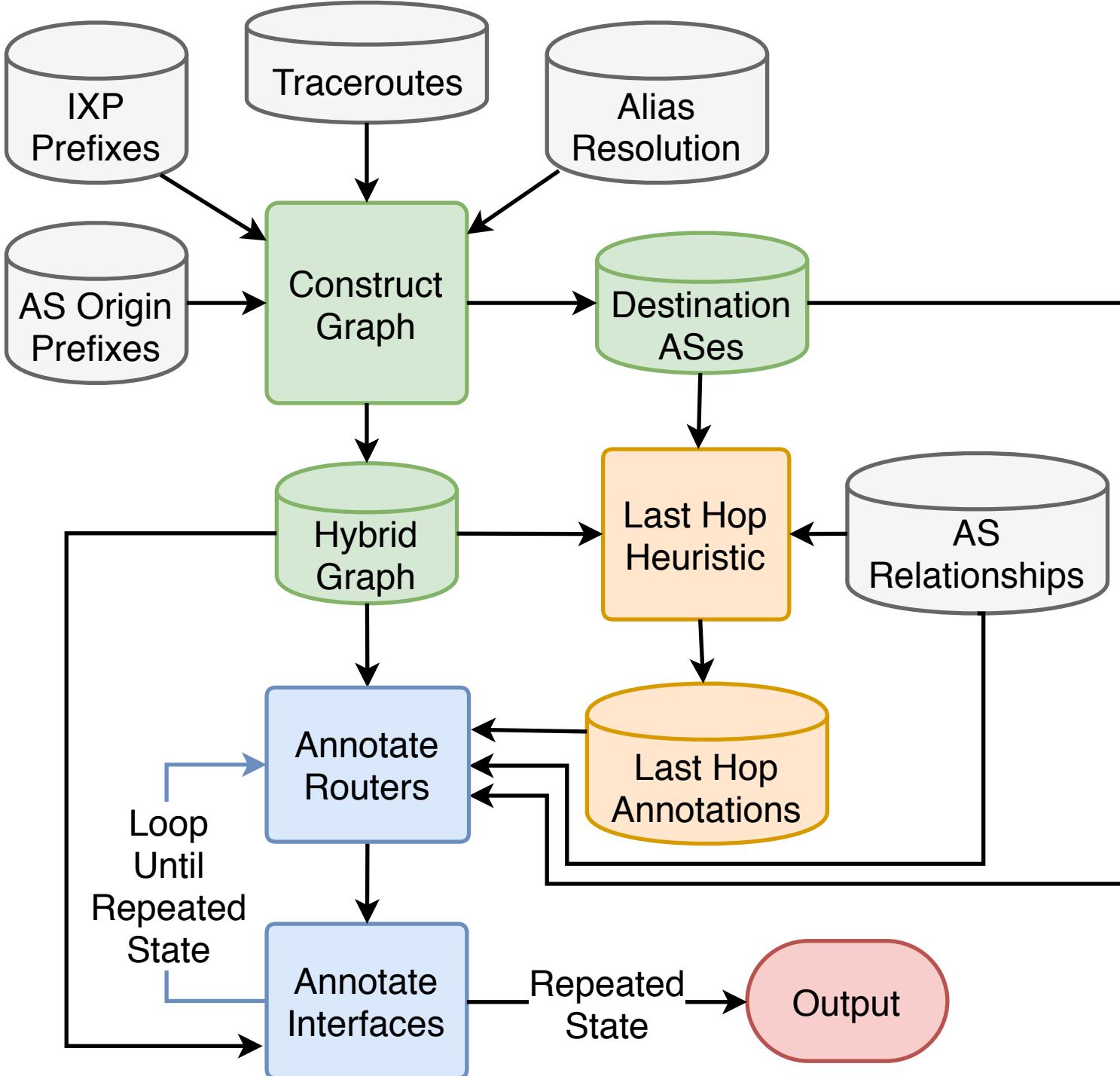
Challenges: Reallocated Prefixes

- Providers can reallocated prefixes to customers

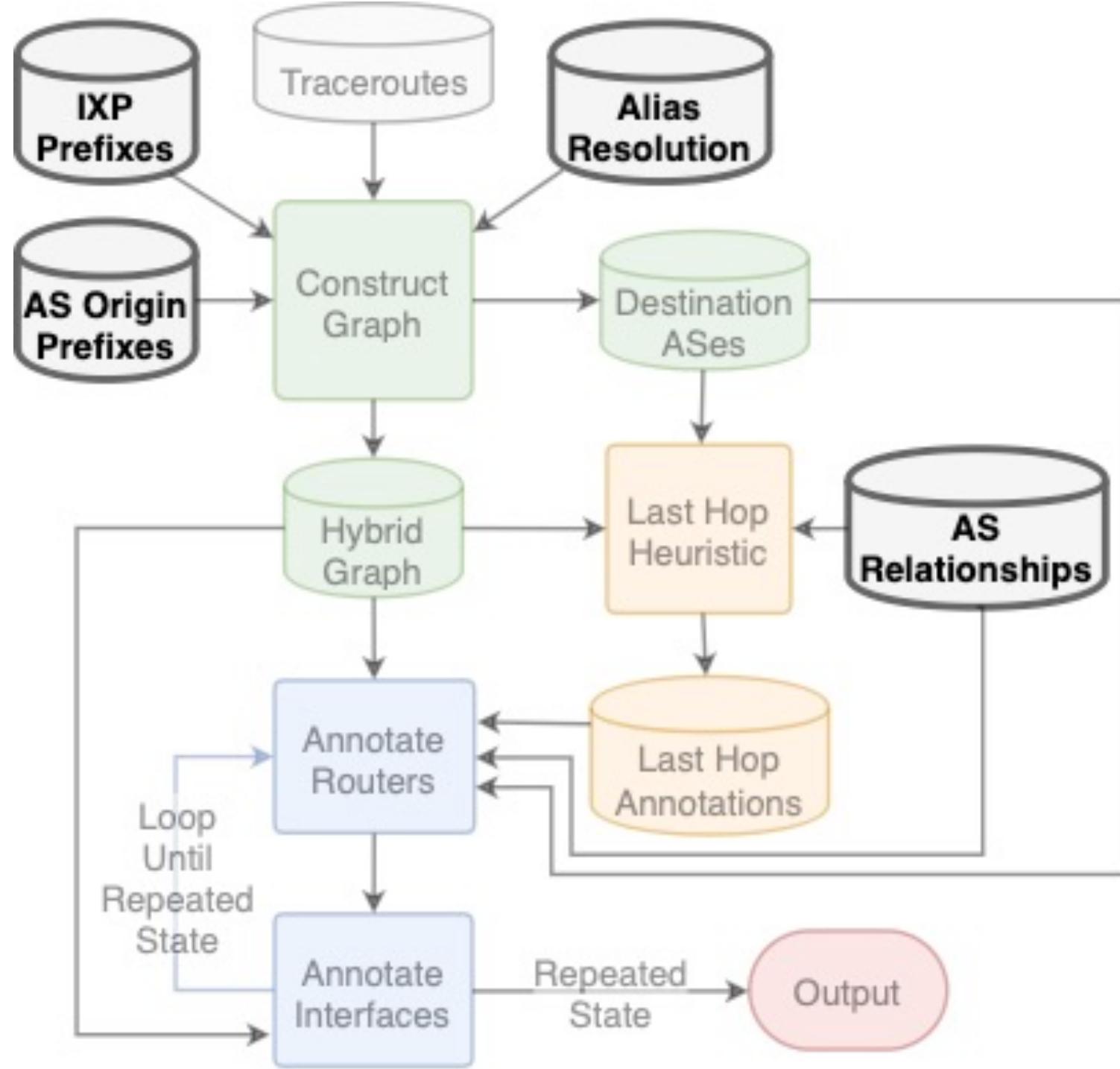


- Often missing from BGP

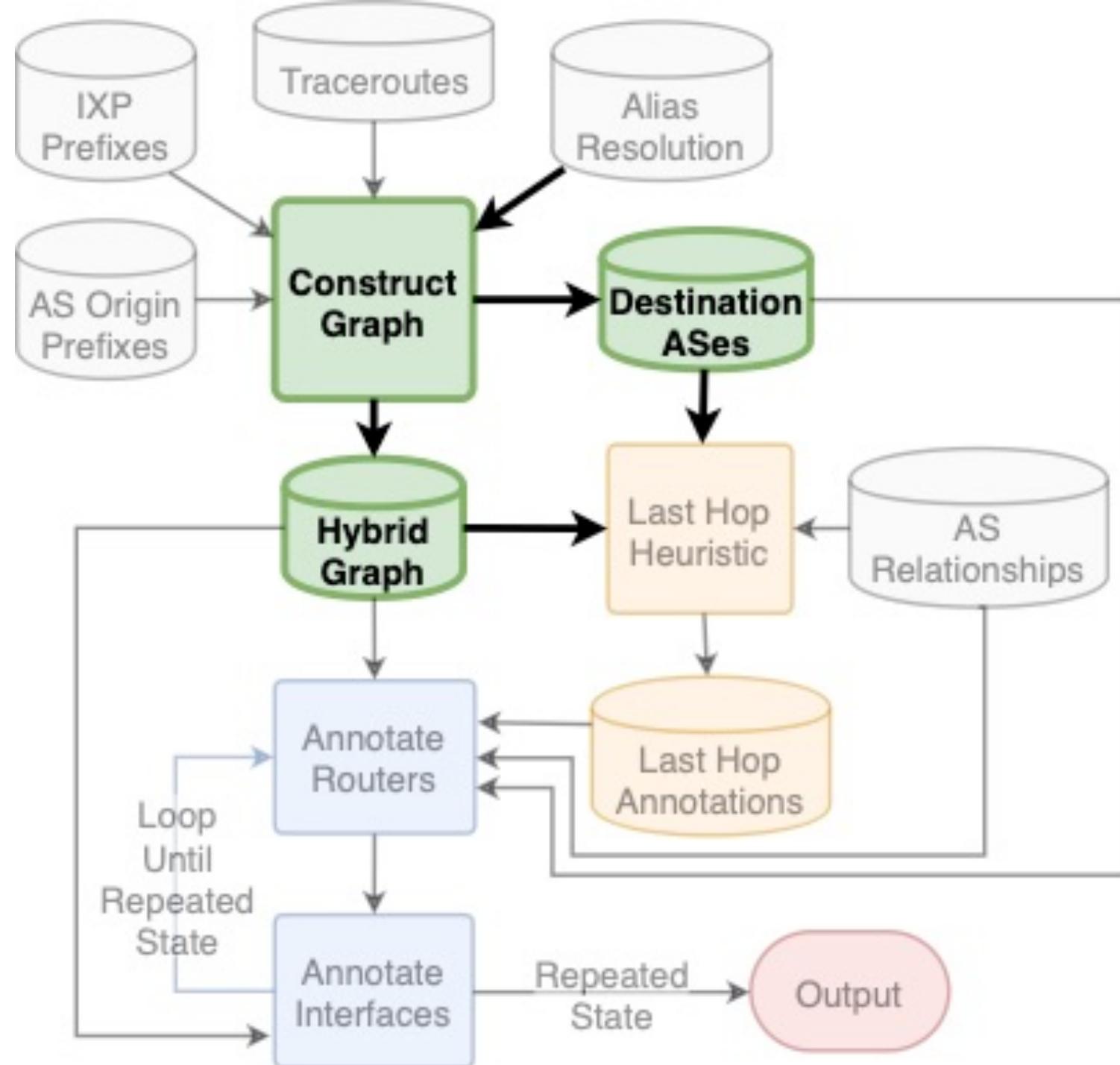
bdrmapIT Flowchart



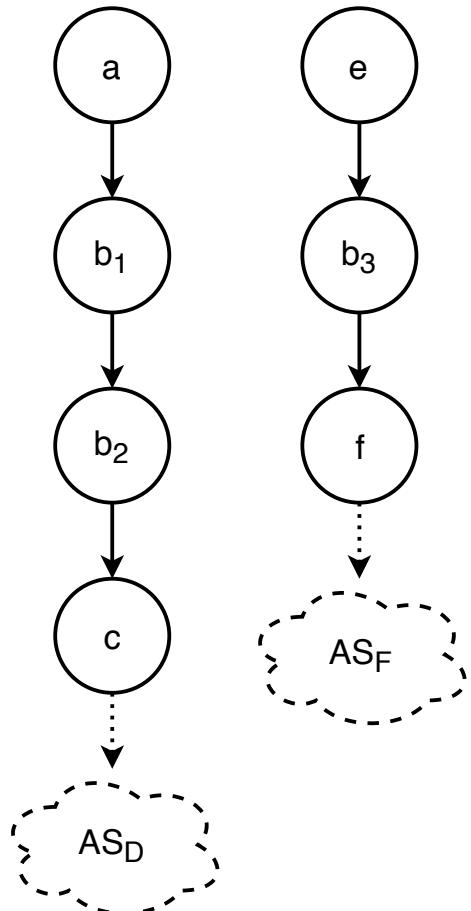
External Data



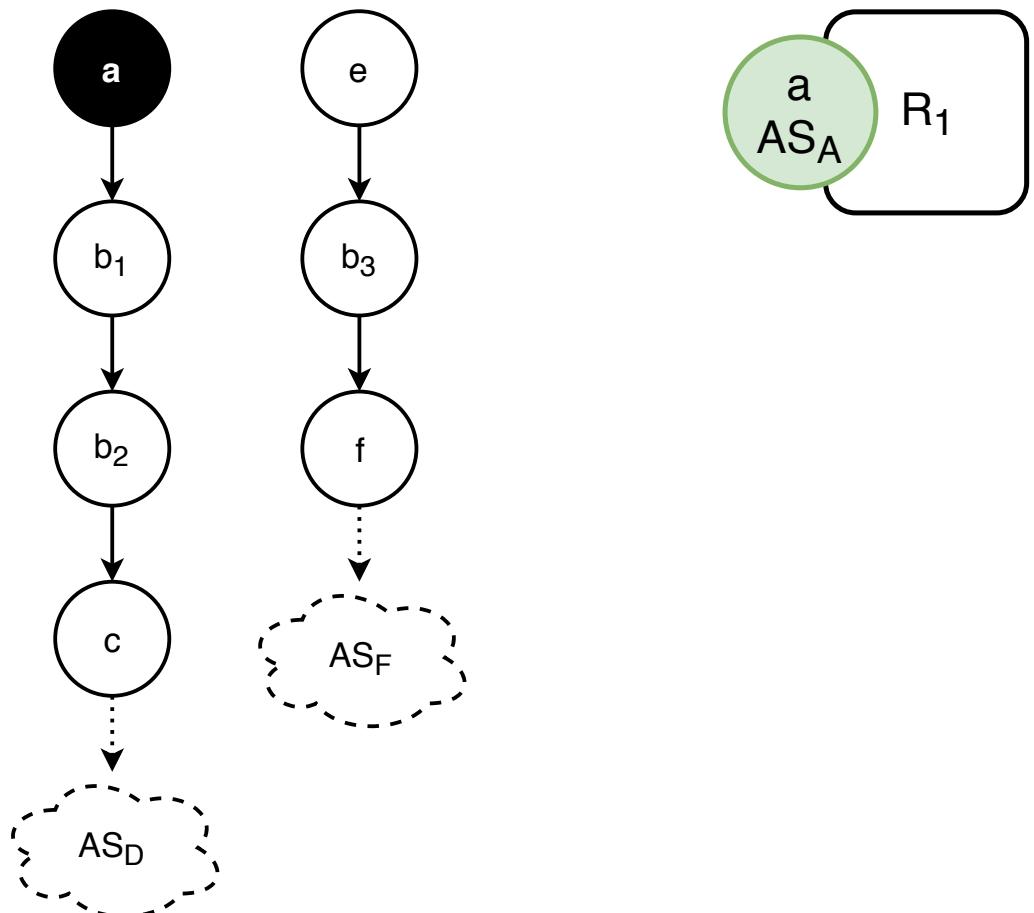
Phase 1: Construct Graph



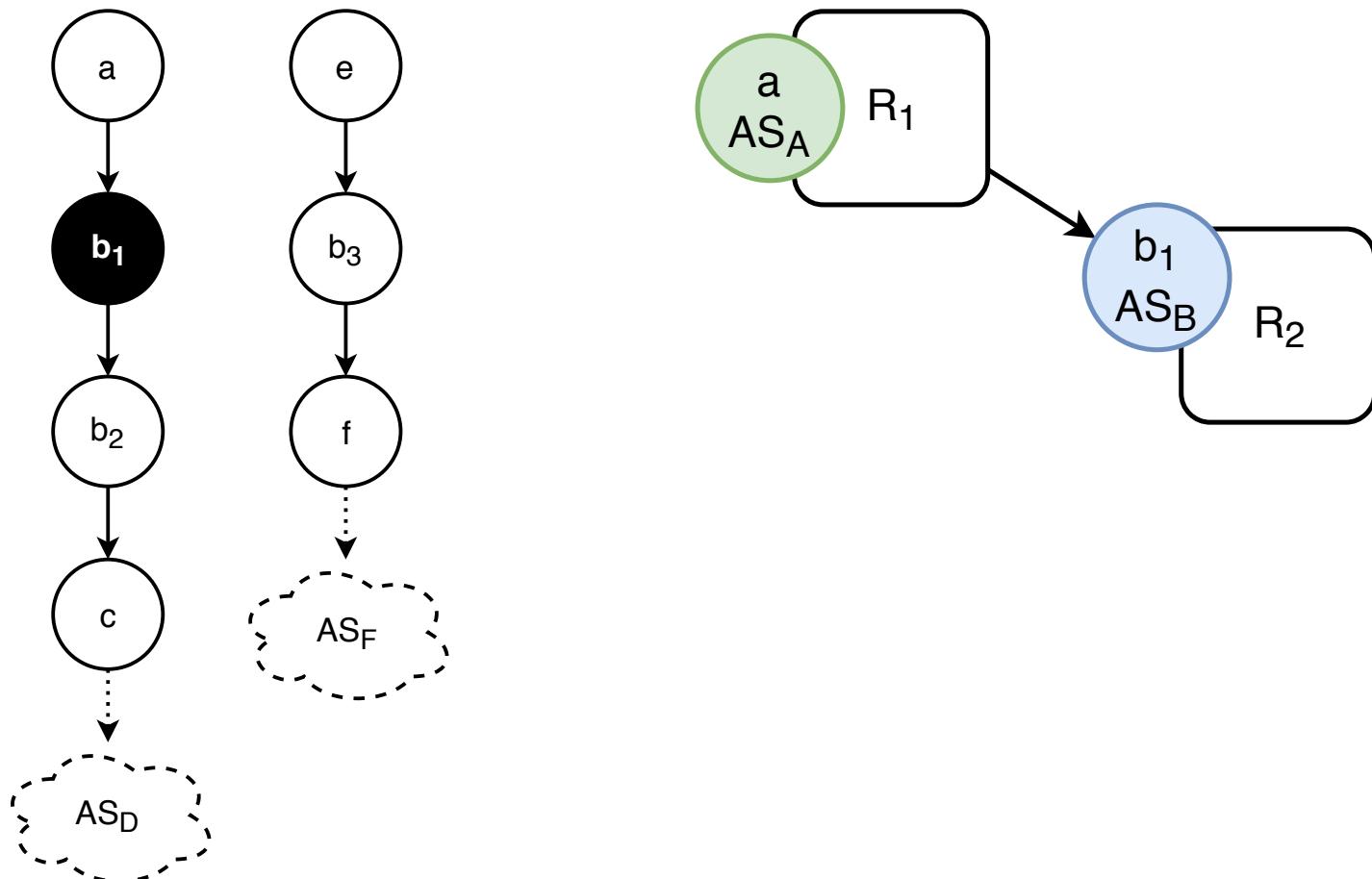
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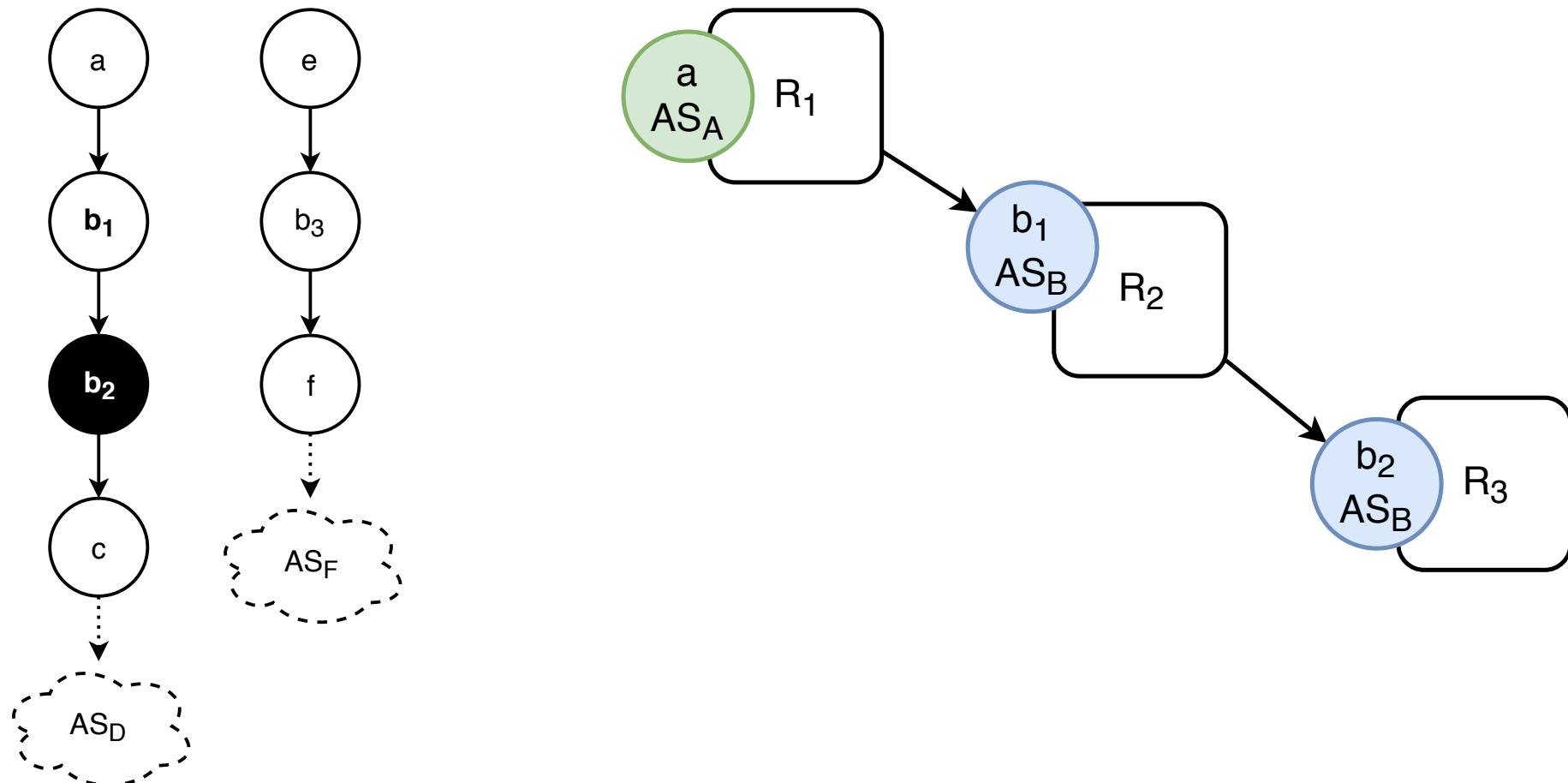
Phase 1: Construct Graph



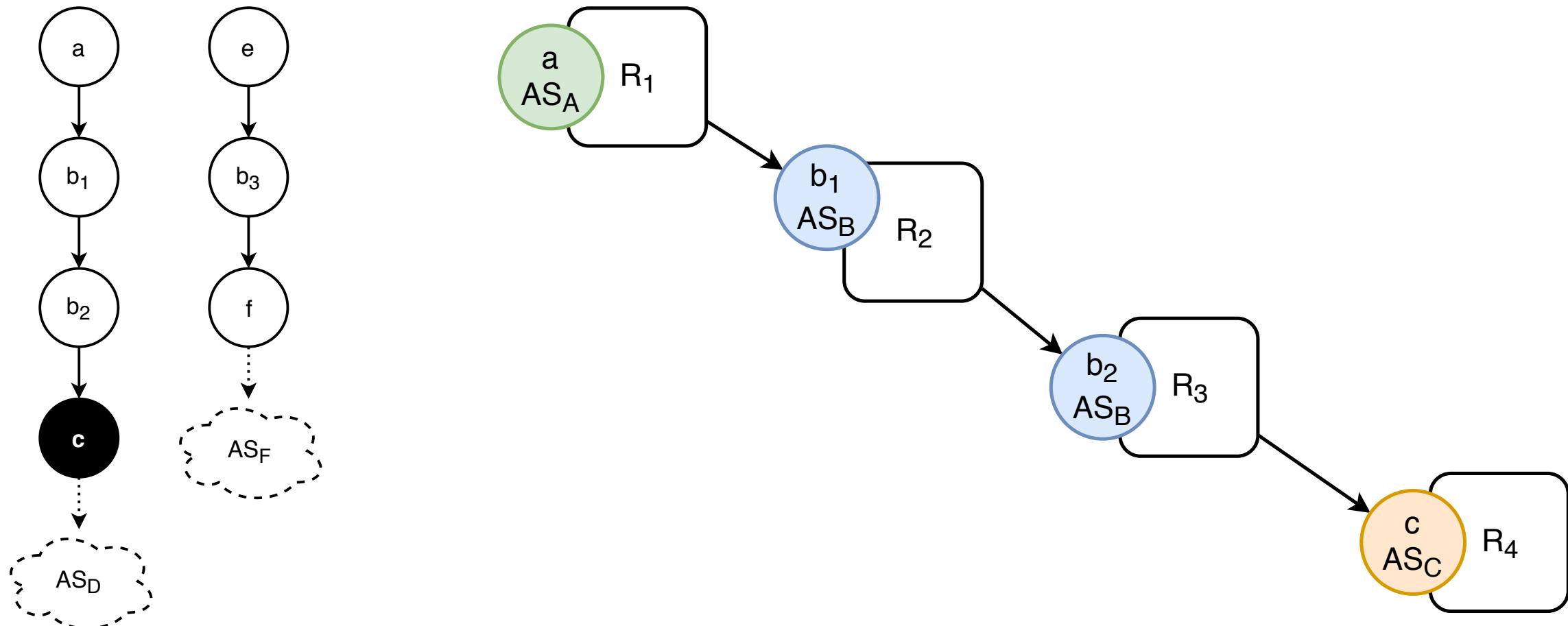
Phase 1: Construct Graph



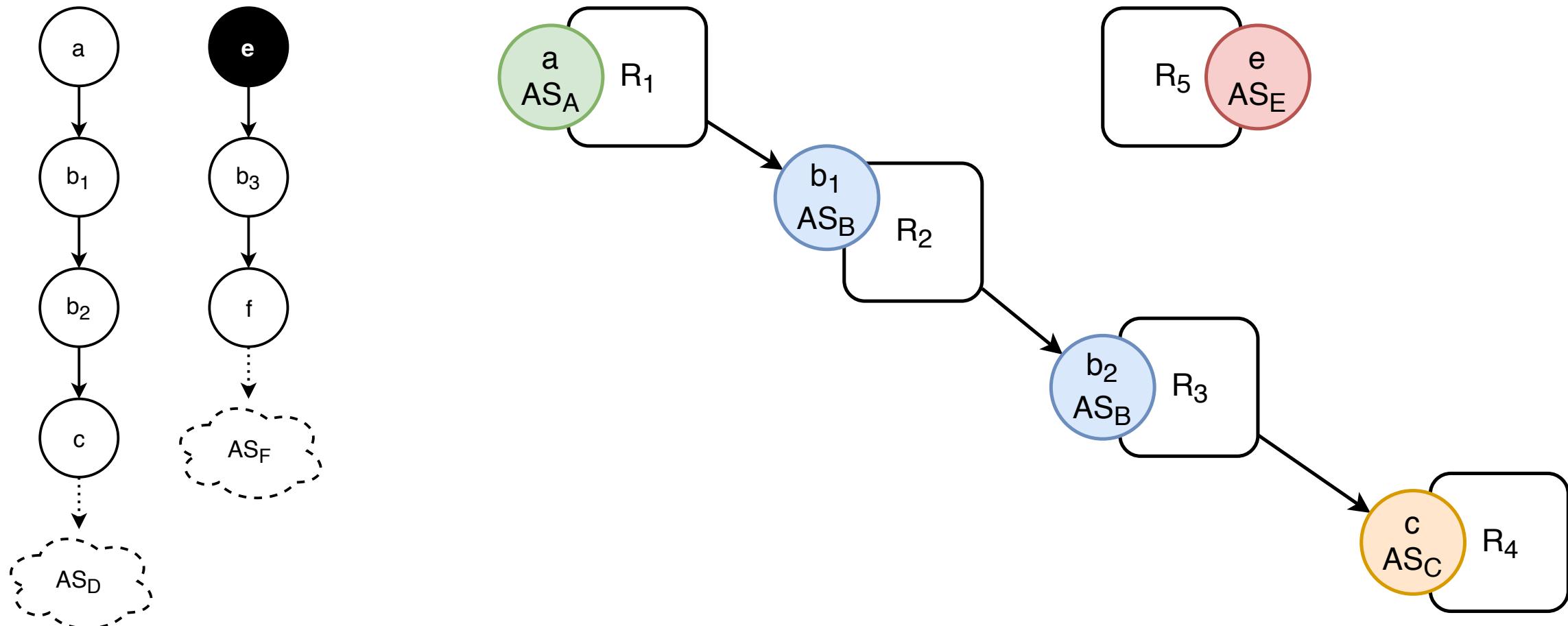
Phase 1: Construct Graph



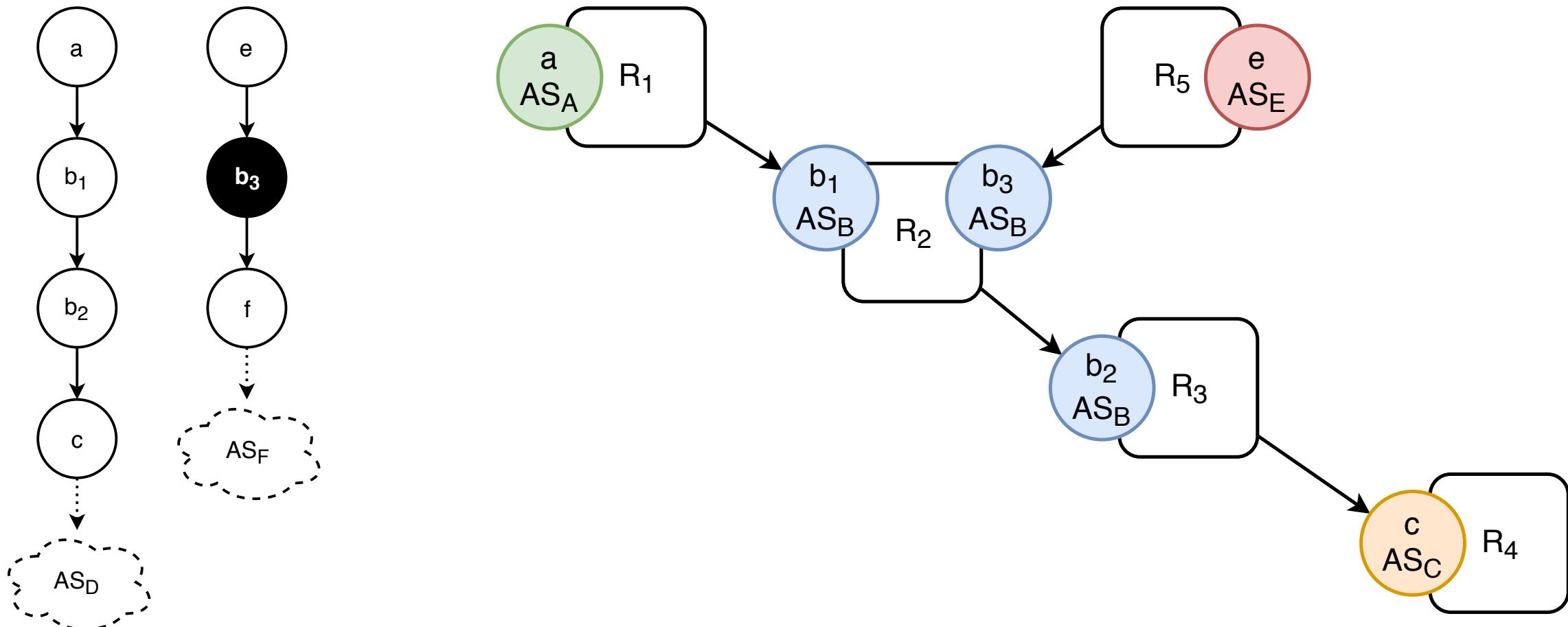
Phase 1: Construct Graph



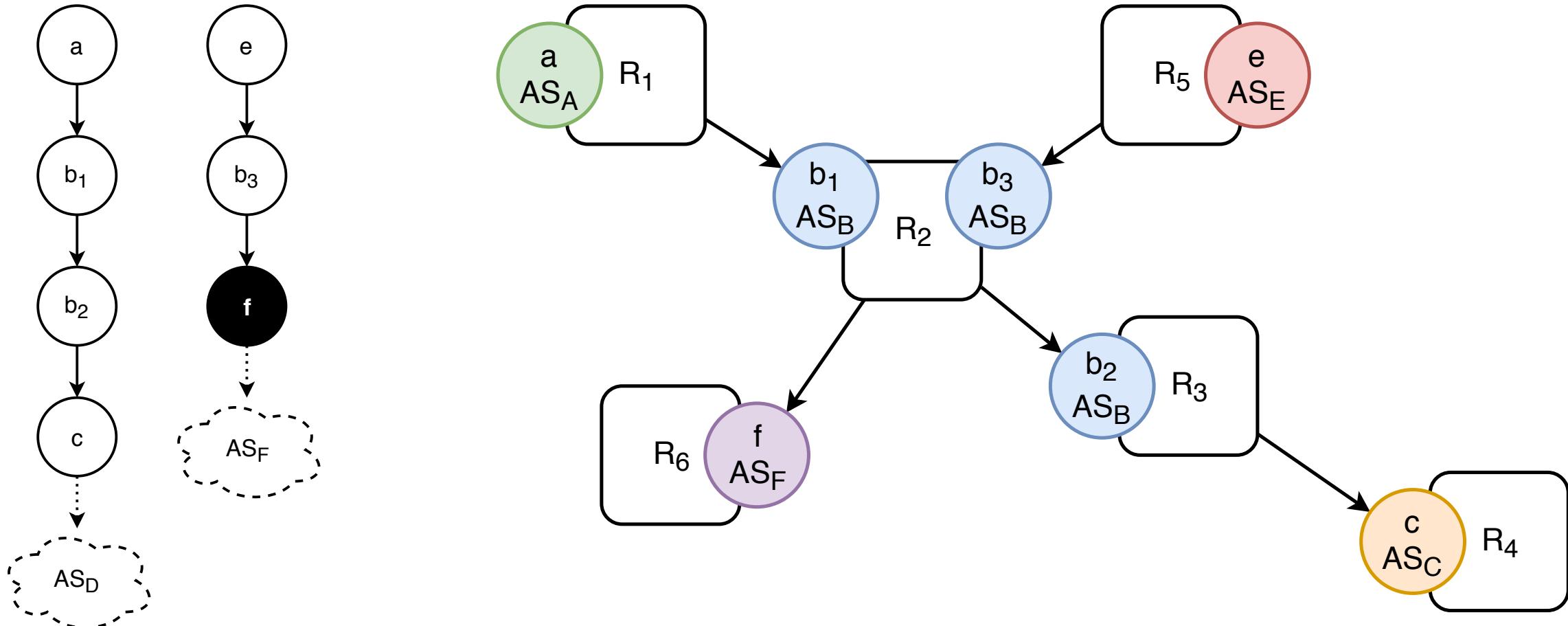
Phase 1: Construct Graph



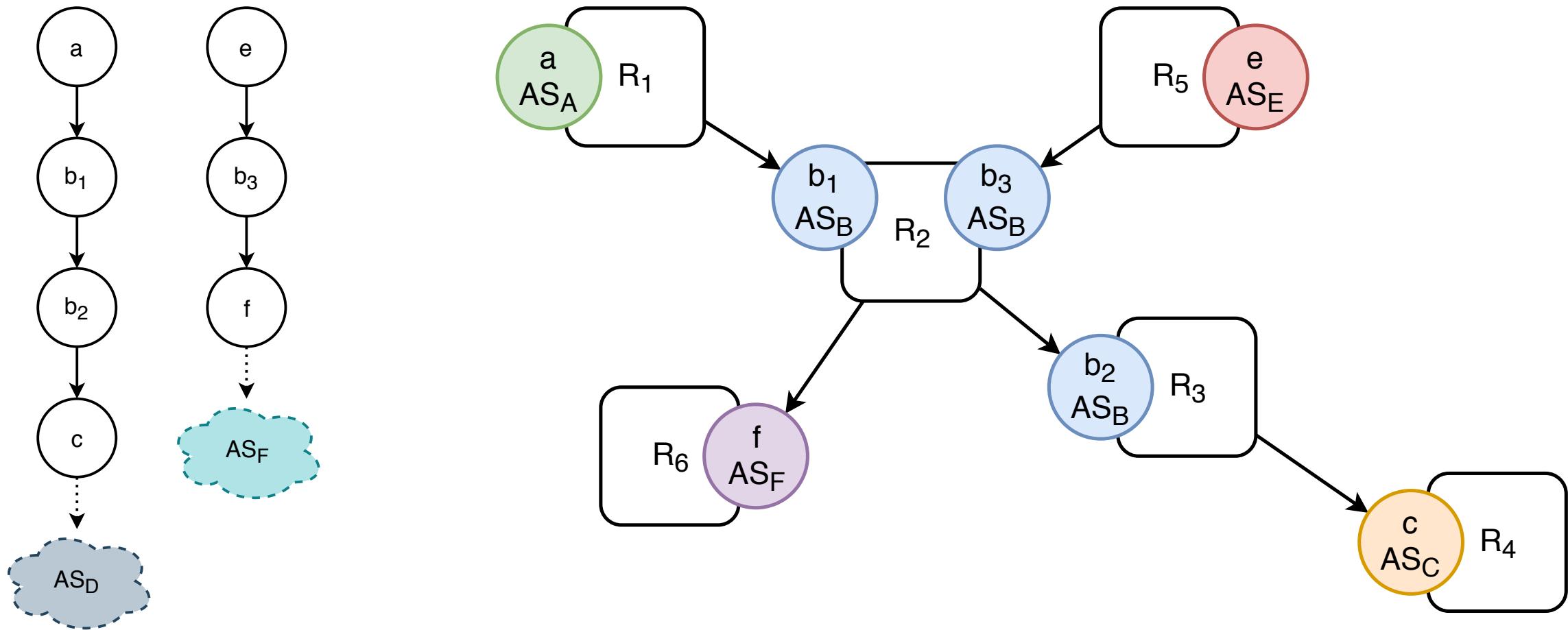
Phase 1: Construct Graph



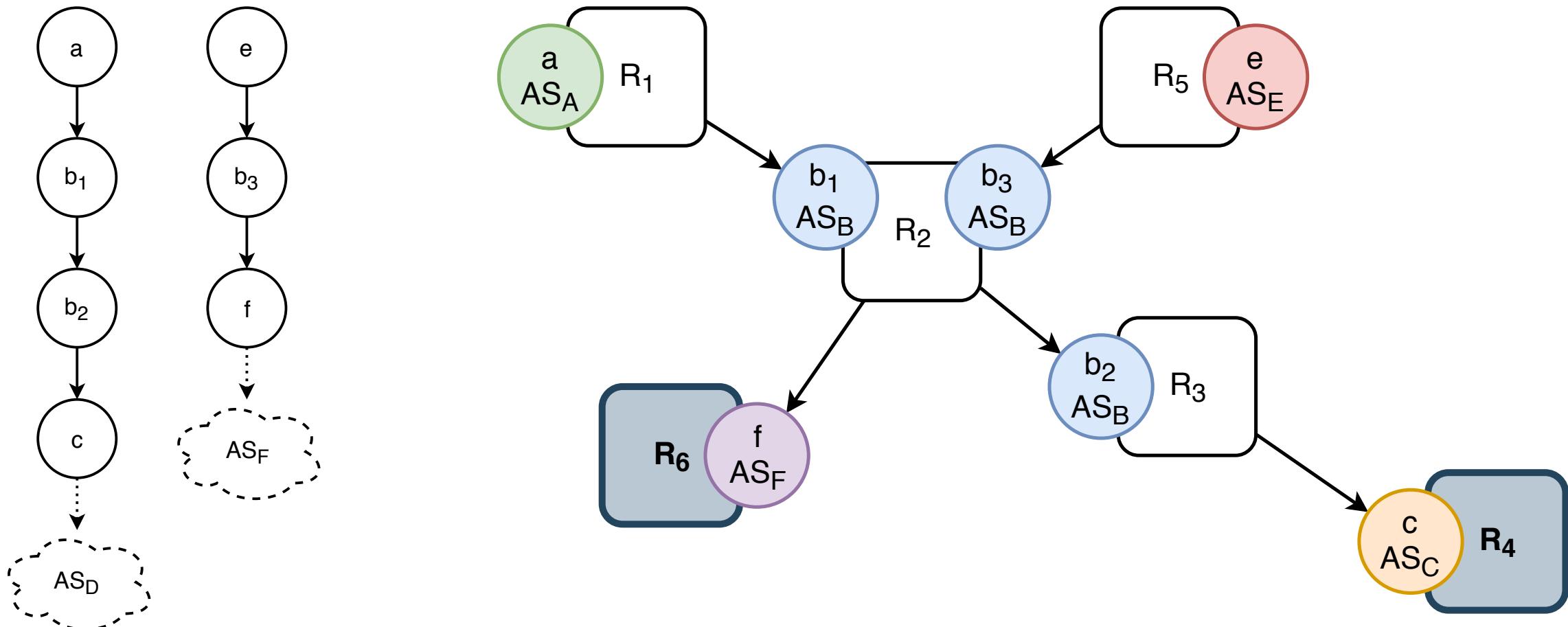
Phase 1: Construct Graph



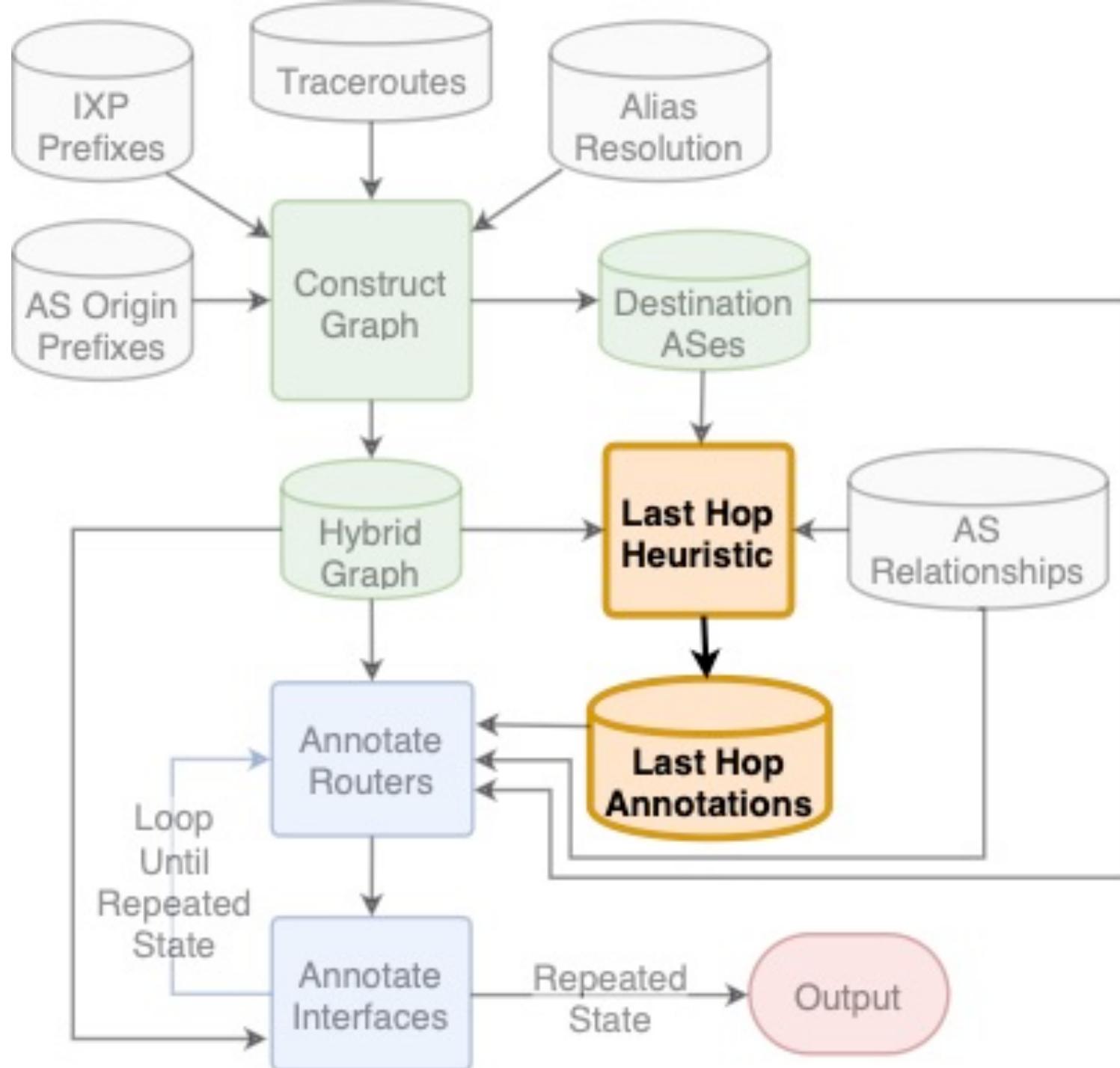
Phase 1: Destination ASes



Phase 1: Last Hop Routers

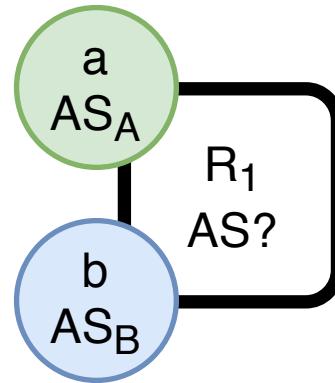


Phase 2: Last Hops



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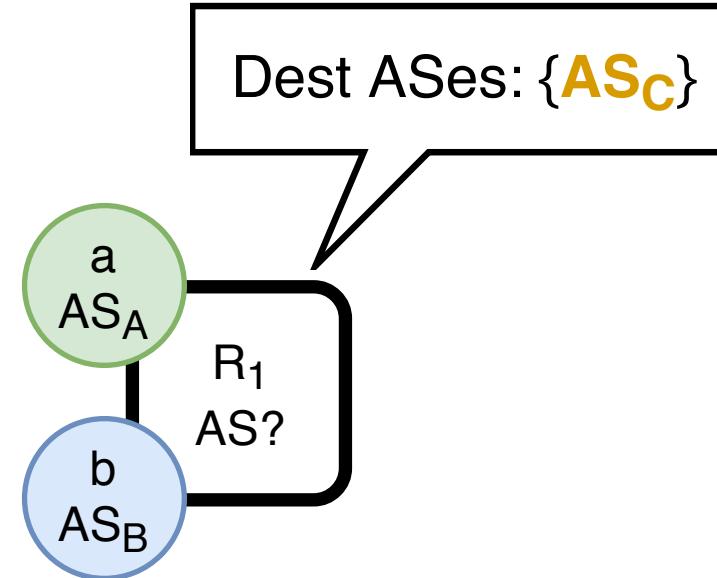
- Who operates R_1 ?



- Look for common reason the traceroutes ended at R_1

Phase 2: Last Hops

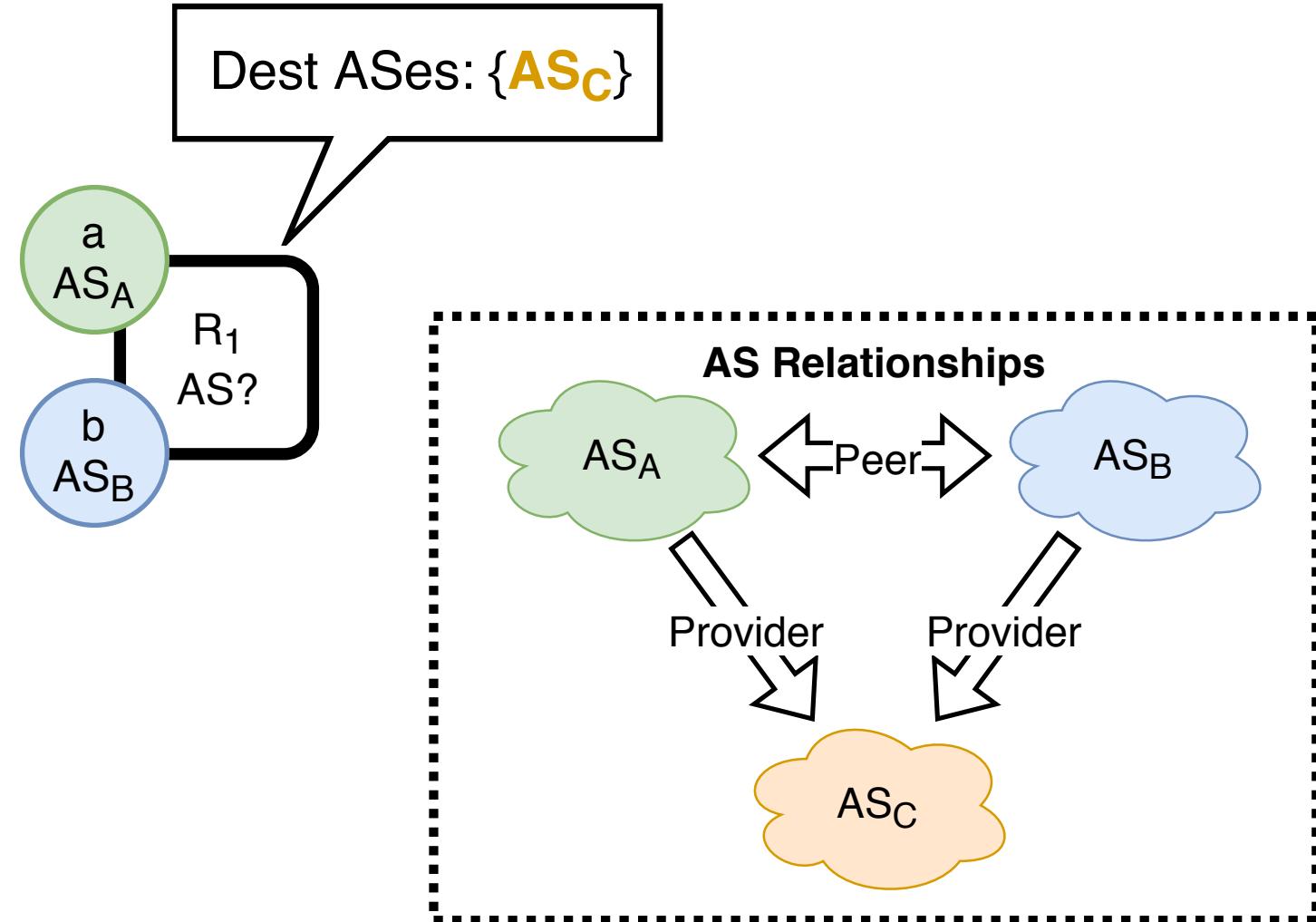
- Include destination ASes



Phase 2: Last Hops

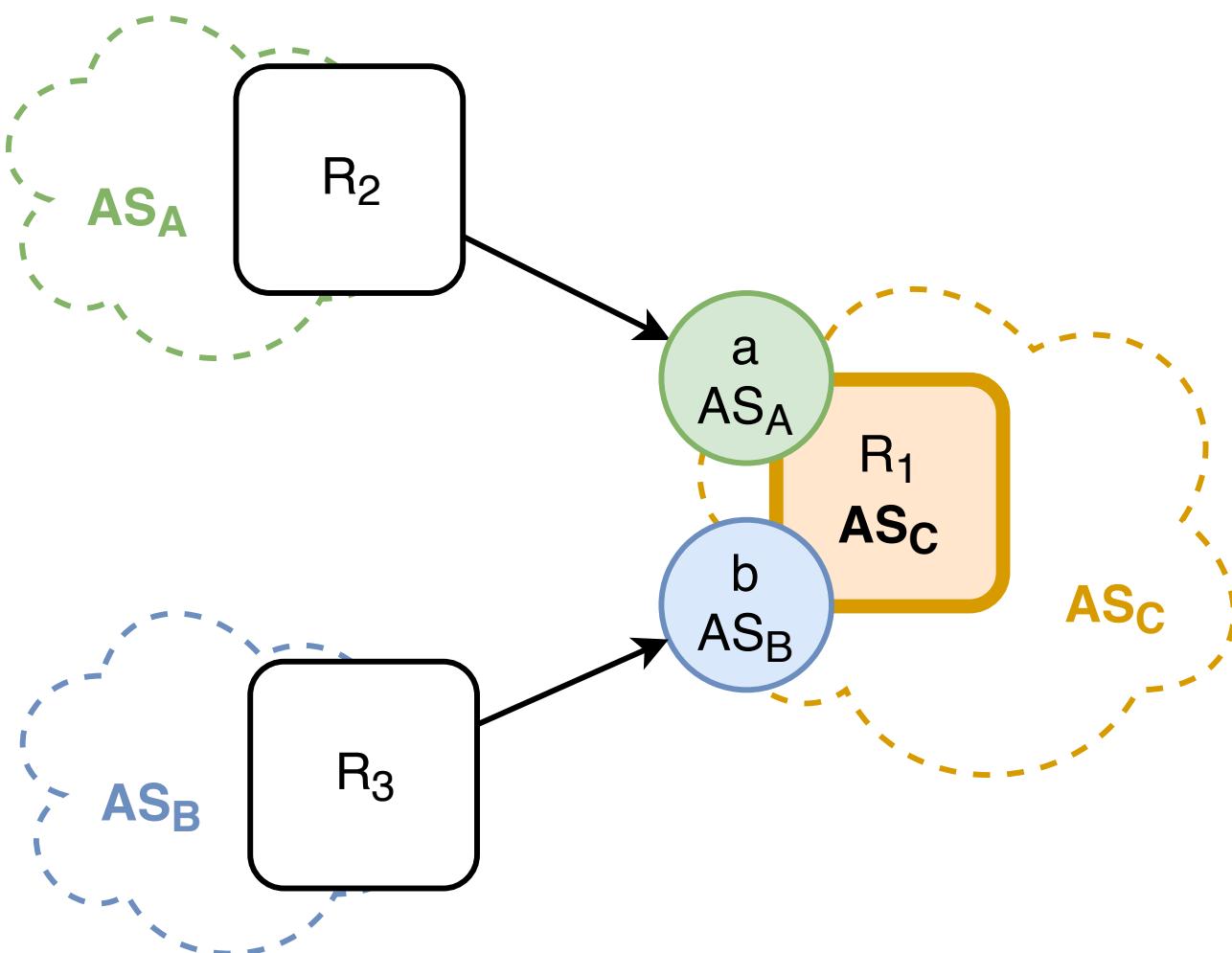
- Check AS relationships

- Transit links are typically addresses from provider

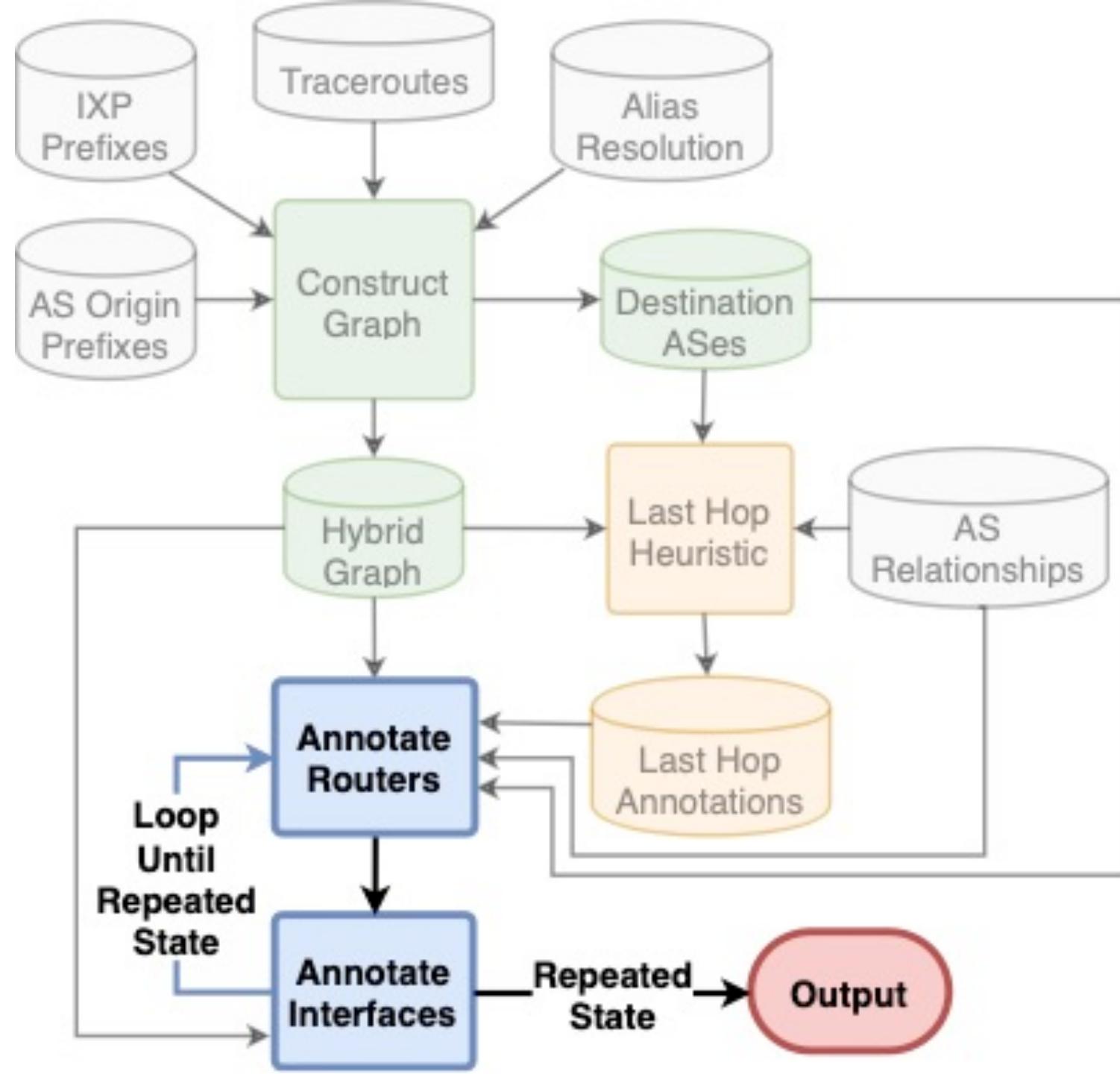


Phase 2: Last Hops

- Annotate R_1 with **C**

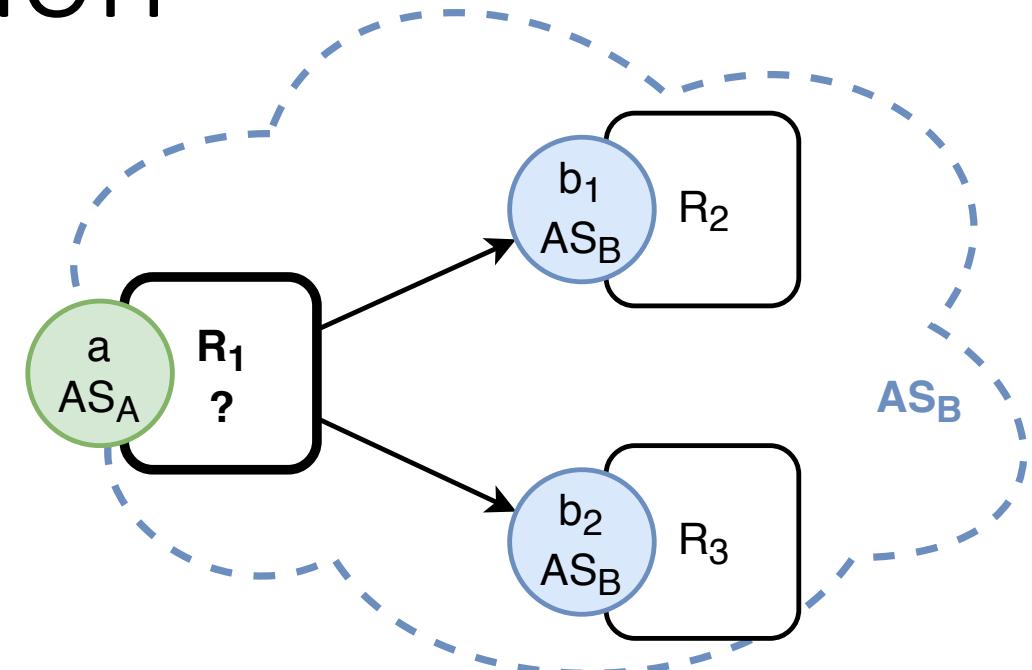


Phase 3: Graph Refinement



Annotate Routers: Election

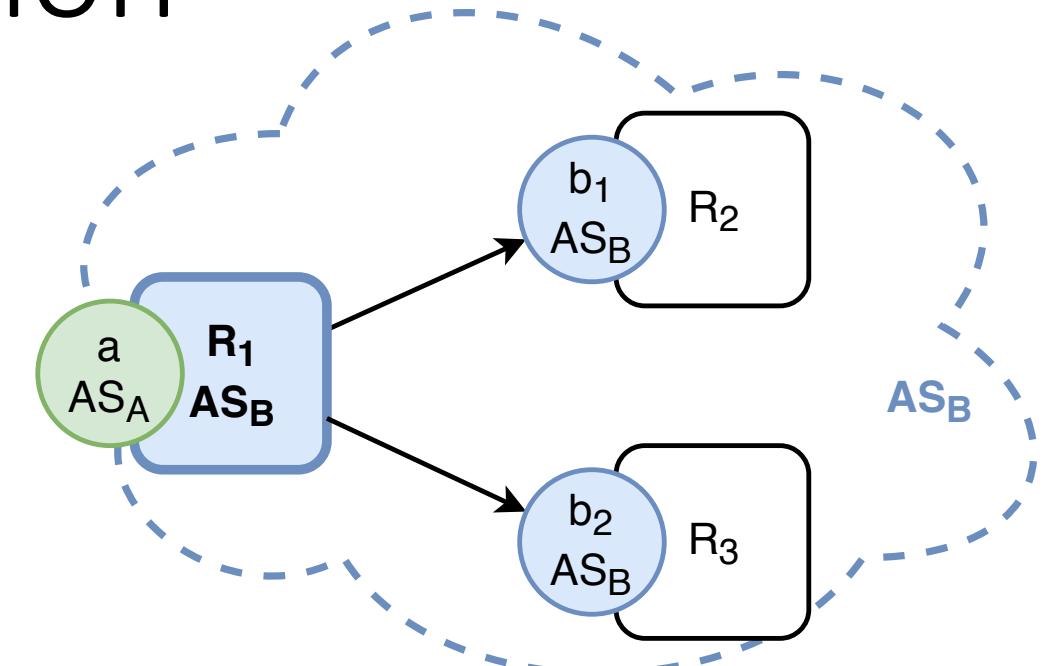
- Most votes win
 - Include subsequent and router interfaces



Network	Votes
AS _A	1
AS _B	2

Annotate Routers: Election

- Most votes win
 - Include subsequent and router interfaces



- Annotate R_1 with B

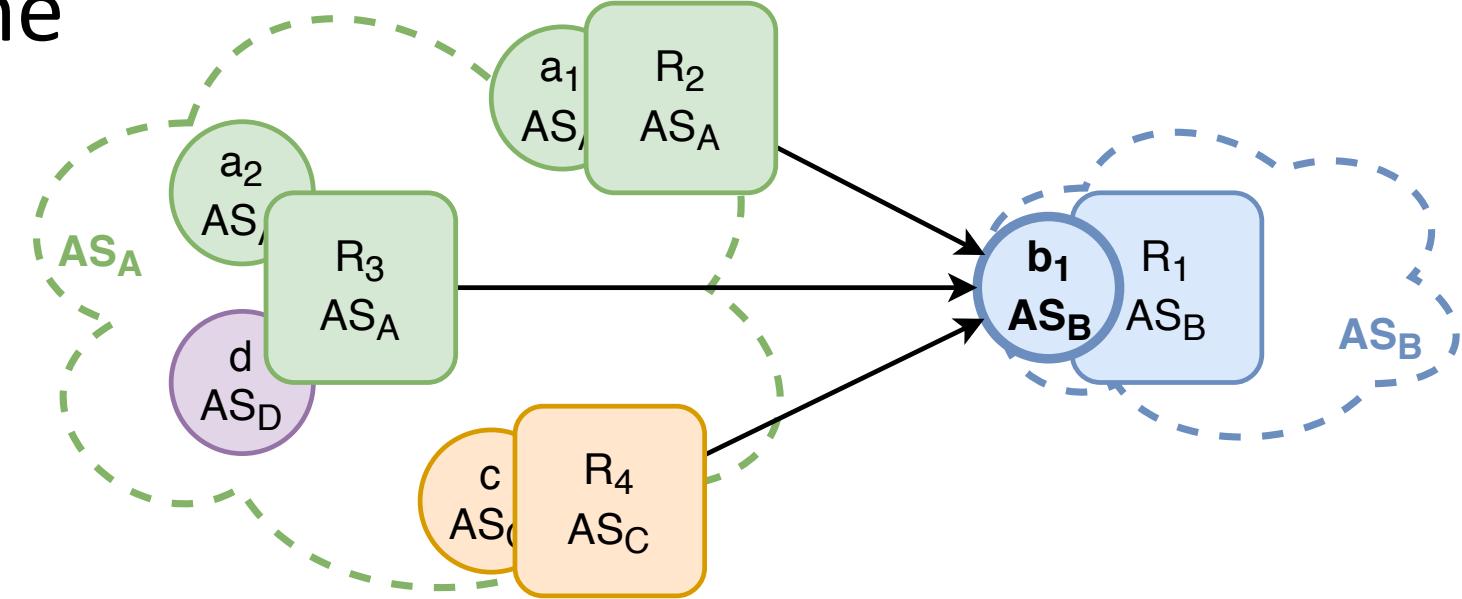
Network	Votes
AS _A	1
AS _B	2

Annotate Routers: There's More

- Change votes:
 - 3rd party addresses
 - Reallocated prefixes
- Ignore election outcome
 - Multihomed to a single provider
 - Many neighboring networks
- Special cases
 - IXP addresses
 - Unannounced addresses
 - Look for hidden ASes
 - Etc.

Annotating Interfaces: Interdomain

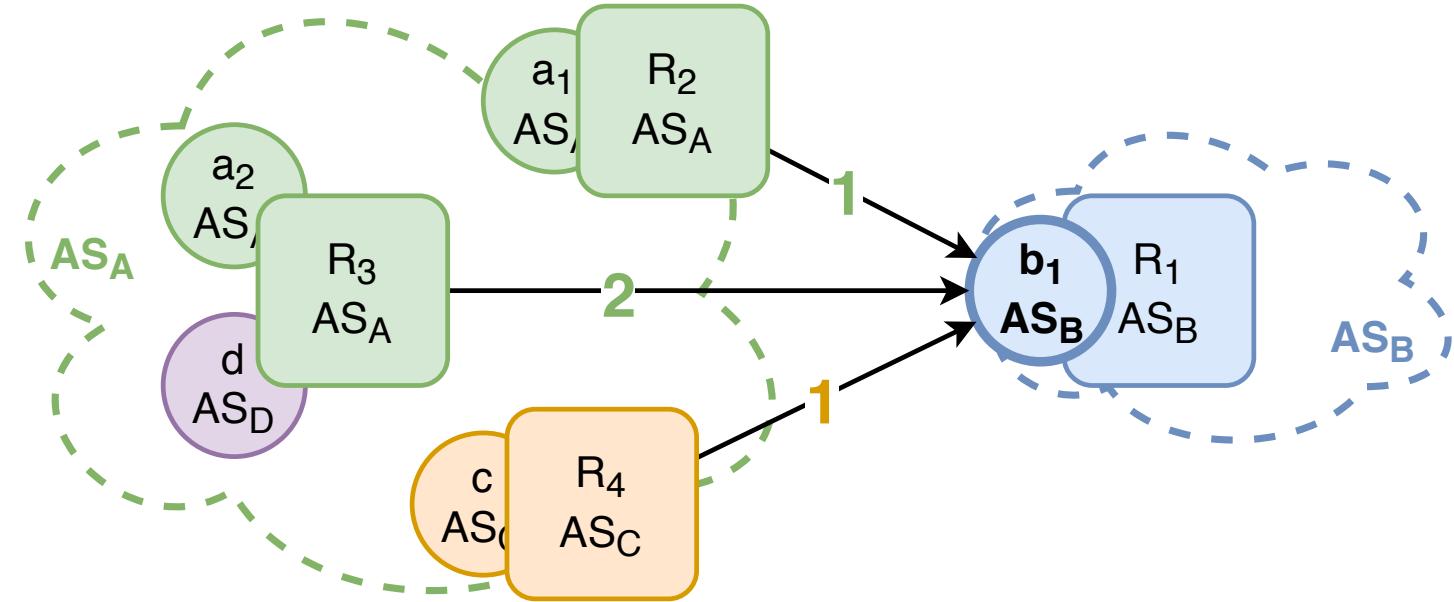
- Origin AS is the same as the router annotation



- Use election

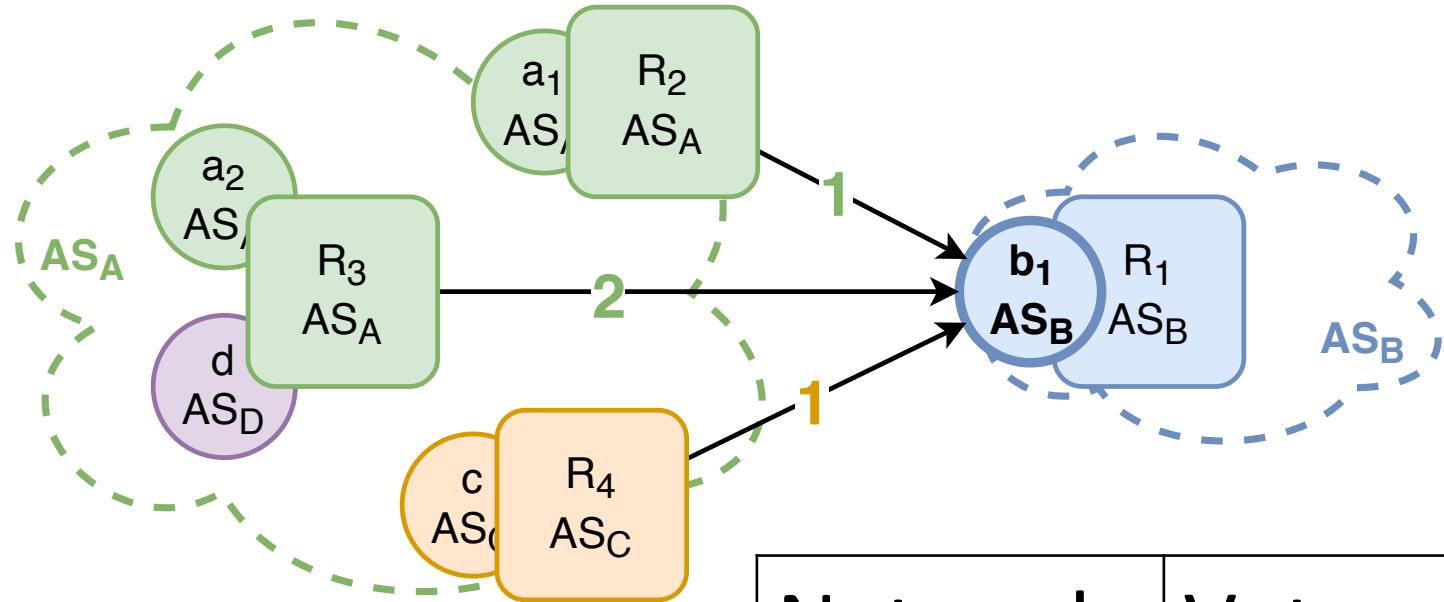
Annotating Interfaces: Interdomain

- Routers vote with AS annotation
- 1 vote per interface



Annotating Interfaces: Interdomain

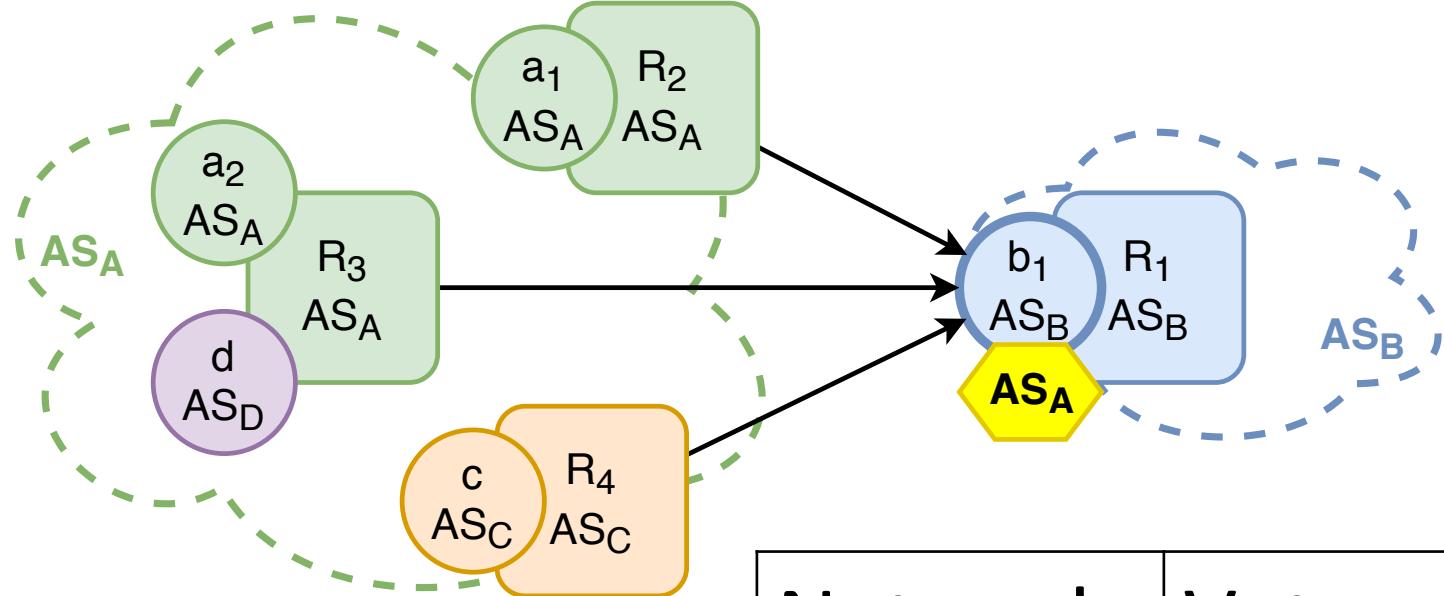
- Routers vote with AS annotation
- 1 vote per interface



Network	Votes
AS _A	3
AS _C	1
AS _B	1

Annotating Interfaces: Interdomain

- Annotate b_1 with **A**

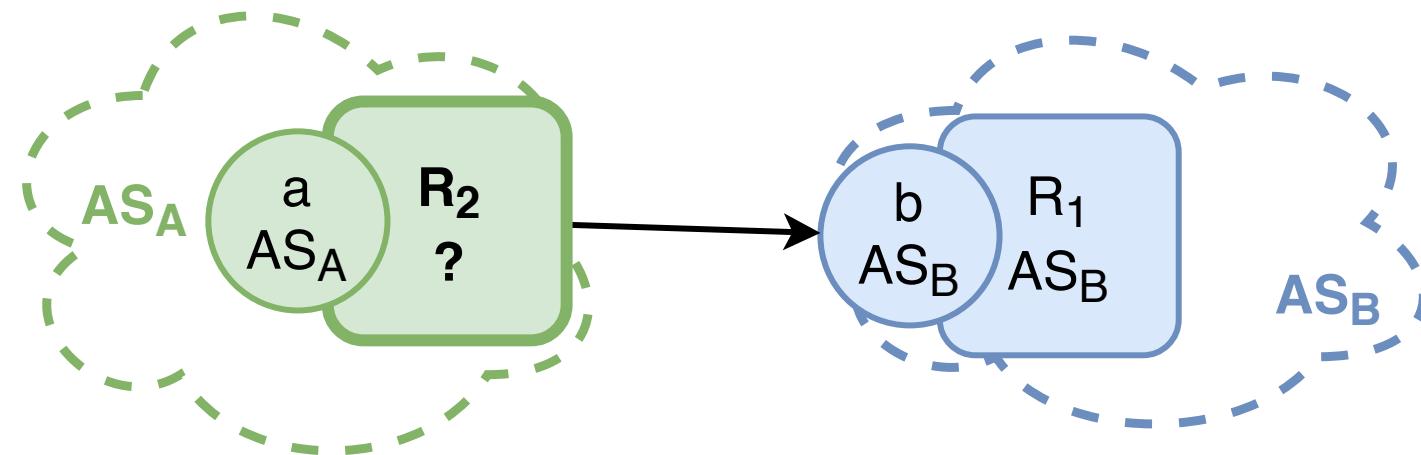


Network	Votes
AS _A	3
AS _C	1
AS _B	1

Multiple Iterations

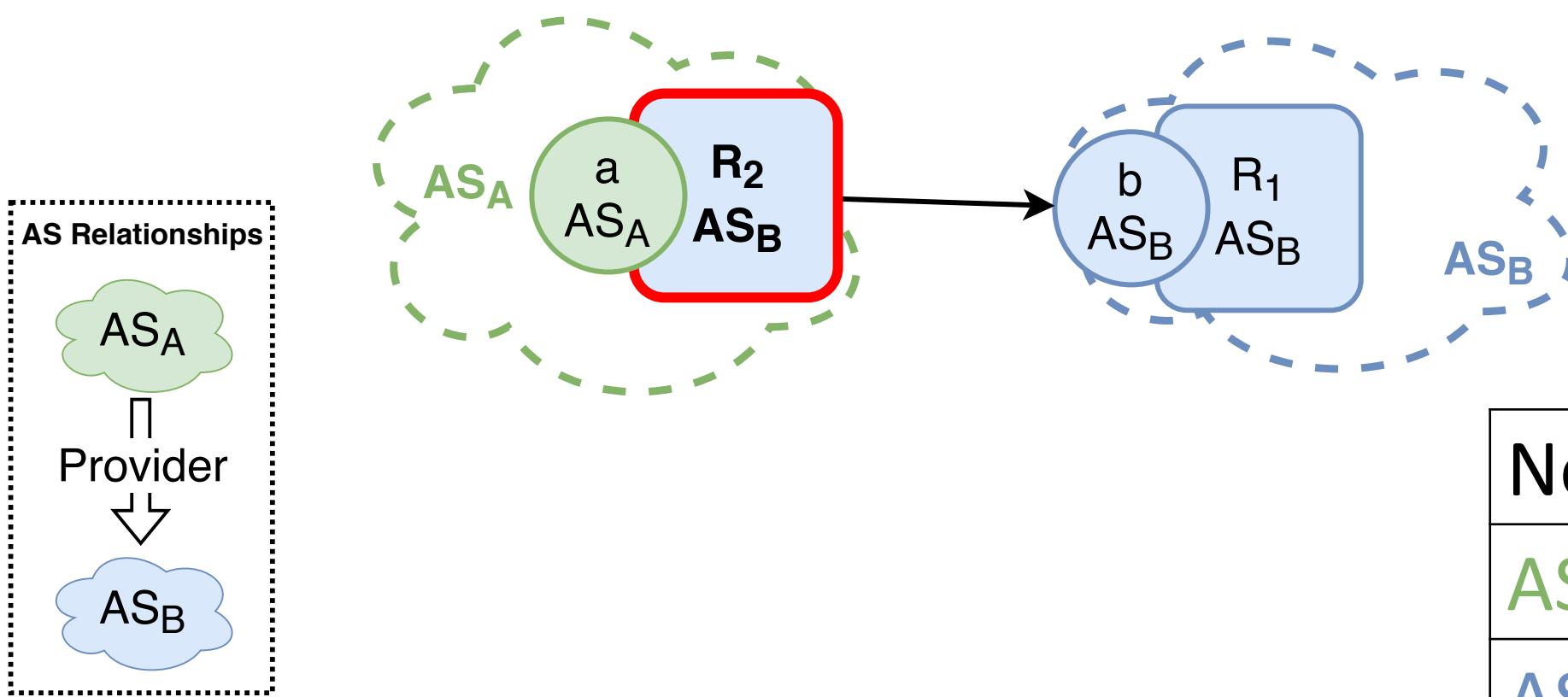
- Repeat annotating routers and interfaces until repeated state
- Improves annotations

1st Iteration: Annotate Routers



1st Iteration: Annotate Routers

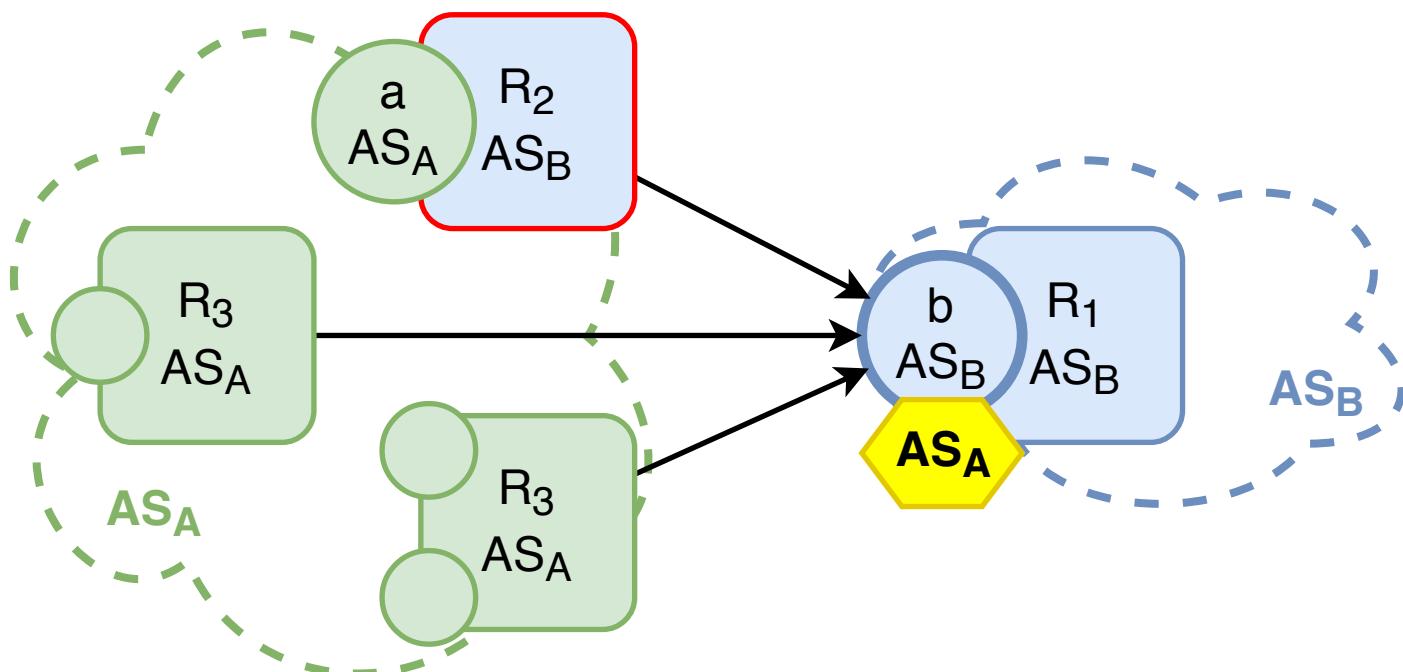
- Annotate with **B** expecting link to come from **A**'s address space



Network	Votes
AS _A	1
AS _B	1

1st Iteration: Annotate Interfaces

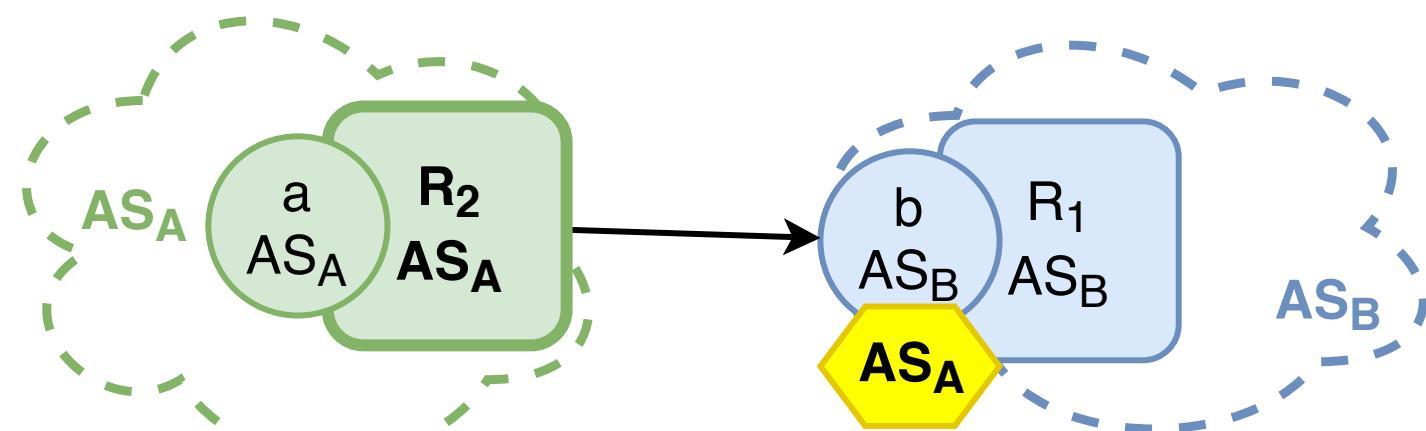
- A wins the election



Network	Votes
AS _A	3
AS _B	2

2nd Iteration: Annotate Routers

- Change annotation to **A**

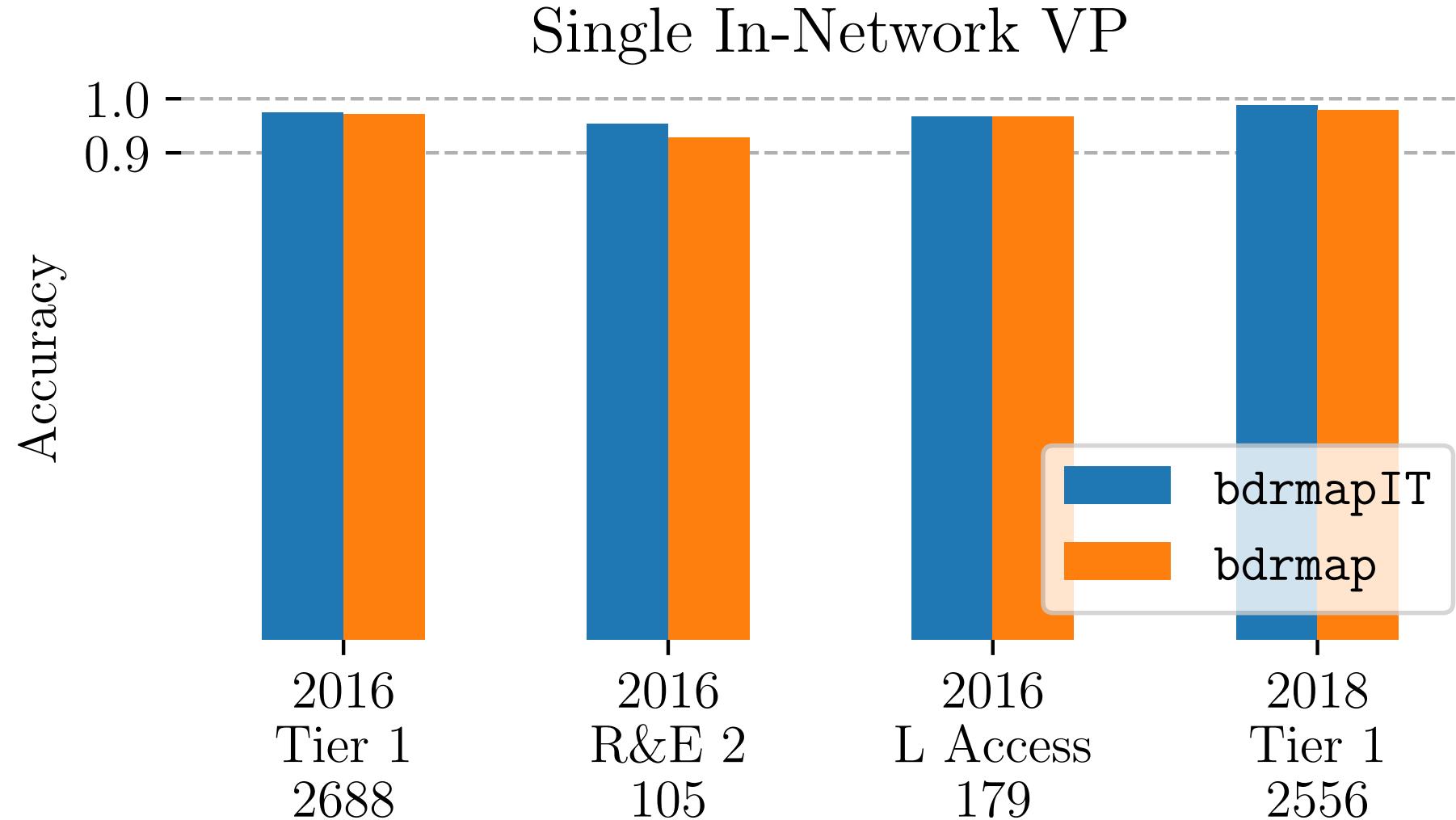


Network	Votes
AS _A	2
AS _B	0

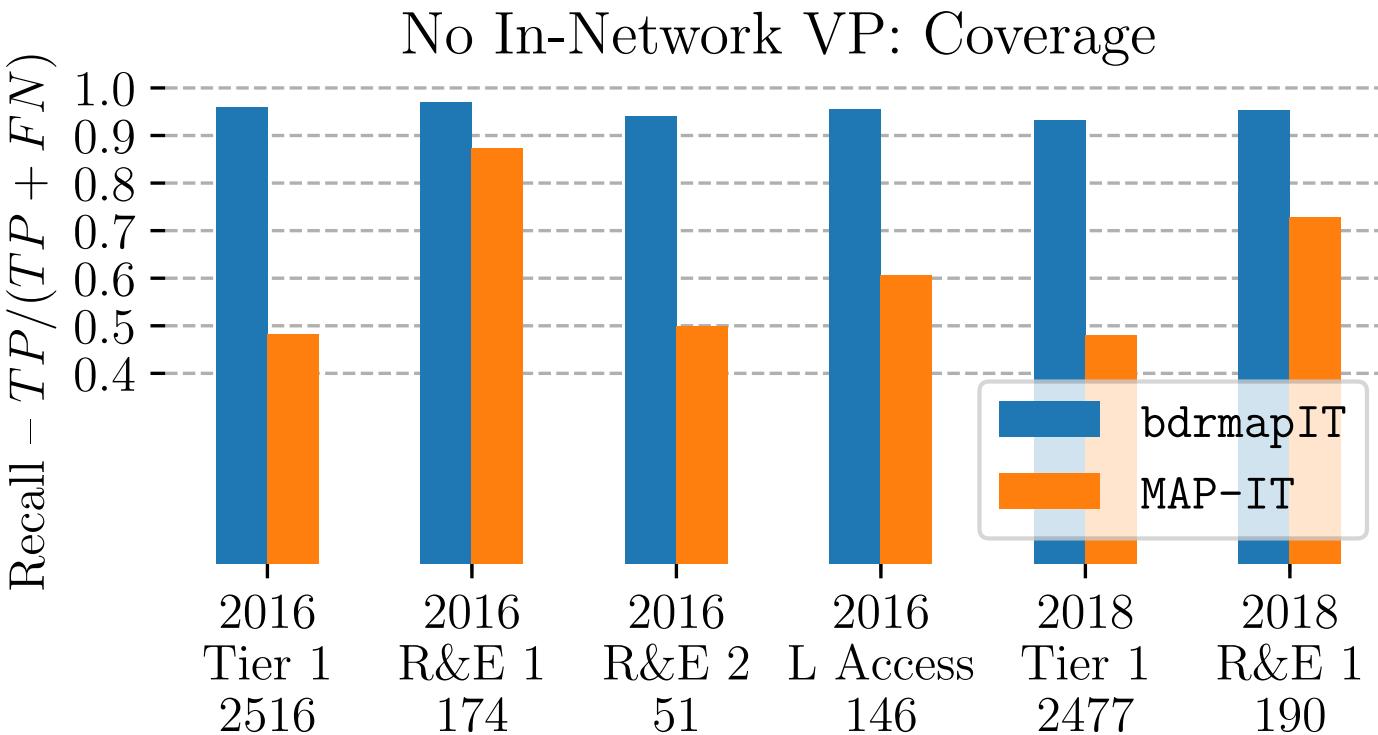
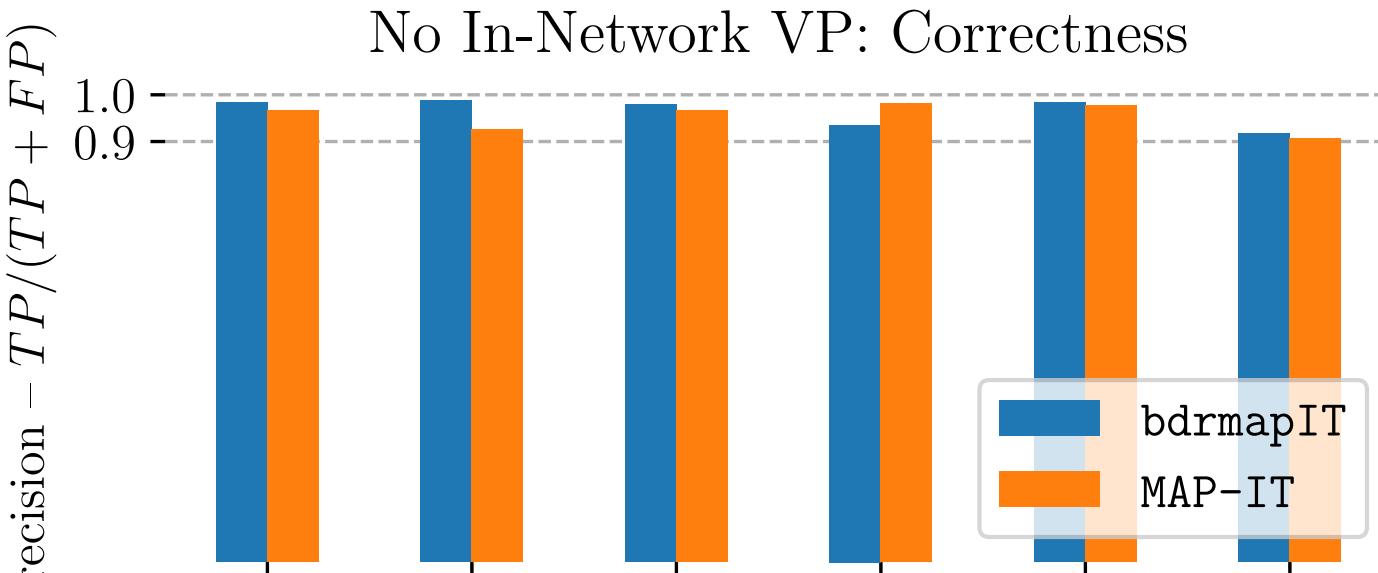
Validation

- Validated against ground truth from 4 networks
 - Tier 1, Large Access, and two large R&E networks
- Three experiments
 - Single network from single vantage point
 - Internet-wide traceroute dataset with no vantage point in validation networks
 - Reduce number of vantage points

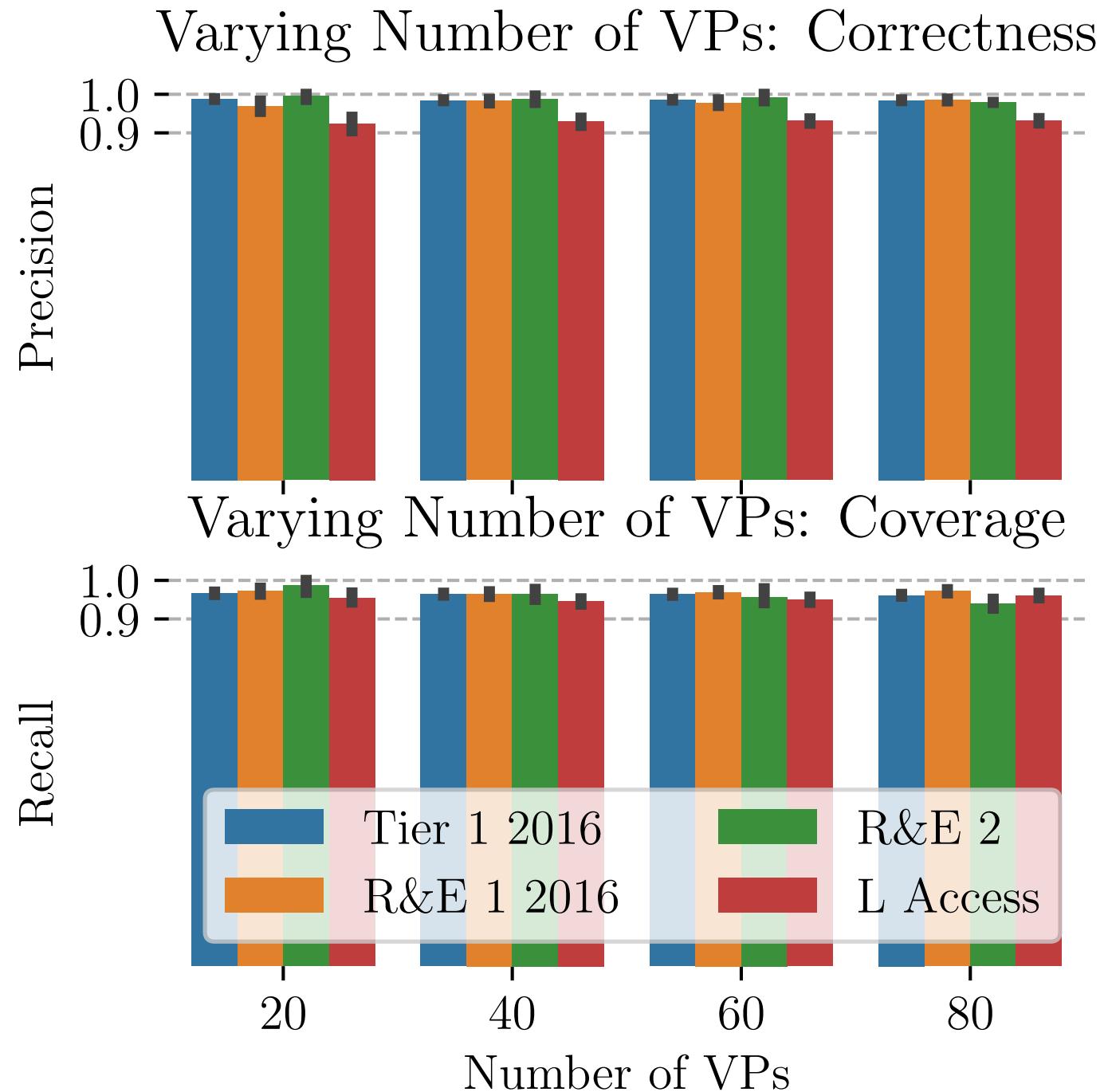
Experiment 1: Single Vantage Point, Single Network



Experiment 2: Internet-Wide Traceroutes



Experiment 3: Reducing the Number of VPs



Conclusion

- bdrmapIT infers router operators and interdomain links
- Synthesis of bdrmap and MAP-IT
- Validated against ground truth
- Future work
 - IPv6
 - Traceroute strategy