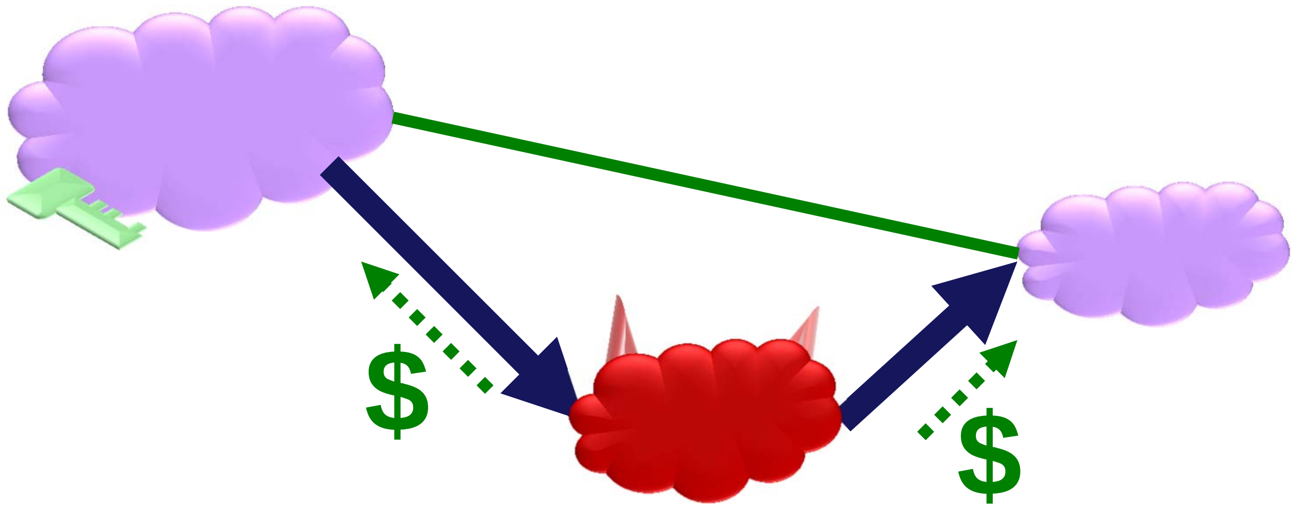
UCSD Systems Seminar
February 10, 2011

How Secure are Secure Internet Routing Protocols?



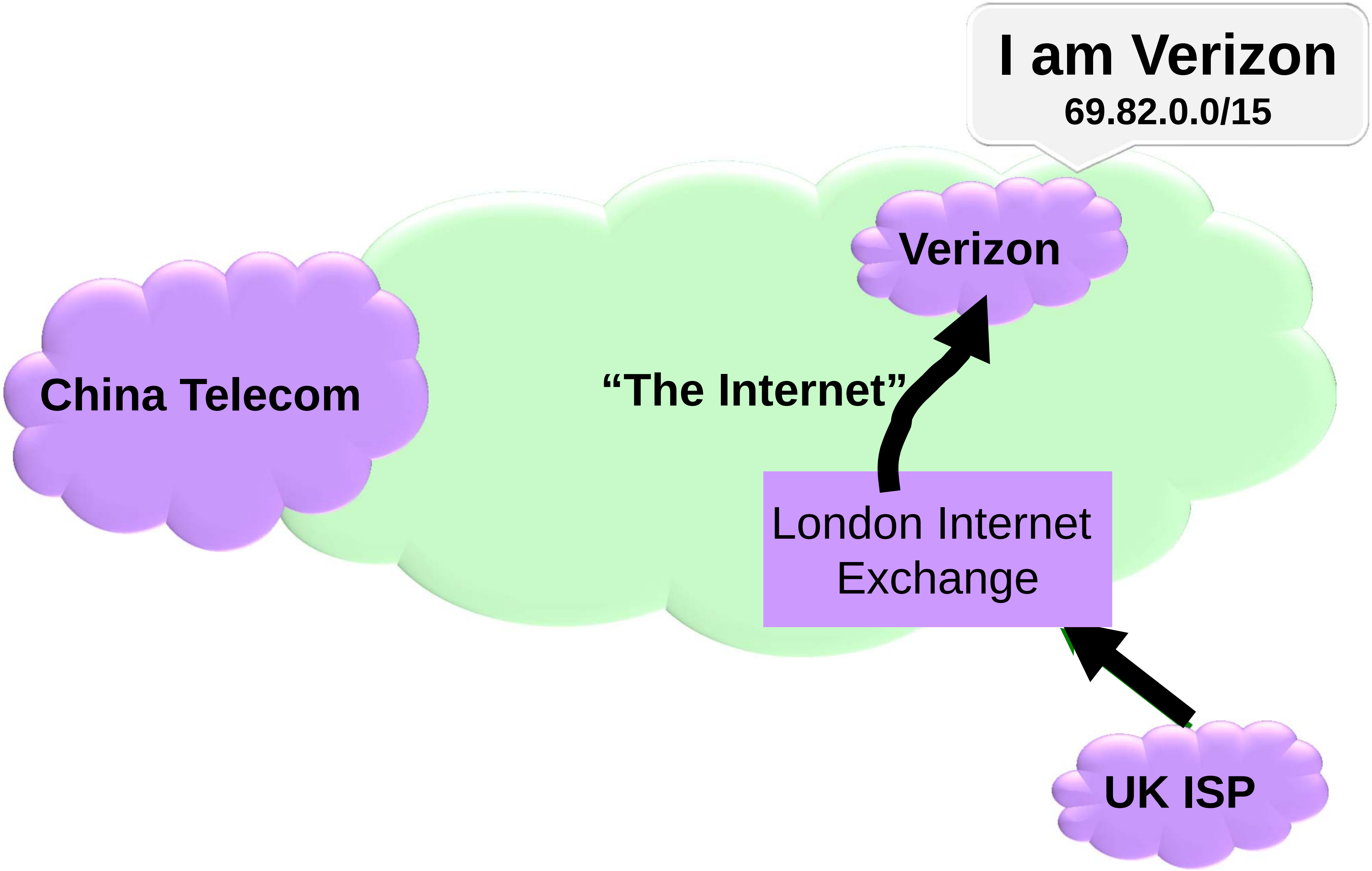
Sharon Goldberg
Boston University

Michael Schapira
Princeton

Pete Hummon
AT&T

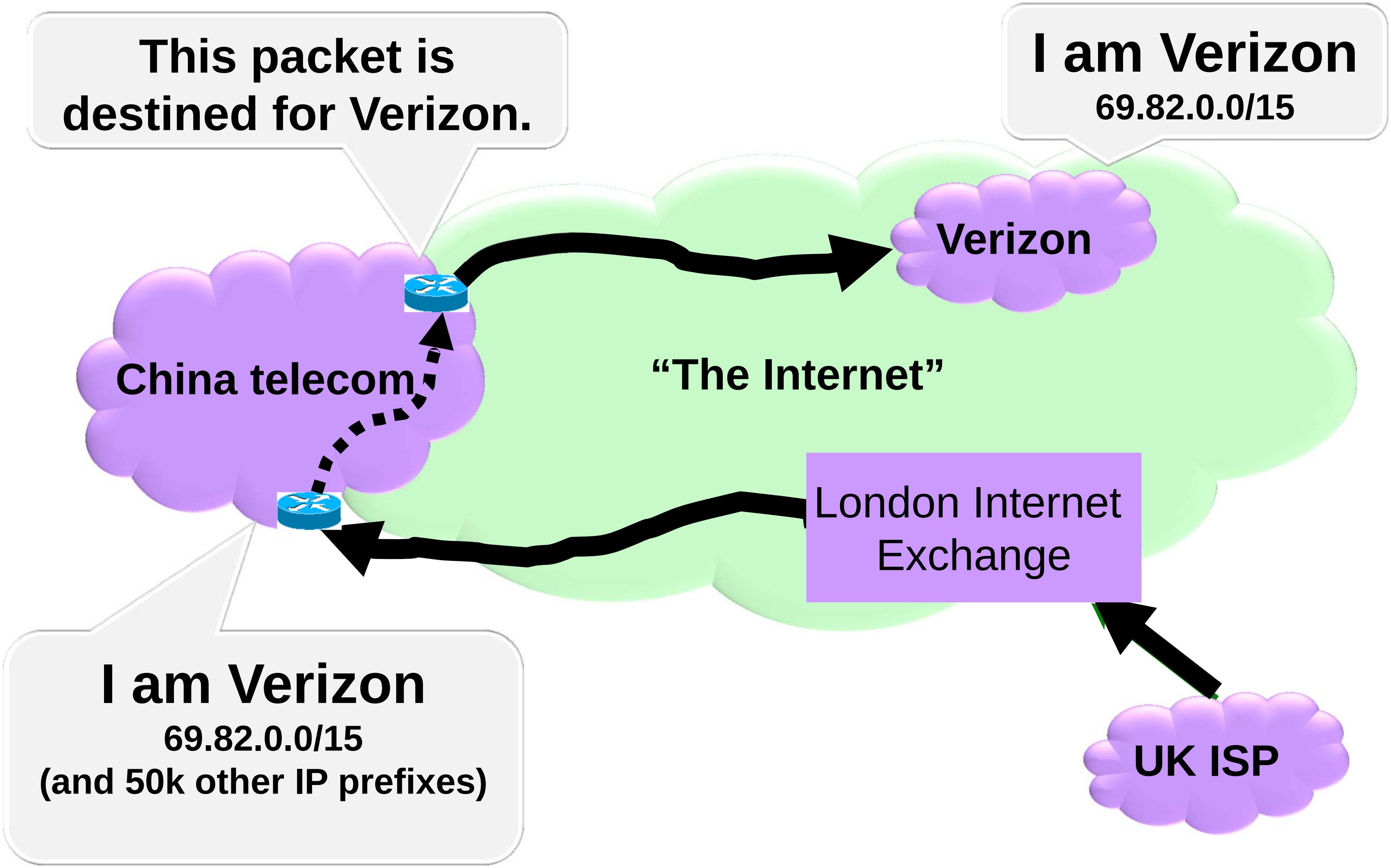
Jennifer Rexford
Princeton

How Secure is Internet Routing Today? (1)



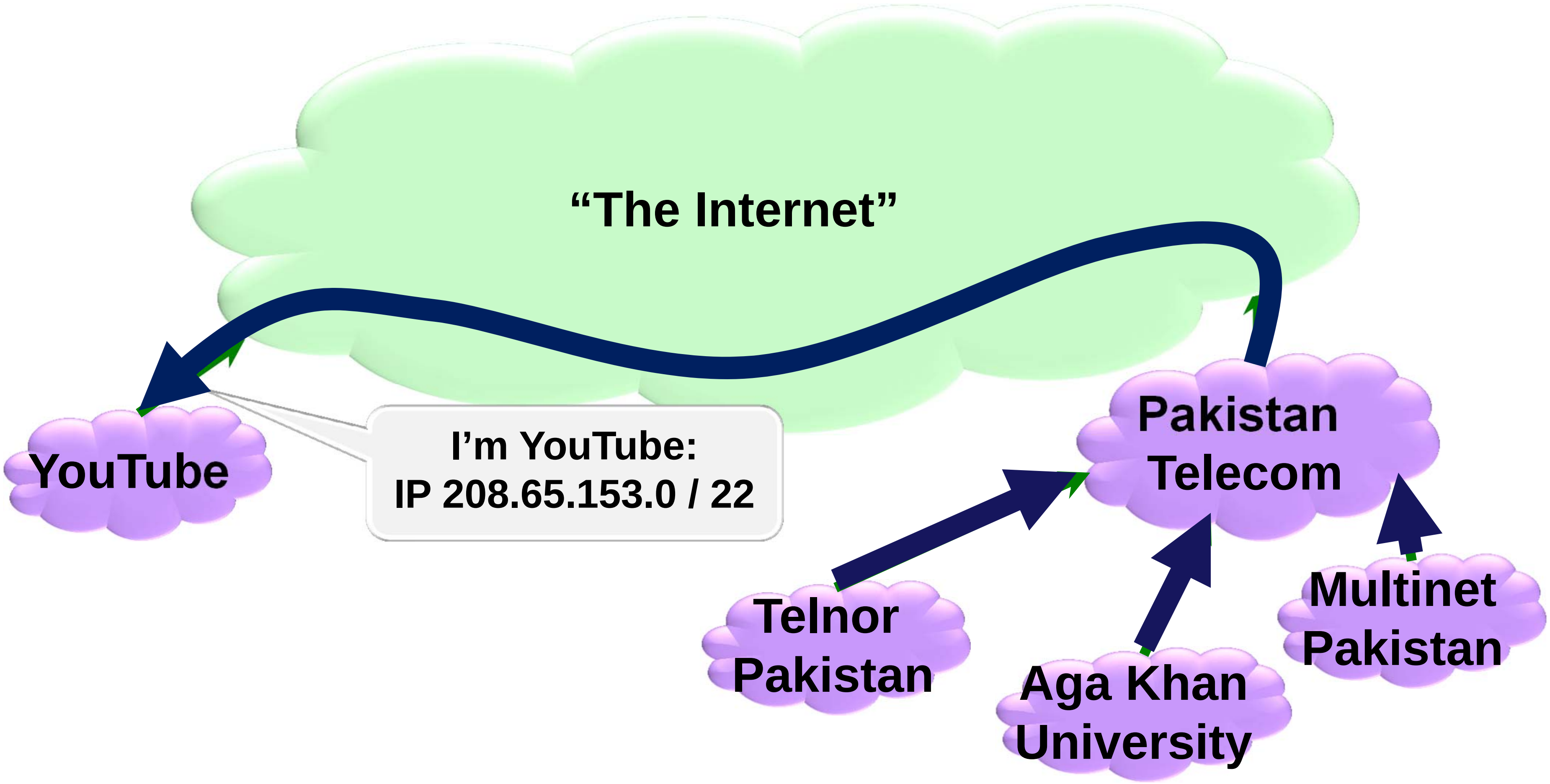
How Secure is Internet Routing Today? (2)

April 2010 : China Telecom intercepts traffic



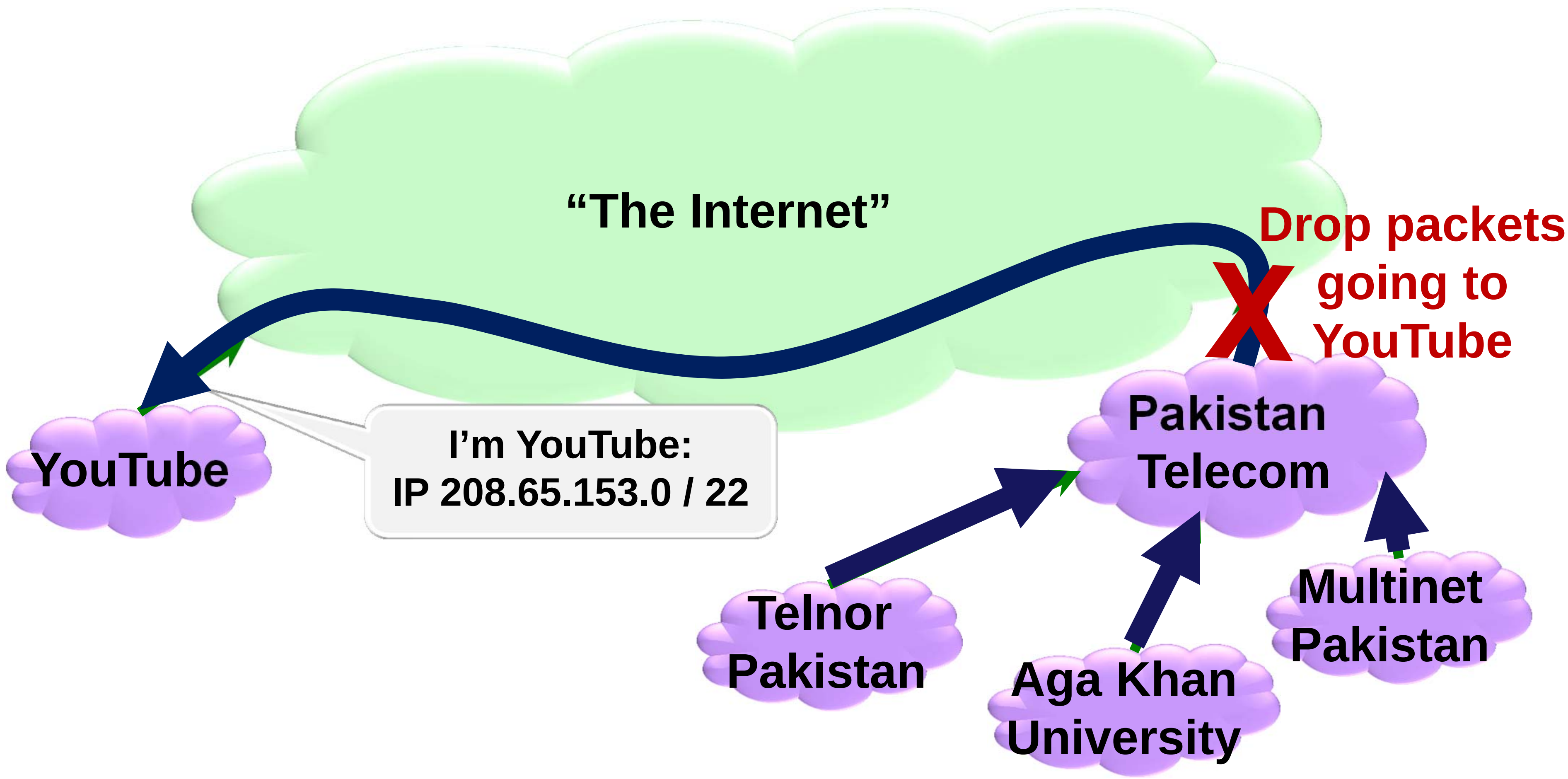
How Secure is Routing on the Internet Today? (3)

February 2008 : Pakistan Telecom hijacks Youtube



How Secure is Routing on the Internet Today? (4)

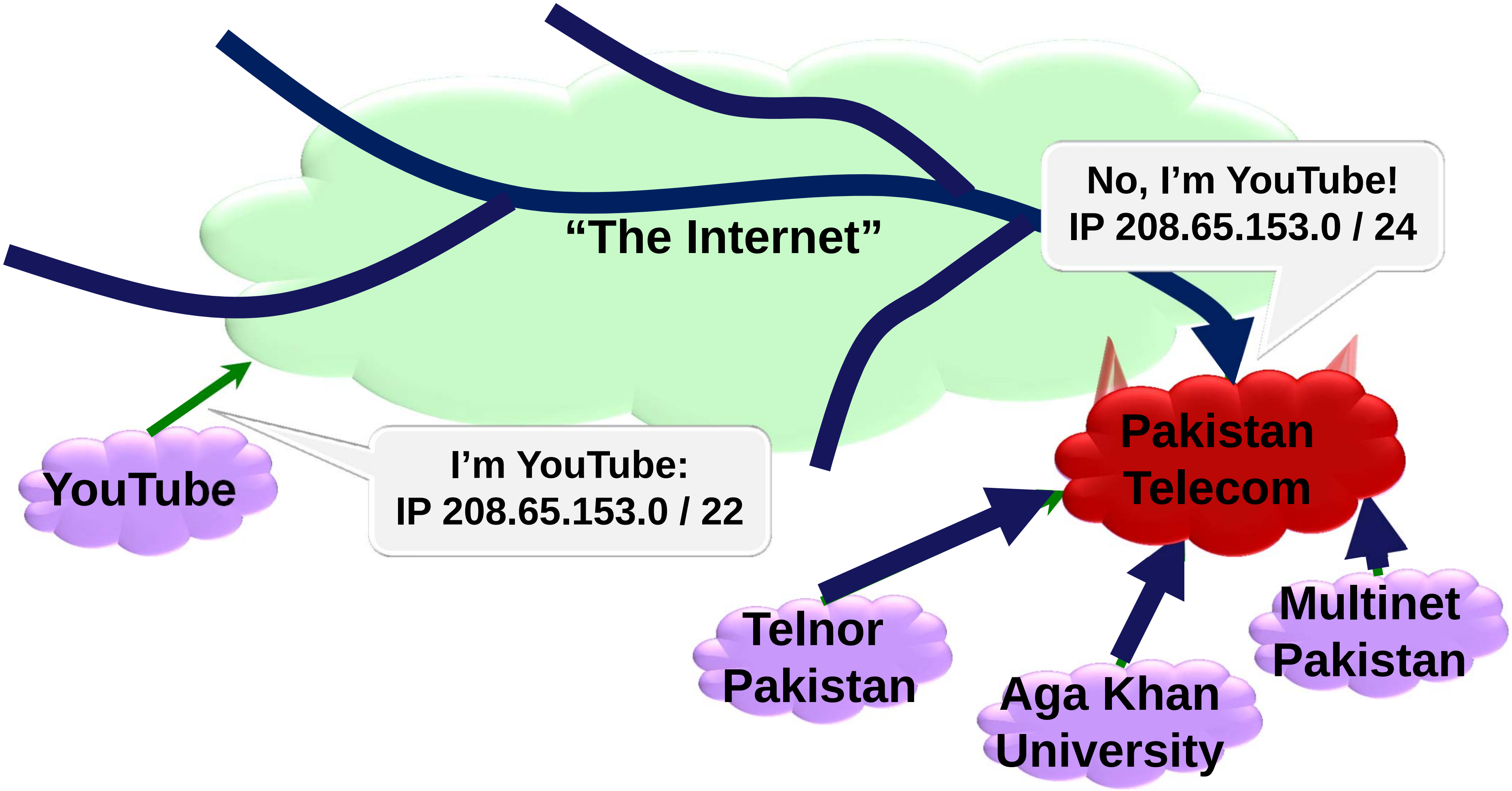
Here's what should have happened….



Block your own customers.

How Secure is Routing on the Internet Today? (5)

But here's what Pakistan ended up doing…



Draw traffic from the entire Internet!

Overview

Today, Internet routing is surprisingly insecure

- Decade of research on secure routing protocols
- With RPKI we can finally consider deploying one.

Our Goal: Compare the effectiveness of these protocols.

- Each has a different set of security properties.
- How well do they prevent attacks?

Our approach: Evaluate via simulation on network data.

- Data: Map of Internet & business relationships
- … from [CAIDA] and [UCLA Cyclops]
- To compare protocols, we must find worst-case attacks

This talk

Pakistan Telecom hijacks YouTube

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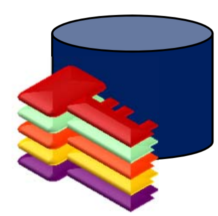
(and why economics matter)

Secure Routing Protocols and Attacks

Theory Interlude

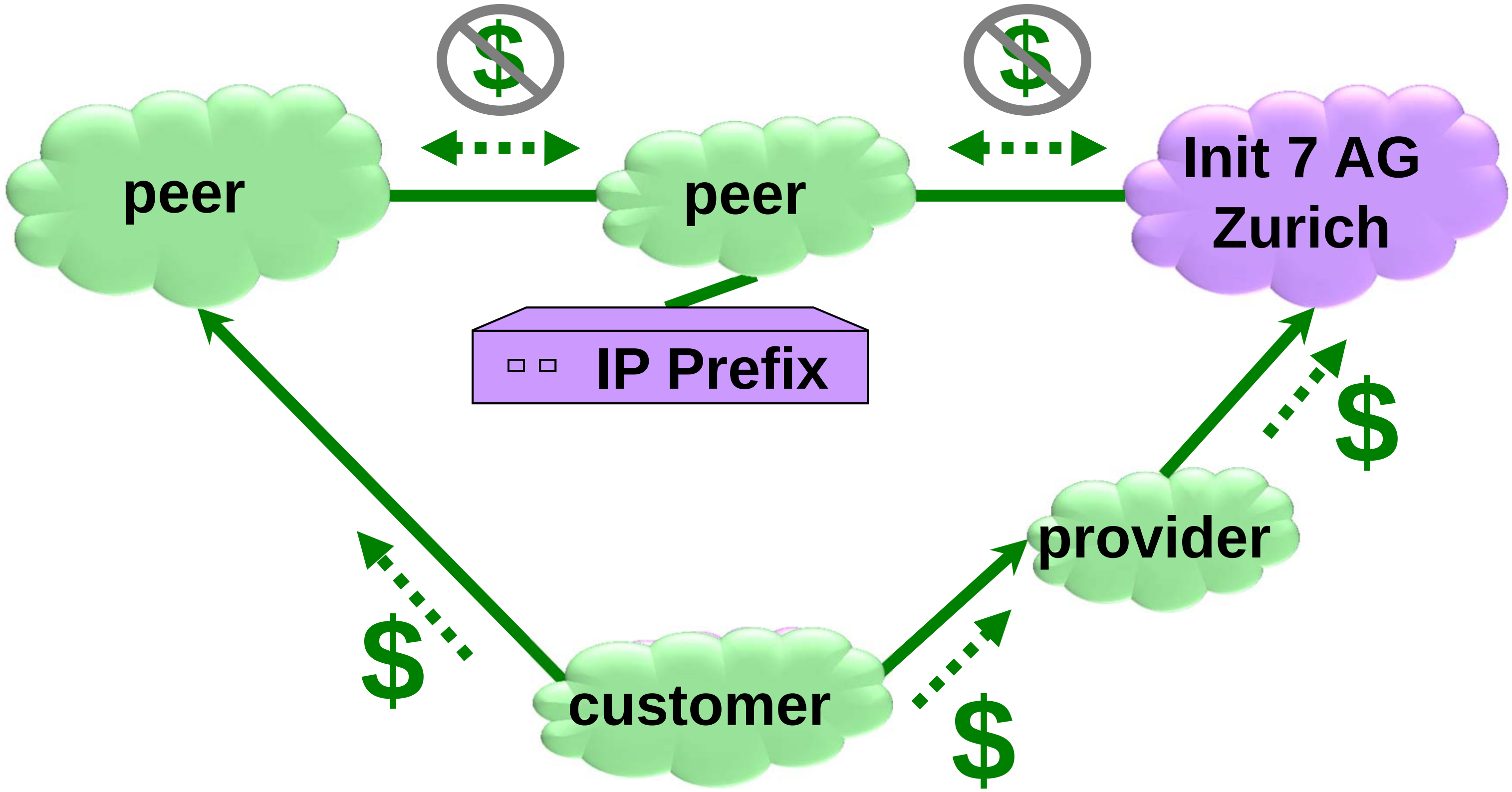
Results!



Implications & Deployment Challenges

BGP: The Internet's Routing Protocol (1)

The Border Gateway Protocol (BGP) sets up paths from Autonomous Systems (ASes) to destination IP addresses.



A model of routing decisions:

- Prefer cheaper paths. Then, prefer shorter paths.

BGP: The Internet's Routing Protocol (2)

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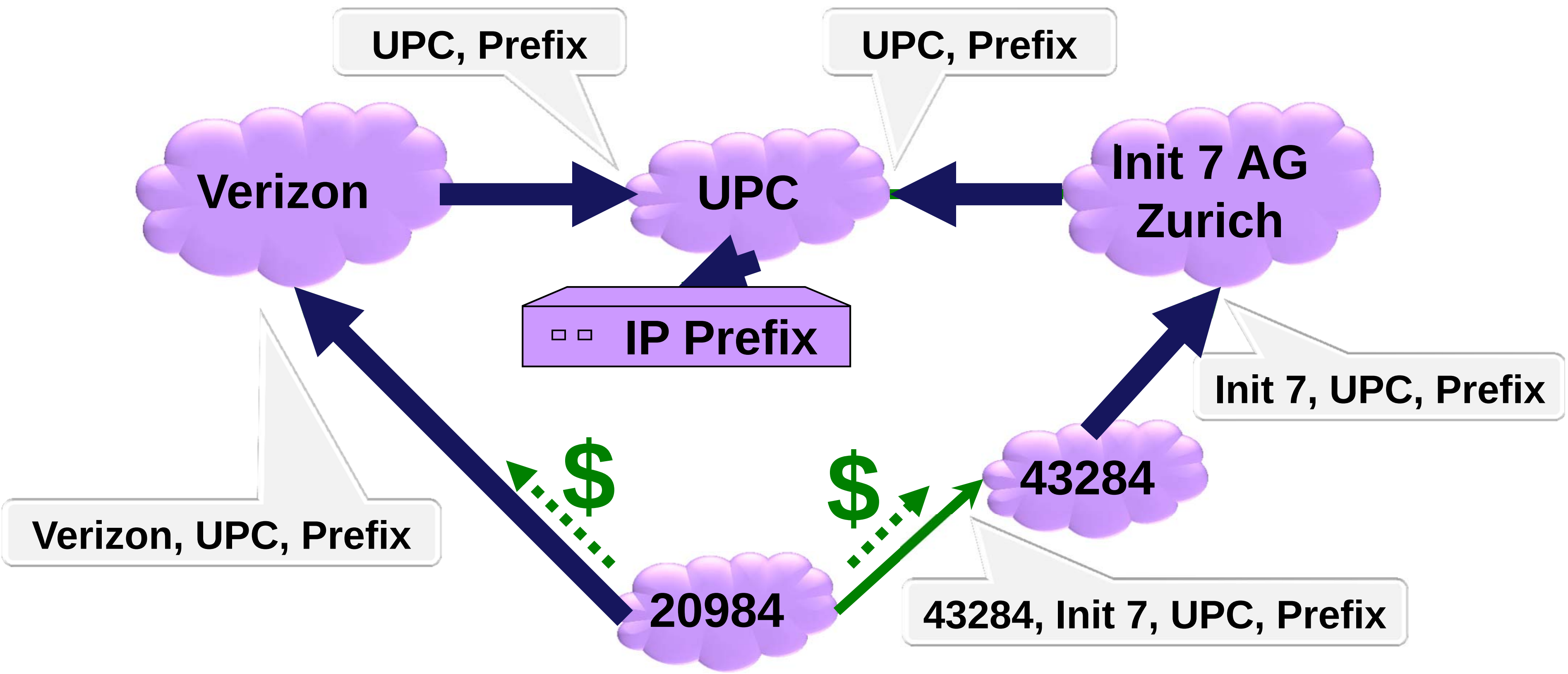

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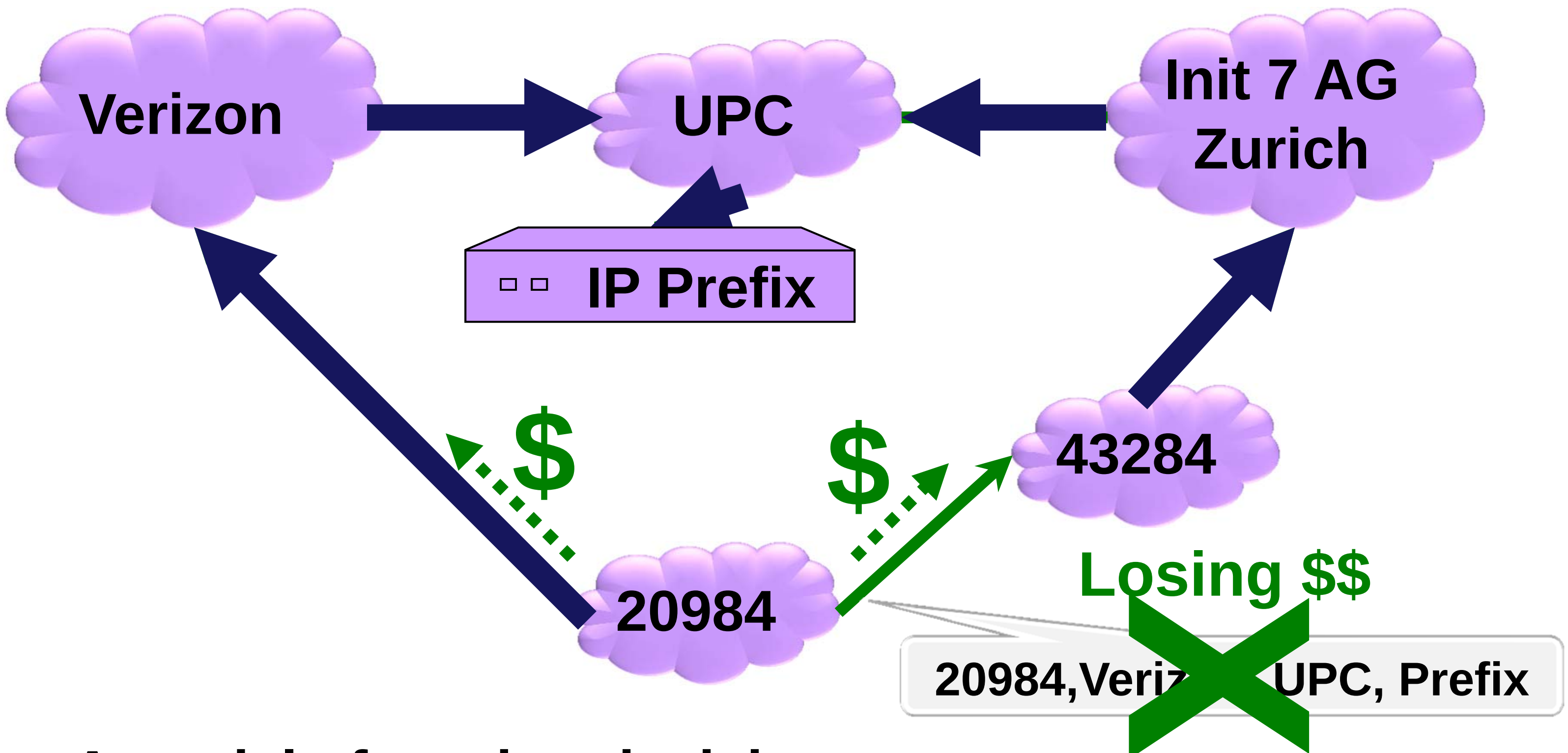

A model of routing decisions:

- Prefer cheaper paths. Then, prefer shorter paths.
- Only carry traffic if it earns you money.

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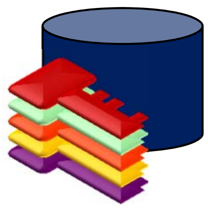


Implications & Deployment Challenges

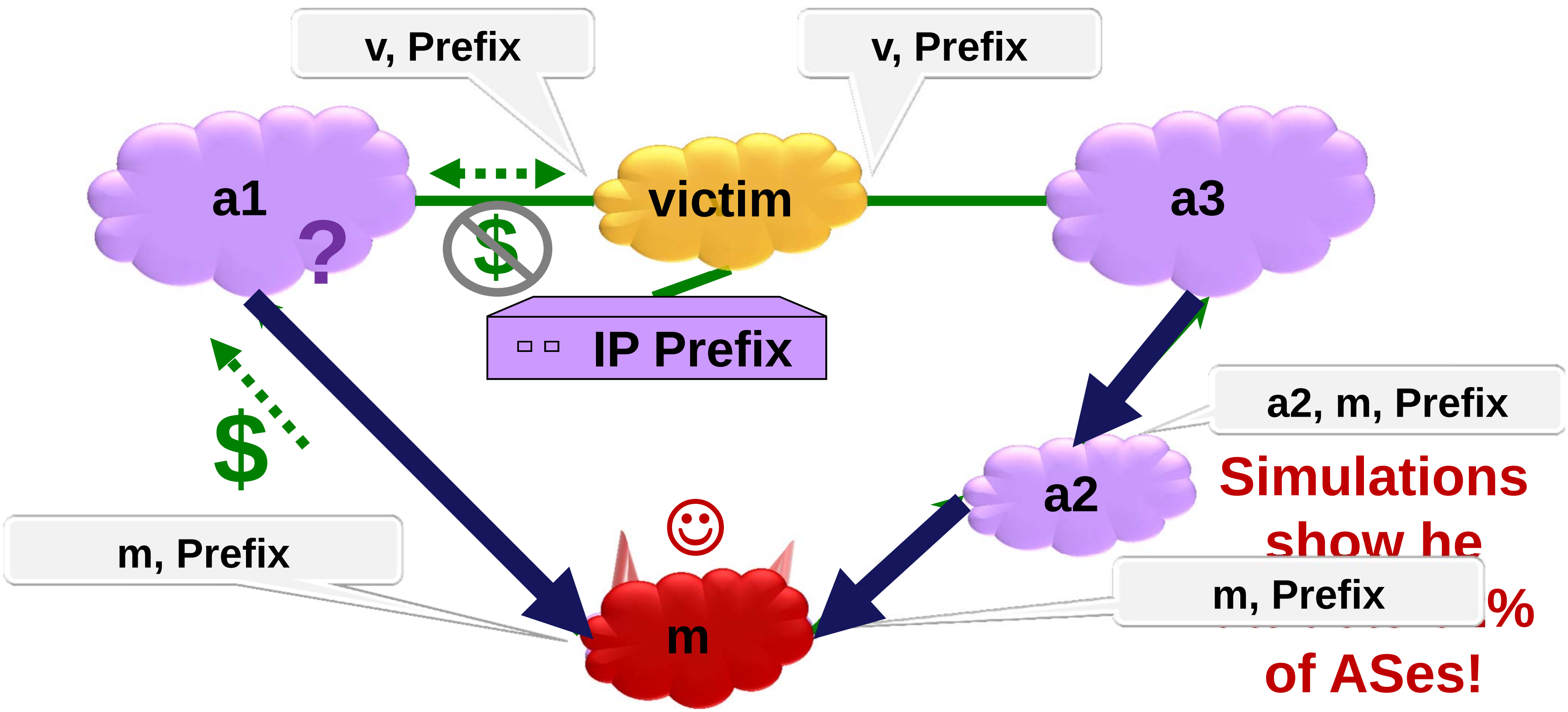
Traffic Attraction Attacks on:

Defensive Filtering

Traffic Attraction Attacks on BGP

Attacker wants max number of ASes to route thru its network.

(For eavesdropping, dropping, tampering, …)

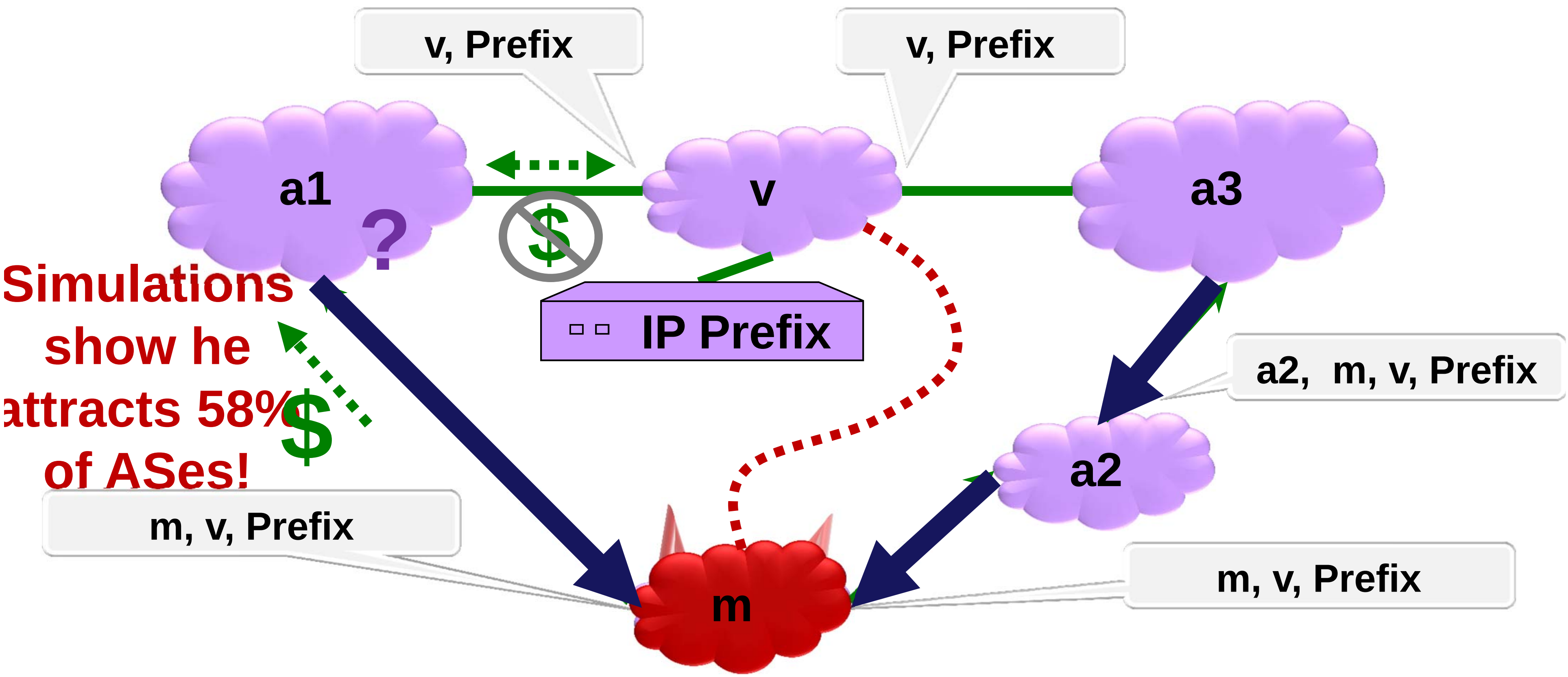


A model of routing decisions:

- Prefer cheaper paths. Then, prefer shorter paths.
- Only transit traffic if it earns you money, ie. for customers.

Proposed Security Mechanism: Origin Authentication

RPKI: A secure database that maps IP Prefixes to owner ASes.

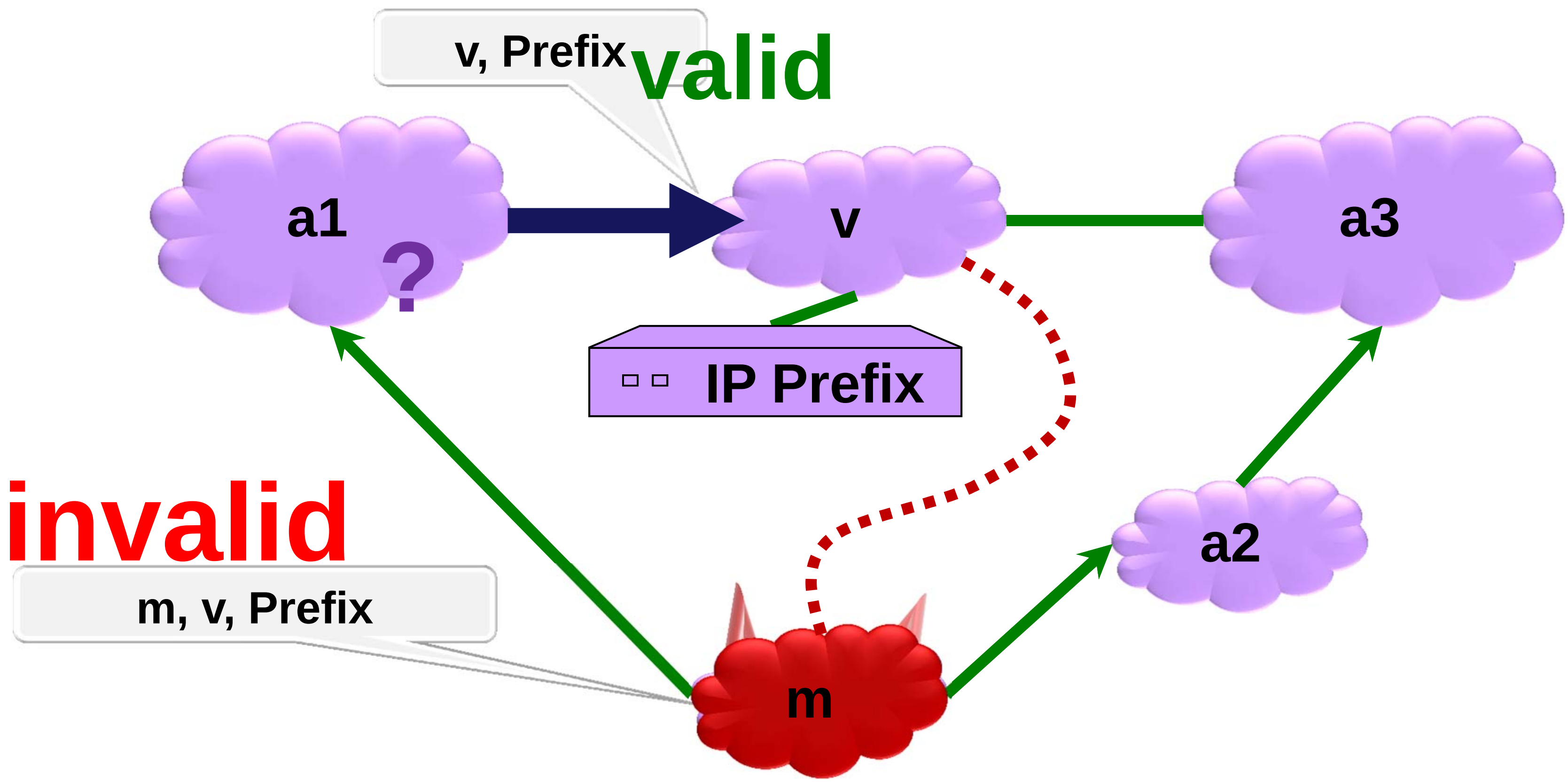


Smart Attack Strategy: Announce the shortest path I can get away with to all my neighbors.

Proposed Security Mechanism: secure origin BGP

RPKI: A secure database that maps IP Prefixes to owner ASes.

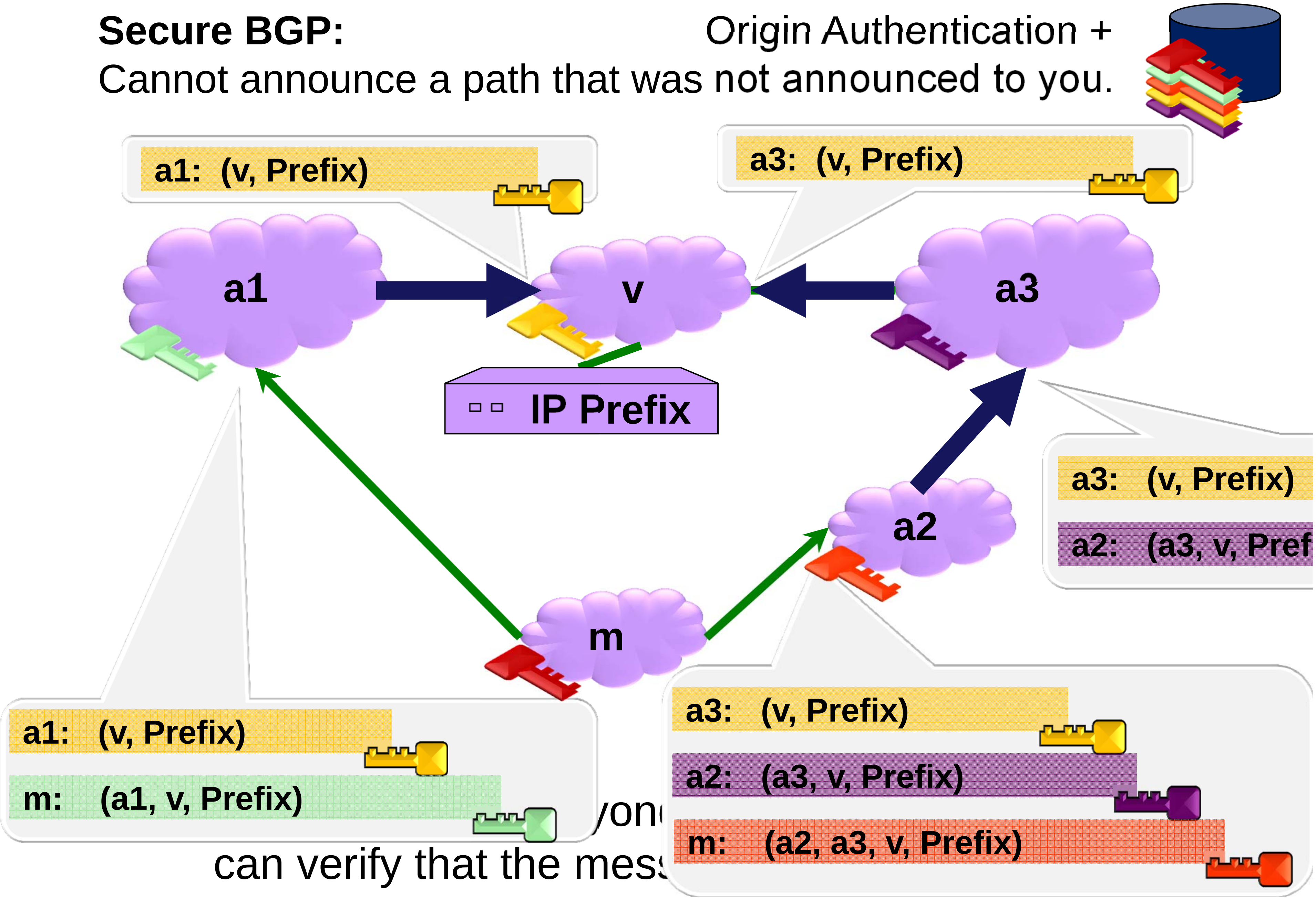
soBGP: A database of all the links in the AS-level topology.



Smart Attack Strategy: Announce the shortest path I can get away with to all my neighbors.

Proposed Security Mechanism: "Secure BGP" [KLS98]

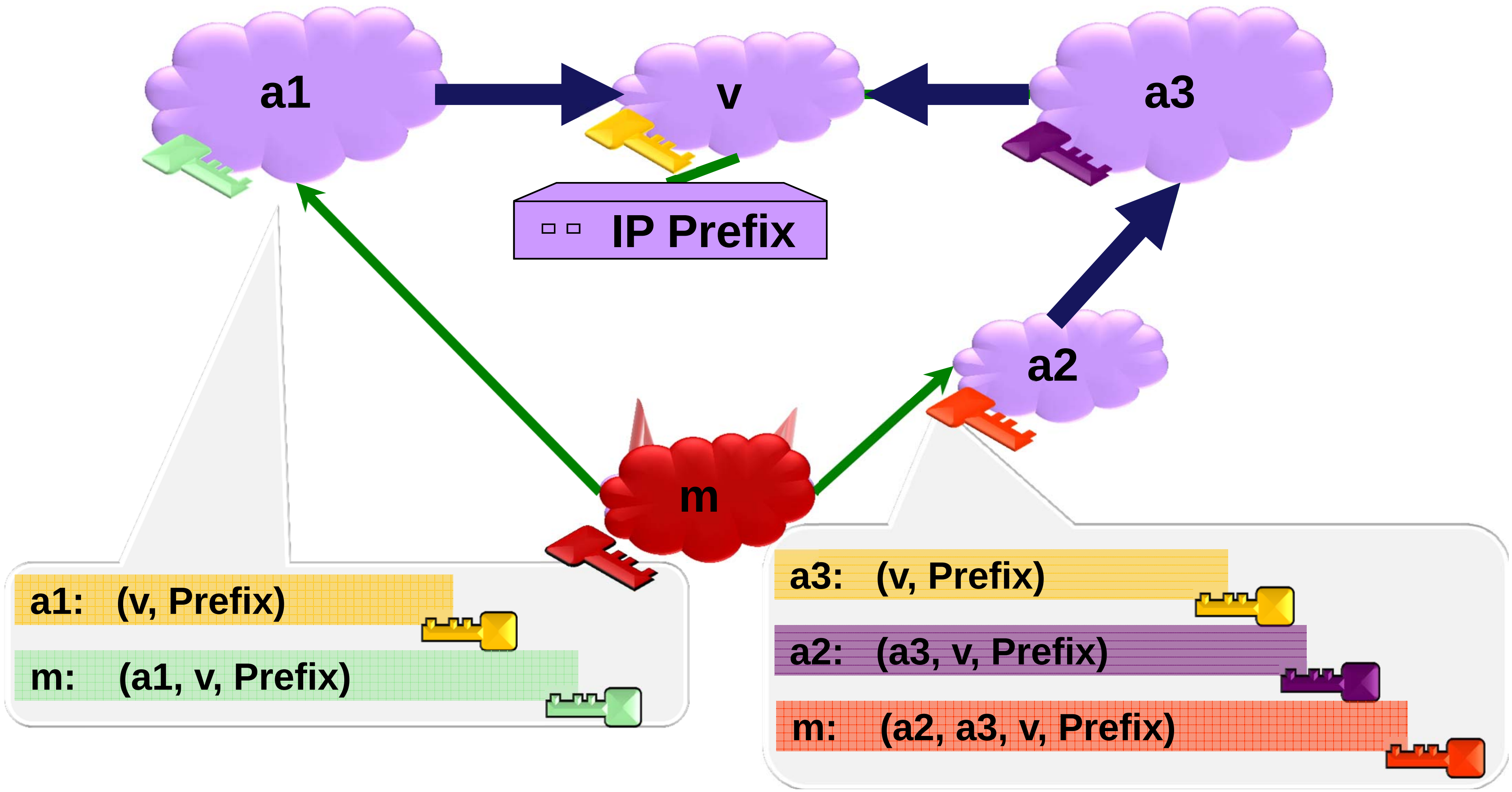
Secure BGP: Origin Authentication +
Cannot announce a path that was not announced to you.



…yon…
can verify that the mess…

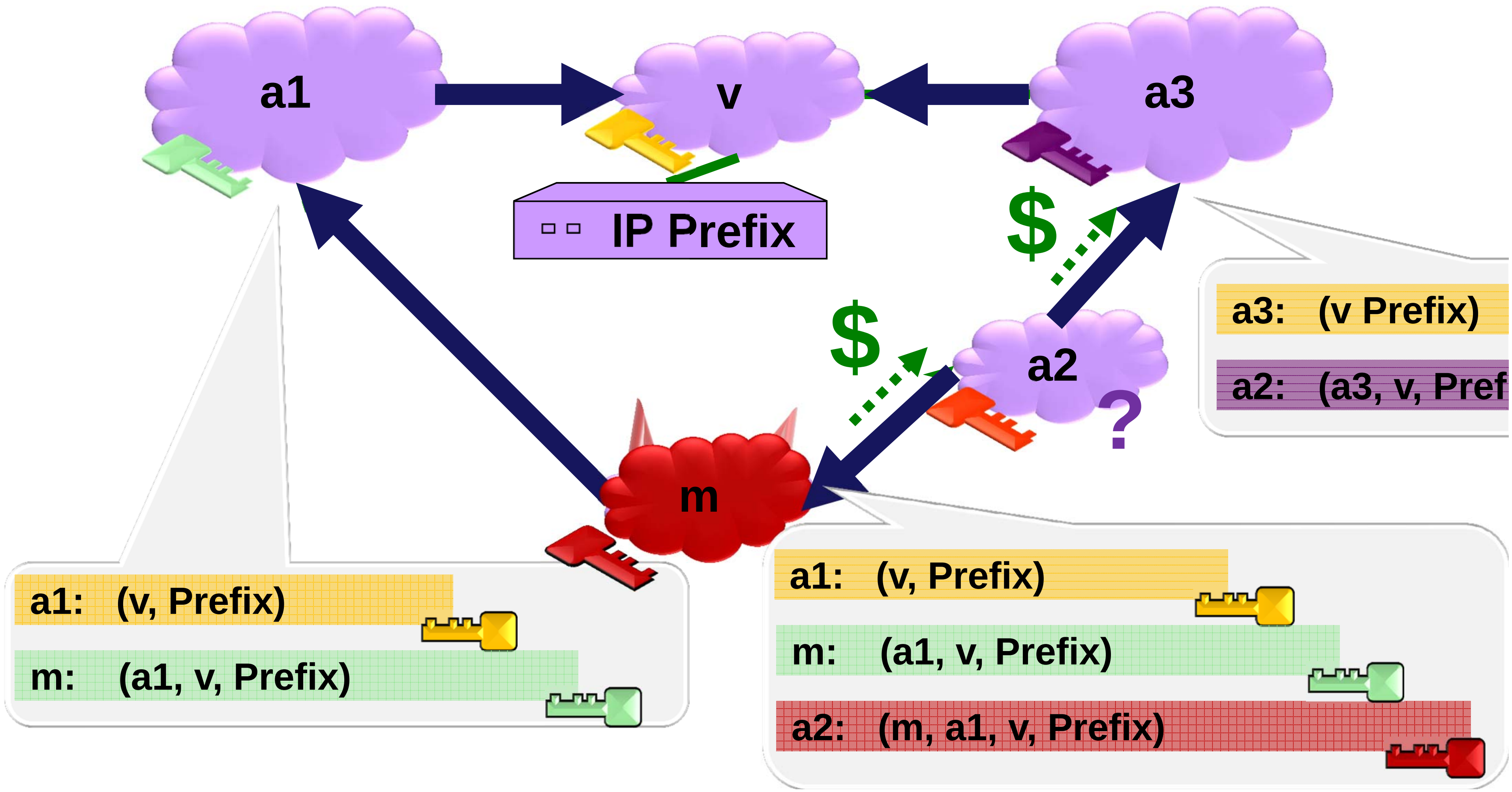
Are attacks still possible with Secure BGP? (1)

Smart Attack Strategy: Announce the shortest path I can get away with to all my neighbors!



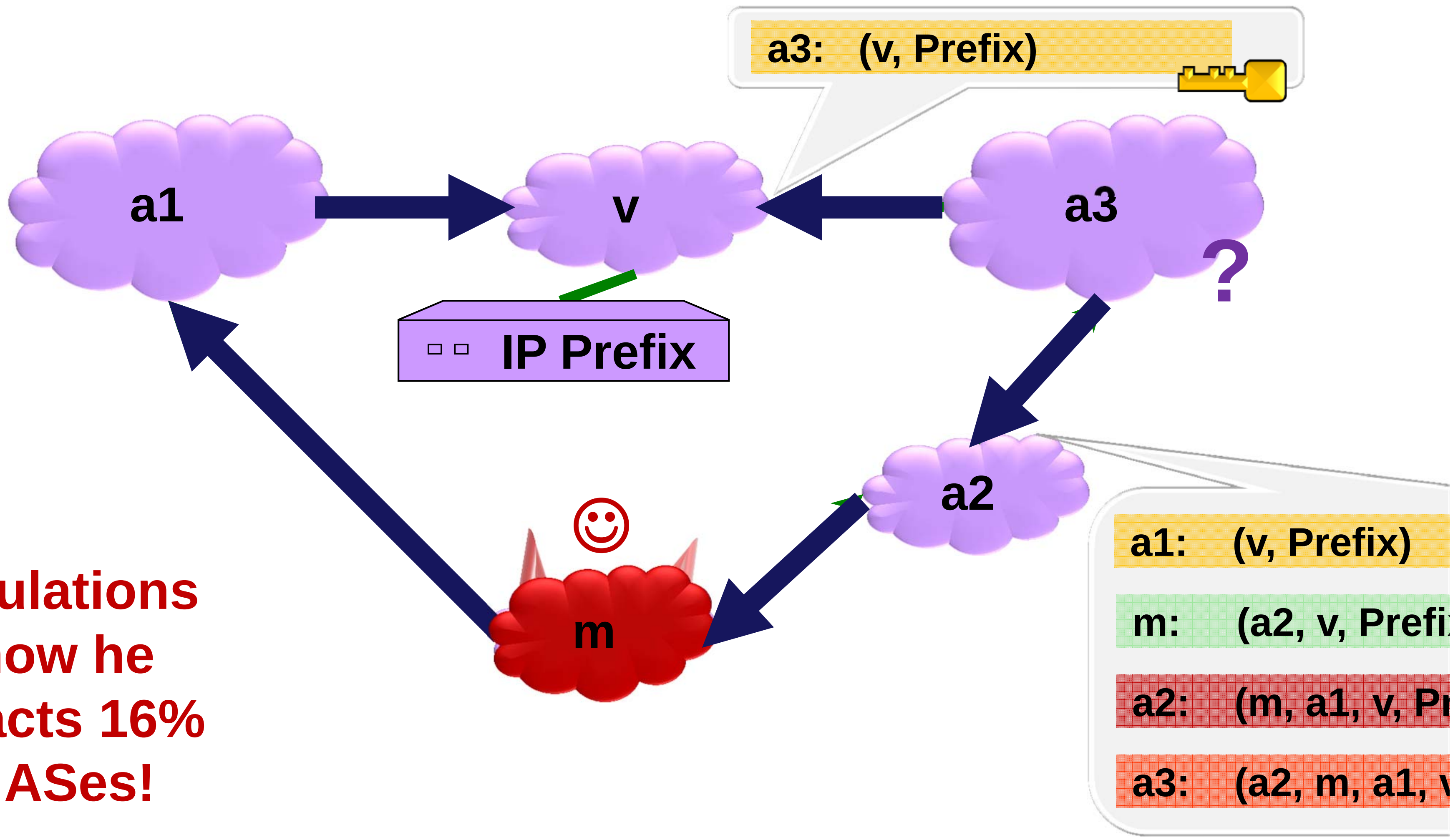
Are attacks still possible with Secure BGP? (2)

Smart Attack Strategy: Announce the shortest path I can get away with to all my neighbors!



Are attacks still possible with Secure BGP? (3)

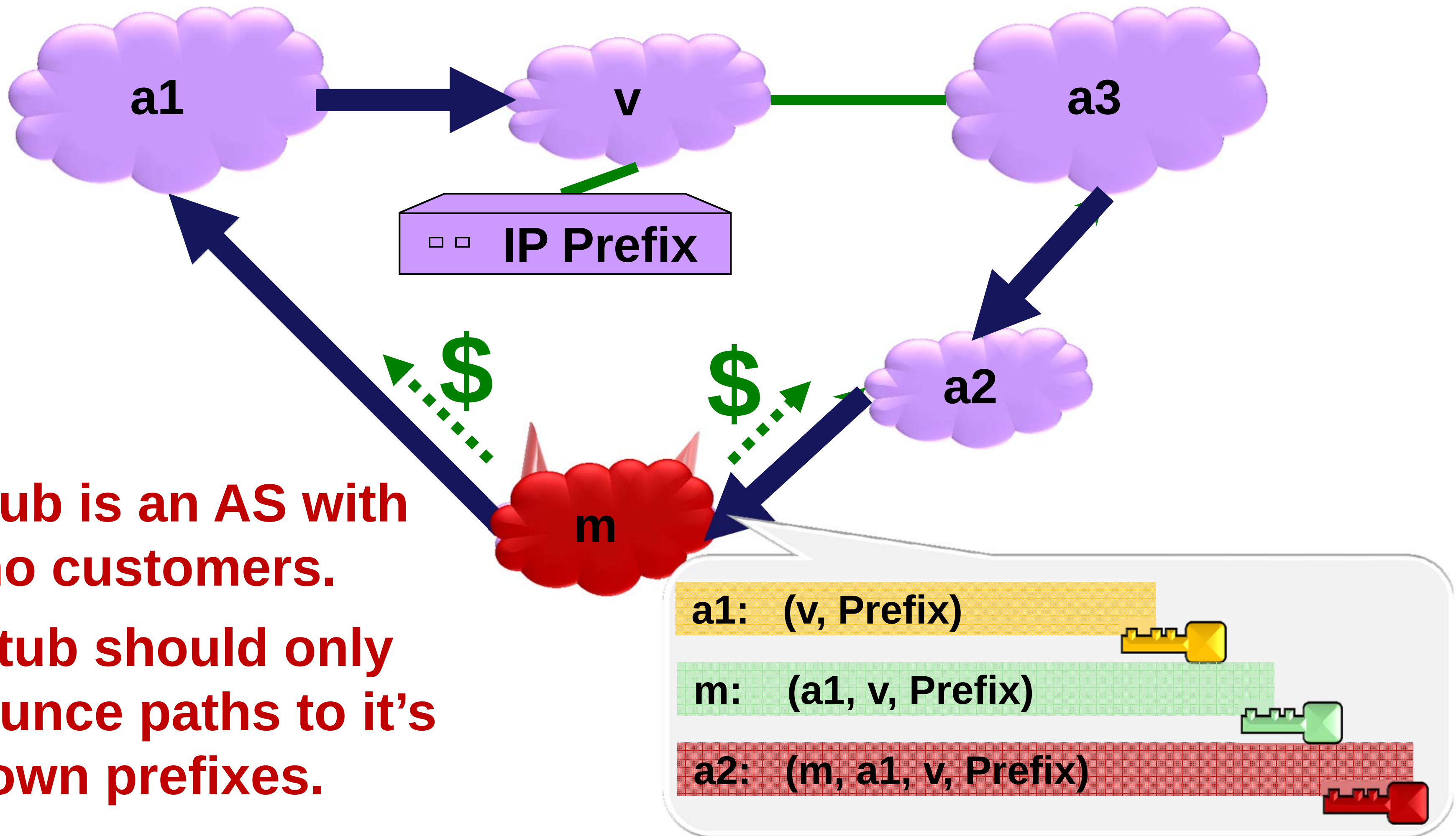
Smart Attack Strategy: Announce the shortest path I can get away with to all my neighbors!



Simulations show he attracts 16% of ASes!

Wait! Why is this an "attack"?

Smart Attack Strategy: Announce the shortest path I can get away with to all my neighbors!

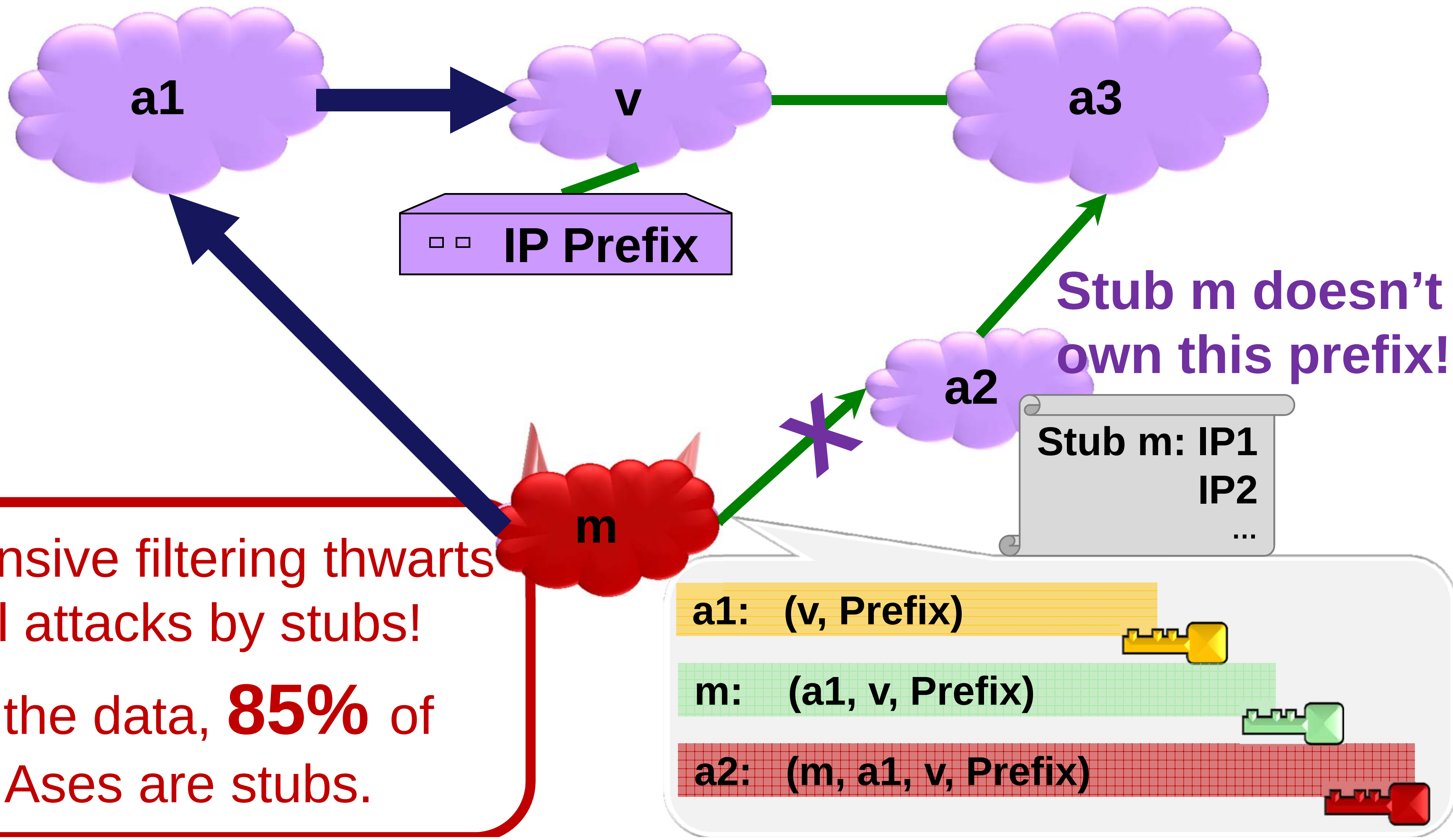


A stub is an AS with no customers.

A stub should only announce paths to it's own prefixes.

Security Mechanism: Defensive Filtering (of Stubs)

Defensive Filtering: The provider drops announcements for prefixes not owned by it's **stubs**.



Defensive filtering thwarts all attacks by stubs!

In the data, **85%** of Ases are stubs.

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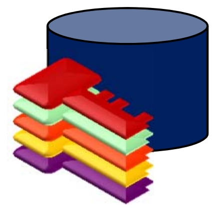
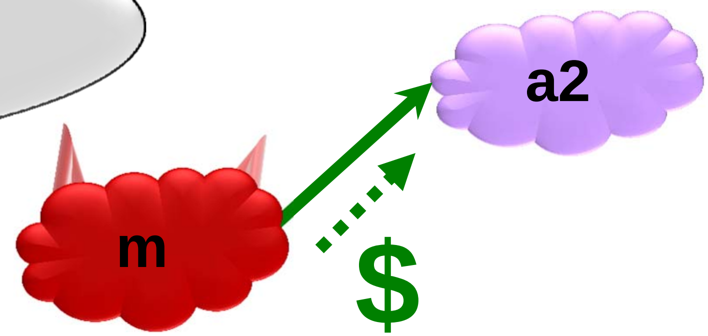


Implications & Deployment Challenges

Wait! Is this the “best” attack strategy?!?

Can’t lie about my business relationship with a2, so I might as well announce the shortest path I can.



But Not Optimal !

Smart ^ Attack Strategy: Announce the shortest path I can get away with to all my neighbors!

Sometimes announcing to **fewer** neighbors is better**!**

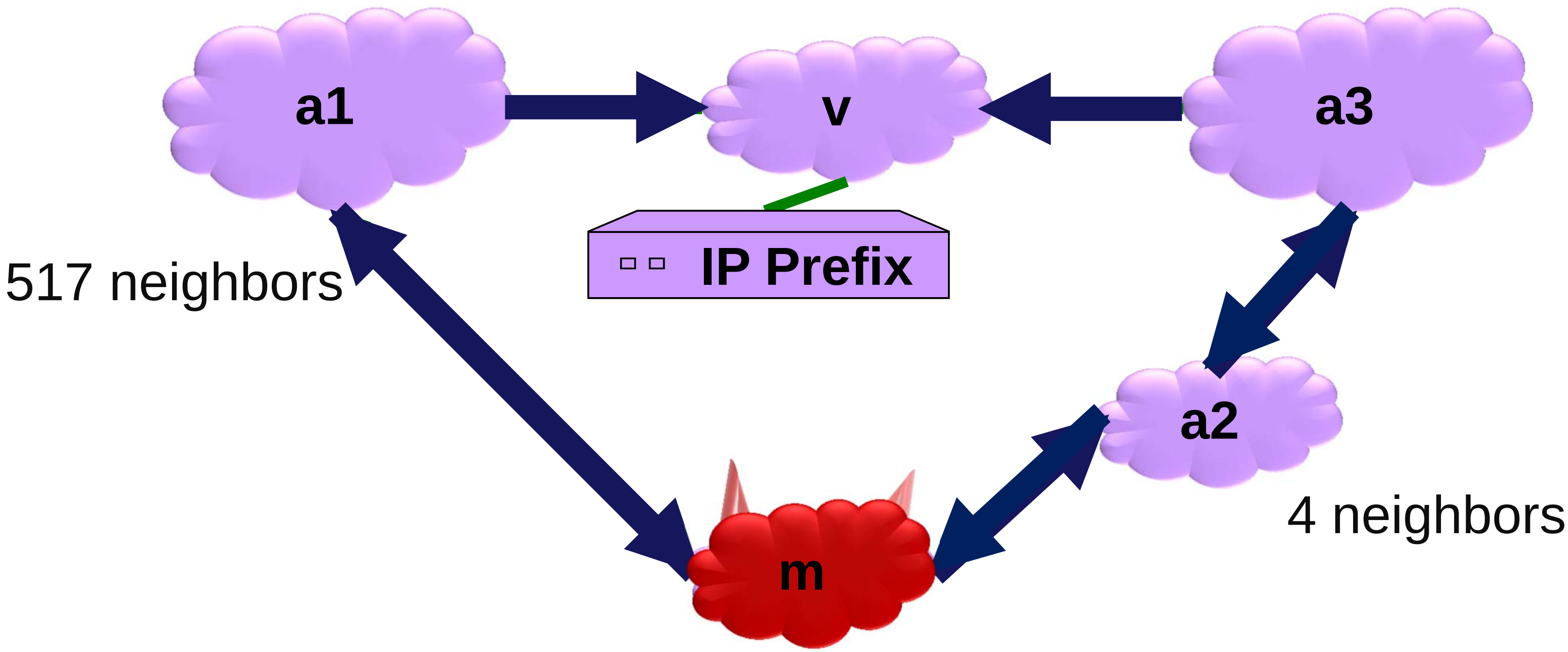
Sometimes **longer** paths are better!

Theorem: It’s NP hard to find the optimal attack strategy.

➔ Smart Attack Strategy **underestimates** damage.

Sometimes longer paths are better?!?

Announce **3-hop path** to **a2**, **a3**:	**16%** of ASes
Announce **4-hop path** to **a1**:	**56%** of ASes
Attack on insecure BGP:	**62%** of ASes



Key Observation: **Who** you announce to is as important as **what** you announce.

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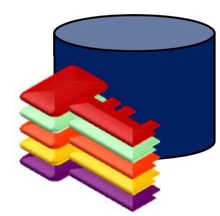
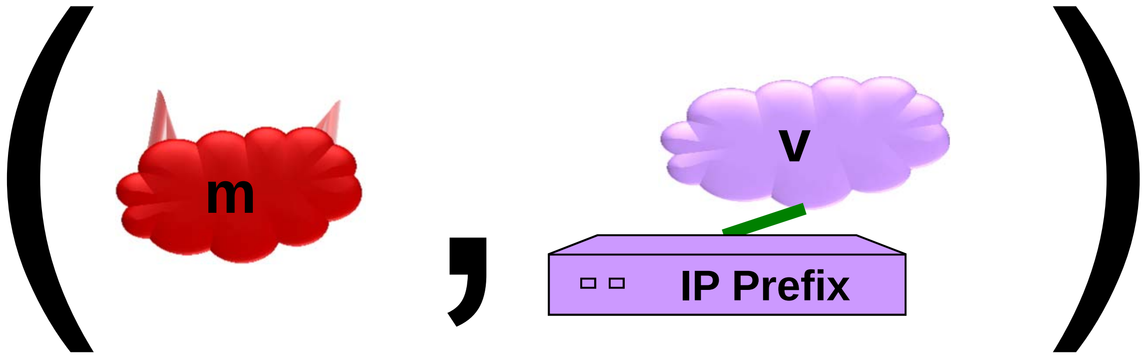


Implications & Deployment Challenges

Obtaining our Results



We ran multiple experiments

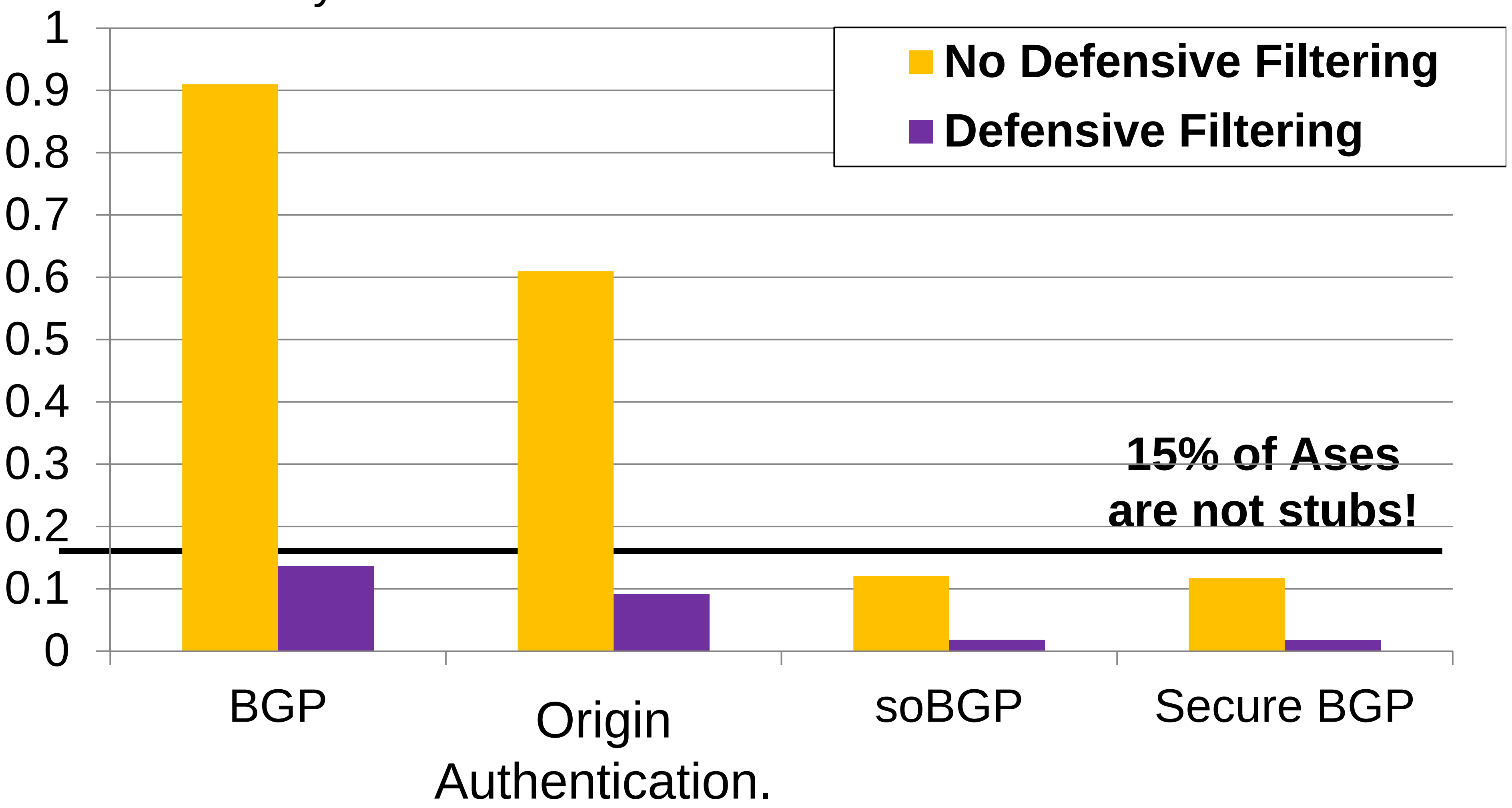
- For each, randomly chose (attacker, victim) pair, and
- … simulate Smart Attack on each security protocol.

In the following graph:

- An attacker is "successful" if it attracts 10% of ASes.
- What fraction of pairs have a successful attacker?

Probability* Smart Attack attracts 10% of ASes

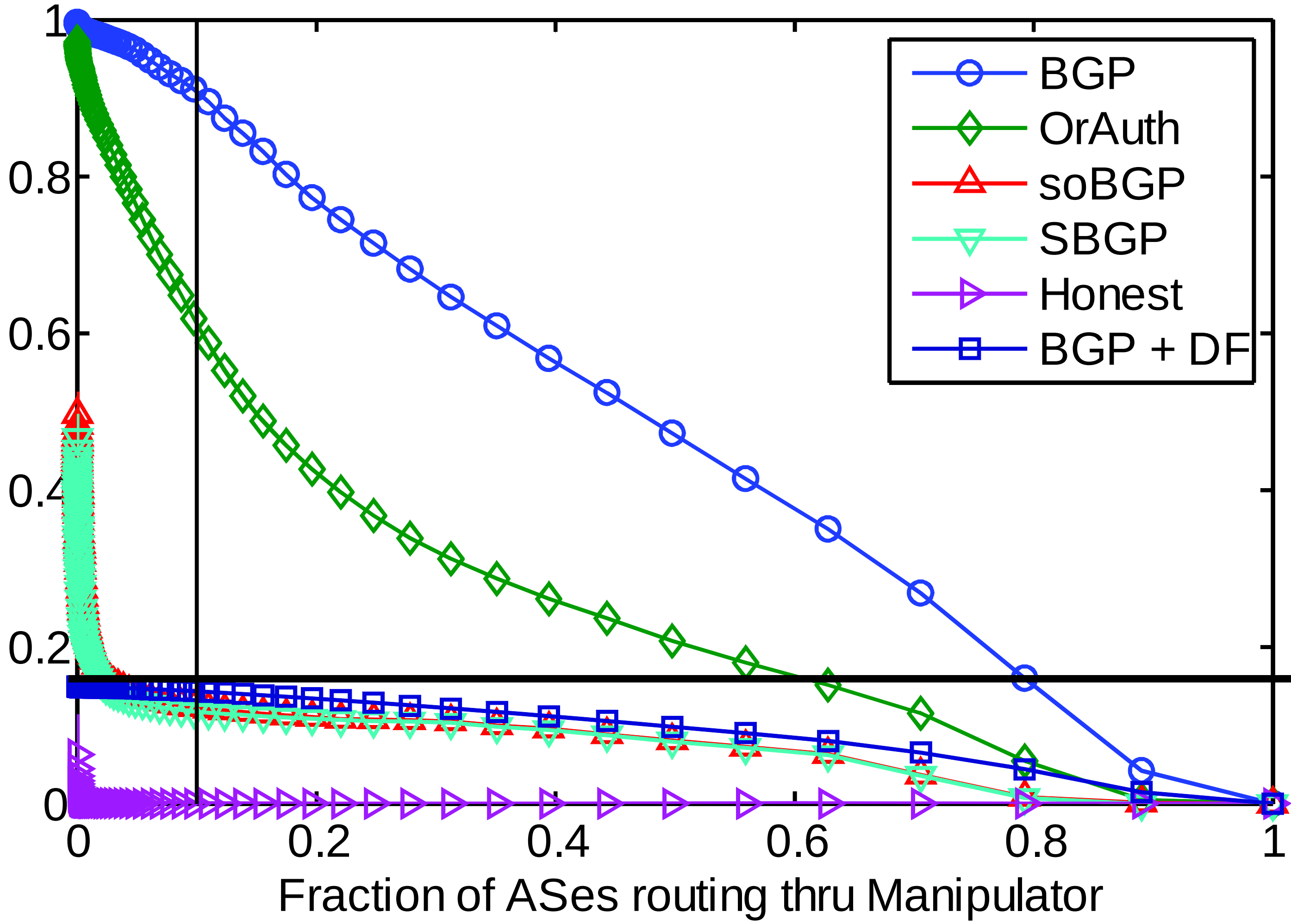
*Probability is taken over random choice of attacker and victim.



Recall that the **Smart Attack Strategy** **underestimates** damage.

Probability* Smart Attack attracts >x% of ASes (1)

*Probability is taken over random choice of attacker and victim.



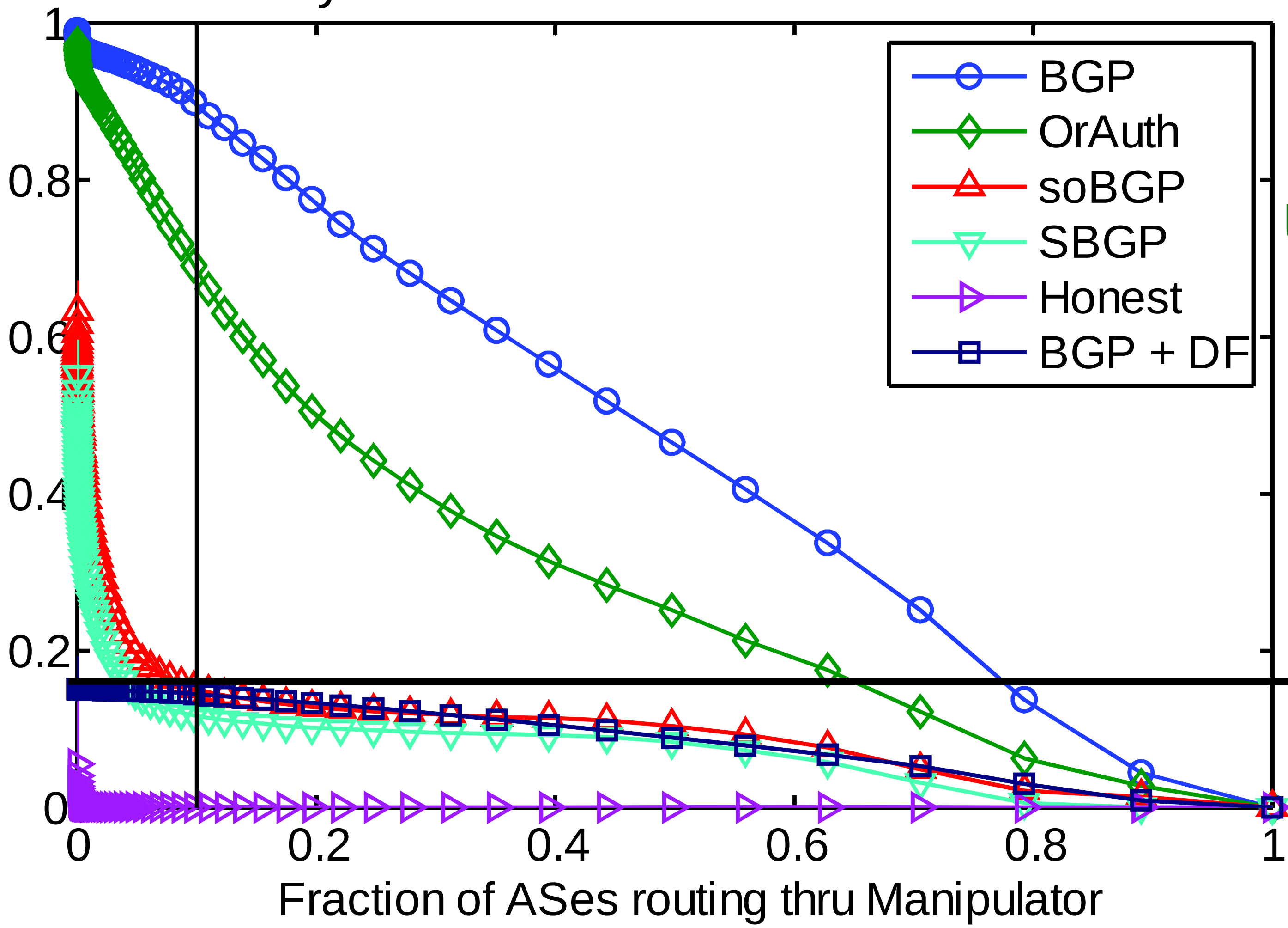
CAIDA
Nov 20, 2009

15% of Ases are not stubs!

Recall that the **Smart Attack Strategy** **underestimates** damage.

Probability* Smart Attack attracts >x% of ASes (2)

*Probability is taken over random choice of attacker and victim.



UCLA Cyclops
Nov 20, 2009

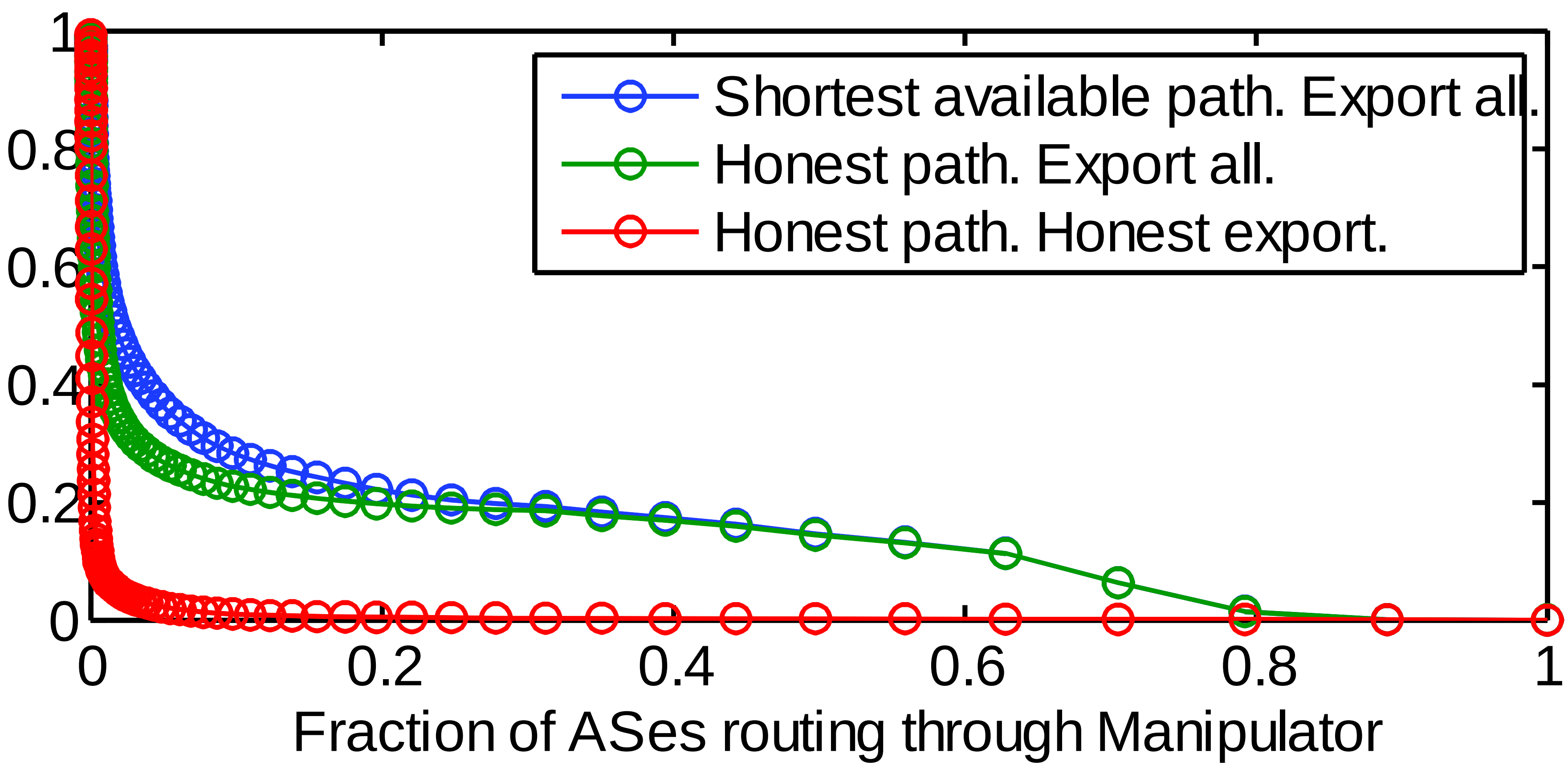
15% of Ases
are not stubs!

Recall that the **Smart Attack Strategy** **underestimates** damage.

The Importance of Aggressive Export Policies

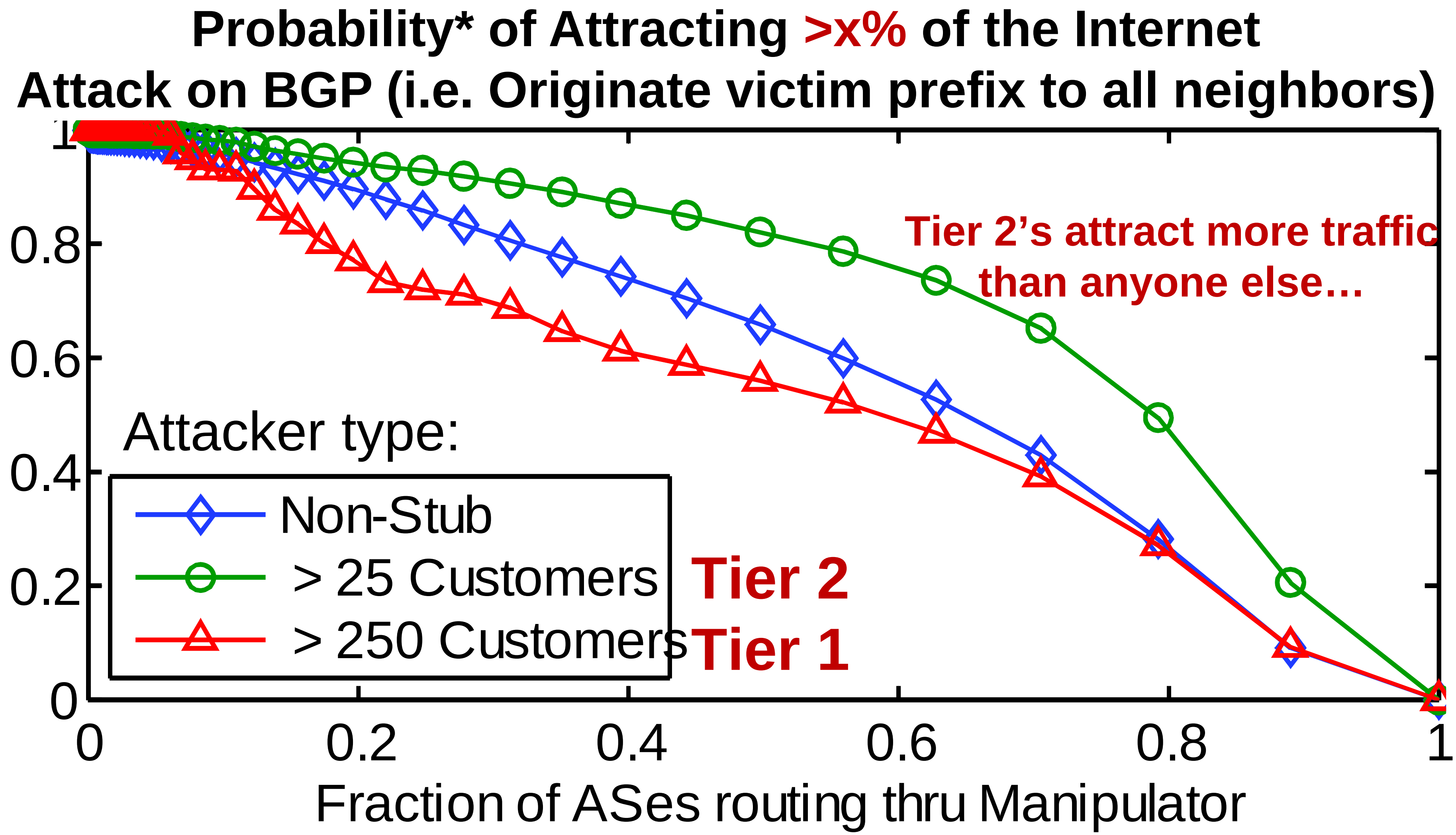
Probability* of Attracting >x% of the Internet

***Probability is over random victim and **attacker with > 25 customers**.



Key Observation: **Who** you announce to is as important as **what** you announce.

Tier 2's are the most effective attackers



*Probability is over random victim and attacker from different classes

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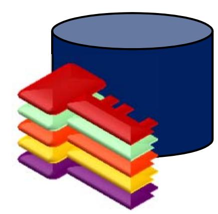


Implications & Deployment Challenges

Summary

WHO you announce to is as important as WHAT you announce

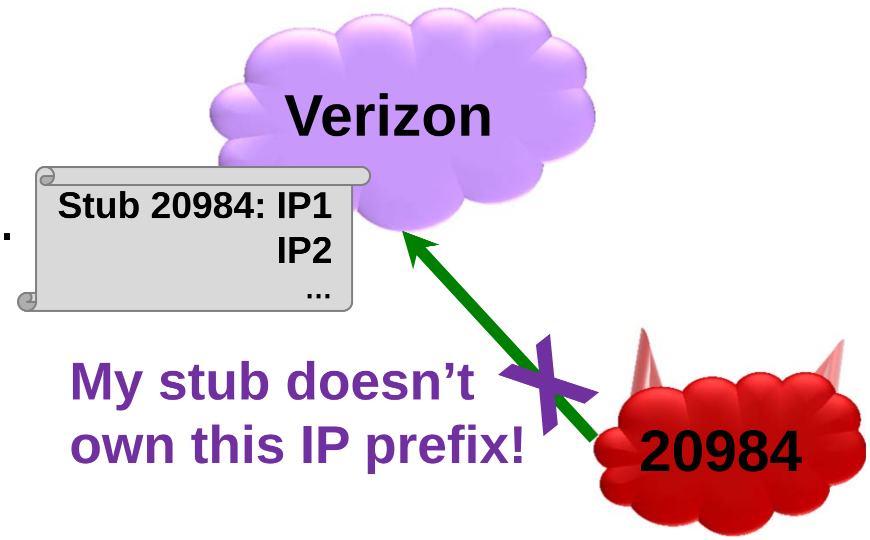
Defensive filtering is as effective as Secure BGP.

- **Each mitigates a different attack strategy**
- **Secure BGP limits path-shortening attacks**
- **Filtering prevent stubs from announcing paths too widely**

Why is it so hard to implement these things in practice?

Implementing Defensive Filtering ?

Today: The provider locally keeps a list of the prefixes that its stubs own.

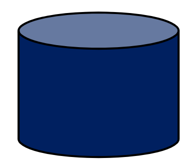


Issues:

1) **Relies on altruism & trust.**
2) **Maintaining prefix lists is hard.**

But, some good news:

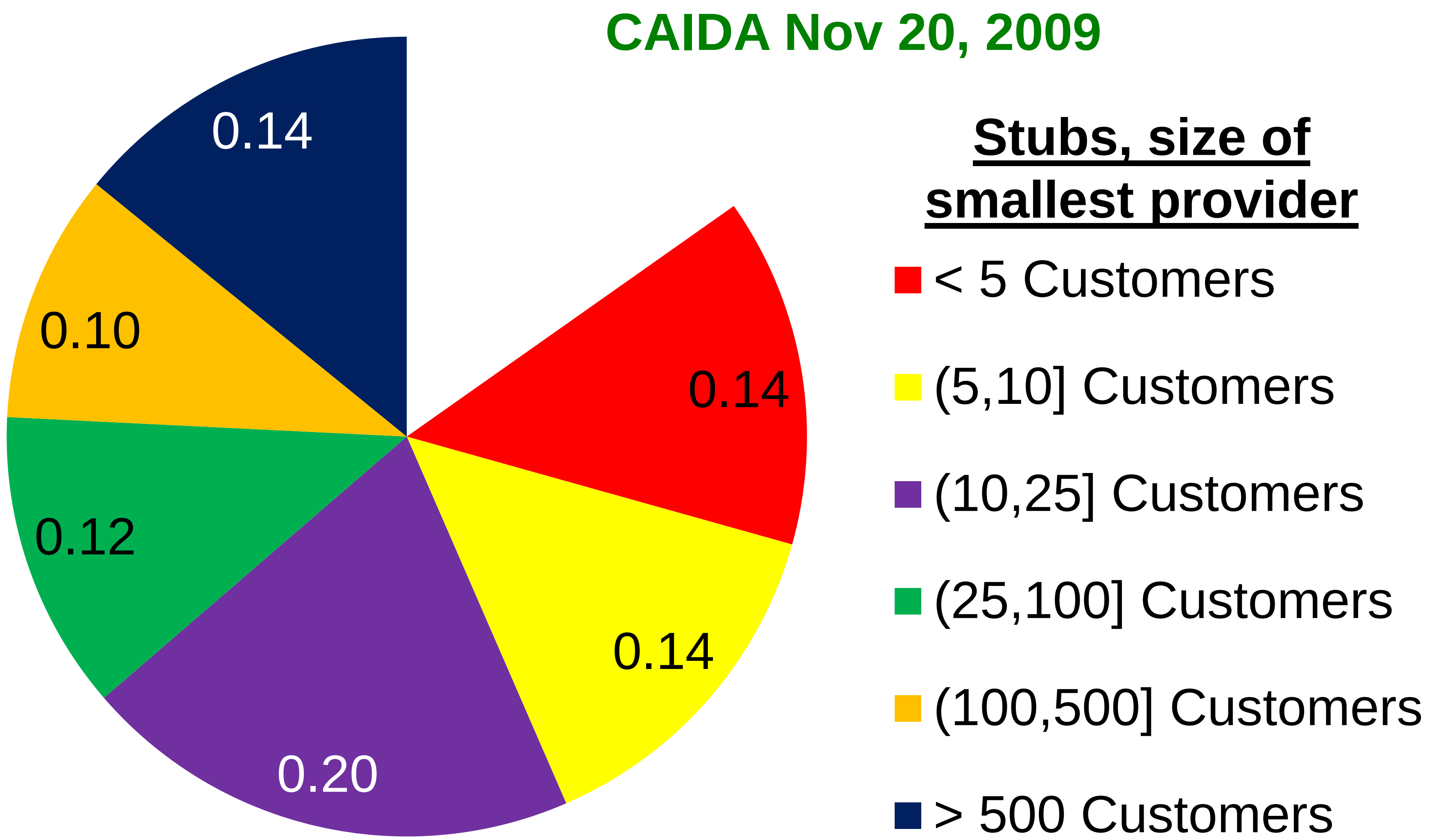
Origin Authentication: A secure database that maps IP Prefixes to their owner ASes.



Being deployed as RPKI!

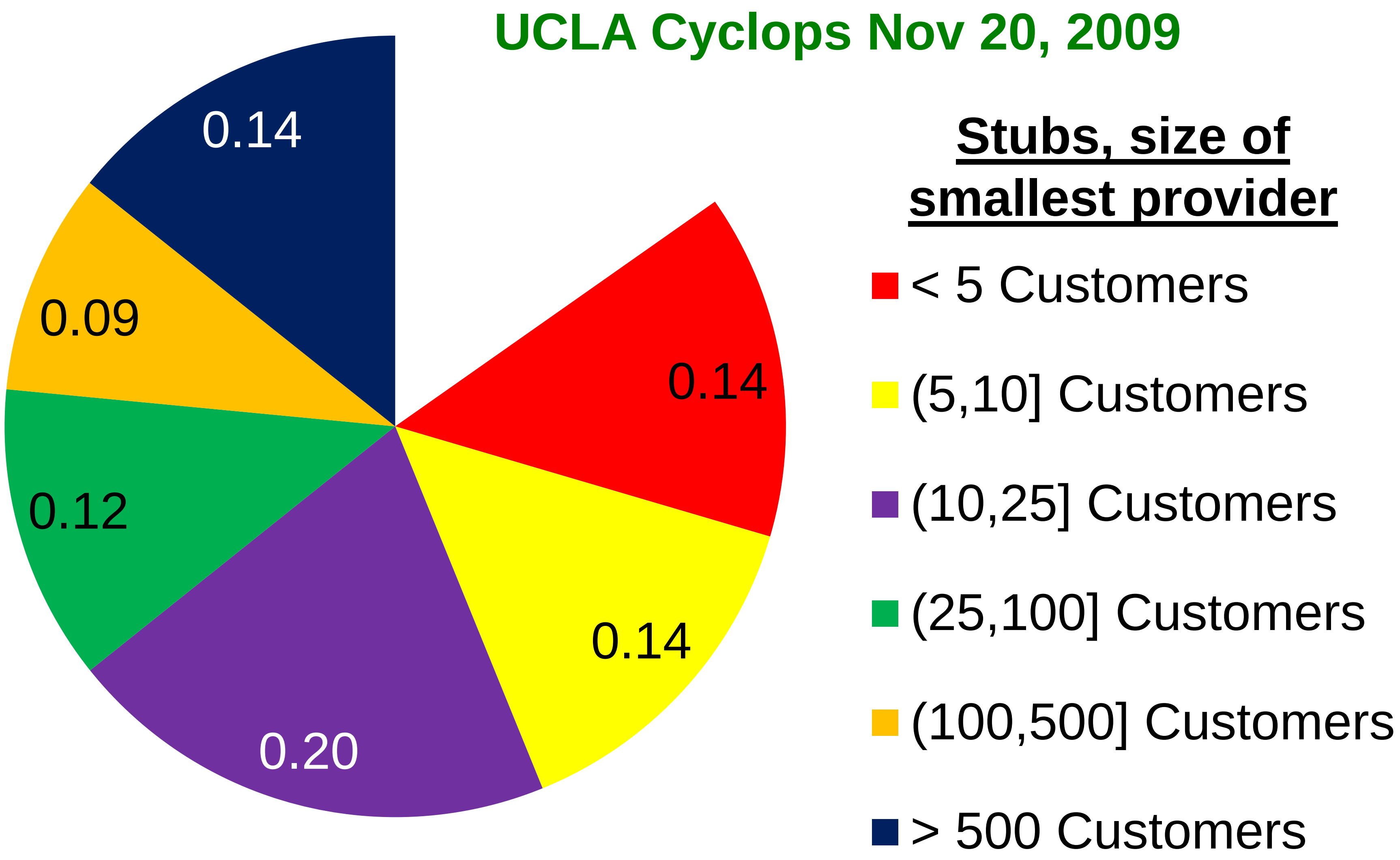
(For past few months?) prefix lists can be derived from RPKI!

What if only large ASes implement prefix lists? (1)



If ISPs with > 10 customers filter, 56% of attacks stopped.

What if only large ASes implement prefix lists? (2)



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