CPS 590.5 Computer Security
Lecture 14: Other Network Security Problems

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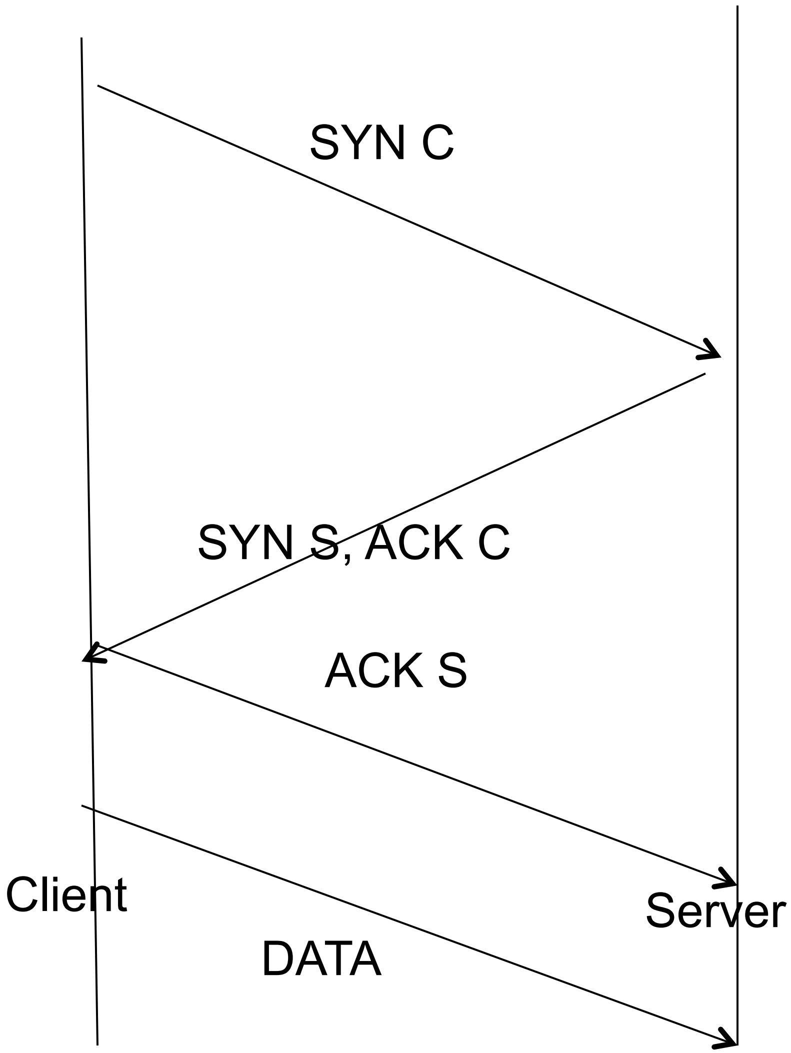
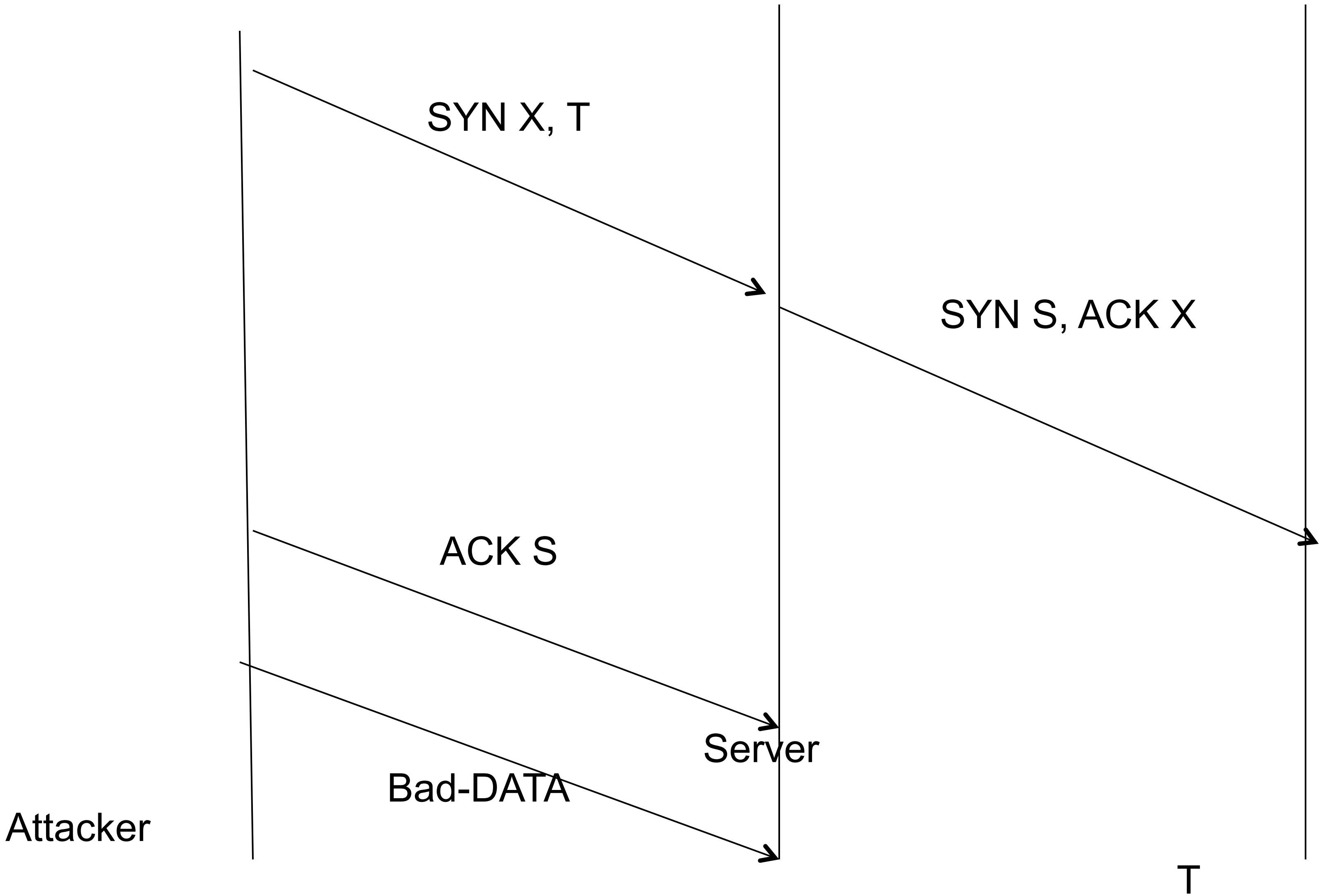
Roadmap

- Previous lecture
  - Proof of Work
    - Bandwidth
    - Computation
- Security problems we have discussed
  - Worms, Malware
  - Source address spoofing
  - DDoS
- Today
  - Other network security problems

TCP Sequence Number Prediction



Attack



Vulnerabilities

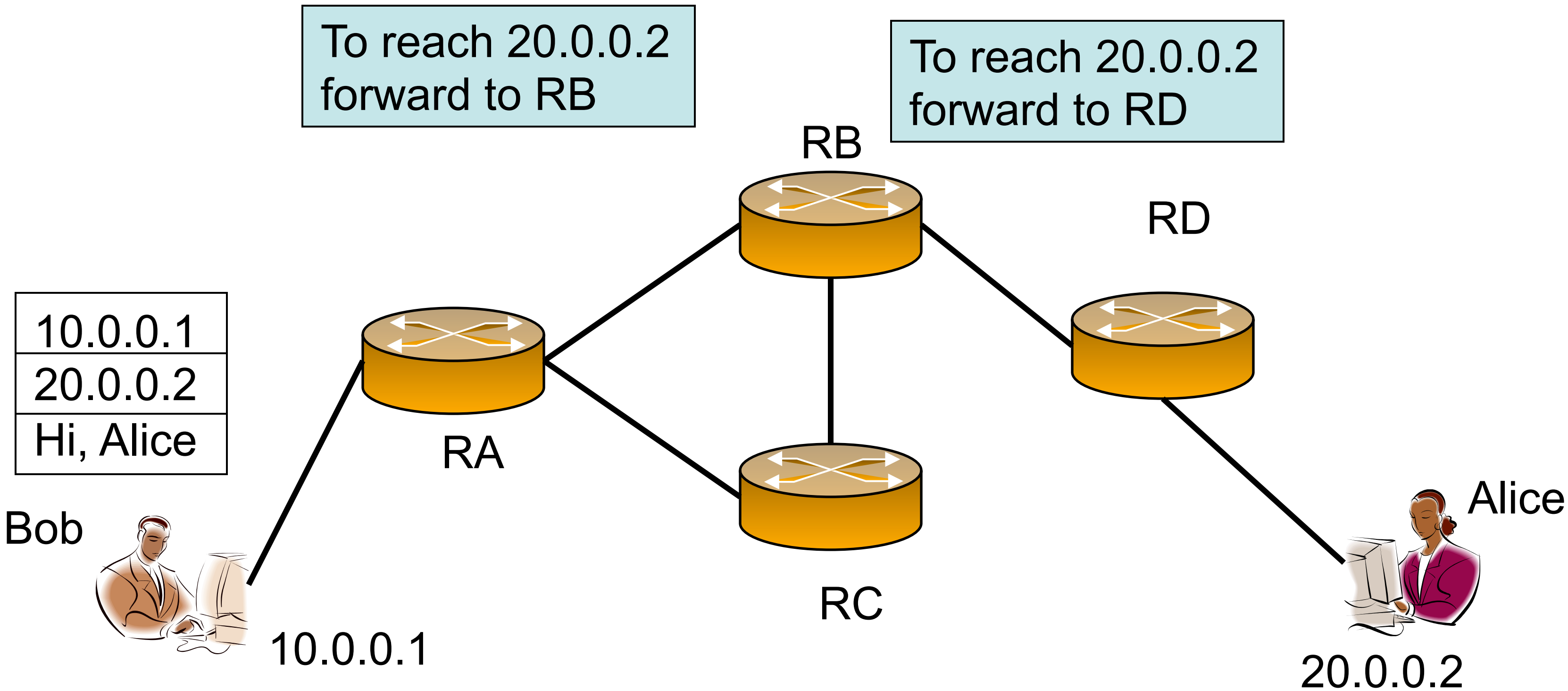
- Sequence numbers predictable
- R* services use IP addresses to authenticate hosts

Fixes?

Routing attacks

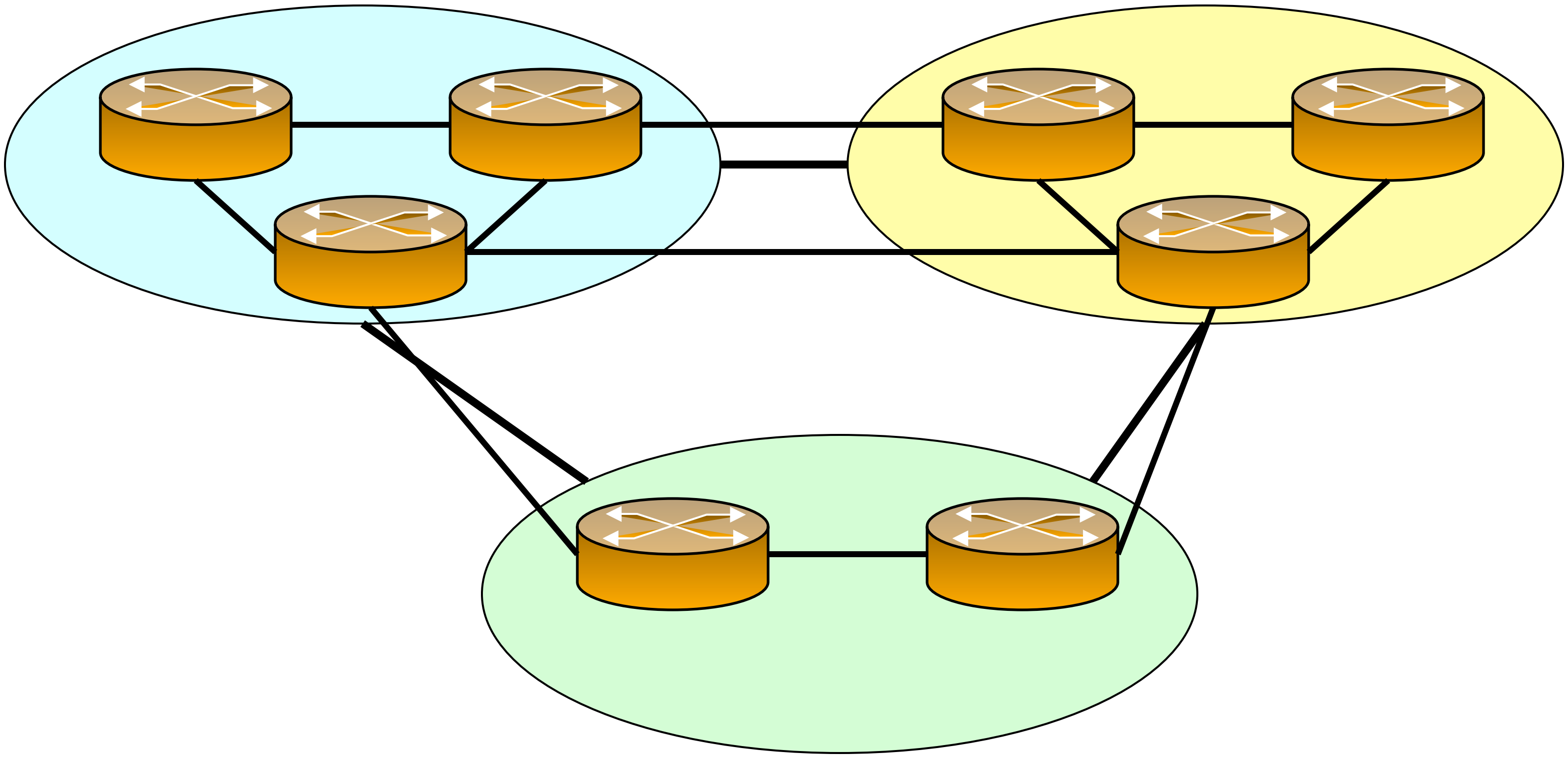
- Source routing
  - T, X, S
- Prefix hijacking attacks

Routing Background



- Routing is about finding a path.

Border Gateway Protocol



- A domain is a network under a single administration.
- Vulnerabilities
  - Lack of integrity: no mechanism to verify the integrity of route announcement
  - Global contamination: lies propagate globally

Type of attacks

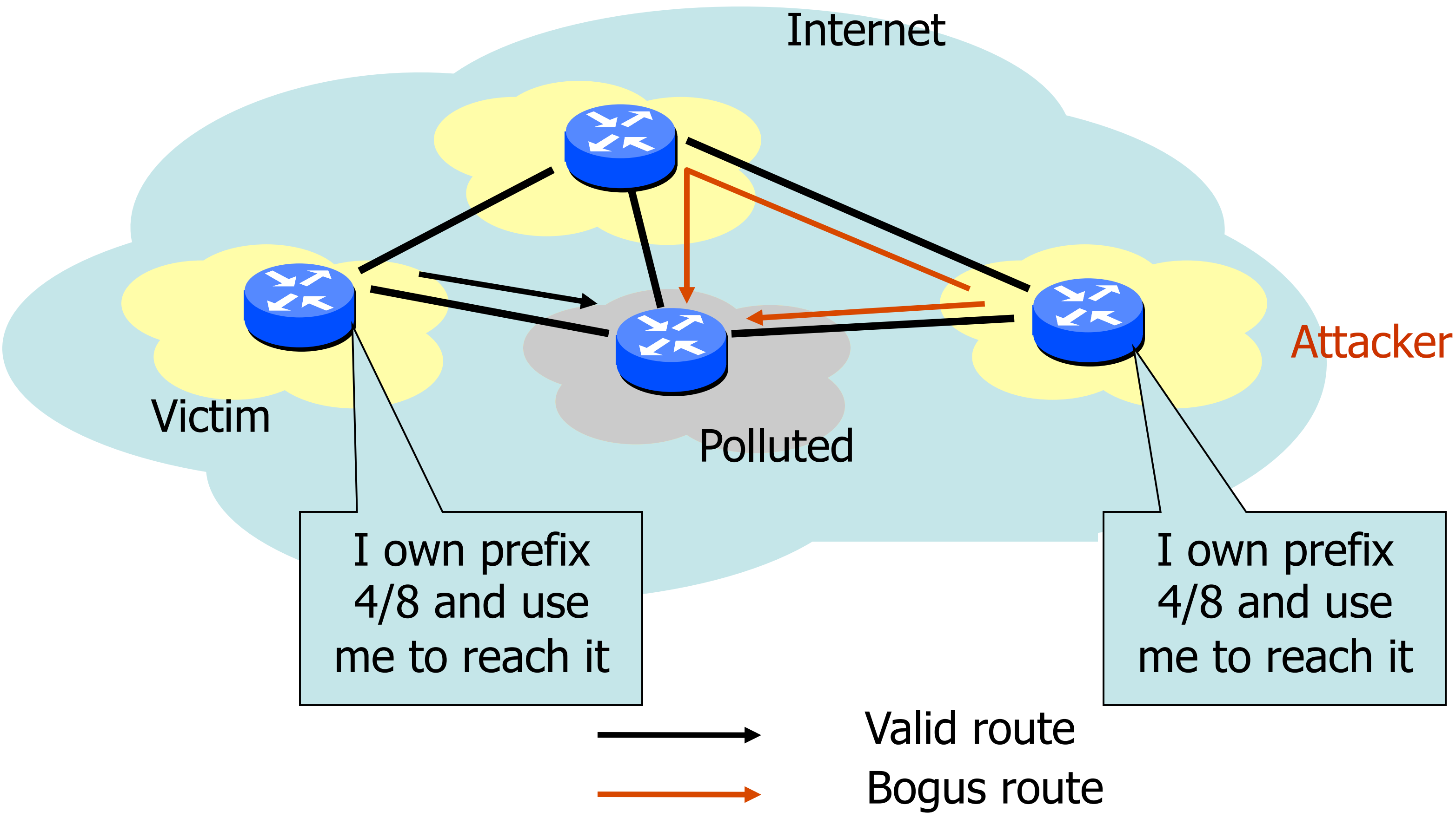
- Blackholing
  - Hijacking
- Redirection
  - Interception
- Instability

Attack mechanisms

- False UPDATEs and prefix hijacking
  - Most serious attack
  - We'll deal with this today

- De-Aggregation
- Contradictory advertisements
  - Is it really an attack?
- Update modifications
- Link flapping
- Instability
- Congest-induced BGP session failures

How prefix hijacking attacks are launched?



Past Prefix Hijacking Incidents

- Apr 1997: AS7007 subprefix hijacked most of the Internet for 2 hours;
- Dec 2004: AS 9121 incorrectly originated routes to 106,089 prefixes, almost 70% of all the prefixes;
- Jan 2006: Panix’s /16 stolen by Con Edison;
- Feb 2006: Sprint and Verio briefly announced TTNET as the origin AS for 4/8, 8/8, and 12/8;
- Feb 2008: YouTube's prefix hijacked by Pakistan Telecom for 2 hours.
- And more …

Defenses

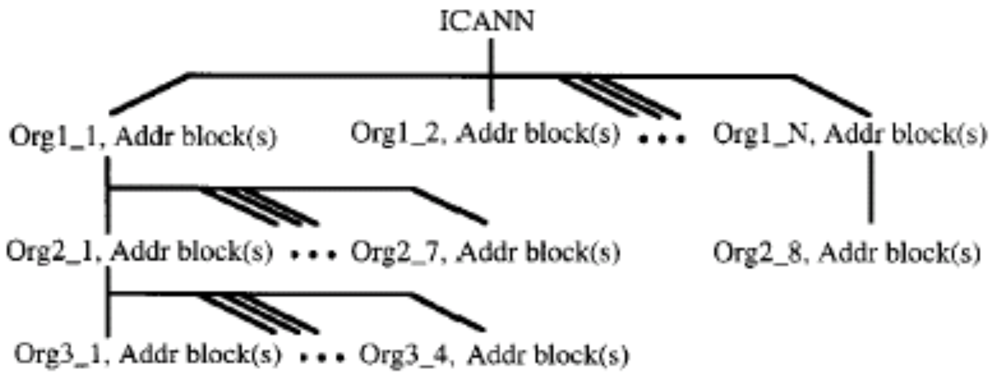
- Prevention
  - Router filters to filter bogus announcements
  - Cryptographic enhancement to BGP
    - SBGP, SoBGP etc.
- Detection
  - Hijacking
  - Interception
- Mitigation
- Impact analysis

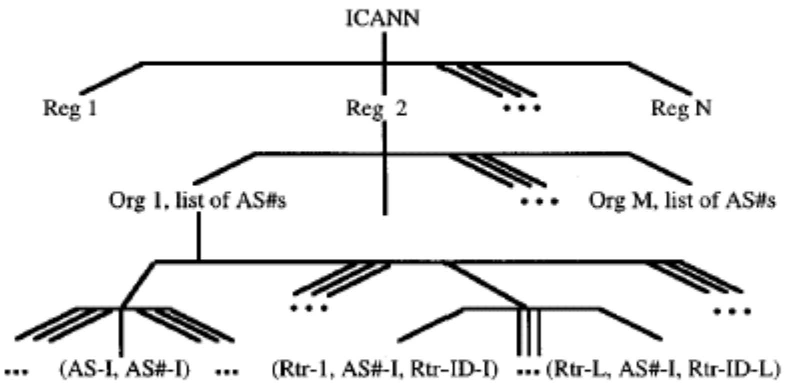
Cryptographic enhancement to BGP

SBGP

- PKIs that authorize prefix ownership and validate routes
- Signed BGP updates
- IPsec for routing message exchanges

sBGP's PKIs





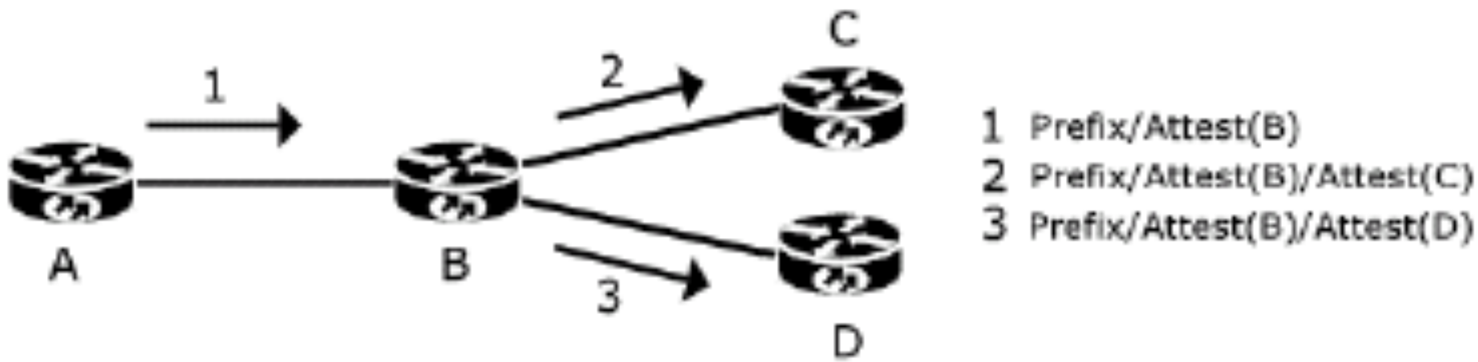
- Two hierarchical PKIs.
  - address allocation: binds addresses to org names
  - AS number and router association: bind org names to ASes and routers
- BGP announcements have AS numbers, not org names

sBGP's attestations

- Address attestation (AA):
  - Which AS can originate which address prefix
  - Requires address allocation certificate

- Route attestation (RA):
  - Each transit AS signs the AS path from the next AS to the originator AS

Validate an sBGP announcement



1. A generates RA for P, including B as the next hop.
2. A sends RA and prefix update to B
3. B validates RA and verifies AA (fetched offline)
4. B generates new RAs for its peers C and D, and forwards the updates to C and D.

Disadvantages of sBGP

- Two hierarchical PKIs: address allocation, and AS number and router association
- Heavy weight

SoBGP

- Replace a hierarchical PKI with a web of trust PKI
- Goals:
  - **Validate an AS is authorized to originate a prefix.**
  - **Verify a peer which is advertising a prefix has at least one valid path to the destination.**
- Requirements:
  - Take advantage of operational experience
  - Minimize changes
  - No central authority
  - Must not rely on routing to secure routing
  - Incrementally deployable
  - Easy to manage

Certificate structure

- EntityCert: who are you?
  - Web-of-trust, signed by 3rd party
- AuthCert: Are you authorized?
  - Bind an AS to the address prefix it advertises
  - Wrapped in Policycert
  - Q: how can authcert be verified?
- PolicyCert: Do You Really Have a Path
  - Build a topology map

Pros and Cons

- Pros:
  - Prebuild databases, so that no cryptographic operation on UPDATEs
- Cons
  - Difficult to verify AuthCert
  - Paths integrity is not guaranteed

Detection mechanisms

- iSPY: detecting IP prefix hijacking on my own
- A Study of Prefix Hijacking and Interception in the Internet

Key Idea of iSpy

- **Hijack of a prefix X causes a significant fraction of Internet to be polluted**

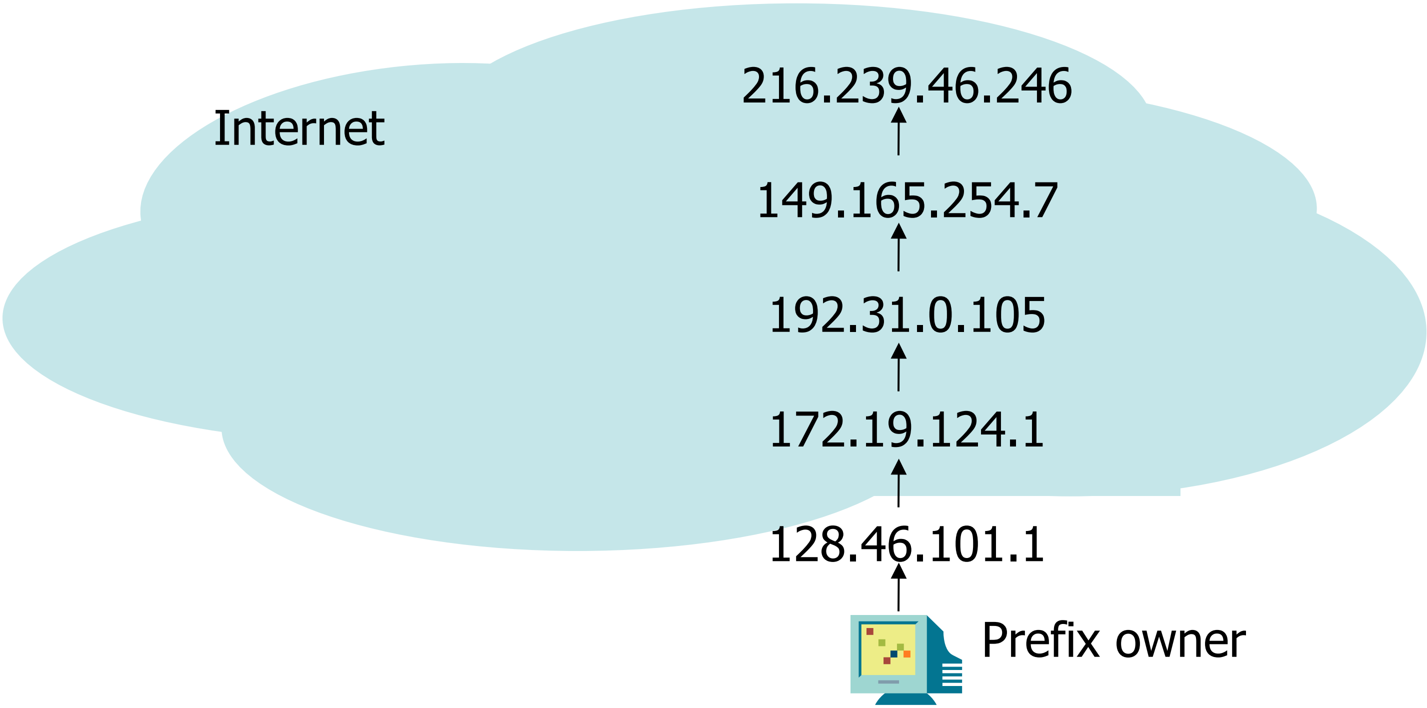
- **A significant fraction of probes sent out from prefix X to the Internet will not come back**

Design Challenge

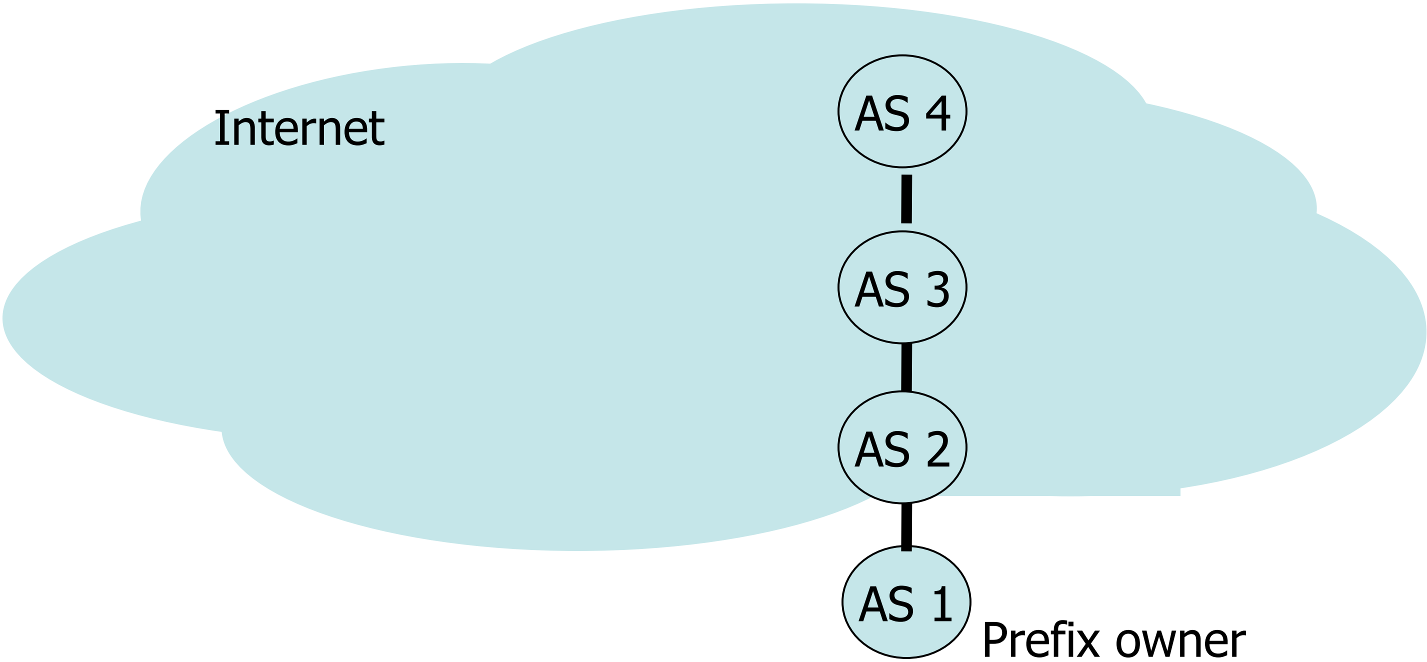
- How to distinguish unreachability caused by hijacks from other events (e.g. link failure and congestion)?

1. Reachability view from the prefix owner
2. Definition of cut
3. Cut distinguishes hijacks from other events

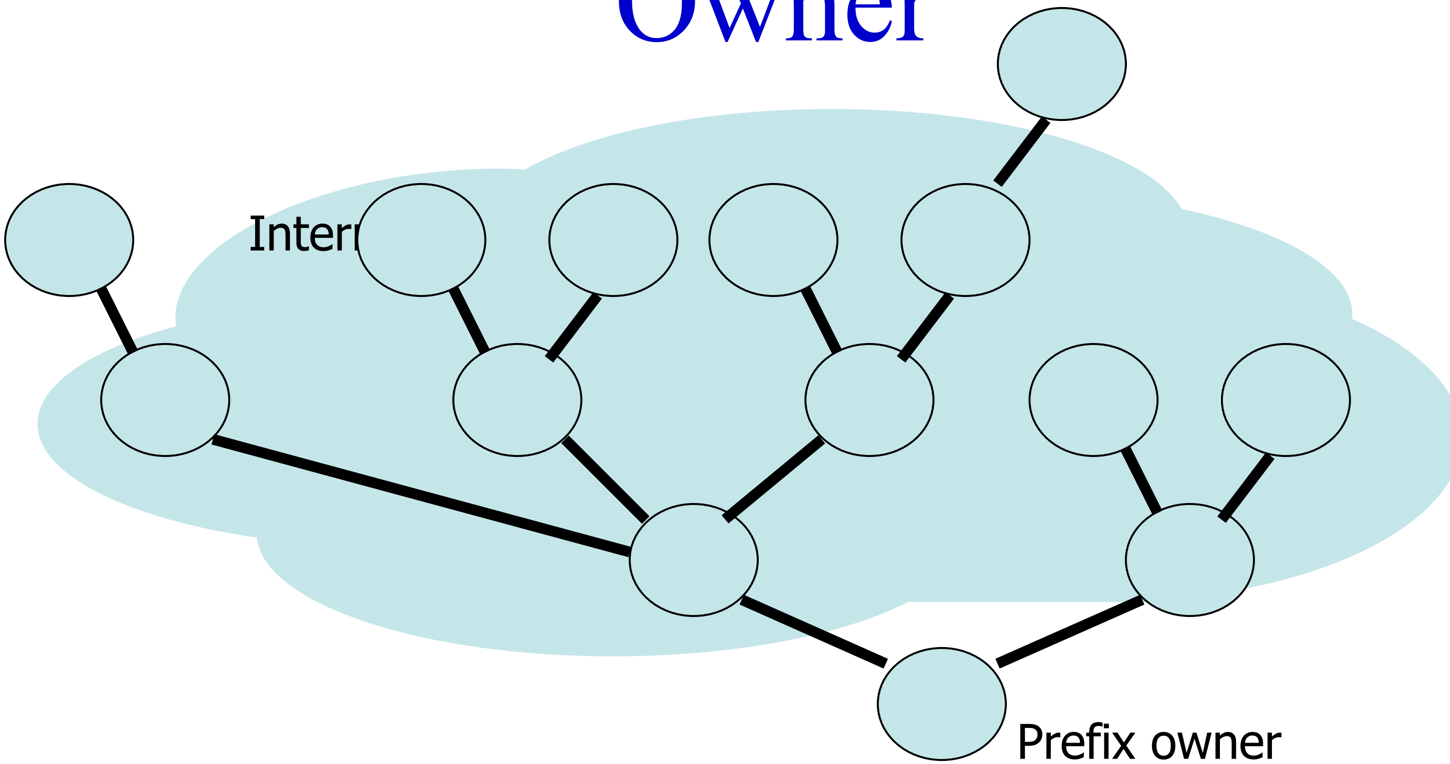
Reachability View from Prefix Owner



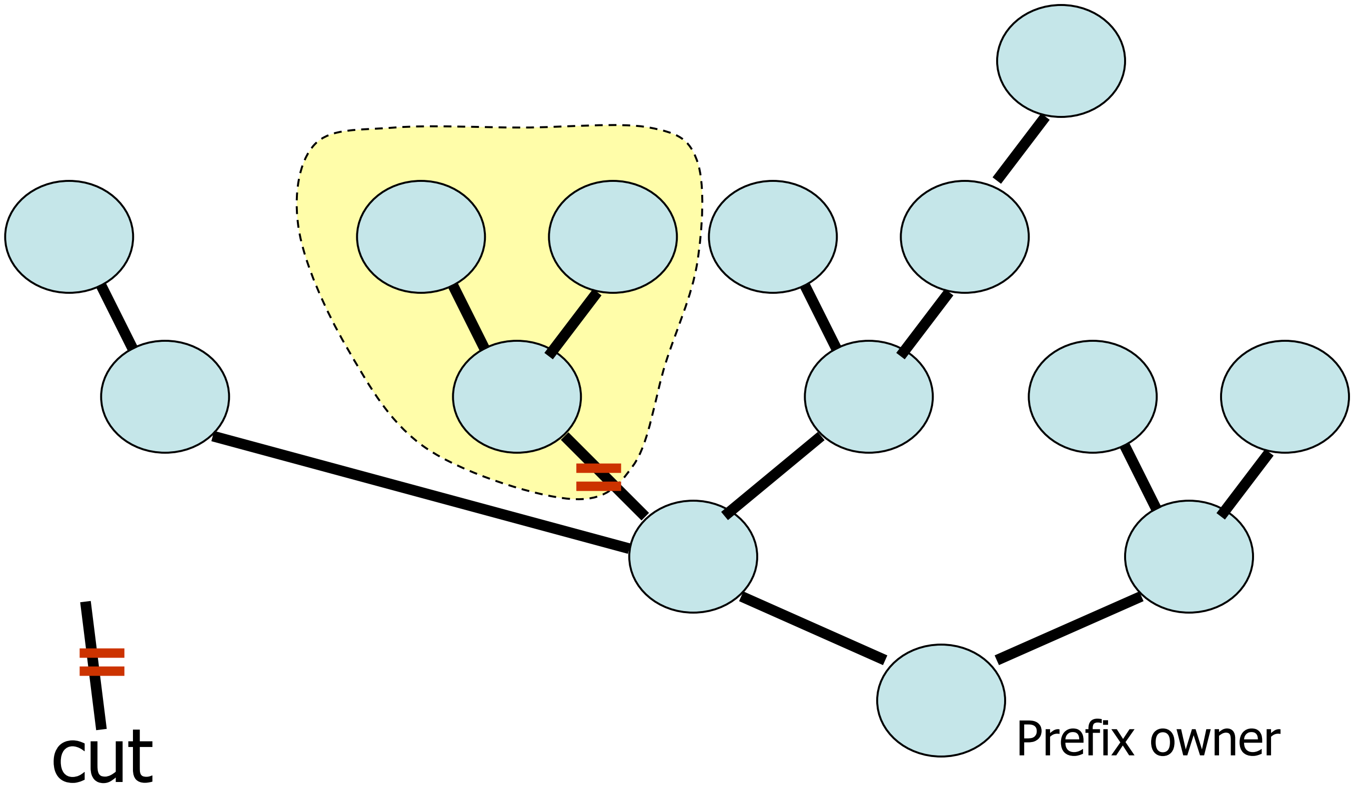
Reachability View from Prefix Owner



Reachability View from Prefix Owner

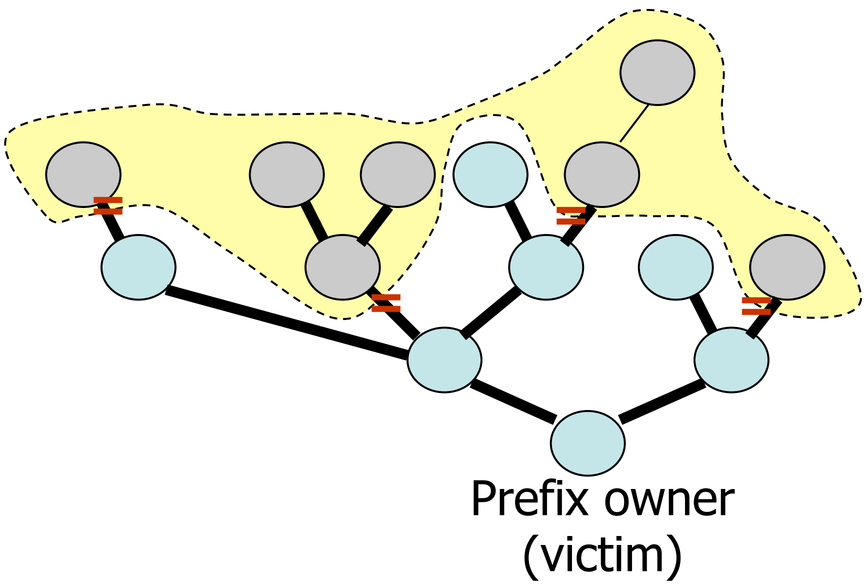


“Cut” on the Reachability View

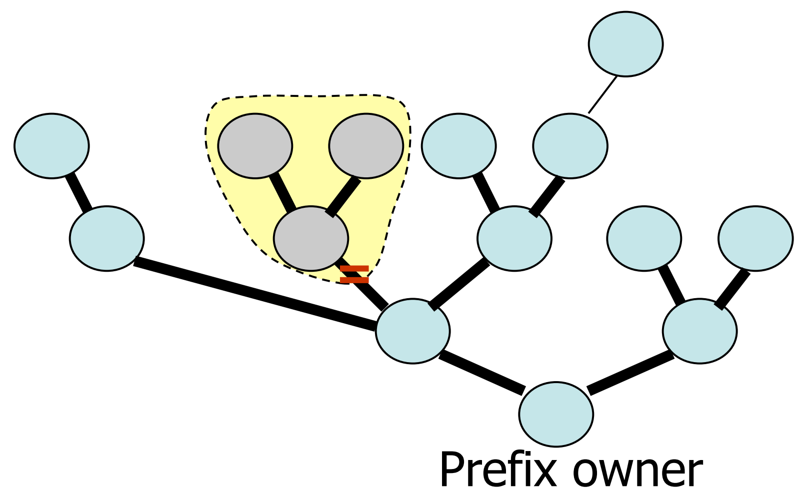


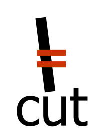
|Cuts|: Distinguish Hijacks from Other Events

- Hijack causes many cuts



Other event causes few cuts





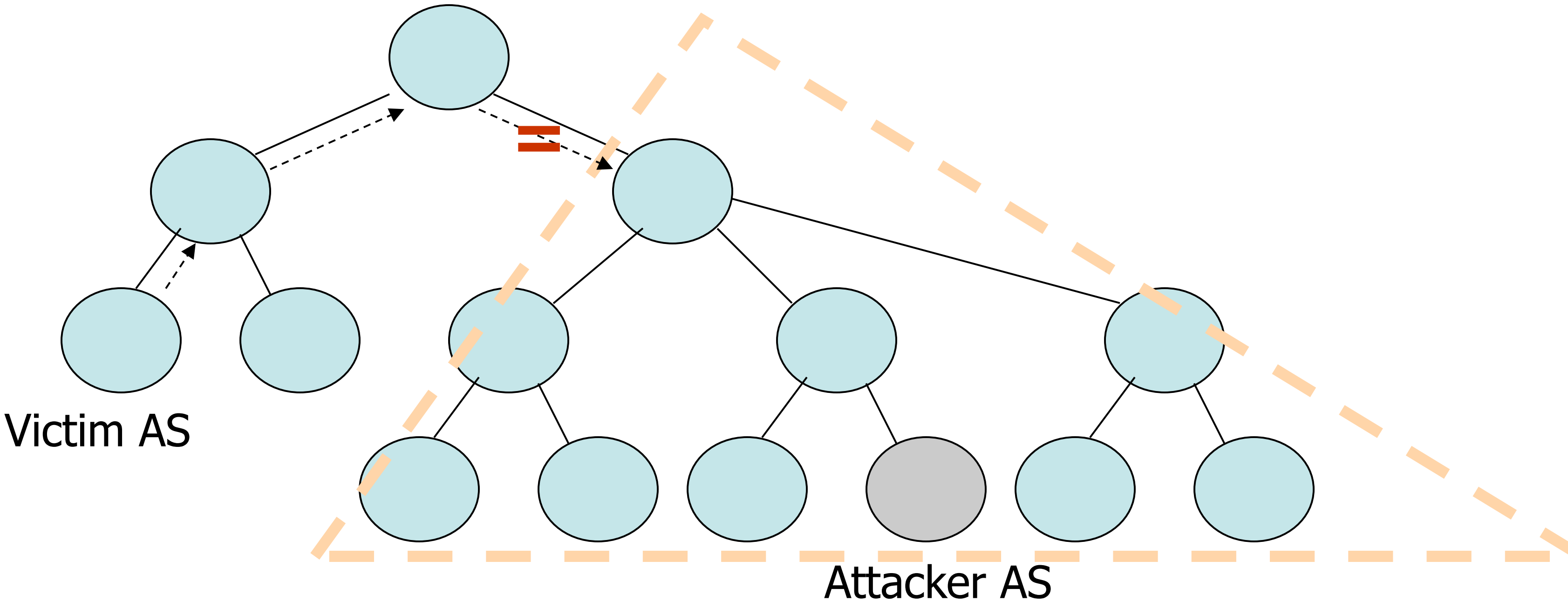
Why Does Hijacking Causes Many Cuts?

1. A single cut if Internet topology were a tree

2. Actual Internet topology is different, and its implication

3. Simulation validation

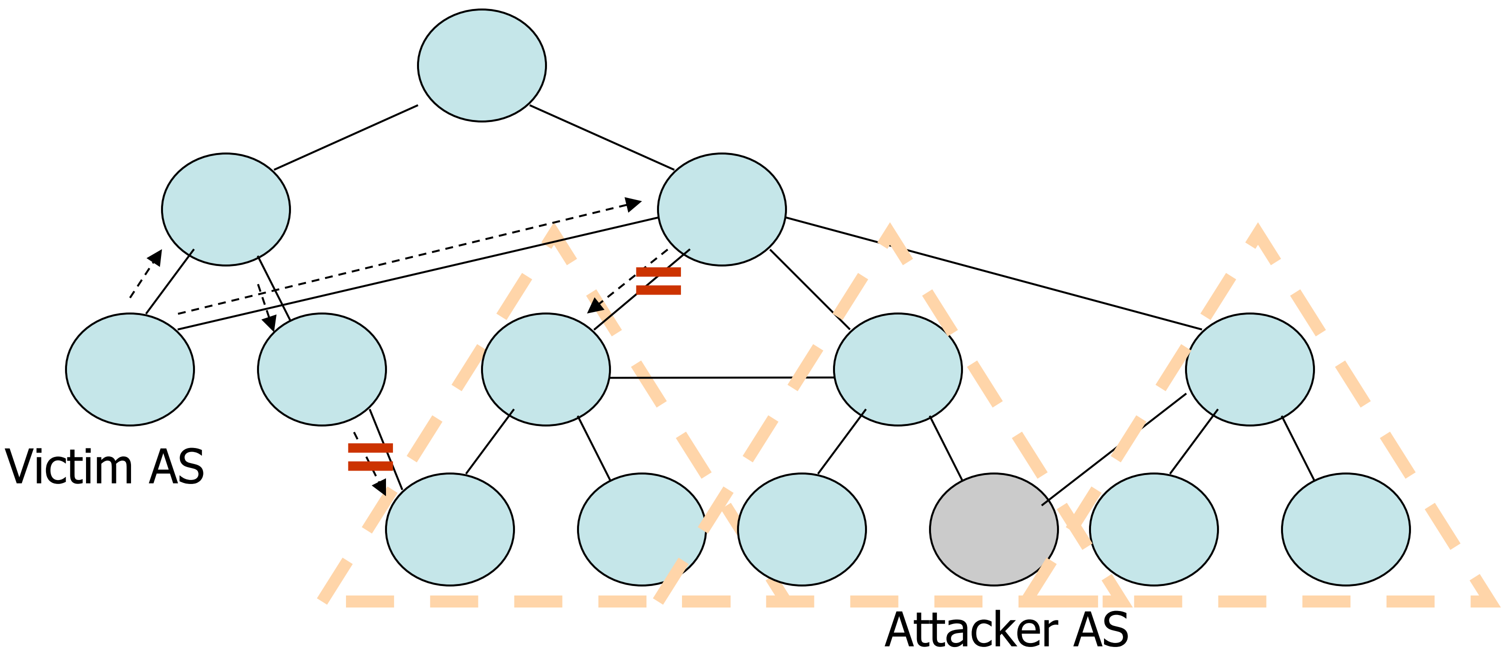
Tree Topology Causes Single Cut



- Polluted region is a subtree
- A single cut at the subtree root

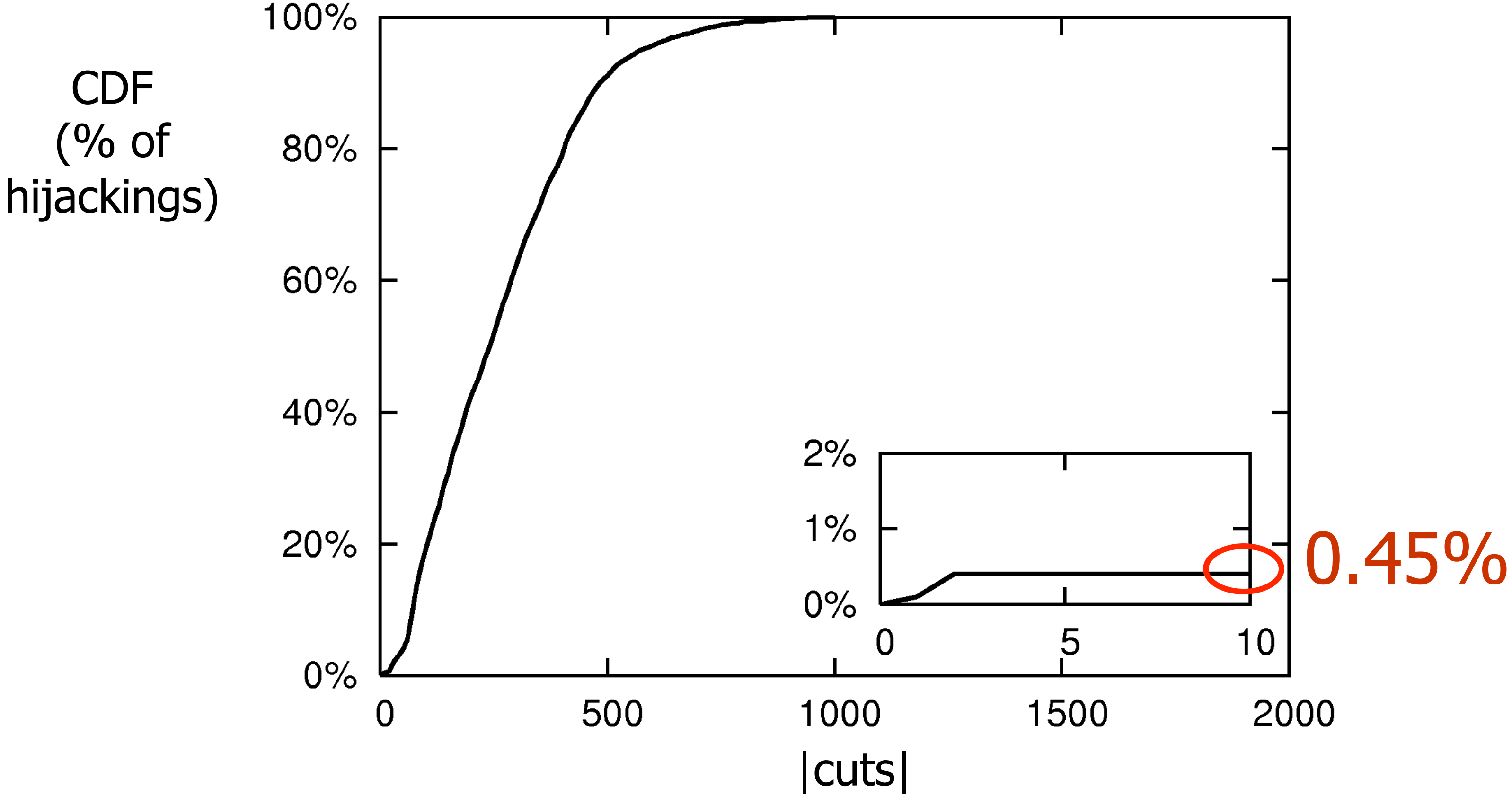
Mesh Topology Causes Multiple Cuts

Many peering links and multi-homing links → Mesh



- Polluted region consists of multiple subtrees
- Each subtree creates multiple cuts

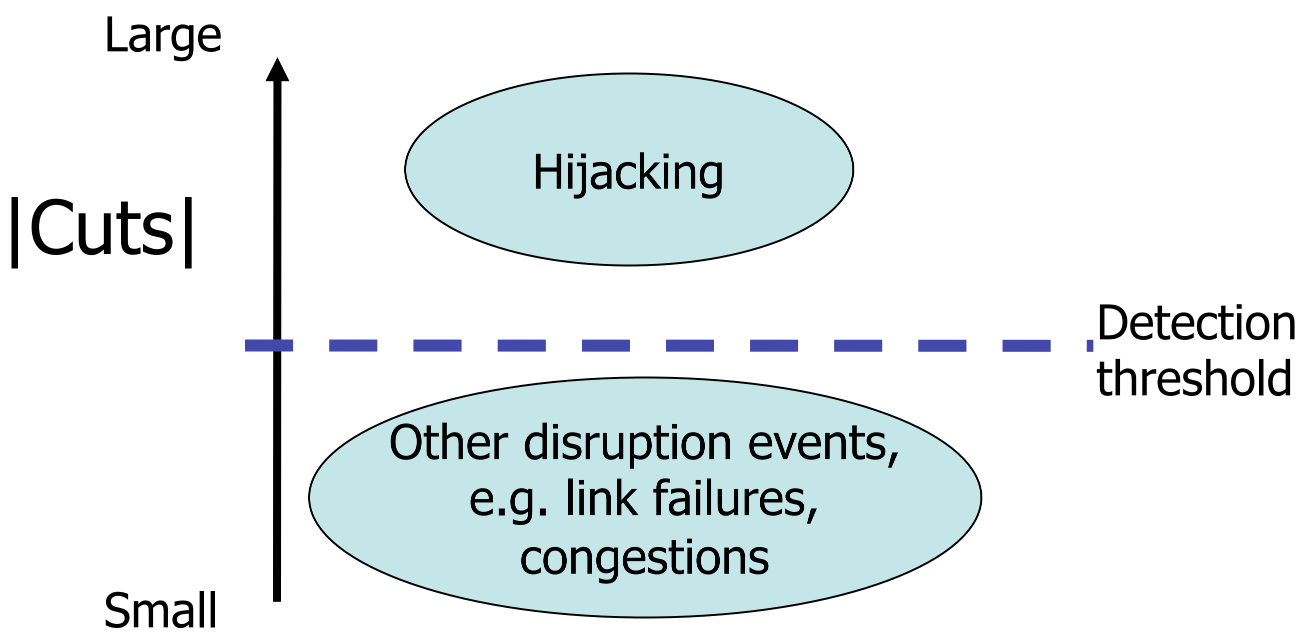
Simulation: How Many Cuts?



Simulated 2450 hijacking instances on a realistic AS topology inferred by running Gao's relationship inference algorithm

iSPY Design

- Continuous probing
- Threshold-based Detection



iSPY's Implementation Details

- Lightweight traceroute
  - How does traceroute work?

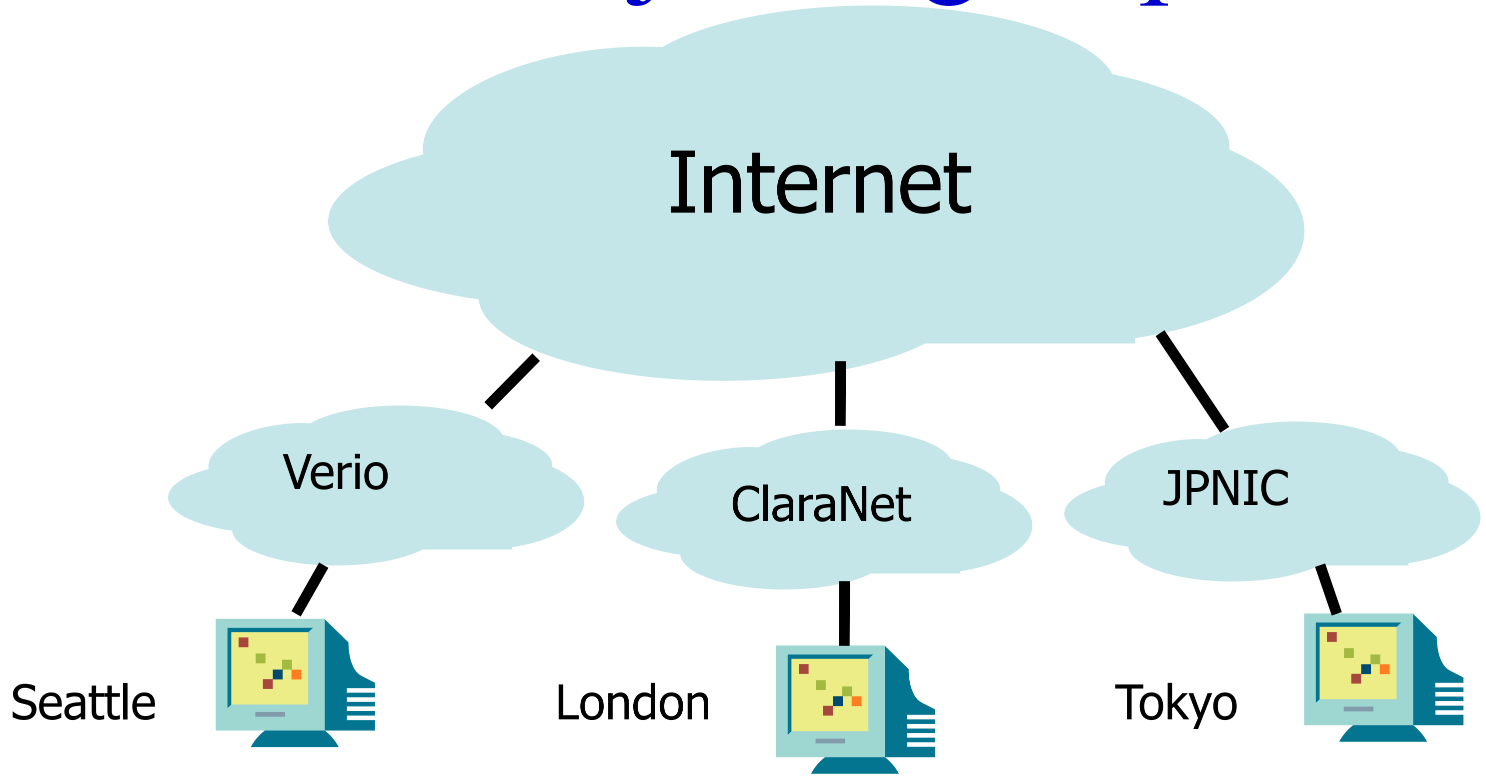
  - Sample one destination per transit AS (total ~4000 transit ASes) with no loss of accuracy
    - –If hijacked, ICMP replies will not come back to prefix owner
  - One round of probing takes every 10~15 mins

iSPY's Accuracy

Experiment	Purpose	Results
Simulating hijacks on an Internet AS topology	False negative	0.45%
Deploying iSPY on 108 Planetlab sites (over 25 days)	False positive	0.17%

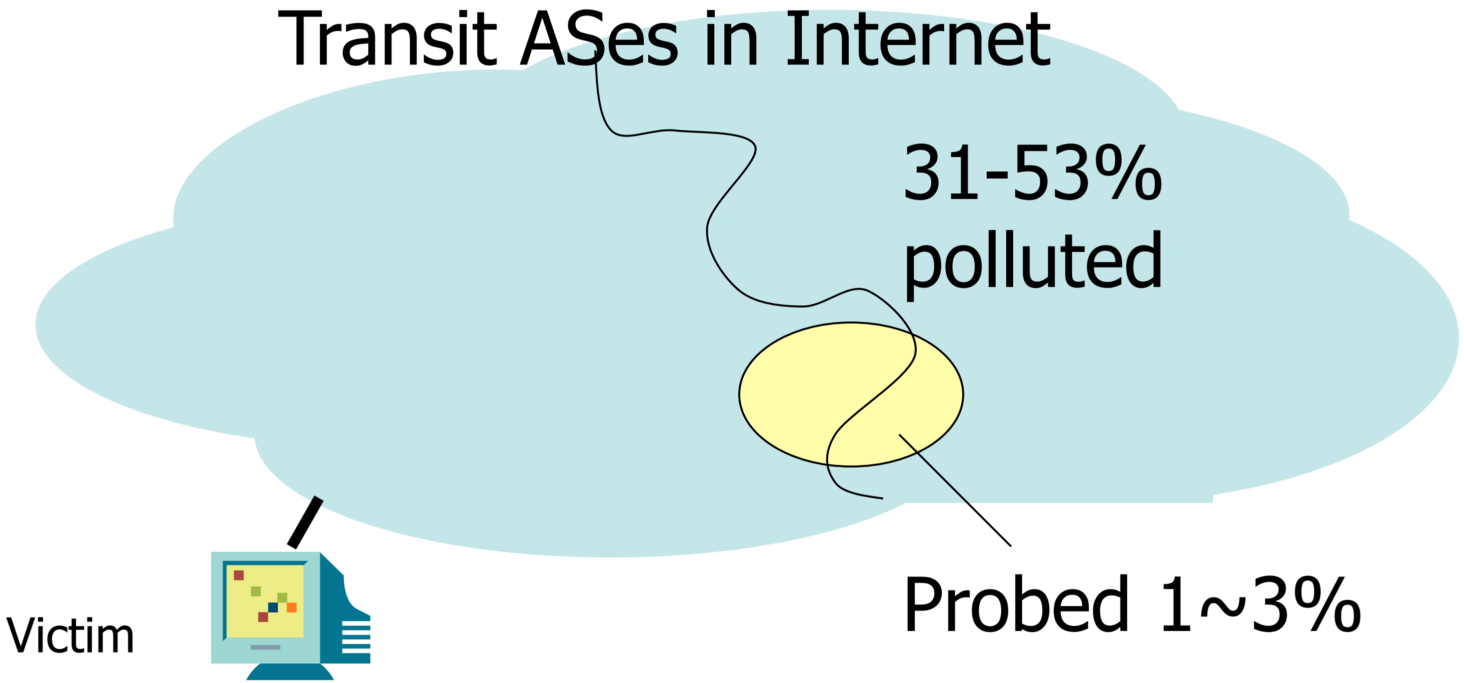
Detection threshold = 10

Internet Hijacking Experiment



Performed 15 hijacks with different attacker and victim

iSPY is Real-time !



- iSPY detected all 15 hijacks in 1.4~3.1 mins
- All hijacks have over 200 cuts

Security Properties of iSPY

- Deal with regular prefix hijacking
  - Not subprefix hijacking
  - Not interception
    - –Why?

- Evasion attacks on iSPY
  - Probe spoofing needs an interception attack
  - Pollution shaping is not easy

Conclusion

iSPY prefix-owner centric hijacking detection

√ Real-time (1.4-3.1 minutes)

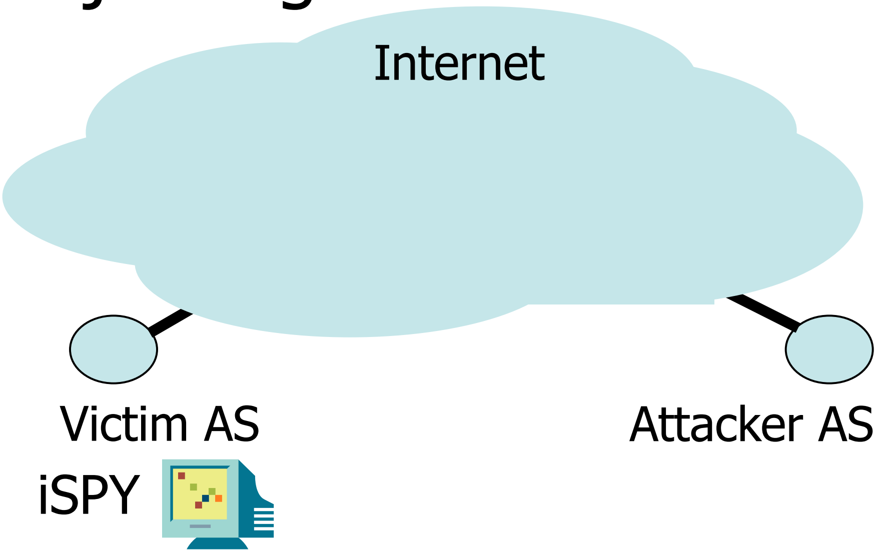
√ Lightweight

√ Accurate (F.N.=0.45%, F.P.=0.17%)

√ Easy to deploy

√ Incentive to deploy

√ Robust in victim notification



A Study of Prefix Hijacking and Interception in the Internet

Ballani et al.

Who can hijack/intercept my prefix?

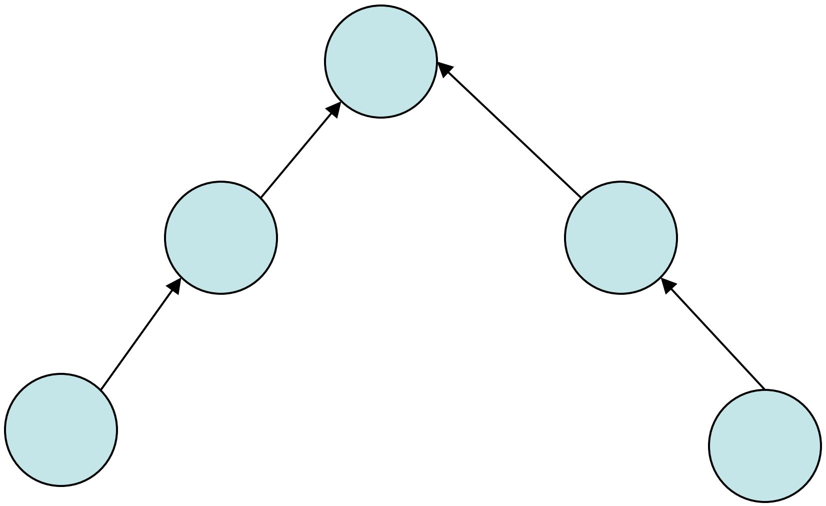
- Hijack
  - As long as I can announce a more preferable route
  - Which routes are more preferable?
    - Customers > peers > providers
    - AS path length to break ties
      - Announce a direct path: p X
      - Or a two-hop path: p XO
        - » Why not direct path?

Interception

- Two conditions must be met
  - I can announce a more preferable path
  - My original path to hijacked prefix is not polluted

- Challenge: how to ensure both conditions are met?

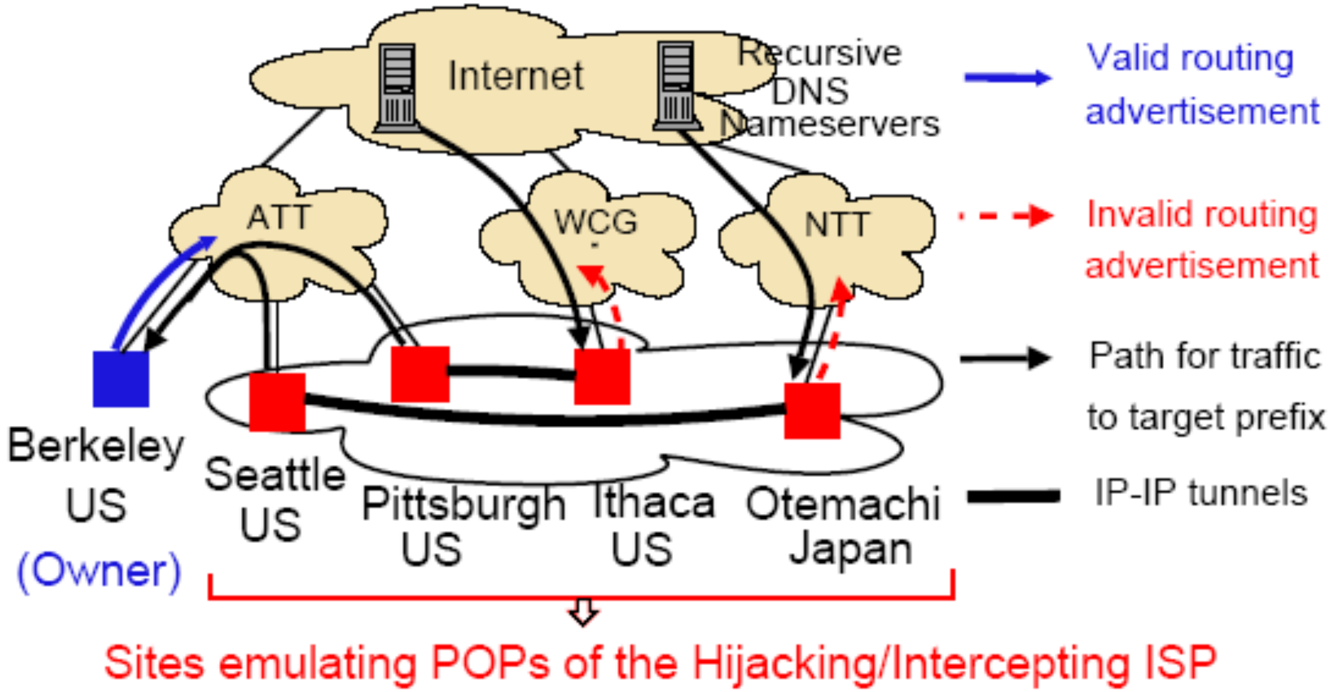
Valley-free properties



- After traversing one provider-to-customer or peer-to-peer edge, no more such edges can be traversed

```
If (existing route to p is through a provider)
then
 Advertise to all peers and customers a route
 for prefix p with AS-PATH [X];
else
 Advertise to all neighbors a route for prefix
 p with AS-PATH [X];
endif
If (the invalid advertisement causes the
  existing route for p to change)
then
    Stop the advertisement to the
    anomaly-causing neighbor;
endif
```

Evaluation



Generated traffic from 23,588 recursive nameservers

For each site as owner, hijacked and intercepted traffic using other sites

Ber	Pit	Sea	Ith	Ote	% of traffic Hijacked	% of traffic Intercepted
O	×	×	✓	✓	91.7	78.8
×	O	×	✓	✓	68.8	67.5
×	×	O	✓	✓	97.4	66.2
×	×	×	O	✓	66.0	47.3
✓	✓	✓	×	O	76.1	23.4

O : Site owning the prefix

× : Site not advertising an invalid route during interception

✓ : Site advertising an invalid route during interception

Detection

- Compare traceroute from dataplane with AS path from BGP

Conclusion

- Tier-1 ASes can hijack and intercept significant fraction of traffic to any p
- Small ASes can hijack and intercept a non-negligible amount of traffic
- Verified using known prefix hijacking events

Summary

- TCP attacks and fixes
- BGP and prefix hijacking attacks
- sBGP and soBGP
- Detection of hijacking attacks
  - Traffic will not return to prefix owners