

# vrfinder: Finding Outbound Addresses in Traceroute

Alex Marder, Matthew Luckie, Bradley Huffaker, kc claffy



# Overview

- What are outbound addresses?
  - Layer 3 Virtual Private Networks (L3VPNs)
  - Impact on topology inference
- Methodology:
  - Finding outbound addresses
  - Challenges – forwarding loops, /31 and /127 subnets
- Results
  - Evaluation against ground truth
  - Modified bdrmapIT

# Overview

- **What are outbound addresses?**
  - **Layer 3 Virtual Private Networks (L3VPNs)**
  - **Impact on topology inference**
- Methodology:
  - Finding outbound addresses
  - Challenges – forwarding loops, /31 and /127 subnets
- Results
  - Evaluation against ground truth
  - Modified bdrmapIT

# Overview

- What are outbound addresses?
  - Layer 3 Virtual Private Networks (L3VPNs)
  - Impact on topology inference
- **Methodology:**
  - **Finding outbound addresses**
  - **Challenges – forwarding loops, /31 and /127 subnets**
- Results
  - Evaluation against ground truth
  - Modified bdrmapIT

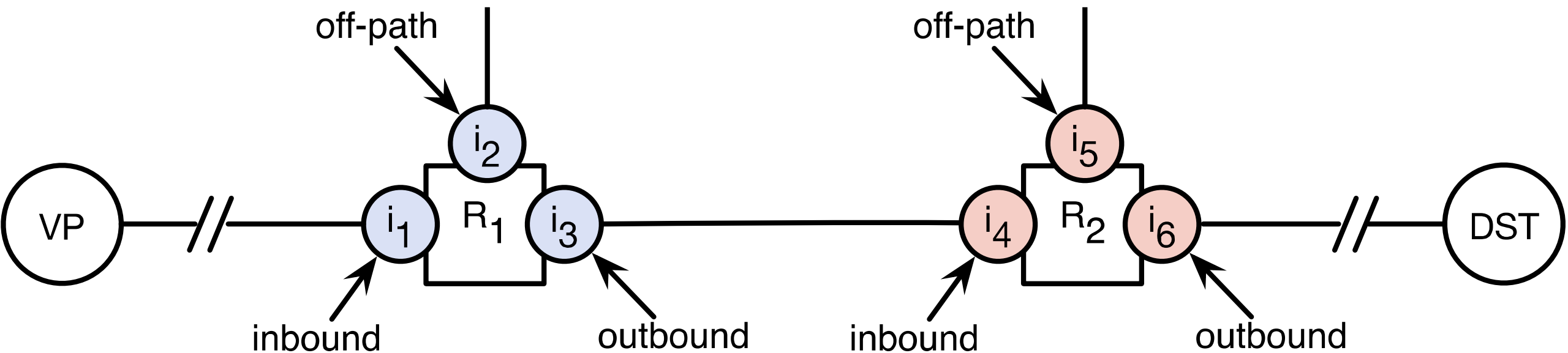
# Overview

- What are outbound addresses?
  - Layer 3 Virtual Private Networks (L3VPNs)
  - Impact on topology inference
- Methodology:
  - Finding outbound addresses
  - Challenges – forwarding loops, /31 and /127 subnets
- **Results**
  - **Evaluation against ground truth**
  - **Modified bdrmapIT**

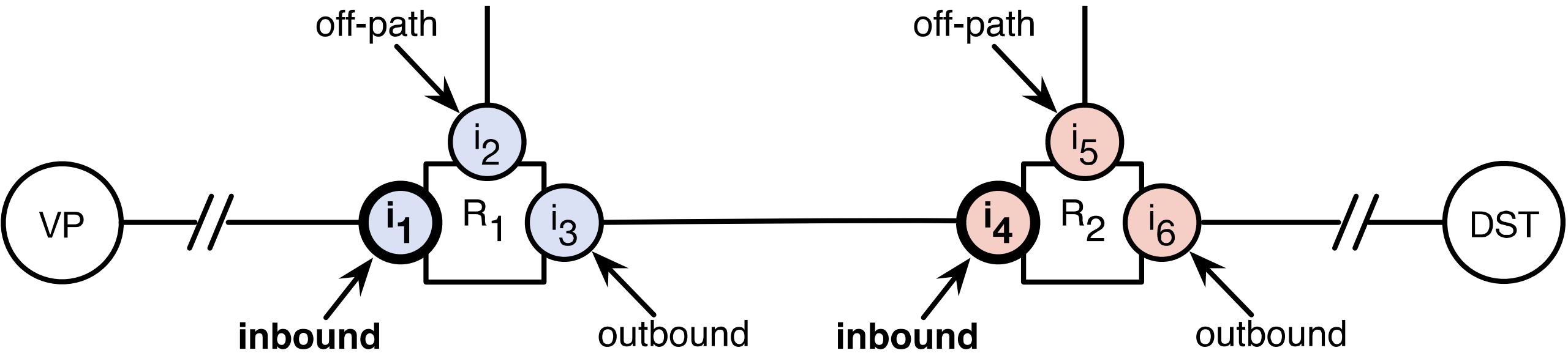
# Overview

- **What are outbound addresses?**
  - **Layer 3 Virtual Private Networks (L3VPNs)**
  - **Impact on topology inference**
- Methodology:
  - Finding outbound addresses
  - Challenges – forwarding loops, /31 and /127 subnets
- Results
  - Evaluation against ground truth
  - Modified bdrmapIT

# Traceroute Response Types

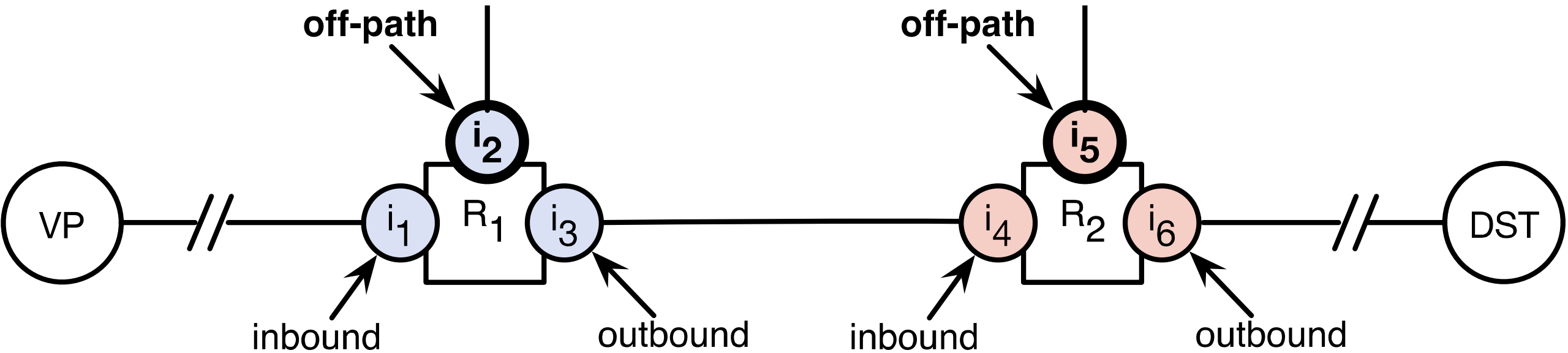


# Traceroute Response Types: Inbound

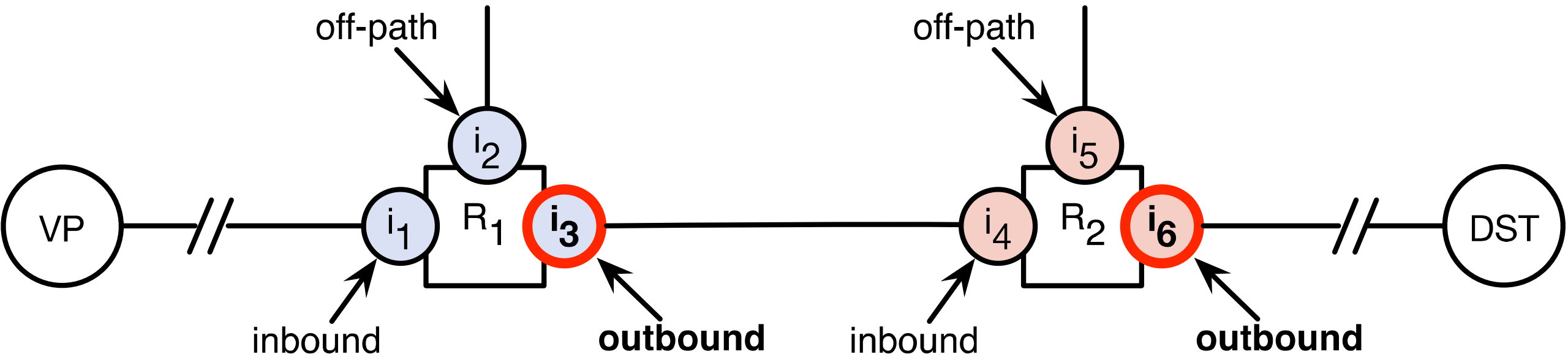




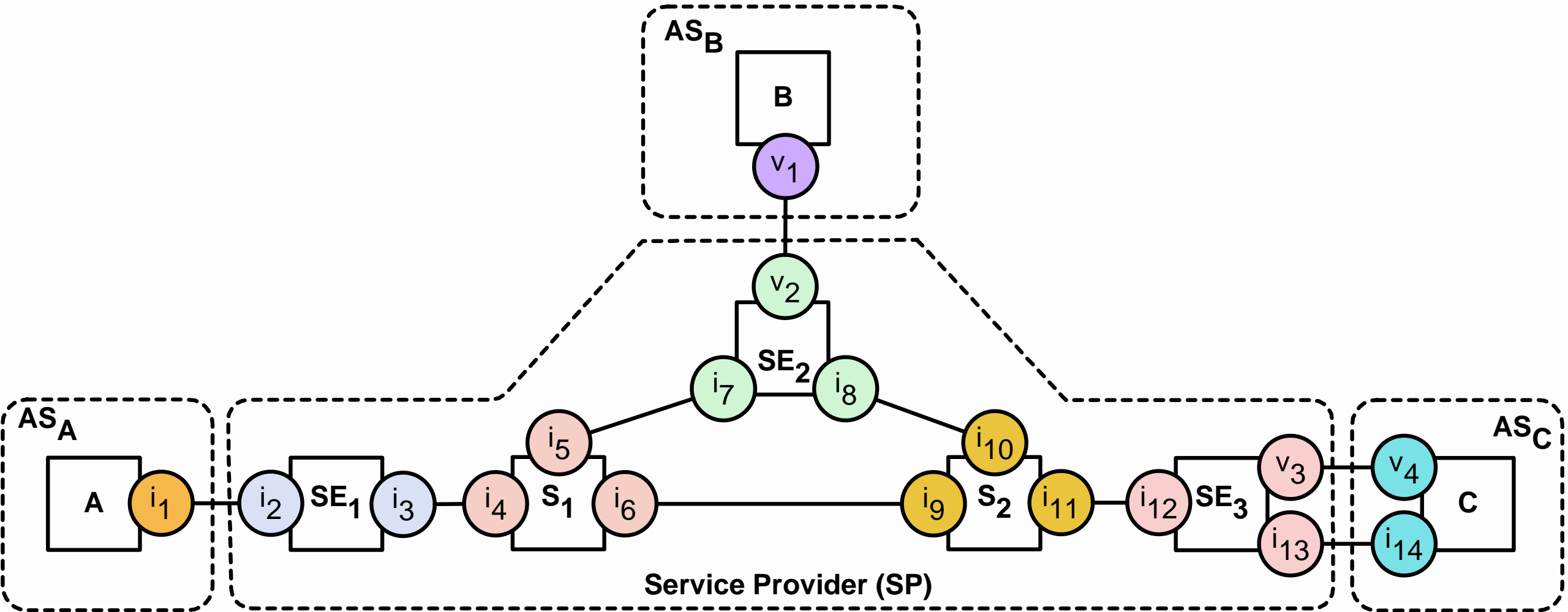
# Traceroute Response Types: Off-Path



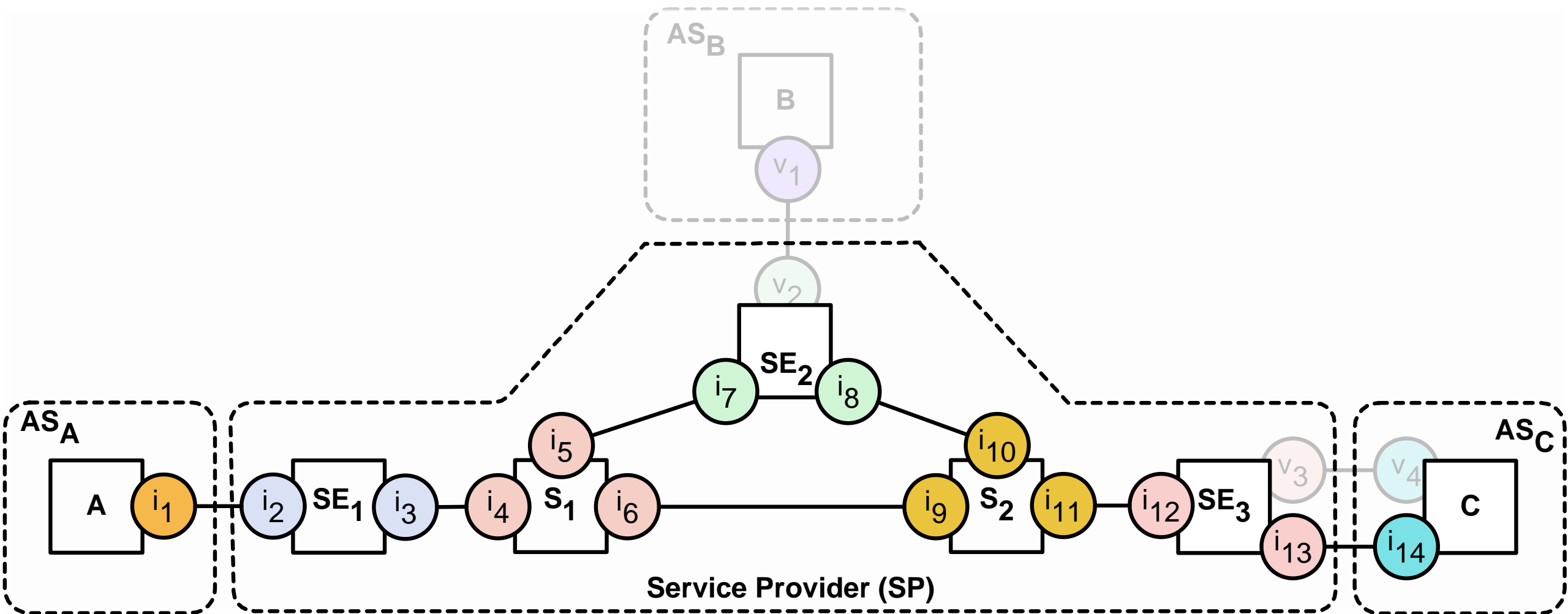
# Traceroute Response Types: Off-Path



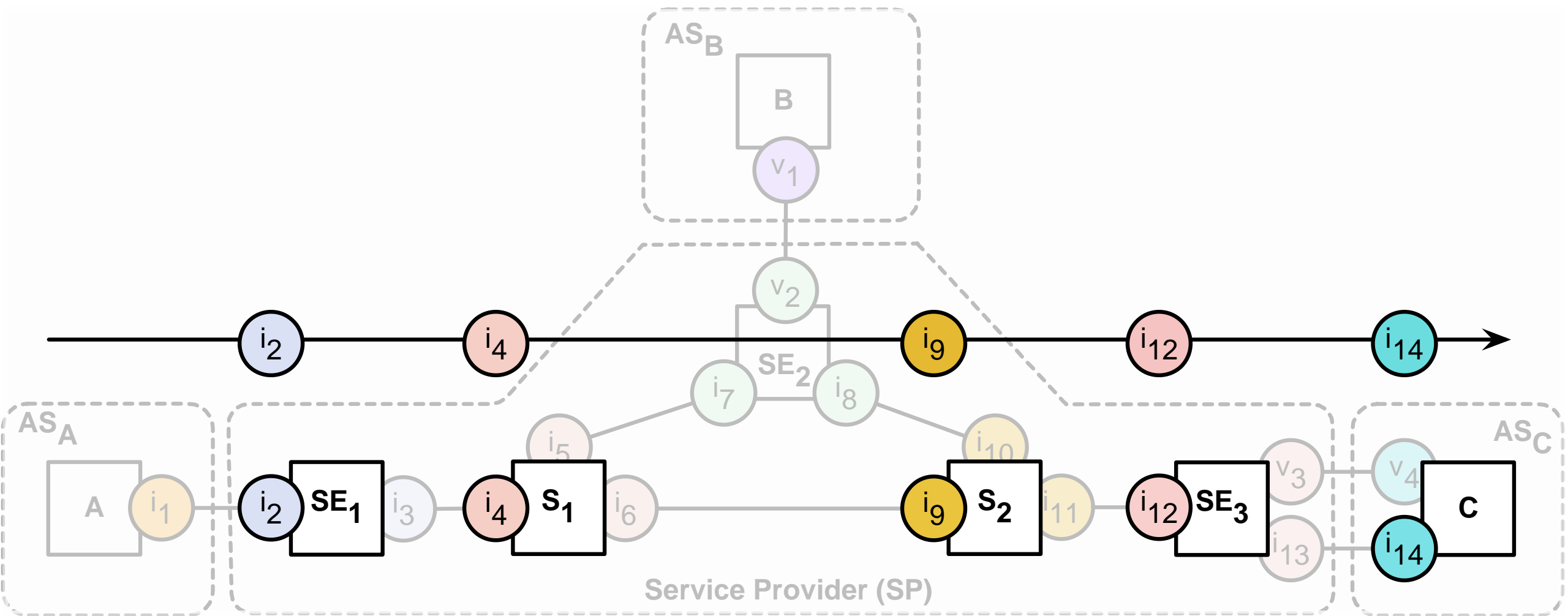
# Layer 3 Virtual Private Network



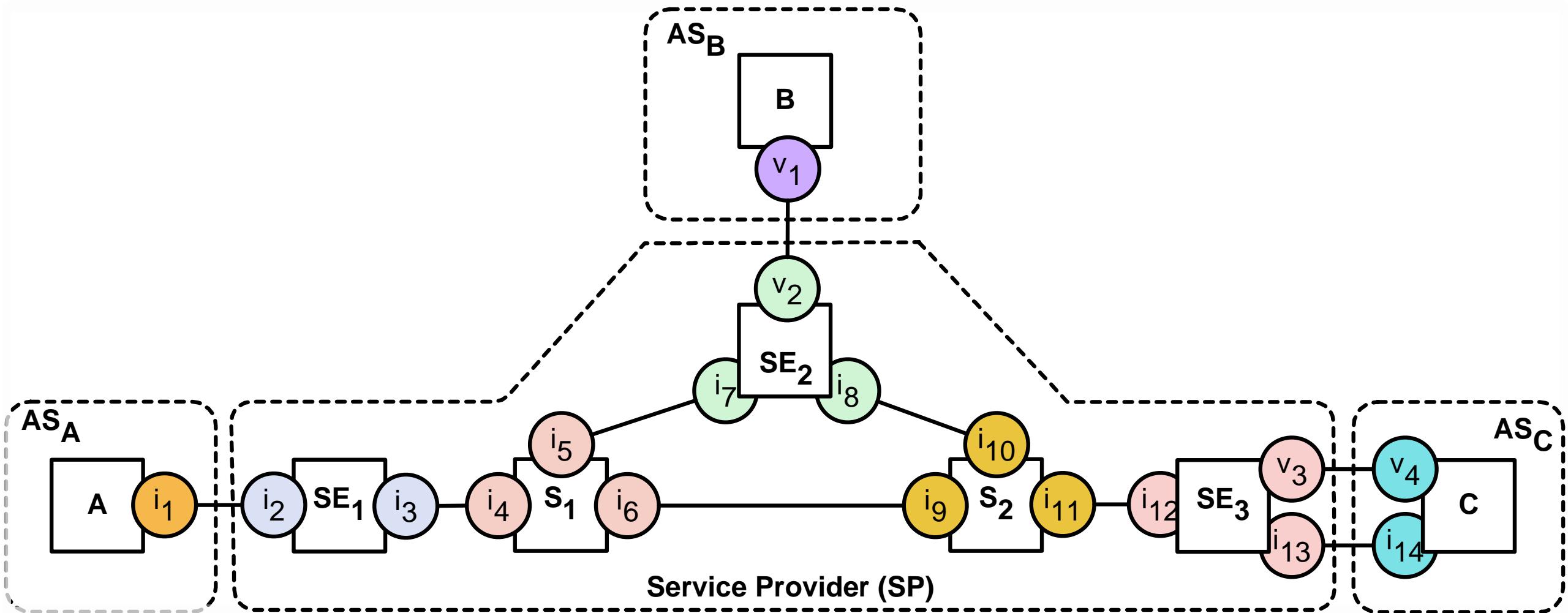
# L3VPN: Default Forwarding



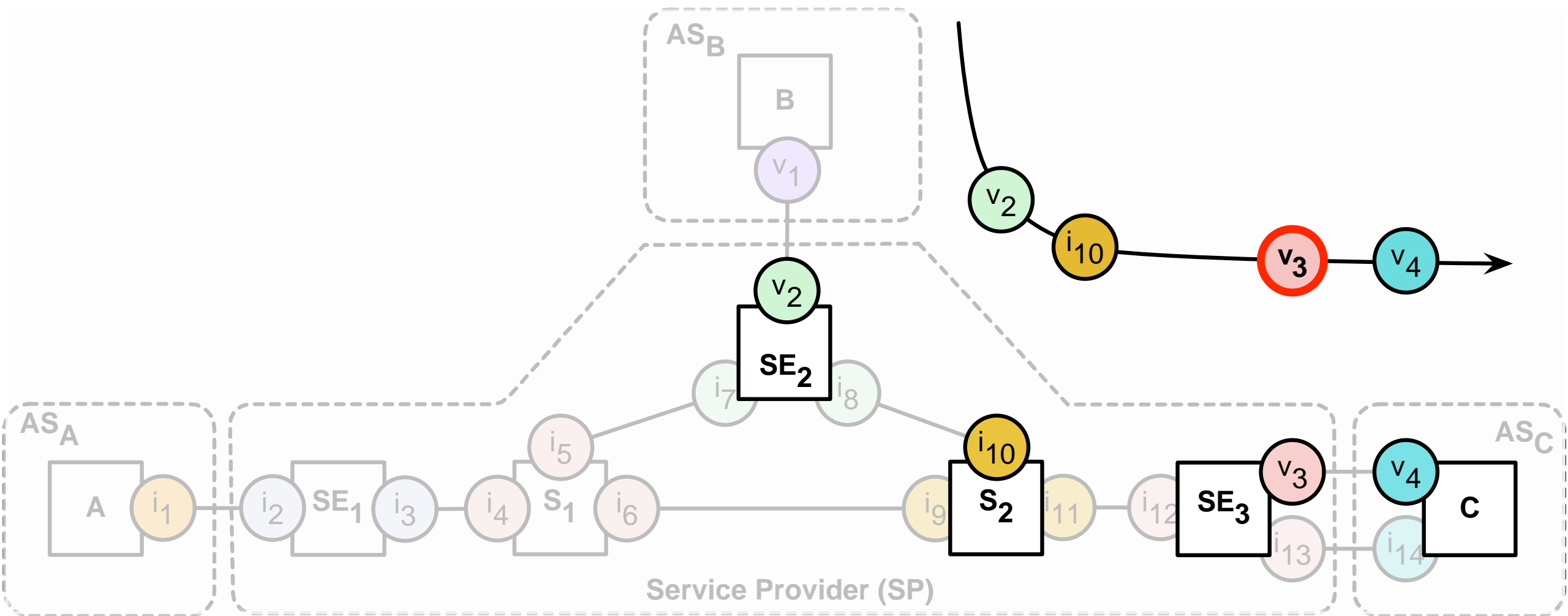
# L3VPN: Default Forwarding



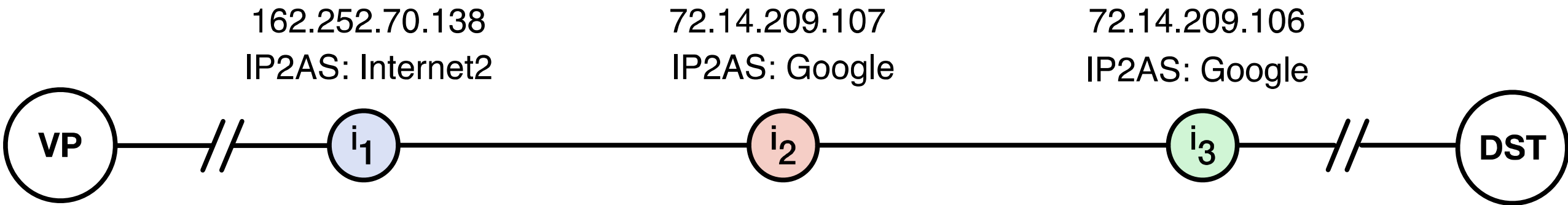
# L3VPN: Virtual Forwarding



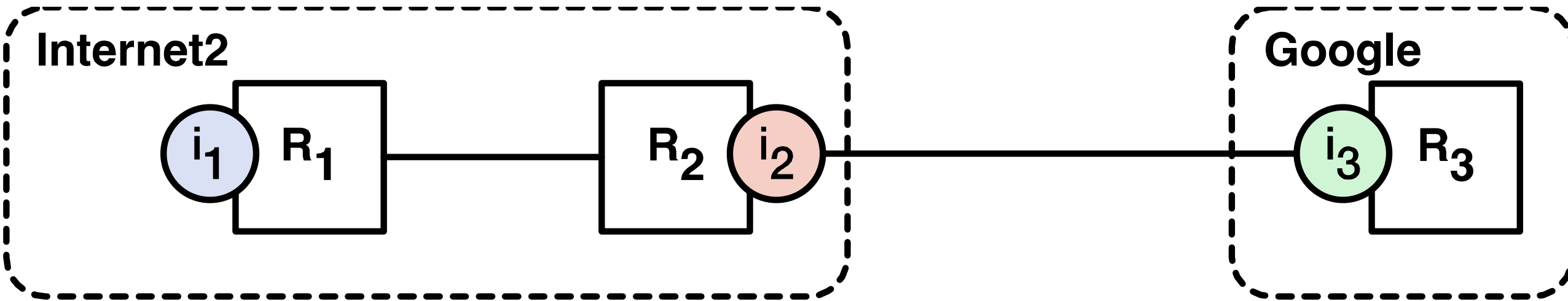
# L3VPN: Virtual Forwarding



# Impact on Traceroute Analysis

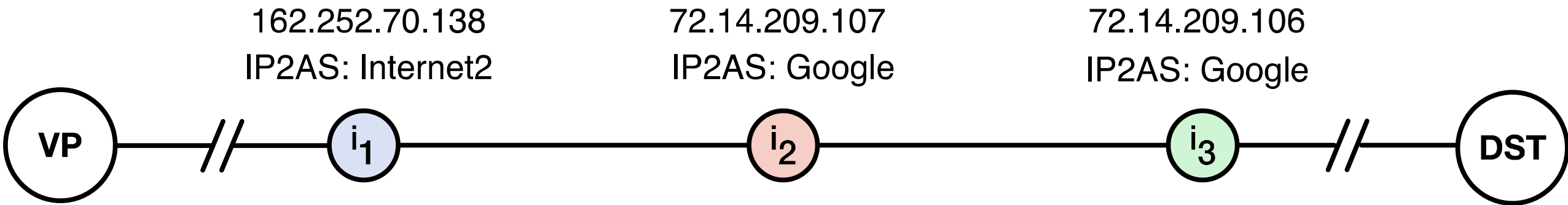


## Real Topology

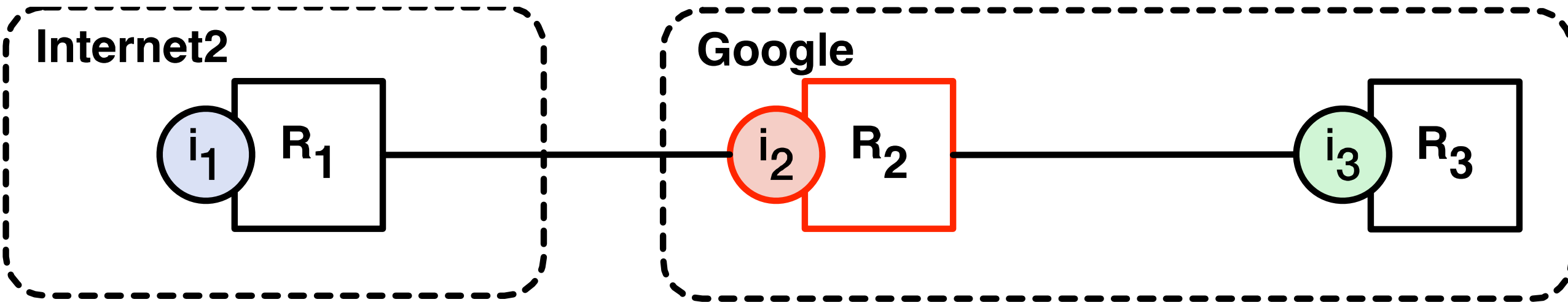




# Impact on Traceroute Analysis



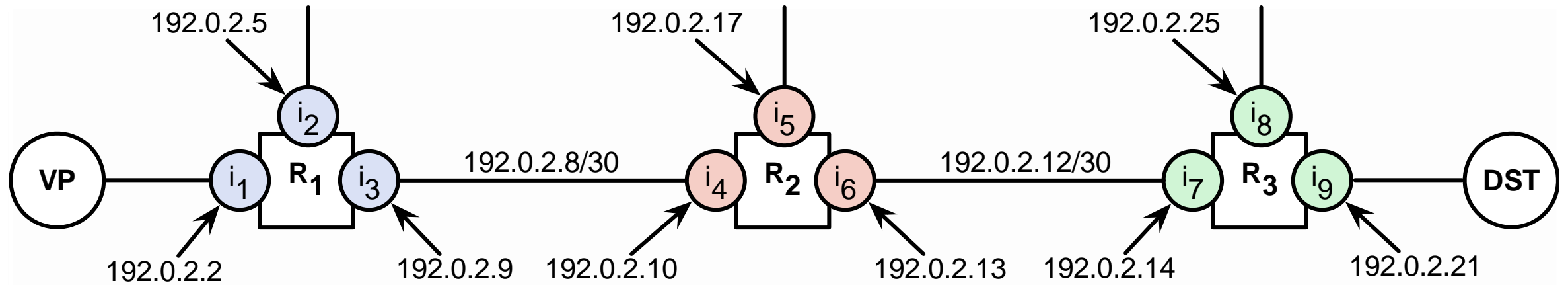
## Incorrect Inferred Topology



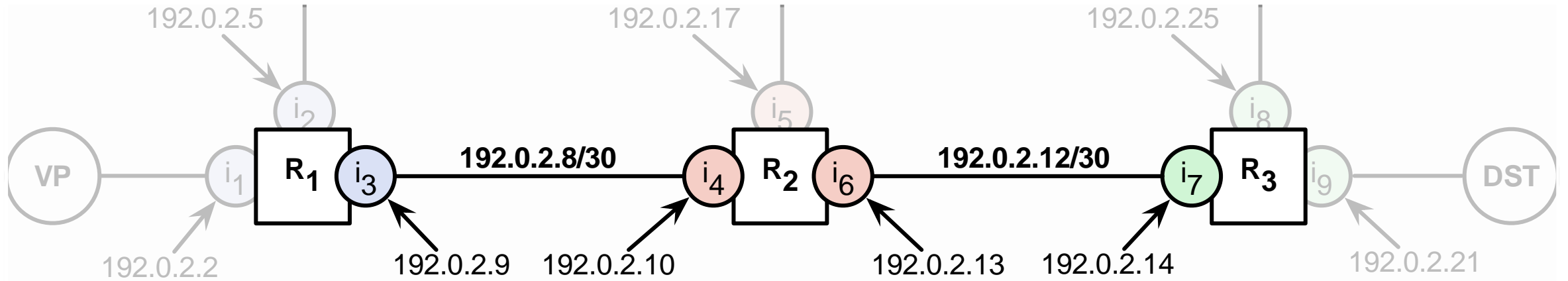
# Overview

- What are outbound addresses?
  - Layer 3 Virtual Private Networks (L3VPNs)
  - Impact on topology inference
- **Methodology:**
  - **Finding outbound addresses**
  - **Challenges – forwarding loops, /31 and /127 subnets**
- Results
  - Evaluation against ground truth
  - Modified bdrmapIT

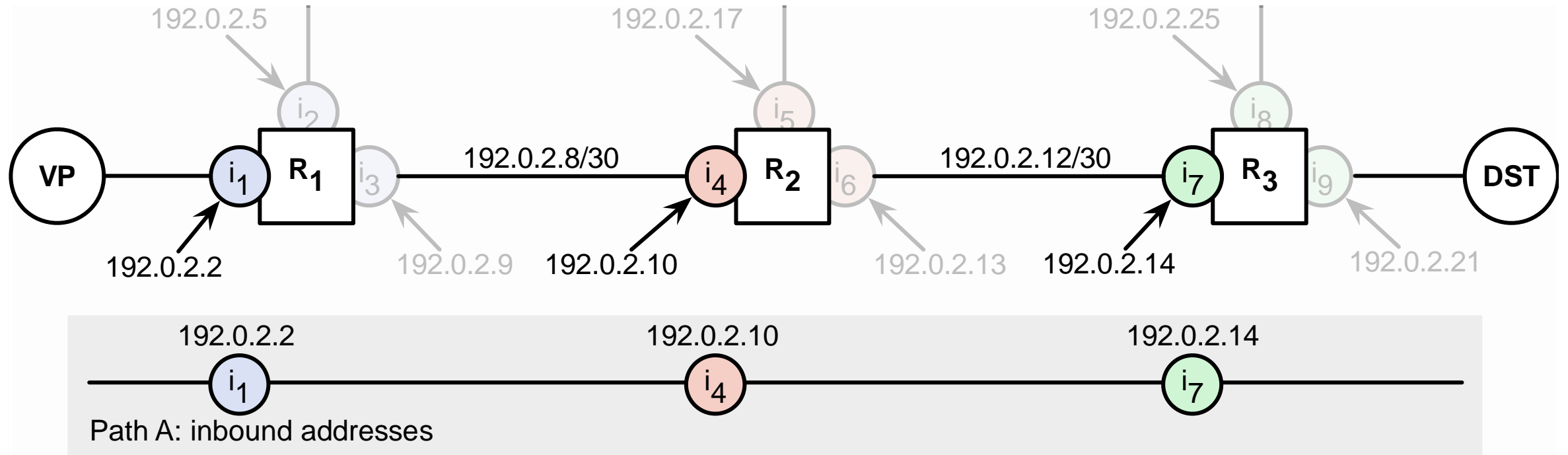
# Inferring Outbound Addresses



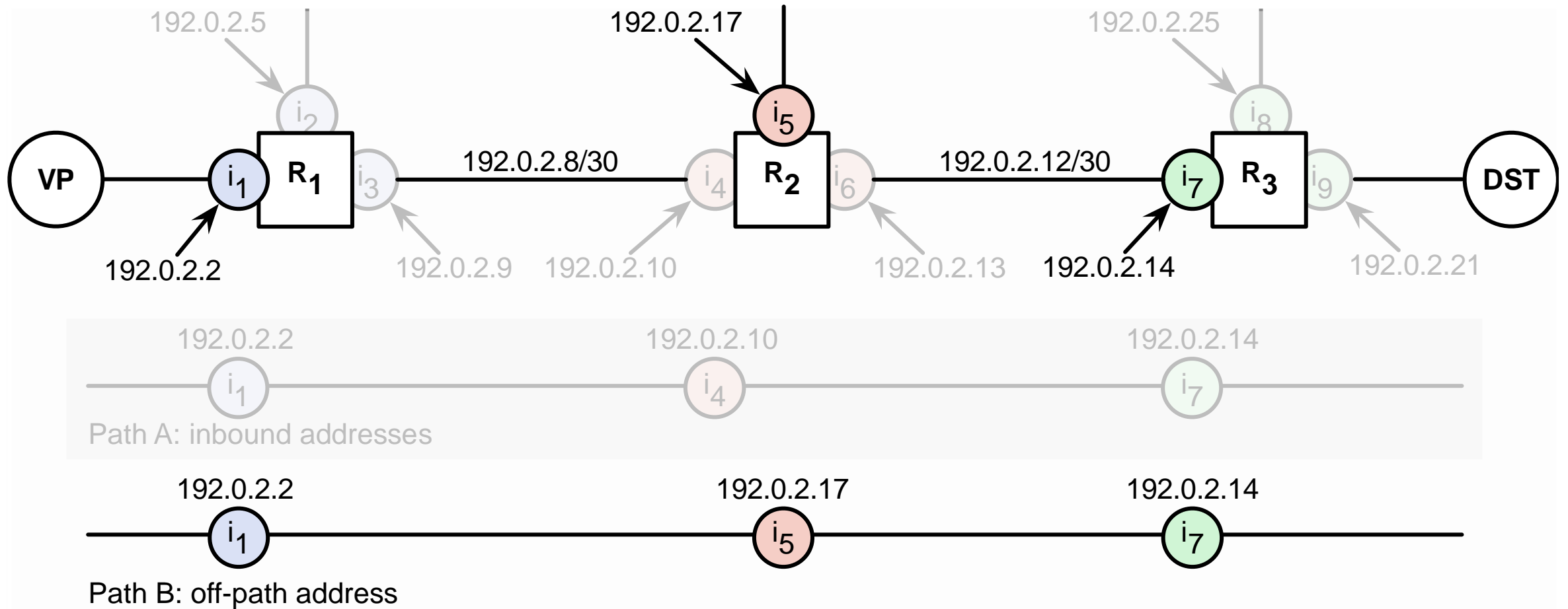
# Inferring Outbound Addresses



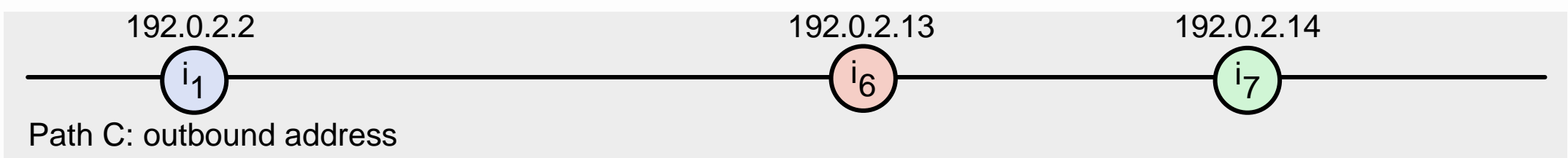
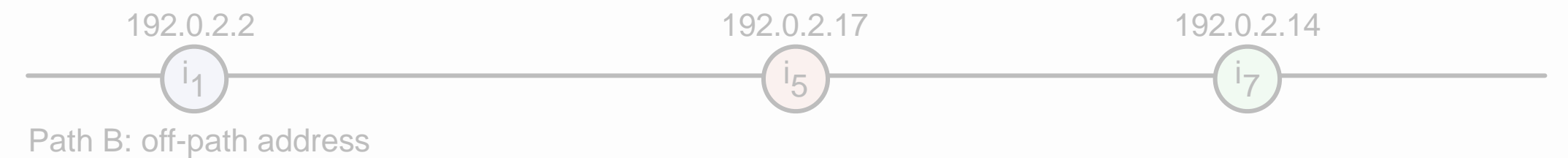
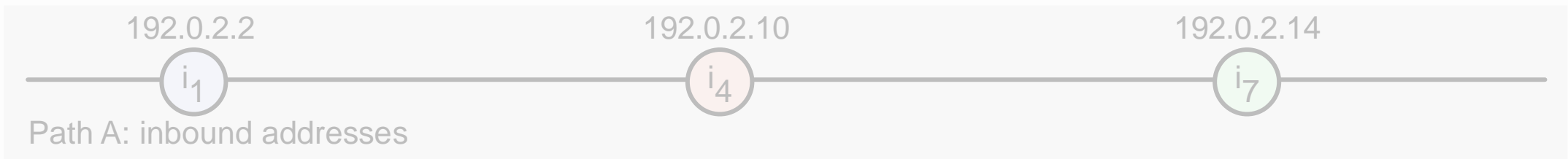
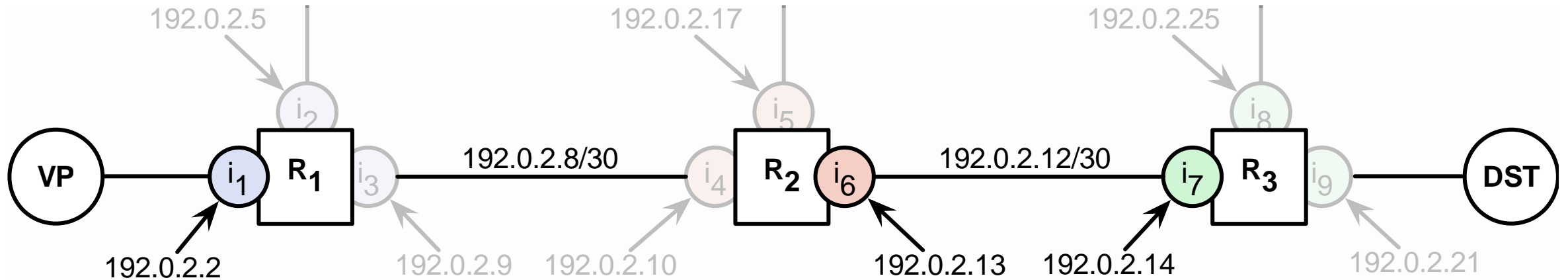
# Inferring Outbound Addresses



# Inferring Outbound Addresses



# Inferring Outbound Addresses



# Challenges

- Inefficient routing at IXPs
- Unresponsive routers
- Forwarding loops
- Two address subnets - /31 and /127



# Challenges

- **Inefficient routing at IXPs**
- Unresponsive routers
- Forwarding loops
- Two address subnets - /31 and /127

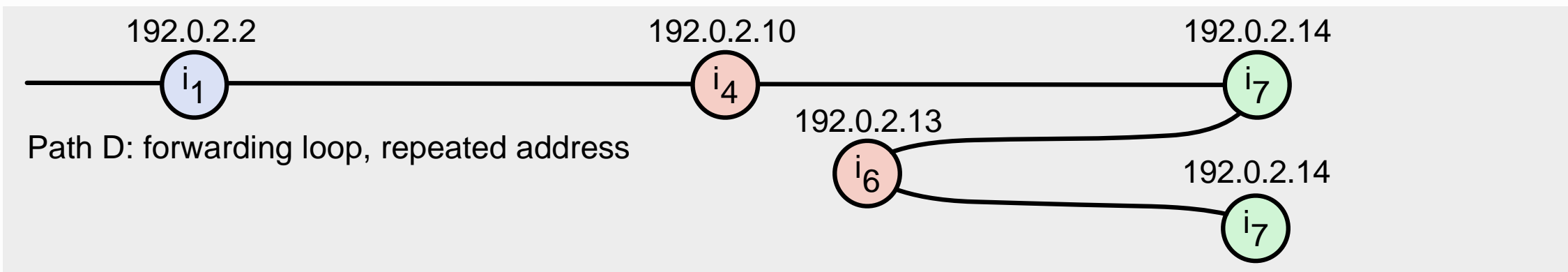
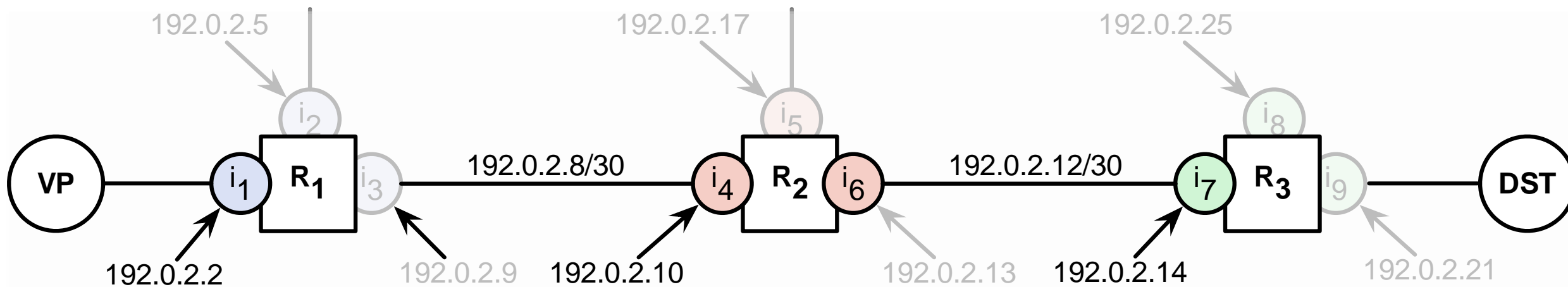
# Challenges

- Inefficient routing at IXPs
- **Unresponsive routers**
- Forwarding loops
- Two address subnets - /31 and /127

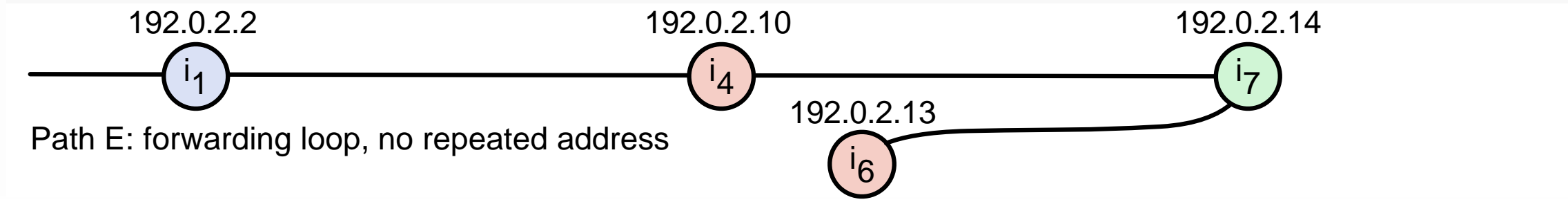
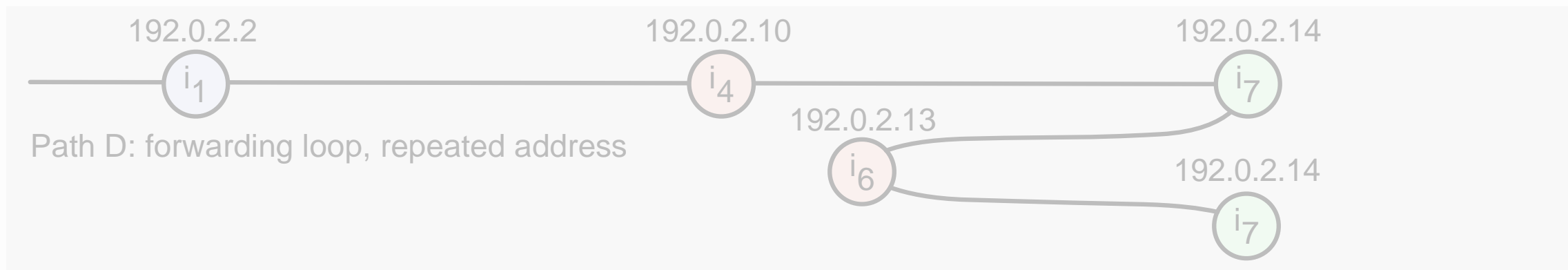
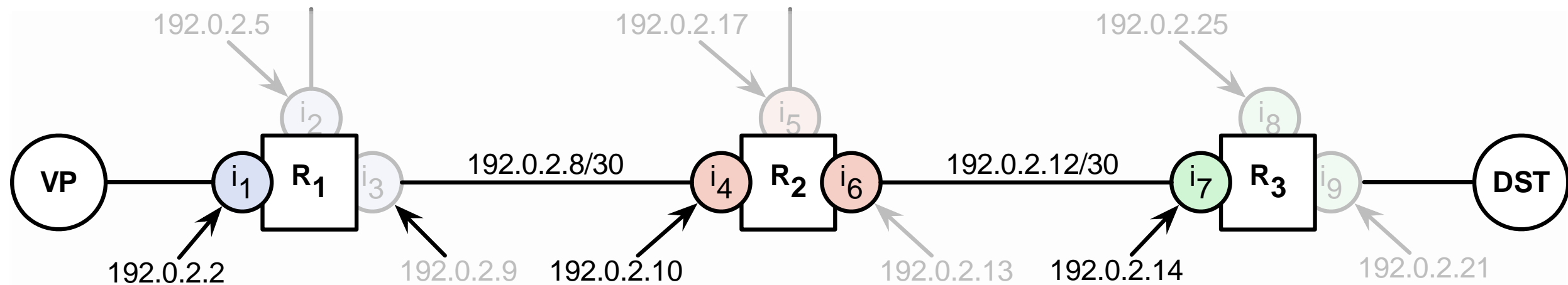
# Challenges

- Inefficient routing at IXPs
- Unresponsive routers
- **Forwarding loops**
- **Two address subnets - /31 and /127**

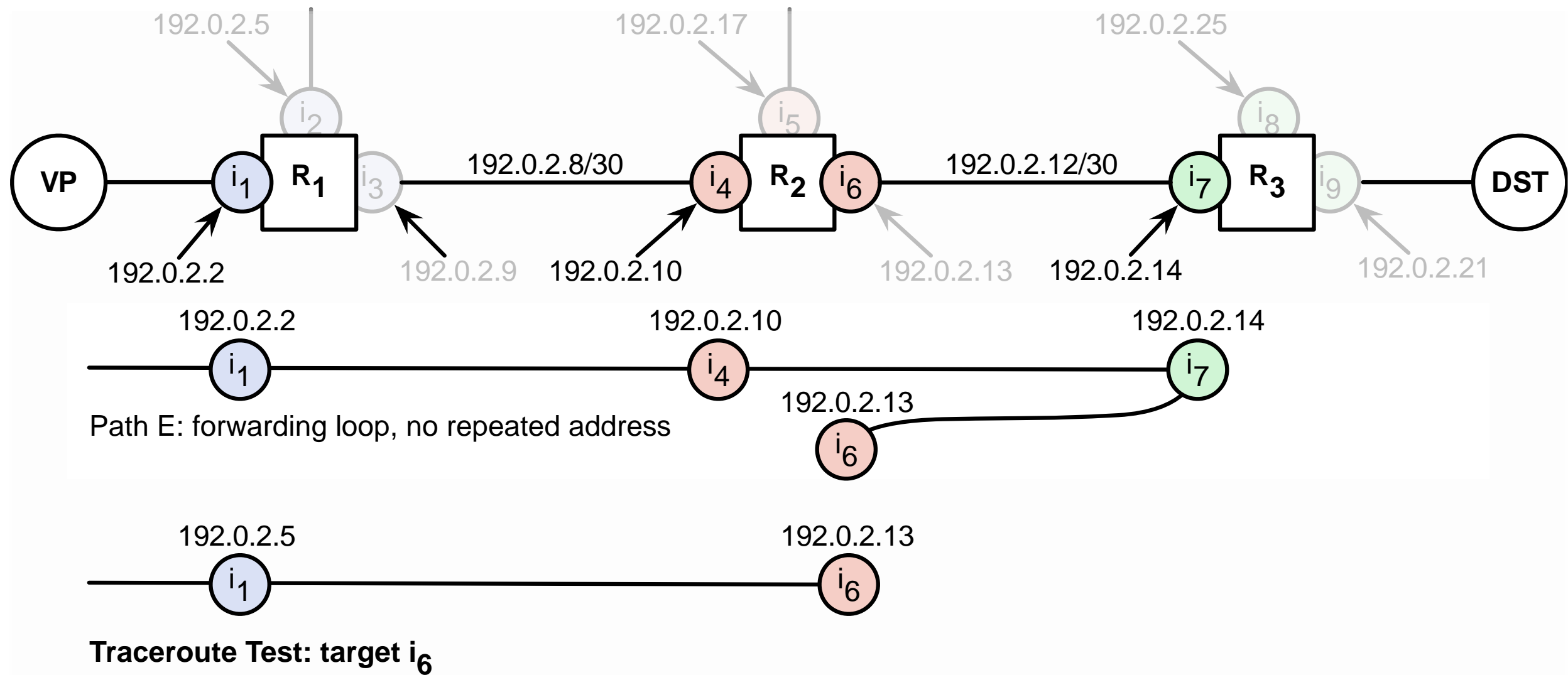
# Challenges: Loops



# Challenges: Loops



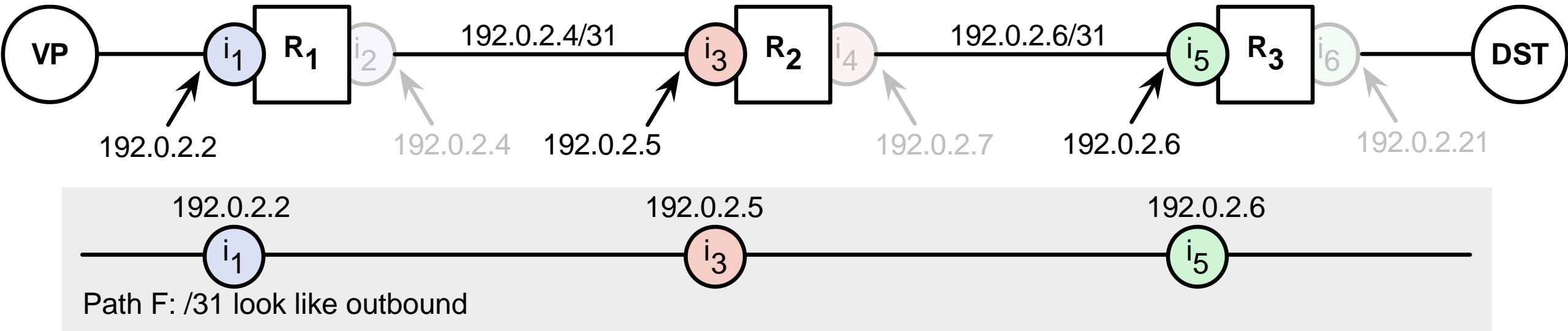
# Challenges: Loops



# Challenges

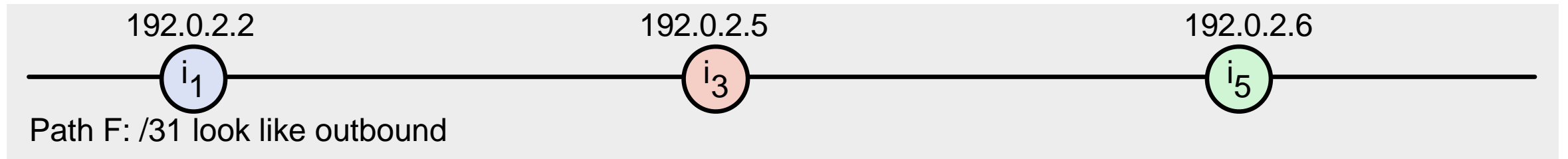
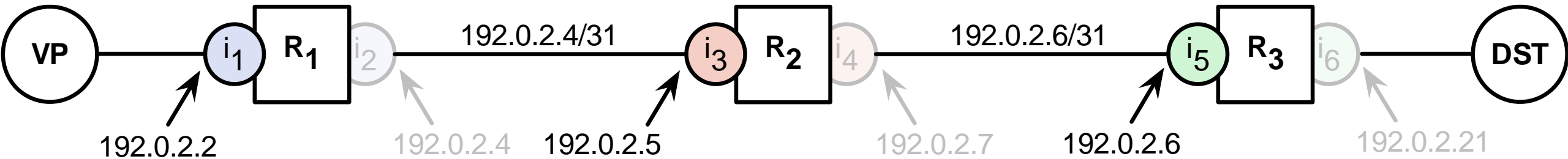
- Inefficient routing at IXPs
- Unresponsive routers
- Forwarding loops
- **Two address subnets - /31 and /127**

# Challenge: /31 and /127 Subnets





# Challenge: /31 and /127 Subnets



**192.0.2.4**

**192.0.2.5**

**192.0.2.6**

**192.0.2.7**

# Overview

- What are outbound addresses?
  - Layer 3 Virtual Private Networks (L3VPNs)
  - Impact on topology inference
- Methodology:
  - Finding outbound addresses
  - Challenges – forwarding loops, /31 and /127 subnets
- **Results**
  - **Evaluation against ground truth**
  - **Modified bdrmapIT**

# Experiments

- IPv4 and IPv6 traceroutes from January 2020
- Inferred outbound addresses
  - 5.8% in IPv4
  - 1.7% in IPv6

# Validation Against Internet2 and REANNZ

## Internet2

- Default forwarding connects members
- L3VPN connects members to commercial peers

## REANNZ

- Default forwarding supports MPLS
- All members connected via L3VPN

	Internet2		REANNZ
	PPV	TPR	TPR
IPv4	100.0%	95.3%	82.1%
IPv6	100.0%	91.5%	86.4%

# Validation Against Internet2 and REANNZ

## Internet2

- **Default forwarding connects members**
- **L3VPN connects members to commercial peers**

## REANNZ

- Default forwarding supports MPLS
- All members connected via L3VPN

	<b>Internet2</b>		<b>REANNZ</b>
	<b>PPV</b>	<b>TPR</b>	<b>TPR</b>
IPv4	<b>100.0%</b>	<b>95.3%</b>	82.1%
IPv6	<b>100.0%</b>	<b>91.5%</b>	86.4%

# Validation Against Internet2 and REANNZ

## Internet2

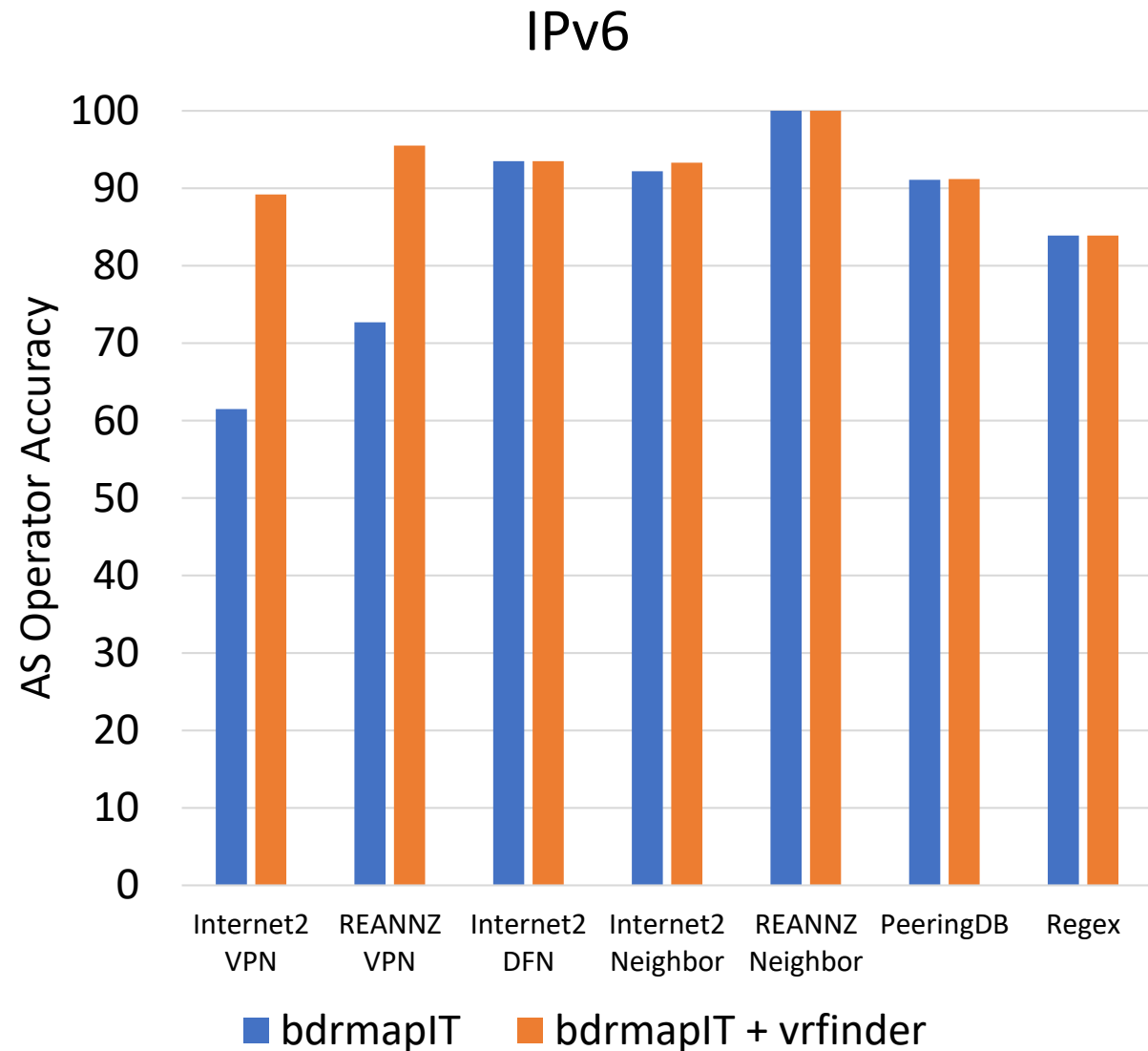
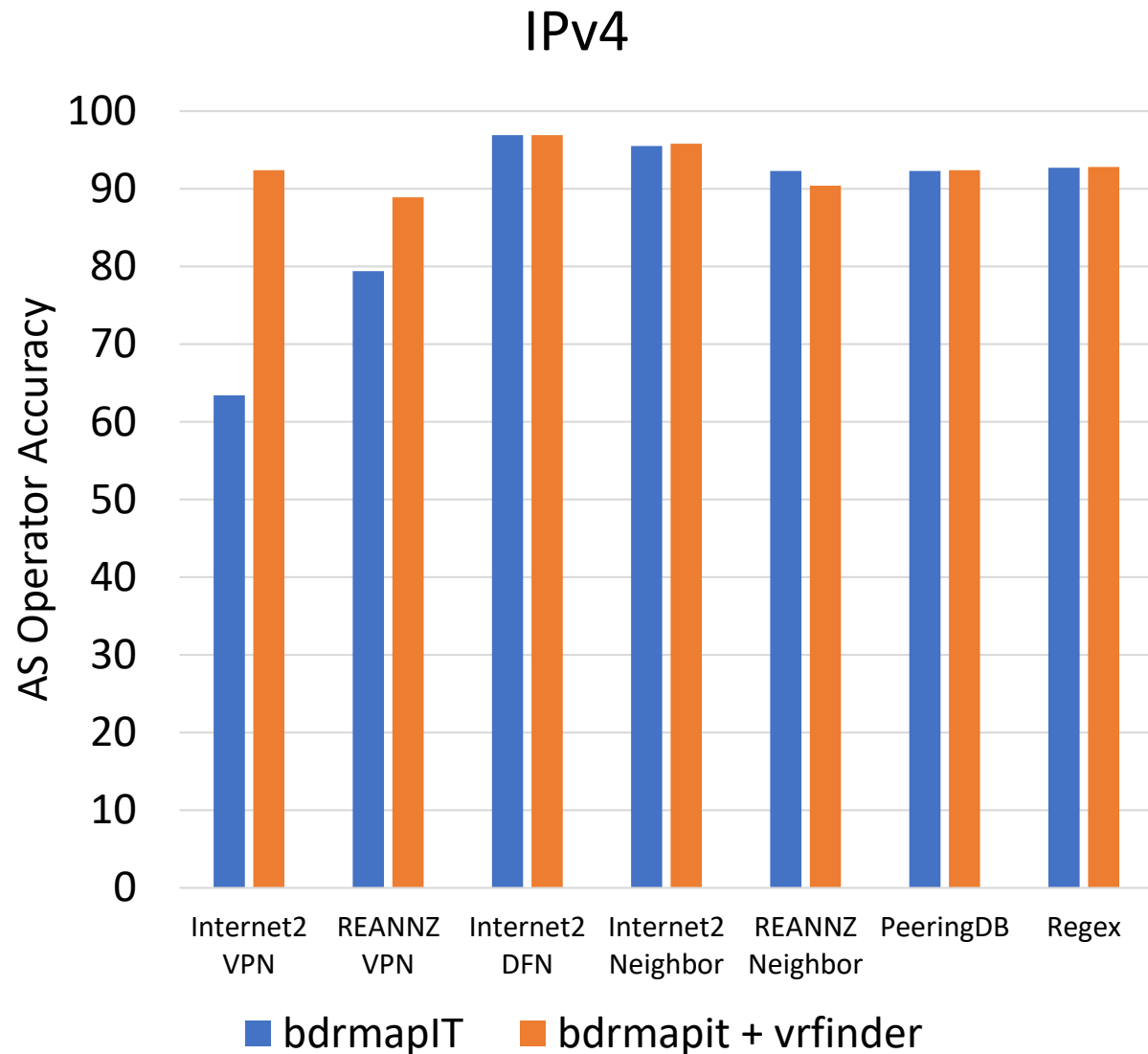
- Default forwarding connects members
- L3VPN connects members to commercial peers

## REANNZ

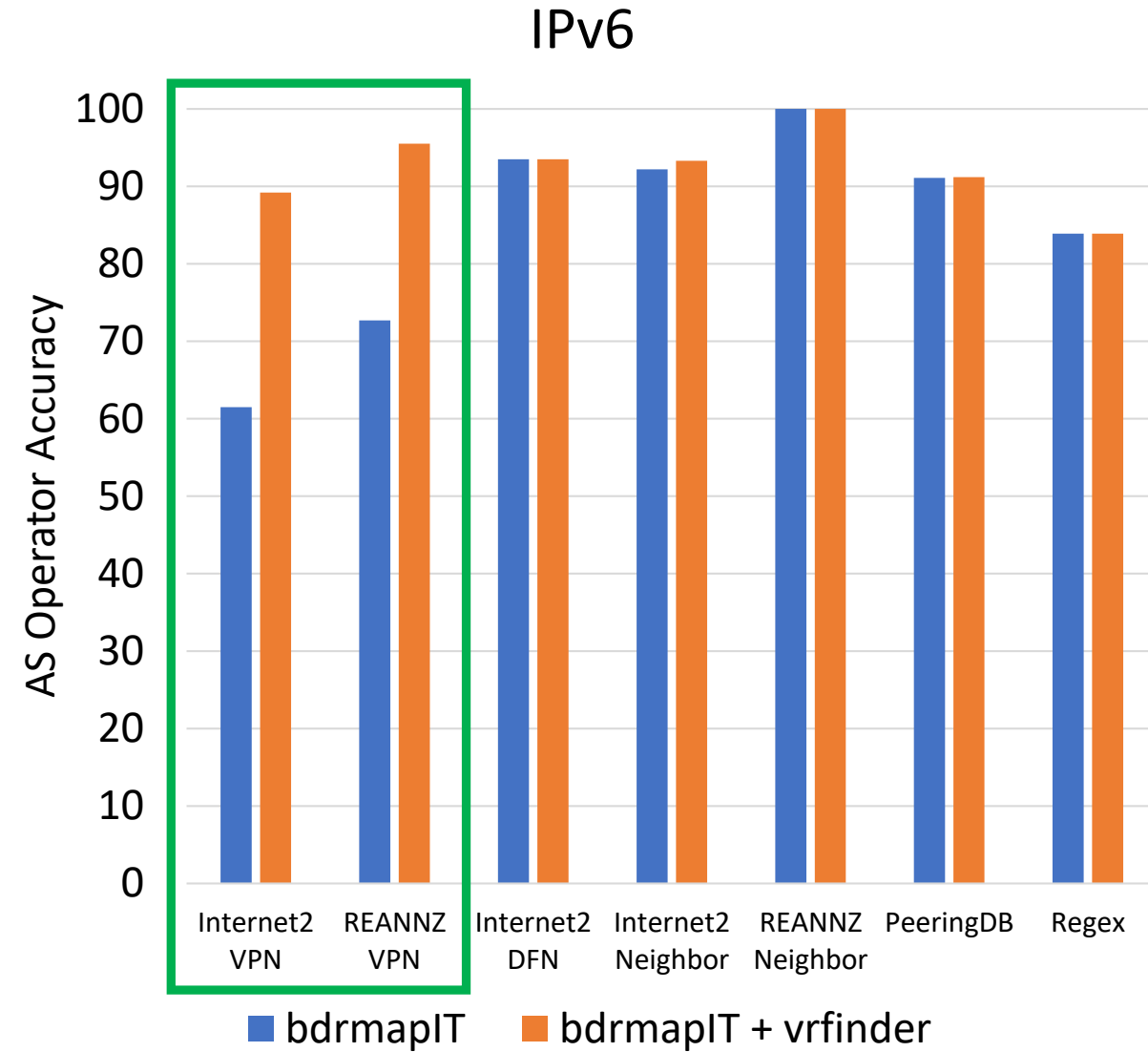
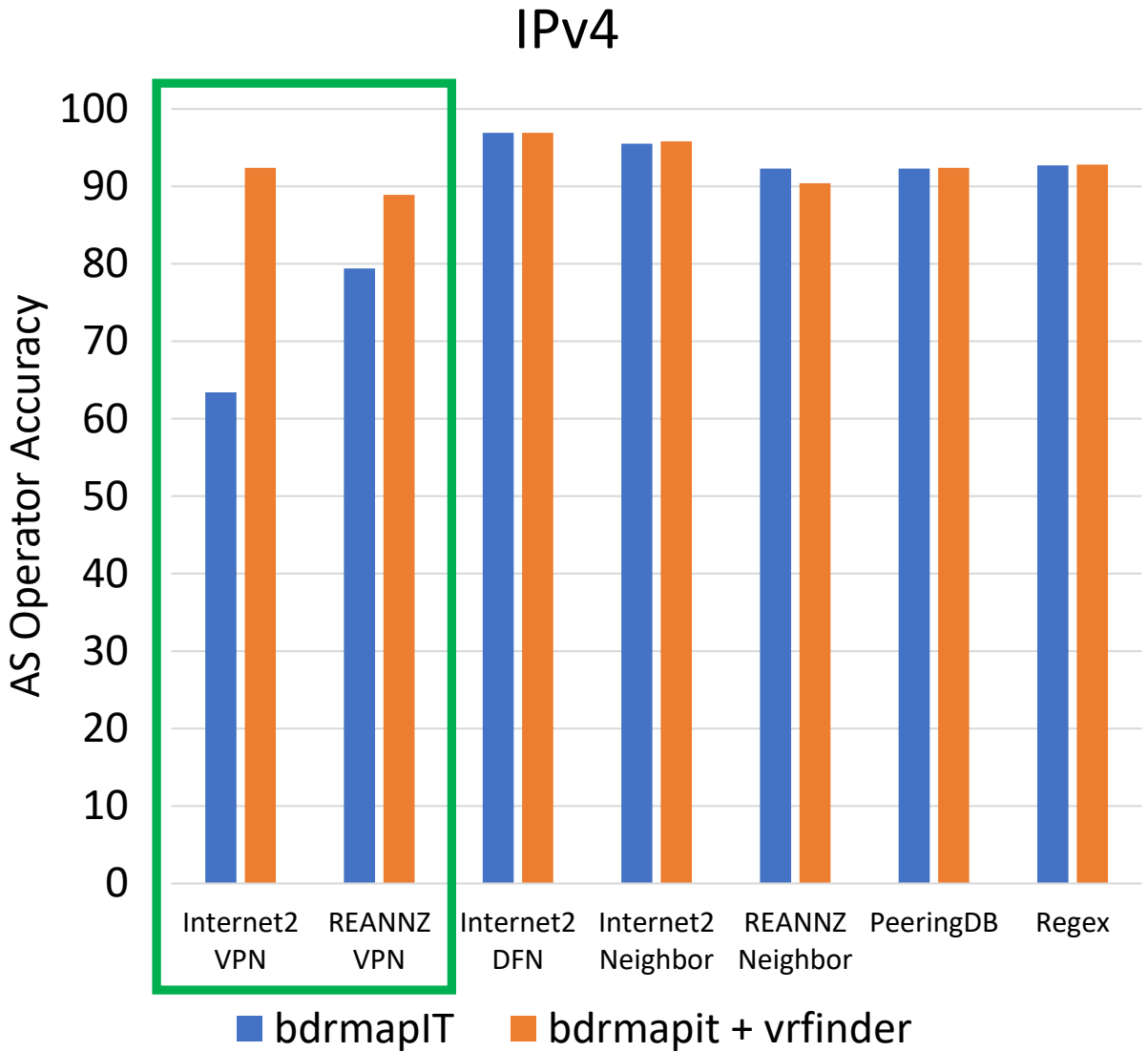
- **Default forwarding supports MPLS**
- **All members connected via L3VPN**

	Internet2		REANNZ
	PPV	TPR	TPR
IPv4	100.0%	95.3%	<b>82.1%</b>
IPv6	100.0%	91.5%	<b>86.4%</b>

# Improvements for AS Operator Accuracy

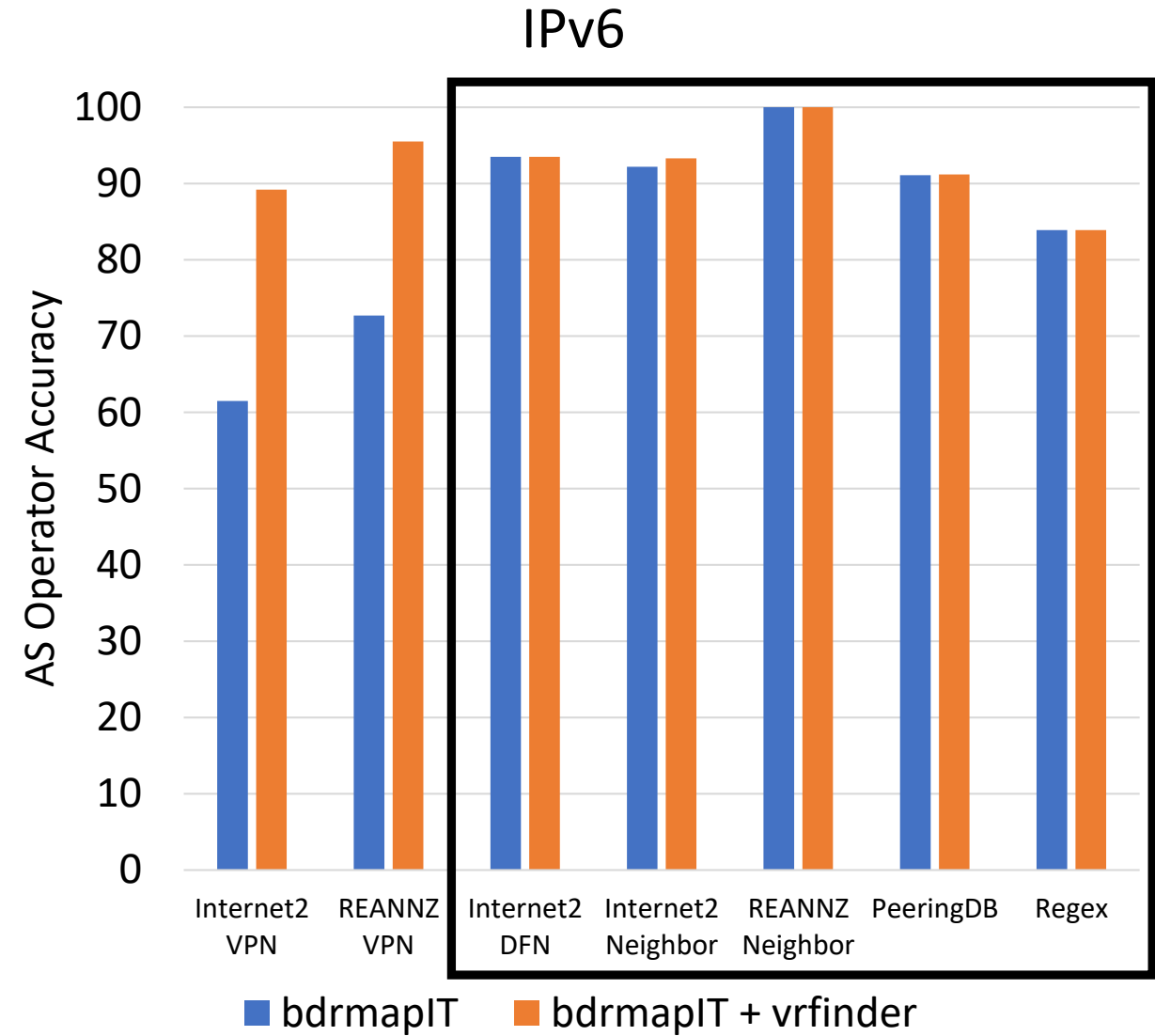
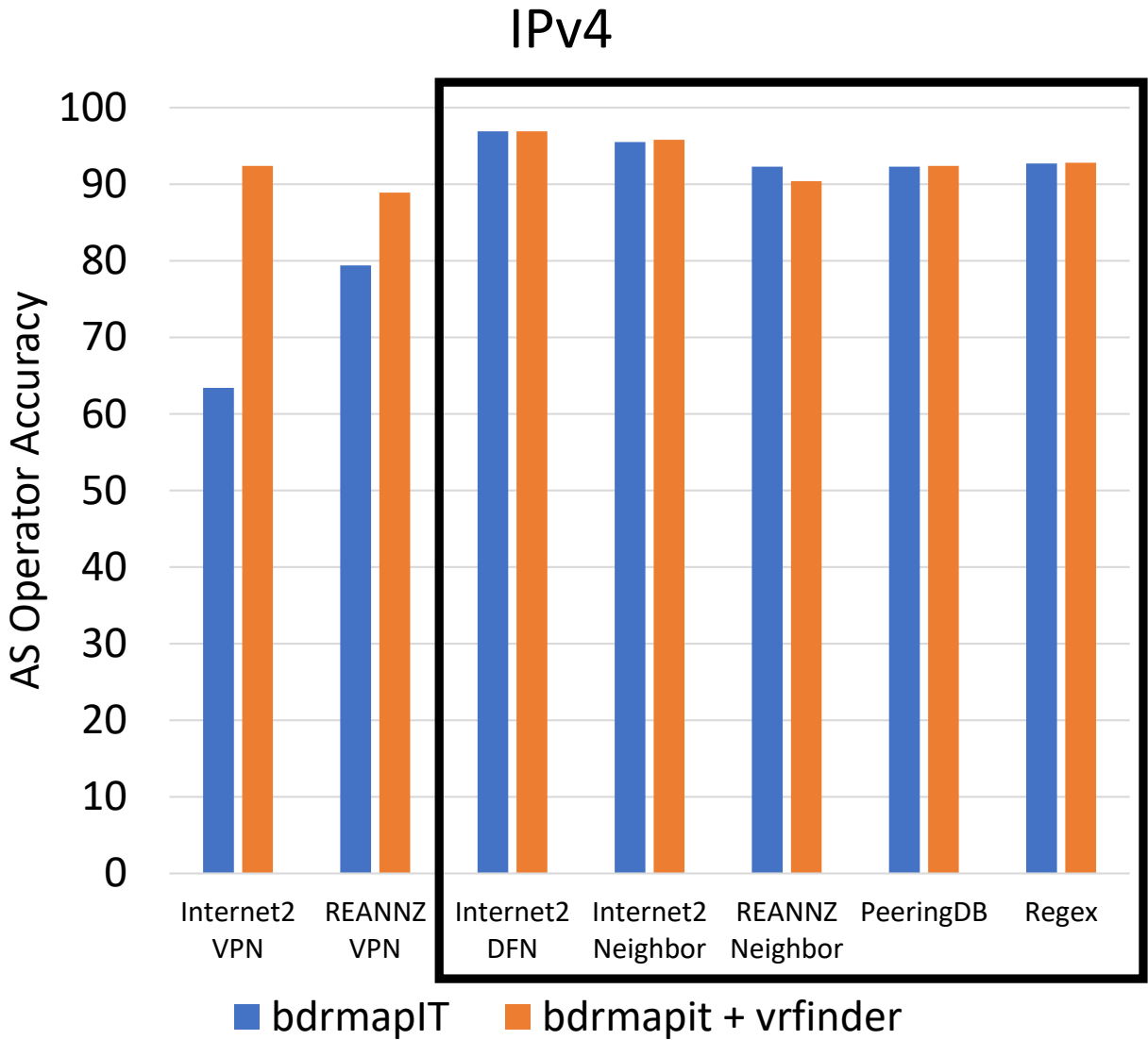


# Improvements for AS Operator Accuracy





# Improvements for AS Operator Accuracy



# Conclusion

- Outbound addresses complicate traceroute interpretation
- vrfinder infers outbound addresses in traceroute
- High PPV and TPR
- Vrfinder improves AS operator inferences