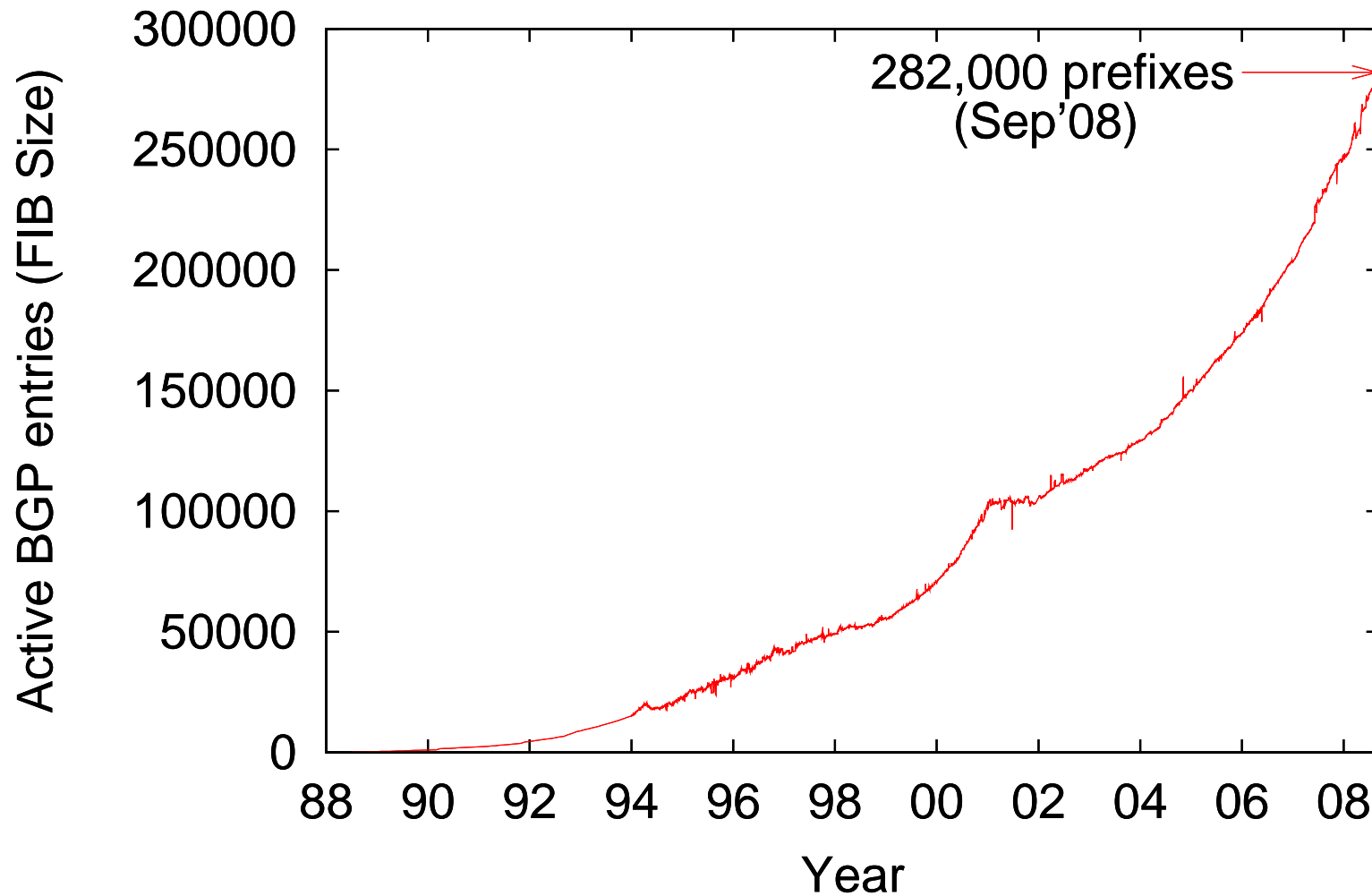# ViAggre: Making Routers Last Longer!

Hitesh Ballani
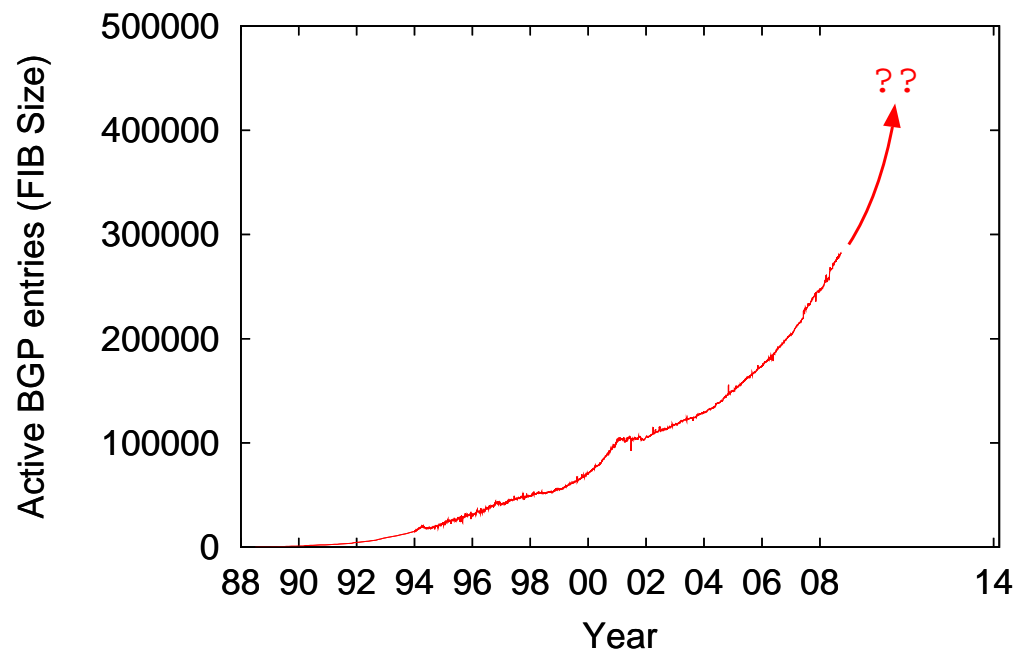
Paul Francis, Tuan Cao and Jia Wang
Cornell University and AT&T Labs – Research

HotNets 2008

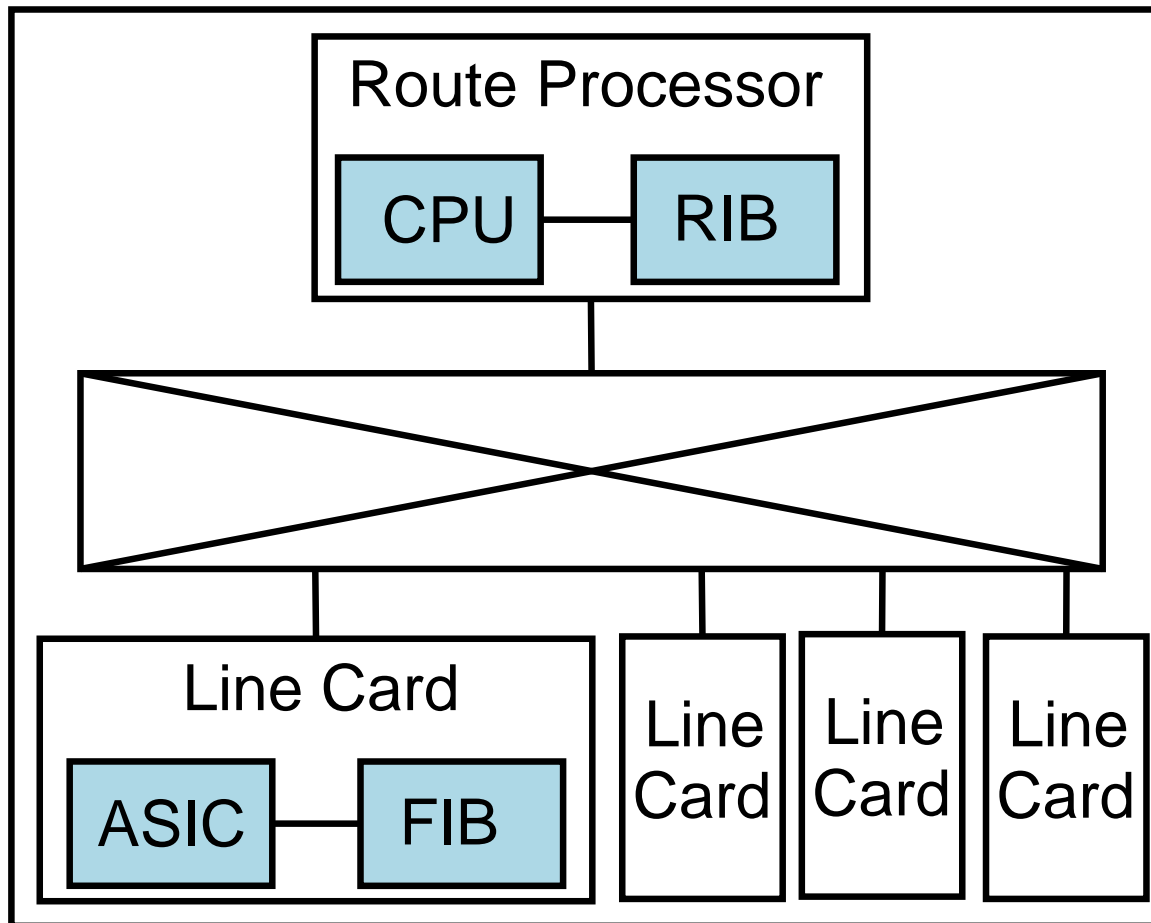# Motivation: Rapid Routing Table Growth

Motivation: Rapid Routing Table Growth

Rapid future growth
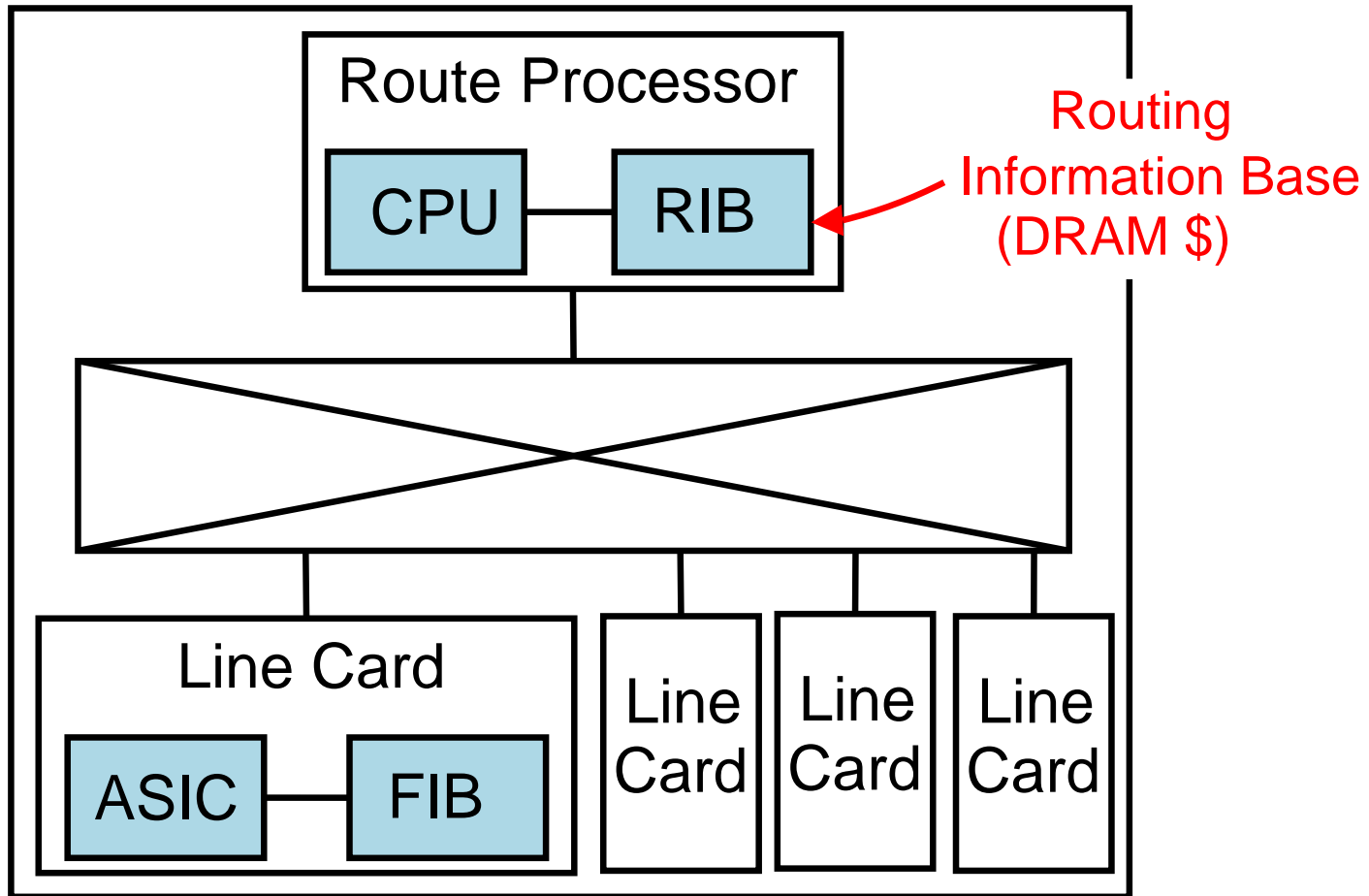
- ► IPv4 exhaustion
- ► IPv6 deployment

Typical Router Innards

Typical Router Innards
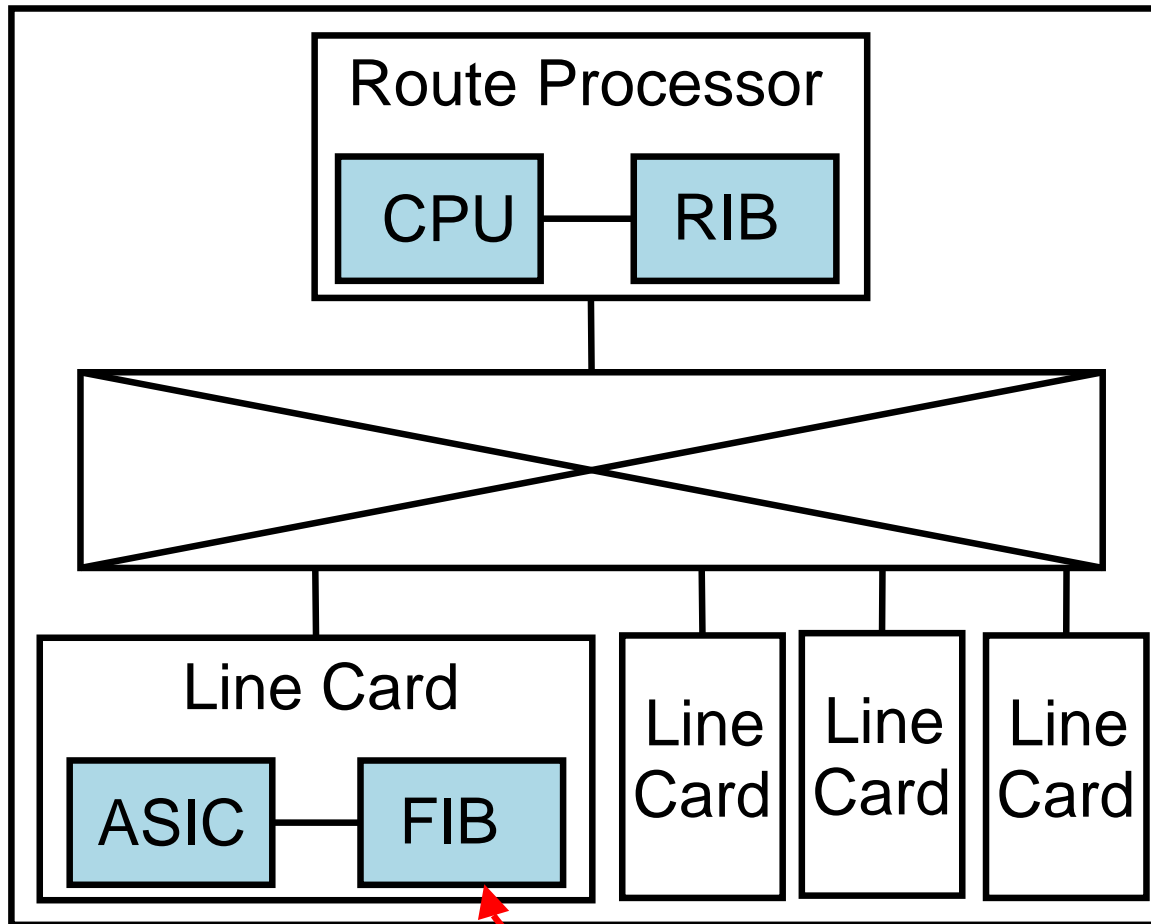
Route Processor

CPU — RIB

Routing Information Base (DRAM $)

Line Card

ASIC — FIB

Line Card

Line Card

Line Card

Typical Router Innards

Does (FIB) Size Matter?

Technical concerns

- ▶ More Memory

- ▶ More Processing
- ▶ Power and Heat dissipation problems

Does (FIB) Size Matter?

Technical concerns

- More Memory

- More Processing

- Power and Heat dissipation problems

Business concerns

- Less cost-effective networks
  - Price per byte forwarded increases
- Router memory upgrades
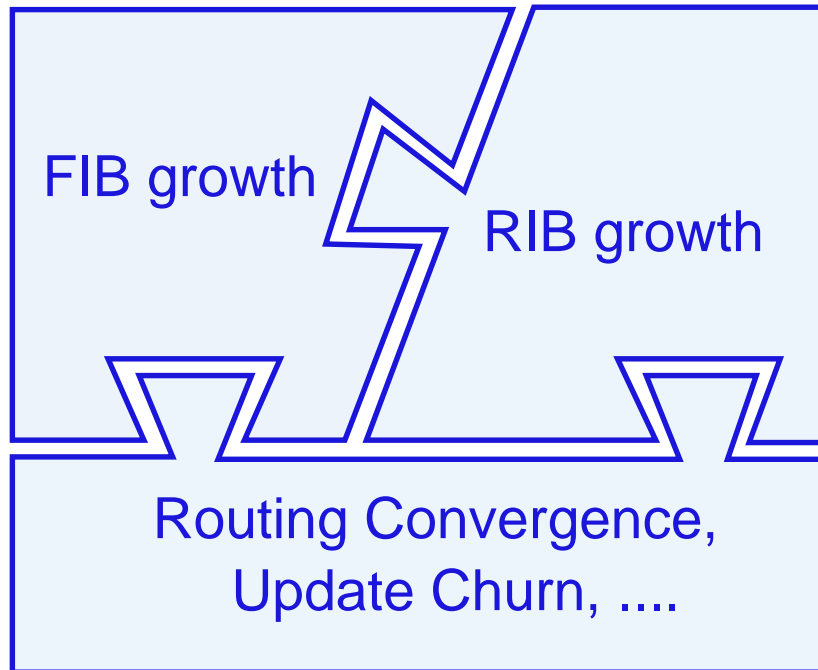
Does (FIB) Size Matter?

Technical concerns

- More Memory

- More Processing

- Power and Heat dissipation problems

Business concerns

- Less cost-effective networks
  - Price per byte forwarded increases

- Router memory upgrades

ISPs are willing to undergo some pain to reduce FIB size

Routing Scalability Problem Space

FIB growth

RIB growth

Routing Convergence,
Update Churn, ...

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
[Farinacci, ID'07]
[Massey et. al., ID'07]
[Jen et. al., HotNets'08]

[Francis, CNIS'94]
[Deering et. al., ID'00]
[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

Routing Scalability Problem Space

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
[Farinacci, ID'07]
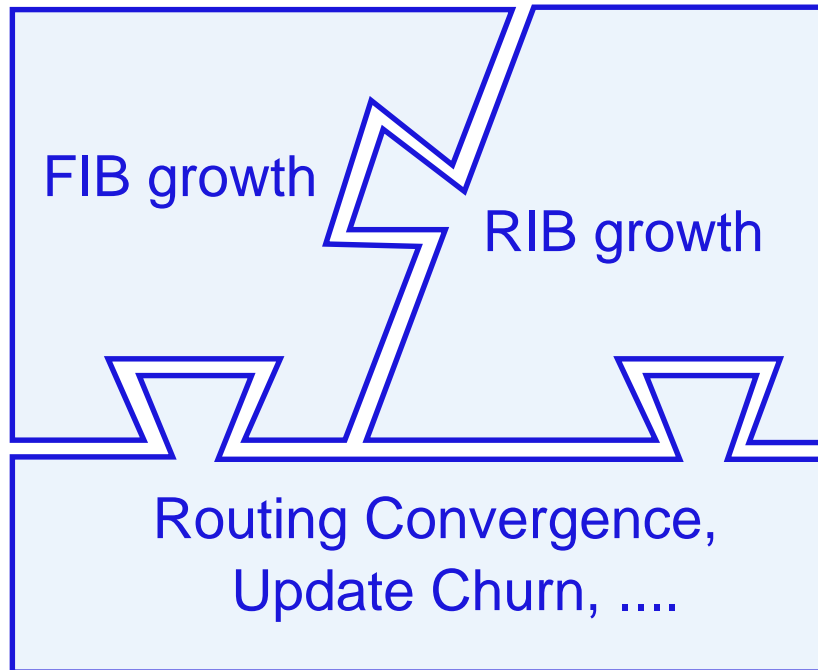[Massey et. al., ID'07]
[Jen et. al., HotNets'08]

[Francis, CNIS'94]
[Deering et. al., ID'00]
[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

Separate edge from the core

Routing Scalability Problem Space

FIB growth

RIB growth

Routing Convergence,
Update Churn, ...

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
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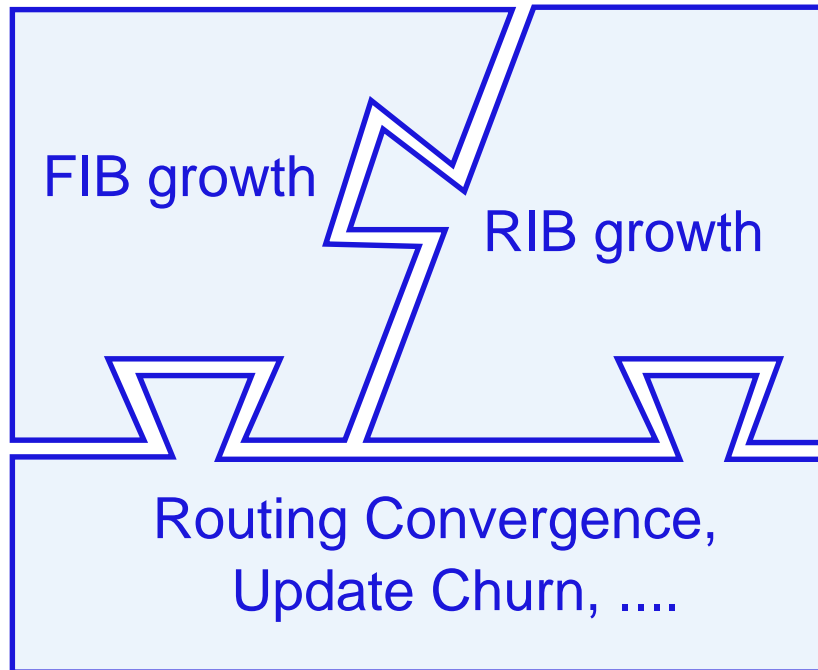[Massey et. al., ID'07]
[Jen et. al., HotNets'08]

[Francis, CNIS'94]
[Deering et. al., ID'00]
[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

Geographical routing

Routing Scalability Problem Space

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
[Farinacci, ID'07]
[Massey et. al., ID'07]
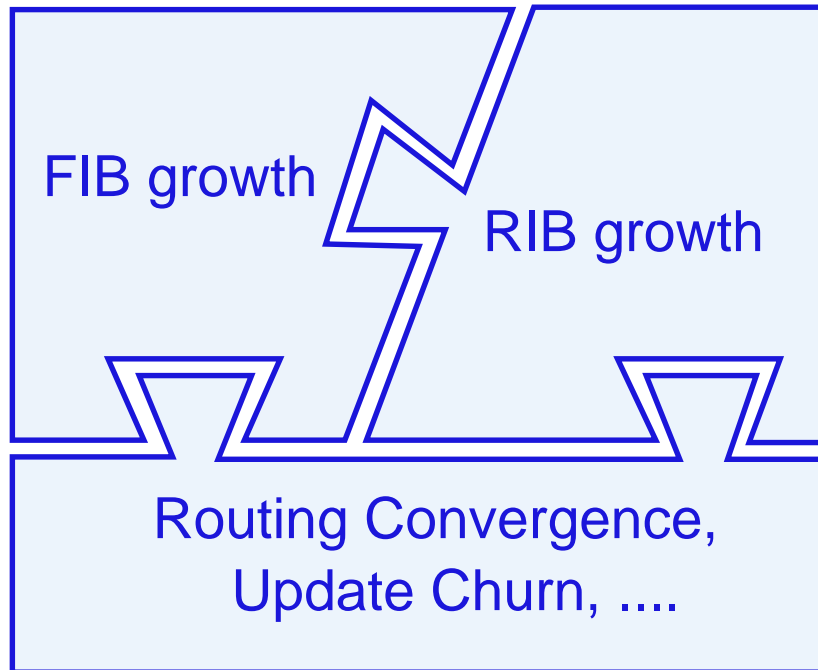[Jen et. al., HotNets'08]

[Francis, CNIS'94]
[Deering et. al., ID'00]
[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

Compact routing

Routing Scalability Problem Space

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
[Farinacci, ID'07]
[Massey et. al., ID'07]
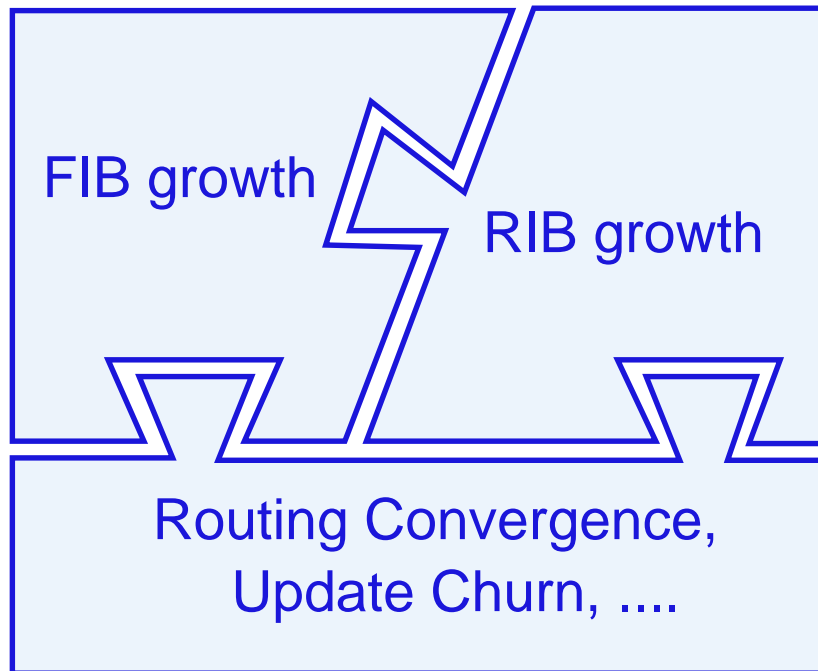[Jen et. al., HotNets'08]

[Francis, CNIS'94]
[Deering et. al., ID'00]
[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

All require architectural change
So many ideas, so little impact!

Routing Scalability Problem Space

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
[Farinacci, ID'07]
[Massey et. al., ID'07]
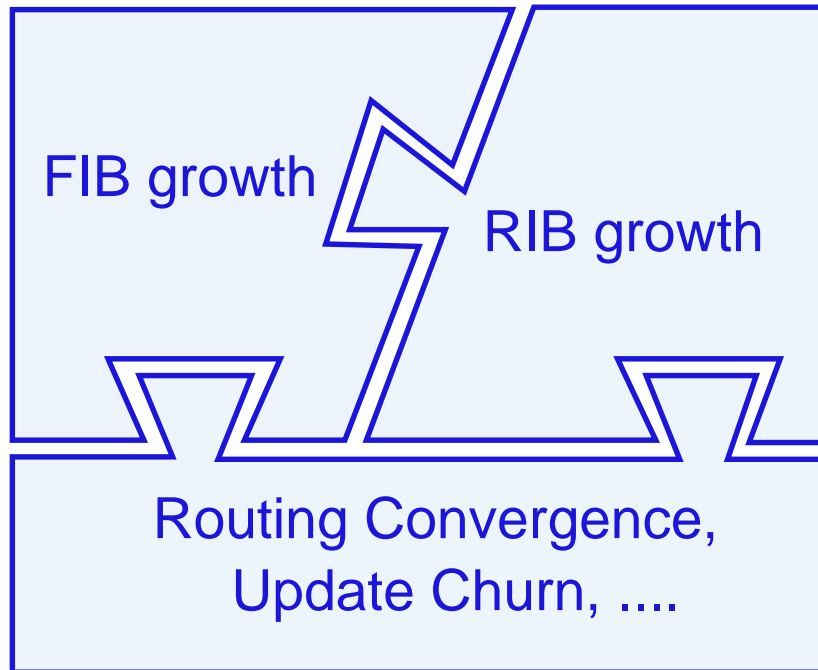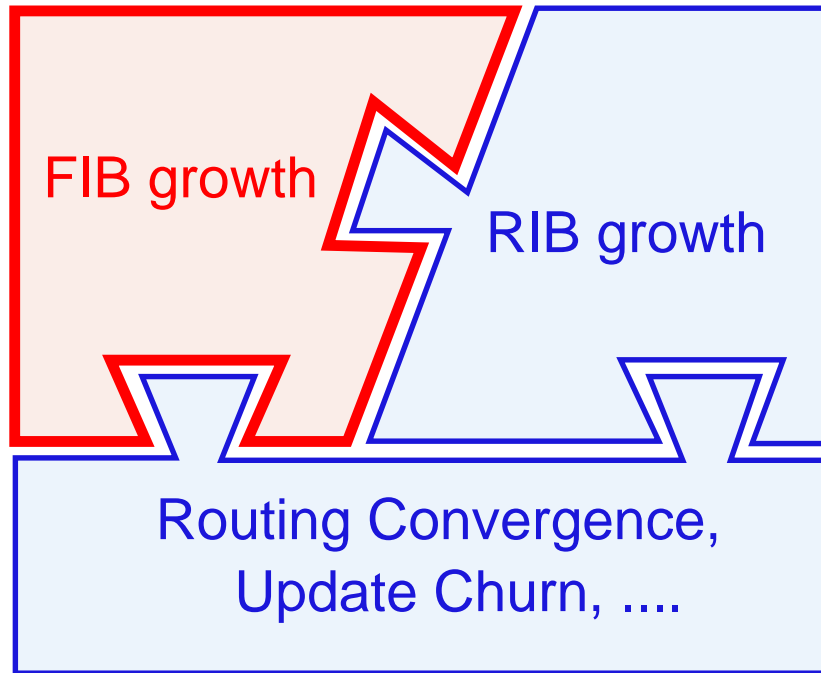[Jen et. al., HotNets'08]

[Francis, CNIS'94]
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[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

Tackle routing scalability through a series of incremental, individually cost-effective upgrades

Routing Scalability Problem Space

[Deering, '96]
[O'Dell, ID'97]
[Zhang et. al., ICNP'06]
[Farinacci, ID'07]
[Massey et. al., ID'07]
[Jen et. al., HotNets'08]

[Francis, CNIS'94]
[Deering et. al., ID'00]
[Hain, ID'02]

[Krioukov et. al., Arxiv'05]

This Paper: Focuses on reducing FIB size

Virtual Aggregation, aka ViAggre

A "configuration-only" approach to shrinking router FIBs

- ▶ Applies to legacy routers
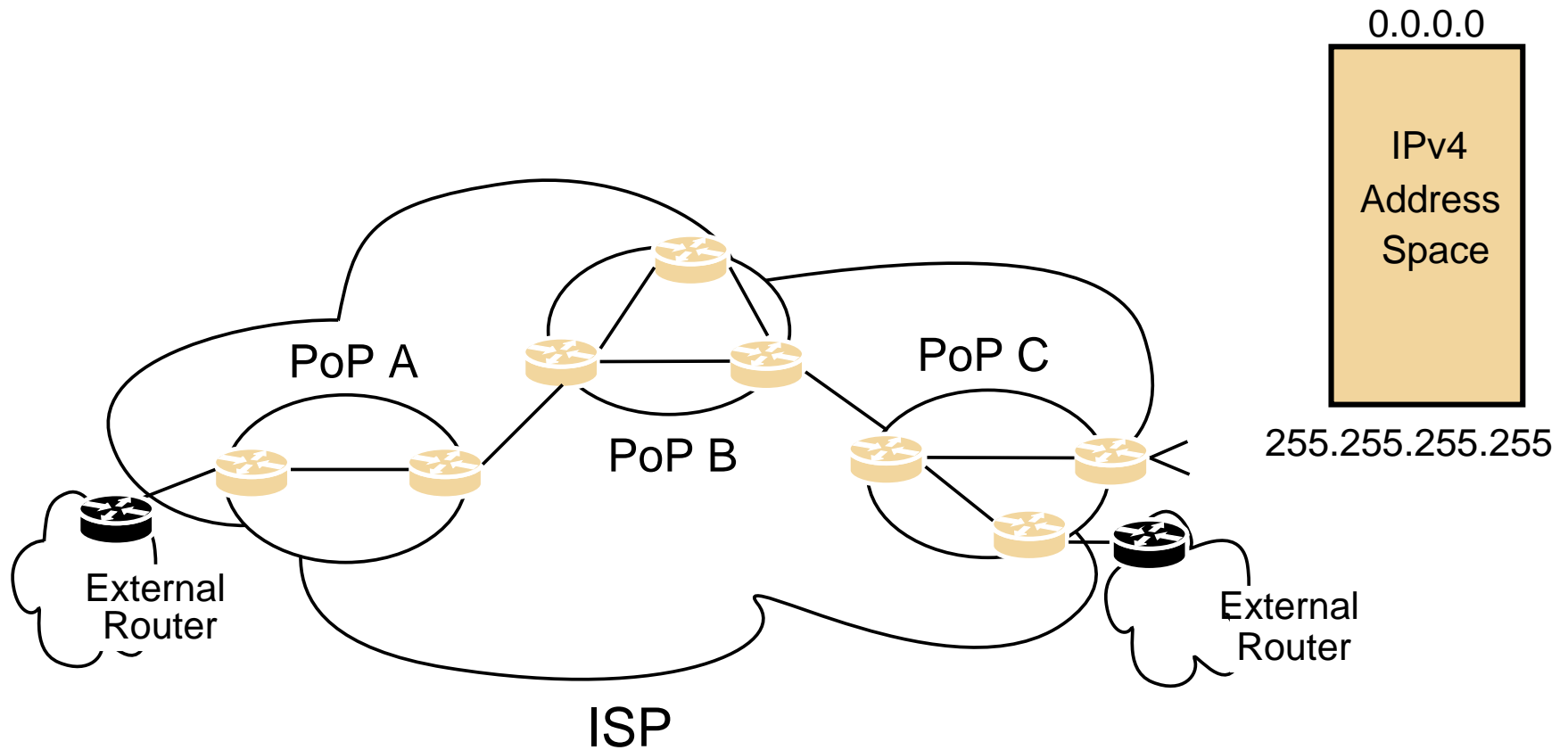- ▶ Can be adopted independently by any ISP

Key Insight: Divide the routing burden

A router only needs to keep routes for a fraction of the address space
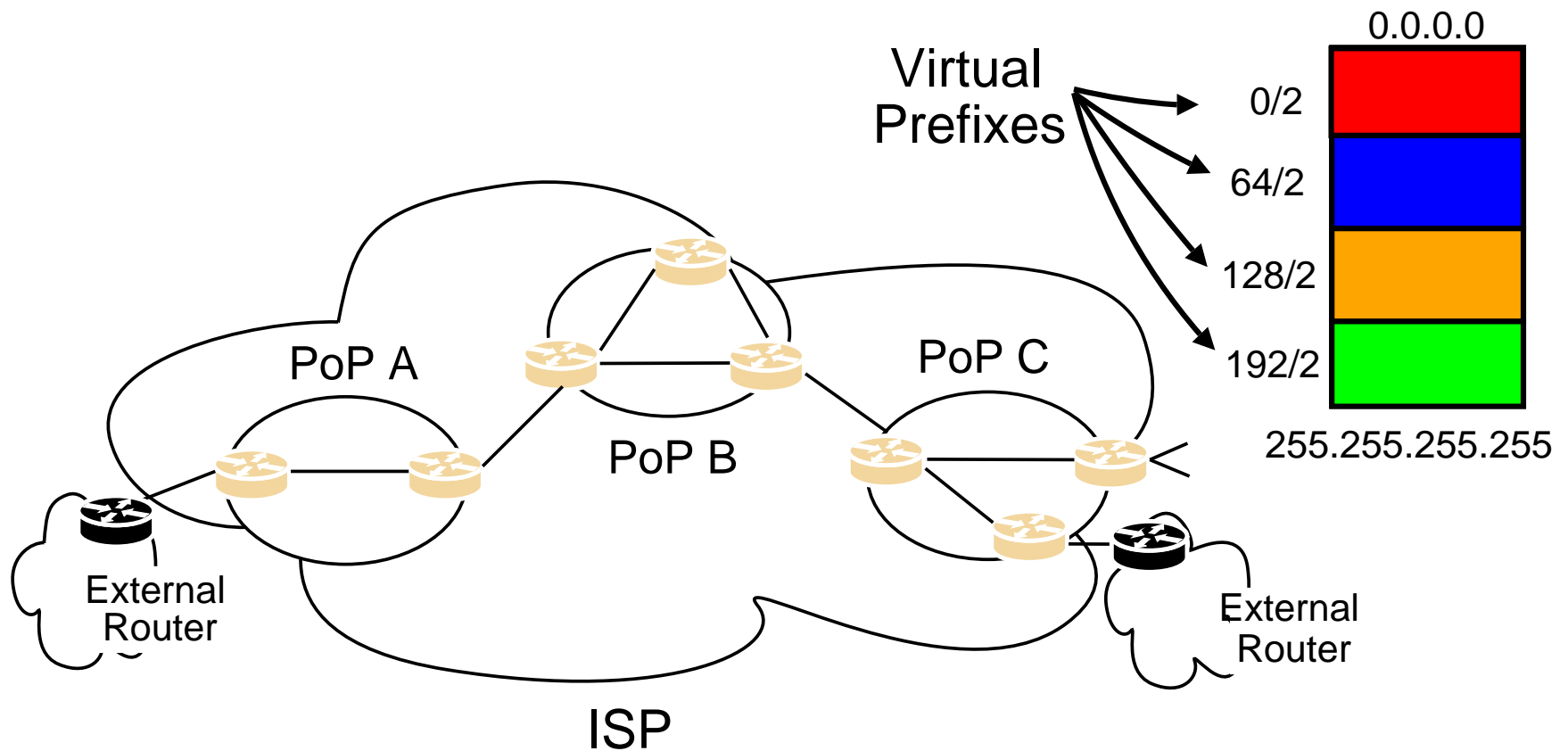
Talk Outline

- Introduction
- ViAggre: Basic Idea
- ViAggre Design
- Evaluation
- Deployment
- Conclusions

ViAggre: Basic Idea

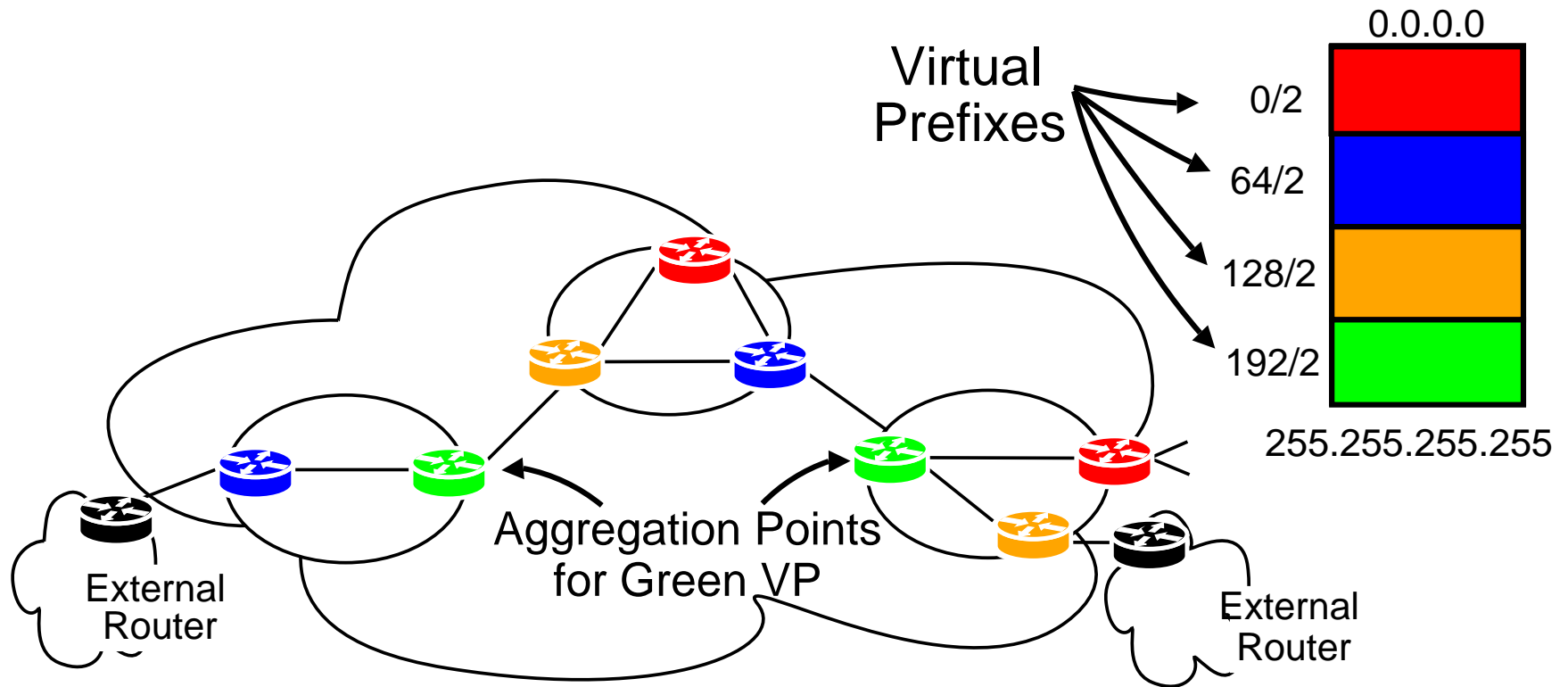**Today:** All routers have routes to all destinations

ViAggre: Basic Idea

Virtual Prefixes

0.0.0.0

0/2

64/2

128/2

192/2

255.255.255.255

PoP A

PoP B

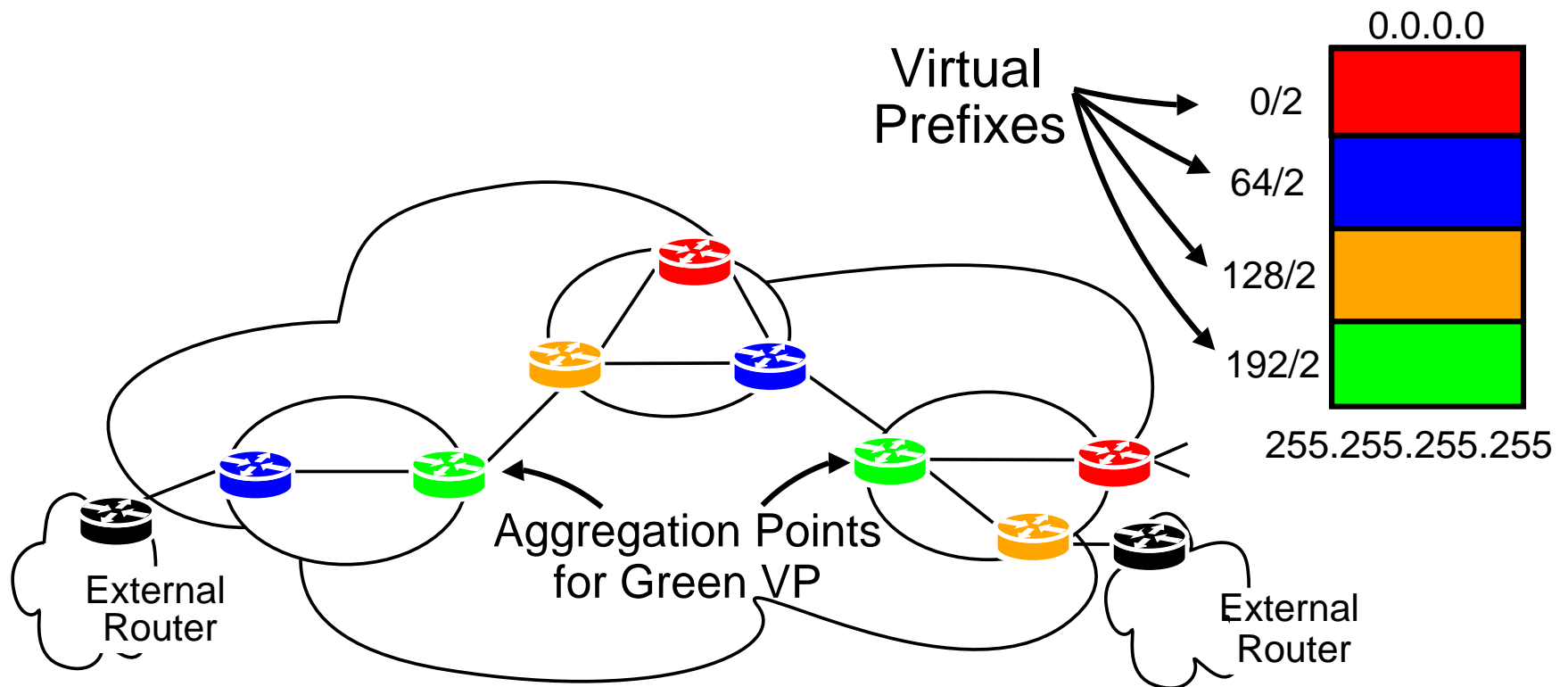PoP C

External Router

External Router

ISP

Divide address space into Virtual Prefixes (VPs)

ViAggre: Basic Idea

Assign Virtual Prefixes to the routers
Routers only have routes to a fraction of the address space

ViAggre: Basic Idea

Virtual Prefixes

0.0.0.0

0/2

64/2

128/2

192/2

255.255.255.255

External Router

Aggregation Points for Green VP

External Router
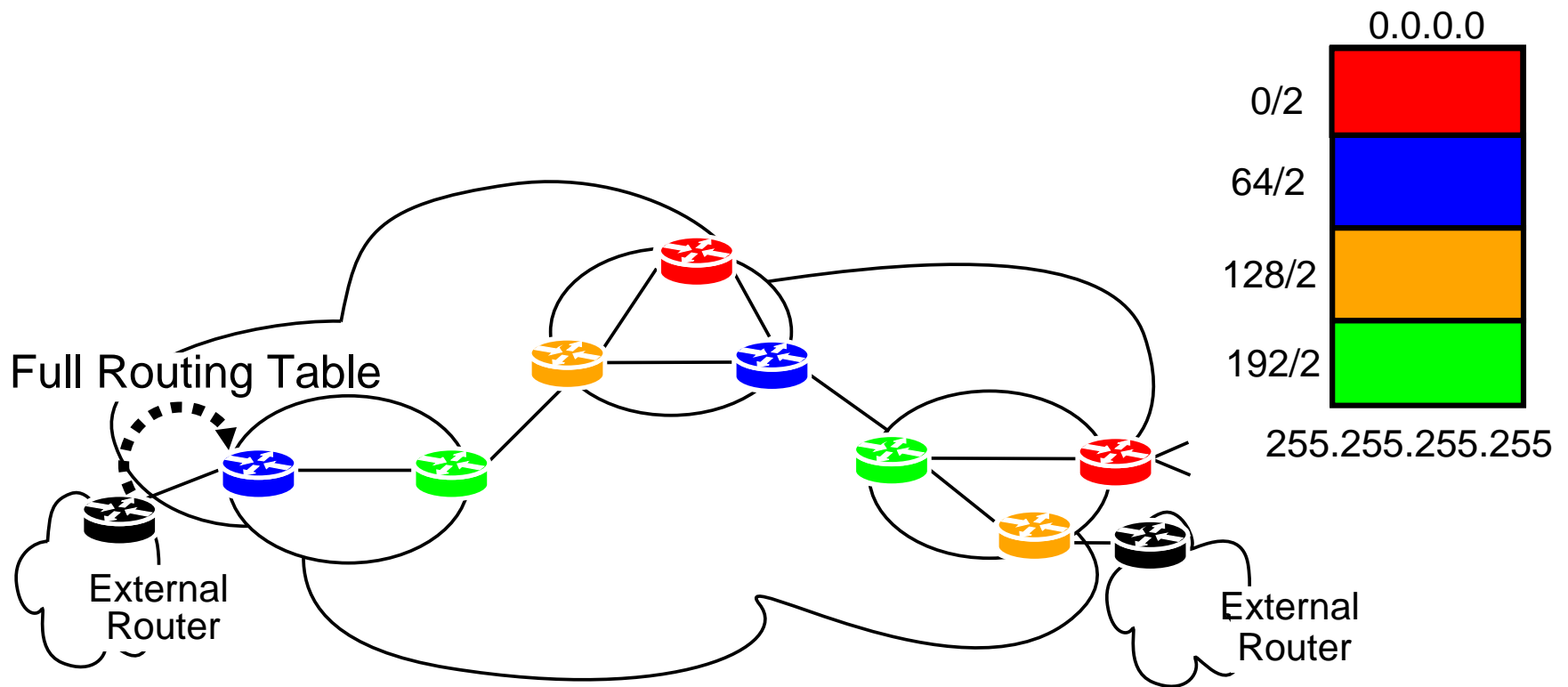
How to achieve such division of the routing table?
Without changes to routers and routing protocols
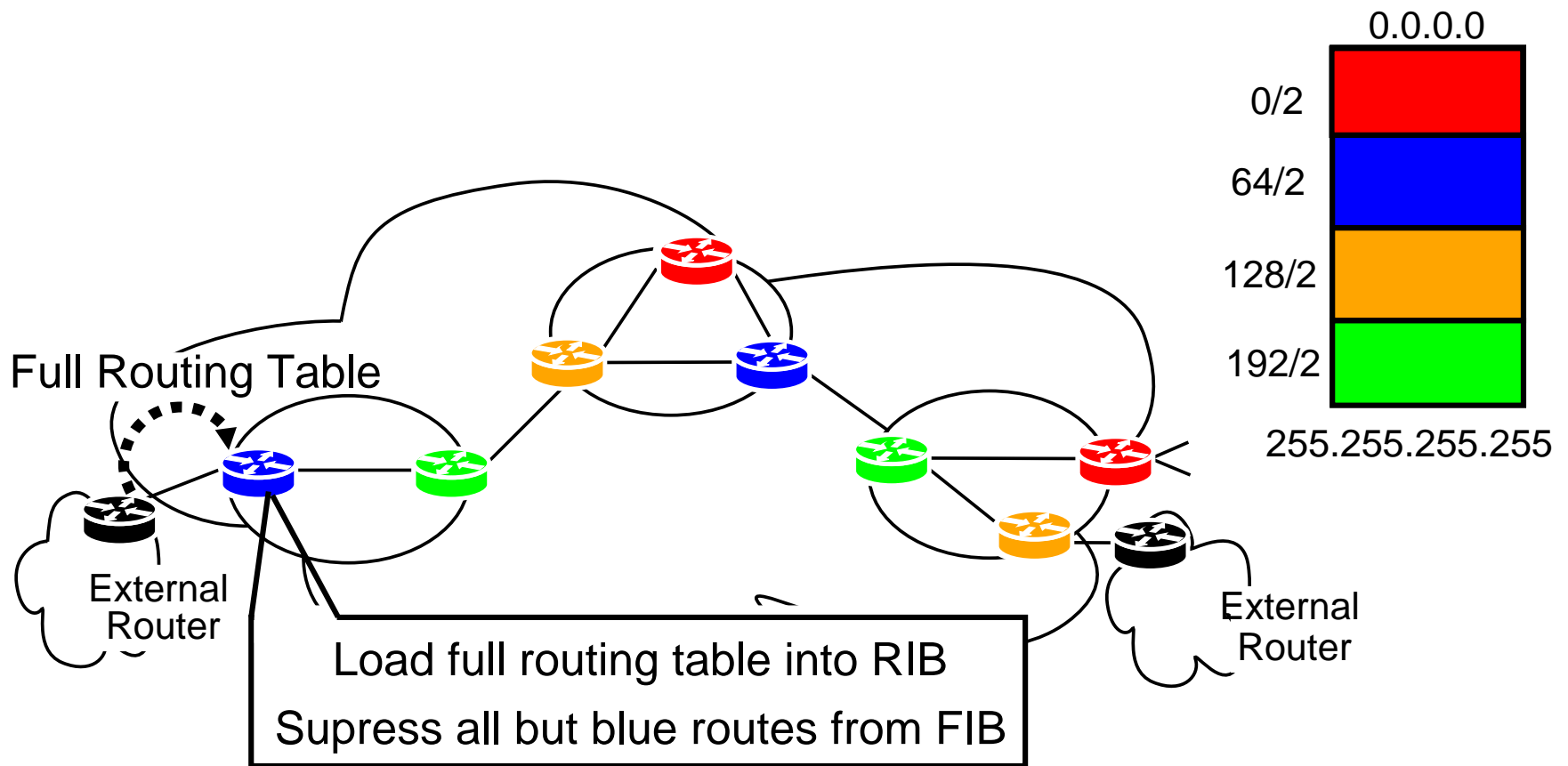Without cooperation from external networks

Talk Outline

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ViAggre Control-Plane

eBGP Peers may advertise full routing table

ViAggre Control-Plane

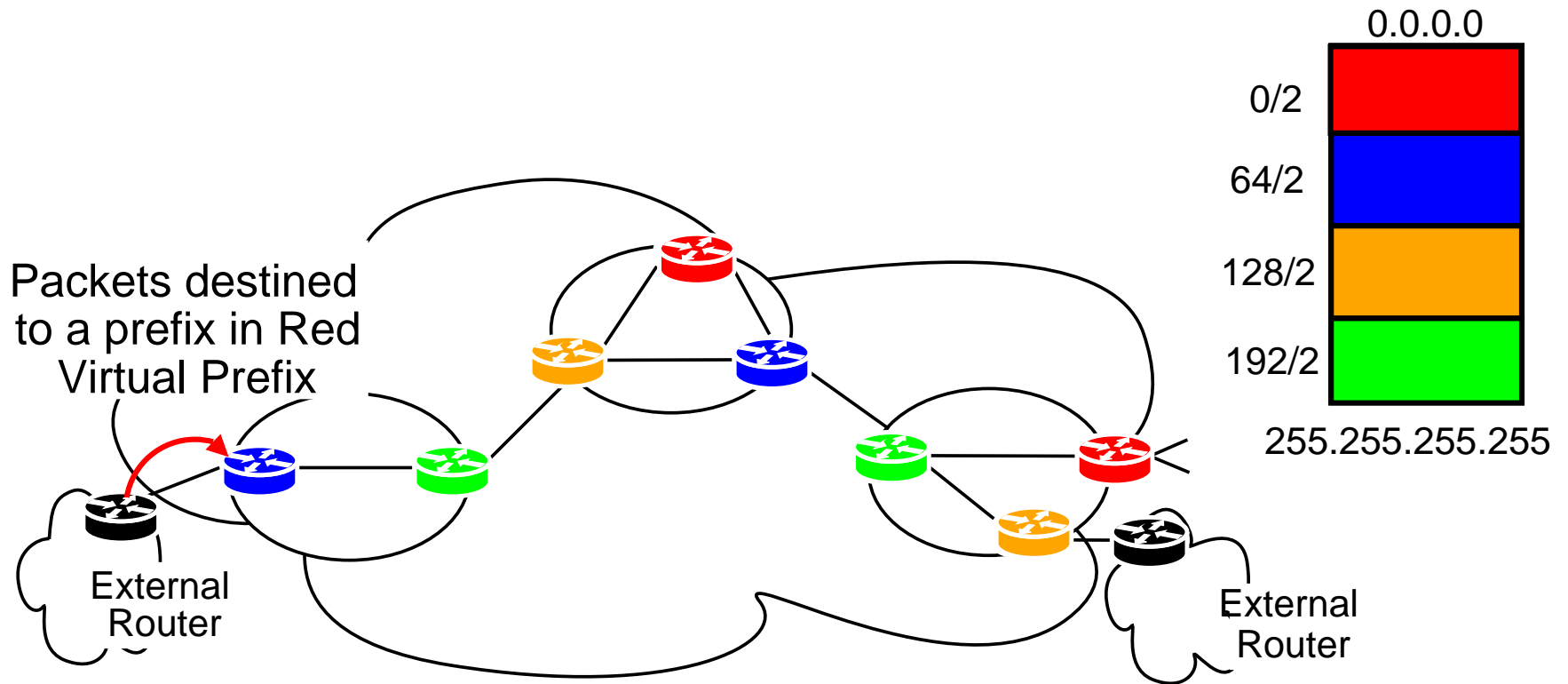

Full Routing Table
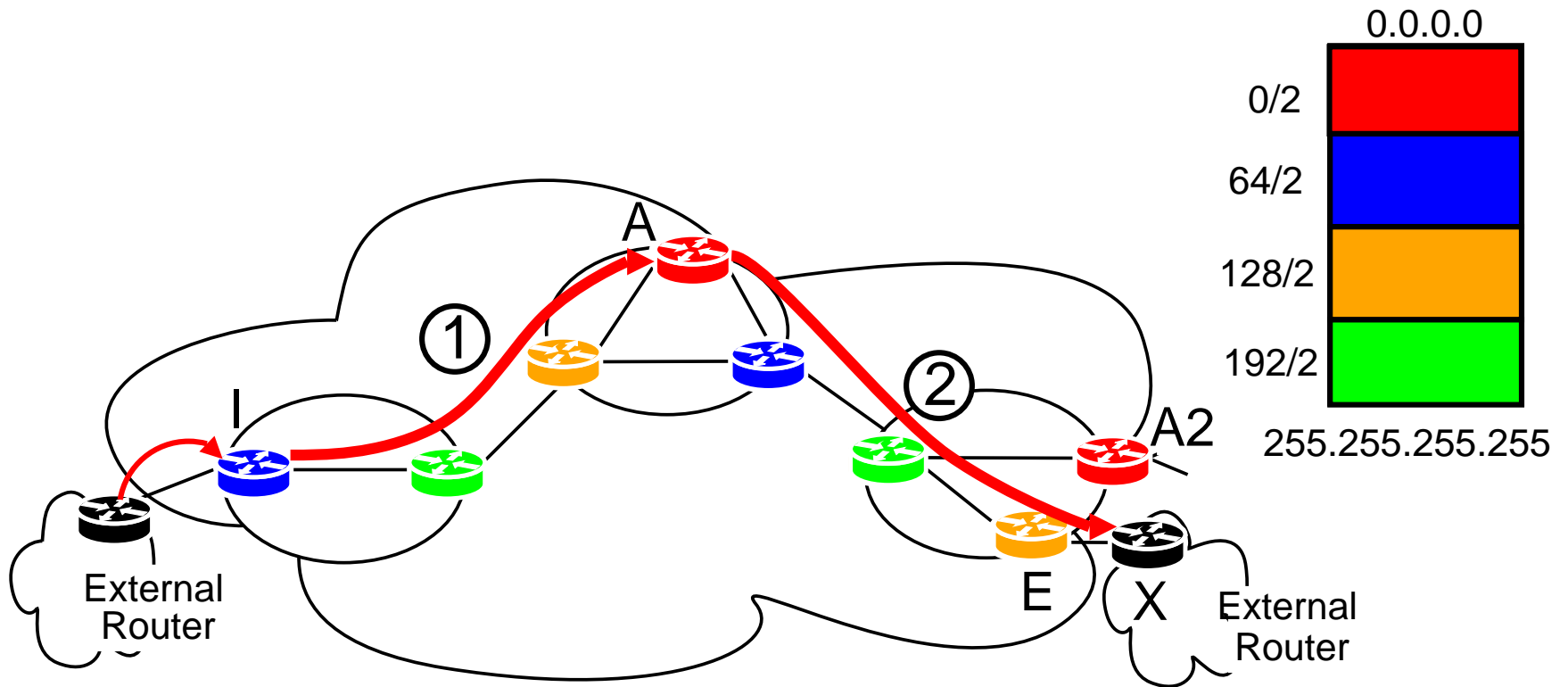
Load full routing table into RIB

Supress all but blue routes from FIB

External Router

External Router

0.0.0.0

0/2

64/2

128/2

192/2

255.255.255.255

FIB Suppression
Blue routers only load blue routes into their FIB

Data-Plane paths

Packets destined
to a prefix in Red
Virtual Prefix

External
Router

External
Router

0.0.0.0

0/2

64/2

128/2

192/2

255.255.255.255

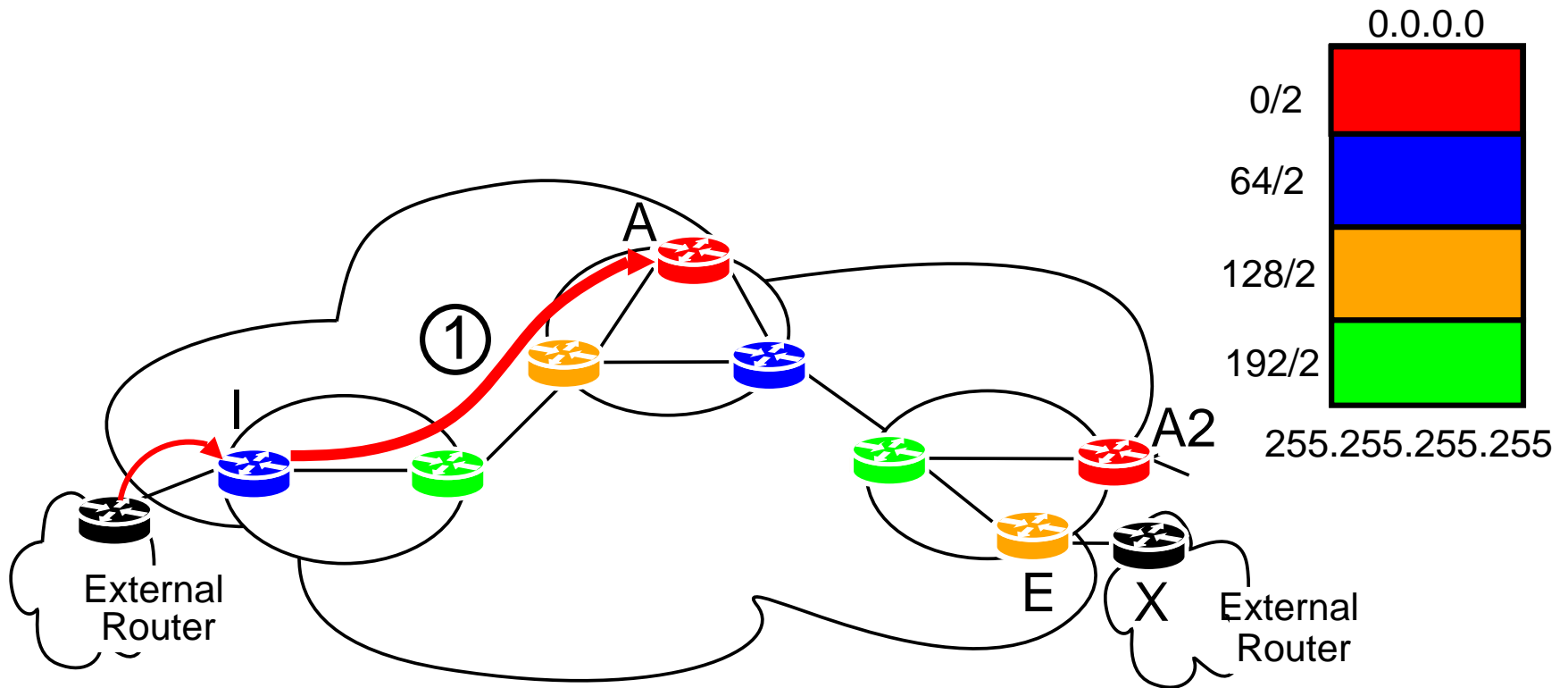Consider packets destined to a prefix in the red VP
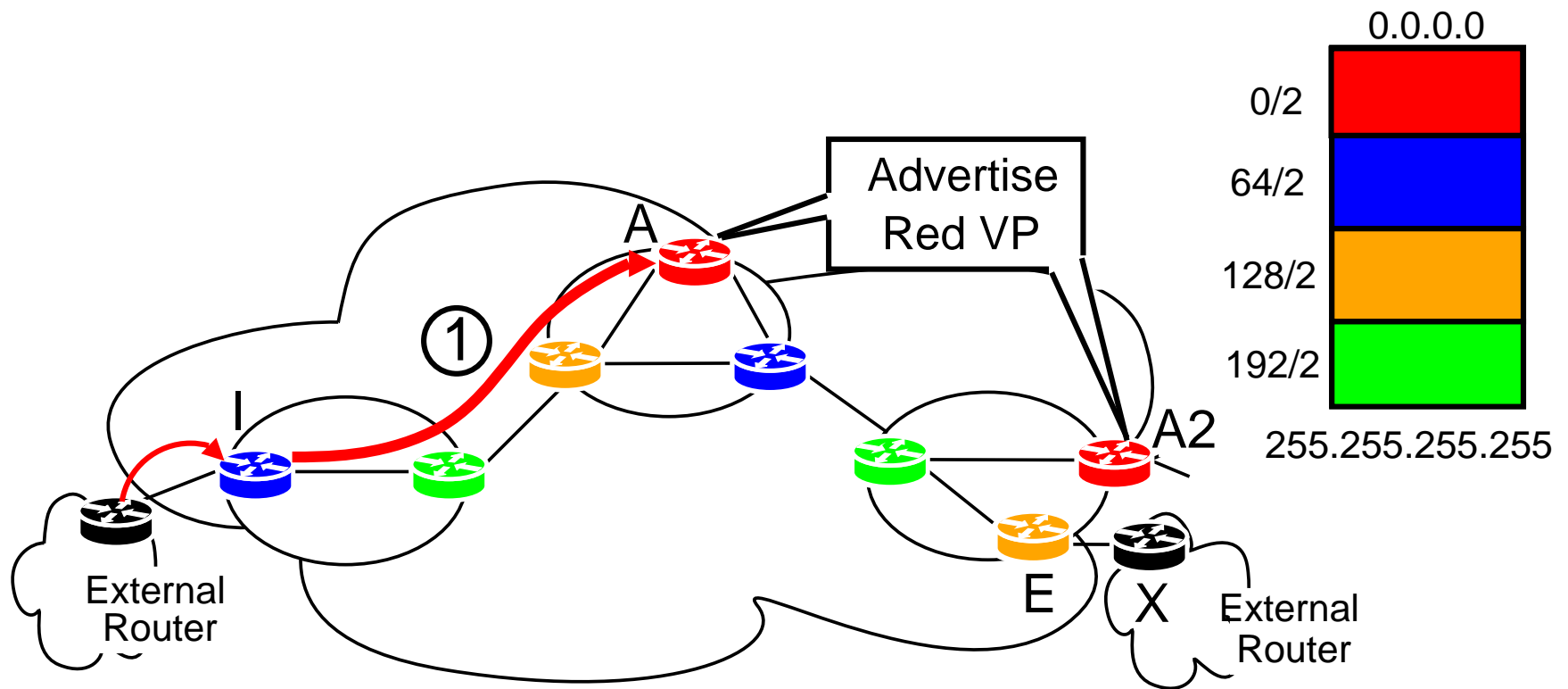
Data-Plane paths

ViAggre path

Ingress (I) → Aggregation Pt (A) → Egress (E)
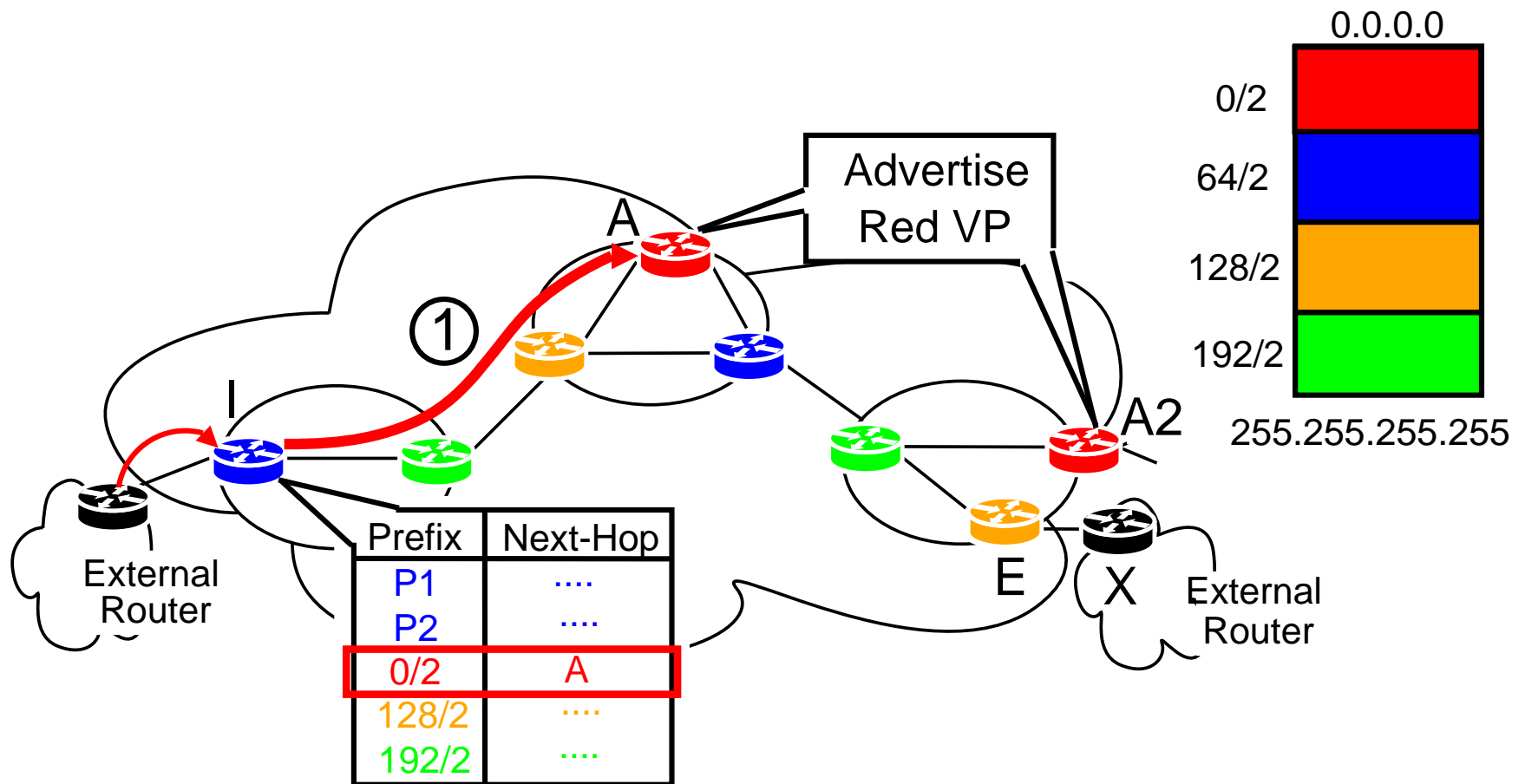
Ingress → Aggregation Point

Router I doesn't have a route for destination prefix

Aggregation Points advertise corresponding Virtual Prefixes

Blue router has a route for the red Virtual Prefix

Prefix	Next-Hop
P3	X
P4	....
64/2	....
128/2	....
192/2	....

0.0.0.0

0/2

64/2

128/2

192/2

255.255.255.255

A

I

External Router

②

A2

E   X   External Router

Aggregation Pt. A tunnels packet to external router

Aggregation Point → Egress
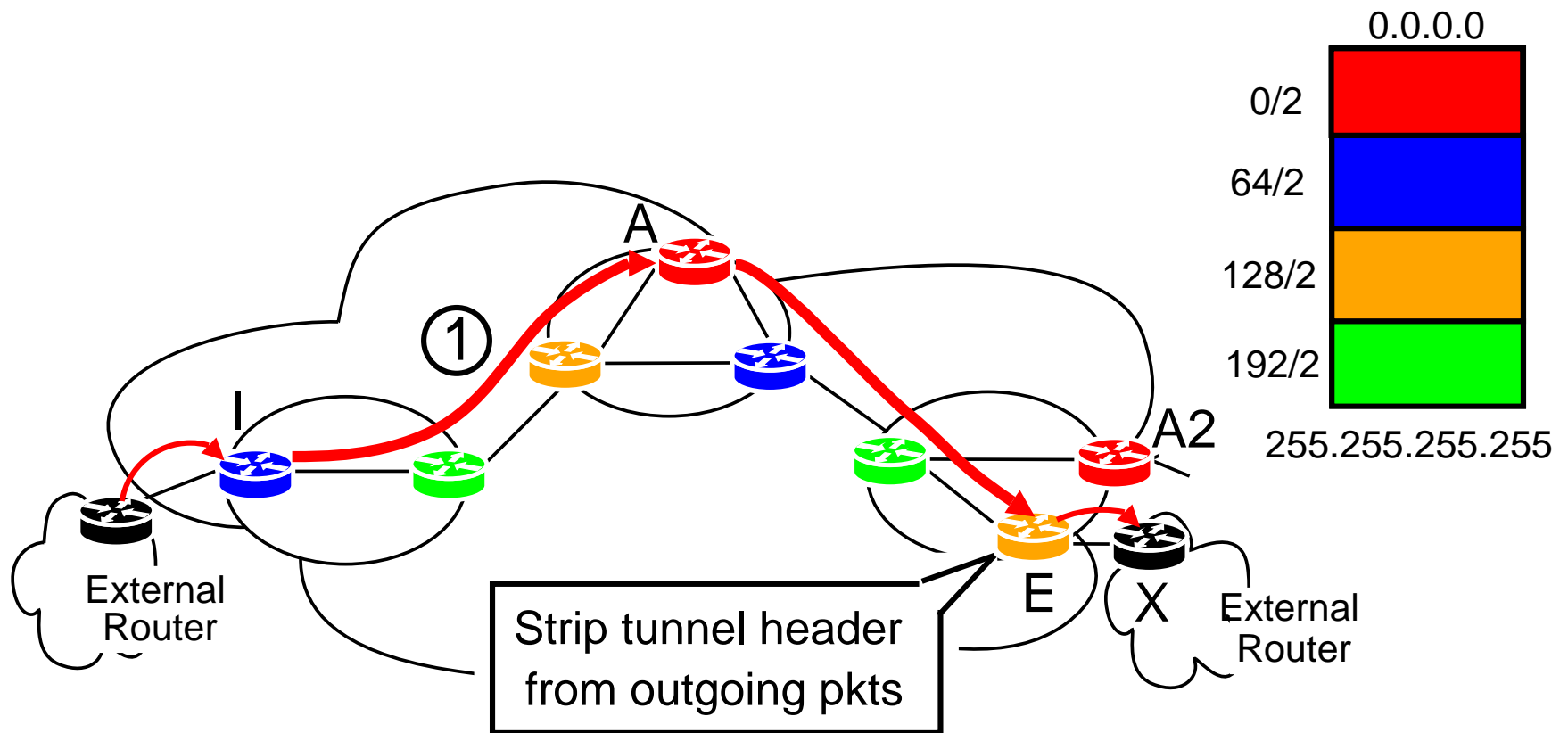
Egress Router strips the tunnel header off outgoing packets

Failure of Aggregation Point

0.0.0.0

0/2	
64/2	
128/2	
192/2	

255.255.255.255

A1

A2

I

E

X

External Router

External Router

①
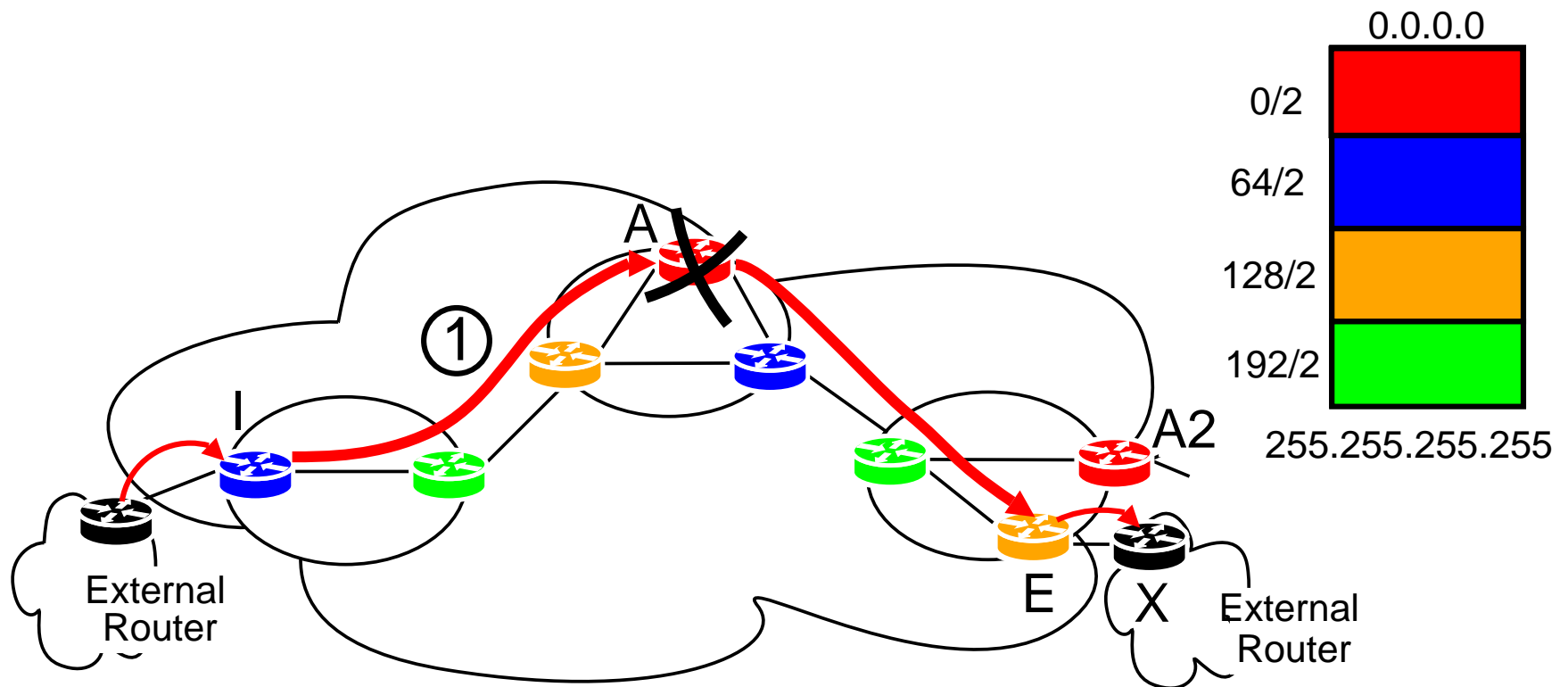
What if Aggregation Pt. A fails?

Failure of Aggregation Point
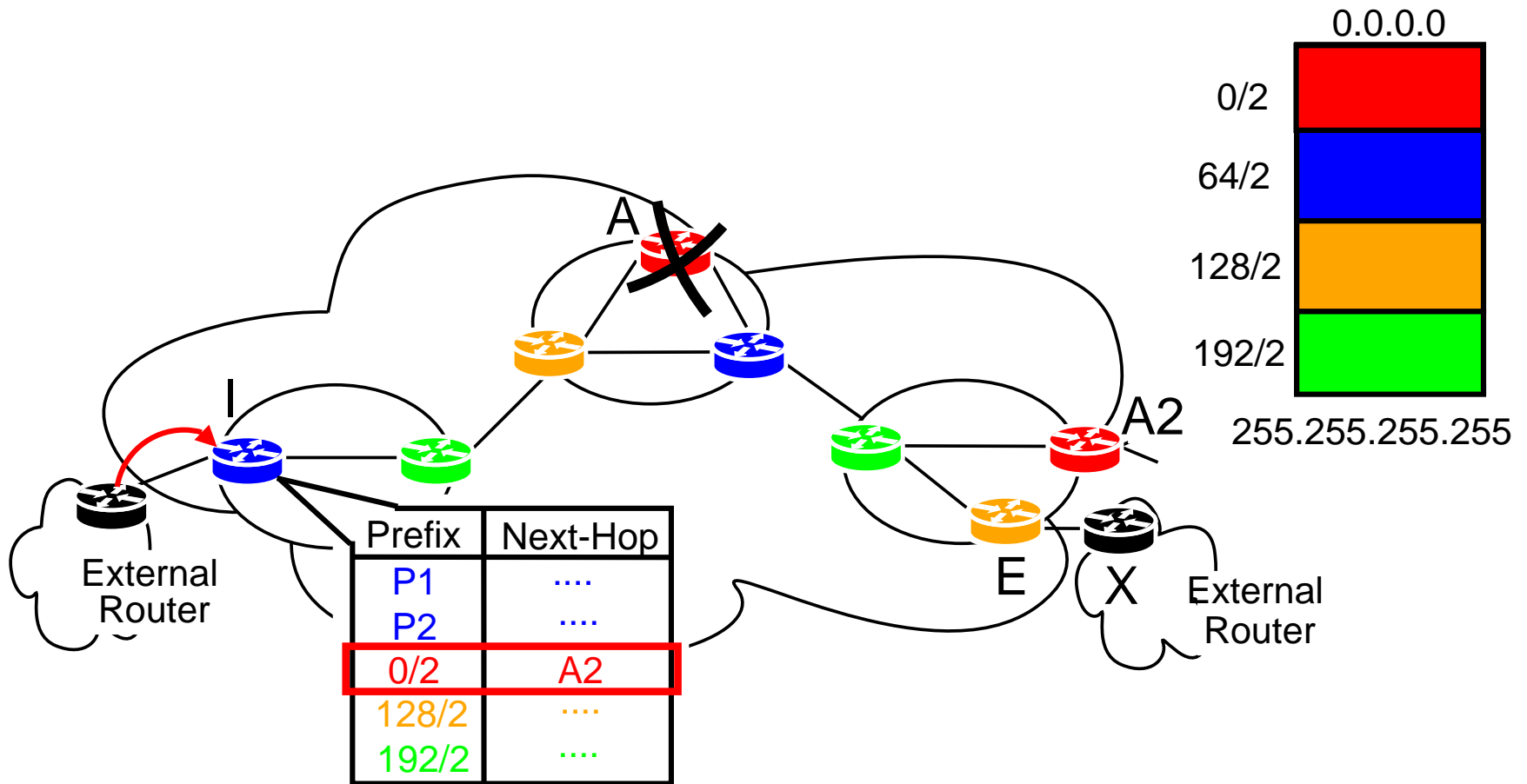
Router I installs the route advertised by A2

Failure of Aggregation Point

Packets are re-routed appropriately

ViAggre's impact on ISP's traffic
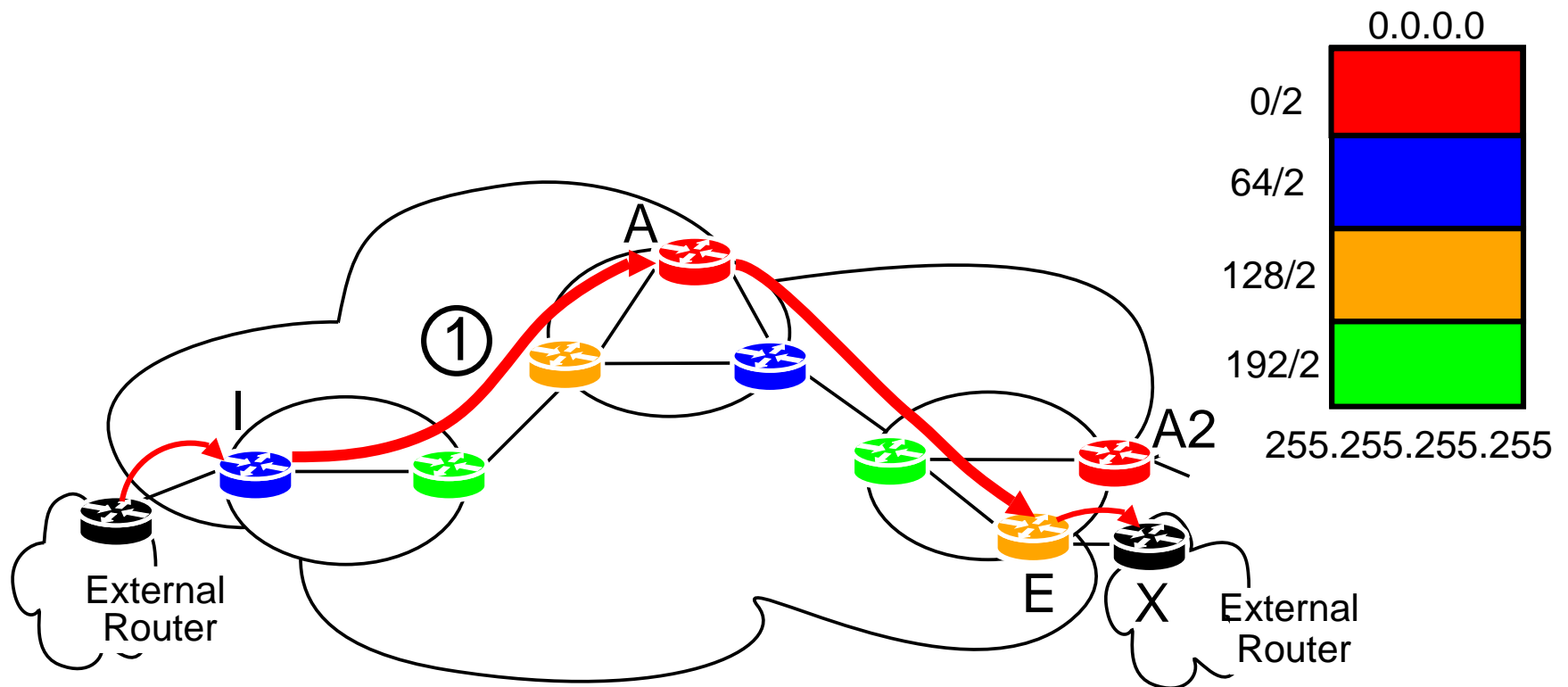
ViAggre paths can be longer than native paths
Traffic stretch, increased router and link load, etc.
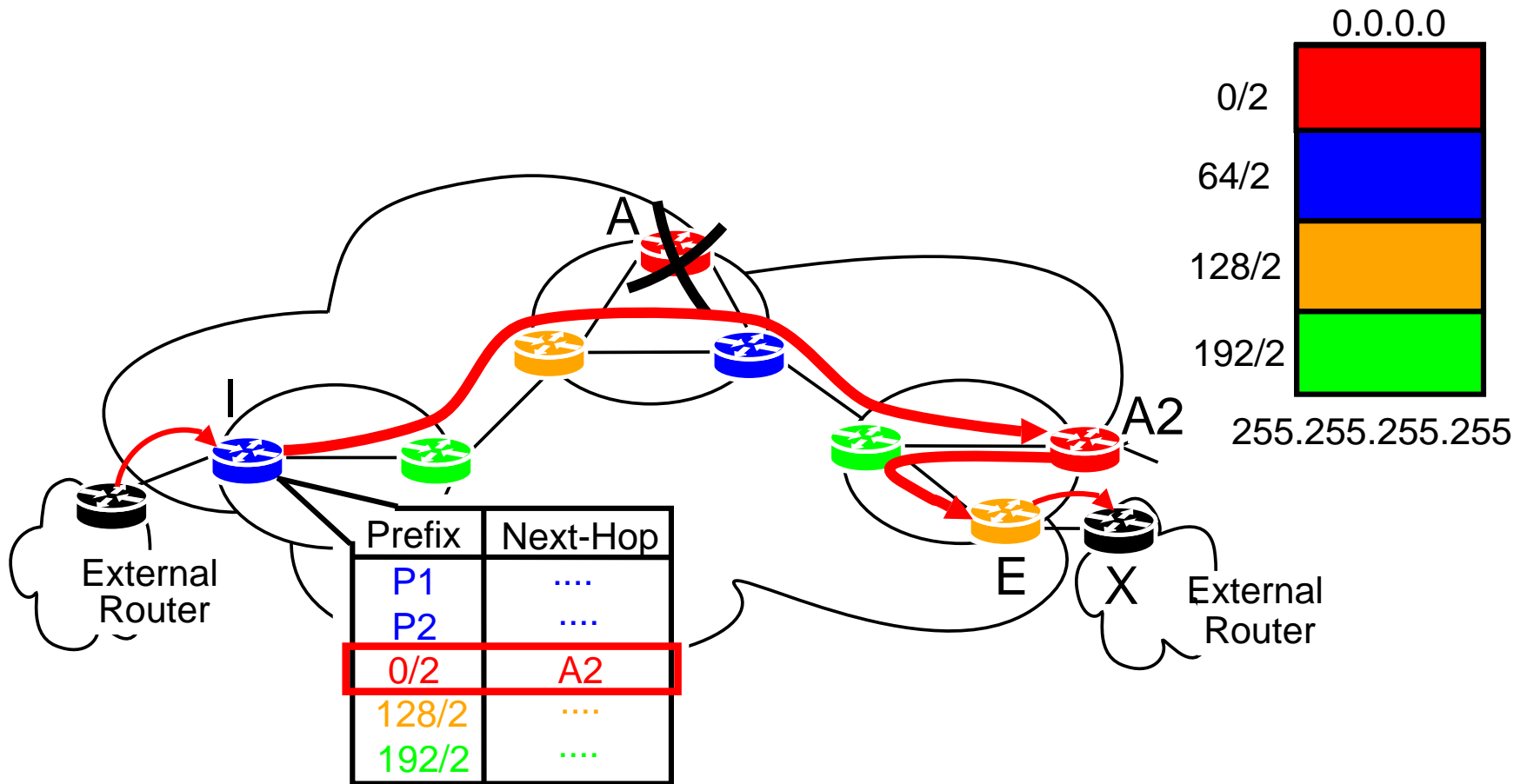
Popular Prefixes

Traffic volume follows power-law distribution

- ▸ 95% of the traffic goes to 5% of prefixes
- ▸ Has held up for years

Install "Popular Prefixes" in routers

- ▸ Stable over weeks
- ▸ Mitigates ViAggre's impact on the ISP's traffic

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Stretch Vs FIB Size

Assigning more routers to aggregate a virtual prefix

- ▶ Reduces Stretch imposed on Traffic
- ▶ Increases FIB size

Aggregation Point Assignment Problem

- ▶ Minimize Worst FIB size, subject to constraint on Worst stretch
- ▶ NP-complete problem
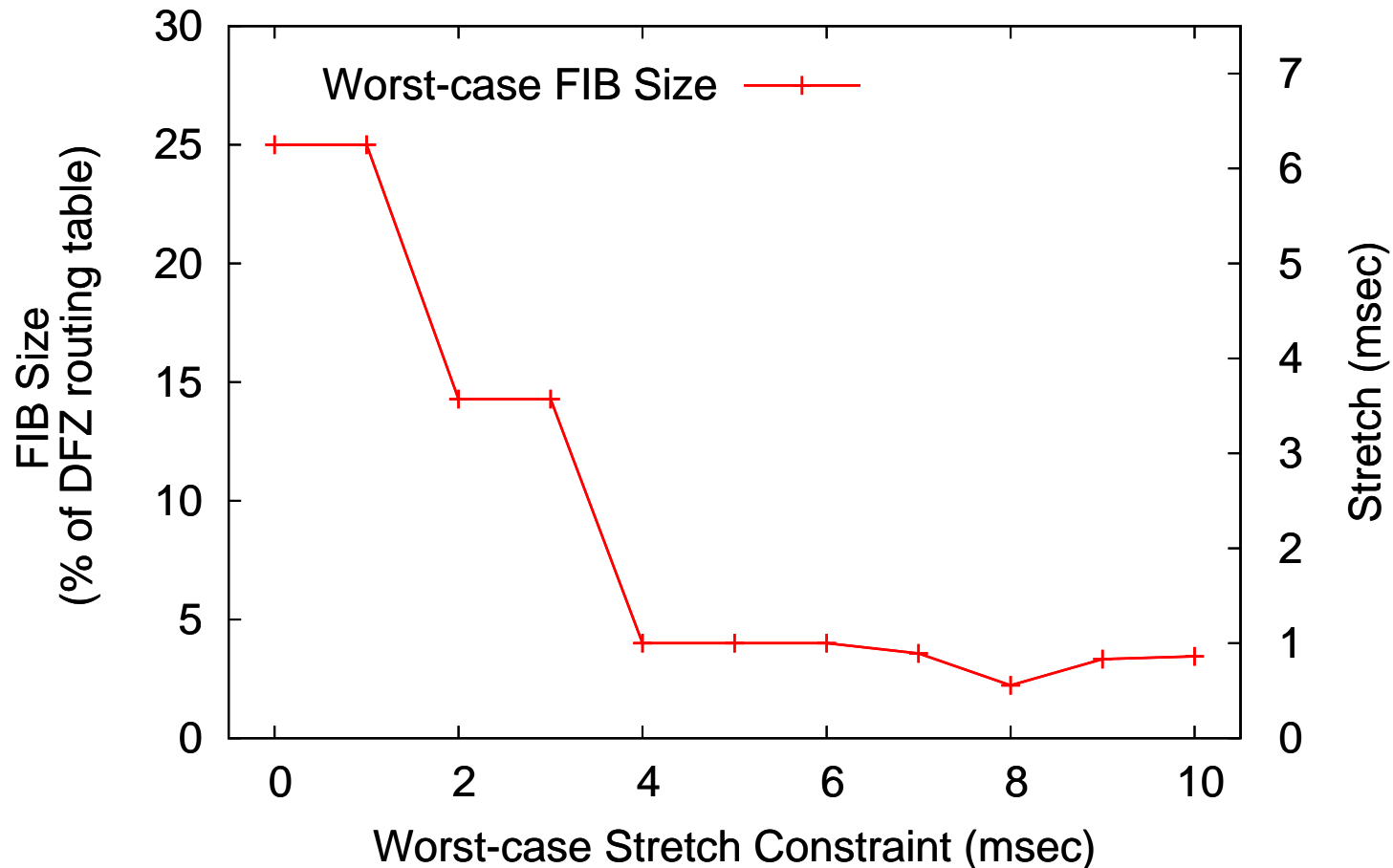- ▶ Implemented a greedy approximation

Performance Study

Data from tier-1 ISP

- ▶ Topology, Routing tables, Traffic matrix
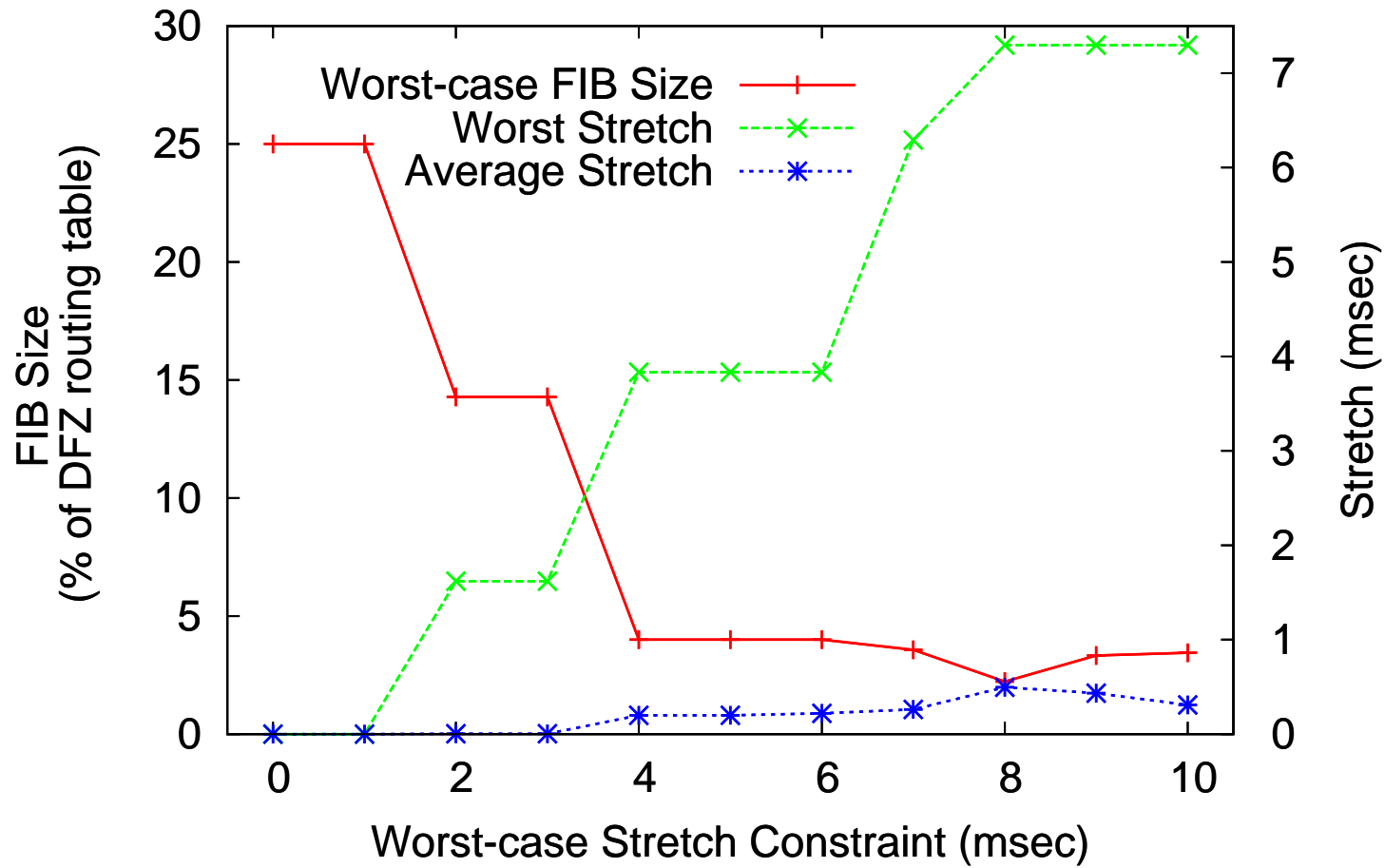
Used out algorithm with varying stretch constraints

Constraining Worst Stretch

FIB Size reduces as Stretch constraint is relaxed

Worst-case Stretch $\leq$ 4ms $\Rightarrow$ Worst FIB = 10,226 prefixes
(4% of global routing table)

Constraining Worst Stretch

Average Stretch is negligible

Worst-case Stretch ≤ 4ms ⇒ Average Stretch = 0.2msec

Router Load

Deployment with Worst-case Stretch $\leq$ 4msec

- ▶ Shrinks FIB by more than 20x
- ▶ Median router load increases by 31.3%

Using popular prefixes

- ▶ 5% popular prefixes carry 96.7% of traffic
- ▶ Median and Worst-case router load increase $\approx$ 1%

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ViAggre Pros

- Shrinks router FIB substantially
- Can be incrementally deployed
- Can be deployed on a limited-scale
- Incentive for deployment
- No change to ISP's routing setup
  - Does not affect convergence times
  - Does not affect routes advertised to neighbors
  - Does not restrict routing policies
  - . . .

Can it be deployed?

Configuration overhead of a configuration-only solution

- ▶ Configuring FIB suppression on routers
- ▶ Configuring LSP advertisements on edge routers

Planning Overhead

- ▶ Choosing virtual prefixes
- ▶ Assigning aggregation points
- ▶ Assuring network robustness
- ▶ . . .

ViAggre management overhead

Deployed ViAggre on WAIL

- Cisco 7300 routers
- Developed Configuration Tool
  - $\sim$330 line python script
  - Extracts information from existing configuration files
  - Generates ViAggre configuration files
- Planning tool in the works

Working with a router vendor (Huawei)

- Implement ViAggre natively
- IETF Draft

Conclusion

ViAggre shrinks the FIB on routers

- ▶ Can extend the lifetime of installed routers

Is this a "complete" solution? No

- ▶ A simple and effective first step
- ▶ Next Step: Inter-domain ViAggre

Thank You!